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Inflation Dynamics: Dead, Dormant, or Determined Abroad?

ABSTRACT Inflation dynamics have been difficult to explain over the last decade. This paper explores whether 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 nonfuel 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 are still largely domestic processes.

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

Conflict of Interest Disclosure: The author is the Jerome and Dorothy Lemelson Professor of Management and Global Economics at the Sloan School of Management at the Massachusetts Institute of Technology. Beyond these affiliations, over the last two years the author has received payment for speeches or consulting work with the asset management firm Citadel, the government of Iceland, JPMorgan, and State Street. She is currently not an officer, director, or board member of any organization with an interest in this paper. No outside party had the right to review this paper before circulation. The views expressed in this paper are those of the author and do not necessarily reflect those of the Sloan School of Management or the Massachusetts Institute of Technology.

countries fell less than expected. Since then, as economies have largely recovered and unemployment has 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 consumer price index (CPI) inflation over the last decade—but has 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 wage 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 trade-off 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 1960s, the oil shocks of the 1970s highlighted the need to supplement this framework to account for changes in global oil prices (Gordon 1977, 1985). In the mid-2000s, several prominent policymakers questioned whether globalization, especially increased imports from low-wage economies, was moderating inflationary pressures at that time (Bean 2006; Kohn 2006; Yellen 2006). Research at the Bank for International Settlements (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 had only limited effects on the underlying inflation process. Ball (2006, abstract) 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 the role of financial frictions (Gilchrist and Zakrajšek 2015; Gilchrist and others 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; Hong and others 2018), nonlinearities in the relationship between slack and inflation (Hooper, Mishkin, and Sufi 2019; Gagnon and Collins 2019), the large component of inflation indexes which are not "cyclically sensitive" (Stock and Watson 2018), and the stabilizing role of inflation expectations and central bank credibility (Coibion and Gorodnichenko 2015; Bernanke 2007). Closely related, if central banks target 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 I). 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 body of literature, with the former focusing on emerging markets

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 (see Jordà and Nechio 2018) or more disaggregated data, for example, state data used in McLeay and Tenreyro (2019). These issues are attenuated in this paper through its focus on changes over time within countries.

and developing economies and the latter on the United States. Obstfeld (2019) concludes that there are important interactions between the global economy and U.S. inflation (such as through the global neutral interest rate and role of the dollar), but the evidence on whether globalization has affected U.S. inflation dynamics is inconclusive.

Most prominent papers modeling inflation in advanced economies, however, continue to place minimal emphasis on global factors. A generally accepted strategy for modeling inflation in the United States 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 modeling 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 whether global variables are directly affecting the relationship with domestic slack.[3]

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

2. For a recent prominent example, see Hooper, Mishkin, and Sufi (2019).
3. One exception is Ihrig and others (2010).

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 controls to identify effects. Second, this paper not only tests whether adding global variables to different models can improve our understanding of inflation but also whether 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 that 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 focusing on an individual country, and the combination of the cross-section and time-series dimensions of the data can better identify the role of global factors for inflation dynamics over time.[4]

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.

4. New work by Ha, Kose, and Ohnsorge (2019) and Jašová, Moessner, and Takáts (2018) also uses large cross-sections of countries to explore how inflation dynamics have changed over time.

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 nonfuel 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 toward 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 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 percent in 1990–94 to almost 57 percent in 2015–17), but for core and wage inflation it 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.[5] 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

5. 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.

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 nonfuel 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 have also become important since the GFC, including world slack and global value chains.

In order to better understand whether 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 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 percent 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 autoregressive stochastic volatility (ARSV) model developed in Forbes, Kirkham, and Theodoridis (2019), which is grounded in the unobserved component stochastic volatility (UCSV) model 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 and 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 a weaker role for domestic slack—supporting the conclusions from the Phillips curve analysis of CPI inflation.

Next, the paper explores whether these results for CPI inflation and its cyclical component also apply to 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.

A more complete exploration of which aspects of globalization are driving these patterns is an area for future research, but 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). The results highlight an important role for world slack, exchange rates, oil prices, nonfuel 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 from commodity prices increasingly co-moving 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 which global measures are most important varies based on the period and country characteristics and is an important area for future work.[6] 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 I discusses how globalization could affect inflation dynamics, including a brief literature review. Section II estimates the shared global principal components of different inflation measures and how they have evolved over time. Section III uses

6. For recent work, see Forbes (2019) and Ha, Kose, and Ohnsorge (2019).

a Phillips curve framework augmented with global variables and rolling regressions to evaluate the role of different factors, whether their role has changed over time, and whether they meaningfully improve our understanding of inflation dynamics. Section IV breaks inflation into a cyclical component and a slow-moving trend and then evaluates the role of the global factors in the cyclical component. Section V repeats key parts of the analysis for core CPI inflation, wage inflation, and the slow-moving trend component of inflation. Section VI concludes.

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

The academic literature modeling inflation—and the many proposals to improve on these frameworks to solve new puzzles—is lengthy.[7] At the core of most models, from the simplest Phillips curve equations to the most complicated dynamic stochastic general equilibrium (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 by adding a control for global slack or adjusting for import competition in firm markups), domestic variables remain central.[8] 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).[9] 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 are included), so that these variables are sufficient statistics to control for changes in the global economy.[10] This secondary role for global effects and global interactions is surprising given the extensive literature on globalization and evidence of how increased

7. For excellent overviews that capture the key issues, see Stock and Watson (2010); Gordon (2013); Ball and Mazumder (2015); Berganza, Borrallo, and del Río (2018); Miles and others (2017); Blanchard (2018); and Ha, Kose, and Ohnsorge (2019).

8. Papers studying the role of globalization in inflation include Ball (2006); Borio and Filardo (2007); Ihrig and others (2010); Berganza, Borrallo, and del Río (2018); Mikolajun and Lodge (2016); Auer, Borio, and Filardo (2017); Auer, Levchenko, and Sauré (2019); and Borio (2017).

9. 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.

10. See Eickmeier and Pijnenburg (2013) for an example of this line of reasoning.

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.[11]

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—through the effect on the imported component of any domestic inflation index as well as on exporters' competitiveness, margins, and pricing decisions.[12]

A second change in the global economy since the early 1990s has been the increased role of emerging markets. Emerging markets have accounted for over 75 percent of global growth since the GFC and have been the key source of demand for commodities.[13] As a result, global commodity prices have become more tightly linked to growth in emerging markets (particularly China) and 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 (Hamilton 2011). This would occur in sticky-price

11. See Ha, Kose, and Ohnsorge (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.

12. 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.

13. See World Bank (2018) and Miles and others (2017).

models in which firms are more 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 in purchasing final goods from their cheapest locations or using global supply chains to shift production to where it can be done at the lowest cost.[14] 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).[15] 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.[16] 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 for 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.[17] This possibility is clearly modeled 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

14. Potentially counteracting this somewhat is the trend toward greater concentration in some markets, especially in the United States. See Guilloux-Nefussi (2018) and Autor and others (forthcoming) for a discussion of how greater concentration may have increased firm pricing power.

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

16. See Auer, Levchenko, and Sauré (2019) and Wei and Xie (2019) for models of these effects of global supply chains on inflation.

17. Blanchard (2016), Ha, Kose, and Ohnsorge (2019), and Jašová, Moessner, and Takáts (2018) provide evidence of the flattening of the Phillips curve over time for different groups of countries. Karabarbounis and Neiman (2013) provide evidence on the decline in the labor share since the 1980s.

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, Degen, and Fischer 2013), and the increased ease of shifting parts of production to cheaper locations could further reduce the ability of domestic workers to bargain for higher wages (Auer, Borio, and Filardo 2017). Moreover, increased mobility of some workers (such as in the eurozone), or even just the possibility of increased immigration to fill vacancies, could further reduce worker bargaining power. Although there are many other domestic developments that 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), these multifaceted changes in the global economy could further weaken the link between domestic slack and inflation.[18]

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, Kose, and Ohnsorge (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

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

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.

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) suggest adding global slack and find 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.[19] 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 (Auer, Levchenko, and Sauré 2019; Auer, Borio, and Filardo 2017). Analyses of U.K. inflation suggest incorporating exchange rates and commodity prices in a Phillips curve framework (Forbes 2015) as well as in a trend-cycle model (Forbes, Kirkham, and Theodoridis 2019). Ihrig and others. (2010) interact key terms with measures of openness to capture how globalization could change relationships between different variables. Mikolajun and Lodge (2016) study the role of globalization in a Phillips curve framework, similar to parts of section III below.[20]

Rather than focusing on one channel, or one framework, by which globalization could affect inflation, this paper takes a more comprehensive approach. It borrows from three methodologies to assess different aspects of globalization and whether 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.

19. Ha, Kose, and Ohnsorge (2019) provide an excellent overview of the evidence for and against a role for global slack in Annex 3.1.

20. Mikolajun and Lodge (2016) do not use the other modeling approaches (such as the trend-cycle decomposition) or control for global value chains, but they add a "global inflation" variable which may capture other effects (such as from global pricing competition).

II. 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 indexes: 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 indexes for each series are from the Organization for Economic Cooperation and Development (OECD) and the International Monetary Fund (IMF) for as many countries as available from 1990 through 2017, with more information in online appendix A.[21] Each inflation measure is on a quarterly basis, annualized and seasonally adjusted.[22] There are up to 43 countries for each series, listed in online appendix B and divided into advanced economies and emerging markets based on IMF definitions. Data are 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.[23] There is a noteworthy shared global component in CPI and PPI inflation. More specifically, 40 percent of the variance in CPI inflation, and 52 percent 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 percent 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, the top graph of figure 1 shows the first principal component for each inflation measure over

21. The online appendixes may be found at the *Brookings Papers* web page, www.brookings.edu/bpea, under "Past BPEA Editions."

22. 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 value-added tax (VAT) increases that caused a one-quarter spike in inflation. The final inflation series is winsorized at the 10 percent level for each tail to remove several periods of extreme inflation (largely in emerging markets).

23. 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 are available.

Table 1. Global Principal Component (PC) of Four Inflation Series

	Percentage of variance accounted for			
	PPI	*CPI*	*Core*	*Wages*
Full sample				
No. of countries	*35*	*43*	*38*	*20*
First PC	51.6	40.2	20.9	22.5
First five PCs	76.0	66.7	51.1	54.1
Sample of countries with wage data				
No. of countries	*19*	*20*	*20*	*20*
First PC	56.3	44.8	26.0	22.5
First five PCs	83.8	74.0	60.6	54.1
Advanced economies				
No. of countries	*29*	*31*	*31*	*18*
First PC	60.5	41.1	25.1	22.7
First five PCs	81.5	69.1	53.2	55.3
Emerging markets				
No. of countries	*6*	*12*	*7*	—
First PC	39.2	25.4	23.2	—
First five PCs	95.7	75.5	85.4	—

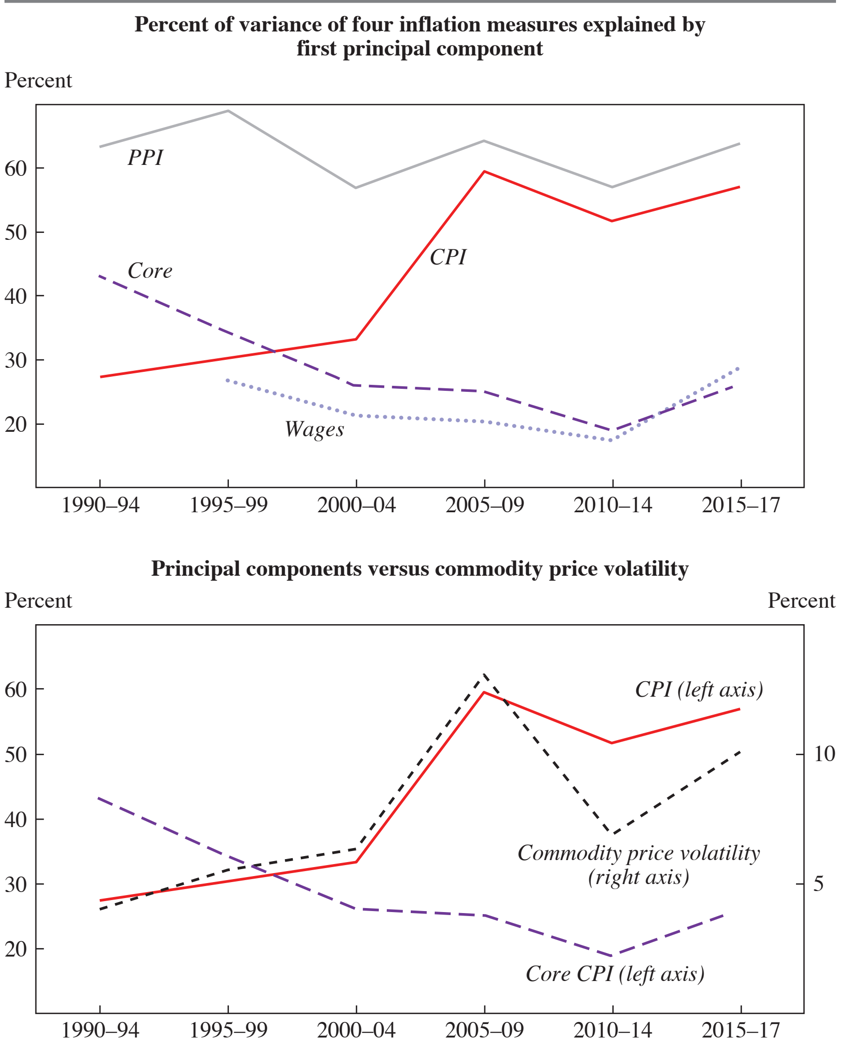
Source: Author's calculations.

