ECONOMIC COMMENTARY

The Impacts of Supply Chain Disruptions on Inflation

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Since early 2021, inflation has consistently exceeded the Federal Reserve's target of 2 percent. Using a combination of data, economic theory, and narrative information around historical events, we empirically assess what has caused persistently elevated inflation. Our estimates suggest that both aggregate demand and supply factors, including supply chain disruptions, have contributed significantly to high inflation.

Since early 2021, roughly one year after the SARS-CoV-2 (COVID-19) pandemic began, inflation has consistently exceeded the Federal Reserve's target of 2 percent. The resurgence of aggregate demand in late 2021 and 2022, a tight labor market, disruptions of energy supplies, and disruptions in supply chains for other inputs have all potentially contributed to persistently elevated inflation. This confluence of events makes it challenging to disentangle what has driven the persistent rise of inflation since early 2021 and to what extent individual elements have played a part.

Since early 2020, news reports have made it clear that COVID-19 related shutdowns slowed, and in some instances shuttered, industry. These slowdowns and closures resulted in order backlogs for many raw and intermediate goods and were exacerbated by simultaneous bottlenecks in transportation, as evidenced in backlogs at shipping ports. While supply chain disruptions have received increasing public attention over the past few years, they have a longer history. Laschat and Ehrmann (2022) and Kashiwagi, Todo, and Matous (2021) detail how earthquakes, hurricanes, trade wars, and other similar events disrupt supply chains. Benigno et al. (2022) also note that geopolitical events can disrupt supply chains. In fact, Lund et al. (2020) find that supply chain disruptions lasting a month or longer occur every 3.7 years on average.

The question then shifts: To what extent do supply chain disruptions influence inflation? In the past few years, supply problems effectively constrained the ability of suppliers to meet the resurgence of demand following the easing of COVID-19 restrictions and may have contributed to inflationary pressures. Some studies have found evidence that disruptions to the supply chain following the onset of COVID-19 have significantly affected inflation.[1] For example, Benigno et al. (2022) construct an index of global supply chain conditions and find that increases in global supply chain pressures contribute to inflation pressures in the United States. Celasun et al. (2022) estimate that half of the rise in manufacturing producer price inflation for the eurozone can be attributed to supply constraints. Historical supply chain problems may have also affected inflation in prior years.

This *Economic Commentary* examines the drivers of the persistent increase in inflation since early 2021 and their historical importance. We focus on disruptions in supply chains and use a combination of data, economic theory, and narrative information around historical events to assess the relative importance of demand and supply to inflation's movements. According to our estimates, both aggregate demand and supply factors, including supply chain disruptions, have contributed significantly to inflation's rise since early 2021.

Our Approach

We examine inflation's drivers using a vector autoregression (VAR) model, which consists of equations relating the current value of each variable to past values of all variables. The model's variables include important monthly indicators of economic

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activity, supply chain conditions, consumer price inflation, monetary policy, and financial conditions (growth in nonfarm payroll employment, supplier delivery times from the Institute of Supply Management (ISM), core PCE inflation, the two-year Treasury bond yield, and the spread between Baa corporate bonds and 10-year Treasury yields).[2] Like some other studies, we use the two-year Treasury yield to capture monetary policy because the federal funds rate (FFR) was constrained by a zero lower bound—that is, the FFR was close to zero and could go no lower—for extended periods following the recessions of 2007–2009 and 2020. We estimate the model with Bayesian methods using data from January 1990 to December 2022.

To disentangle the complicated dynamic relationships between aggregate demand and supply captured by the model, we impose assumptions based both on economic theory and the narrative consensus around historical events.[3] We impose these assumptions on what researchers commonly refer to as "economic shocks," which can be thought of as events—not predictable by the model—that drive unexpected movement in the data.[4] A federal tax cut is an example of a demand shock because it would be unpredictable by our model and stimulate aggregate demand, thereby leading to increases in job growth and inflation. Conversely, a politically driven cutback in oil production by a major exporter of oil is an example of a supply shock.

We begin our analysis with relatively simple assumptions commonly used in macroeconomic analysis and focus on demand and supply effects without attempting to disentangle the effects of supply chain disruptions. We then attempt to disentangle the effects of more specific supply chain disruptions using stronger, but perhaps more debatable, assumptions.

Impacts of Demand and Supply Shocks

To assess the relative influences of overall demand and supply shocks on inflation and economic activity, we assume that demand shocks, interest rate (monetary policy) shocks, financial shocks, and supply shocks drive unexpected movement in the model's variables. More specifically, a demand shock increases employment, interest rates, and inflation, whereas a supply shock increases inflation but decreases employment. To further inform the identification of supply shocks we use narrative information surrounding COVID-19 shutdowns in March and April 2020, supply chain disruptions in 2021, the United States–China trade disagreements that occurred starting in 2017, and Hurricane Katrina in 2005. (Our replication appendix provides additional detail on these assumptions.)

