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INFLATION DYNAMICS:
DEAD, DORMANT, OR DETERMINED ABROAD?

Kristin Forbes

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Cambridge, MA 02138
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ABSTRACT

Inflation dynamics have been difficult to explain over the last decade. This paper explores if a more comprehensive treatment of globalization can help. CPI inflation has become more synchronized around the world since the 2008 crisis, but core and wage inflation have become less synchronized. Global factors (including commodity prices, world slack, exchange rates, and global value chains) are significant drivers of CPI inflation in a cross-section of countries, and their role has increased over the last decade, particularly the role of non-fuel commodity prices. These global factors, however, do less to improve our understanding of core and wage inflation. Key results are robust to using a less-structured trend-cycle decomposition instead of a Phillips curve framework, with the set of global variables more important for understanding the cyclical component of inflation over the last decade, but not the underlying slow-moving inflation trend. Domestic slack still plays a role for all the inflation measures, although globalization has caused some "flattening" of this relationship, especially for CPI inflation. Although CPI inflation is increasingly "determined abroad", core and wage inflation is still largely a domestic process.

Kristin Forbes
MIT Sloan School of Management
100 Main Street, E62-416
Cambridge, MA 02142
and CEPR
and also NBER
kjforbes@mit.edu

I. Introduction

Over the last decade, the performance of standard models used to understand and forecast inflation has deteriorated. When growth collapsed during the 2008 Global Financial Crisis (GFC), inflation in most countries fell less than expected. Since then, as economies have largely recovered and unemployment fallen—even to record lows in some countries—inflation has not picked up as expected. A burgeoning literature has proposed a range of possible explanations for these puzzles—ranging from claims that the key frameworks are "dead", to arguments that the models are alive and well but inflation has been "dormant" due to temporary factors or a long healing process after the GFC. This paper explores an explanation between these extremes: whether inflation is increasingly determined abroad. The results suggest that globalization has meaningfully affected the dynamics of CPI inflation over the last decade—but had a more moderate effect on core inflation and wages. A more comprehensive treatment of globalization can meaningfully improve CPI inflation models, but the dynamics of wages and core inflation are still largely "domestic" rather than "determined abroad".

This question of whether globalization is affecting inflation dynamics is taking on increased urgency as central banks evaluate their ability to continue (or expand) loose monetary policies in the presence of extremely tight labor markets. If inflation is largely determined abroad, a central bank could be less concerned about inflation exceeding its target and more able to pursue a "high-pressure" economy that prioritizes job creation (Yellen, 2016). If inflation is largely determined globally and less responsive to domestic conditions, central banks may also need to make larger adjustments to interest rates to stabilize inflation (even ignoring the challenges around starting from lower rates). In the extreme, if inflation has increasingly been determined abroad and the global factors that have dampened inflationary pressures over the last few years reverse (such as movement away from global supply chains), then countries could suddenly experience a sharp increase in domestic inflation and face a difficult tradeoff between supporting growth and stabilizing prices.

The debate on how globalization—defined broadly as increased integration between individual countries and the rest of the world—affects inflation dynamics is not new. Soon after the Phillips-curve relationship between domestic unemployment and wage inflation gained prominence in the late 1960's, the oil shocks of the 1970's highlighted the need to supplement this framework to account for changes in global oil prices (Gordon, 1977 and 1985). In the mid-2000's, several prominent policymakers questioned whether globalization, especially increased imports from low-wage economies, was moderating inflationary pressures at that time (Bean, 2006, Kohn, 2006, and Yellen, 2006). Research at the BIS suggested that global slack was becoming more important than domestic slack in determining inflation (Borio and Filardo, 2007). The corresponding discussion and analysis, however, generally concluded that although globalization was an important phenomenon, and may have acted as a temporary supply shock reducing inflation, it had only had limited effects on the underlying inflation process. Ball (2006) surveyed the evidence at that time on whether the "globalization of the U.S. economy has changed the behavior of inflation" and summarized the results as "no, no, and no."

The impact of globalization on inflation received less attention during and after the GFC as most work attempting to explain the "missing disinflation" in this period focused on domestic variables, such as financial frictions (Gilchrist and Zakrajsek, 2015 and Gilchrist *et al.*, 2017). As the recovery progressed, attention shifted to why inflation was slow to recover, and the majority of papers continued to highlight domestic factors. Some prominent explanations are: challenges in measuring slack (Albuquerque and Baumann, 2017 and Hong *et al.*, 2018), nonlinearities in the relationship between slack and inflation (Hooper, Mishkin and Sufi, 2019 and Gagnon and Collins, 2019), the large component of inflation indices which are not "cyclically-sensitive" (Stock and Watson, 2018), and the stabilizing role of inflation expectations and central bank credibility (Coilbion and Gorodnichenko, 2015 and Bernanke, 2007). Closely related, if a central bank targets inflation, then inflation should remain around target and be less sensitive to economic slack, as highlighted in McLeay and Tenreyro (2019) and Jordà and Nechio (2018).[1]

Only recently, as inflation has remained muted in many countries, attention has shifted to how globalization may be affecting inflation dynamics (discussed in more detail in Section II). One line of research highlights the growing importance of a shared global common factor in inflation dynamics—but does not explain what is behind this increased inflation synchronization. Other research highlights specific aspects of globalization, such as structural changes (including increased trade and global supply chains) or larger global shocks (particularly in oil and commodity prices). Ha, Kose and Ohnsorge (2019) and Obstfeld (2019) provide excellent reviews of this large literature, with the former focusing on emerging markets and developing economies and the later on the US. Obstfeld (2019) concludes that there are important interactions between the global economy and US inflation (such as through the global neutral interest rate and role of the dollar), but the evidence on whether globalization has affected US inflation dynamics is inconclusive.

[1] This long-standing challenge for estimating Phillips curves has been known since at least Goldfeld and Blinder (1972) and can be addressed through instrumental variables (*i.e.*, Jordà and Nechio, 2018) or more disaggregated data (*i.e.*, state data in McLeay and Tenreyro, 2019). These issues are attenuated in this paper through its focus on changes over time within countries.

Most prominent papers modelling inflation in advanced economies, however, continue to place minimal emphasis on global factors. A generally accepted strategy for modelling inflation in the U.S. is to control for domestic variables (domestic slack, inflation expectations and often lagged inflation) and add a control for import prices to capture any international supply or demand shocks. This is perceived to be a "sufficient statistic" to capture any influences of the global economy on domestic inflation, with no additional benefit from more comprehensive global controls or explicitly modelling global interactions.[2] Also, although there is prominent discussion of how globalization could be "flattening" the Phillips curve, there have only been limited attempts to test if global variables are directly affecting the relationship with domestic slack (with Ihrig *et al*., 2010, one exception).

This paper assesses whether globalization should play more than this ancillary role in the basic framework for understanding and forecasting inflation. It concludes that a more comprehensive treatment of global variables can meaningfully improve our ability to understand CPI inflation over the last decade, but only marginally improve our ability to understand core and wage inflation. More specifically, higher commodity and oil prices, exchange rate depreciations, less world slack, and weaker global value chains are all associated with higher CPI inflation, and the role of these variables (particularly non-oil commodity prices) has increased. Commodity and oil prices and world slack have also been important for understanding the cyclical component of CPI inflation—which has also increased. In fact, when global variables are added to simple models of CPI inflation, the explanatory power of these models recovers to pre-crisis levels. In contrast, core inflation, wage growth, and the trend component of inflation continue to be predominantly driven by domestic variables. Adding global variables provides minimal boost to the ability of simple models to explain these measures, although commodity prices have played a greater role for core inflation over the last decade. Domestic slack plays a role in explaining all measures of inflation, although its role has generally weakened over time, especially for CPI inflation. This "flattening" of the Phillips curve for CPI inflation can largely (but not entirely) be explained by increased import exposure, while globalization has had less impact on the relationship between domestic slack and other measures of inflation—particularly wage inflation.

This paper provides new insights on inflation dynamics due to five key elements of the analysis—some of which have been used in other research—but not combined simultaneously. First, this paper focuses on multiple channels by which globalization could affect the inflation process, a more granular approach that is important as many global trends are correlated and thereby require multiple

[2] For a recent prominent example, see Hooper, Mishkin and Sufi (2019).

controls to identify effects. Second, it not only tests if adding global variables to different models can improve our understanding of inflation, but also if interactions between domestic slack and globalization can explain the "flattening" of the Phillips curve. Third, this paper explores the dynamics of several inflation measures: the CPI, core CPI, wages, and the short-term cyclical and slow-moving trend components. The results provide a more comprehensive picture of how globalization has had different effects on different price dynamics. Fourth, the paper uses three different empirical frameworks (a trend-cycle decomposition, as well as the more common Phillips curve and principal components models), each of which provides information on different aspects of the inflation process. The combination of approaches ensures results are not driven by the theoretical construct of a specific model, and several consistent findings across methodologies help build a more convincing picture of the role of globalization—especially given well-known issues with the popular Phillips curve framework. Finally, the paper analyzes a large cross-section of countries, instead of most work that focuses on an individual country, and the combination of the cross-section and time-series dimension of the data can better identify the role of global factors for inflation dynamics over time.[3]

The analysis begins by discussing changes in the world economy that could cause global factors to have a greater role in inflation dynamics and briefly summarizes the limited literature evaluating any such effects. Increased trade flows, the greater heft of emerging markets and their impact on commodity prices, the greater ease of using supply chains to shift parts of production to cheaper locations, and a corresponding reduction in local worker bargaining power could all affect different inflation measures. These changes may not be sufficiently captured in inflation models that only control for global influences through a single measure of import prices or ignore the interaction of globalization with domestic slack. Instead, controlling for variables such as world slack, prices of non-fuel commodities (as well as of oil), exchange rates, and global supply chains, as well as interacting domestic slack with a measure of globalization, could all go some way towards better capturing changes in the global economy—even in fairly simple frameworks.

The paper then tests these various channels through which global factors may affect inflation dynamics using three different approaches: principal components, a Phillips-curve framework, and a trend-cycle decomposition. Each approach has advantages and disadvantages and encapsulates different aspects of inflation. The principal component analysis focuses on the variance in inflation and

[3] New work by Ha *et al*. (2019) and Jasová *et al*. (2018) also use large cross-sections of countries to explore how inflation dynamics have changed over time.

finds an important shared global component—but a striking divergence in how this component has evolved over time for different inflation measures. Over the last 25 years the shared global component of CPI inflation in advanced economies has more than doubled (from 27% in 1990-94 to almost 57% in 2015-17), but for core and wage inflation has fallen to about half that for the CPI. These patterns are consistent with global factors (such as commodity price volatility) playing a large and increasingly important role for CPI inflation, while having less impact on core and wage inflation. There are other possible explanations, however, and this framework does not address what is driving these patterns.

To better understand this divergence and what these patterns imply for the level of inflation in different countries, the main body of the paper shifts to the most common approach for analyzing inflation—a Phillips curve model. It augments a standard New Keynesian model with a set of global factors: exchange rates, world slack, oil prices, commodity prices, and global value chains. It also interacts domestic slack with a country's import share. When the model is estimated using fixed effects for CPI inflation for a cross-section of countries from 1996 to 2017, all of the domestic and global variables have the expected sign and are significant.[4] This long period, however, masks important changes in these relationships over time. The "Phillips curve" relationship between CPI inflation and domestic slack is significant throughout the sample, but weakens in the last decade, with much (but not all) of this "flattening" explained by increased import exposure. The role of the individual global variables in explaining inflation also increases in the last decade, especially for commodity prices (which are insignificant in the pre-crisis window). The increased role of the global variables partially reflects sharp movements during the GFC, as well as greater volatility in commodity prices and a greater elasticity of commodity prices on CPI inflation, but this is only part of the story. The other global variables are also important since the GFC, including world slack and global value chains.

In order to better understand if this more comprehensive treatment of globalization meaningfully improves the ability of basic models to explain inflation dynamics, the paper next estimates a series of rolling regressions for CPI inflation in order to allow the relationships between inflation and the different variables to fluctuate over time. The resulting rolling estimates are then used to calculate the "error" between actual inflation and inflation explained by models incorporating different controls for globalization. The results suggest that CPI inflation has become harder to explain in domestic-focused models, but that adding the more comprehensive global controls meaningfully

[4] Results when the model is estimated for individual countries vary, often reflecting different country characteristics. Forbes (2019) provides more information on country-specific estimates using a similar Phillips curve model.

improves our understanding of inflation dynamics over the last decade—by so much that the model "errors" fall to pre-crisis levels. More specifically, including the full set of global variables reduces the median prediction error for CPI inflation by about 0.34 percentage points (or 12% of median inflation) over the last decade. Including these global variables, however, does much less to improve our understanding of inflation dynamics before 2008, possibly explaining why global variables received less attention in inflation models in the past.

Given the instability in the role of different variables for inflation dynamics over time, and especially given shortcomings of the Phillips-curve framework, it is also useful to model inflation dynamics using a less structured approach. The next section of the paper shifts to an atheoretical framework that decomposes inflation into two components: a slow-moving trend and shorter-term cyclical movements. It uses the "ARSV" approach developed in Forbes, Kirkham and Theodoridis (2019), which is grounded in the unobserved component stochastic volatility model (UCSV) developed by Stock and Watson (2007), but allows the deviations in trend inflation to have an autoregressive component. The results suggest that CPI inflation is partially determined by a slow-moving trend, but the cyclical component of inflation has become more volatile and more correlated with global developments—especially world slack, oil and commodity prices. The role of different variables also changes over time, with a more prominent role for commodity prices in cyclical inflation over the last decade, but weaker role for domestic slack—supporting the conclusions from the Phillips-curve analysis of CPI inflation.

Next, the paper explores if these results for CPI inflation and its cyclical component also apply for other inflation measures—core CPI and wage inflation and the slow-moving trend in core inflation (estimated using the ARSV framework described above). Some of the key results are similar across measures, such as a significant negative relationship between each inflation measure and domestic slack, and evidence that the relationship has weakened over the last decade for core inflation and the slow-moving trend (even after controlling for interactions with increased import exposure or for the full set of global variables). A few of the global variables are consistently significant—such as the role of commodity prices for core inflation over the last decade—but most of the global variables have fluctuating significance and play a less important role. In fact, including the more comprehensive global variables only provides a minimal improvement in the fit of rolling-regression models attempting to explain core and wage inflation, even over the last decade.

This series of results, obtained using very different approaches, helps form a more comprehensive understanding of the role of globalization for different aspects of inflation. The large and growing shared global principal component in CPI inflation supports the increased variance in the cyclical component of CPI inflation, as well as the larger role for global factors in CPI inflation (in the Phillips curve model) and in the cyclical component of inflation (in the trend-cycle decomposition). In sharp contrast, the much smaller and declining shared principal component in core and wage inflation supports the greater role of the trend in core inflation, as well as the more muted role for global factors in core and wage inflation (in the Phillips curve model), and in the slow-moving component of inflation (in the trend-cycle decomposition). Linking these results, the global variables could therefore help explain the growing wedge between CPI inflation and wage inflation, which roughly corresponds to firm margins and profitability, and could therefore help explain the well-documented trend of increased profits and declining labor share in many advanced economies.

The results in this paper suggest that the changing relationship between prices and the world economy cannot be fully captured by a single variable (such as import prices). There is an important role for world slack, exchange rates, oil prices, non-fuel commodity prices, and global value chains for at least some of the different measures and aspects of inflation. One consistent finding across methodologies is also the greater role of commodity prices over the last decade—for CPI inflation, core inflation, and the cyclical component of inflation. This appears to reflect more volatility in commodity prices combined with nonlinear effects on inflation. This could also result from a greater willingness of central banks to look through inflation driven by commodity prices, or that commodity prices increasingly commove with other variables that influence inflation (such as growth in emerging markets or the spread of global supply chains). Whichever channels of globalization are most important, however, they do not appear to fully explain the weaker relationship between domestic slack and inflation. This paper confirms previous evidence of the “flattening” of the Phillips curve (albeit less so for wages than other inflation measures), and finds that although increased import exposure can explain much of this flattening for CPI inflation, it has had a more moderate effect on the slope of the Phillips curve for other inflation measures. Although globalization can make the Phillips curve seem “dormant”, especially for CPI inflation, this key relationship is not “dead”.

Finally, while these patterns apply across the sample of advanced economies and several emerging markets, it is important to highlight that the results vary when estimated for individual countries. For some economies, global factors play a dominant role in explaining the variation in inflation, while in other countries domestic variables are more important. Even in the countries for which the global variables are jointly significant, different global factors can drive the joint significance.

Exactly what global measures are most important varies based on the period and country characteristics and is an important area for future work.[5] These varied results for different countries could also be one reason why past research, which often focused on an individual country or small set of advanced economies over a shorter period, often found seemingly contradictory results for global variables.

The remainder of the paper is as follows. Section II discusses how globalization could affect inflation dynamics, including a brief literature review. Section III estimates the shared global principal components of different inflation measures and how they have evolved over time. Section IV uses a Phillips curve framework augmented with global variables and rolling regressions to evaluate the role of different factors, if their role has changed over time, and if they meaningfully improve our understanding of inflation dynamics. Section V breaks inflation into a cyclical component and slow-moving trend and then evaluates the role of the global factors in the cyclical component. Section VI repeats key parts of the analysis for core CPI inflation, wage inflation, and the slow-moving trend component of inflation. Section VIII concludes.

II. Globalization and Inflation Dynamics: The Arguments and Previous Evidence

The academic literature modelling inflation—and the many proposals to improve on these frameworks to solve new puzzles—is lengthy.[6] At the core of most models, from the simplest Phillips curve equations to the most complicated DSGE models, is a central role for domestic slack and inflation expectations. Although many papers and frameworks partially incorporate the rest of the world by adding a control for import prices (and in a few cases adding a control for global slack, or adjusting for import competition in firm markups), domestic variables remain central.[7] Global interactions play a minor, ancillary role—and in some simple models are completely ignored (albeit less so in the DSGE models used by central banks that include a fuller treatment of the international economy).[8] A common justification is that any changes in the global economy should be captured in measures of domestic slack and import prices (if the latter is included), so that these variables are sufficient statistics to control for

[5] For recent work, see Forbes (2019) and Ha *et al.* (2019).
[6] For excellent overviews that capture the key issues, see Stock and Watson (2010), Gordon (2013), Ball and Mazumder (2015), Berganza *et al.*, (2016), Miles *et al.* (2017), Blanchard (2018), and Ha *et al*. (2019).
[7] Papers studying the role of globalization in inflation include: Ball (2006), Borio and Filardo (2007), Ihrig *et al.* (2010), Berganza *et al.* (2016), Mikolajun and Lodge (2016), Auer *et al.* (2016, 2017), and Borio (2017).
[8] One noteworthy exception is Jordà and Nechio (2018), which uses the "trilemma" and how different types of countries were affected by the GFC as an instrument to estimate changes in the Phillips curve during this period.

changes in the global economy.[9] This secondary role for global effects and global interactions is surprising given the extensive literature on globalization and evidence how increased integration through trade and capital flows has affected an array of economic variables.

