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Global Supply Chain Disruptions: Challenges for Inflation and Monetary Policy in Sub-Saharan Africa

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Global Supply Chain Disruptions: Challenges for Inflation and Monetary Policy in Sub-Saharan Africa
Prepared by Zo Andriantomanga, Marijn A. Bolhuis, Shushanik Hakobyan*

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ABSTRACT:

The Covid-19 pandemic has led to a large disruption of global supply chains. This paper studies the implications of supply chain disruptions for inflation and monetary policy in sub-Saharan Africa. Increases in supply chain pressures have had a sizeable impact on headline, food, and tradable inflation for a panel of 29 sub-Saharan African countries from 2000 to 2022. Our findings suggest that central banks can stabilize inflation and output more efficiently by monitoring global supply chains and adjusting the monetary policy stance before the disruptions have fully passed through into all inflation components. The gains from monitoring supply chain disruptions are particularly large for open economies which tend to experience outsized second-round effects on the prices of non-tradable goods and services.

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1. Introduction

The Covid-19 pandemic has caused major disruptions to global supply chains, hampering trade in goods between countries. During the first phase of the pandemic, factory shutdowns and mobility restrictions disrupted the logistics of manufacturing firms. As countries opened up and the increased demand for goods began to outstrip supply, port congestions raised shipping costs, putting additional pressure on global supply chains.[1]

An attempt to define supply chain disruptions would be a business' inability to receive, produce, ship, and sell their products. Supply chain disruptions are high-dimensional in nature. Nonetheless, two dimensions of supply chain disruptions stand out: disruptions in manufacturing production and higher transportation costs. A newly developed indicator by the Federal Reserve Bank of New York, the Global Supply Chain Index (GSCPI), captures both these dimensions by combining several cross-border transportation cost indicators and global manufacturing data. The GSCPI suggests that the disruptions in 2021 and 2022 were three to four standard deviations above the historical average.

The volatility of supply chains and the prospect that these disruptions may remain elevated for a sustained period pose a significant challenge for monetary policymakers. There is growing evidence that supply chain disruptions have contributed to the recent increase in global inflation (e.g., Benigno et al 2022; LaBelle and Santacreu 2022; Finck and Tillmann 2022). One concern is that this effect could become entrenched, leading to expectations of permanently higher inflation that in turn could spill over into higher wage demands and higher prices for non-tradable goods and services. Another concern is that attempting to stabilize inflation in the face of such high volatility could have significant economic costs. These concerns are most acute in sub-Saharan African countries, where the share of food and tradable goods in the consumption basket is high, and weak monetary policy frameworks increase the risk of inflation expectations becoming un-anchored.

In many ways, supply chain disruptions resemble traditional global commodity supply shocks. Standard policy advice for such shocks, particularly for advanced economies, is to accommodate the direct first-round impact of global supply shocks on the consumer price index (CPI), but not the indirect second-round impact on other CPI components (IMF 2011). However, disruptions to global supply chains are profoundly different from commodity supply shocks because they directly affect manufactured imported goods. The direct impact of spikes in commodity prices is mainly on food and energy inflation,

[1] For example, Komaromi et al (2022) document that ports have contributed to increased trade frictions in the global transport system since the onset of the pandemic by virtually tracking cargo ships based on radio messages.

affecting core inflation through second-round effects. Global supply chain disruptions, on the other hand, have a direct impact on the prices of other tradable goods that account for a large share of countries' core consumption basket. Second-round effects materialize in non-tradable goods and services.

How then should monetary policy respond to the inflationary effects of global supply chain disruptions? This paper studies the impact of global supply chain pressures on inflation in sub-Saharan Africa and assesses implications of global supply chain shocks for the conduct of monetary policy.[2] We focus on sub-Saharan Africa for two reasons. First, food and tradable goods, directly affected by global supply chain disruptions, account for an outsized share of the consumption basket in sub-Saharan Africa. Second, despite progress in recent decades, monetary policy credibility in sub-Saharan Africa remains relatively weak (Berg et al 2018). These factors undermine the central banks' ability to fight inflation, making the second-round effects from external shocks, like global supply chain disruptions, more likely.

We start by estimating the impact of global supply chain disruptions on domestic inflation for a panel of 29 countries in sub-Saharan Africa at a monthly frequency. We leverage a new dataset that contains detailed components of the CPI series for each country. This allows us to not only analyze headline and food inflation but also distinguish between first- and second-round effects by studying the tradable (alcohol, clothing, household furnishings, and transportation) and non-tradable components (health, communications, recreation, education, restaurants, housing) of core inflation.[3] We compute the impulse response function (IRF) to a one standard deviation shock by means of local projections following Jordà (2005). We use the GSCPI as a proxy of supply chain pressures.

After documenting the impulse responses of different inflation measures to global supply chain shocks, we quantify the contribution of global supply chain pressures to headline, food, tradable and non-tradable inflation in sub-Saharan Africa over the 2020-2022 period. Following Benigno et al (2022), we decompose the realized inflation by identifying three shocks: global supply chain disruptions, global food prices, and global oil prices.

