

Tackling the surge in inflation: Lessons from theory, recent history and state-of-the-art empirical models

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Abstract

In the times of economic turmoil and rising inflation rates we are experiencing, it is of pivotal importance to make informed policy decisions. We use state-of-the-art empirical methods, the broadly accepted framework of the New Keynesian model, and insights from determinants of inflation in recent history to provide policy recommendations on how to tackle the current surge in inflation. Our report disentangles the influence of demand and supply shocks on the inflation rate. We identify demand shocks using monetary policy shocks obtained from high-frequency market transaction data. Our identification of supply shocks is based on a novel application of the narrative approach, combining data on supply chain disturbances with information from newspaper articles. We create a measure of supply chain shocks based on catastrophes and natural disasters, exogenous to any potential economic causes. Our estimates show that inflation is extremely sensitive to demand and supply shocks, with effects persisting over several years. A second econometric approach using theory-informed sign restrictions confirms these findings. It further allows us to do a historical decomposition of the relative importance of demand and supply shocks in driving the inflation rate. We show that, while supply shocks play a substantial role in the current economic crises, it is by no means a purely supply-driven rise in inflation: demand shocks contribute substantially to the current rise. Based on our findings, we suggest that a decisive intervention of the ECB is required to tame the surge in inflation; keep inflation expectations grounded; and prevent a rise in inequality through higher exposure to rising prices of already disadvantaged socioeconomic groups.

1. EXECUTIVE SUMMARY

After a long period of central banks struggling to reach their inflation targets, a recent surge in inflation has brought rising prices back into the headlines. One of the crucial questions in handling inflation is to understand its determinants. From an economic perspective, this question can be addressed by differentiating between reasons stemming from aggregate demand changes and aggregate supply changes. However, evaluating the relative importance of the two shocks goes beyond purely academic interest: different determinants of the changes in inflation require different responses by central banks and policymakers.

Disentangling demand from supply shocks presents itself with complications due to simultaneity problems. Given the sparsity of the data at hand, we combine insights from the modern theoretical literature in macroeconomics with econometrical identification strategies and the use of exogenous variables. We then use our estimates to assess to what extent demand and supply factors have contributed to the inflation rate over the last two decades, as well as the evolution of the factors' influence during the start of the recent rise in inflation. We combine the insights from theoretical models, our estimation and the knowledge gained from the recent history to provide recommendations to policymakers for the current high-inflation period.

This report's theoretical framework is based on the three-equation New Keynesian model, the workhorse model in modern macroeconomic analysis. We use the model to study how shocks to demand and supply affect the economy and how different variables respond to them.

We follow a wide strand of the literature by using the theory to distinguish shocks observed in the data into demand and supply shocks. Specifically, we tackle this challenging identification problem in the multivariate framework of a structural VAR and identify the shocks using a set of sign restrictions. Our results show that inflation in the Euro Area significantly and persistently responds to both shocks.

In a second empirical estimation, we extend our baseline VAR specification by introducing exogenous instruments for demand and supply shocks (i.e., VARX). The intuition behind this approach is to use shocks which have isolated impacts on demand respectively supply, without directly affecting other economic variables nor having economical causes. To identify demand shocks, we use surprises in monetary policy, measured using high-frequency market

transaction data. Our identification of supply shocks is based on a novel application of the narrative approach, combining data on supply chain disturbances with information from newspaper articles. We create a measure of supply chain shocks based on catastrophes and natural disasters, exogenous to any potential economic causes. Our results show that demand shocks lead to a sizable increase in unemployment and a decrease in inflation. Exogenous supply shocks have a more muted effect on GDP and unemployment, but the inflation rate responds significantly and positively.

The two VAR-based analysis document that the response of inflation to supply and demand shocks is extremely persistent. When looking at a supply-side shock, our estimates show that the effect of the shock on the inflation rate has faded between 14 and 16 quarters after the shock. When we focus on the impact of a demand shock, we see that the effect on inflation persists 12 quarters in the sign-restriction-based model and 8 quarters in the VARX model using exogenous shocks.

The historical decomposition of the contribution of demand and supply shocks in explaining the evolution of the inflation rate shows that both shocks have played an important role. However, during the global financial crisis, there were predominantly supply shocks driving the change in inflation. Looking at the beginning of the current surge in inflation, we observe that during the Covid crisis period, the upwards inflation pressure is not entirely attributable to supply shocks but demand shocks matter as well.

The third contribution of this paper is to propose several educated policy recommendations trying to support central bankers in tackling the current high-inflation period. Based on the supply and demand shocks decomposition and on our previous findings on the relatively small size and weakening slope of the Phillips curve, we suggest that changes in the interest rate might not be enough to restore price stability. Unconventional monetary policies like Forward Guidance and Quantitative Easing constitute a potential circumvention of this problem. Moreover, a convincing communication strategy and coordination with the fiscal side are necessary as well to stabilize the observed increase in prices.