Notes: PPI is producer price inflation. CPI is consumer price inflation. "Core" is CPI less food and energy. "Wages" is private sector, household hourly wages. All inflation measures are relative to the previous quarter, annualized and seasonally adjusted. See online appendix A for more details on data. Advanced economies and emerging markets are defined according to the IMF as of 2017.

five-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 percent in the 1990–94 window to 57 percent in the 2015–17 window. In contrast, the shared global component of core inflation has steadily fallen, from 43 percent at the start of the sample to 26 percent 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 is driving these different patterns across time and inflation measures. An increase in the principal component could be explained by larger common global shocks (greater commodity price volatility), a greater sensitivity of countries to common global shocks (from greater trade or financial integration), or tighter direct linkages

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



Source: Author's calculations.

Notes: Commodity price volatility measured as the standard deviation over the same windows using the IMF's index of global commodity prices (including fuel). See online appendix A for details on the price series.

between economies (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 these channels but focuses on the more easily quantifiable measures of globalization discussed in section I.

As a preliminary look at one factor that could be contributing to this increased co-movement in CPI inflation (and which is highlighted in the results below), the bottom graph of figure 1 adds the standard deviation of commodity prices to the first principal components of CPI and core inflation.[24] Commodity price volatility moves closely with the shared global component of CPI inflation—with an 89 percent 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 percent.[25] 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 figure 1 in the online appendix 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.

III. The Role of Globalization in CPI Inflation

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, Gertler, and López-Salido (2005), which includes domestic slack, inflation expectations, and lagged inflation. This framework is used frequently by central

24. Commodity prices are measured using the IMF's index of global commodity prices, including fuel.

25. Oil prices are measured using Datastream's index of Brent crude oil spot world prices in US$.

bankers (Yellen 2017; Powell 2018) and has become a standard starting point for research on monetary policy (Eberly, Stock, and Wright 2019; Hooper, Mishkin, and Sufi 2019). The section begins by discussing the baseline variables and specifications which incorporate global variables, then estimates different variants of the Phillips curve assuming that coefficients are fixed over the full sample period. The following sections allow coefficients to vary over time and then assess how allowing a dynamic role for the global variables improves the fit of the model. The section ends with a summary of a series of sensitivity tests.

III.A. The Framework and Variables

This section develops several specifications that will be used for the different segments of analysis: a domestic version of the Phillips curve 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.

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:[26]

$$\pi_{i,t} = \beta_1 \pi^e_{i,t} + \beta_2 \pi^L_{i,t} + \beta_3 SLACK^D_{i,t} + \alpha_i + \epsilon_{i,t}. \quad (1)$$

Variables are defined for each country i in quarter t:

—$\pi_{i,t}$ is quarterly CPI inflation, annualized and seasonally adjusted and described in section II.

—$\pi^e_{i,t}$ is inflation expectations, measured by the five-year ahead forecast for CPI inflation from the IMF's *World Economic Outlook*.

—$\pi^L_{i,t}$ is lagged inflation over the previous four quarters (before quarter t).

—$SLACK^D_{i,t}$ is domestic slack, measured as a principal component of seven variables: output gap, participation gap, unemployment gap, and the

26. 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, Cerutti, and Summers (2015); Eberly, Stock, and Wright (2019); Hooper, Mishkin, and Sufi (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.

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.

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 1, following recent work supporting a more flexible framework (Jordà and Nechio 2018; McLeay and Tenreyro 2019). Sensitivity tests show the key results are robust to random effects and constraining the inflation coefficients to equal 1.

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

$$\pi_{i,t} = \beta_1 \pi^e_{i,t} + \beta_2 \pi^L_{i,t} + \beta_3 SLACK^D_{i,t} + \gamma_1 ImpPrices_{i,t} + \alpha_i + \epsilon_{i,t}. \tag{2}$$

All variables are defined as in equation (1) except $ImpPrices_{i,t}$, 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 ($Oil^W_{i,t}$) with import prices.[27]

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:

$$\begin{aligned} \pi_{i,t} = {} & \beta_1 \pi^e_{i,t} + \beta_2 \pi^L_{i,t} + \beta_3 SLACK^D_{i,t} + \gamma_1 Oil^W_{i,t} + \gamma_2 Comm^W_{i,t} \\ & + \gamma_3 ER_{i,t} + \gamma_4 SLACK^W_t + \gamma_5 GVC^W_t + \alpha_i + \epsilon_{it}. \end{aligned} \tag{3}$$

Definitions for each additional variable are as follows:

—$Oil^W_{i,t}$ is defined above.

—$Comm^W_{i,t}$ is quarterly inflation in an index of world commodity prices (excluding fuel) from Datastream relative to quarterly CPI price inflation, lagged one quarter.

27. 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 oil spot world prices in US$.

—$ER_{i,t}$ 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.[28]

—$SLACK_t^W$ is world slack, measured as a weighted combination of the output gap in advanced economies and China.

—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.

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.

$$\pi_{i,t} = \beta_1 \pi_{i,t}^e + \beta_2 \pi_{i,t}^L + \beta_3 \left(SLACK_{i,t}^D * ImpSh_{i,t}^D \right) + \gamma_1 Oil_{i,t}^W + \gamma_2 Comm_{i,t}^W + \gamma_3 ER_{i,t} + \gamma_4 SLACK_t^W + \gamma_5 GVC_t^W + \alpha_i + \epsilon_{i,t}. \quad (4)$$

Equation (4) is the same as equation (3), except $SLACK_{i,t}^D$ is interacted with the import share to GDP.[29]

Each of these specifications in equations (1) through (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 thirty-one countries from 1996 through 2017. Online appendix A provides detail on definitions and sources, and section III.E examines robustness. The first three control variables (with coefficients denoted with β) are the "domestic" variables, and the remaining five (with coefficients denoted with γ) are the "global" variables. 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.[30] Beginning with domestic slack, researchers such as Albuquerque

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

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

30. Many of the variables used to create measures of slack (domestic and global) and global value chains are only available annually, so they are interpolated to quarterly frequency.

and Baumann (2017) and Hong and others (2018) have convincingly demonstrated the importance of measuring slack more broadly than simply as the deviation of unemployment from a hard-to-estimate non-accelerating inflation rate of unemployment (NAIRU). This unemployment gap may not capture the discouraged workers—those who are no longer recorded as looking for work—or people who are working part-time or working fewer hours but would prefer to be working full-time or more hours at a company or self-employed. 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 and others (2018). More specifically, I calculate the principal component using seven measures of slack. The first three are from the OECD: 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).[31] 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.[32] World slack is then 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

31. The hours data from the OECD and data for involuntary workers, temporary workers, and self-employed were all shared by Hong and others (2018). Many are only available annually and are interpolated to quarterly to calculate the principal component.

32. The difference between average GDP growth in China over the previous two years less GDP growth in the current quarter.

economy share of world GDP. The resulting measure of world slack is shown in the top panel of figure 1 in the online appendix, along with the IMF's measure of slack in advanced economies and the OECD's measure of slack in OECD economies.[33] 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).[34] The fourth variable in the principal component is the dispersion of PPI inflation across the countries in the sample for which data is available.[35] This measure is used by Auer, Levchenko, and Sauré (2019) and Wei and Xie (2019) to capture how global supply chains have affected PPI indexes by increasing the synchronization of producer prices across countries. The bottom panel of figure 1 in the online appendix graphs the resulting measure of GVCs, with the principal component suggesting that the role of GVCs increased quickly during the early 2000s, collapsed during the 2008 crisis, largely recovered from 2009 to 2011, and then was fairly stable before declining slightly at the end of the sample.

III.B. CPI Inflation with 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 (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

33. The IMF and OECD measures are both of the output gap, which I convert to slack by reversing the sign.

34. These measures were kindly shared by Zhi Wang.

35. Measured as the standard deviation in quarterly PPI inflation, with inflation relative to 4Q earlier to avoid seasonal issues.

Table 2. Phillips Curve Regressions for Quarterly CPI Inflation, 1996–2017

	Different control variables				*Different specifications*			
	Domestic only (1)	*+ Import prices (2)*	*+ Oil price (3)*	*+ All global variables (4)*	*DomSlack × impShare (5)*	*Only lagged inflation (6)*	*Random effects (RE) (7)*	*RE + constraints (8)*
Inflation Expectations	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)
R^2	*0.418*	*0.498*	*0.470*	*0.487*	*0.458*	*0.476*	*0.610*	
No. observations	*2,635*	*1,366*	*2,635*	*2,635*	*2,531*	*2,635*	*2,635*	*2,635*

Source: Author's calculations.

Notes: See online appendix A for data definitions. Columns 1–6 estimated using fixed effects 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. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

variants augmented for supply shocks—with either import or oil prices. The more limited data on import prices reduce 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 column 5 interacts 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 1.

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 is usually significant at the 1 percent 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.[36]

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 (that is, from 2 percent to 3 percent) is associated with an increase in annual CPI inflation of 0.65 pp. A 10 percent increase in oil or commodity prices in one quarter is associated with an increase in CPI inflation of about

36. 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.

0.30 pp. A 10 percent depreciation of the real exchange rate relative to two years ago corresponds to an increase in CPI inflation of 0.29 pp per quarter—which if accumulated over eight quarters would imply an increase in the level of the CPI of about 2.3 pp 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 U.S. slack from 2015:Q3 to 2017:Q4) is associated with inflation 0.09 pp higher in each year.[37] Similarly, a decrease in world slack by 1 percent of global GDP (which occurred from 2014:Q2 to 2017:Q4) is associated with inflation higher by 0.15 pp.[38] These estimates agree with other work suggesting that the relationship between slack and inflation is very flat, but also suggest that world slack, and not just domestic slack, might 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.[39] To put these estimates in context, consider a country with the mean import share in this sample of 41 percent. 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 percent), 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).

37. To further put this in context, this measure of domestic slack increased by 5.05 in the United States from 2008:Q1 through 2009:Q4.

38. To further put this in context, this measure of world slack increased by 4.65 from 2008:Q1 through 2009:Q4.

39. 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 and others [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.

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.[40] 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.[41] This could be one reason why studies that 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).

III.C. CPI Inflation with 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.[42] This could occur due to the changes in the global economy discussed in section I, 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 (2008–17).[43]

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.[44] Domestic slack continues to be negatively

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

41. This is beyond the scope of this paper, but see Ha, Kose, and Ohnsorge (2019).

42. For evidence, see Albuquerque and Baumann (2017), Blanchard, Cerutti, and Summers (2015), IMF (2016), and Mikolajun and Lodge (2016).

43. The sensitivity analysis shows that excluding the period around the GFC has minimal impact on the key results.

44. 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.

Table 3. Phillips Curve Regressions for Quarterly CPI Inflation, 1996–2007 and 2008–2017

	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 Expectations	0.663***	0.720***	0.684***	0.741***	0.696***	0.685	0.408	0.508	0.284	0.324
	(0.169)	(0.190)	(0.155)	(0.163)	(0.208)	(0.425)	(0.506)	(0.373)	(0.274)	(0.273)
Lagged Inflation	0.556***	0.672***	0.588***	0.589***	0.559***	0.490***	0.431***	0.519***	0.556***	0.556***
	(0.065)	(0.048)	(0.064)	(0.067)	(0.081)	(0.050)	(0.070)	(0.045)	(0.040)	(0.037)
Domestic Slack	–0.212***	–0.157**	–0.198***	–0.188***	–0.410**	–0.154***	–0.112	–0.157***	–0.105**	–0.171*
	(0.054)	(0.058)	(0.050)	(0.061)	(0.155)	(0.034)	(0.066)	(0.034)	(0.041)	(0.088)
Import Prices		0.061					0.136*			
		(0.057)					(0.066)			
World Oil Prices			0.030***	0.030***	0.031***			0.034***	0.026***	0.028***
			(0.004)	(0.004)	(0.004)			(0.003)	(0.003)	(0.003)
World Comm. Prices				0.004	0.002				0.031***	0.028***
				(0.013)	(0.013)				(0.009)	(0.009)
Real Exchange Rate				–0.027**	–0.029***				–0.039***	–0.040***
				(0.011)	(0.010)				(0.013)	(0.013)
World Slack				–0.410***	–0.430***				–0.434***	–0.517***
				(0.092)	(0.091)				(0.073)	(0.080)
Global Value Chains				–0.258***	–0.253***				–0.357***	–0.407***
				(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)
R^2	*0.361*	*0.497*	*0.394*	*0.414*	*0.365*	*0.252*	*0.196*	*0.356*	*0.419*	*0.425*
No. observations	*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****

Source: Author's calculations.