There are, however, a range of channels by which globalization could affect inflation dynamics. This paper focuses on four changes in the global economy that could be relevant: increased trade integration, increased role of emerging markets, increased use of global value chains to divide production across borders, and reduced worker bargaining power. There are other ways in which globalization could affect the inflation process, and many of these changes are related and could interact in important ways, but the channels in this paper provide a useful starting point.[10]

The first of these changes in the global economy, increased trade integration, is well documented. As the share of exports to GDP increases for a given economy, demand in global markets will likely have a greater impact on national income and price setting by domestic firms. Similarly, as shown in Cravino (2019), as the share of imports to GDP increases, domestic inflation will be more affected by import prices (simply due to their higher share in the price basket)—and these import prices will at least partially be determined by foreign demand conditions, foreign markups, and foreign marginal costs (assuming incomplete pricing-to-market). Closely related, as the share of traded goods to GDP increases, a given exchange rate movement could have a larger impact on prices—both through the effect on the imported component of any domestic inflation index, as well as on exporters' competitiveness, margins and pricing decisions.[11]

A second change in the global economy since the early 1990's has been the increased role of emerging markets. Emerging markets have accounted for over 75% of global growth since the GFC and been the key source of demand for commodities.[12] As a result, global commodity prices have become more tightly linked to growth in emerging markets (particularly China) and become more volatile. This could cause more volatility in inflation in advanced economies due simply to the larger price movements, volatility that could be magnified if the effects of commodity price movements on inflation are nonlinear (as in Hamilton, 2010). This would occur in sticky-price models in which firms are more

[9] See Eickmeier and Pijnenbrug (2013) for an example of this line of reasoning.
[10] See Ha *et al.* (2019) for a detailed discussion, including other channels, such as a more common framework for inflation targeting or greater synchronization of financial conditions around the world due to greater financial market integration.
[11] Obstfeld (2019), however, highlights that the effect of trade on the Phillips curve relationship is not straightforward; if increased import competition drives out smaller domestic firms and thereby increases the market power for remaining firms.
[12] See World Bank (2018) and Miles *et al.*, 2017.

likely to adjust prices after larger shocks (Ball and Mankiw, 1995). Working in the other direction, however, the reduced reliance of most advanced economies on natural resources as they shift to less commodity-intensive forms of production could lessen the impact of commodity price movements on inflation in these economies.

A third global development that could affect inflation dynamics is greater price competition and pressure on firm markups, resulting from greater ease purchasing final goods from their cheapest locations and/or using global supply chains to shift production to where it can be done at the lowest cost. [13] As a result, companies that export or compete with imports must make decisions on markups that take greater account of prices from foreign competitors. Even holding trade flows constant, greater "contestability" from global markets reduces the pricing power of companies and lowers markups, especially in sectors with less differentiated goods (Grossman and Rossi-Hansberg, 2008).[14] As it becomes easier to shift activities abroad—even just small stages of the production process—domestic costs will be more closely aligned with foreign costs.[15] A greater use of supply chains could also reduce the sensitivity of prices to exchange rate movements, as more integrated supply chains better allow firms to absorb exchange rate movements at various stages of production without adjusting final prices (Bank of International Settlements, 2015).

Finally, each of these changes in the global economy could simultaneously reduce the labor share and bargaining power of workers, dampening the key Phillips curve relationship between domestic slack and wage (and price) inflation.[16] This possibility is clearly modelled in Cravino (2019), which shows that an increase in the import share of GDP could reduce the sensitivity of inflation to domestic slack. There are also other ways in which globalization could affect this Phillips curve relationship. For example, if there is some substitution between labor and energy costs as firms attempt to keep margins constant, the greater volatility in commodity prices could weaken the relationship between wage growth and slack (Bean, 2006). Increased trade competition could make it more difficult for domestic firms to raise prices in response to tight labor markets and worker demands for higher pay (Auer *et al.*, 2013) and the increased ease of shifting parts of production to cheaper locations could

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[13] Potentially counteracting some of however, is the trend toward greater concentration in some markets, especially in the U.S. See Guilloux-Nefussi (2018) and Autor *et al.* (2017) for a discussion of how greater concentration may have increased firm pricing power.

[14] Also see Sbordone (2010), which models how an increase in traded goods reduces the slope of the Phillips curve.

[15] See Auer, Levchenko and Sauré (2016) and Wei and Xie (2018) for models of these effects of global supply chains on inflation.

[16] Blanchard (2016), Ha *et al.* (2019) and Jasová *et al.* (2018) provide evidence of the flattening of the Phillips curve for different groups of countries. Karabarbounis and Neiman (2013) provide evidence on the decline in the labor share since the 1980s.

further reduce the ability of domestic workers to bargain for higher wages (Auer *et al.* 2017). Moreover, increased mobility of some workers (such as in the euro zone), or even just the possibility of increased immigration to fill vacancies, could further reduce worker bargaining power. Although there are many other domestic developments which are also likely affecting wage growth and worker bargaining power (such as the increased role of flexible jobs in the "sharing economy" and greater employer concentration in some industries[17]), these multifaceted changes in the global economy could further weaken the link between domestic slack and inflation.

This range of channels through which globalization could be affecting firm pricing decisions suggests that a more complete treatment of global factors could improve our understanding of inflation dynamics. Simply controlling for domestic slack and import prices does not seem to be a "sufficient statistic" to capture these multifaceted ways in which the global economy affects price setting. For example, the price of foreign goods and ability to shift production through supply chains may affect pricing even if not incorporated in import prices, as foreign prices may act as a counterweight on domestic pricing decisions even if goods are not traded. Measures of slack in the domestic economy may not capture the expected evolution of slack in other major economies, expectations that could affect firm price setting and therefore inflation. The price of imported oil may fluctuate due to geopolitical events and provide little information about the changes in global demand or other input costs relevant for firm pricing decisions.

Several papers have drawn attention to the increased role of globalization on inflation dynamics, using two very different approaches. This extensive literature is well summarized in Ha *et al.* (2019). One approach estimates a global common factor or principal component for inflation in a set of countries. Examples of this approach include: Hakkio (2009), Ciccarelli and Mojon (2010), and Neely and Rapach (2011). These papers generally find a significant common global factor in inflation, but mixed evidence on whether the role of the global factor has increased over time. The major shortcoming of this approach, however, is that it does not identify what drives this common component in inflation across countries. For example, it could reflect a greater role of common shocks (such as from more volatile commodity prices), structural changes (such as increased trade or financial integration), or more similar reaction functions in central banks. Each of these influences would have different implications for forecasting inflation and inflation models.

[17] For evidence on the role of increased employer bargaining power on wage growth, see Benmelech, Bergman and Kim (2017).

The other approach for evaluating the role of globalization in inflation dynamics is to add a variable to standard models to capture a specific aspect of globalization. For example, Borio and Filardo (2007) suggests adding global slack and finds evidence that it has had a greater effect on inflation over time, even supplementing domestic slack in some cases. This result is supported in some work, but disputed in others.[18] Jordà and Nechio (2018) focus on how the 2008 financial crisis may have had global effects on inflation dynamics in different countries for an extended period. Other papers, usually using industry data, have focused on supply chains (such as Auer *et al*., 2016 and 2017). Analyses of UK inflation suggest incorporating exchange rates and commodity prices in a Phillips curve framework (Forbes, 2015) as well as in a trend-cycle model (Forbes *et al*., 2019). Ihrig *et al.* (2010) interacts key terms with measures of openness to capture how globalization could change relationships between different variables. Mikolajun and Lodge (2016) studies the role of globalization in a Phillips curve framework and is similar to parts of Section IV below.[19]

Rather than focusing on one channel by which globalization could affect inflation, or one framework, this paper takes a more comprehensive approach. It borrows from three methodologies to assess different aspects of globalization and if their roles have changed in the last decade. While this approach is broad, it is not inclusive and does not address a number of issues that could also influence inflation dynamics—such as the increased commoditization of many goods, changes in market concentration, or improved anchoring of inflation expectations. These topics are important, but have received prominent attention elsewhere.

III. First Look: The Global Principal Component of Different Inflation Measures

As an initial look at the role of global factors in inflation, this section estimates the global principal component for inflation based on four price indices: the consumer price index (CPI), core CPI (excluding food and energy prices), the producer price index (PPI), and private sector hourly earnings (wages). How important is this global component to countries' inflation rates? Has its role changed over time?

The original price indices for each series are from the OECD and IMF for as many countries as available from 1990 through 2017, with more information in Appendix A. Each inflation measure is on a

[18] Ha *et al.* (2019) provides an excellent overview of the evidence for and against a role for global slack in Annex 3.1.

[19] Mikolajun and Lodge (2016) does not use the other modelling approaches (such as trend-cycle decomposition) or control for GVCs, but adds a "global inflation" variable, which may capture other effects (such as from global pricing competition).

quarterly basis, annualized and seasonally adjusted.[20] There are up to 43 countries for each series, listed in Appendix B and divided into advanced economies and emerging markets based on IMF definitions. Data is more limited for some price series—especially for wages and early in the sample. Table 1 reports the first principal component (and first five) for each inflation measure, for the full sample, and then divided into advanced and emerging economies.[21] There is a noteworthy shared global component in CPI and PPI inflation. More specifically, 40% of the variance in CPI inflation, and 52% for PPI inflation, are explained by a single, common principal component for all countries in the sample. The role of this shared principal component, however, is substantially smaller for core and wage inflation—where the first principal component explains only about 21-26% of the inflation variation for the different samples.

As discussed above, however, there have been significant changes in the global economy that could affect inflation dynamics. To test if the role of this shared global component has changed over time, Figure 1a graphs the first principal component for each inflation measure over 5-year windows since 1990. The graph only includes advanced economies in order to have a more stable sample (as most emerging markets only have data for the later years). While the global component of the PPI has been large and relatively stable over the full period, there is a sharp divergence over time in the role of the shared component for the other inflation measures. This global component of CPI inflation has increased sharply over the sample period—more than doubling from 27% in the 1990-94 window to 57% in the 2015-2017 window. In contrast, the shared global component of core inflation has steadily fallen, from 43% at the start of the sample to 26% at the end—a pattern mirrored for wage inflation.

One challenge with this principal component analysis, however, is that it does not provide information on what drives these patterns across time and inflation measures. An increase in the principal component could be caused by: larger common global shocks (*i.e.*, greater commodity price volatility), a greater sensitivity of countries to common global shocks (*i.e.*, from greater trade or financial integration), or tighter direct linkages between economies (*i.e.*, through greater reliance on global supply chains). An increase in the first principal component could also be explained by factors that are not typically included as "globalization", such as more central banks adopting inflation targeting and therefore sharing similar reaction functions. This paper will not be able to differentiate between all of

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[20] Seasonal adjustment is performed with the X-13ARIMA-SEATS program at: https://www.census.gov/srd/www/x13as/. Data are also adjusted for well-known VAT increases that caused a one-quarter spike in inflation. The final inflation series is winsorized at the 0.1% level for each tail to remove several periods of extreme inflation (largely in emerging markets).
[21] To ensure that differences across inflation measures are not driven by sample changes, the second section of the table repeats the estimates for the smaller sample for which wage data is available.

these channels, but focuses on the more easily quantifiable measures of globalization discussed in Section II.

As a preliminary look at one factor that could be contributing to this increased comovement in CPI inflation (and which is highlighted in the results below), Figure 1b adds the standard deviation of commodity prices to the first principal components of CPI and core inflation.[22] Commodity price volatility moves closely with the shared global component of CPI inflation—with an 89% correlation for the advanced economies. This high correlation does not appear to be driven by oil prices, as the correlation between oil price volatility and the first principal component of CPI inflation is only 8%.[23] This high correlation between CPI inflation and commodity prices could reflect greater volatility in commodity prices, or a greater sensitivity of the CPI to this volatility (such as through shared responses or technological change that increases sensitivity to global developments). It could also reflect omitted factors that simultaneously affect the volatility of CPI inflation and commodity prices—such as global slack and growth in global supply chains (both shown in Appendix Figure 1 and showing similar trends over time). A more formal empirical analysis that can jointly control for these variables is necessary to better identify the role of at least some of these different global factors.

IV. The Role of Globalization in CPI Inflation

A. The Framework and Variables

To better understand what is driving these different patterns, this section focuses on the most common (albeit also regularly criticized and highly imperfect) framework for analyzing inflation: the Phillips curve. It uses a hybrid version developed in Galí and Gertler (1999) and Galí and Lopez-Salido (2005), which includes domestic slack, inflation expectations, and lagged inflation. This framework is used frequently by central bankers (see Yellen, 2017 and Powell, 2018) and has become a standard starting point for research on monetary policy (see Eberly *et al.*, 2019 and Hooper *et al.*, 2019). This analysis compares: domestic versions of the model; standard extensions with controls for import or oil prices; the "baseline" version for this paper with more comprehensive global controls; and an extension that also allows the Phillips curve relationship with domestic slack to vary with a country's global exposure.

[22] Commodity prices are measured using the IMF's index of global commodity prices, including fuel.
[23] Oil prices are measured using Datastream's index of Brent, crude spot world oil prices in US$.

More specifically, I begin with the standard New Keynesian Phillips curve for CPI inflation, which includes inflation expectations in order to allow for forward-looking behavior:[24]

$$\pi_{it} = \beta_1 \pi_{it}^e + \beta_2 \pi_{it}^L + \beta_3 SLACK_{it}^D + \alpha_i + \epsilon_{it}. \tag{1}$$

Variables are defined for each country *i* in quarter *t* as:

- π_{it} is quarterly CPI inflation, annualized and seasonally adjusted and described in Section III;
- π_{it}^e is inflation expectations, measured by the five-year ahead forecast for CPI inflation from the IMF's *World Economic Outlook;*
- π_{it}^L is lagged inflation over the previous four quarters (before quarter *t*);
- $SLACK_{it}^D$ is domestic slack, measured as a principal component of seven variables: the output gap, participation gap, and unemployment gap, and the percent deviation of hours worked, share of self-employed, share of involuntary part-time employed, and share of temporary employment from the relevant average over the sample. (More details below.)

The baseline model is estimated using fixed effects (with robust standard errors clustered by country) in order to focus on the within-country relationships. The baseline model does not constrain the coefficients on inflation expectations and lagged inflation to equal one, following recent work supporting a more flexible framework (*i.e.*, Jordà and Nechio, 2018 and McLeay and Tenreyro, 2019). Sensitivity tests show the key results are robust to random effects and constraining the inflation coefficients to equal one.

Then I estimate the triangular variant (Gordon, 1977 and 2013) with supply shocks:

$$\pi_{it} = \beta_1 \pi_{it}^e + \beta_2 \pi_{it}^L + \beta_3 SLACK_{it}^D + \gamma_1 ImpPrices_{it} + \alpha_i + \epsilon_{it}. \tag{2}$$

All variables are defined as in equation (1), except $ImpPrices_{it}$, which is measured as quarterly inflation in the country's import price index from the IMF, relative to quarterly CPI inflation. This variable is only reported for a subset of countries in the sample. Therefore, to compare results with a consistent sample, equation (2) is also estimated replacing world oil prices (Oil_{it}^W) with import prices.[25]

[24] Although some papers only control for inflation expectations or lagged inflation (or use lagged inflation to proxy for inflation expectations), controlling for both has become standard, such as in Blanchard *et al.* (2015), Eberly *et al.* (2019), Hooper *et al.* (2019), Jordà and Nechio (2018), and McLeay and Tenreyro (2019). Albuquerque and Baumann (2017) derive a model showing the importance of controlling for lagged inflation and inflation expectations simultaneously if some firms are forward-looking and set prices to maximize profits, while others are backward-looking and set prices according to past values.

[25] Also measured as quarterly inflation in the oil price index relative to quarterly CPI inflation. The oil price index is Datastream's index of Brent, crude, spot world oil prices in US$.

Next, for the baseline specification, I add a more comprehensive set of global variables to this standard domestic model to better control for changes in the global economy that could affect inflation:

$$\pi_{it} = \beta_1 \pi_{it}^e + \beta_2 \pi_{it}^L + \beta_3 SLACK_{it}^D + \gamma_1 Oil_{it}^W + \gamma_2 Comm_{it}^W + \gamma_3 ER_{it} + \gamma_4 SLACK_t^W + \gamma_5 GVC_t^W + \alpha_i + \epsilon_{it} \qquad (3)$$

Definitions for each additional variable are:

- Oil_{it}^W is defined above;
- $Comm_{it}^W$ is quarterly inflation in an index of world commodity prices (excluding fuel) from Datastream relative to quarterly CPI price inflation, lagged one quarter;
- ER_{it} is the percent change in the trade-weighted, real effective exchange rate index based on consumer prices (from the IMF) relative to two years earlier[26];
- $SLACK_t^W$ is world slack, measured as a weighted combination of the output gap in advanced economies and China. (See discussion below.)
- GVC_t^W is global value chains, measured as a principal component of four variables: the relative growth in merchandise trade (to global GDP growth), the volume of intermediate trade, the complexity of intermediate trade, and the average change in the dispersion in PPI prices for all countries in the sample. (See discussion below.)

Finally, I estimate an extension that allows the key Phillips curve relationship between domestic slack and inflation to vary based on a country's exposure to the rest of the world.

$$\pi_{it} = \beta_1 \pi_{it}^e + \beta_2 \pi_{it}^L + \beta_3 (SLACK_{it}^D * ImpSh_{it}^D) + \gamma_1 Oil_{it}^W + \gamma_2 Comm_{it}^W + \gamma_3 ER_{it} + \gamma_4 SLACK_t^W + \gamma_5 GVC_t^W + \alpha_i + \epsilon_{it} \qquad (4)$$

Equation (4) is the same as equation (3), except $SLACK_{it}^D$ is interacted with the import share to GDP.[27]

Each of these specifications in (1) – (4) is estimated with the sample for which all the domestic and global variables for the baseline in equation (3) are available. This yields a sample of 31 countries from 1996 through 2017. Appendix A provides detail on definitions and sources, and Section IV. E. examines robustness. The first three control variables (with coefficients denoted with a *β)* are the "domestic" variables, and the last five, (with coefficients denoted with a *γ*) are the "global" variables.

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[26] Relative to two years earlier due to the longer lags by which exchange rate movements pass-through to prices.

[27] Results using different interactions between openness and slack (or other variables) are also discussed below.

Although the real exchange rate captures both domestic and global influences, it is usually not explicitly included in Phillips curve regressions (only implicitly in measures of import prices in foreign currency).

These variables are measured using standard conventions in this literature, with three exceptions: domestic slack, world slack, and global value chains.[28] Beginning with domestic slack, 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. This unemployment gap may not capture 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. Therefore, I follow the approach suggested by Albuquerque and Baumann (2017) for the United States 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, I calculate the principal component using seven measures of slack. The first three are from the OECD: the output gap, unemployment gap, and participation gap. I also include a calculated percent "gap" from the "normal" level (with "normal" defined as the relevant mean for each country over the sample period) for four measures: hours worked per person employed, the share of involuntary part-time workers, the share of temporary workers, and the share of self-employed workers (with the last three as a share of total employed).[29] Many of these variables are not available for all countries in the sample, in which case I calculate the principal component using as many as are available for each country, ensuring that a consistent set of variables is included throughout the sample period.