2. REVIEW OF PREVIOUS WORK ON THE TOPIC

This report complements and extends the large body of empirical evidence on the relative importance of demand and supply shocks on inflation. Based on Galí (2015), and Goodfriend and King (1997), we remind the theoretical framework of New Keynesian models that shapes current monetary policies as well as their main predictions. Moreover, Ball and Mankiw (1995) provides important literature on the link between inflation and aggregate supply shock using the Phillips Curve. Referring to Schmitt-Grohé and Uribe (2008)'s paper, we describe the most important policy implication derived from NKM theory.

Following Barnichon and Mesters (2020) and McLeay and Tenreyro (2020), we rely on external instruments to capture exogenous variation in the demand. We use the high frequency surprise from Jarociński and Karadi (2020) as a measure of monetary policy shock, like Gürkaynak et al. (2005). We adopt the VAR, and VAR-X specification of Del Negro et al. (2020) and Paul (2020) respectively, and show that demand and supply shocks significantly influence inflation rate in the Euro Area.

3. DATA

In this paper, the analysis uses quarterly data provided by ECB, Eurostat, Federal Reserve Bank of New York, and HWWI. The dataset contains 93 observations from 1999Q1 to 2021Q4. It includes information on various macroeconomic variables. However, we will mainly use harmonized index of consumer prices, unemployment rate, SPF inflation expectations one, two, and five years ahead oil price, non-energy commodity index, real effective exchange rate CPI deflated of the Euro against a group of 42 trading partners and Global Supply Chain Pressure Index for the Euro area.

As a wild card, we choose the high-frequency monetary surprises computed by Jarociński and Karadi (2020). The exogenous changes in the interest rate can be considered as pure demand shocks since they are orthogonal to the state of the economy.

4. CONCEPTIONAL FRAMEWORK: THE NEW KEYNESIAN MODEL

In this section, we describe a standard New Keynesian model which we use to better discipline our empirical approach¹. The three equations of the model are the IS curve (1), the Philips curve (2) and the interest rate rule (3). These equations relate the output gap \tilde{y}_t (defined as the deviation of output from its flexible price counterpart), the inflation rate π_t and the nominal interest rate i_t :

$$\tilde{y}_t = -\frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^n) + E_t \tilde{y}_{t+1} \quad (1)$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \quad (2)$$

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t \quad (3)$$

where r_t^n is the natural rate of interest, σ is the intertemporal elasticity of substitution and β the discount factor. The interest rate rule coefficients, ϕ_π and ϕ_x , capture the response of the central bank to changes in inflation and output gap, respectively.

Despite its simplicity, this system of equations can capture quite well the dynamics of the demand and supply side of the economy and their responses to shocks. Therefore, we use the model to study how output and inflation react to demand and supply shocks.

Galí (2015) shows analytically and through IRFs simulation that demand shocks in the economy, like a monetary shock to the interest rate rule (3), lead to co-movements in output and inflation. Like a cost-push shock to the Phillips curve, supply shocks result in output and inflation moving in opposite directions.

We rely on the theoretical predictions from the three equation model to discipline our empirical analysis. In particular, we disentangle demand from supply shocks by imposing different sign restrictions on a VAR model: Demand shocks on impact should move the real GDP and the Euro Area inflation rate in the same direction, while supply shocks move real GDP and inflation in opposite directions.

¹The derivation of the model is rather standard in the literature, so we refer the interested reader to Galí (2015).

5. VAR ANALYSIS

The Vector-Autoregression (VAR) model has been extensively used in the literature to disentangle demand and supply shocks. In its simple formulation, a VAR model can be described as:

$$y_t = c + B_1 y_{t-1} + \dots + B_p y_{t-p} + u_t \quad (4)$$

where y_t is the vector with the macroeconomic variables of interest which are a function of their own past values, a constant term, and a vector of forecast errors.

To jointly identify the different effects that demand and supply shocks have on the economy, we propose two specifications. First, we use a combination of sign restrictions on output and inflation. Second, we exploit two exogenous instruments, one for demand and one for the supply shock.

In the VAR we include: (i) unemployment rate; (ii) Harmonized CPI; (iii) real GDP; and (iv) the 3-month interest rate. The data are quarterly, and we include four lags for each variable.