Figure 1 shows the estimated response of employment, the core PCE price level, and supplier delivery times to a typical demand or supply shock for up to 35 months after the shock.[5]

Figure 1: Estimated Responses to Aggregate Demand and Supply Shocks
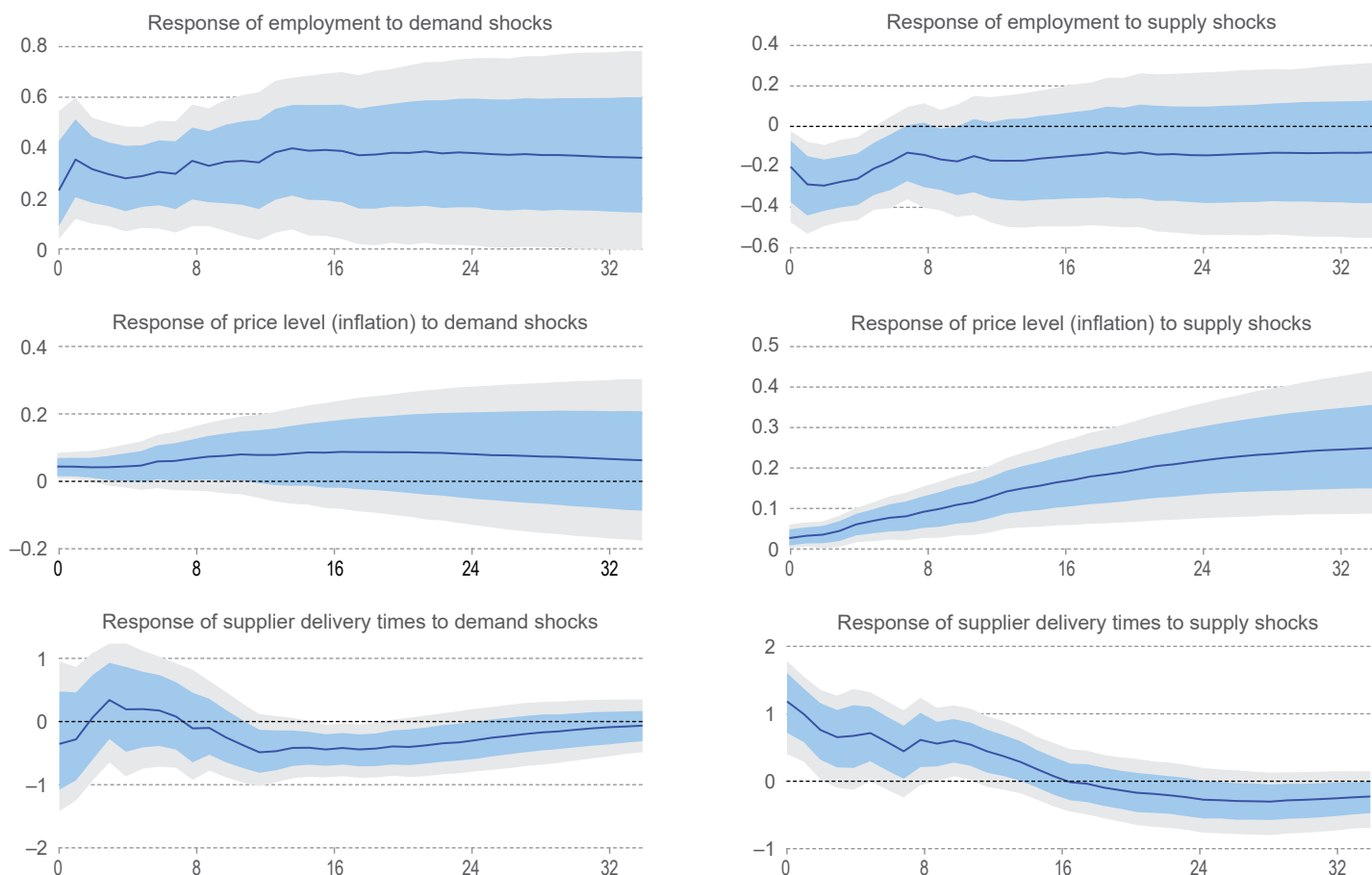
Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

Notes: The figure reports point estimates in blue lines, 68 percent confidence intervals in blue, and 90 percent confidence intervals in gray.

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The blue lines provide point estimates, and the shaded regions provide 68 percent (blue) and 90 percent (gray) confidence intervals.[6] The estimates provide the total percent changes in employment and the price level and index point changes in ISM supplier delivery times (which is a diffusion index).[7] A higher (lower) value of the ISM represents suppliers' taking a longer (shorter) time to deliver goods.

Consistent with the assumptions we impose, a shock to aggregate demand causes employment and the core PCE price index to increase, but it has little impact on supplier delivery times. At most horizons, the shock's impact on employment is larger than its impact on the price level. However, the confidence bands around the estimates are wide, meaning there is considerable uncertainty around the estimates. That uncertainty stems in part from the limited nature of the restrictions imposed on the model to disentangle the impacts of shocks; adding restrictions could yield more precise estimates of the impacts of shocks but would require taking a stronger stand to justify additional assumptions.