Next, in order to measure slack in the global economy, I begin with a measure of the output gap for advanced economies reported by the IMF in the *World Economic Outlook Database*. Corresponding estimates of the output gap for other economies are not reported, and the principal components for domestic slack calculated for this paper do not include data on most major emerging and developing economies (including China). Therefore, as a proxy for slack outside the advanced economies, I estimate slack in China based on the deviation in its GDP growth from recent averages.[30] "World slack" is then

[28] Many of the variables used to create the measures of slack (domestic and global) and global value chains are only available annually, so they are interpolated to quarterly frequency.
[29] 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.
[30] The difference between average GDP growth in China over the previous two years less GDP growth in the current quarter.

estimated as the weighted average of slack in advanced economies and non-advanced economies (proxied by slack in China), with weights varying over time based on IMF estimates of the advanced economy share of world GDP. The resulting measure of world slack is shown in Appendix Figure 1a, along with the IMF's measure of slack in advanced economies and the OECD's measure of slack in OECD economies.[31] The different series largely move together, but the constructed measure of world slack used in this paper shows more slack during the GFC, and a faster reduction after the crisis, as expected given the faster recovery in the emerging markets that are not included in the IMF and OECD measures.

The final variable meriting further explanation is global value chains (GVCs). A range of different statistics on GVCs are available, but many show very different trends over time and are only available for fairly short periods. Therefore, I calculate a principal component of four different statistics. The first three are: the relative growth of merchandise trade volumes relative to global GDP; traded intermediate goods as a share of global GDP; and the share of these traded intermediate goods that are "complex" in the sense that they cross country borders at least twice. All three measures are from Li, Meng and Wang (2019).[32] The fourth variable in the principal component is the dispersion of PPI inflation across the countries in the sample for which data is available.[33] This measure is used in Auer, Levchenko and Sauré (2016) and Wei and Xie (2018) to capture how global supply chains have affected PPI indices by increasing the synchronization of producer prices across countries. Appendix Figure 1b graphs the resulting measure of global value chains, with the principal component suggesting that the role of global value chains increased quickly during the 2000s, collapsed during the 2008 crisis, largely recovered from 2009-2011, and then was fairly stable before declining slightly at the end of the sample.

B. CPI Inflation, Domestic and Global Variables: First Tests with Fixed Coefficient Estimates

Table 2 reports results for the different variants of equations (1) – (4) for CPI inflation, using fixed effects with robust standard errors clustered by country over the full period (from 1996-2017). These estimates assume that the relationships between CPI inflation and the explanatory variables are stable over time (an assumption revisited below). Columns (2) and (3) report variants augmented for supply shocks—with either import or oil prices. The more limited data on import prices reduces the sample by about half, but the other coefficient estimates are very similar when oil prices are used to expand the sample. Column (4) includes the full set of global variables, and then column (5) interacts

[31] The IMF and OECD measures are both of the output gap, which I convert to "slack" by reversing the sign.
[32] These measures were kindly shared by Zhi Wang from Li, Meng and Wang (2019).
[33] Measured as the standard deviation in quarterly PPI inflation, with inflation relative to 4Q earlier to avoid seasonal issues.

domestic slack with the import share. Columns (6)-(8) use several different specifications for the baseline in column (4). Column 6 drops inflation expectations and only includes lagged inflation (which often proxies for inflation expectations, as in Ball and Mazumder, 2011 and Gordon, 2013). Columns 7 and 8 use random effects (instead of fixed effects), with column 8 constraining the sum of the coefficients on inflation expectations and lagged inflation to equal one.

In each specification in Table 2 the domestic variables central to the Phillips curve model have the expected sign and are significant over the full period. Higher CPI inflation is associated with higher inflation expectations, higher lagged inflation, and less domestic slack. The estimated coefficients on import prices and oil prices also have the expected positive signs (although the coefficient on import prices fluctuates in significance). In the specifications with the full set of global variables in columns (4) – (8), each of the global variables also has the expected sign and are usually significant at the 1% level. More specifically, higher CPI inflation is associated with higher oil prices, higher commodity prices, larger exchange rate depreciations, lower levels of global slack and weaker global value chains. The magnitudes of the coefficient estimates on the global variables are also fairly stable across specifications (with the only exception the coefficient on global value chains). This suggests that augmenting the standard Phillips curve model with more comprehensive controls for global factors could improve our ability to explain CPI inflation dynamics.[34]

The magnitudes of the estimated coefficients also provide a sense of which variables have a more meaningful impact on inflation in this cross-section of countries. For example, focusing on the baseline results in column 4, the 0.654 coefficient on inflation expectations implies that a 1 percentage point (pp) increase in five-year ahead inflation expectations (*i.e.*, from 2% to 3%) is associated with an increase in annual CPI inflation of 0.65pp. A 10% increase in oil or commodity prices in one quarter is associated with an increase in CPI inflation of about 0.30pp. A 10% depreciation of the real exchange rate relative to two years ago corresponds to an increase in CPI inflation of 0.29pp per quarter—which if accumulated over 8 quarters would imply an increase in the level of the CPI of about 2.3pp after two years. The coefficients on the different measures of slack are more difficult to interpret given the construction of the underlying variables, but a concrete example helps put them in context. A reduction in domestic slack by 1 percent of GDP (equivalent to the reduction in US slack from 2015q3 to 2017q4)[35] is associated with inflation 0.09pp higher in each year. Similarly, a decrease in world slack by 1 percent

[34] The higher R^2 in column (2) relative to columns (3) or (4) reflects the more limited sample size. With a consistent sample, the R^2 is similar when either oil or import prices are included, and increases with the full set of global variables.
[35] To further put this in context, this measure of domestic slack increased by 5.05 in the US from 2008q1 through 2009q4.

of global GDP (which occurred from 2014q2 to 2017q4) [36] is associated with inflation higher by 0.15pp. These estimates agree with other work suggesting that the relationship between slack and inflation is very "flat", but also suggests that world slack, and not just domestic slack, my affect CPI inflation.

It is also worth noting that the coefficient on domestic slack remains highly significant and increases in column (5) when domestic slack is interacted with the country's import share, supporting the hypothesis that globalization contributes to a flattening of the key Phillips curve relationship between domestic slack and inflation.[37] To put these estimates in context, consider a country with the mean import share in this sample of 41%. Combining this import share with the estimated β_3 implies that the corresponding "Phillips curve" slope for just domestic slack is -0.56. If the country's import share was one standard deviation higher (rising to 58%), the corresponding Phillips curve coefficient falls to -0.40. This supports the hypothesis that more globalization (at least in the form of more imports to GDP) corresponds to a weaker relationship between domestic slack and inflation (as in Cravino, 2019).

These results in columns 1 through 6 capture the relationship between inflation and the other variables within countries over time. Even though these are country fixed effects, using the pooled sample of countries is an important advantage of this paper as it helps identify the different variables. The results when estimated for individual countries, however, are more often insignificant and can vary widely, often reflecting country characteristics and different forms of exposure to the global economy.[38] For example, consider two very different European nations: Germany and Iceland. World slack is negatively and significantly associated with CPI inflation for Germany, but not Iceland. Exchange rate movements are significantly associated with CPI inflation for Iceland—but not for Germany. Better understanding these different sensitivities of inflation to global factors in different countries is an important topic for research,[39] and could be one reason why studies which focus on individual countries or smaller samples can find contradicting results (such as for global slack); the composition of countries in the sample can significantly affect results (as well as other differences in methodology, time periods, and specification).

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[36] To further put this in context, this measure of world slack increased by 4.65 from 2008q1 through 2009q4.

[37] I have also estimated several variants of this interaction. First, when domestic slack is interacted with trade openness (exports plus imports relative to GDP) the β_3 remains significant and increases, but to a smaller extent (to -0.108 for column 5). Second, when an interaction between domestic slack and the import share is added to equation (3) (as suggested in Ihrig *et al.*, 2010), the interaction term is usually negative and significant, but the coefficient on domestic slack is insignificant. Third, when domestic slack is interacted with global value chains, the interaction term is often insignificant. Finally, when all the global variables are interacted with trade openness, most coefficients become insignificant and many have counterintuitive signs.

[38] See Forbes (2018, 2019) for results for individual countries of Phillips curve models.

[39] This is beyond the scope of this paper, but see Ha *et al.* (2019).

C. CPI Inflation, Domestic and Global Variables: Have the Relationships Changed?

The role of different variables in the Phillips curve framework could vary not only across countries, but also over time.[40] This could occur due to the changes in the global economy discussed in Section II, as well as due to many other factors—such as changes in domestic labor markets or the credibility of central banks. To test if the role of the domestic and global variables in these Phillips-curve based regressions have changed, I re-estimate the basic Phillips curve models in equations (1) – (4) for a "pre-crisis" window (from 1996-2007) and over the "last decade" (from 2008-2017).[41]

Table 3 reports results. Beginning with the domestic variables, inflation expectations and lagged inflation both continue to be positively associated with inflation in both periods.[42] Domestic slack continues to be negatively associated with CPI inflation, and although this relationship is significant in both periods, it becomes weaker over the last decade. More specifically, the magnitude of this "Phillips curve" association between domestic slack and CPI inflation falls by about 20% -45% across periods for the specifications in columns (1)-(4). The estimates in column 5, when domestic slack is interacted with the import share, however, provide information on whether this apparent flattening of the Phillips curve reflects a higher import share or a weaker underlying relationship between slack and inflation (after controlling for this form of globalization). The magnitude of the coefficient on this interaction term declines over the last period by a large 58%, but when the coefficient is evaluated using the mean import share in each period, the underlying Phillips curve elasticity between just domestic slack and CPI inflation only falls by 10%.[43] This suggests that globalization has caused much—but not all—of the flattening of the Phillips curve for CPI inflation, and that this key Phillips curve relationship is not "dead"—especially after controlling for globalization.

The global variables are also independently important in both windows, and more tightly linked to CPI inflation over the last decade. More specifically, higher oil prices, higher commodity prices, exchange rate depreciations, less world slack, and weaker global value chains all correspond to higher inflation in both periods. The magnitudes of the coefficients on most of the global variables also increase (in absolute value) over the last decade. All the global coefficients are significant, except on commodity

[40] For evidence, see Albuquerque and Baumann (2017), Blanchard *et al.* (2015), IMF (2016), and Mikolajun and Lodge (2016).
[41] The sensitivity analysis shows that excluding the period around the GFC has minimal impact on the key results.
[42] The coefficient on inflation expectations is insignificant over the last decade, reflecting the lack of variation in most countries. When estimated using random effects, the coefficient on inflation expectations is consistently positive and significant.
[43] The mean import share for the pre-crisis sample is 39%, and for the last decade is 43%. This suggests that the elasticity between domestic slack and CPI inflation (after controlling for the import share) is -1.05 in the earlier window and -0.95 in the later period.

prices, which are only significant over the last decade. The result that this coefficient is insignificant in the pre-crisis window, and becomes highly significant (and much larger in magnitude) in the post crisis window is robust across different specifications (see Section E). This higher elasticity between commodity prices and CPI inflation implies that a given movement in commodity prices had a greater effect on CPI inflation over the last decade. Section III (and Figure 1b), however, also showed that commodity price volatility has increased over time and closely mirrors the increased comovement of CPI inflation rates around the world. This combination of results would be consistent with standard models with menu costs and sticky-prices, in which firms adjust prices more quickly in response to larger cost shocks (*i.e.* Hamilton, 2010 or Ball and Mankiw, 1995).

Finally, F-tests of the joint significance of the five global variables (bottom of Table 3) suggest the global variables are jointly highly significant in both periods. The value of this F-statistic, however, roughly doubles in the more recent period. Part of this increase captures the greater role of commodity prices, but an *F*-test of the four other global variables (excluding commodity prices) is still highly significant (at 30.1 in the last decade for column 4), suggesting that the importance of the global variables does not just reflect the impact of commodity prices. Also, including the global variables leads to a meaningful improvement in the explanatory power of the regressions in the last decade. More specifically, in the baseline specification in column 4, adding the global variables increases the R^2 by only 0.05 in the pre-crisis window, but by 0.17 over the last decade (relative to the corresponding estimates with just the domestic variables in column 1).[44] Controlling for commodity prices is about two-thirds of this improvement in the R^2 over the last decade—although given the high correlation between commodity prices and other global developments (such as slack/growth in emerging markets), it is hard to isolate this effect.[45] This series of results supports the hypothesis that global developments are more important for understanding inflation dynamics over the last decade than before the GFC, and that commodity prices are an important part of this, but not the full story.

D. How much do Global Variables Improve our Understanding of CPI Inflation Dynamics?

But can the global variables meaningfully improve our ability to understand inflation dynamics—especially some of the puzzles over the last decade? And does the greater role of the global variables simply reflect extreme movements in certain variables and/or during certain years (such as in

[44] No single global variable accounts for the majority of the improved fit in the last decade, and many of the global variables are correlated, so simply adding one variable at a time to equation (1) could bias estimates.
[45] Estimating the regression with the domestic variables and only commodity prices for the global variables improves the within-R^2 from 0.25 to 0.33 in the last decade, compared to 0.42 with the full set of global variables.

commodity prices and/or during the GFC)? To better understand the evolving relationship between globalization and inflation, I next calculate rolling regressions for CPI inflation over eight-year windows with three model variants: with just the domestic variables (equation 1), the "triangle" model with import prices (equation 2), and the full set of domestic and global variables (equation 3). The regression windows are rolled forward one quarter at a time so that the number of observations remains constant, and in order to maintain a consistent sample across models, I only include observations with the more limited data on import prices. Many of coefficient estimates fluctuate sharply, suggesting that the role of these different variables can also change over time.

Figure 2a graphs the resulting "error" between actual inflation and inflation explained using the rolling estimates. The "error" is calculated as the median absolute value of the deviations of actual from predicted inflation for each country in each quarter, so that a lower value indicates a better model fit (and estimates that are too high or low are equal misses). The graph shows the superior performance of the model with the global variables (in red) relative to that with only the domestic variables (in grey) and with the domestic variables plus import prices (dashed black). Although the errors are similar in some quarters, especially in the first part of the sample, the errors are meaningfully smaller in the global model during most quarters over the last decade. The biggest improvements are during the GFC—when the errors of the domestic models spike—but there are also noteworthy improvements from including the global variables over much of the window from 2011-2015.

Figure 2b attempts to better quantify this visual improvement in the global model's performance. It graphs the same "errors" in predicted inflation for the same three models, averaged over the full period, pre-crisis window and last decade. Over the pre-crisis window, the median absolute error is 0.90pp for the model with just the domestic variables, and falls to only 0.82pp with the addition of the five global variables. In contrast, over the last decade, the median error jumps to 1.11pp for the model with just the domestic variables, but falls more meaningfully to 0.77pp with the addition of the global variables. (Including just import prices instead of the full set of global variables only yields a minor improvement, with the median error falling to 1.05pp.) The improvement is also meaningful when assessed relative to median inflation rates—with the reduction in errors from adding the global variables equal to 12% of median inflation over the last decade (and 5% in the pre-crisis window).[46]

[46] Calculated as the reduction in median errors from adding the global variables relative to median inflation in that window. For example, over the last decade median inflation was 2.87%, so the corresponding calculation is: (1.11-0.77)/2.87=12%.

These results confirm that Phillips curve models were less successful at explaining inflation over the last decade if they only included domestic variables or limited global controls. They also show, however, that adding more comprehensive controls for global factors can reduce the model's errors over the last decade such that the overall explanatory power slightly improves—instead of deteriorating (relative to pre-crisis performance). But how much of this improvement over the last decade occurs during the GFC—when the global model outperforms the other variants by the largest margins in Figure 2a? To test this, Figure 2c breaks down the median errors over the last decade into three periods: around the crisis (2008-2010) and then from 2011-2014 and 2015-2017 (for comparison with Figure 1).[47] Including the global variables generates a particularly large improvement in the model's fit during the crisis window (reducing the errors from 1.51pp to 0.90pp), but continues to meaningfully reduce the errors outside the crisis window (from 1.07pp to 0.82pp over 2010-14 and 0.84pp to 0.68pp over 2015-17). When these improvements are assessed relative to median inflation rates for each window, they correspond to an improvement of 27% during the crisis window, 17% over 2011-14, and 18% over 2015-2017 (when median inflation was only 0.86%).

How much of this improved fit from including the five global variables over the last decade reflects the influence of commodity prices? Commodity price volatility has increased sharply (Section III and Figure 1b) and the elasticity of a changes in commodity prices to CPI inflation has increased over the last decade (Section IV. C). Both of these changes could cause commodity prices to explain a larger share of the variation in CPI inflation. To test if the increased role of the global factors is primarily capturing the effects of commodity prices, I reestimate the rolling regressions for CPI inflation using two variants: only include commodity prices as a global variable, or include all four global variables except commodity prices. Figure 2d shows the resulting median errors. Including commodity prices improves the model fit from that with just the domestic variables, but only yields part of the error reduction compared to for the full set of global variables. Including the other four global variables (but not commodity prices), yields a larger improvement in each window. This further supports the hypothesis that a more comprehensive treatment of global variables is important--and the key changes in the global economy cannot be captured with single measure (including just commodity prices).

As a final test, and to better understand the role of these global variables to inflation puzzles over the last decade, Figure 3 shows the impact of each of the global variables and domestic slack on US CPI inflation from combining the coefficient estimates from the full global model (used for Figure 2) and

[47] Breaking out results for the earlier 5-year windows in Figure 1 show errors similar to the pre-crisis window.

US data. The global variables have had a meaningful effect on US inflation over some windows. In the period immediately after the peak of the GFC, when US inflation was higher than expected, oil prices, commodity prices, and the dollar's depreciation all contributed to higher inflation. In contrast, over the window from 2012-2016, global variables such as dollar appreciation, the increased use of global value chains, high levels of world slack, and periods of lower oil and commodity process, all contributed to keeping CPI inflation lower than would have been expected given the decline in US slack. The magnitudes shown in the chart suggest that the contribution of the global factors changes over time, and that although the contributions of individual global variables can be small, their combined effect can be larger than that of domestic slack. The global variables can be important for understanding inflation dynamics, even in a large economy such as the US that is relatively less exposed to the global economy.