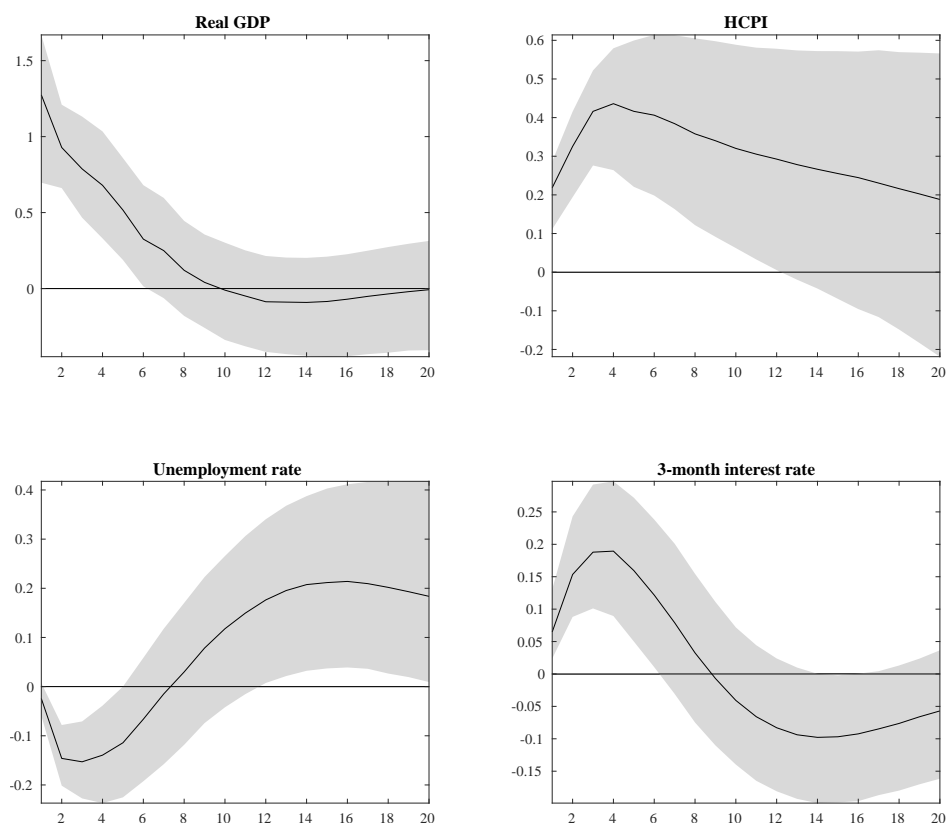
5.1 BVAR WITH SIGN RESTRICTIONS

Similarly to Blanchard (1989), and Kilian and Lütkepohl (2017), we jointly identify an aggregate supply (AS), an aggregate demand (AD) disturbance using the following restrictions: (1) the aggregate demand disturbance increases the real GDP and the Euro Area inflation rate (HCPI); (2) the aggregate supply disturbance increases real GDP and decreases prices. We impose the sign restrictions only on impact.

Figure 1 reports the impulse responses to a demand shock. By construction, a demand shock increases both real GDP and inflation rate. Interestingly, the effects are rather persistent over time, well beyond the restriction we impose. Following the demand shock unemployment rate significantly decreases, and the central bank responds to this overheating of the economy by increasing the interest rate.

The supply shock in Figure 2 has a more muted effect on real GDP but an extremely persistent effect on inflation. The unemployment and interest rate responses are not significant, although they have the expected sign. Similar results are found by Cover et al. (2006) and Stock and Watson (2001).