The results of our local projections suggest that global supply chain pressures have a sizable, positive, persistent, and statistically significant impact on all measures of domestic inflation. A one-standard deviation shock to the GSCPI increases headline inflation by 0.41 percentage points five months after the initial shock.[4] Headline inflation

[2] According to a recent IMF survey, sub-Saharan African countries implemented more than 100 policy measures since January 2022 in response to food and fuel price shocks, including cutting taxes on food or fuel; foregoing import tariff revenues; deferring tax payments; introducing new food, fuel, and fertilizer subsidies; and adjusting wage bills (IMF 2022a).

[3] We define core inflation as headline inflation excluding food. We also distinguish between tradable and non-tradable core inflation.

[4] During the pandemic, global supply chain pressures peaked at almost 4.5 standard deviations in late-2022.

remains elevated, and the effect reverts to zero after 14 months. Most of the impact on headline inflation comes from tradable goods, including food. A one-standard deviation shock to the GSCPI increases both food inflation and tradable core inflation by about half a percentage point five months later. We also document indirect second-round effects from supply chain disruptions. Seven months after the shock to the GSCPI, non-tradable core inflation increases by 0.2 percentage points on average. Compared to tradable inflation, this effect is smaller and delayed.

The magnitudes of the effects we document, combined with the sharp increase in global supply chain pressures during the pandemic, imply that disruptions have contributed greatly to the recent increase in inflation in sub-Saharan Africa. We quantify that supply chain pressures pushed up headline, food, and tradable core inflation by about 2 percentage points during the 2020-22 period. As such, disruptions accounted for 45 and 55 percent of headline and tradable core inflation, respectively.

After documenting the empirical results, we use model simulations to assess the implications of our findings for monetary policy. We set up a New Keynesian small open economy model that combines a supply curve, which links tradable inflation to the direct impact of global supply chain disruptions, with an expectations-augmented Phillips curve, which links non-tradable inflation to the output gap and second-round effects from global supply chain disruptions. We calibrate the model to our empirical findings and use it to answer two questions. First, we examine to what extent central banks can better achieve their objectives by monitoring global supply chains and anticipating the inflationary effects of incipient global supply chain disruptions. Second, we examine the role of cross-country heterogeneity in the exposure to global supply chain disruptions and central bank credibility in its ability to respond to inflation caused by shocks to global supply chains.

With global supply chain disruptions, like other supply shocks, a policy trade-off arises between stabilizing inflation and closing the output gap. When central bank credibility is low, large movements in the policy rate may be required to stabilize inflation and the output gap. Our model simulations suggest that central banks can stabilize inflation and output more efficiently by pre-emptively raising policy rates as supply chain disruptions increase. Tighter monetary policy cannot solve the supply chain issues and thus cannot prevent the direct inflationary impact of disruptions. But by raising rates early, central banks lower the second-round effects on non-tradable inflation and inflation expectations. While tightening comes at the expense of a negative output gap, it is preferable for central banks with low credibility to tighten early to kill off second-round effects. This forward-looking path of monetary policy is thus especially effective in low-income countries, where tradable goods account for a larger share of the consumption basket and second-round effects are more likely.

Our paper relates to three strands of literature. The first pertains to the impact of shipping costs and supply chain disruptions on inflation. Benigno et al (2022) construct a new indicator, the GSCPI, to gauge supply chain pressures and to study the impact of such pressures on CPI and PPI inflation in the United States and the euro area. Using local projections and historical decomposition of inflation, they show that the contribution of the GSCPI shock to inflation is substantial. LaBelle and Santacreu (2022) estimate the contributions of supply chain disruptions to PPI inflation of 26 industries in the United States. Finck and Tillmann (2022) show that a global supply chain shock causes a strong increase in consumer prices and a fall in real economic activity in the euro area. Before the pandemic, Herriford et al (2016) estimate the pass-through of global shipping costs to US core inflation to be 0.10 percentage point. Recently, Carrière-Swallow et al (2022) study the impact of global shipping costs, measured by the Baltic Dry Index, on domestic inflation in 46 countries since 1992. They document that a one standard deviation shock to shipping costs increases inflation by 0.15 percentage points over 12 months. This impact is similar in magnitude but more persistent than for shocks to global food and oil prices. Di Giovanni et al (2022) find that external shocks and global supply chain bottlenecks played an outsized role relative to domestic aggregate demand shocks in explaining Eurozone inflation during 2020-21.

The second strand of literature examines global drivers of inflation, focusing primarily on the pass-through from global commodity price shocks to domestic inflation (Gelos and Ustyugova 2017; Sekine and Tsuruga 2018). Some papers examine the effect of global oil prices on domestic inflation, including the decline in pass-through in recent decades (LeBlanc and Chinn 2004, Chen 2009, De Gregorio et al 2007, Choi et al 2018). Others study the effect of global food prices on inflation (IMF 2011; Furceri et al 2016). Papers that focus on sub-Saharan Africa include Barnichon and Peiris (2008), Caceres et al (2013), Nguyen et al (2015) and Alper et al (2017). In a recent paper, Baptista et al (2022) estimate the pass-through from global to local food prices in the region.