A shock to aggregate supply depresses employment, raises the core PCE price level, and increases supplier delivery times. Supply shocks have somewhat larger impacts on the price level than do demand shocks. For example, after a little less than three years, the point estimates indicate that the supply shock boosts the price level by about 0.25 percent, whereas the demand shock raises it by 0.05 percent. Similarly, supply shocks have a larger impact on supplier delivery times (lengthening delivery times) than do demand shocks. This fact suggests that supply shocks are an important factor in driving supply chain disruptions, which we analyze below.

We next decompose the unexpected inflation (that is, the inflation unpredicted by the model) from January 2020 to December 2022 into estimated contributions from demand, interest rate, financial, and supply shocks. Figure 2 shows the estimated contribution of each shock to unexpected inflation during this period, with inflation measured on an annualized month-over-month basis.[8]

According to these estimates, supply shocks contributed significantly to unexpected inflation from 2020 through 2022, pushing up core PCE inflation. Other shocks, including to demand and interest rates, also played important roles in the high inflation that began in early 2021. The measured demand shocks and interest rate shocks (the latter reflecting accommodative monetary policy) can both be seen as aggregate demand forces.

Figure 2: Historical Decomposition of Unexpected Inflation from January 2020 to December 2022
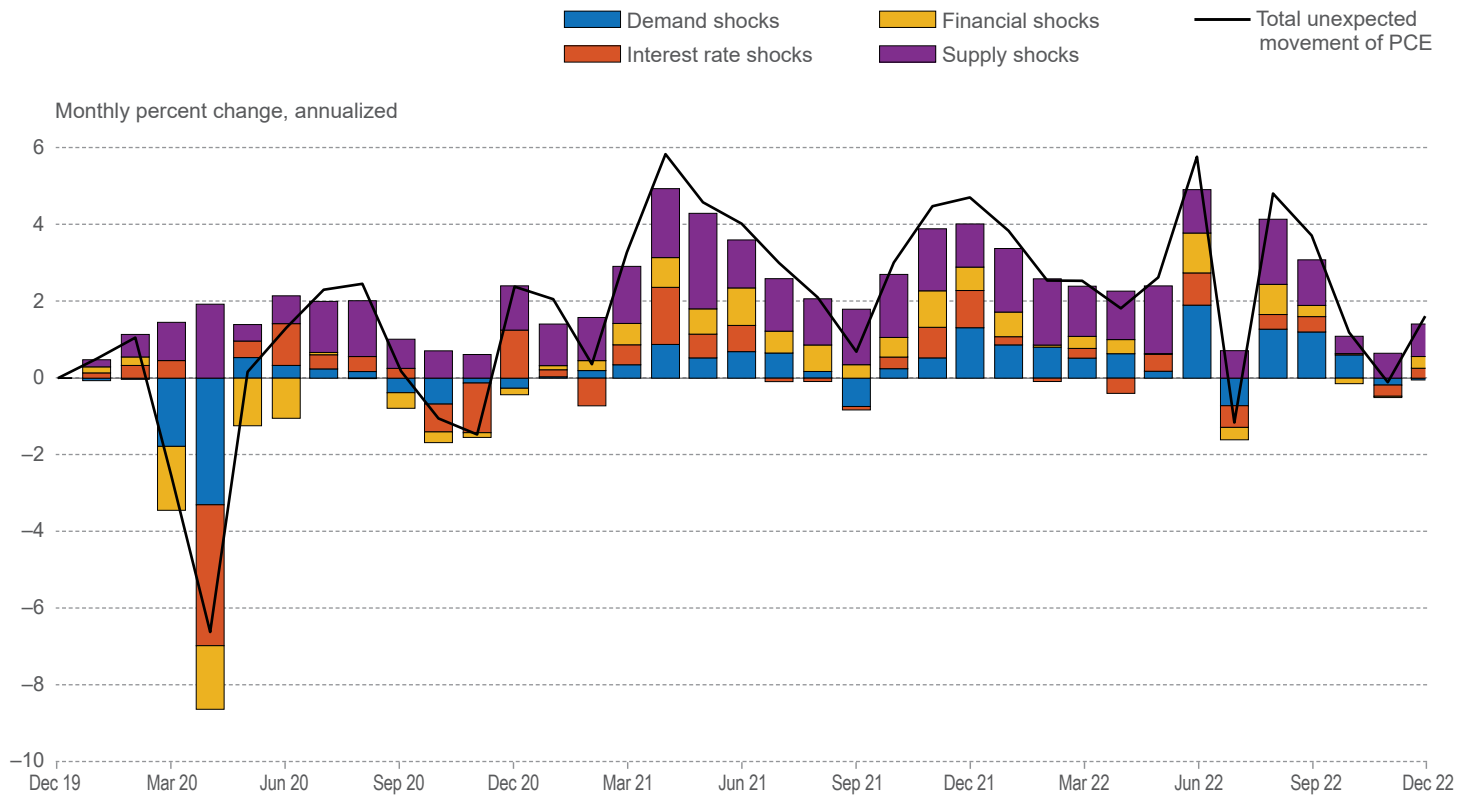
Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