E. CPI Inflation, Domestic and Global Variables: Sensitivity Tests

The key results that the global variables have played a more important role, and domestic slack a weaker (but still significant) role, in explaining CPI inflation over the last decade are based on estimates that required making a number of choices about specification, variable definitions, and timing conventions. Therefore, the remainder of this section summarizes a series of sensitivity tests exploring if these key results are robust. It focuses on the baseline equation (3), which uses the full set of domestic and global variables and compares the pre-crisis period to the last decade, and performs over twenty sensitivity tests which can be roughly categorized into three groups:

(1) Different variable definitions: Several papers have highlighted the challenges in measuring the output gap (or slack) and global value chains,[48] so I try several different measures. To measure domestic slack, instead of using a principal component drawing information from up to seven different variables, I simply use the "unemployment gap" (the difference between unemployment and NAIRU, reported by the OECD) or a simpler principal component which draws information from only three variables—the unemployment gap, output gap, and participation gap (all from the OECD and more consistently available across countries than the larger set of variables). I also interact domestic slack with the variable for global value chains or the country's trade openness (measured as total trade to GDP). Then, instead of using a constructed measure for world slack which incorporates growth in China, I use the IMF measure of global slack (which only includes

[48] See Albuquerque and Baumann (2017), Hong *et al.* (2018), and discussion in Section IV.A.

advanced economies) or the OECD measure of global slack (which only includes OECD members). Finally, instead of using the principal component of several measures to capture the role of global value chains, I use the ratio of traded intermediate goods to GDP or growth in exports from China (over the last four quarters).

(2) Different time periods and country samples: The analysis above highlights how the relationships can change over time, especially during the GFC. Therefore, I re-estimate the model, except exclude just 2008, or exclude 2008-2009. Also, although the sample only includes a few emerging markets due to data availability, I reestimate the model using only advanced economies.[49]

(3) Different specifications: There is some evidence that the relationship between domestic slack and inflation is non-linear, so I try three variants proposed in Hooper *et al*. (2019): a "spline" model (which allows the slope of the Phillips curve to vary when labor markets are tight by adding a dummy variable when slack is negative); a "cubic" model (which includes squared and cubed slack); and a "piecewise quadratic" model (which allows for non-linearity in countries with less slack by including slack squared when slack is negative).[50] Next, I include the restriction that the sum of the coefficients on inflation expectations and lagged inflation equal one, or exclude inflation expectations and assume that lagged inflation can proxy for inflation expectations (as in Ball and Mazumder, 2011 and Gordon, 2013), or use random effects. I also try different combinations of the global variables, such as only including one control for commodity prices (including oil and commodity prices together), or only including world slack. Finally, I experiment with different lag structures and timing conventions for key variables—such as focusing on annual changes in oil and commodity prices (instead of quarterly), or different lengths of time for the pass-through from exchange rate movements to inflation.[51]

Appendix Table 1 reports a selection of these sensitivity tests, including those that have received the most attention in other papers or that vary meaningfully from the baseline. Most of the key results discussed above are robust to these changes, and most of these modifications do not improve the model fit, but a few changes are worth noting. In some cases the different variable definitions and specifications matter. For example, when domestic slack is measured with the less comprehensive

[49] The sample of emerging markets is so limited that results for this group are not robust to minor changes in specification.
[50] For more details on these specifications, see Hooper *et al.* (2019). Also see Gagnon and Collins (2019) for evidence of nonlinearity.
[51] Forbes, Hjortsoe and Nenova (2017 and 2018) discusses the challenges in measuring the duration of pass-through from exchange rate movements to inflation.

measure (just the unemployment gap instead of a principal component, in Column 1), it is less often significant (as in Hong *et al.*, 2018). Similarly, using a narrower measure of world slack that does not include slack in emerging markets (column 2) reduces the magnitude of the coefficient on world slack meaningfully over the last decade. Using different measures for global value chains can affect its sign and significance. The non-linear specifications for domestic slack also yield mixed results for the coefficients on slack—with significance varying based on exactly where thresholds are set and which non-linear specification is used—but generally has no effect on the other key variables.

These modifications to the baseline specification suggest that the key results highlighted above are robust to a wide range of definitions, samples, and specifications. More specifically, higher inflation is associated with higher lagged inflation in both periods, and with less domestic slack. The Phillips curve relationship between CPI inflation and domestic slack appears to have weakened and often becomes insignificant if the 2008-2009 crisis is excluded. This "flattening" persists even when the full set of global controls is included, or when domestic slack is interacted with different measures of openness, although much of this flattening reflects greater import exposure.[52] Global variables are consistently significant in both periods, except global commodity prices, which are only consistently significant over the last decade. An F-test of the joint significance of the global variables (at the bottom of the table) indicates that the global variables are jointly significant in all the specifications. This joint significance is not just a crisis-related effect, as the global variables are each still significant over the last decade when 2008 (or 2008-2010) are excluded from the sample (column 4).

F. CPI Inflation: Summary of Phillips Curve Analysis

To summarize, this section finds that the Phillips curve relationship between domestic slack and CPI inflation has flattened (but is not "dead"), and a meaningful share of this flattening reflects increased import exposure. Global variables are also independently important in explaining CPI inflation, suggesting that a component of inflation is "determined abroad", particularly during the last decade. Greater volatility in commodity prices, combined with a greater impact of commodity prices on CPI inflation, are part of the reason for this increased role of global factors. This may reflect a greater role of commodity prices, or could capture shifts in global demand, especially changes in the growth outlook for emerging markets that are closely linked to commodity demand. But commodity prices are not the full

[52] When domestic slack is interacted with openness, the coefficient is still negative and significant and becomes smaller in absolute value during the last decade; when domestic slack is interacted with GVCs the coefficient is insignificant in both windows.

story. The results also suggest that world slack, oil prices, exchange rate movements, and global value chains all play a role, and that over the last decade it has become even more important to include a broad set of controls for globalization to understand CPI inflation dynamics.

V. An Alternate Framework to Test for The Role of Globalization: Trend-Cycle Analysis

Although the Phillips curve relationship between slack and inflation is central to most frameworks for thinking about inflation, and models such as equations (1) and (2) are frequently used by policymakers and academics, this framework has a number of shortcomings. As shown above, parameter instability could limit their ability to explain inflation dynamics in real time and forecast inflation. As also highlighted in McLeay and Tenreyro (2019) and Jordà and Nechio (2018), if monetary policy is endogenous to expected inflation, this could weaken the relationship between inflation and other variables expected to impact inflation (such as domestic slack). Other frameworks can therefore be a useful compliment. One such framework is a “trend-cycle” approach, which separates inflation into a slow-moving, persistent trend and a temporary cyclical component. This section uses this approach to analyze CPI inflation, evaluate the role of the same domestic and global factors, and test if their role has changed over time.

A. The Trend-Cycle Model

Although the majority of work analyzing and forecasting inflation has focused on structural relationships grounded in the Phillips curve framework, Stock and Watson (2007) provides an alternate, data-driven and more atheoretical approach. It proposes focusing on the time-series dynamics of price levels to isolate a low frequency and slow-moving component of inflation (the “trend”) from deviations around this trend (what I call the “cycle”). Stock and Watson (2007) develops this framework in an unobserved component stochastic volatility (UCSV) model, which inspired a series of papers. Most of these papers have focused on inflation dynamics in the U.S. (such as Stock and Watson, 2010, Chan *et al*., 2013, and Cecchetti *et al.*, 2017), while Cecchetti *et al.* (2007) applies the UCSV model to the G-7 countries, and Forbes *et al*. (2019) builds on these models to analyze inflation dynamics in the U.K.

This section applies the trend-cycle model developed in Forbes *et al.* (2019) to the larger sample of developed and emerging markets used in this paper. This model is grounded in the UCSV model developed by Stock and Watson (2007), but also allows deviations in trend inflation to follow an autoregressive process (as in the ARUC model developed in Chan *et al.*, 2013), with minimal other assumptions. This resulting "ARSV" model used below (and discussed in detail in Forbes *et al.,* 2019 and Forbes, 2019) can make it more difficult to achieve convergence, but better captures the inflation dynamics in this paper's more diverse sample of countries (as compared to the US example for which the original UCSV model was developed).

This framework can be used to estimate trend inflation (τ_t) for CPI and core inflation for each of the countries in the sample, using the quarterly, annualized, seasonally-adjusted inflation data from 1990 through 2017 discussed in Section III and Appendix A.[53] The resulting estimates of trend inflation are then subtracted from CPI and core inflation to back out the "cyclical" component of inflation for each country, with key statistics reported in Appendix Table 2.[54] Columns 1 and 2 report the average distance from the 15th to the 85th percentiles of the estimated trends and suggest there is some imprecision in the estimates (with an average distance of 0.95 and 0.71 for CPI and core inflation, respectively). Columns 3 through 6 show that the median variances of the trends are substantially lower than for the cyclical components, consistent with the trend as a slow-moving and more stable component. Columns 7 and 8 report the percent of the variation in inflation for each country explained by the trend.[55] Over the full sample period, the trend explains 31% of the variation in CPI inflation and 55% in core inflation. This suggests that most of the volatility in CPI inflation in advanced economies is driven by short-term cyclical movements (albeit the volatility in the trend still plays a meaningful role), while volatility in core inflation is driven by roughly equal contributions from the cyclical and trend components. Also noteworthy are changes over the two periods, with the variance in the trend falling over last decade, while the variance in the cyclical component of CPI inflation (but not core), increases in the later period. This would be consistent with greater volatility in commodity prices over the last decade. At the same time, however, the role of the slow-moving trend has increased over the last decade—for both CPI and core inflation.

B. The Cyclical Component of CPI Inflation: The Role of Domestic and Global Variables

What is the relative importance of the domestic and global variables in this framework? Has their role changed over time? To answer these questions and facilitate a comparison with earlier parts of this

[53] The first 12 observations for each country are used to calibrate the prior information, resulting in a trend inflation from 1993 through 2017 for most advanced economies (but limited coverage of emerging markets). Estimates are the (pointwise) median of 1000 draws. If the algorithm did not converge within five hours, the estimation was terminated.

[54] Most emerging markets do not have sufficient data to calculate the trend for the longer periods for this table, and for the few which do, all have periods of very high inflation which skew estimates. See Forbes (2018 and 2019) for estimates by country.

[55] Calculated as: $\frac{\sum_{t=1}^{T} (\tau_t - \bar{\pi}_t)^2}{\sum_{t=1}^{T} (\pi_t - \bar{\pi}_t)^2}$.

paper, this section focuses on the same domestic and global variables as in the Phillips curve analysis in Section IV. To assess the ability of these variables and the slow-moving trend to explain the cyclical component of inflation, I estimate the following fixed-effects model for the full sample from 1993 through 2017:

$$\pi_{it} = \alpha_i + \beta\tilde{\tau}_{it} + \sum_{k=1}^{7} \boldsymbol{\gamma_k X_{kit}} + e_{it}. \qquad (5)$$

The π_{it} is CPI inflation for country *i* in quarter *t* (seasonally-adjusted and annualized), $\tilde{\tau}_{it}$ is the slow moving trend (estimated in Section V.A.), and the $\boldsymbol{X_{it}}$ are *k* additional variables that could help explain the cyclical movements in inflation around this trend. Following the format in Section IV, the variables in X_{it} begin with just domestic variables (inflation expectations and domestic slack), then add a control for oil prices (to focus on a consistent sample)[56], then the full set of five global variables (world oil prices, world commodity prices, the country's real exchange rate, world slack, and global value chains), and then extend this with an interaction of domestic slack with the import share.[57] Each variable in $\boldsymbol{X_{kit}}$ is defined as in the last section, with details in Appendix A.

Columns (1)-(4) of Table 4 report results for the full sample period. The coefficients on the trend are highly significant, showing an important role for the trend in CPI inflation (which is not surprising given that the trend is a function of the inflation data). The other variables have the expected sign, and all except the exchange rate are significant in the baseline. As noted above, however, the relationships with inflation could change over time. To test this, Table 4 also reports results for the pre-crisis period and last decade. The coefficient on trend inflation increases by about 1/3 in the last decade in the baseline.

A comparison of the other estimates for the two different windows yields similar conclusions as for the Phillips curve results in Table 3. CPI inflation is associated with less domestic slack, and this relationship is meaningfully weaker over the last decade, although slack continues to be significant. When domestic slack is interacted with the import share, the underlying Phillips curve relationship between just domestic slack and cyclical inflation still declines, although by less, and the decline is still meaningful even after adjusting for changes in the import share.[58] The global variables usually have the expected sign, and are often (but not always) significant. Higher oil prices and less world slack are

[56] Substituting import prices does not change any of the key results, but shrinks the sample by more than half.
[57] Lagged inflation is not included due to its high collinearity with the trend.
[58] More specifically, after adjusting for the increase in the import share from 38% to 42% across the two periods in this sample, the underlying Phillips curve coefficient evaluated at the sample means declines by 16%.

significantly correlated with higher CPI inflation in both periods, and higher commodity prices are only significant in the later period. Real exchange rate depreciations are not significantly correlated with this component of CPI inflation—although any such effects may now be captured by the slow-moving trend since the pass-through effects of exchange rates on inflation tend to be prolonged. Global value chains are also usually not significant at the 5% level.

The bottom of Table 4 provides final evidence on the role of the global variables for the cyclical component of CPI inflation, and how their role has changed. F-tests suggest that the global variables are jointly significant in the pre-crisis period, but add minimal explanatory power. In the last decade, however, the F-statistics of the joint significance of the global variables are much larger, and adding the global variables increases the R^2 by about three times more. As also found for CPI inflation, the explanatory power of the domestic models falls over the last decade, but including the full set of global variables can improve the model's fit to around pre-crisis levels (at least as assessed by the R^2). Also, once again, much of this improvement—but not all—comes from including world commodity prices.[59] This supports the conclusion in the last section that more comprehensive controls for global variables have become more important for understanding inflation dynamics in the last decade, and that commodity prices are part, but not all, of the story. A series of the same sensitivity tests reported in the last section supports each of these conclusions.

VI. The Role of Globalization in Core Inflation, Wage Growth, and the Trend

Over the last decade, CPI inflation and the cyclical component of CPI inflation have had a weaker relationship with domestic slack (partly explained by increased import exposure) and a stronger relationship with global variables—especially commodity prices. Do these patterns apply to other measures of inflation—such as core CPI, wages and the slow-moving trend—all of which might be more tightly linked to domestic developments and less sensitive to global factors?

A. Core and Wage Inflation: The Role of Domestic and Global Variables

To begin, I return to the Phillips-curve model discussed in Section IV, and repeat the analysis for core CPI and wage inflation (defined in Appendix A), measured quarterly, seasonally-adjusted and annualized. I continue to report four specifications for each inflation measure: with only domestic variables, adding

[59] When commodity prices are dropped from the set of global variables, the F-statistic from a joint test of the global variables is 52.5 and the R^2 is almost unchanged at 0.47 for the period covering the last decade.

import (or oil) prices, adding the full set of global controls (the baseline) and an extension that interacts domestic slack with the import share. I make three changes from equations (1)-(4) to more closely follow the literature: (1) instead of including oil and commodity (ex-fuel) prices separately, I just include one broader commodity price index;[60] (2) drop real exchange rate movements in the model of wage growth (which would capture Balassa-Samuelson effects); and (3) add a control for productivity growth to some models of wage growth.

Table 5 reports results for core inflation over the full period, the pre-crisis window (1996-2007) and last decade (2008-2017). Some of the results are similar to those for CPI inflation. Higher core inflation is positively correlated with higher inflation expectations (which is more consistently significant across windows), higher lagged inflation, and less domestic slack, and the elasticity with domestic slack has weakened in the last decade. Results when slack is interacted with the import share, however, suggest that most of this flattening reflects a weaker underlying relationship between domestic slack and core inflation, even after controlling for the import share.[61] Adding the global variables has less impact, and they are less often significant. Commodity prices continue to be positively and significantly associated with inflation in the last decade, but not the pre-crisis window, and the magnitude of the estimated effect is more muted (about half that for CPI inflation). The other global variables are usually insignificant over the last decade (with the significance of exchange rates and world slack fluctuating across specifications). Not surprisingly, adding the global variables leads to a much more muted improvement in the explanatory power of the regression in all the windows.[62] More specifically, even though an F-test suggests that the global variables are jointly significant in each period, adding the global variables only improves the R^2 by 0.01 for the full sample and by 0.02 for the last decade (compared to 0.07 and 0.17, respectively, for CPI inflation).

To check the robustness of these results, I repeat the same series of over 20 sensitivity tests reported for the CPI regressions in Section IV.D. A sample of estimates are in Appendix Table 3. The results highlighted above are robust; the association between core inflation and domestic slack is still usually significant, but has weakened over the last decade, and increased import exposure only plays a

[60] If oil prices are included separately (as in the CPI regressions), the coefficient is usually insignificant. I lag the broader measure of commodity prices by one period to allow for slower pass-through to core and wage inflation.
[61] More specifically, when the coefficient on domestic slack is adjusted for the increase in the mean import share across periods (from 39% to 43%), this still implies a decline in the underlying Phillips curve coefficient of about 39%.
[62] The significance of the coefficient on world slack fluctuates based on what other variables are included and the specification. For example, when domestic slack is measured using the non-linear specifications, or if domestic slack is interacted with GVCs or trade openness, the coefficient on world slack often becomes significant.

minor role in explaining this "flattening". Global variables usually have the expected sign, but are less often significant, with the noteworthy exception of commodity price inflation, which is more tightly linked to core CPI inflation over the last decade. Exchange rate depreciations can be significantly associated with higher core inflation, especially in the pre-crisis window and over the last decade when the peak year of the crisis (2008) is excluded.

Table 6 reports the comparable results for wage inflation. The sample size is meaningfully smaller—so results are not as comparable across inflation measures. With this caveat, wage inflation is less strongly correlated with inflation expectations or lagged inflation, but continues to be negatively and significantly associated with domestic slack. This Phillips curve relationship does not appear to have weakened over the last decade (with or without the interaction between domestic slack and the import share)—even when the full set of global controls is included. It is worth highlighting that these results partially reflect the focus on within-country changes through the fixed-effects specification. When the model is estimated with random effects (shown in the sensitivity tests), inflation expectations and lagged inflation are more often significant, while domestic slack is weaker and often insignificant. Higher wage growth is also positively correlated with higher productivity growth in the pre-crisis window (as expected), but this relationship seems to reverse over the last decade. Including productivity growth also shrinks the sample size, so I focus on results without this control. The global variables have the expected signs, and are often significant for the full period, but not the shorter windows. This suggests that global variables may play a role in explaining differences in wage growth over longer periods, but not shorter windows.

To check the robustness of these results, I repeat the same series of over 20 sensitivity tests in Section IV.D. Key results are in Appendix Table 4. The one consistent result is that most variables are not consistently significant. The most robust finding is that higher levels of domestic slack are correlated with lower inflation, although this relies on using a fixed-effects model. When the cross-country dimension is included (such as column 7), the relationship between domestic slack and wage inflation often weakens and becomes insignificant. There is also stronger evidence of a nonlinear relationship between wages and slack than for the other inflation measures. These results suggest a more limited role for the global variables in wage inflation than for CPI or core inflation. This is supported by the F-tests of the joint significance of the global variables (bottom of the table) which suggest that the global variables are rarely significant (unlike for CPI and core inflation). Wage inflation is still primarily a domestic phenomenon and does not appear to be "determined abroad."

As a final test of whether the global variables can improve our understanding of core CPI and wage dynamics, and especially if the role of these variables has changed over time, I return to the analysis with rolling regressions from Section IV.D. I estimate rolling regressions for core and wage inflation over eight-year windows for the different models in Tables 5 and 6, and then calculate the "error" between actual inflation and inflation explained by the model in each quarter. The resulting errors for the different models are shown in the top panels in Figure 4. The simple model is far more successful at explaining core inflation than wage inflation, with not only lower "errors", but much less variation over time. The graphs also suggest that adding the global variables does little to reduce the errors for either core or wage inflation—with the lines for the different models very close to each other.