Figure 1: IRFs to an demand shock, VAR with sign restrictions



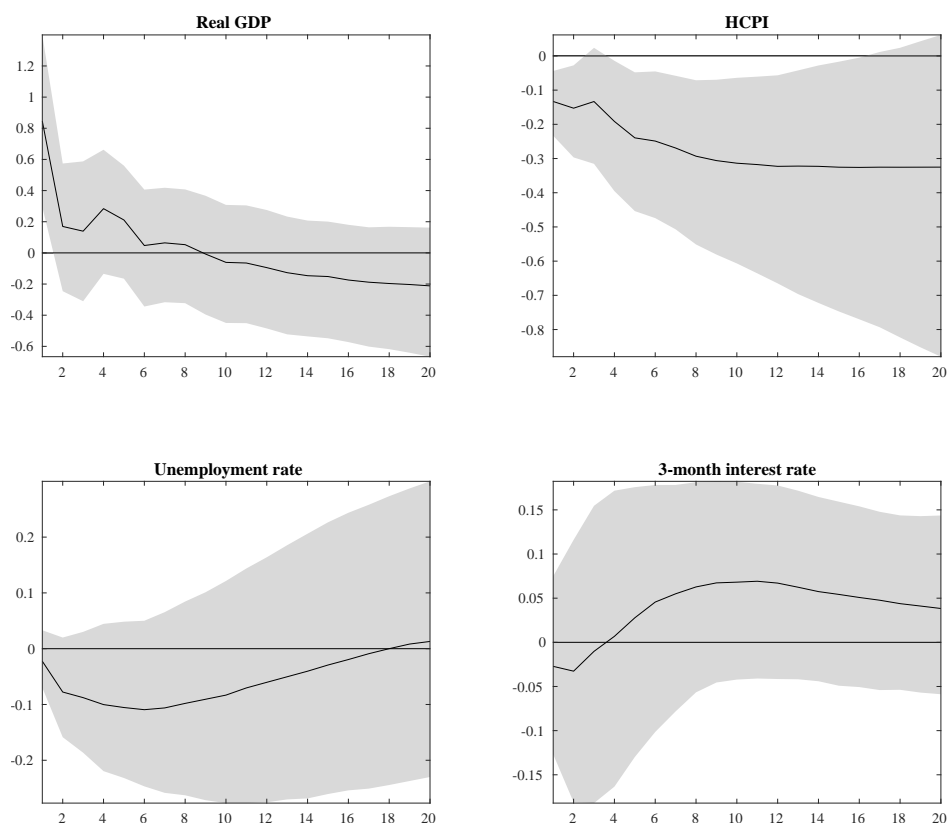
Notes: Impulse responses to a demand shock. The impulse responses are from the baseline VAR. The shock is identified using a sign restrictions. Shaded areas correspond to the 68-percent confidence interval. The samples period is from 1999m1 to 2021m4.

To what extent the current rise in inflation is driven by supply and demand shocks? Figure 3 reports the contribution of demand shocks, supply shocks, other shocks, and the initial condition to the evolution over time of the annual inflation. As one can notice, both demand and supply shocks influenced the dynamics of the Euro Area. However, supply shocks seem to contribute more to many important episodes of the Euro Area history, like the increase and drop in inflation before and after the Global Financial crisis.

Looking in particular at the Covid period, supply shocks are the main driver behind the decrease in inflation observed in 2020. They also contribute to the current rise in the inflation rate, but demand shocks still play an important role. Therefore, the observed high level in the inflation rate should not be considered a purely supply phenomenon.

The fact that both shocks are increasing inflation is not unexpected. Governments worldwide responded to the Covid lockdowns by implementing transfer programs to financially support the households who were mostly affected by the crisis. The government stimulus packages and

Figure 2: IRFs to an supply shock, VAR with sign restrictions



Notes: Impulse responses to a supply shock. The impulse responses are from the baseline VAR. The shock is identified using a sign restrictions. Shaded areas correspond to the 68-percent confidence interval. The samples period is from 1999m1 to 2021m4.

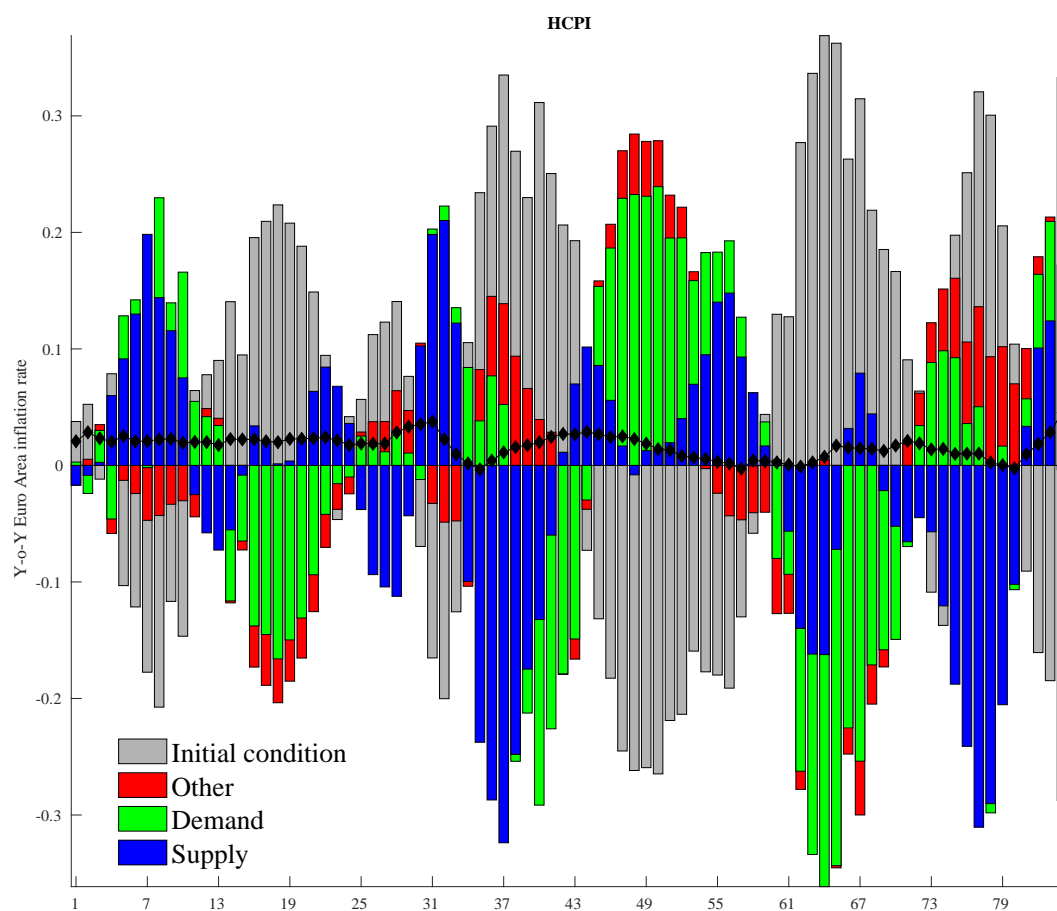
the relaxed monetary policy stance in response to the pandemic are the most likely reasons behind the important role played by demand shocks. At the same time, supply shocks like the bottleneck in the supply chain, the instability in the provision of energy, increase in oil price, and relative uncertainty added pressure to inflation.