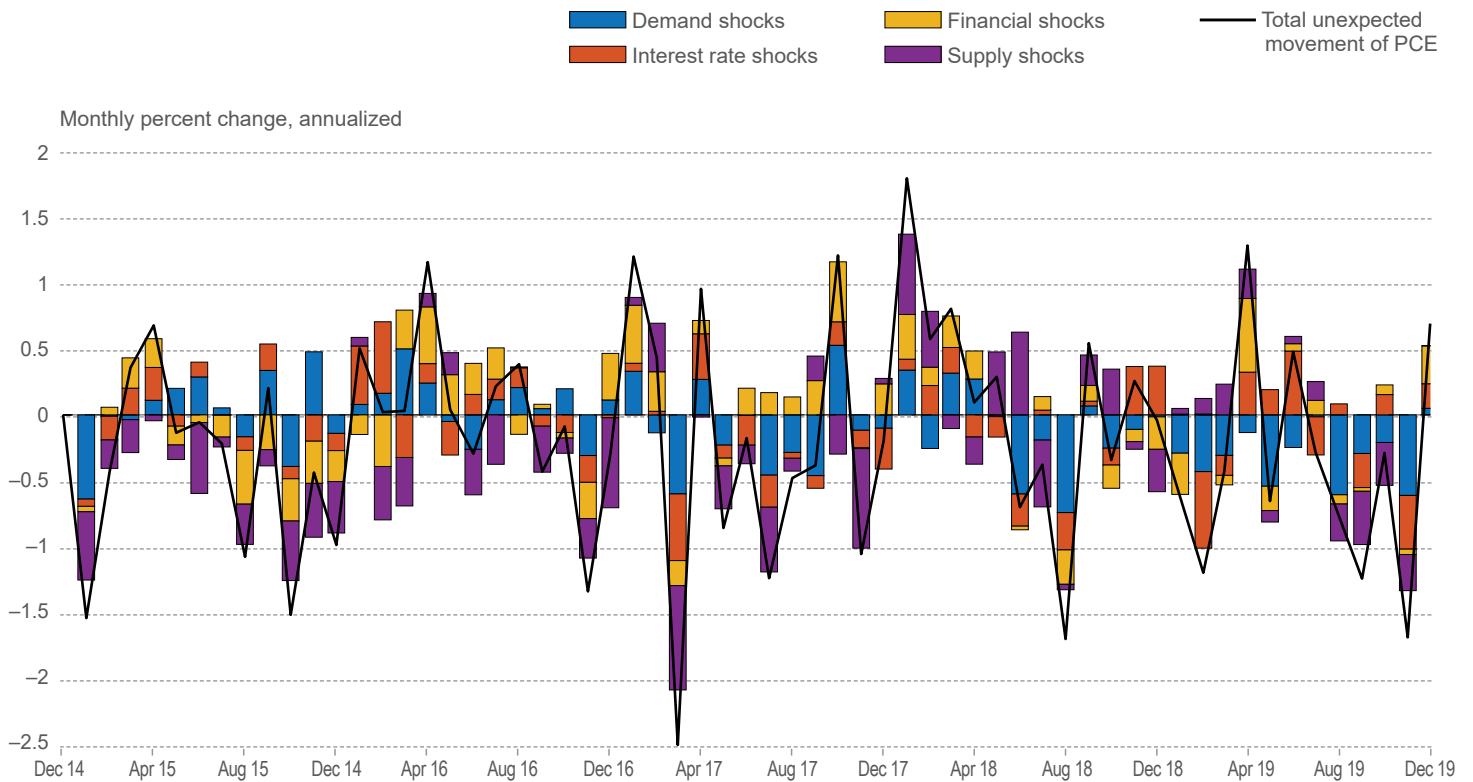Notes: The figure reports point estimates that are mean values.

Figure 3: Historical Decomposition of Unexpected Inflation from January 2015 to December 2019

Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

Notes: The figure reports point estimates that are mean values.

Of course, unprecedented pandemic developments have made the past few years unusual by historical standards. This fact naturally raises a question as to whether the estimated importance of supply shocks to inflation from 2020 through 2022 is also unusual by historical standards. To shed light on this question, Figure 3 shows a decomposition of the drivers of unexpected inflation from January 2015 to December 2019. Over this period, the US economy expanded continuously, and inflation remained at a low level. According to our model, both demand and supply shocks played important roles in driving inflation over the 2015–2019 period. Demand shocks tended to push up inflation in the first part of the sample but then pushed it down in the second part. Supply shocks are estimated to have pushed inflation down over most of the period, although with varying magnitudes.

Disruptions in the Supply Chain

Having used a relatively limited set of assumptions to disentangle the impacts of aggregate demand and supply shocks, we turn now to assessing the impacts of supply chain disruptions. To isolate the effects of disruptions, we require more stringent, and perhaps more debatable, assumptions. Specifically, we break supply shocks into supply chain shocks

and what economists call cost-push shocks, while retaining the other aforementioned shocks. We intend for our supply chain shocks to capture sudden decreases in the capacity of suppliers stemming from events such as transportation or factory shutdowns due to COVID-19 outbreaks, natural disasters such as a hurricane or earthquake, or geopolitical events. Cost-push shocks are general increases in prices because of an increase in the cost of inputs such as wages or raw materials (for example, oil prices in the 1970s).