To more formally capture differences in the explanatory power of the different models, the bottom of Figure 4 reports summary statistics of the estimated errors. The graphs are a sharp contrast to the same analysis for CPI inflation. There is no meaningful reduction in the errors from adding the global variables over any period for core inflation (with the largest improvement only 0.12pp during the 2008-10 window). There are slightly more modest improvements for wage inflation over the last decade (such as the median error falling by 0.17pp during the 2008-10 window and by 0.13pp from 2011-2014), but no improvement in 2015-17. When these errors are assessed relative to median core and wage inflation, the improvements are also much more modest than for CPI inflation, with the global variables only improving the "fit" by 2.9% and 2.6% for core and wage inflation, respectively, as compared to 11.8% for CPI inflation, over the last decade.[63]

B. Trend Inflation: The Role of Domestic and Global Variables

To further explore the role of globalization for other measures of inflation, I return to the trend-cycle decomposition from Section V. Global factors had become more important for the cyclical movements in CPI inflation around its trend, but what explains this slow-moving trend? Are global factors less important for this more persistent component of inflation—just as they seem to be less important for the slower-moving core and wage inflation than the CPI?

To better understand the slow-moving trend—especially for core inflation where the global variables play a less important role—this section uses the estimates of trend core inflation (from Section V.A) and follows Cecchetti *et al.* (2017) and Forbes *et al.* (2019) to examine its correlates:

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[63] Calculated as the reduction in the median error from adding the global variables relative to median inflation in that window. Median core and wage inflation over the last decade are 2.64% and 3.82%, respectively.

$$\Delta\tilde{\tau}_{it} = \alpha_i + \sum_{k=1}^{7} \boldsymbol{\gamma_k} \Delta \boldsymbol{X_{kit_t}} + e_{it} , \quad (6)$$

where all variables are defined above, except now expressed in first differences.[64] As explained in Cecchetti *et al*. (2017) it is necessary to estimate the equation in first differences due to the assumption that the trend is a random walk (equation 5), so that the level of inflation is non-stationary.

Table 7 reports results from these panel regressions of trend core inflation on similar groups of variables as in equations (1)-(4).[65] Domestic slack continues to be negatively correlated with inflation, and this relationship continues to weaken over the last decade (including when slack is interacted with the import share). The "flatter" Phillips curve relationship over the last decade is only partially due to increased import exposure, with a meaningful decline that does not appear to reflect globalization (through the interaction term or other global controls).[66] The global variables show noteworthy differences relative to the comparable regressions for the cyclical component of CPI inflation, but results are closer to the estimates for core and wage inflation (as would be expected). Most of the global variables are not significantly correlated with inflation. The only global variable significant at the 5% level (in the earlier period and sometimes the later window) is exchange rates— the global variable that was not significantly correlated with the cyclical component of inflation in Table 4. This suggests that exchange rates have more persistent effects on inflation than the other global variables. The global variables are not jointly significant, however, and the overall fit of these regressions is fairly low—with the within-R^2 only 0.02 with the full set of global variables in the last decade. While global variables can meaningfully improve our ability to understand CPI inflation and the cyclical component of CPI inflation over the last decade, they only have limited ability to improve our understanding of the dynamics of the underlying, slow-moving trend in inflation, and they do not appear to have become more important over the last decade.

VII. Summary and Conclusions

The global economy has changed in many ways over the last twenty years—including through increased trade and financial integration, a greater role for emerging markets in driving global growth and

[64] The change in the trend is relative to the previous quarter. The change in the other variables is relative to one year ago for the base case in order to allow for lagged effects on trend inflation. Sensitivity tests show that using different lag structures does not affect the key results. The current approach reduces concern about seasonality.
[65] I use the full set of control variables but exclude lagged inflation, which is highly correlated with the trend.
[66] The Phillips curve coefficient falls from -0.35 to -0.10 across the two periods when evaluated at the mean import shares.

commodity price fluctuations, and the increased use of global supply chains to shift segments of production to cheaper locations. These forms of globalization could all affect inflation dynamics. They could also simultaneously weaken the role of domestic factors in inflation models, explaining the recent "flattening" in the Phillips curve relationship between domestic slack and inflation in many economies.

This paper uses three different approaches (principal components, a Phillips curve framework, and a trend-cycle decomposition) to evaluate the role of global factors for the dynamics of different inflation measures (CPI, core CPI, wages, the cyclical component and slow-moving trend) and assess if the role of the global factors has changed over time or can explain the flattening of the Phillips curve. The rich set of results helps form a more comprehensive picture of how globalization has influenced different price dynamics. Global factors play a significant and increasingly important role in the dynamics of CPI inflation and the cyclical component of inflation. Part of this reflects increased volatility in commodity prices—but not all. Global factors have played a more muted role, but can still be significant, for core inflation, wage inflation, and the slow-moving trend in core inflation, with little evidence that the role of the global variables has increased for any of these inflation measures over the last decade. The relationship between most measures of inflation and domestic slack has weakened over the last decade, even after interacting domestic slack with a country's exposure to the global economy or including more comprehensive controls for globalization that are often cited as causing the flattening of the Phillips curve. This does not mean, however, that the traditional domestic factors are no longer relevant for inflation; domestic slack continues to play a significant role (albeit often smaller) for many specifications and inflation measures, especially for core and wage inflation. Moreover, the weaker relationship between domestic slack and the different measures of inflation may reflect central banks being more attentive to slack and more willing to look-through changes in inflation that result from other factors, such as commodity price movements, which have had a stronger relationship with CPI inflation over the last decade.

The results in this paper also raise a number of new questions. Are the changes in the relationships between the global factors and CPI inflation that have occurred over the last decade long lasting? If these developments have contributed to higher margins, a higher profit share and reduced labor share—are they sustainable? If global variables have dampened CPI inflation over the last few years, could inflation quickly rebound if increased tariffs reduce the use of global supply chains? Which country characteristics determine the role of these different global variables for individual countries? And could other aspects of globalization be affecting inflation dynamics—such as changes in global capital flows or the "superstar" effect that is leading to increased firm concentration in some industries? Finally, given the key result that global variables have become more important for understanding CPI inflation dynamics, but not wage inflation, could these patterns help improve our understanding of the factors behind the declining labor share in global income?

While this paper leaves many questions for future work, it makes some progress in understanding recent inflation puzzles. Simple frameworks for understanding inflation dynamics are not "dead", and even though inflation has been "dormant", some of the puzzling patterns in CPI inflation can be explained by CPI inflation being more "determined abroad". In fact, the explanatory power of basic models for CPI inflation are meaningfully improved over the last decade with the addition of the global variables discussed in this paper. This does not mean, however, that there is no longer a role for central banks or domestic developments in inflation dynamics. Even though CPI inflation is increasingly affected by globalization, and most inflation measures move less tightly with domestic slack, domestic variables are still important determinants of inflation dynamics.

REFERENCES

Albuquerque, Bruno and Ursel Baumann. (2017). "Will US Inflation Awake from the Dead? The Role of Slack and Non-Linearities in the Phillips Curve." *European Central Bank Working Paper Series No. 2001.*

Auer, Raphael, Claudio Borio and Andrew Filardo. (2017). "The Globalisation of Inflation: the Growing Importance of Global Value Chains." *Bank for International Settlements Working Paper No. 602*.

Auer, Raphael, Kathrin Degen and Andreas Fischer. (2013). "Low-wage Import Competition, Inflationary Pressure, and Industry Dynamics in Europe." *European Economic Review* 59 (issue C): 141-166.

Auer, Ralphael, Andrei Levchenko and Philip Sauré. (2016). "International Inflation Spillovers through Input Linkages." Mimeo. University of Michigan.

Autor, David, David Dorn, Lawrence Katz, Christina Patterson and John Van Reenan. (2017). "The Fall of the Labor Share and the Rise of Superstar Firms." MIT Working paper, available at: https://economics.mit.edu/files/12979.

Ball, Laurence. (2006). "Has Globalization Changed Inflation?" *NBER Working Paper 12687.* November.

Ball, Laurence and N. Gregory Mankiw. (1995). "Relative-Price Changes as Aggregate Supply Shocks." *The Quarterly Journal of Economics* 110(1): 161-193.

Ball, Laurence and Sandeep Mazumder. (2015). "A Phillips Curve with Anchored Expectations and Short-term Unemployment." *IMF Working Paper No 15/39.*

Ball, Laurence and Sandeep Mazumder. (2011). "Inflation Dynamics and the Great Recession." *Brookings Papers on Economic Activity,* Spring, pgs. 337-381.

Bank for International Settlements. (2015). “Another Year of Monetary Policy Accommodation.” *85th Annual Report*, Chapter 4, pgs. 65-82.

Bean, Charles. (2006). “Globalisation and Inflation.” *Bank of England Quarterly Bulletin* Q4, pgs. 468-475.

Benmelech, Efraim, Nittai Bergman and Hyunseob Kim. (2017). “Strong Employers and Weak Employees: How Does Employer Concentration Affect Wages?” *NBER Working Paper No. 24307.*

Berganza, Juan Carlos, Petro del Rio and Fructuoso Borrallo. (2016). “Determinants and Implications of Low Global Inflation Rates.” *Banco de Espana Documentos Ocasionales No. 1608*.

Bernanke, Benjamin. (2007). “Inflation Expectations and Inflation Forecasting.” Speech delivered at the *Monetary Economics Workshop of the National Bureau of Economic Research in Cambridge, MA,* July 10.

Blanchard, Olivier. (2018). “Should We Reject the Natural Rate Hypothesis?” *Journal of Economic Perspectives* 32(1): 97-120.

Blanchard, Olivier. (2016). "The U.S. Phillips Curve: Back to the 60s? " *Peterson Institute for International Economics Policy Brief Number PB16-1.*

Blanchard, Olivier, Eugenio Cerutti and Lawrence Summers. (2015). “Inflation and Activity: Two Explorations and their Monetary Policy Implications,” in *Inflation and Unemployment in Europe: Conference proceedings*, ECB Forum on Central Banking, Frankfurt: European Central Bank.

Borio, Claudio. (2017). “Through the Looking Glass.” BIS Lecture. 22 September.

Borio, Claudio and Andrew Filardo. (2007). “Globalisation and Inflation: New Cross-country Evidence on the Global Determinants of Domestic Inflation.*” BIS Working Papers No 227.*

Cecchetti, Stephen, Peter Hooper, Bruce Kasman, Kim Schoenholtz and Mark Watson. (2007). “Understanding the Evolving Inflation Process.” Paper prepared for the 2007 US Monetary Policy Forum and available at: http://people.brandeis.edu/~cecchett/Polpdf/USMPF2007.pdf

Cecchetti, Stephen, Michael Feroli, Peter Hooper, Anil Kashyap and Kermit Schoenholtz. (2017). “Deflating Inflation Expectations: The Implications of Inflations’ Simple Dynamics.” Paper prepared for the 2017 US Monetary Policy Forum and available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2941510.

Chan, Joshua, Gary Koop and Simon Potter. (2013). “A New Model of Trend Inflation.” *Journal of Business and Economic Statistics* 31(1): 94-106.

Ciccarelli, Matteo and Benoit Mojon. (2010). “Global Inflation.” *The Review of Economics and Statistics* 92(3): 524-535.

Cravino, Javier. (2019). “Discussion of Inflation Dynamics: Dead, Dormant or Determined Abroad? By Kristin Forbes.” *Brookings Papers on Economic Activity, Fall 2019 meetings.*

Eberly, Janice, James Stock and Jonathan Wright. (2019). “The Federal Reserve’s Current Framework for Monetary Policy: A Review and Assessment.” *Paper prepared for the Conference on Monetary Policy Strategy, Tools, and Communication Practices,* June 4- 5, 2019, Federal Reserve Bank of Chicago. Available at: https://www.chicagofed.org/conference-sessions/session-1

Eickmeier, Sandra and Katharina Pijnenburg. (2013). “The Global Dimension of Inflation – Evidence from Factor-augmented Phillips Curves.” *Oxford Bulletin of Economics and Statistics* 75(1): 103-122.

Forbes, Kristin. (2019). "Has Globalization Changed the Inflation Process?" *BIS Working Papers No. 791.* June.

Forbes, Kristin. (2018). "Fixing the Astrolabe: Global Factors and Inflation Models." In *Price and Wage Setting in Advanced Economies,"* Conference Proceedings from ECB Forum on Central Banking in Sintra, Portugal, June 16-18, pages 170-186. Available at: https://www.ecb.europa.eu/pub/pdf/sintra/ecb.forumcentbank201810.en.pdf

Forbes, Kristin. (2015). "When, Why, and What's Next for Low Inflation? No Magic Slippers Needed." Speech at the London School of Economics, June 17. Available at: https://www.bankofengland.co.uk/speech/2015/when-why-and-whats-next-for-low-inflation-no-magic-slippers-needed

Forbes, Kristin, Ida Hjortsoe and Tsvetelina Nenova. (2018). "The Shocks Matter: Improving Our Estimates of Exchange Rate Pass-Through." *Journal of International Economics* 114(Sept):25-275.

Forbes, Kristin, Ida Hjortsoe and Tsvetelina Nenova. (2017). "Shocks versus Structure: Explaining Differences in Exchange Rate Pass-Through across Countries and Time." *Bank of England External MPC Unit Discussion Paper No. 50.*

Forbes, Kristin, Lewis Kirkham and Konstantinos Theodoridis. (2019). "A Trendy Approach to UK Inflation Dynamics." *The Manchester School,* June: 1-53.

Gagnon, Joseph and Christopher Collins. (2019). "Low Inflation Bends the Phillips Curve." *Peterson Institute of International Economics Working Paper 19-6.*

Galí, Jordi and Mark Gertler. (1999). "Inflation Dynamics: A Structural Econometric Analysis." *Journal of Monetary Economics* 44:195-222.

Galí, Jordi and David Lopez-Salido. (2005). "Robustness of Estimates of the Hybrid New Keynesian Phillips Curve." *Journal of Monetary Economics* 52: 1107-18.

Gilchrist, Simon and Egon Zakrajsek. (2015). "Customer Markets and Financial Frictions: Implications for Inflation Dynamics." *Proceedings of the Jackson Hole Symposium.* Federal Reserve Bank of Kansas City, pgs. 1-52.

Gilchrist, Simon, Raphael Schoenle, Jae Sim and Egon Zakrajsek. (2017). "Inflation Dynamics During the Financial Crisis." *American Economic Review* 107(3): 785-823.

Goldfeld, Stephen and Alan Blinder. (1972). "Some Implications of Endogenous Stabilization Policy." *Brookings Papers on Economic Activity,* no. 3: 585-640.

Gordon, Robert. (2013). "The Phillips Curve is Alive and Well: Inflation and the NAIRU during the Slow Recovery." *NBER Working Paper 19390.*

Gordon, Robert. (1985). "Understanding Inflation in the 1980s." *Brookings Papers on Economic Activity,* no. 1: 263-299.

Gordon, Robert. (1977). "World Inflation and Monetary Accommodation in Eight Countries." *Brookings Papers on Economic Activity,* no. 2: 409-468.

Grossman, Gene and Esteban Rossi-Hansberg. (2008). "Trading Tasks: A Simple Theory of Offshoring." *American Economic Review* 98(5): 1978–1997.

Guilloux-Nefussi, Sophie. (2018). “Are Monopolies a Danger to the United States?” *Banque de France, Eco Notepad.*

Ha, Jongrim, M. Ayhan Kose, and Franziska Ohnsorge. (2019). *Inflation in Emerging and Developing Economies: Evolution, Drivers, and Policies.* Washington, DC: World Bank. Available at: https://www.worldbank.org/en/research/publication/inflation-in-emerging-and-developing-economies

Hakkio, Craig. (2009). “Global Inflation Dynamics.” *The Federal Reserve Bank Of Kansas City, Research Working Paper No 09-01.*

Hamilton, James. (2010). “Nonlinearities and the Macroeconomic Effects of Oil Prices.” *NBER Working Paper 16186.*

Hong, Gee Hee, Zsóka Kóczán, Weicheng Lian and Malhar Nabar. (2018). “More Slack than Meets the Eye? Wage Dynamics in Advanced Economies.” *IMF Working Paper WP/18/50.*

Hooper, Peter, Frederic Mishkin and Amir Sufi. (2019). “Prospects for Inflation in a High Pressure Economy: Is the Phillips Curve Dead or is it Just Hibernating?” Paper prepared for the 2019 US Monetary Policy Forum.

Ihrig, Jane, Steven Kamin, Deborah Lindner and Jaime Marquez. (2010). “Some Simple Tests of the Globalization and Inflation Hypothesis.” *International Finance* 13(3): 343–375.

International Monetary Fund. (2016). “Global Disinflation in an Era of Constrained Monetary Policy.” *World Economic Outlook, Chapter 3.* October.

International Monetary Fund. (2013). “The Dog That Didn’t Bark: Has Inflation Been Muzzled or Was it Just Sleeping?” *World Economic Outlook, Chapter 3,* April.

Jasová, Martina, Richhild Moessner and Elód Takáts. (2018). “Domestic and Global Output Gaps as Inflation Drivers: What Does the Phillips Curve Tell?” *BIS Working Papers No. 748.*

Jordà, Òscar, and Fernanda Nechio. (2018). “Inflation Globally.” Unpublished mimeo.

Karabarbounis, Loukas and Brent Neiman. (2013). “The Global Decline of the Labor Share.” *The Quarterly Journal of Economics* 129(1, Feb): 61-103.

Kohn, Donald. (2006). “The Effects of Globalization on Inflation and their Implications for Monetary Policy.” Remarks at Federal Reserve Bank of Boston’s 51st Economic Conference, June 16, available at: https://www.federalreserve.gov/newsevents/speech/kohn20060616a.htm.

Li, Xin, Bo Meng and Zhi Wang. (2019). “Recent Patterns of Global Production and GFC Participation.” In *Global Value Chain Production Report 2019.* Geneva: World Trade Organization.

McLeay, Michael and Silvana Tenreyro. (2019). “Optimal Inflation and the Identification of the Phillips Curve.” *NBER Working Paper No. 25892.*

Mikolajun, Irena and David Lodge. (2016). “Advanced Economy Inflation: The Role of Global Factors.” *ECB Working Paper No 1948.* August.

Miles, David, Ugo Panizza, Ricardo Reis and Ángel Ubide. (2017). *And Yet it Moves: Inflation and the Great Recession.* Geneva Reports on the World Economy #19.

Neely, Christopher and David Rapach. (2011). “International Comovements in Inflation Rates and Country Characteristics.” *Journal of International Money and Finance* 30(7): 1471-1490.

Obstfeld, Maurice. (2019). “Global Dimensions of US Monetary Policy.” Unpublished mimeo.

Powell, Jerome (2018). “Monetary Policy and Risk Management at a Time of Low Inflation and Low Unemployment.” S*peech at the "Revolution or Evolution? Reexamining Economic Paradigms" 60th Annual Meeting of the National Association for Business Economics,* October 2.