Notes: See online appendix A for data definitions. Estimated using fixed effects with robust standard errors clustered by country. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

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 percent 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 percent, 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 falls by only 10 percent.[45] 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 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 III.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. However, section II (and the bottom panel of figure 1) also showed that commodity price volatility has increased over time and closely mirrors the increased co-movement 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 (Hamilton 2011; Ball and Mankiw 1995).

45. The mean import share for the pre-crisis sample is 39 percent and for the last decade is 43 percent. 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.

Finally, F-tests of the joint significance of the five global variables (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).[46] 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.[47] 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.

III.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 or during certain years (such as in commodity prices 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

46. 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.

47. 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.

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.

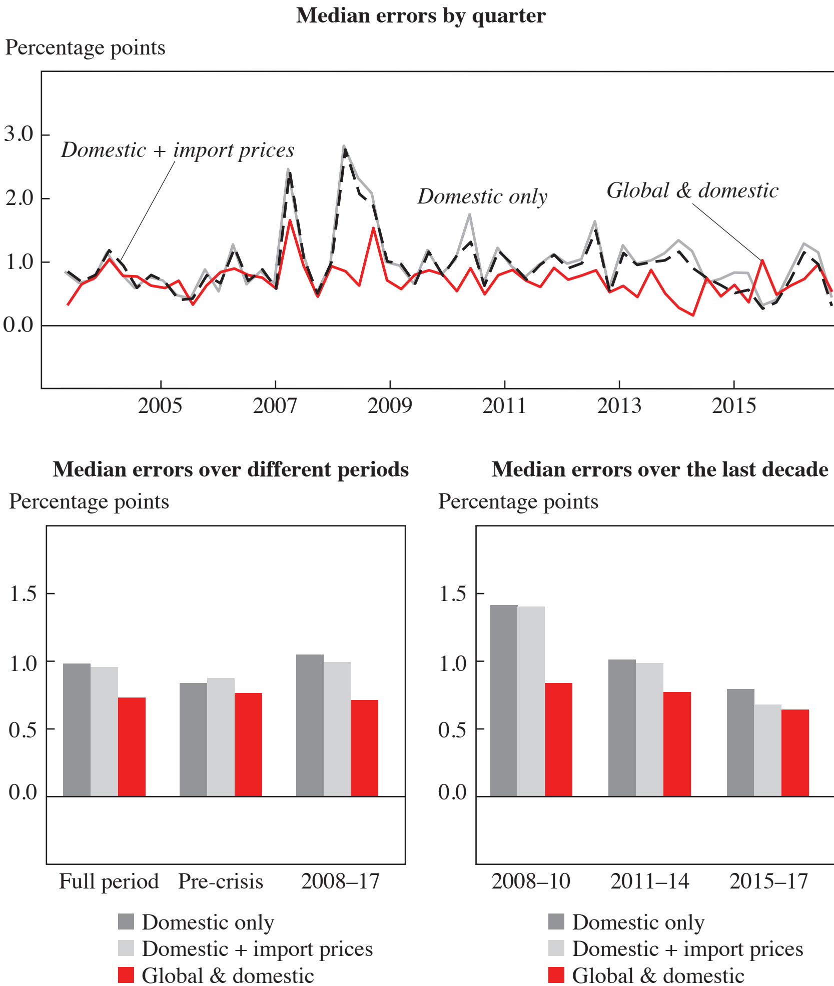
Figure 2, top panel, graphs the resulting error between actual inflation and inflation explained using the rolling estimates. The error is calculated as the median absolute value of the deviations of actual from predicted inflation for each country in each quarter, so that a lower value indicates a better 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 (darker line relative to that with only the domestic variables (lighter lines) and with the domestic variables plus import prices (striped). 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 to 2015.

Figure 2, middle left panel, 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 0.90 pp for the model with just the domestic variables and falls to only 0.82 pp with the addition of the five global variables. In contrast, over the last decade, the median error jumps to 1.11 pp for the model with just the domestic variables but falls more meaningfully to 0.77 pp 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 1.05 pp.) 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 percent of median inflation over the last decade (and 5 percent in the pre-crisis window).[48]

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

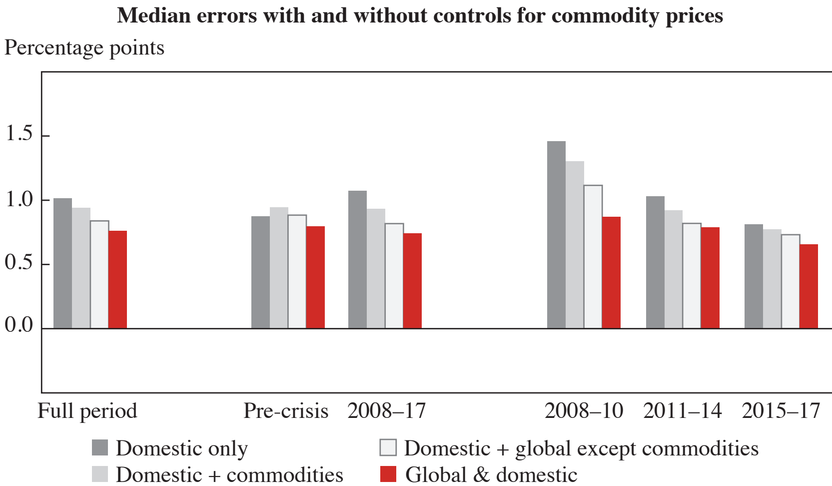
48. Calculated as the reduction in median errors from adding the global variables relative to median inflation in that window. For example, over the last decade median inflation was 2.87 percent, so the corresponding calculation is (1.11 – 0.77) / 2.87 = 12 percent.

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



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 the top panel of figure 2? To test this, figure 2, the middle right panel, breaks down the median errors over the last decade into three

Figure 2. Gap between Actual and Predicted CPI Inflation in Different Models (*Continued*)



Source: Author's calculations.

Notes: Median values of the absolute value of the difference between reported and predicted inflation based on coefficients from eight-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 (except fuel) prices. "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.

periods: around the crisis (2008–10) and then 2011–14 and 2015–17.[49] Including the global variables generates a particularly large improvement in the model's fit during the crisis window (reducing the errors from 1.51 pp to 0.90 pp) but continues to meaningfully reduce the errors outside the crisis window (from 1.07 pp to 0.82 pp over 2011–14 and 0.84 pp to 0.68 pp over 2015–17). When these improvements are assessed relative to median inflation rates for each window, they correspond to an improvement of 27 percent during the crisis window, 17 percent over 2011–14, and 18 percent over 2015–17 (when median inflation was only 0.86 percent).

How much of this improved fit from including the five global variables over the last decade reflects the influence of commodity prices? Commodity

49. Breaking out results for the earlier five-year windows in figure 1 show errors similar to the pre-crisis window.

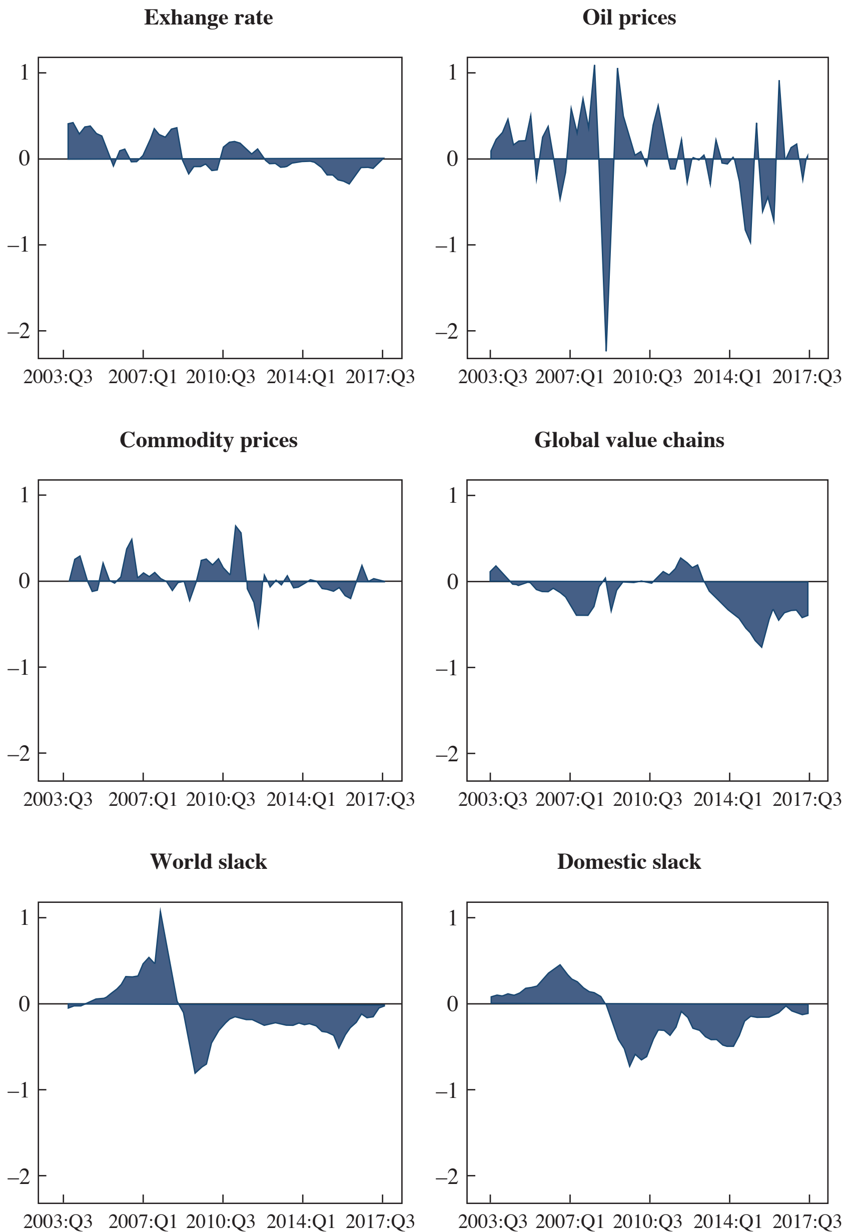
price volatility has increased sharply (section II and the bottom panel of figure 1) and the elasticity of changes in commodity prices to CPI inflation has increased over the last decade (section III.C). Both of these changes could cause commodity prices to explain a larger share of the variation in CPI inflation. To test if the increased role of the global factors is primarily capturing the effects of commodity prices, I re-estimate the rolling regressions for CPI inflation using two variants: only including commodity prices as a global variable, or including all four global variables *except* commodity prices. Figure 2, bottom panel, 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 using 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 a 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 U.S. CPI inflation from combining the coefficient estimates from the full global model (used for figure 2) and U.S. data. The global variables have had a meaningful effect on U.S. inflation over some windows. In the period immediately after the peak of the GFC, when U.S. inflation was higher than expected, oil prices, commodity prices, and the dollar's depreciation all contributed to higher inflation. In contrast, over the window 2012–16, 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 U.S. slack. The magnitudes shown in figure 3 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 United States that is relatively less exposed to the global economy.

III.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

Figure 3. Estimated Impact of Global Variables and Domestic Slack on CPI Inflation in the United States



Source: Author's calculations.

Notes: Based on coefficients estimated from equation (3) using rolling eight-year windows and the sample of countries/periods used in figure 2. Variables are defined in online appendix A.

timing conventions. This section summarizes a series of sensitivity tests exploring whether 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 more than twenty sensitivity tests which can be roughly categorized into three groups:

—*Different variable definitions:* Several papers have highlighted the challenges in measuring the output gap (or slack) and global value chains, so I try several different measures.[50] 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 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).

—*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 I exclude just 2008 or exclude 2008–9. Also, although the sample only includes a few emerging markets due to data availability, I re-estimate the model using only advanced economies.[51]

—*Different specifications:* There is some evidence that the relationship between domestic slack and inflation is nonlinear, so I try three variants proposed by Hooper, Mishkin, and Sufi (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"

50. See Albuquerque and Baumann (2017), Hong and others (2018), and discussion in section III.A.

51. The sample of emerging markets is so limited that results for this group are not robust to minor changes in specification.

model (which allows for nonlinearity in countries with less slack by including slack squared when slack is negative).[52] Next, I include the restriction that the sum of the coefficients on inflation expectations and lagged inflation equal 1, 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.[53]

Table 1 in the online appendix 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 measure (just the unemployment gap instead of a principal component, in column 1), it is less often significant, as in Hong and others (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 nonlinear 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 nonlinear 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

52. For more details on these specifications, see Hooper, Mishkin, and Sufi (2019); see also Gagnon and Collins (2019) for evidence of nonlinearity.

53. Forbes, Hjortsoe, and Nenova (2017, 2018) discuss the challenges in measuring the duration of pass-through from exchange rate movements to inflation.

crisis window 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.[54] 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 table 1 in the online appendix) 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 2008–10) is excluded from the sample (column 4).

III.F. CPI Inflation: Summary of Phillips Curve Analysis

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, is part of the reason for this increased role of global factors. This increased role of commodity prices on CPI inflation could also 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 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 in order to understand CPI inflation dynamics.