In our treatment, both supply chain and cost-push shocks increase inflation and decrease employment. To distinguish supply chain shocks from cost-push shocks, we assume that supply chain shocks lengthen supplier delivery times (raising the ISM index), while cost-push shocks shorten delivery times (lowering the ISM index).[9] Our rationale is that cost-push shocks slow the economy, and supplier delivery times tend to improve (reflecting shorter delivery times) when the economy slows. The assumed impact of supply chain shocks on supplier delivery times derives naturally from its definition; however, both demand and supply forces may contribute to changes in observed supply chain conditions. In our research, we are particularly interested in supply chain problems driven by actual supply-side factors, reflecting the unusual problems occurring in

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the past few years. We attempt to isolate supply-driven changes in supply chain conditions by using narrative information on historical supply chain disruptions. These incidents supported by narrative information comprise the COVID-19 shutdowns in March and April 2020, supply chain disruptions in 2021, the United States–China trade disagreements occurring starting in 2017, and Hurricane Katrina in 2005.[10]

Figure 4 shows the estimated responses of employment, the core PCE price level, and supplier delivery times to typical aggregate demand, cost-push, and supply chain shocks. The blue lines provide point estimates, and the shaded regions provide 68 percent (blue) and 90 percent (gray) confidence intervals.

These estimates in Figure 4 for demand, cost-push, and supply chain shocks are similar to the earlier estimates for demand and supply shocks as seen in Figure 1. A shock to aggregate demand causes employment and the core PCE price index to increase but has little impact on supplier delivery times. The effects of a supply chain shock strongly resemble the earlier estimates of responses to a simple supply shock. A disruption to supply chains reduces employment, raises the core PCE price level, and lengthens supplier delivery times. The cost-push shock reduces employment and supplier delivery times while boosting the aggregate price level, but the estimates are highly imprecise such that it is difficult to be confident in the impacts captured in the point estimates. Given that a cost-push shock might be expected to yield a significant rise in the price level, the imprecision in our model's estimate could be seen as a manifestation of the challenges of disentangling cost-push and supply chain shocks and could, in turn, warrant caution in drawing strong conclusions.

Figure 4: Estimated Responses to Aggregate Demand, Cost-Push, and Supply Chain Shocks
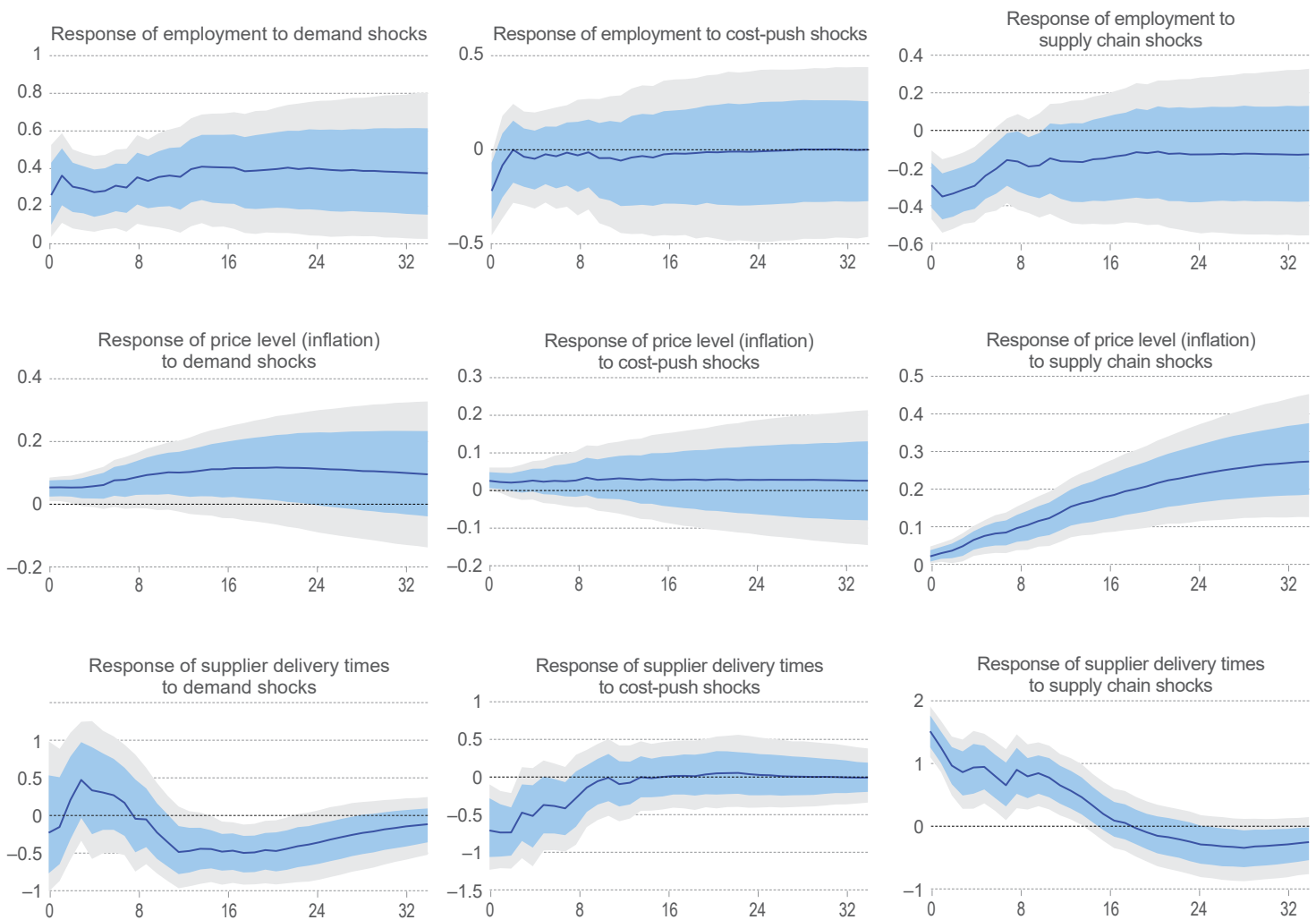
Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