Sbordone, Argia. (2010). “Globalization and Inflation Dynamics: The Impact of Increased Competition,” in Jordi Galí and Mark Gertler, eds. *The International Dimensions of Monetary Policy.* University of Chicago Press, pgs. 547-579.

Stock, James and Mark Watson. (2018). “Slack and Cyclically Sensitive Inflation.” In *Price and Wage Setting in Advanced Economies,”* Conference Proceedings from ECB Forum on Central Banking in Sintra, Portugal, June 16-18, pages 41-79. Available at: https://www.ecb.europa.eu/pub/pdf/sintra/ecb.forumcentbank201810.en.pdf

Stock, James and Mark Watson. (2010). “Modeling Inflation after the Crisis.” *Proceedings of the Jackson Hole Symposium.* Federal Reserve Bank of Kansas City, pgs. 173-220.

Stock, James and Mark Watson. (2007). “Why Has U.S. Inflation Become Harder to Forecast?” *Journal of Money, Credit, and Banking* 39: 3-34.

Wei, Shang-Jin and Yinxi Xie. (2018). “On the Divergence between CPI and PPI as Inflation Gauges: The Role of Supply Chains.” *NBER Working Paper 24319.*

World Bank. (2018). *Global Economic Prospects.* Chapter “The Role of Major Emerging Markets in Global Commodity Demand.” June.

Yellen, Janet. (2017). “Inflation, Uncertainty and Monetary Policy.” Speech delivered in Cleveland on Sept. 26. Available at*:* https://www.federalreserve.gov/newsevents/speech/yellen20170926a.htm

Yellen, Janet. (2016). “Macroeconomic Research After the Crisis.” Speech delivered in Boston on Oct. 14. Available at: https://www.federalreserve.gov/newsevents/speech/yellen20161014a.htm

Yellen, Janet. (2006). “Monetary Policy in a Global Environment.” Speech delivered at U.C. Santa Cruz on May 27. Available at: https://www.frbsf.org/our-district/press/presidents-speeches/yellen-speeches/2006/may/monetary-policy-in-a-global-environment/

Table 1

Global Principal Component of Different Inflation Series

	Fraction of Variance Accounted for:			
	PPI	**CPI**	**Core**	**Wages**
Full sample:				
1st PC	51.6%	40.2%	20.9%	22.5%
1st 5 PCs	76.0%	66.7%	51.1%	54.1%
# countries	***35***	***43***	***38***	***20***
Sample of countries with wage data:				
1st PC	56.3%	44.8%	26.0%	22.5%
1st 5 PCs	83.8%	74.0%	60.6%	54.1%
# countries	***19***	***20***	***20***	***20***
Advanced economies:				
1st PC	60.5%	41.1%	25.1%	22.7%
1st 5 PCs	81.5%	69.1%	53.2%	55.3%
# countries	***29***	***31***	***31***	***18***
Emerging markets				
1st PC	39.2%	25.4%	23.2%	.
1st 5 PCs	95.7%	75.5%	85.4%	.
# countries	***6***	***12***	***7***	***.***

Notes: *Fraction of variance accounted for by either one or five principal components (PC) for each of four inflation measures. PPI is producer price inflation. CPI is consumer price inflation. Core inflation is CPI less food and energy, and Wages is private sector, household hourly wages. All inflation measures are relative to the previous quarter, annualized and seasonally adjusted. See Appendix A for more details on data. Advanced economies and emerging markets are defined according to the IMF as of 2017.*

Table 2: Phillips Curve Estimates,
CPI Inflation for Full Period (1996-2017)

	Different Control Variables				Different Specifications			
	Domestic Only (1)	**+ Import Prices (2)**	**+ Oil Prices (3)**	**+ All Global Variables (4)**	**DomSlack* ImpShare (5)**	**Only Lagged Inflation (6)**	**Random Effects (7)**	**RE + Constraints (8)**
Inflation Expect.	0.685***	0.717***	0.656***	0.654***	0.631***		0.708***	0.257***
	(0.105)	(0.161)	(0.108)	(0.101)	(0.104)		(0.065)	(0.036)
Lagged Inflation	0.599***	0.679***	0.626***	0.641***	0.612***	0.716***	0.684***	0.743***
	(0.041)	(0.030)	(0.037)	(0.039)	(0.047)	(0.037)	(0.029)	(0.036)
Domestic Slack	-0.144***	-0.103***	-0.126***	-0.090***	-0.231***	-0.086**	-0.065***	-0.052**
	(0.027)	(0.021)	(0.026)	(0.030)	(0.069)	(0.031)	(0.023)	(0.024)
Import Prices		0.091						
		(0.054)						
World Oil Prices			0.033***	0.029***	0.030***	0.029***	0.030***	0.029***
			(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
World Comm. Prices				0.030***	0.030***	0.028***	0.031***	0.028***
				(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
Real Exchange Rate				-0.029***	-0.031***	-0.025***	-0.028***	-0.022***
				(0.007)	(0.007)	(0.006)	(0.006)	(0.006)
World Slack				-0.153***	-0.160***	-0.149***	-0.158***	-0.158***
				(0.036)	(0.034)	(0.036)	(0.037)	(0.039)
Global Value Chains				-0.055**	-0.052*	-0.108***	-0.037	-0.068***
				(0.026)	(0.028)	(0.030)	(0.024)	(0.025)
Constant	-0.514*	-0.772*	-0.587**	-0.541**	-0.418*	0.710***	-0.776***	0.062
	(0.260)	(0.374)	(0.263)	(0.227)	(0.218)	(0.102)	(0.129)	(0.049)
R2	***0.418***	***0.498***	***0.470***	***0.487***	***0.458***	***0.476***	***0.610***	
# obs.	***2,635***	***1,366***	***2,635***	***2,635***	***2,531***	***2,635***	***2,635***	***2,635***

Notes: *Phillips curve regressions of equations (1) – (4) for quarterly CPI inflation from 1996-2017. See Appendix A for data definitions. Estimated using fixed effects in columns 1-6 with robust standard errors clustered by country. Columns 7 and 8 estimated using random effects. Column 8 constrains the coefficients on the two inflation coefficients (inflation expectations and lagged inflation) to equal 1. Column 5 interacts domestic slack with the import share of GDP. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Table 3: Phillips Curve Estimates,
CPI Inflation for Different Periods

	Pre-Crisis (1996-2007)					**Last Decade (2008-2017)**				
	Domestic Only (1)	**+ Import Prices (2)**	**+ Oil Prices (3)**	**+ All Global Variables (4)**	**DomSlack* ImpShare (5)**	**Domestic Only (1)**	**+ Import Prices (2)**	**+ Oil Prices (3)**	**+ All Global Variables (4)**	**DomSlack* ImpShare (5)**
Inflation	0.663***	0.720***	0.684***	0.741***	0.696***	0.685	0.408	0.508	0.284	0.324
Expect.	(0.169)	(0.190)	(0.155)	(0.163)	(0.208)	(0.425)	(0.506)	(0.373)	(0.274)	(0.273)
Lagged	0.556***	0.672***	0.588***	0.589***	0.559***	0.490***	0.431***	0.519***	0.556***	0.556***
Inflation	(0.065)	(0.048)	(0.064)	(0.067)	(0.081)	(0.050)	(0.070)	(0.045)	(0.040)	(0.037)
Domestic	-0.212***	-0.157**	-0.198***	-0.188***	-0.410**	-0.154***	-0.112	-0.157***	-0.105**	-0.171*
Slack	(0.054)	(0.058)	(0.050)	(0.061)	(0.155)	(0.034)	(0.066)	(0.034)	(0.041)	(0.088)
Import		0.061					0.136*			
Prices		(0.057)					(0.066)			
World Oil			0.030***	0.030***	0.031***			0.034***	0.026***	0.028***
Prices			(0.004)	(0.004)	(0.004)			(0.003)	(0.003)	(0.003)
World Comm.				0.004	0.002				0.031***	0.028***
Prices				(0.013)	(0.013)				(0.009)	(0.009)
Real Exchange				-0.027**	-0.029***				-0.039***	-0.040***
Rate				(0.011)	(0.010)				(0.013)	(0.013)
World				-0.410***	-0.430***				-0.434***	-0.517***
Slack				(0.092)	(0.091)				(0.073)	(0.080)
Global Value				-0.258***	-0.253***				-0.357***	-0.407***
Chains				(0.068)	(0.072)				(0.078)	(0.086)
Constant	-0.270	-0.700	-0.517	-0.938***	-0.773**	-0.370	0.254	-0.063	1.142*	1.202*
	(0.380)	(0.450)	(0.350)	(0.321)	(0.351)	(0.858)	(1.150)	(0.761)	(0.606)	(0.607)
R2	***0.361***	***0.497***	***0.394***	***0.414***	***0.365***	***0.252***	***0.196***	***0.356***	***0.419***	***0.425***
# obs.	***1,404***	***769***	***1,404***	***1,404***	***1,350***	***1,231***	***597***	***1,231***	***1,231***	***1,181***
F-Test: Joint Significance of Global Variables				***32.38****	***36.11****				***71.33****	***68.09****

Notes: *Phillips curve regressions of equations (1) – (4) for quarterly CPI inflation from 1996-2007 and 2008-2017. See Appendix A for data definitions. Estimated using fixed effects with robust standard errors clustered by country. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Table 4:
Explaining the Cyclical Component of CPI Inflation for Different Periods

	Full Period				Pre-Crisis (1996-2007)				Last Decade (2008-2017)			
	Domestic Only (1)	**+ Oil Prices (2)**	**+ All Global Variables (3)**	**DomSlack* ImpShare (4)**	**Domestic Only (5)**	**+ Oil Prices (6)**	**+ All Global Variables (7)**	**DomSlack* ImpShare (8)**	**Domestic Only (9)**	**+ Oil Prices (10)**	**+ All Global Variables (11)**	**DomSlack* ImpShare (12)**
Trend	0.641***	0.629***	0.636***	0.749***	0.550***	0.548***	0.542***	0.715***	0.841***	0.797***	0.781***	0.772***
Inflation	(0.089)	(0.086)	(0.089)	(0.047)	(0.099)	(0.099)	(0.099)	(0.059)	(0.148)	(0.135)	(0.145)	(0.145)
Inflation	0.172	0.234	0.360**	0.310*	0.465**	0.539**	0.635***	0.491	0.076	0.045	-0.026	0.021
Expect.	(0.178)	(0.184)	(0.153)	(0.169)	(0.209)	(0.212)	(0.183)	(0.229)	(0.454)	(0.417)	(0.371)	(0.371)
Domestic	-0.189***	-0.181***	-0.162***	-0.264***	-0.282***	-0.277***	-0.238***	-0.355***	-0.178***	-0.196***	-0.165***	-0.329**
Slack	(0.040)	(0.041)	(0.042)	(0.068)	(0.061)	(0.061)	(0.070)	(0.097)	(0.053)	(0.050)	(0.055)	(0.152)
World Oil		0.025***	0.023***	0.024***		0.023***	0.023***	0.024***		0.026***	0.023***	0.024***
Prices		(0.003)	(0.002)	(0.002)		(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)
World Commodity			0.018***	0.017***			-0.008	-0.007			0.024**	0.021**
Prices			(0.006)	(0.006)			(0.011)	(0.010)			(0.009)	(0.009)
Real Exchange			-0.017	-0.024*			-0.011	-0.017			-0.033	-0.034
Rate			(0.014)	(0.013)			(0.014)	(0.012)			(0.021)	(0.022)
World			-0.083**	-0.082*			-0.392***	-0.384***			-0.266***	-0.329***
Slack			(0.038)	(0.043)			(0.122)	(0.124)			(0.046)	(0.046)
Global Value			0.065*	0.084***			-0.170*	-0.127			-0.075	-0.109
Chains			(0.035)	(0.028)			(0.091)	(0.088)			(0.071)	(0.073)
Constant	0.565	0.411	0.160	0.007	0.091	-0.148	-0.562*	-0.652	0.468	0.621	1.141	1.163
	(0.298)	(0.318)	(0.301)	(0.331)	(0.328)	(0.348)	(0.320)	(0.475)	(0.926)	(0.829)	(0.698)	(0.703)
R2	***0.507***	***0.537***	***0.545***	***0.543***	***0.474***	***0.494***	***0.506***	***0.500***	***0.384***	***0.444***	***0.471***	***0.476***
# obs.	***2,456***	***2,456***	***2,456***	***2,355***	***1,313***	***1,313***	***1,313***	***1,259***	***1,143***	***1,143***	***1,143***	***1,096***
F-Test: Joint Significance of Global Variables							***16.55****	***15.53****			***42.74****	***44.00****

Notes: *Regressions of quarterly, annualized and seasonally-adjusted CPI inflation on the trend and other variables using fixed effects with robust standard errors clustered by country. See Appendix A for variable definitions and Section V for estimation of the trend. The ***, **, * are significant at the 1%, 5% and 10% levels, respectively.*

Table 5:
Phillips Curve Estimates—Core Inflation for Different Periods

	Full Period					Pre-Crisis (1996-2007)					Last Decade (2008-2017)				
	Domestic Only	**+ Import Prices**	**+ Oil Prices**	**+ All Global Variables**	**DomSlack* ImpShare**	**Domestic Only**	**+ Import Prices**	**+ Oil Prices**	**+ All Global Variables**	**DomSlack* ImpShare**	**Domestic Only**	**+ Import Prices**	**+ Oil Prices**	**+ All Global Variables**	**DomSlack* ImpShare**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**
Inflation	0.501***	0.434***	0.503***	0.515***	0.543***	0.467***	0.472***	0.466***	0.483***	0.498***	0.580***	0.487	0.527***	0.522***	0.596***
Expect.	(0.054)	(0.080)	(0.054)	(0.054)	(0.058)	(0.085)	(0.074)	(0.085)	(0.092)	(0.120)	(0.165)	(0.299)	(0.157)	(0.165)	(0.173)
Lagged	0.646***	0.711***	0.647***	0.664***	0.639***	0.630***	0.682***	0.630***	0.653***	0.641***	0.458***	0.390***	0.461***	0.474***	0.466***
Inflation	(0.039)	(0.046)	(0.039)	(0.039)	(0.043)	(0.061)	(0.077)	(0.061)	(0.059)	(0.070)	(0.050)	(0.062)	(0.050)	(0.051)	(0.053)
Domestic	-0.115***	-0.082***	-0.113***	-0.094***	-0.216***	-0.165***	-0.148***	-0.165***	-0.170***	-0.327***	-0.127***	-0.089*	-0.128***	-0.116***	-0.223***
Slack	(0.018)	(0.019)	(0.018)	(0.018)	(0.041)	(0.037)	(0.043)	(0.037)	(0.042)	(0.108)	(0.026)	(0.044)	(0.026)	(0.027)	(0.068)
Import		0.032*					-0.002					0.071***			
Prices		(0.017)					(0.020)					(0.018)			
World Oil			0.005***					0.000					0.007***		
Prices			(0.002)					(0.002)					(0.002)		
World Comm.				0.009***	0.008***				-0.001	-0.002				0.015***	0.013***
and Oil Prices				(0.003)	(0.003)				(0.006)	(0.006)				(0.004)	(0.004)
Real Exchange				-0.017***	-0.018***				-0.026***	-0.027***				-0.013	-0.013
Rate				(0.005)	(0.005)				(0.006)	(0.006)				(0.009)	(0.009)
World				-0.078***	-0.080***				-0.124**	-0.129**				-0.038	-0.070
Slack				(0.022)	(0.021)				(0.059)	(0.062)				(0.056)	(0.059)
Global Value				-0.003	-0.002				-0.069	-0.056				0.077	0.052
Chains				(0.018)	(0.019)				(0.043)	(0.045)				(0.062)	(0.065)
Constant	-0.353***	-0.350**	-0.369***	-0.390	-0.397	-0.209	-0.378*	-0.207	-0.360	-0.356	-0.215	0.066	-0.110	-0.164	-0.245
	(0.111)	(0.162)	(0.113)	(0.088)	(0.091)	(0.138)	(0.182)	(0.136)	(0.111)	(0.146)	(0.276)	(0.612)	(0.257)	(0.324)	(0.332)
R2	***0.507***	***0.531***	***0.508***	***0.515***	***0.495***	***0.475***	***0.505***	***0.475***	***0.488***	***0.456***	***0.224***	***0.162***	***0.235***	***0.243***	***0.241***
# obs.	***2,636***	***1,374***	***2,636***	***2,636***	***2,532***	***1,402***	***766***	***1,402***	***1,402***	***1,348***	***1,234***	***608***	***1,234***	***1,234***	***1,184***
F-Test: Joint Significance of Global Variables									***6.58****	***6.92****				***5.71****	***6.44****

Notes: *Phillips curve regressions of equations (1) – (4) for core CPI inflation from 1996-2017. See Appendix A for data definitions. Estimated using fixed effects with robust standard errors clustered by country. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Table 6:
Phillips Curve Estimates—Wage Inflation for Different Periods

	Full Period				Pre-Crisis (1996-2007)				Last Decade (2008-2017)			
	Domestic Only	**+ Product Growth**	**+ All Global Variables**	**DomSlack* ImpShare**	**Domestic Only**	**+ Product Growth**	**+ All Global Variables**	**DomSlack* ImpShare**	**Domestic Only**	**+ Product Growth**	**+ All Global Variables**	**DomSlack* ImpShare**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Inflation	0.535***	0.183	0.472**	0.504***	0.030	-0.536	0.052	0.030	0.233	0.866	0.235	0.428
Expect.	(0.175)	(0.322)	(0.172)	(0.160)	(0.197)	(0.731)	(0.202)	(0.196)	(0.595)	(0.588)	(0.638)	(0.637)
Lagged	0.244***	0.141	0.217	0.216	0.241***	0.199*	0.237***	0.254***	-0.036	0.003	-0.026	-0.008
Inflation	(0.075)	(0.156)	(0.064)	(0.065)	(0.062)	(0.105)	(0.058)	(0.062)	(0.111)	(0.179)	(0.104)	(0.112)
Domestic	-0.273***	-0.246***	-0.153***	-0.326**	-0.213***	-0.195**	-0.197***	-0.320**	-0.369***	-0.227**	-0.306***	-0.574***
Slack	(0.050)	(0.056)	(0.047)	(0.114)	(0.069)	(0.081)	(0.066)	(0.124)	(0.088)	(0.079)	(0.092)	(0.144)
Productivity		0.512				1.035***				-0.847**		
Growth		(0.305)				(0.322)				(0.388)		
World Comm.			0.002	0.003			0.005	0.006			0.006	0.007
and Oil Prices			(0.006)	(0.006)			(0.013)	(0.013)			(0.008)	(0.008)
World			-0.351***	-0.352***			-0.230	-0.227			-0.233	-0.230
Slack			(0.092)	(0.086)			(0.178)	(0.181)			(0.167)	(0.147)
Global Value			-0.144**	-0.154**			-0.126	-0.117			-0.066	-0.046
Chains			(0.066)	(0.067)			(0.107)	(0.107)			(0.093)	(0.084)
Constant	1.863***	2.299**	2.167***	2.085***	3.307***	3.664**	3.100***	3.112***	2.807**	1.211	3.052**	2.512*
	(0.286)	(0.802)	(0.326)	(0.315)	(0.415)	(1.583)	(0.438)	(0.425)	(1.244)	(1.119)	(1.332)	(1.328)
R2	***0.122***	***0.069***	***0.150***	***0.152***	***0.061***	***0.049***	***0.065***	***0.057***	***0.052***	***0.039***	***0.059***	***0.056***
# obs.	***1,660***	***1,148***	***1,660***	***1,643***	***878***	***601***	***878***	***871***	***782***	***547***	***782***	***772***
F-Test: Joint Significance of Global Variables							***1.21***	***1.25***			***1.13***	***1.36***