5.2 VARX

Imposing sign restrictions in a VAR model, especially if educated by the theoretical model, is common to disentangle different shocks. However, one of the main drawbacks is that the variables restricted by the sign restrictions are not much informative since the sign of their response is forced by construction. A more agnostic approach is to use exogenous instruments and evaluate how they affect the variables of interest.

We propose two instruments: one for demand and one for the supply shocks. Components of monetary policy shocks that were not anticipated by the markets are used to identify exogenous movements in demand, and major natural events disrupting the global supply

Figure 3: Historical decomposition of the annual inflation rate



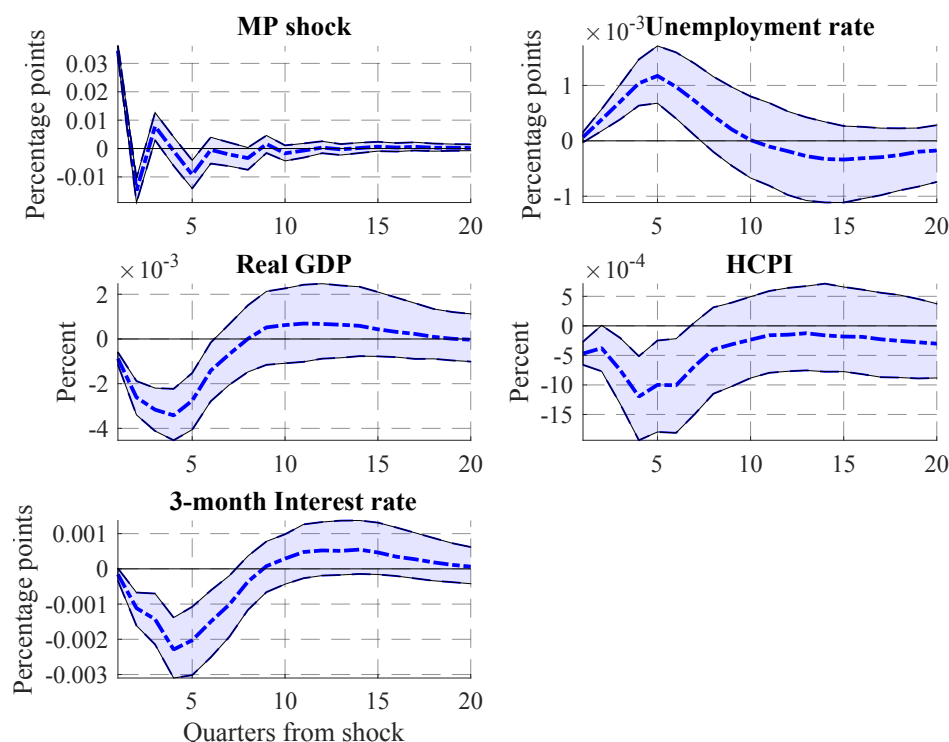
Notes: The plot reports the contribution of demand and supply shocks in explaining the evolution over time of the annual inflation rate. The historical decomposition is computed using the estimates from the VAR with sign restrictions. The samples period is from 1999m1 to 2021m4.

chain will isolate exogenous movements in supply.