Notes: The figure reports point estimates in blue lines, 68 percent confidence intervals in blue, and 90 percent confidence intervals in gray.

Figure 5 shows the decomposition of the unexpected inflation from January 2020 to December 2022 into estimated contributions from demand, interest rate, financial, cost-push, and supply chain shocks. These estimates suggest that disruptions to supply chains were the single most important driver of inflation during this period. While other shocks, including demand, interest rate, and cost-push shocks also contributed to inflation's movements, the contributions of supply chain shocks were typically larger than any other single shock. With widespread factory and transportation shutdowns, the impacts of supply chain shocks were likely due to labor or other input shortages or difficulties in transportation that reduced the ability of suppliers to meet orders.

To shed light on whether the recent importance of supply chain disruptions was historically unusual, Figure 6 shows an estimated decomposition of the drivers of unexpected inflation from January 2015 to December 2019. Broadly over this period, all of the shocks considered—including supply chain shocks—contributed to inflation's movements. Demand and supply

chain often pushed in opposite directions (for example, demand shocks pushing inflation up and supply chain shocks pushing it down). Cost-push shocks were also a notable contributor to inflation, tending to push up inflation from about 2015 through 2017 and often pushing it down in the following two years. Admittedly, the importance of supply chain disruptions over this period is somewhat difficult to interpret because while history has provided clear examples of positive supply chain shocks that slow delivery times, what constitutes a negative supply chain shock is less clear. It is possible that transportation became increasingly more accessible during this period, allowing supply chains to move products more quickly or that some technological change made supply chains more efficient. It is also possible that, outside of the COVID-19 period in which we are certain there were large supply chain shocks, our estimated supply chain shock mixes with general supply effects. As a result, our supply chain shock may be capturing general supply effects in this period rather than cleanly isolating supply chain disruptions.