IV. 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

54. Results are not reported, but 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.

academics, this approach has a number of shortcomings. As shown above, parameter instability could limit its ability to explain inflation dynamics in real time and forecast inflation. As also highlighted by 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 have an impact on inflation (such as domestic slack). Other frameworks can therefore be a useful complement. One such framework is a trend-cycle approach, which separates inflation into a slow-moving, persistent trend and a temporary cyclical component. In this section this approach is used to analyze CPI inflation, evaluate the role of the same domestic and global factors, and test whether their role has changed over time.

IV.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) provide an alternate, data-driven, and more atheoretical approach. They propose 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 (which I call the "cycle"). Stock and Watson (2007) develop 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 United States, while Cecchetti and others (2007) apply the UCSV model to the G-7 countries and Forbes, Kirkham, and Theodoridis (2019) build on these models to analyze inflation dynamics in the United Kingdom.[55]

This section applies the trend-cycle model developed in Forbes, Kirkham, and Theodoridis (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 autoregressive unobserved components (ARUC) model developed by Chan, Koop, and Potter (2013), with minimal other assumptions. The resulting ARSV model used below, and discussed in detail in Forbes, Kirkham, and Theodoridis (2019) and in Forbes (2019), can make it more difficult to achieve

55. For examples of papers focusing on the United States, see Stock and Watson (2010), Chan, Koop, and Potter (2013), and Cecchetti and others (2017).

convergence but better captures the inflation dynamics in this paper's more diverse sample of countries (as compared to the U.S. 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 *i* in the sample, using the quarterly, annualized, seasonally adjusted inflation data from 1990 through 2017 discussed in section II and detailed in online appendix A.[56] 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 online appendix table 2.[57] Columns 1 and 2 report the average distance from the 15th to the 85th percentiles of the estimated trends and suggest that 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 percentage of the variation in inflation for each country explained by the trend.[58] Over the full sample period, the trend explains 31 percent of the variation in CPI inflation and 55 percent 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 the 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.

56. The first twelve 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 one thousand draws. If the algorithm did not converge within five hours, the estimation was terminated.

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

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

IV.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 paper, this section focuses on the same domestic and global variables as in the Phillips curve analysis in section III. 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:

$$\pi_{i,t} = \alpha_i + \beta\tilde{\tau}_{i,t} + \sum_{k=1}^{7} \gamma_k \boldsymbol{X}_{k,i,t} + e_{i,t}. \tag{5}$$

The $\pi_{i,t}$ is CPI inflation for country i in quarter t (seasonally adjusted and annualized), $\tilde{\tau}_{i,t}$ is the slow-moving trend (estimated in section IV.A), and the $\boldsymbol{X}_{i,t}$ are k additional variables that could help explain the cyclical movements in inflation around this trend. Following the format in section III, the variables in $X_{i,t}$ begin with just domestic variables (inflation expectations and domestic slack), then add a control for oil prices (to focus on a consistent sample).[59] 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) is added and this is extended with an interaction of domestic slack with the import share.[60] Each variable in $\boldsymbol{X}_{k,i,t}$ is defined as in the last section, with details in online 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 roughly 40 percent 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

59. Substituting import prices does not change any of the key results but shrinks the sample by more than half.

60. Lagged inflation is not included due to its high collinearity with the trend.

Table 4. The Cyclical Component of CPI Inflation

	Full period			
	Domestic only (1)	*+ Oil prices (2)*	*+ All global variables (3)*	*DomSlack × impShare (4)*
Trend Inflation	0.641***	0.629***	0.636***	0.749***
	(0.089)	(0.086)	(0.089)	(0.047)
Inflation Expectations	0.172	0.234	0.360**	0.310*
	(0.178)	(0.184)	(0.153)	(0.169)
Domestic Slack	–0.189***	–0.181***	–0.162***	–0.264***
	(0.040)	(0.041)	(0.042)	(0.068)
World Oil Prices		0.025***	0.023***	0.024***
		(0.003)	(0.002)	(0.002)
World Commodity Prices			0.018***	0.017***
			(0.006)	(0.006)
Real Exchange Rate			–0.017	–0.024*
			(0.014)	(0.013)
World Slack			–0.083**	–0.082*
			(0.038)	(0.043)
Global Value Chains			0.065*	0.084***
			(0.035)	(0.028)
Constant	0.565	0.411	0.160	0.007
	(0.298)	(0.318)	(0.301)	(0.331)
R^2	*0.507*	*0.537*	*0.545*	*0.543*
No. observations	*2,456*	*2,456*	*2,456*	*2,355*
F-Test: joint significance of global variables				

Source: Author's calculations.

Notes: Estimated using fixed effects with robust standard errors clustered by country. See online appendix A for variable definitions and section V for estimation of the trend. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

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.[61] The global variables usually have the expected sign and are often (but not

61. More specifically, after adjusting for the increase in the import share from 38 percent to 42 percent across the two periods in this sample, the underlying Phillips curve coefficient evaluated at the sample means declines by 16 percent.

Pre-crisis (1996–2007)				Last decade (2008–2017)			
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)*
0.550***	0.548***	0.542***	0.715***	0.841***	0.797***	0.781***	0.772***
(0.099)	(0.099)	(0.099)	(0.059)	(0.148)	(0.135)	(0.145)	(0.145)
0.465**	0.539**	0.635***	0.491	0.076	0.045	–0.026	0.021
(0.209)	(0.212)	(0.183)	(0.229)	(0.454)	(0.417)	(0.371)	(0.371)
–0.282***	–0.277***	–0.238***	–0.355***	–0.178***	–0.196***	–0.165***	–0.329**
(0.061)	(0.061)	(0.070)	(0.097)	(0.053)	(0.050)	(0.055)	(0.152)
	0.023***	0.023***	0.024***		0.026***	0.023***	0.024***
	(0.003)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)
		–0.008	–0.007			0.024**	0.021**
		(0.011)	(0.010)			(0.009)	(0.009)
		–0.011	–0.017			–0.033	–0.034
		(0.014)	(0.012)			(0.021)	(0.022)
		–0.392***	–0.384***			–0.266***	–0.329***
		(0.122)	(0.124)			(0.046)	(0.046)
		–0.170*	–0.127			–0.075	-0.109
		(0.091)	(0.088)			(0.071)	(0.073)
0.091	–0.148	–0.562*	–0.652	0.468	0.621	1.141	1.163
(0.328)	(0.348)	(0.320)	(0.475)	(0.926)	(0.829)	(0.698)	(0.703)
0.474	*0.494*	*0.506*	*0.500*	*0.384*	*0.444*	*0.471*	*0.476*
1,313	*1,313*	*1,313*	*1,259*	*1,143*	*1,143*	*1,143*	*1,096*
		*16.55****	*15.53****			*42.74****	*44.00****

always) significant. Higher oil prices and less world slack are 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 percent 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. 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.[62] 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.

V. 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?

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

To begin, I return to the Phillips curve model discussed in section III and repeat the analysis for core CPI and wage inflation (defined in online appendix A), measured quarterly, seasonally adjusted, and annualized. I continue to report four specifications for each inflation measure: with only domestic variables, adding 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: First, instead of including oil and commodity (ex-fuel) prices separately, I just include one broader commodity

62. 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.

price index.[63] Second, I drop real exchange rate movements in the model of wage growth (which would capture Balassa-Samuelson effects). Finally, I 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.[64] 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.[65] 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 more than twenty sensitivity tests reported for the CPI regressions in section III.D. A sample of estimates are in table 3 in the online appendix. The results highlighted above are robust; the association between core inflation and domestic slack is still usually significant but has weakened

63. 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.

64. More specifically, when the coefficient on domestic slack is adjusted for the increase in the mean import share across periods (from 39 percent to 43 percent), this still implies a decline in the underlying Phillips curve coefficient of about 39 percent.

65. 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 nonlinear specifications, or if domestic slack is interacted with GVCs or trade openness, the coefficient on world slack often becomes significant.

Table 5. Phillips Curve Estimates for Core CPI Inflation, 1996–2017

	Full period				
	Domestic only (1)	*+ Import prices (2)*	*+ Oil prices (3)*	*+ All global variables (4)*	*DomSlack × impShare (5)*
Inflation Expectations	0.501***	0.434***	0.503***	0.515***	0.543***
	(0.054)	(0.080)	(0.054)	(0.054)	(0.058)
Lagged Inflation	0.646***	0.711***	0.647***	0.664***	0.639***
	(0.039)	(0.046)	(0.039)	(0.039)	(0.043)
Domestic Slack	–0.115***	–0.082***	–0.113***	–0.094***	–0.216***
	(0.018)	(0.019)	(0.018)	(0.018)	(0.041)
Import Prices		0.032*			
		(0.017)			
World Oil Prices			0.005***		
			(0.002)		
World Comm. and Oil Prices				0.009***	0.008***
				(0.003)	(0.003)
Real Exchange Rate				–0.017***	–0.018***
				(0.005)	(0.005)
World Slack				–0.078***	–0.080***
				(0.022)	(0.021)
Global Value Chains				–0.003	–0.002
				(0.018)	(0.019)
Constant	–0.353***	–0.350**	–0.369***	–0.390	–0.397
	(0.111)	(0.162)	(0.113)	(0.088)	(0.091)
R^2	*0.507*	*0.531*	*0.508*	*0.515*	*0.495*
No. observations	*2,636*	*1,374*	*2,636*	*2,636*	*2,532*
F-Test: joint significance of global variables					

Source: Author's calculations.

Notes: See online appendix A for data definitions. Estimated using fixed effects with robust standard errors clustered by country. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

over the last decade, and increased import exposure only plays a 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 precrisis 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

Pre-crisis (1996–2007)					*Last decade (2008–2017)*				
Domestic only (6)	*+ Import prices (7)*	*+ Oil prices (8)*	*+ All global variables (9)*	*DomSlack × impShare (10)*	*Domestic only (11)*	*+ Import prices (12)*	*+ Oil prices (13)*	*+ All global variables (14)*	*DomSlack × impShare (15)*
0.467***	0.472***	0.466***	0.483***	0.498***	0.580***	0.487	0.527***	0.522***	0.596***
(0.085)	(0.074)	(0.085)	(0.092)	(0.120)	(0.165)	(0.299)	(0.157)	(0.165)	(0.173)
0.630***	0.682***	0.630***	0.653***	0.641***	0.458***	0.390***	0.461***	0.474***	0.466***
(0.061)	(0.077)	(0.061)	(0.059)	(0.070)	(0.050)	(0.062)	(0.050)	(0.051)	(0.053)
−0.165***	−0.148***	−0.165***	−0.170***	−0.327***	−0.127***	−0.089*	−0.128***	−0.116***	−0.223***
(0.037)	(0.043)	(0.037)	(0.042)	(0.108)	(0.026)	(0.044)	(0.026)	(0.027)	(0.068)
	−0.002					0.071***			
	(0.020)					(0.018)			
		0.000					0.007***		
		(0.002)					(0.002)		
			−0.001	−0.002				0.015***	0.013***
			(0.006)	(0.006)				(0.004)	(0.004)
			−0.026***	−0.027***				−0.013	−0.013
			(0.006)	(0.006)				(0.009)	(0.009)
			−0.124**	−0.129**				−0.038	−0.070
			(0.059)	(0.062)				(0.056)	(0.059)
			−0.069	−0.056				0.077	0.052
			(0.043)	(0.045)				(0.062)	(0.065)
−0.209	−0.378*	−0.207	−0.360	−0.356	−0.215	0.066	−0.110	−0.164	−0.245
(0.138)	(0.182)	(0.136)	(0.111)	(0.146)	(0.276)	(0.612)	(0.257)	(0.324)	(0.332)
0.475	*0.505*	*0.475*	*0.488*	*0.456*	*0.224*	*0.162*	*0.235*	*0.243*	*0.241*
1,402	*766*	*1,402*	*1,402*	*1,348*	*1,234*	*608*	*1,234*	*1,234*	*1,184*
			*6.58****	*6.92****				*5.71****	*6.44****

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 for the shorter windows. This suggests that global variables may play a role in explaining differences in wage growth over longer periods but not shorter ones.

Table 6. Phillips Curve Regressions for Wage Inflation, 1996–2017

	Full period			
	Domestic only (1)	*+ Product growth (2)*	*+ All global variables (3)*	*DomSlack × impShare (4)*
Inflation Expectations	0.535***	0.183	0.472**	0.504***
	(0.175)	(0.322)	(0.172)	(0.160)
Lagged Inflation	0.244***	0.141	0.217	0.216
	(0.075)	(0.156)	(0.064)	(0.065)
Domestic Slack	–0.273***	–0.246***	–0.153***	–0.326**
	(0.050)	(0.056)	(0.047)	(0.114)
Productivity Growth		0.512		
		(0.305)		
World Comm. and Oil Prices			0.002	0.003
			(0.006)	(0.006)
World Slack			–0.351***	–0.352***
			(0.092)	(0.086)
Global Value Chains			–0.144**	–0.154**
			(0.066)	(0.067)
Constant	1.863***	2.299**	2.167***	2.085***
	(0.286)	(0.802)	(0.326)	(0.315)
R^2	*0.122*	*0.069*	*0.150*	*0.152*
No. observations	*1,660*	*1,148*	*1,660*	*1,643*
F-Test: joint significance of global variables				

Source: Author's calculations.