As a measure of monetary policy shocks, we choose the high-frequency surprises computed by Jarociński and Karadi (2020). Similar to what Gürkaynak et al. (2005) does for the US, the authors compute the change in interest rate in a narrow window around the ECB policy announcements from 1999 to 2016. This identification strategy allows to isolate the changes in interest rate entirely due to monetary announcements, and therefore the surprises can be considered exogenous monetary shocks.

Given the limited time sample and the relatively low frequency of the aggregate data, the monetary shocks cannot be used directly as an instrument. Indeed, regressing the short-term interest rate on the monetary shocks leads to a low F-statistic, suggesting that the surprises are a weak instrument. Therefore, as in Rogers et al. (2018) and Paul (2020), we integrate the surprises directly into a vector autoregressive model as an exogenous variable (VARX).

Figure 4: IRFs to a monetary shock, VARX approach



Notes: Impulse responses to a monetary policy shock. The impulse responses are from the baseline VAR. The shock is identified using a VARX strategy. Shaded areas correspond to the 68-percent confidence interval. The samples period is from 1999m1 to 2016m4.

The model can be considered an extension of the previous specification:

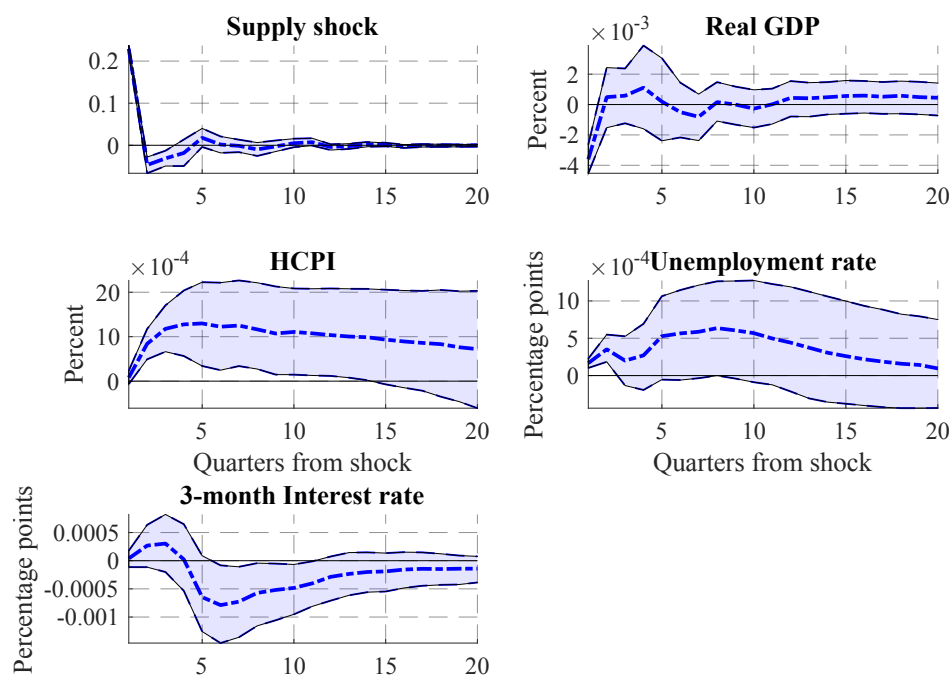
$$y_t = c + B_1 y_{t-1} + \dots + B_p y_{t-p} + A z_t + u_t \quad (5)$$

where z_t is the vector with the exogenous surprises. We use the same lag structure and standard errors as before. More detailed can be found in Paul (2020).

We report responses to monetary policy shocks in Figure 4. Following the contractionary shock, the unemployment rate rises while real GDP and HCPI decrease significantly. As before, the central bank responds by decreasing the short-term interest rate. Even under this specification unemployment rate and inflation rate move in the opposite direction in a significant and sizable way. These findings confirm the important role played by demand shocks.

To isolate shocks to the supply side, we construct an exogenous variable based on global supply chains. Intuitively, a disruption in global supply chains will decrease output in the short run and thereby constitute a negative shock to the supply side. The Global Supply Pressure Index

Figure 5: IRFs to a supply shock, VARX approach



Notes: Impulse responses to a supply shock. The impulse responses are from the baseline VAR. The shock is identified using a VARX strategy. Shaded areas correspond to the 68-percent confidence interval. The samples period is from 1999m1 to 2021m4.

for the Euro Area measures such disruptions in global supply chains. However, such an index is unlikely to be exogenous to our variables of interest². For instance, the Global Financial Crisis led to a big spike in the pressure index on one side. Still, on the other side, the crisis is a market outcome and is likely to be directly related to inflation and unemployment through other channels than the demand shock.