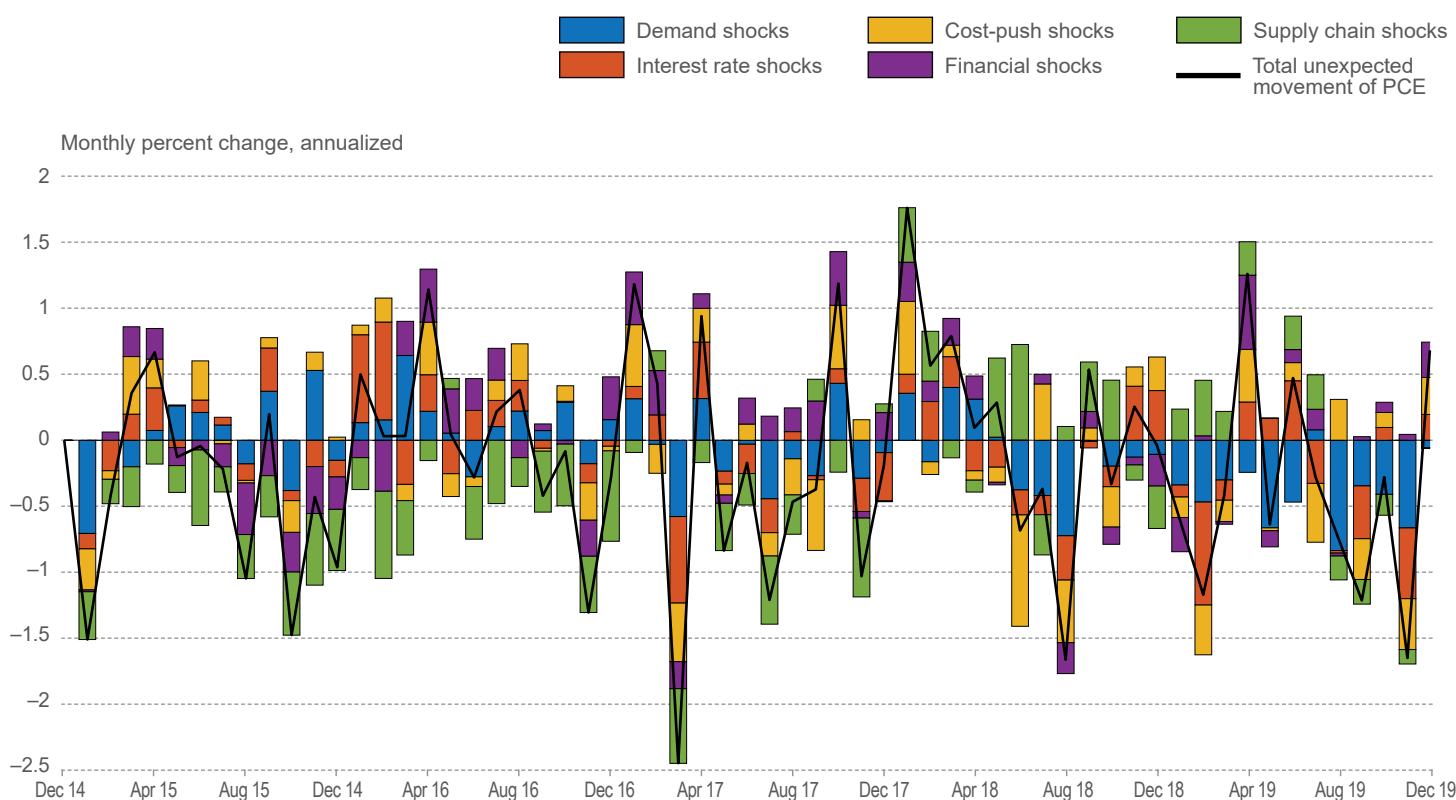Figure 5: Historical Decomposition of Unexpected Inflation from January 2020 to December 2022 Including Supply Chain Shocks
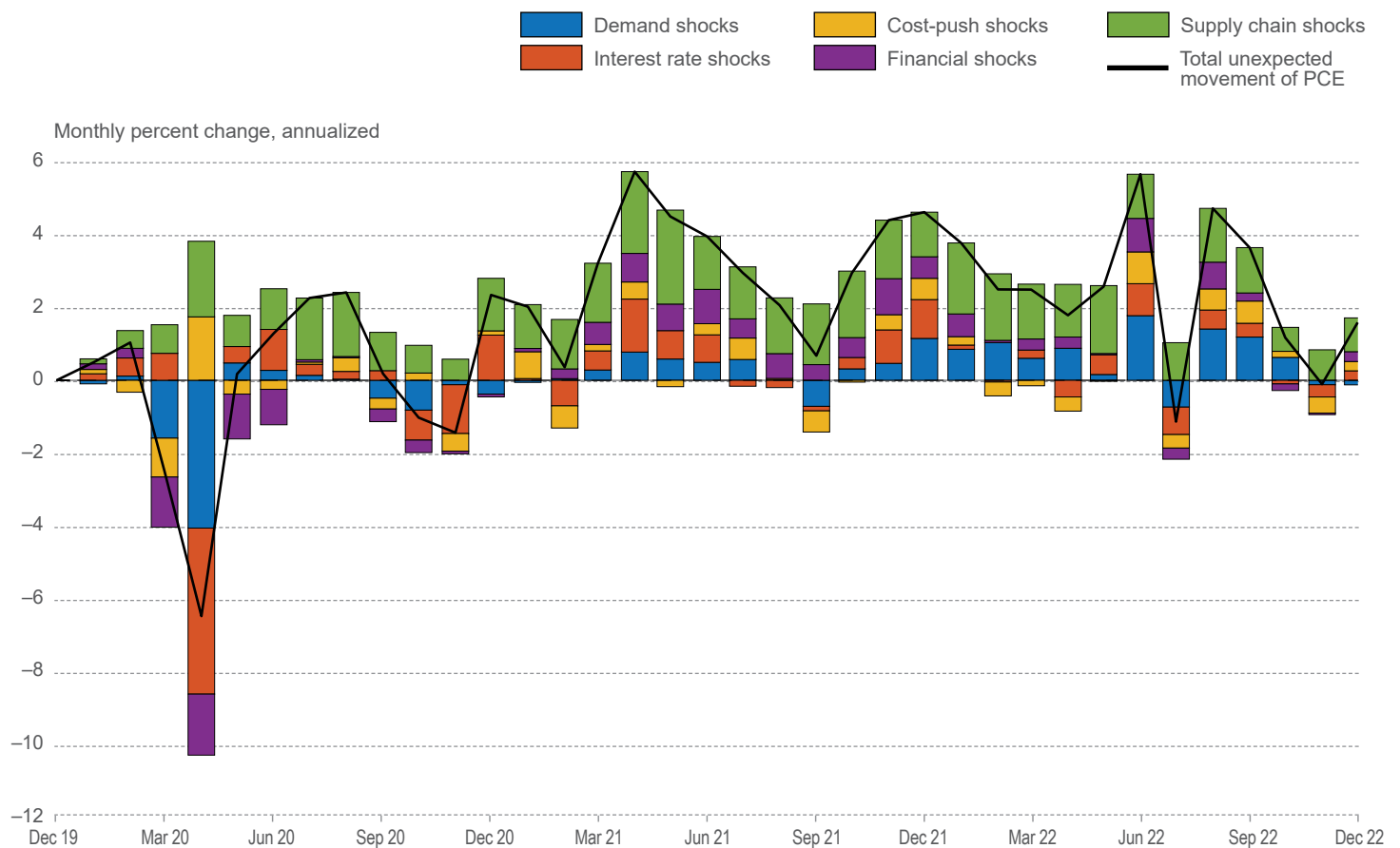
Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