Notes: Wages are private-sector household wages. See online appendix A for data definitions. Estimated using fixed effects with robust standard 0errors clustered by country. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

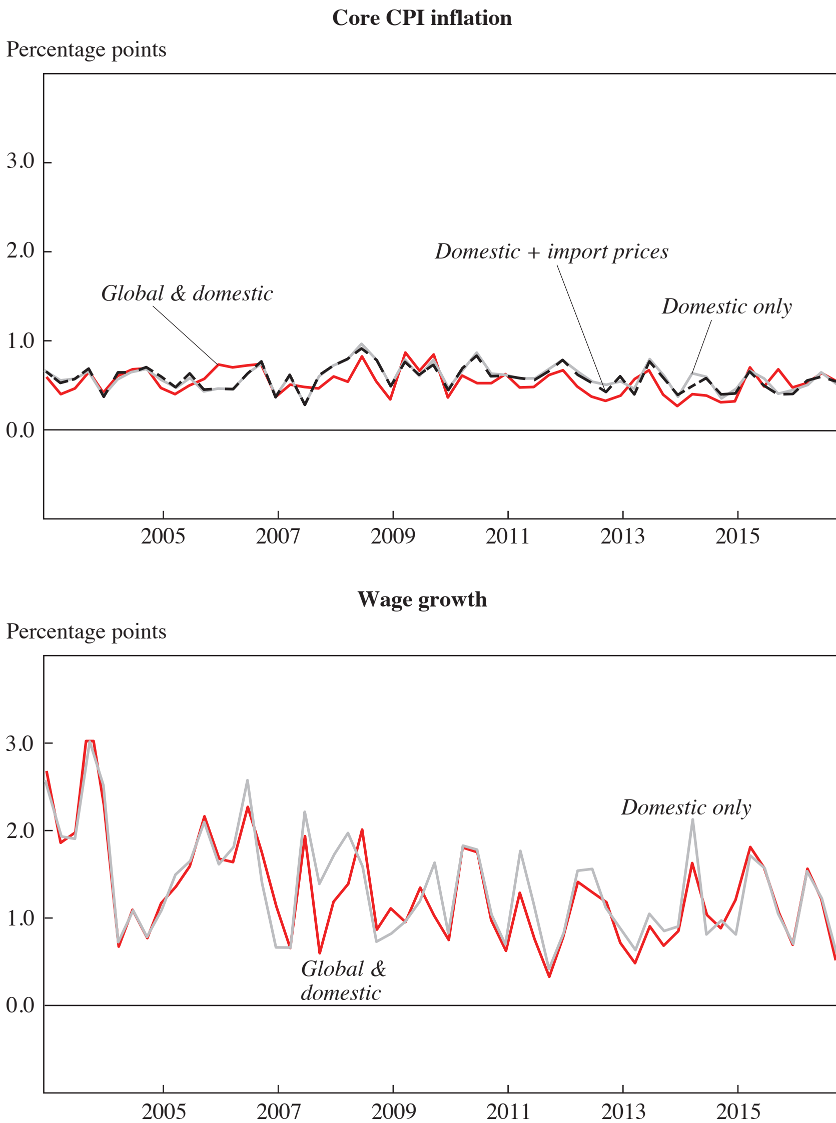
To check the robustness of these results, I repeat the same series of more than twenty sensitivity tests described in section III.D. Key results are in table 4 of the online appendix. The one consistent result is that most variables are not consistently significant. The most robust finding is that higher 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

Pre-crisis (1996–2007)				*Last decade (2008–2017)*			
Domestic only (5)	*+ Product growth (6)*	*+ All global variables (7)*	*DomSlack × impShare (8)*	*Domestic only (9)*	*+ Product growth (10)*	*+ All global variables (11)*	*DomSlack × impShare (12)*
0.030	−0.536	0.052	0.030	0.233	0.866	0.235	0.428
(0.197)	(0.731)	(0.202)	(0.196)	(0.595)	(0.588)	(0.638)	(0.637)
0.241***	0.199*	0.237***	0.254***	−0.036	0.003	−0.026	−0.008
(0.062)	(0.105)	(0.058)	(0.062)	(0.111)	(0.179)	(0.104)	(0.112)
−0.213***	−0.195**	−0.197***	−0.320**	−0.369***	−0.227**	−0.306***	−0.574***
(0.069)	(0.081)	(0.066)	(0.124)	(0.088)	(0.079)	(0.092)	(0.144)
	1.035***				−0.847**		
	(0.322)				(0.388)		
		0.005	0.006			0.006	0.007
		(0.013)	(0.013)			(0.008)	(0.008)
		−0.230	−0.227			−0.233	−0.230
		(0.178)	(0.181)			(0.167)	(0.147)
		−0.126	−0.117			−0.066	−0.046
		(0.107)	(0.107)			(0.093)	(0.084)
3.307***	3.664**	3.100***	3.112***	2.807**	1.211	3.052**	2.512*
(0.415)	(1.583)	(0.438)	(0.425)	(1.244)	(1.119)	(1.332)	(1.328)
0.061	*0.049*	*0.065*	*0.057*	*0.052*	*0.039*	*0.059*	*0.056*
878	*601*	*878*	*871*	*782*	*547*	*782*	*772*
		1.21	*1.25*			*1.13*	*1.36*

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 III.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 figure 4. The simple model is far more successful

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



Source: Author's calculations.

Notes: Median values of the absolute value of the difference between reported and predicted inflation based on eight-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 and periods with import price data to maintain a consistent sample.

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, figure 5 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 0.12 pp 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 0.17 pp during the 2008–10 window and by 0.13 pp from 2011–14) 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 percent and 2.6 percent for core and wage inflation, respectively, as compared to 11.8 percent for CPI inflation, over the last decade.[66]

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

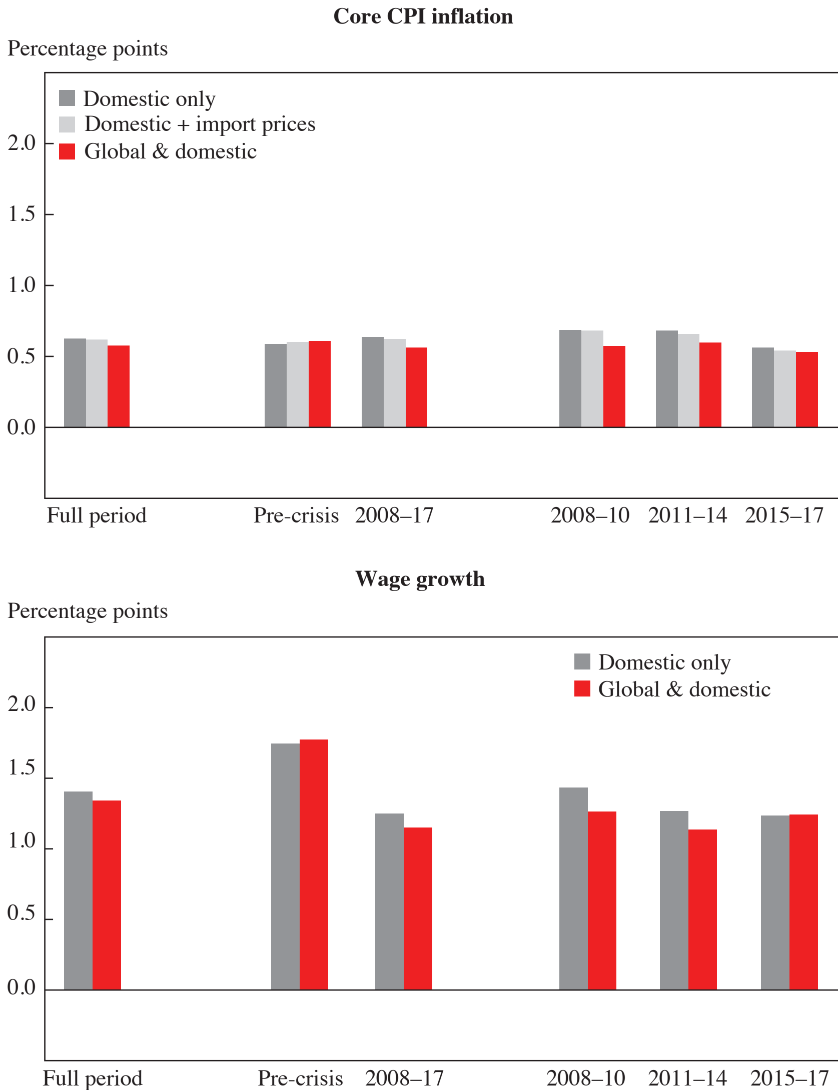
To further explore the role of globalization for other measures of inflation, I return to the trend-cycle decomposition from section IV. Global factors had become more important for the cyclical movements in CPI inflation around its trend, but what explains this slow-moving trend? Are global factors 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 IV.A) and follows Cecchetti and others (2017) and Forbes, Kirkham, and Theodoridis (2019) to examine its correlates:

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

66. 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 percent and 3.82 percent, respectively.

Figure 5. Summary Statistics: Gap between Actual and Predicted Inflation for Core CPI and Wages in Different Models



Source: Author's calculations.

Notes: Median values of the absolute value of the difference between reported and predicted inflation based on eight-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 and periods with import price data to maintain a consistent sample.

where all variables are defined above, except now expressed in first differences.[67] As explained by Cecchetti and others (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 nonstationary.

Table 7 reports results from these panel regressions of trend core inflation on similar groups of variables as in equations (1)–(4).[68] 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).[69] 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 percent 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.

67. 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.

68. I use the full set of control variables but exclude lagged inflation, which is highly correlated with the trend.

69. The Phillips curve coefficient falls from –0.35 to –0.10 across the two periods when evaluated at the mean import shares.

Table 7. The Trend in Quarterly Core Inflation

	Full period			
	Domestic only (1)	*+ Oil prices (2)*	*+ All global variables (3)*	*DomSlack × impShare (4)*
Inflation Expectations	0.105**	0.108**	0.113**	0.078***
	(0.039)	(0.039)	(0.043)	(0.025)
Domestic Slack	–0.029**	–0.033**	–0.036***	–0.075**
	(0.011)	(0.012)	(0.012)	(0.033)
World Oil Prices		0.001		
		(0.001)		
World Comm. and Oil Prices			0.003	0.003
			(0.002)	(0.002)
Real Exchange Rate			–0.002**	–0.001**
			(0.001)	(0.001)
World Slack			–0.014	–0.019
			(0.012)	(0.011)
Global Value Chains			–0.018**	–0.012*
			(0.008)	(0.007)
Constant	–0.028***	–0.028***	–0.024***	–0.020***
	(0.001)	(0.001)	(0.002)	(0.001)
R^2	*0.009*	*0.015*	*0.022*	*0.022*
No. observations	*2,260*	*2,260*	*2,165*	*2,067*
F-Test: joint significance of global variables				

Source: Author's calculations.

Notes: Estimated using fixed effects with robust standard errors clustered by country. See online appendix A for variable definitions and section V for estimation of the trend. ***Significant at the 1 percent level; **significant at the 5 percent level; *significant at the 10 percent level.

VI. 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 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

Pre-crisis (1996–2007)				*Last decade (2008–2017)*			
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)*
0.109**	0.109**	0.120***	0.092***	0.059*	0.047	0.034	0.035
(0.042)	(0.042)	(0.042)	(0.032)	(0.033)	(0.034)	(0.028)	(0.028)
–0.058***	–0.058***	–0.067***	–0.131*	–0.014	–0.024**	–0.023*	–0.041*
(0.018)	(0.018)	(0.023)	(0.067)	(0.011)	(0.011)	(0.012)	(0.024)
	0.000				0.002		
	(0.000)				(0.002)		
		0.001	0.001			0.003	0.003
		(0.001)	(0.001)			(0.003)	(0.003)
		–0.004**	–0.003			–0.001	0.000
		(0.002)	(0.002)			(0.001)	(0.001)
		0.005	–0.008			–0.026*	–0.030**
		(0.029)	(0.026)			(0.013)	(0.014)
		–0.010	–0.004			–0.017*	–0.016*
		(0.011)	(0.010)			(0.009)	(0.008)
–0.044***	–0.044***	–0.041***	–0.033***	–0.017***	–0.014***	–0.010*	–0.011**
(0.003)	(0.003)	(0.009)	(0.009)	(0.002)	(0.003)	(0.005)	(0.004)
0.042	*0.042*	*0.052*	*0.051*	*0.001*	*0.014*	*0.020*	*0.020*
1,197	*1,197*	*1,102*	*1,051*	*1,063*	*1,063*	*1,063*	*1,016*
		1.62	*1.32*			*1.76*	*1.84*

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 their role 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 company 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 can be 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.

ACKNOWLEDGMENTS Special thanks to Javier Cravino, Ayhan Kose, and Jim Stock for detailed comments and suggestions on this draft, to Kostas Theodoridis for joint work on the trend-cycle analysis used in this paper, to Gee Hee Hong, Zsóka Kóczán, Weicheng Lian, and Malhar Nabar for kindly sharing their labor market data, and to Zhi Wang for sharing his data on global value chains. Additional thanks to participants at the Brookings Panel on Economic Activity held in Washington, D.C., on September 6, 2019, and to Simon Gilchrist, Carlos Viana de Carvalho, and other participants at the 17th BIS Annual Research Conference held in Zurich on June 22, 2018, for comments on initial work on this topic. Author contact information: kjforbes@mit.edu.