To solve the endogeneity issue, we rely on the so-called narrative approach, first introduced by Romer and Romer (2004). We use the information on major events that are not in any way caused by market forces, such as earthquakes or fires. We construct a simple narrative database by collecting information from news articles on such disruptions to the supply chain³. We then regress the quarter-to-quarter changes in the Global Supply Pressure Index on binary variables indicating the timing of the events ($F\text{-Stat} = 10.49$) and use the fitted values as an exogenous instrument for supply shocks.

²As a robustness check, we try using the Global Supply Pressure Index directly in the VAR as an instrument. The responses of the macroeconomic variables are basically unaffected, but the response of the supply shocks is rather persistent, suggesting the Global Supply Pressure Index should not be used as an exogenous instrument.

³The events used are: A fire in a Philips Electronics plant in New Mexico (2000Q2), A blockage in the Suez canal (2004Q4), Hurricane Katrina (2005Q3), Boeing (2008Q1), Major earthquake in Japan causing a Tsunami (2011Q1), Major flood in Thailand (2012Q1), Heavy rains in Chennai, India (2016Q1), China-US trade dispute (2018Q1), Covid (2020Q2), Covid & another Suez canal blockage (2021Q2)

Figure 5 reports the responses of the variable of interest to an exogenous increase in the supply shock measure. As for the baseline VAR specification, real GDP and unemployment response are only marginally significant. The inflation rate significantly and persistently reacts to the shocks.

Overall, in this section, we document that both demand and supply shocks contributed to the evolution of the inflation rate in the Euro Area. However, supply shocks played a more determinant role in several critical episodes like around the GFC and the drop in inflation in 2020. However, the current high inflation level is caused by both demand and supply shocks.

6. POLICY IMPLICATIONS

We now use the results from our empirical analysis to discuss how our findings might contribute to the current debate on tackling issues caused by the increase in inflation. Therefore, we divide this section into two current problems: 1) the flattening of the Phillips Curve and 2) the high pressure on recent inflation caused by supply and demand shocks. We address them by suggesting policies. Moreover, we remind why central banks should be proactive in reducing inflation by intervening. Finally, we summarize our recommendations.

6.1 THE FLATTENING OF THE PHILLIPS CURVE

In the first part of the competition, we used different econometric specifications to document that the slope of the Phillips curve is negative and significant, although small in size. On top of that, regression using rolling windows of beta suggested that the slope has become flatter in the last years.

These findings suggest that the effectiveness of conventional monetary policy might have weakened over time: the sensitivity of inflation to changes in economic activity is lower than it used to be. Consequently, the ECB needs a strong increase in the policy rate to stabilize inflation. We suggest that unconventional monetary policy tools should also be considered in such a situation. Forward Guidance and Quantitative Easing (i.e., asset purchase programs) could help reduce inflation beyond the direct channel of a change in the interest rate. The empirical evidence regarding the efficacy of these tools is still limited and sometimes conflicting. However, in any case, the announcement of such a measure can send the important

message to the markets that stabilizing inflation has been, is, and will always be the ECB's main objective, "whatever it takes".

6.2 DEMAND AND SUPPLY SHOCKS

To guide our policy recommendations, we assess how the dynamics of inflation have been influenced by demand and supply shocks. We find that both shocks are important, but supply shocks are the main driver during major historical events like the GFC.

Focusing on the Covid period, supply shocks are still a major source of inflationary pressure. However, calling the current high inflation rate a purely supply-sided phenomenon would be an underestimation of the importance of the demand shocks, as can be seen from Figure 3. We can also point out that – opposed to previous crises – supply and demand shocks can account for the rise in inflation almost exclusively.

Based on the results from our overall analysis, we believe the ECB should focus on 1) adopting a more proactive role in fighting inflation using monetary policy instruments, 2) disciplining expected inflation, and 3) stabilizing supply shocks (i.e., changes in the price of the energy sectors).

The first point serves to reduce the role played by positive demand shocks. Regarding the second point, we demonstrate how inflation expectations play a major role in determining inflation in the first part of the competition. Therefore, a stronger stance against the rise in inflation would signal the economic agents that inflation will return to its target, thus lowering their expectations. The third point should be mainly addressed in coordination with the national governments. Guaranteeing a more stable supply of gas and oil – independent of potential geo-strategical interests of suppliers – would result in a smaller pass-through of input costs to final prices.

Given the relatively important role of temporary factors in explaining the current increase in the inflation rate, some policymakers might be tempted to conclude that an active response by the monetary authority is not necessary. In the following subsection, we argue why the ECB should play an active role in fighting the current surge in inflation.

6.3 MOTIVATION FOR MONETARY INTERVENTION

The ECB has recently chosen a more passive approach than other central banks like the BoE or the FED. We strongly urge caution in concluding so for mainly two reasons: First, an important role is played by persistent factors as well. Second, even if of temporary nature, the rise in inflation is likely to have heterogeneous negative effects on the economy.