Notes: The figure reports point estimates that are mean values.

Figure 6: Historical Decomposition of Unexpected Inflation from January 2015 to December 2019, Including Supply Chain Shocks

Legend:
- Demand shocks
- Interest rate shocks
- Cost-push shocks
- Financial shocks
- Supply chain shocks
- Total unexpected movement of PCE

Monthly percent change, annualized

Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Board, and Institute for Supply Management via Haver Analytics; Moody's via FRED, Federal Reserve Bank of St. Louis; and authors' calculations

Notes: The figure reports point estimates that are mean values.

Conclusion

This *Economic Commentary* combines data, economic theory, and narrative information around historical events to empirically assess the key drivers of inflation in the pandemic period since early 2021. According to estimates from one of our approaches, both aggregate demand and supply factors have contributed significantly to high inflation. Under some more stringent but potentially debatable assumptions, we are able to isolate disruptions in supply chains due to forces such as the pandemic or natural disasters. With this latter approach, estimates indicate that both aggregate demand and supply forces, including supply chain disruptions, have driven inflation. Further research is needed to more confidently isolate supply chain changes in two respects: first, to capture the kind of bottlenecks that emerged in the pandemic but are not just generally reflective of broader supply shocks and, second, to pinpoint shocks that would amount to surprise improvements in supply chains.

Endnotes

1. A number of studies have examined the roles of supply and demand forces in recent inflation dynamics. Examples include Eickmeier and Hofmann (2022), Shapiro (2022), and references therein. Eickmeier and Hofmann find that a combination of demand and supply conditions have driven inflation's surge since mid-2021. Shapiro also finds both demand and supply forces to be important in inflation movements since the pandemic's outbreak. Benigno et al. (2022) conclude that global supply factors contributed to the recent rise of consumer price inflation, although other forces were quantitatively more important. In the estimates of Celasun et al. (2022), supply and demand shocks each accounted for roughly one-half of the 2021 increase in producer price index (PPI) inflation in the United States.

2. Employment growth and inflation are measured as annualized monthly percent changes. We use the ISM measure of supply chain conditions rather than the index of global supply chain conditions published by the Federal Reserve Bank of New York because the ISM measure provides a longer history of data and focuses on the United States.

3. Our approach follows that similarly used by De Santis (2021) to assess the importance of supply bottlenecks in eurozone (euro area) economic activity.

4. Specifically, following Arias, Rubio-Ramírez, and Waggoner (2018), we apply what are known as "sign restrictions" and make specific assumptions on whether shocks in the model have positive or negative effects on the variables of interest. Additionally, following Antolín-Díaz and Rubio-Ramírez (2018), we impose what are known as "narrative restrictions" and assume shocks on specific dates have particular signs or sizes. For example, we assume that negative demand shocks, associated with COVID-19 shutdowns, occurred in March and April 2020.

5. We follow common research practice and define the shock magnitude to be one standard deviation.

6. For simplicity, we use "point estimate" and "confidence interval" as shorthand for the more formally correct (in the terminology of Bayesian methods) "posterior median" and "credible set," respectively. We recognize that sign restrictions identify a set of equally likely results and that presenting the median or a credible set may imply these results are more likely or "truthful" than others of the set. However, we characterize our results in the form of its posterior median and credible sets so that our results are comparable to others in the literature.

7. We estimate our models in month-over-month growth rates for employment and the price level but accumulate the responses so that they represent the total percent change in the employment or price level compared to before the shock occurred. This representation more intuitively displays the cumulative effect a shock will have upon both employment and prices.

8. In this case, the estimate is the posterior mean.

9. Dropping this assumption on cost-push shocks slightly increases the estimated contributions of cost-push shocks to inflation, but not by enough to change our broad findings.

10. These are the same narrative events used to identify the supply shock in the simpler model. However, as detailed in our replication appendix, we enforce slightly stronger narrative interpretations of these events in order to distinguish the supply chain shock from a general supply shock. We use contemporaneous news articles to justify the relevance of these events in isolating supply chain shocks. Results based on an alternative approach to isolating the supply chain effect are available upon request. These alternative results are largely similar to our estimates but show slightly higher contributions of cost-push shocks to unexpected inflation.

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