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Comments and Discussion

COMMENT BY

JAVIER CRAVINO In "Inflation Dynamics: Dead, Dormant, or Determined Abroad?" Kristin Forbes argues that inflation dynamics have changed since the global financial crisis (GFC). She notes two important changes: first, the Phillips curve has become flatter, that is, large changes in the unemployment rate have been associated with small changes in inflation; second, inflation dynamics since the GFC have been difficult to explain using existing empirical models. Forbes asks whether globalization is behind these changes and shows how empirical models of inflation can be extended to better account for global factors.

The idea that foreign factors can affect domestic inflation has a long tradition in economics.[1] The main premise in the paper is that globalization can affect CPI inflation beyond its effect on import prices. Forbes argues that to properly control for the effects of globalization, it is important to introduce a broad set of global variables into the workhorse empirical models of inflation.

The paper highlights three main empirical findings. First, it shows that CPI inflation has become more synchronized since the GFC, while core and wage inflation have not. Second, it shows that workhorse empirical models of inflation lose explanatory power after the GFC. However, the models maintain their explanatory power if they are extended to include global variables. Finally, the paper argues that much of the flattening of the Phillips curve can be accounted for by an increase in the share of imported goods in the CPI.

1. For a modern treatment of the Phillips curve in open economies, see Galí and Monacelli (2005) and the literature that followed.

Forbes's extensions to the existing models flexibly control for global variables in a way that is loosely grounded in theory. One drawback of this approach is that the mapping of the results to existing theories of inflation is not always straightforward. This discussion attempts to interpret the results of the paper in light of a standard (though highly stylized) open economy model of the Phillips curve.

The discussion is organized as follows. First, I present a small open economy model to guide the discussion on how foreign factors can affect domestic inflation. I then use this model to evaluate how changes in these factors affect the slope of the Phillips curve. Finally, I use the model to evaluate how adding foreign variables can increase the explanatory power of the Phillips curve.

THE PHILLIPS CURVE IN A STYLIZED SMALL OPEN ECONOMY MODEL This section provides a stylized small open economy model to illustrate how globalization can affect domestic inflation. The ingredients of the model intend to capture the main mechanisms described in Forbes's paper: the economy consumes commodities and non-commodities and imports intermediate inputs and final goods, firms' desired markups are variable, and nominal prices are sticky.[2] Since Forbes does not emphasize how globalization affects inflation expectations, I abstract from dynamic decisions and focus on a two-period economy to facilitate the exposition.

Environment. Consider a small open economy that lasts for two periods, $t = 1,2$. The consumption basket in the economy contains commodities and non-commodities. The (log) aggregate price index in period t is

$$p_t = \omega p_t^{Core} + [1 - \omega] p_t^{Com}, \tag{1}$$

where p_t^{Core} and p_t^{Core} are, respectively, the core and the commodity price indexes, and ω is the share of non-commodities in the consumption basket. All variables are denoted in logs. The core price index is

$$p_t^{Core} = \mu p_t^D + [1 - \mu] p_t^M, \tag{2}$$

2. Another mechanism mentioned in the paper is that globalization may reduce workers' bargaining power. Changes in workers' bargaining power should be reflected in a change in the slope of the wage Phillips curve (that is, the relation between wage inflation and unemployment or domestic slack). Forbes notes that the slope of the wage Phillips curve has not changed since the GFC. I will thus assume that this slope is constant and not model this mechanism explicitly.

where p_t^D and p_t^M are the price indexes for domestic and imported goods respectively, and μ is the share of domestic goods in the core price index. Commodity and import prices are determined in world markets and are exogenously given.

Domestic goods are produced by a continuum of monopolistically competitive producers. These producers would like to set prices equal to

$$\bar{p}_t^D = [1 - \alpha] w_t + \alpha p_t + \bar{\rho}, \tag{3}$$

in each period t. The desired price $\bar{p}_t^D$ depends on the nominal wage and the aggregate price index, w_t and p_t, up to a constant $\bar{\rho}$. The parameter α captures the extent to which the price that a domestic producer would like to set depends on the prices set by other producers in the economy. This dependence may arise from strategic complementarities in either production or demand.[3]

All producers know w_1 and p_1 before choosing prices in period 1 and thus set prices equal to $p_1^D = \bar{p}_1^D$. I introduce nominal price rigidities by assuming that only a fraction θ of producers know w_2 and p_2 before setting prices in period 2. These producers set prices equal to $\bar{p}_2^D$. The remaining producers $1 - \theta$ price according to their expectations of w_2 and p_2. I assume that these producers expect wages and prices in period 2 to equal those in period 1 and thus set prices equal to $\bar{p}_1^D$ in the second period. Note that the parameter θ controls the fraction of prices that adjust in the second period.

The aggregate price index for domestic goods is thus given by

$$p_2^D = \theta \bar{p}_2^D + [1 - \theta] p_1^D. \tag{4}$$

Combining equations (1)–(4) and denoting aggregate inflation by $\pi_t \equiv p_2 - p_1$, we obtain

$$\pi_t = \frac{\mu[1 - \alpha]\omega\theta}{1 - \mu\alpha\omega\theta} \pi_t^w + \frac{[1 - \mu]\omega}{1 - \mu\alpha\omega\theta} \pi_t^M + \frac{1 - \omega}{1 - \mu\alpha\omega\theta} \pi_t^{com}, \tag{5}$$

where π_t^w, π_t^M, and π_t^{com}, respectively, denote wage, import, and commodity price inflation.

3. For example, strategic complementarities in production can arise if production uses intermediate inputs produced by other firms in the economy. Strategic complementarities in demand can arise if the producer's desired markup depends on the prices set by its competitors. Blanco and Cravino (forthcoming) show how various models of strategic complementarities can be mapped to equation (3).

Globalization and slope of the Phillips curve. Equation (5) can help us understand how globalization affects the relationship between the aggregate inflation rate and the slack of the domestic economy. Since import and commodity prices are exogenous, domestic slack affects aggregate inflation only through its effect on nominal wage inflation, π_t^w. Forbes highlights that the relationship between wage inflation and domestic slack has not changed since the GFC. I will thus assume that this relationship is constant and focus on how globalization may have affected the slope between aggregate price and wage inflation, which is given by

$$\beta \equiv \frac{\mu[1-\alpha]\omega\theta}{1-\mu\alpha\omega\theta}.$$

Import share. Forbes highlights that one way in which globalization can reduce the slope of the Phillips curve is through increased trade integration. This is indeed the case in the model, where the slope β depends positively on the share of domestic goods in the core price index μ. Intuitively, inflation is more responsive to domestic wages (and domestic slack) the larger the share of domestic goods in the price index.

Commodity prices and nominal price rigidities. Forbes also highlights that the increased role of emerging markets in the global economy has made commodity prices more volatile, which can affect inflation dynamics. Note that while the slope β depends on the share of non-commodities in the CPI ω, it does not depend directly on the volatility of commodity prices.

Forbes argues that increased volatility of commodity prices can affect inflation dynamics indirectly if firms change prices more frequently in the presence of large commodity price shocks. However, in the model laid out above, the slope of the Phillips curve becomes steeper, not flatter, as we increase the fraction of firms that adjust prices, θ.[4] Thus, while greater commodity price volatility may affect inflation dynamics, it is unclear how it can flatten the Phillips curve.

Variable markups and global value chains. Finally, Forbes notes that globalization could affect inflation dynamics by putting pressure on markups via foreign competition and on costs via global supply chains. Indeed, in the model, the slope β depends on the degree of strategic complementarities α. The higher the strategic complementarities, the lower the slope of the Phillips curve. The degree of strategic complementarities depends on both the cost share of intermediate inputs and the curvature of the demand function. It is not obvious that globalization affects either of

4. This is a common feature of New Keynesian models; see, for example, Galí (2008).

these things directly. Instead, the effects mentioned in Forbes are likely to arise from the interaction between the degree of complementarities and the import share, $1 - \mu$. In particular, in the presence of complementarities, domestic prices depend more on foreign markups and costs (and less on domestic wages) the higher the import share.[5]

In sum, equation (5) validates Forbes's point that globalization can affect inflation beyond its effect on import prices. It also reveals that increased trade integration can flatten the slope of the Phillips curve.

Connection with the empirics. The discussion above highlights that to evaluate how globalization affects the slope of the Phillips curve, one must evaluate how it affects the parameters μ, α, θ, and ω. It is important to note that these effects cannot be gauged simply by adding global variables to the existing Phillips curve framework.

If we abstract from the strategic complementaries, $\alpha = 0$, the slope is given by $\beta = \mu\omega\theta$. In this case, if the change in inflation dynamics following the GFC was driven by globalization, and globalization did not affect ω, θ, or the slope of the wage Phillips curve, a regression of the form $\pi_t = b \times [\mu \times slack_t] + \varepsilon_t$ should yield a slope b that does not change after the GFC.

Forbes runs a version of the Phillips curve model in which the dependent variable is an interaction between the import share and the domestic slack.[6] This is somewhat different from what the theory suggests, since slack is interacted with the share of imports rather than with the share of domestic goods. Setting this difference aside, Forbes shows that the coefficient b falls after the GFC, from –0.41 to –0.17. Taken at face value, these numbers suggest that the decline in the slope of the Phillips curve since the GFC was not simply due to the mechanical effect of an increase of the share of imports on the CPI. Instead, the evidence indicates that one of the following pertains:

1. Globalization somehow affected the slope of the Phillips curve through the share of commodities in the CPI ω, the degree of price stickiness θ, the slope of the wage Phillips curve, or through channels not considered in this model.

5. To see this, note that combining equations (1)–(4) we obtain domestic inflation given as $\pi_t^D = \frac{\theta[1-\alpha]}{1-\theta\alpha\omega\mu}\pi_t^w + \frac{\theta\alpha\omega[1-\mu]}{1-\theta\alpha\omega\mu}\pi_t^M + \frac{\theta\alpha\omega[1-\omega]}{1-\theta\alpha\omega\mu}\pi_t^{Com}$. Thus, the relation between domestic inflation and wages is increasing in μ.

6. This is equation (4) in the paper, which also has controls for inflation expectation and other global variables. In the notation of this discussion, equation (4) in the paper corresponds to running $\pi_t = b \times [[1 - \mu] \times slack_t] + \varepsilon_t$.

2. The change in the slope of the Phillips curve was not driven solely by increased globalization.

3. The nonlinear effects of μ on the slope of the Phillips curve that arise from the strategic complementarities are not well captured by this specification.

While further research is needed to disentangle these explanations, it is hard to conclude from the evidence given by Forbes that globalization was the main cause for the decline in the slope of the Phillips curve. In contrast, the evidence in the paper speaks more directly to the effect of globalization on the explanatory power of the Phillips curve.

Globalization and the explanatory power of the Phillips curve. Equation (5) underscores how globalization may affect the explanatory power of the Phillips curve. In particular, this model's version of equation (1) in the paper is given by

$$\pi_t = \tilde{\beta} slack_t + \varepsilon_t, \tag{6}$$

where $\tilde{\beta} \equiv \beta\Gamma$ and Γ is the elasticity of wage inflation with respect to economic slack (which is assumed to be constant). The error term is given by

$$\varepsilon_t \equiv \frac{[1-\mu]\omega}{1-\mu\alpha\theta\omega}\pi_t^M + \frac{1-\omega}{1-\mu\alpha\theta\omega}\pi_t^{Com}.$$

The equation states that if import and commodity prices are omitted from the regression, they will be captured by the error term. Globalization can increase the variance of the error term by increasing $1-\mu$ or by increasing the volatility of import and commodity prices or both. Clearly, augmenting equation (5) to control for π_t^M and π_t^{Com} should increase the explanatory power of the regression. While high trade integration (high $1-\mu$) is one consequence of globalization, further research is needed to pin down the relation between commodity price volatility and the growth of emerging markets.

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COMMENT BY

M. AYHAN KOSE[1] It is difficult to think of a more important question for the design and conduct of monetary policy than the one this paper focuses on: Have the forces of globalization changed our understanding of inflation? The paper also has all the hallmarks of Kristin Forbes's work: after starting with a well-defined, topical, and policy-relevant question, she attacks the question with a comprehensive empirical analysis. She then concludes with a set of clear results and carefully crafted policy messages.