Notes: *Phillips curve regressions for wage inflation from 1996-2017. Wages are private-sector household wages. See Appendix A for data definitions. Estimated using fixed effects with robust standard errors clustered by country. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Table 7:
Explaining the Trend in Core Inflation for Different Periods

	Full Period				Pre-Crisis (1996-2007)				Last Decade (2008-2017)			
	Domestic Only	+ Oil Prices	+ All Global Variables	DomSlack* ImpShare	Domestic Only	+ Oil Prices	+ All Global Variables	DomSlack* ImpShare	Domestic Only	+ Oil Prices	+ All Global Variables	DomSlack* ImpShare
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Inflation	0.105**	0.108**	0.113**	0.078***	0.109**	0.109**	0.120***	0.092***	0.059*	0.047	0.034	0.035
Expect.	(0.039)	(0.039)	(0.043)	(0.025)	(0.042)	(0.042)	(0.042)	(0.032)	(0.033)	(0.034)	(0.028)	(0.028)
Domestic	-0.029**	-0.033**	-0.036***	-0.075**	-0.058***	-0.058***	-0.067***	-0.131*	-0.014	-0.024**	-0.023*	-0.041*
Slack	(0.011)	(0.012)	(0.012)	(0.033)	(0.018)	(0.018)	(0.023)	(0.067)	(0.011)	(0.011)	(0.012)	(0.024)
World Oil		0.001				0.000				0.002		
Prices		(0.001)				(0.000)				(0.002)		
World Comm.			0.003	0.003			0.001	0.001			0.003	0.003
and Oil Prices			(0.002)	(0.002)			(0.001)	(0.001)			(0.003)	(0.003)
Real Exchange			-0.002**	-0.001**			-0.004**	-0.003			-0.001	0.000
Rate			(0.001)	(0.001)			(0.002)	(0.002)			(0.001)	(0.001)
World			-0.014	-0.019			0.005	-0.008			-0.026*	-0.030**
Slack			(0.012)	(0.011)			(0.029)	(0.026)			(0.013)	(0.014)
Global Value			-0.018**	-0.012*			-0.010	-0.004			-0.017*	-0.016*
Chains			(0.008)	(0.007)			(0.011)	(0.010)			(0.009)	(0.008)
Constant	-0.028***	-0.028***	-0.024***	-0.020***	-0.044***	-0.044***	-0.041***	-0.033***	-0.017***	-0.014***	-0.010*	-0.011**
	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.009)	(0.009)	(0.002)	(0.003)	(0.005)	(0.004)
R2	***0.009***	***0.015***	***0.022***	***0.022***	***0.042***	***0.042***	***0.052***	***0.051***	***0.001***	***0.014***	***0.020***	***0.020***
# obs.	***2,260***	***2,260***	***2,165***	***2,067***	***1,197***	***1,197***	***1,102***	***1,051***	***1,063***	***1,063***	***1,063***	***1,016***
F-Test: Joint Significance of Global Variables							***1.62***	***1.32***			***1.76***	***1.84***

Notes: *Regressions of the trend in quarterly core inflation on changes in the explanatory variables using fixed effects with robust standard errors clustered by country. See Appendix A for variable definitions and Section V for estimation of the trend. The ***, **, * are significant at the 1%, 5% and 10% levels, respectively.*

Figure 1
Principal Component of Different Inflation Measures and Commodity Prices:
Advanced Economies

Figure 1a: Percent of Variance of Four Inflation Measures Explained by 1st Principal Component

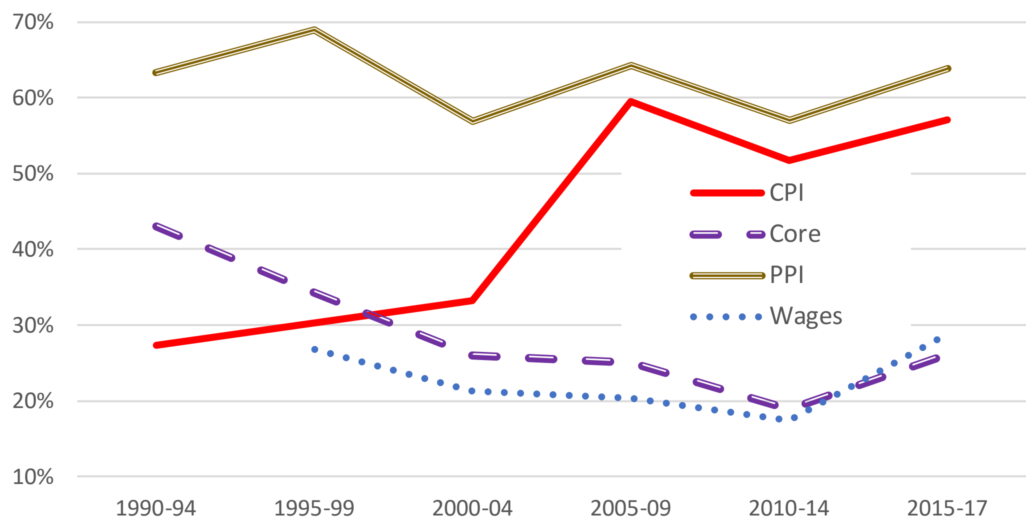
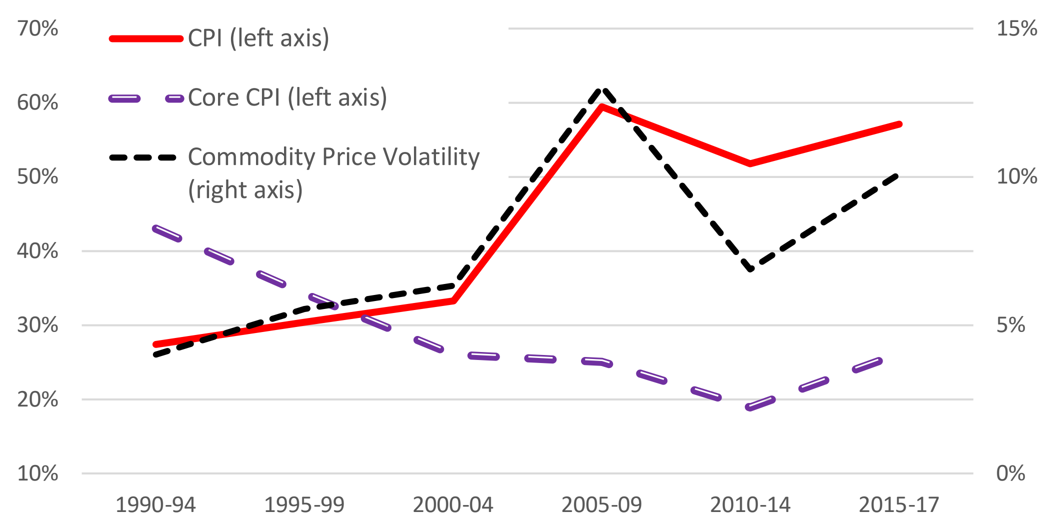
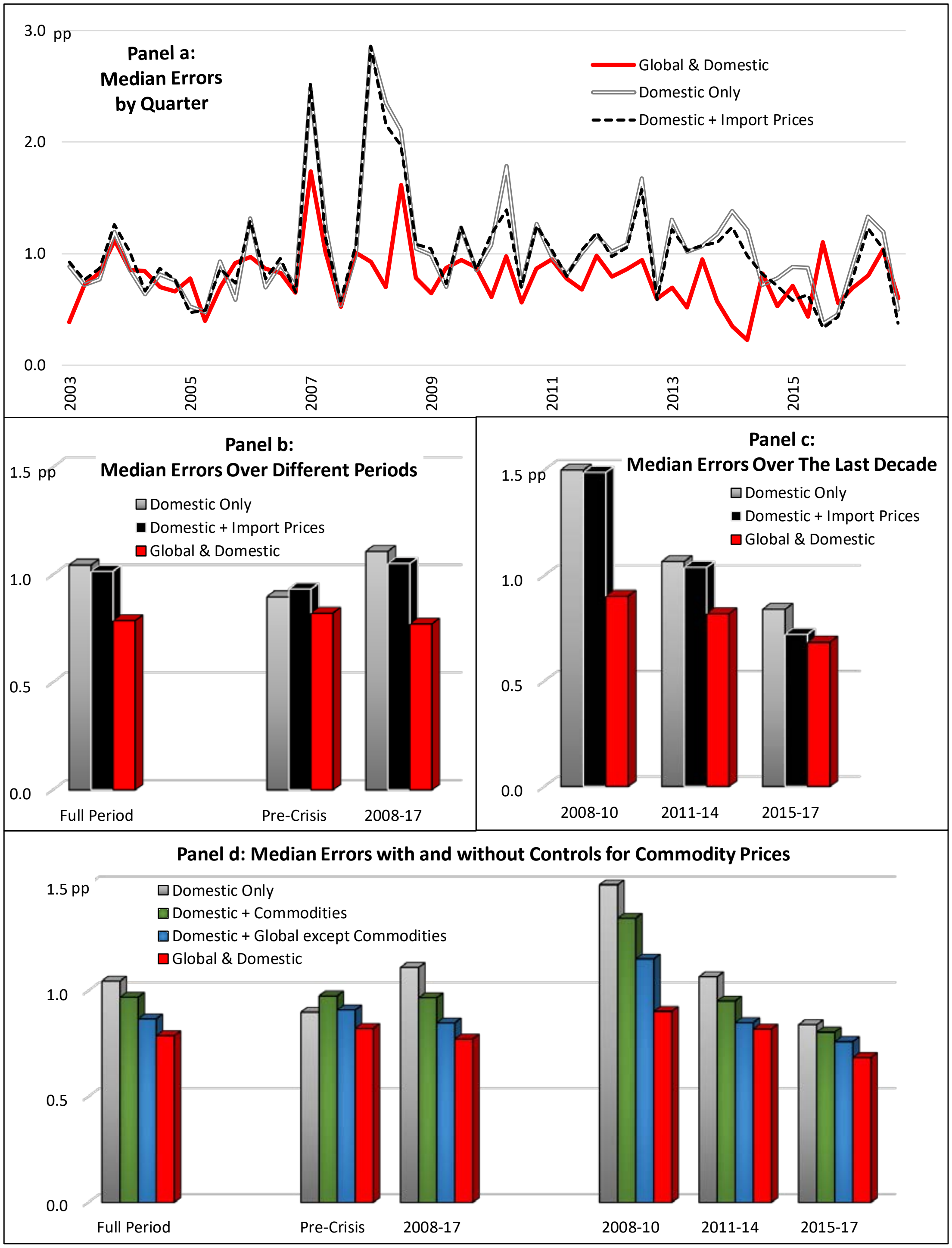


Figure 1b:
Principal Components vs. Commodity Price Volatility



Notes: *Percent of variance of each inflation measure explained by the first principal component over 5-year windows starting in 1990-94. Commodity Price Volatility measured as the standard deviation over the same windows using the IMF's index of global commodity prices (including fuel). See text for details on calculation of the first principal component and Appendix A for details on the price series.*

Figure 2: Gap between Actual and Predicted CPI Inflation in Different Models

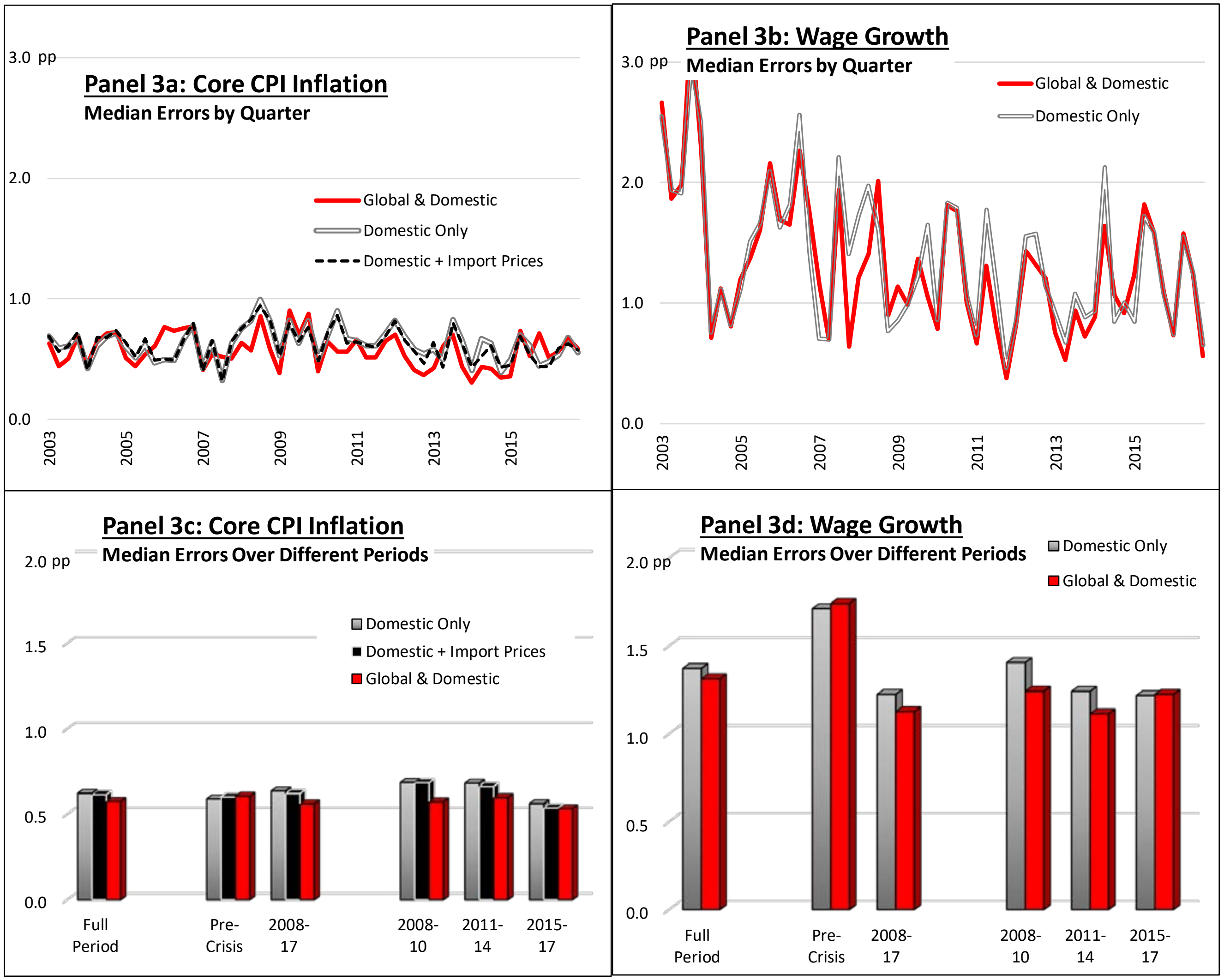


Notes: Median values of the absolute value of the difference between reported and predicted inflation based on coefficients from 8-year rolling regressions. “Domestic Only” is equation (1), which only includes controls for inflation expectations, lagged inflation, and domestic slack. “Domestic + Import Prices” is equation (2), which adds import price inflation. “Global & Domestic” is the full set of domestic variables plus five global variables in equation (3), including world oil prices, world commodity prices, exchange rate movements, world slack, and global value chains. “Domestic + Commodities” is the domestic variables plus commodity (ex. fuel) prices, while “Domestic + Global except Commodities” is the full set of domestic and global variables except commodity prices. The sample size is limited to countries/periods with import price data to maintain a consistent sample.

Figure 3: The Role of the Global Variables and Domestic Slack on CPI Inflation in the United States

Notes: Figure reports the estimated impact of each variable on US CPI inflation based on coefficients estimated from equation (3) using rolling 8-year windows and the sample of countries/periods used to estimate Figure 2. Variables defined in Appendix A.

Figure 4: Gap between Actual and Predicted Inflation for Core CPI and Wages in Different Models



Notes: Median values of the absolute value of the difference between reported and predicted inflation based on 8-year rolling regressions. ""Domestic Only" is equation (1), which only includes controls for inflation expectations, lagged inflation, and domestic slack. "Domestic + Import Prices" is equation (2), which adds relative import price inflation. "Global & Domestic" is the full set of domestic variables plus global variables, including an index of world oil and other commodity prices, world slack, and global value chains. The regressions for core CPI also include exchange rate movements. The sample size is limited to countries/periods with import price data to maintain a consistent sample.

APPENDIX A: 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
Import prices	Import prices, all items	Calculated as quarterly percent changes, in regressions measured as difference relative to quarterly CPI inflation	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
Producer price inflation	Producer prices, all commodities	Calculated as quarterly percent changes, annualized, seasonally adjusted[1]	Index data from IMF
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
Domestic slack * Import Share	Interaction of domestic slack and import share	Domestic slack defined above. Import share is the ratio of the country's imports to GDP (both in nominal domestic currency), over the last four quarters	Calculated. Import share data from the IMF, IFS.
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*. (2017) 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
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*. (2017) 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
World slack-IMF Measure	Negative of output gap for advanced economies	Calculated as a % of GDP for relevant economies; available annually and interpolated to quarterly	IMF
World slack-OECD Measure	Negative of output gap for OECD economies	Calculated as a % of GDP for relevant economies; available annually and interpolated to quarterly	OECD
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, Meng and Wang (2019).
PPI dispersion	Dispersion of producer prices	Standard deviation in producer price inflation for all countries in sample in each quarter, PPI inflation measured relative to 4 quarters earlier	Calculated based on IMF PPI
Real exchange rate index	Real effective exchange rate based on consumer prices	% change in real exchange rate, relative to 8 quarters earlier	IMF, IFS

Note: (1) Adjustments for VAT increases: Australia in 2000q3, Japan in 1997q2 and 2014q2, New Zealand in 2010q4, and United Kingdom in 2010q1 and 2011q1.