Regarding the first reason, the literature well document that households and firms tend to extrapolate from their perceived/experienced inflation in forming their inflation expectations and that these expectations are extremely persistent. Therefore, inflation might keep increasing through the expectations channel even after the temporary factors have faded away. Moreover, changes in short-term inflation expectations can significantly affect long-term expectations. Through this propagation channel, the anchoring in expectations achieved after decades of efficient communication by the ECB and increased transparency might weaken with severe implications for the central bank's ability to stabilize prices.

This is, moreover, related to consumer confidence. Only if households firmly believe in the commitment of the monetary authorities to the 2 percent inflation target, it can be achieved. Observing such a high inflation rate for a prolonged period might cast some doubts in the mind of the economic agents.

Regarding the second reason, households are not exposed to the same inflation rate. Low- and middle-income households experience a much higher inflation rate since they tend to devote a larger share of their consumption bundle to energy and food. The extremely high level of the inflation rate is likely to impact them more, thus further reducing their real consumption. Therefore, a passive response by the central bank will increase real inequality, which is against the inclusive monetary policy that the ECB is pursuing.

6.4 SUMMARY OF POLICY RECOMMENDATIONS

Making use state-of-the-art econometric tools, a broadly accepted theoretical framework and insights on the determinants of inflation in the recent history, we recommend the following policies to the ECB.

- The slope of the Phillips curve is currently close to zero: therefore a strong increase in interest rate is necessary to affect the current inflation rate significantly

- FG and QE should be considered to complement the downward pressure that the contractionary monetary policy would have on inflation. Through changing people's expectations, these tools could have sizable effects beyond the simple direct impact of the change in the policy rate
- Inflation expectations and supply shocks are major drivers. Only through a convincing communication strategy and coordination with the fiscal side of the economy they can be properly addressed
- Regardless of the extent to which the rise in inflation rate is temporary, a more proactive approach by the ECB is crucial to avoid second-order negative effects like over-extrapolation of the perceived inflation to expected inflation, de-anchoring of expectations, loss in consumer confidence.
- Households are heterogeneously exposed to inflation, and low-income households, in particular, have seen the average price of their consumption bundle increase more than the high-income households. Given the inclusive monetary policy that the ECB is pursuing this point should call for a stronger response by the ECB.

7. CONCLUSION

How central banks and governments should address the changes in inflation rate crucially depends on which are its main drivers. This has become particularly important in the last months. Following the Covid crisis and the war in Ukraine, inflation rates have worldwide increased to historically high levels. Only by properly understanding the nature of the shocks that led to this increase the monetary policy can optimally respond, minimizing the negative spillovers of its activity.

Not surprisingly, then, evaluating the relative role of demand and supply shocks in the evolution of inflation has been again at the forefront of economic research. However, disentangling the shocks is particularly challenging from an econometric perspective.

Therefore, through the lens of a standard 3-equation New Keynesian model, we study how demand and supply shock heterogeneously affect the economy. We then use the theoretical findings to discipline the empirical analysis. We adopt a VAR model with sign restrictions on

output and inflation and document that the Euro Area's inflation rate significantly responds to demand and supply shocks. Demand shocks influence GDP and unemployment, and whether the impact of supply shocks on these variables is more muted.

From the estimates of our VAR model, we can assess the relative importance of supply and demand shocks in explaining the historical path of inflation. Both shocks contribute remarkably. However, supply shocks are the main driver behind important inflationary and deflationary episodes. Regarding the Covid period, they are both pushing inflation upward, so the current high level of inflation should not be considered as the result of the supply side only.

We further extend our empirical analysis by including exogenous demand and supply shocks in our VAR model (i.e., the VARX approach). The demand shocks are captured by high-frequency monetary policy shocks, while the supply shocks are constructed using a narrative approach to events relative to the disruption in global supply chains. The responses from the VAR-X confirm that real GDP and unemployment respond to demand shocks and only marginally to supply shocks and that both shocks have a sizable and persistent effect on inflation.

In conclusion, the results of our empirical analysis provide substantial evidence that supply and demand shocks influenced the evolution of the inflation rate in the Euro Area. Moreover, the high inflation rate observed in the last months should not be simply attributed to shocks in the economy's supply side.

Complementing these findings with our results on the slope of the Phillips curve, we conclude that the ECB cannot simply address the current surge in inflation by increasing its policy rate. A combination of unconventional monetary policies like FG or QE, a credible communication strategy to manage expectations as well as coordination with the national governments for an appropriate fiscal response are all necessary policies to decrease the inflation rate to the medium-term target.

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