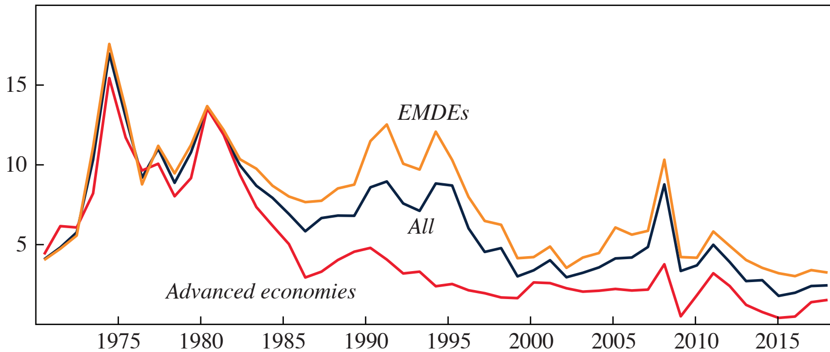
After posing her question and summarizing earlier work, Forbes presents a rich empirical exercise. She employs three different empirical frameworks: a simple factor model (principal component analysis); an augmented Phillips curve model with global variables; and a model with trend-cycle decomposition. For the latter two frameworks, she uses a series of panel regressions. The data set has a total of forty-three countries (thirty-one advanced economies and twelve emerging markets) and covers the period 1996–2017.

Forbes has a basic conclusion: globalization plays an increasingly more important role in driving the dynamics of domestic consumer price index (CPI) inflation, but its role is somewhat less important in the case of core inflation and wage inflation. Domestic forces are still relevant in driving inflation, but their roles have evolved over time and differ across measures of inflation. For example, domestic slack remains important, but it has become less so over time, especially for CPI inflation. These findings push the frontiers of our understanding of the drivers of inflation. They also lead to several new research avenues to explore.

I begin my comments with a brief analysis of the evolution of inflation over the past 50 years to put the motivation behind the paper in a broader context. I then focus on two specific questions to highlight some future areas of research. First, what are the potential factors explaining the behavior of inflation over time? Second, how important is the global factor in driving fluctuations in inflation? I conclude with a couple of observations that also require additional analytical work in light of Forbes's findings.

1. World Bank, Prospects Group; Brookings Institution; CEPR, and CAMA; akose@worldbank.org. I thank my coauthors, Jongrim Ha, Alain Kabundi, Peter Nagle, Franziska Ohnsorge, and Naotaka Sugawara, for many discussions on the links between globalization and inflation. Some of my comments here are based on joint work with Jongrim Ha and Franziska Ohnsorge. The findings, interpretations, and conclusions expressed in this report are entirely those of the author and should not be attributed to the World Bank, its executive directors, or the countries they represent.

Figure 1. Evolution of CPI Inflation



Source: Ha, Kose, and Ohnsorge (2019a).
Note: Median year-on-year consumer price inflation for thirty advanced economies and 125 emerging market and developing economies (EMDEs).

EVOLUTION OF INFLATION Forbes starts with a simple observation about the poor performance of standard models in forecasting inflation during the past decade. It is useful to put this observation in a longer historical context because of the remarkable decline in inflation since the early 1970s (figure 1). The collapse of inflation has been highly synchronized across groups of countries. For example, advanced economies saw their median annual national CPI inflation drop from its highest (15 percent in 1974) to its lowest level (0.4 percent in 2015) in more than 60 years. Since then, it has risen somewhat but remains below the median inflation target of advanced-economy central banks. After 2008, below-target inflation and, in some cases, deflation became pervasive across advanced economies: for example, at some point in 2015, inflation was negative in a number of advanced economies. Some central banks have struggled to lift inflation back to their inflation targets over the past decade.

Emerging market and developing economies (EMDEs) have also experienced a significant decline during the same period: median inflation went down from a peak of 17.5 percent in 1974 to 3.2 percent in 2018. Disinflation over recent decades has been broad-based across many regions. For example, disinflation occurred across all EMDE regions, including those with a history of persistently high inflation, such as Latin America and sub-Saharan Africa (Ha, Kose, and Ohnsorge 2019a).

POTENTIAL SOURCES OF THE SYNCHRONIZED DECLINE IN INFLATION The highly synchronized nature of the decline in inflation points to the possibility of

some global factors driving inflation in many countries. In light of this observation, Forbes motivates her exercise by documenting some prominent changes in the world economy that could affect the dynamics of inflation: "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."

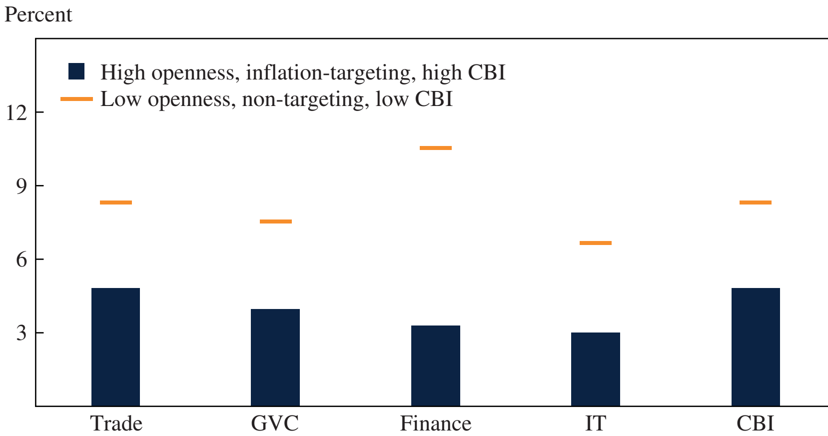
There is no question about the first-order importance of these changes, and it is natural that Forbes focuses on these given the well-known measurement and data challenges with some other changes. However, there is a wide range of sources for the synchronized decline in inflation that will require a much broader examination. These include shocks, similar policy frameworks (and responses), and structural changes (Ha, Kose, and Ohnsorge 2019a).

Shocks. Inflation synchronization could be driven by common shocks that spread across countries or by country-specific shocks that spill over from one country or a subset of countries to others. Commodity price shocks, internationally correlated productivity shocks, other cost-push shocks, and real demand shocks could all affect national inflation rates and often in the same direction, which would represent inflation synchronization.

Similar policy responses/frameworks. Correlated or coordinated monetary policies could also be an important source of inflation co-movement, especially among advanced economies. Even if there is no deliberate coordination of policies, similar monetary policy frameworks can trigger similar policy responses to global shocks. This policy synchronicity would then translate into inflation synchronicity. For example, a growing number of countries have introduced inflation-targeting monetary policy frameworks that in turn potentially lead to similar policy responses to shocks.

Structural changes. Over the past five decades, the degree of global integration in trade and financial markets has grown rapidly. These structural changes have often strengthened cross-country spillovers of real and nominal shocks, which have in turn led to more synchronized movements in inflation. Stronger trade linkages and rapidly expanding global supply chains increase an economy's exposure to external shocks, as Forbes notes. Some also argue that greater international competition has made domestic inflation less sensitive to domestic output gaps, flattening Phillips curves. Increased international financial integration has been accompanied by greater synchronization of financial conditions across countries. As financial stress spreads (or recedes) across global financial markets, it tightens (or loosens) credit and financial conditions in a large number of countries.

Figure 2. Inflation by Country Characteristics



Source: Ha, Kose, and Ohnsorge (2019a).

Note: Columns indicate median inflation rates in country-year pairs with trade-to-GDP ratios ("Trade"), global value chain integration ("GVC"), financial assets and liabilities relative to GDP ("Finance"), or central bank independence and transparency index ("CBI") in the top quartile of 175 economies during 1970–2017 or with inflation targeting monetary policy regimes ("IT"). Horizontal lines denote median inflation rates in the bottom quartile or with monetary policy regimes that are not inflation-targeting. Differences are all statistically significant at the 5 percent level. Inflation-targeting regimes are defined as in Caceres, Carrière-Swallow, and Gruss (2016) and the IMF *Annual Report on Exchange Arrangements and Exchange Restrictions.* Central bank independence is measured by the index independence and transparency, taken from Dincer and Eichengreen (2014). GVC is based on the sum of backward and forward participation in global value chains. See Ha, Kose, and Ohnsorge (2019a) for more details on the definitions of country characteristics.

As a result, movements in domestic demand and disinflationary or inflationary pressures are also synchronized across countries. Technological changes, in addition to deepening supply chains, can also help globalize markets for nontradable service sectors. This may extend and deepen the impact of global forces on domestic inflation.

Preliminary empirical analysis supports the relevance of some of these channels. For example, inflation has typically been lower in economies with greater trade and financial openness (figure 2). Compared with other monetary policy regimes, inflation-targeting regimes were also associated with lower inflation, and countries with more independent and transparent central banks tend to experience lower inflation.

Forbes briefly discusses some of these channels but omits most of them in her empirical exercise. In order to have a more complete understanding of the dynamics of inflation, future work needs to capture the roles of these channels and their interactions with the globalization-related variables.

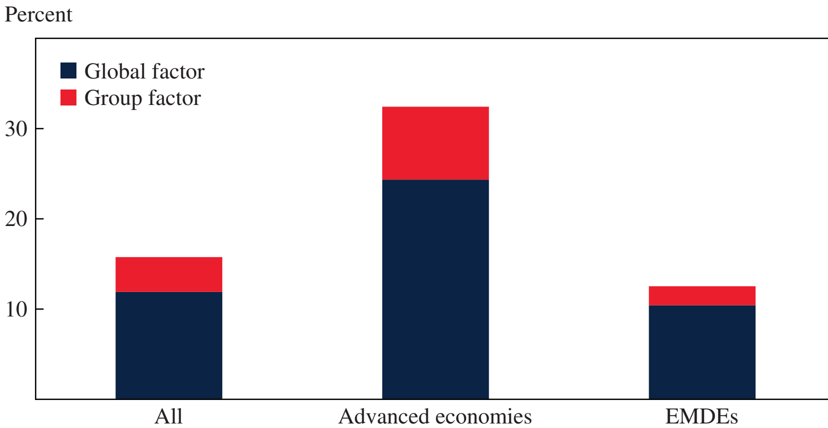
For example, it would be useful to examine how the interactions between stronger trade linkages and changes in monetary policy frameworks translate into inflation outcomes in more integrated economies.

HOW IMPORTANT IS THE GLOBAL FACTOR IN DRIVING INFLATION? Forbes employs a simple principal component analysis (PCA) to estimate the importance of a global factor in driving inflation. The PCA identifies the common movements in the cross-sectional inflation data without imposing any additional model structure. Forbes considers the first principal component estimated by the PCM as the global factor. She examines four measures of inflation: CPI, core CPI (excluding food and energy prices), the producer price index (PPI), and private sector hourly earnings (wages). The data set for the PCA covers forty-three countries over the 1990–2017 period.

It is useful to extend this exercise by employing a richer empirical framework with a much larger and longer data sample. I estimate a dynamic factor model to study the role of common factors in driving inflation. Dynamic factor models are designed to extract a few unobservable common elements from a large number of (observable) variables. In the context of inflation, the dynamic factor I consider here also imposes a much richer structure than the PCA in the paper. Specifically, the model has two types of factors: a global inflation factor that captures common elements in inflation fluctuations across countries and a group-specific factor that accounts for common elements in inflation fluctuations in advanced economies and EMDEs (Ha, Kose, and Ohnsorge 2019b). The presence of group factors allows the model to account for the large differences in country characteristics between advanced economies and EMDEs. In addition, the model includes idiosyncratic factors that cannot be attributed to the other factors. The analysis is based on annual headline CPI inflation data for ninety-nine countries—twenty-five advanced economies and seventy-four EMDEs—for 1970–2017.

The results suggest that during this period, the global inflation factor accounted for a sizable share of inflation variance in advanced economies and EMDEs (figure 3). In the median country, the global factor accounted for 12 percent of inflation variation, but its role varied widely across and within country groups. For example, the contribution of the global inflation factor was much greater in the median advanced economy (24 percent) than in the median EMDE (10 percent). The group-specific factors have also played an important role in driving inflation. For example, in the median advanced economy, the group-specific factor accounted for 8 percent of inflation variation.

Figure 3. Contribution of Global and Group Factors to Inflation Variation



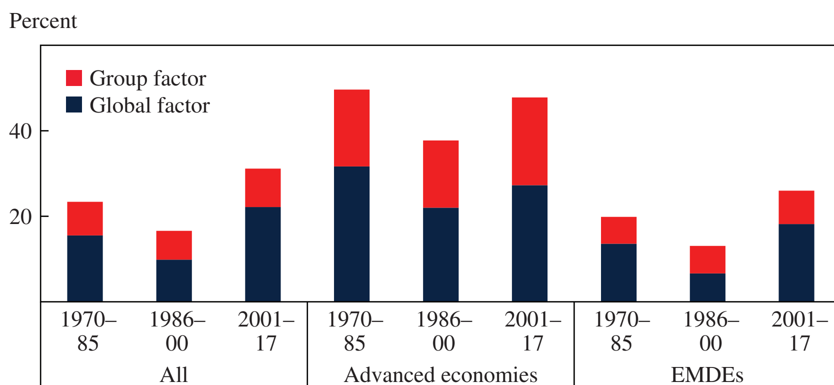
Source: Ha, Kose, and Ohnsorge (2019a).
Note: The contribution of global and group factors to inflation variance is estimated with the dynamic factor model over 1970–2017. The sample includes ninety-nine countries (twenty-five advanced economies and seventy-four EMDEs). The means or medians are unweighted. See Ha, Kose, and Ohnsorge (2019b) for more details on model estimation and results.