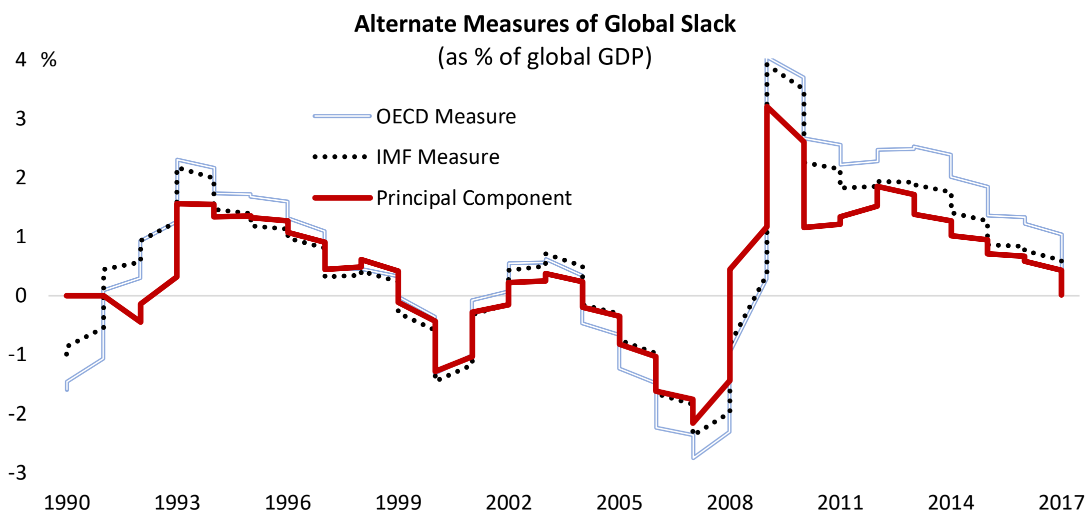
Appendix B: Country Sample

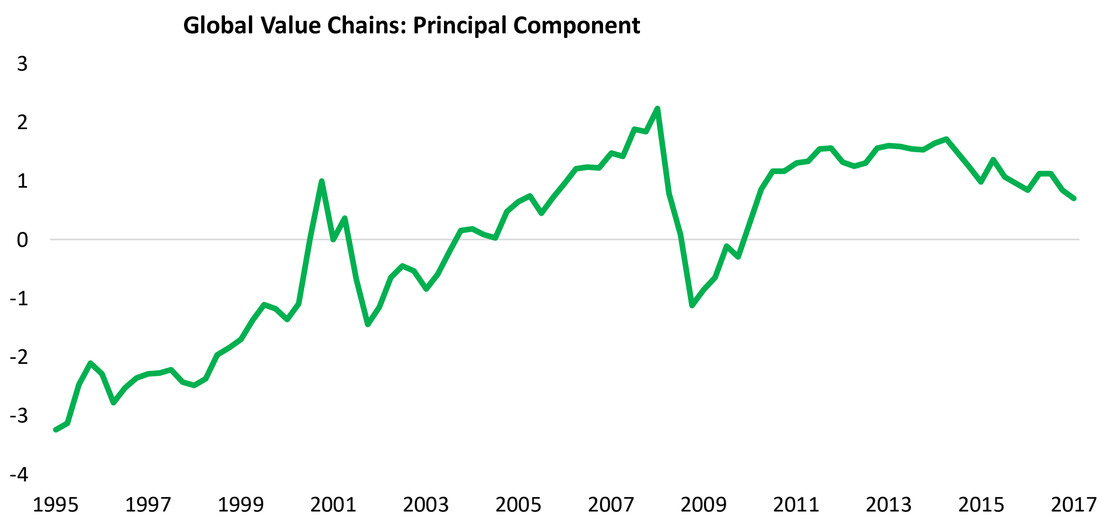
Advanced Economies[1]		*Emerging Economies*[1]
Australia	Korea	Brazil
Austria	Latvia	Chile
Belgium	Lithuania	China
Canada	Luxembourg	Colombia
Czech Republic	Netherlands	Hungary
Denmark	New Zealand	India
Estonia	Norway	Indonesia
Finland	Portugal	Mexico
France	Slovak Republic	Poland
Germany	Slovenia	Russia
Greece	Spain	South Africa
Iceland	Sweden	Turkey
Ireland	Switzerland	
Israel	United Kingdom	
Italy	United States	
Japan		

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

Appendix Figure 1

Global Control Variables: World Slack and Global Value Chains





Notes: "World slack" is a weighted average of slack in advanced economies (from the IMF) and slack in China. Slack in China calculated as the deviation in GDP growth from recent averages. The weight of the advanced economies for this calculation varies over time, based on the share of advanced economy GDP in world GDP according to IMF statistics. The IMF measure of slack only includes advanced economies, and the OECD measure only includes OECD economies. See text and Appendix A for more details.

Global value chains are measured as a principal component of: relative growth of merchandise trade, share of traded intermediate goods, complex share of traded intermediate goods, and dispersion in PPI inflation. See text and Appendix A for more details.

Appendix Table 1

Sensitivity Tests for Phillips Curve Analysis: CPI Inflation

	PRE-CRISIS (1996-2007)							LAST DECADE (2008-2017)						
	Different Definitions			*Diff. Period/Sample*		*Diff. Specifications*		*Different Definitions*			*Diff. Period/Sample*		*Diff. Specifications*	
	Domestic Slack: Unemploy Gap (1)	**World Slack: OECD Measure (2)**	**GVC: China Exp Growth (3)**	**Exclude 2008 (4)**	**Only AEs (5)**	**Drop Inf. Expect. (6)**	**Random Effects (7)**	**Domestic Slack: Unemploy Gap (1)**	**World Slack: OECD Measure (2)**	**GVC: China Exp Growth (3)**	**Exclude 2008 (4)**	**Only AEs (5)**	**Drop Inf. Expect. (6)**	**Random Effects (7)**
Inflation	0.794***	0.708***	0.800***	0.741***	0.640***		0.693***	0.446	0.382	0.435	0.139	0.298		0.596***
Expect.	0.146	0.158	0.166	0.163	0.207		0.084	0.335	0.289	0.320	0.449	0.270		0.105
Lagged	0.583***	0.595***	0.594***	0.589***	0.453***	0.697***	0.709***	0.575***	0.518***	0.452***	0.466***	0.561***	0.562***	0.623***
Inflation	0.068	0.066	0.075	0.067	0.055	0.058	0.041	0.039	0.034	0.034	0.030	0.045	0.039	0.043
Domestic	-0.141*	-0.198***	-0.191***	-0.188***	-0.210***	-0.182**	-0.103***	-0.016	-0.103**	-0.059	-0.070	-0.084*	-0.110**	-0.045*
Slack	0.080	0.059	0.059	0.061	0.068	0.066	0.036	0.040	0.042	0.055	0.047	0.042	0.041	0.027
World Oil	0.030***	0.030***	0.031***	0.030***	0.029***	0.030***	0.032***	0.027***	0.027***	0.026***	0.023***	0.025***	0.026***	0.026***
Prices	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.003	0.003	0.003	0.004	0.003	0.003	0.003
World Comm.	-0.006	0.006	-0.004	0.004	-0.003	0.004	0.005	0.030***	0.039***	0.042***	0.023***	0.038***	0.031***	0.029***
Prices	0.010	0.013	0.012	0.013	0.013	0.013	0.014	0.009	0.009	0.008	0.008	0.008	0.009	0.009
Real Exch.	-0.021*	-0.029***	-0.034***	-0.027**	-0.022**	-0.023**	-0.020**	-0.036***	-0.037***	-0.039***	-0.038***	-0.038**	-0.039***	-0.035***
Rate	0.012	0.010	0.011	0.011	0.010	0.010	0.009	0.013	0.013	0.014	0.011	0.014	0.012	0.010
World	-0.481***	-0.272***	-0.174	-0.410***	-0.404***	-0.358***	-0.469***	-0.443***	-0.203***	-0.442***	-0.186**	-0.443***	-0.439***	-0.455***
Slack	0.106	0.059	0.116	0.092	0.091	0.092	0.083	0.062	0.047	0.081	0.079	0.080	0.071	0.072
Global Value	-0.282***	-0.229***	0.000	-0.258***	-0.197**	-0.295***	-0.239***	-0.354***	-0.247***	0.000***	-0.340***	-0.346***	-0.362***	-0.371***
Chains	0.067	0.064	0.000	0.068	0.072	0.069	0.059	0.083	0.069	0.000	0.072	0.084	0.077	0.078
Constant	-1.025***	-0.842**	-0.721**	-0.938***	-0.425	0.430**	-1.178***	0.690	0.769	2.266***	1.216	1.043*	1.735***	0.338
	0.300	0.319	0.317	0.321	0.372	0.180	0.146	0.715	0.632	0.791	1.030	0.569	0.132	0.273
R2	***0.416***	***0.411***	***0.406***	***0.414***	***0.275***	***0.397***	***0.642***	***0.391***	***0.405***	***0.444***	***0.295***	***0.447***	***0.418***	***0.513***
# obs	***1360***	***1404***	***1404***	***1404***	***1263***	***1404***	***1404***	***1191***	***1231***	***1107***	***1111***	***1080***	***1231***	***1231***
F-Test: Global	***50.9****	***32.0****	***30.0****	***32.4****	***30.6****	***22.8****	***154.7****	***66.2****	***68.7****	***70.5****	***59.0****	***79.7****	***72.7****	***361.1****

Notes: *Phillips curve regressions of equation (3) for quarterly CPI inflation from 1996-2017. See Appendix A for data definitions and text for details. Estimated using fixed effects with robust standard errors clustered by country, except column (7) is estimated with random effects. Column (1) measures domestic slack with the unemployment gap and column (2) measures world slack using the OECD measure. Column (3) measures GVCs using growth in China's exports. Column (4) drops 2008 and column (5) only includes advanced economies, according to IMF definitions. Column (6) drops inflation expectations. F-Test: Global is an F-test for the joint significance of the five global variables. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Appendix Table 2

Median Values for Key Statistics for Trend-Cycle Estimates

	15%-85% Trend Range		Variance in "Trend"		Variance in "Cycle"		% of Variation Explained by Trend	
	CPI	Core	CPI	Core	CPI	Core	CPI	Core
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Full Period *1990-2017*	0.954	0.708	0.382	0.311	1.504	0.710	31%	55%
Pre-crisis *1997-2007*	0.914	0.768	0.262	0.305	1.329	0.841	19%	40%
Last Decade *2008-2017*	1.039	0.648	0.170	0.097	1.504	0.642	40%	68%

Notes: *Table reports median statistics for estimates of the trend and cycle for CPI and core inflation for advanced economies using the ARSV model developed in Forbes et al. (2019) and discussed in Section V.A. The column "15% to 85% Trend Range" reports the range between the 15th and 85th percentile estimates of the corresponding measure of the trend.*

Appendix Table 3

Sensitivity Tests for Phillips Curve Analysis: Core Inflation

	PRE-CRISIS (1996-2007)							LAST DECADE (2008-2017)						
	Different Definitions			*Diff. Period/Sample*		*Diff. Specifications*		*Different Definitions*			*Diff. Period/Sample*		*Diff. Specifications*	
	Domestic Slack: Unemploy Gap	**World Slack: OECD Measure**	**GVC: China Exp Growth**	**Exclude 2008**	**Only AEs**	**Drop Inf. Expect.**	**Random Effects**	**Domestic Slack: Unemploy Gap**	**World Slack: OECD Measure**	**GVC: China Exp Growth**	**Exclude 2008**	**Only AEs**	**Drop Inf. Expect.**	**Random Effects**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Inflation	0.440***	0.474***	0.512***	0.483***	0.471***		0.421***	0.345*	0.529***	0.582***	0.360*	0.553***		0.527***
Expect.	0.097	0.095	0.087	0.092	0.126		0.058	0.179	0.159	0.188	0.200	0.170		0.097
Lagged	0.674***	0.654***	0.643***	0.653***	0.590***	0.737***	0.788***	0.480***	0.469***	0.442***	0.407***	0.444***	0.497***	0.592***
Inflation	0.060	0.060	0.059	0.059	0.060	0.042	0.034	0.053	0.047	0.047	0.061	0.068	0.047	0.046
Domestic	-0.118*	-0.176***	-0.167***	-0.170***	-0.173***	-0.164***	-0.097***	-0.074**	-0.111***	-0.102**	-0.104***	-0.120***	-0.125***	-0.061***
Slack	0.062	0.040	0.043	0.042	0.046	0.044	0.031	0.029	0.031	0.038	0.028	0.035	0.029	0.019
World Comm.	-0.002	0.000	-0.001	-0.001	-0.001	-0.003	0.000	0.016***	0.015***	0.010***	0.011***	0.015***	0.015***	0.014***
+ Oil Prices	0.005	0.006	0.006	0.006	0.006	0.006	0.005	0.004	0.003	0.003	0.003	0.004	0.004	0.004
Real Exch.	-0.020***	-0.027***	-0.024***	-0.026***	-0.026***	-0.024***	-0.023***	-0.015	-0.013	-0.011	-0.018**	-0.010	-0.013	-0.012*
Rate	0.006	0.006	0.007	0.006	0.007	0.006	0.006	0.009	0.009	0.008	0.007	0.010	0.008	0.007
World	-0.208***	-0.062	-0.167**	-0.124**	-0.089	-0.101	-0.184***	-0.045	-0.028	-0.119**	0.042	-0.032	-0.047	-0.074
Slack	0.060	0.044	0.076	0.059	0.066	0.066	0.054	0.050	0.035	0.055	0.089	0.054	0.054	0.048
Global Value	-0.096**	-0.047	0.000*	-0.069	-0.023	-0.092**	-0.051	0.084	0.074	0.000*	0.067	0.062	0.068	0.068
Chains	0.042	0.043	0.000	0.043	0.042	0.042	0.040	0.061	0.054	0.000	0.068	0.065	0.062	0.062
Constant	-0.321**	-0.315**	-0.157	-0.360***	-0.199	0.525***	-0.558***	0.152	-0.166	0.337	0.162	-0.164	0.913***	-0.383*
	0.130	0.120	0.149	0.111	0.172	0.135	0.082	0.382	0.315	0.490	0.441	0.281	0.134	0.200
R2	***0.475***	***0.487***	***0.490***	***0.488***	***0.395***	***0.473***	***0.714***	***0.199***	***0.243***	***0.253***	***0.140***	***0.245***	***0.239***	***0.424***
# obs	***1358***	***1402***	***1402***	***1402***	***1262***	***1402***	***1402***	***1194***	***1234***	***1110***	***1114***	***1080***	***1234***	***1234***
F-Test: Global	***6.2****	***6.0****	***10.6****	***6.6****	***5.8****	***5.6****	***30.7****	***6.2****	***5.3****	***6.6****	***5.8****	***6.1****	***6.1****	***26.6****

Notes: *Phillips curve regressions of equation (3) for quarterly core CPI inflation from 1996-2017. See Appendix A for data definitions and text for details. Estimated using fixed effects with robust standard errors clustered by country, except column (7) is estimated with random effects. Column (1) measures domestic slack with the unemployment gap and column (2) measures world slack using the OECD measure. Column (3) measures GVCs using growth in China's exports. Column (4) drops 2008 and column (5) only includes advanced economies, according to IMF definitions. Column (6) drops inflation expectations. F-Test: Global is an F-test for the joint significance of the four global variables. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*

Appendix Table 4

Sensitivity Tests for Phillips Curve Analysis: Wage Inflation

	PRE-CRISIS (1996-2007)							LAST DECADE (2008-2017)						
	Different Definitions			*Diff. Period/Sample*		*Diff. Specifications*		*Different Definitions*			*Diff. Period/Sample*		*Diff. Specifications*	
	Domestic Slack: Unemploy Gap	World Slack: OECD Measure	GVC: China Exp Growth	Exclude 2008	Only AEs	Drop Inf. Expect.	Random Effects	Domestic Slack: Unemploy Gap	World Slack: OECD Measure	GVC: China Exp Growth	Exclude 2008	Only AEs	Drop Inf. Expect.	Random Effects
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inflation	-0.086	0.039	0.088	0.052	-0.152		0.528***	-0.148	0.341	0.278	0.077	0.238		1.939***
Expect.	0.209	0.204	0.198	0.202	0.381		0.182	0.686	0.647	0.651	0.526	0.639		0.508
Lagged	0.239***	0.241***	0.231***	0.237***	0.120	0.244***	0.330***	0.050	-0.059	-0.139	-0.074	0.000	-0.024	0.113
Inflation	0.044	0.059	0.063	0.058	0.089	0.052	0.039	0.114	0.110	0.127	0.104	0.143	0.103	0.083
Domestic	-0.211*	-0.200***	-0.195**	-0.197***	-0.193**	-0.196***	-0.135**	-0.294***	-0.261**	-0.207**	-0.278**	-0.304***	-0.311***	-0.137
Slack	0.121	0.064	0.068	0.066	0.076	0.068	0.055	0.054	0.108	0.093	0.099	0.096	0.088	0.094
World Comm.	0.006	0.006	0.004	0.005	0.010	0.005	0.008	0.007	0.007	0.000	0.001	0.003	0.006	0.001
+ Oil Prices	0.013	0.013	0.014	0.013	0.014	0.013	0.013	0.008	0.007	0.007	0.009	0.008	0.008	0.008
World	-0.222	-0.159	-0.192	-0.230	-0.152	-0.228	-0.246	-0.233	-0.202*	-0.368**	0.020	-0.147	-0.233	-0.345**
Slack	0.162	0.148	0.134	0.178	0.184	0.178	0.188	0.160	0.109	0.164	0.174	0.141	0.169	0.168
Global Value	-0.125	-0.114	0.000	-0.126	-0.073	-0.128	-0.060	-0.050	-0.102	0.000**	-0.017	-0.045	-0.071	-0.105
Chains	0.105	0.110	0.000	0.107	0.109	0.105	0.116	0.087	0.112	0.000	0.085	0.079	0.097	0.112
Constant	3.487***	3.132***	3.313***	3.100***	3.543***	3.195***	1.823***	3.560**	2.973**	5.232***	3.012**	2.666*	3.542***	-0.748
	0.411	0.445	0.466	0.438	0.856	0.257	0.496	1.440	1.280	1.490	1.182	1.277	0.304	0.914
R2	***0.067***	***0.064***	***0.063***	***0.065***	***0.028***	***0.064***	***0.365***	***0.067***	***0.061***	***0.074***	***0.021***	***0.051***	***0.059***	***0.197***
# obs	***878***	***878***	***878***	***878***	***784***	***878***	***878***	***782***	***782***	***720***	***702***	***703***	***782***	***782***
F-Test: Global	***1.0***	***0.9***	***1.7***	***1.2***	***1.2***	***1.0***	***9.4*****	***1.3***	***1.3***	***2.7****	***0.0***	***0.8***	***1.2***	***5.2***

Notes: *Phillips curve regressions of equation (3) for private sector wage inflation from 1996-2017. See Appendix A for data definitions and text for details. Estimated using fixed effects with robust standard errors clustered by country, except column (7) is estimated with random effects. Column (1) measures domestic slack with the unemployment gap and column (2) measures world slack using the OECD measure. Column (3) measures GVCs using growth in China's exports. Column (4) drops 2008 and column (5) only includes advanced economies, according to IMF definitions. Column (6) drops inflation expectations. F-Test: Global is an F-test for the joint significance of the three global variables. *** is significant at the 1% level, ** at the 5% level and * at the 10% level.*