A critical feature of the international inflation experience of the past five decades has been the emergence of a global inflation cycle. This is reflected in a growing contribution of the global factor to the variation in country-level inflation rates (figure 4). In order to illustrate this, it is useful to consider estimates of the model for three approximately equal subperiods: 1970–85, 1986–2000, and 2001–17. The first period overlaps with the Great Inflation of 1965–82; the second was a period of widespread disinflation; and the third was a period of low but typically stable inflation.

The contribution of the global factor to inflation variation has grown over time: since 2001, it has more than doubled from the earlier period (1986–2000) and now accounts for 22 percent of inflation variation. It has explained about one-fifth and one-quarter of EMDE and advanced economy inflation variation, respectively, since 2001. Over the past five decades, an EMDE-specific factor has also become more prominent. The rising importance of these global and group-specific factors indicates that inflation synchronization has indeed become more broad-based over time.

These findings suggest three important avenues for future research. First, it is useful to examine the importance of the global factor over a

Figure 4. Contribution of Global Factor to Inflation Variation over Time



Source: Ha, Kose, and Ohnsorge (2019a).

Note: The contribution of global and group factors to inflation variance is estimated with the dynamic factor model over three subsample periods. The sample includes ninety-nine countries (twenty-five advanced economies and seventy-four EMDEs). Means or medians are unweighted. See Ha, Kose, and Ohnsorge (2019b) for more details on model estimation and results.

longer time period. Forbes reports that the global factor has become more important in explaining the CPI inflation over time by focusing on the post-1990 period. The results here indicate that in the first period (1970–85), the global factor was quite important probably because of multiple common shocks the world economy experienced. In the case of advanced economies, the global factor played even a more important role in the first period than it did in the last period, which witnessed much stronger global linkages.

Second, the importance of the global factor differs across country groups. The global factor plays a more important role in driving inflation in advanced economies than it does in EMDEs. This implies that one needs to take into account differences between country groups when studying the sources of inflation synchronization. In addition, it is important to consider the role of group-specific inflation cycles (cycles specific to advanced economies and those specific to EMDEs) to get a better understanding of the drivers of inflation. One interpretation of this finding is that China could be playing an increasingly more important role in driving inflation in other EMDEs because of its dominant role in commodity markets.

In this context, there is a need to have a stronger connection between the PCA exercise and the other two empirical frameworks used in the paper. The PCA is all about the variance of inflation but the other two

frameworks are about the level of inflation. The results from the PCA suggest that the global factor has become more important over time in explaining the variance of CPI inflation but less important in the cases of core inflation and wage inflation. If the objective is to understand the variance share of inflation attributable to the global factor, then a different empirical framework should be set up in a way that the dependent variable is this variance share (and one can think of a number of explanatory variables).

However, Forbes takes a different approach by focusing on the level of inflation (in the last two frameworks) after presenting a rough connection between commodity price volatility and the fraction of inflation variance due to the global factor. It would be useful to conduct an empirical exercise to study the roles of globalization-related variables in explaining the inflation variance due to the global factor.

WHAT IS NEXT? Forbes provides a set of intriguing findings that will likely trigger future research in multiple directions. In addition to the specific items I discussed above, there are two additional areas for future work.

Understanding the roles played by country-specific features. Forbes presents a rich cross-country panel exercise. From the perspective of an individual country, these panel-based results are useful, but the big question, of course, is whether they are relevant for an individual country's own domestic inflation process. Future work can usefully consider some basic questions on the importance of country-specific characteristics in driving some of the headline findings in the paper: Do we see a larger impact of global variables in economies with inflation targeting? Do we see a larger impact of the global factors in commodity importers? How do the forces of globalization affect cross-border spillovers of inflation in different groups of countries (advanced economies versus EMDEs)?

Explaining divergence. Forbes presents a truly striking finding: global factors have become more important for CPI inflation over time but have not become important for core inflation, with mixed evidence for wage inflation. It would be useful to explore the divergence of these results across different inflation measures in future work.

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Ha, Jongrim, M. Ayhan Kose, and Franziska L. Ohnsorge. 2019b. "Global Inflation Synchronization." Working Paper 8768. Washington: World Bank. http://documents.worldbank.org/curated/en/733211551994244422/pdf/WPS8768.pdf.

GENERAL DISCUSSION Eswar Prasad suggested an analysis using subindexes of the Consumer Price Index (CPI). The subindexes related to traded goods should capture more of the effects of globalization than service price indexes. He acknowledged that disaggregated data might be more inaccurate, as in the case of Argentina, but noted that nonetheless disaggregating and looking at the subindexes might uncover some useful insights. He wondered whether the co-movement of inflation is only seen when inflation is falling. He questioned how big of a role the characteristics of a country play into the results of the paper, specifically, the role of commodity prices in larger economies. He suggested weighted regressions to control for the role that commodity prices might play in the economies of large and advanced countries.

Peter Henry echoed some of the comments in Ayhan Kose's discussion to expand the framing to include policy shocks. He referenced a paper by Dornbusch and Fischer which found that policy shocks are important in understanding inflation dynamics, particularly for emerging markets in the last 30 years.[1] He noted that it would be useful to include country-specific time series around global policy shocks such as shocks to the global value chain. This addition would help to analyze the transmission mechanism through specific variables, considering that countries have different policy regimes and react differently to various shocks.

Ben Bernanke noted that in 2008 oil prices were very high before falling. Considering this, he asked Forbes what the motivation and narrative was for her results around the financial crisis period. The results showed that international factors were important in 2008 and 2010. He asked Forbes whether she was motivated by the idea that inflation did not

1. Rudiger Dornbusch and Stanley Fischer, "Moderate Inflation," *World Bank Economic Review* 7, no. 1 (1993): 1–44.

fall as much as the recession metrics suggested. Next Bernanke questioned Kose on whether disinflation in the United States in the 1980s influenced inflation globally, and if so, how. After a trend of high inflation, the United States saw disinflation in the 1980s under Volcker. There was then a decline in inflation globally.

Frederic Mishkin stated that one of the most interesting results in the paper is that global factors are less important for core inflation, given that central banks—in particular the Federal Reserve—have focused more on core inflation. The implication of this specific result is that the Federal Open Markets Committee's (FOMC) frameworks—which do not place much importance on global factors—are correct. Second, he noted that a theory is needed when evaluating whether the Phillips curve is "alive or dead." Many people recently, including participants of the FOMC, have argued that the Phillips Curve is dead or flat. Mishkin argued that the curve is alive and well but just hidden. The main cause of a hidden curve, he reasoned, is that monetary policy in recent years has been doing its job properly and has stabilized inflation.

Mishkin stated that when monetary policy is stabilizing inflation, then when there is a positive shock to inflation, central banks will tighten monetary policy. This will cause the unemployment rate to go up and create an upward bias in estimates of the slack coefficient, resulting in an estimated slack coefficient that is biased toward zero. He noted that when monetary policy is not doing its job properly and is not stabilizing inflation, as in the late 1960s and 1970s, this bias won't be present and then the estimated slack coefficient is large and negative. On the other hand, when the Federal Reserve moved toward a focus on stabilizing inflation in the mid-1980s and afterward, the bias toward zero would become large, so these large coefficients disappear. Thus the fact that estimated slack coefficients were large and negative before the mid-1980s and then declined to near zero afterward strongly suggests that the Phillips curve still exists.

Mishkin remarked that Phillips curve estimates for wage inflation, in comparison with price inflation, are less likely to be biased toward zero because the endogeneity of monetary policy affects wages much less than it affects prices. The fact that wage Phillips curves have larger, more negative slack coefficients than price Phillips curves provides further evidence that the Phillips curve is not dead. In addition, when evaluating state and local data there are limited endogenous effects of monetary policy; thus the finding that the slack variable on the subnational level is significant and does not change much with policy also provides support

for the Phillips curve being alive. For international factors, these endogeneity effects are less likely to be less present. All in all, this evidence suggests that the Phillips curve is still active. Mishkin cautioned that believing that the Phillips curve is dead could lead to serious monetary policy mistakes.

Jordi Galí noted that it is understandable that the channels through which global factors affect energy inflation or imported inflation differ from those that affect core domestic inflation. The real challenge and the need for analysis is to understand the latter. When evaluating how global factors affect core domestic inflation, he commented, it is not optimal to look only at the core inflation defined in Forbes's analysis as this measure includes imported goods. In addition, he suggested that Forbes think carefully about the measure of slack used in her analysis. For example, he remarked, in models with monopolistic competition and price rigidities, the driver of inflation is markup misalignment—the gap between average markups and desired markups. Alternative measures of slack that focus on markups can be useful in interpreting the results and understanding the channels through which global factors operate.

Narayana Kocherlakota recommended looking at the models that central banks use to make policy. In these models, the endogenous response of policy to inflation is stripped out of the equation. In the model of the U.S. economy constructed by the Federal Reserve (the FRB/US model) the Phillips curve is very flat. When analyzing the policy choices and errors that have resulted from these models, it can be argued that the Phillips curve should be even flatter than presented in the FRB/US model. Similarly, it can be argued that the FRB/US model does not consider global factors. One can then ask about the ramifications of incorrectly using global factors in the FRB/US model's calculations of the Phillips curve. For example, he wondered whether such incorrect specifications have led to monetary policy mistakes. Similarly, he pondered whether inflation would have been closer to target or farther away from target. Lastly, he questioned whether there would have been different outcomes had those constructing the FRB/US model considered global factors.

Justin Wolfers focused on a table in the appendix which contained the list of countries used in the analysis. He noted that the sample of countries includes thirty-one advanced countries and twelve emerging countries. He commented that although Forbes describes the paper as "the world," the small amount of emerging market economies in the sample is not representative. Furthermore, of the thirty-one advanced counties, twenty-four

are European countries. He remarked that because the sample is largely European it is not surprising that the results show common factors affecting inflation during this period. For example, sixteen of the thirty-one countries use the euro, and within this group five of them adopted the euro over the sample period. He commented that this sample choice explains why there are common factors in the analysis that gain importance over time.

John Haltiwanger commented that the volatility of commodity prices might play a bigger role than stated. The commodities that have high volatility are basic industrial inputs and metals. Although commodities may not be the whole story, the endogenous transmission of commodity prices may be reflected in other variables.

Richard Cooper stated that Western macroeconomics did not pay much attention to inflation in the ’50s, ’60s, and early ’70s. Starting in the ’80s, inflation was brought down, mainly attributable to Volcker. Cooper wondered how this experience has influenced the thinking in governments and central banks about inflation. He noted that this question can be investigated by evaluating how the International Monetary Fund’s (IMF) Article IV consultations have changed over time. The same analysis can be completed with the World Bank’s advice about inflation to emerging markets and developing countries. Cooper hypothesized that the results of doing such an analysis would show that since the late 1970s there has been greater emphasis on inflation targeting and the independence of central banks when compared with the earlier periods.

Olivier Blanchard urged Forbes to consider further analysis of heterogeneity across countries. There would be different transmission mechanisms for countries depending on if they had fixed or variable exchange rates. Blanchard also emphasized Kose’s suggestion to use a measure of openness in the analysis.

James Stock recommended the Goldfeld and Blinder paper that discusses how the flattening of the Phillips curve could be a result of endogenous policy.[2]

Forbes thanked the participants for their comments and intended to follow up with the commenters on those comments she would not have time to address. On Stock’s recommendation of the Goldfeld and Blinder paper, Forbes noted that it is impressive how many Brookings papers there are on many of these topics. At one point, she was referred to a

2. Stephen M. Goldfeld and Alan S. Blinder, “Some Implications of Endogenous Stabilization Policy,” *Brookings Papers on Economic Activity*, no. 3 (1972): 585–640.

Gordon paper on inflation in a certain year but there were multiple papers by Gordon on inflation in that same year.[3]

Addressing a major theme in the comments about identifying country variation within the results, Forbes noted that she had looked at aspects of this through her sensitivity analyses. In one set of tests, she controls for openness by country and interacts openness with some of the elastic variables. She noted that the empirical analysis of these sensitivity tests would require its own paper. If such a further paper were to be written, she noted, it should include how the country-specific characteristics change the results and interact with the channels described.

Forbes acknowledged Wolfers's comment about the sample containing a majority of advanced economies. Forbes performed sensitivity tests without euro countries and the results remained consistent. She noted that it is difficult to focus on emerging market economies due to the lack of data for those countries. She remarked that when focusing on only emerging markets the results are inconsistent. Because of this, she did not focus on them in her paper or discussion. Forbes recommended some of Kose's work on developing countries because it includes a larger sample of emerging markets.

Responding to comments about the Phillips curve, Forbes noted that her analysis both shows that the Phillips curve still exists and shows evidence of nonlinearity. She commented that because there are already several papers providing evidence of this nonlinearity, she does not focus on it in her analysis.

Lastly, Forbes touched on the results for wages where she found that globalization was not as important. She had found these results surprising, and other empirical work has found mixed evidence that globalization matters for wage dynamics. She noted that there may be other techniques and models that could be helpful, such as evaluating different channels of globalization. There could also be lagged inflation effects that might not be captured. Regardless, she observed that it is important to acknowledge the non-results for wages as that might have an impact on the central banks' response to the various inflation metrics.

3. The specific paper she was referred to is Robert J. Gordon, "World Inflation and Monetary Accommodation in Eight Countries," *Brookings Papers on Economic Activity*, no. 2 (1977): 409–68.