The third strand of literature focuses on appropriate monetary policy in the face of global supply shocks. Habermeier et al (2009) study the monetary policy response to rising inflation in emerging economies associated with commodity price shocks in late 2000s. IMF (2011) and De Gregorio (2012) examine the optimal monetary policy response to global food shocks in emerging economies with differing degrees of first- and second-round effects.

This paper contributes to the literature in three ways. First, it examines the impact of global supply chain disruptions on different measures of inflation, highlighting the first- and second-round effects on tradable and non-tradable core inflation. It also covers a large number of emerging and low-income economies. Second, it shows that global supply chain shocks differ from commodity price shocks due to their outsized impact on the tradable components of the core inflation basket. Third, this paper is the first to study optimal monetary policy in the face of global supply chain shocks.

The remainder of the paper is organized as follows. Section 2 discusses recent global supply chain pressures and inflation developments in sub-Saharan Africa. Sections 3 through 5 describe data, methods, and empirical findings. Section 6 presents the implications for monetary policy, and Section 7 concludes.

2. Global supply chain pressures and inflation in sub-Saharan Africa

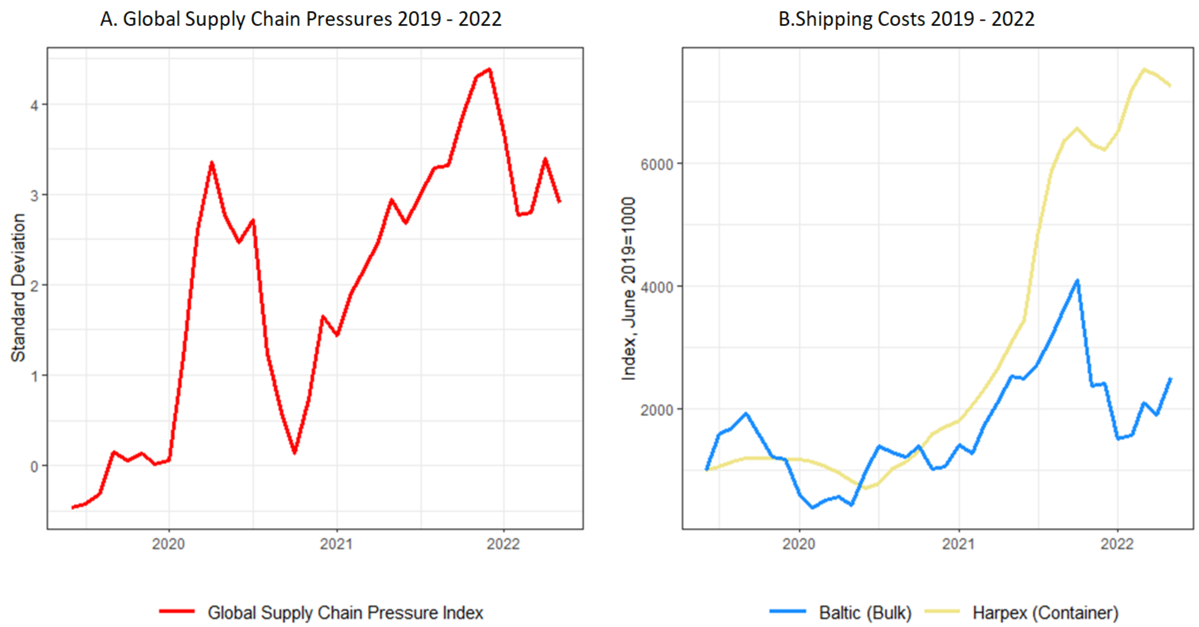
2.1 Global supply chains during Covid-19 pandemic

Since the onset of the pandemic, global supply chain disruptions have been a major challenge for the global economy. These disruptions manifested themselves at different stages of the supply chain, impacting businesses' ability to receive, produce, ship, and sell their products. Supply chain disruptions are high-dimensional in nature. Nonetheless, two dimensions of supply chain disruptions stand out: disruption of *production* and *trade* of manufactured goods.

In the manufacturing sector, firms have struggled to deliver goods on time over the 2020-21 period because of different input shortages, including labor shortages. For example, the automotive industry experienced microchip shortages, resulting in longer delivery times and higher used-car prices (Wilkes and Patel 2021). In the sea transportation sector, port congestions have contributed to increased trade frictions since the pandemic began. Not only the transit time of goods, but also the processing time at the ports have increased (Komaromi et al 2022). Shipping costs soared to all-time highs during the pandemic.

The GSCPI, a new indicator of global supply chain pressures constructed by the Federal Reserve Bank of New York, combines the two dimensions of global supply chain pressures using cross-border transportation cost data and survey data from purchasing managers in manufacturing. The GSCPI has spiked twice since the onset of the pandemic (Figure 1, panel A). The first spike in the spring of 2020 was driven by the first wave of lockdowns and characterized by disruptions in the manufacturing sector with longer delivery times, piling backlogs, and low inventories. Supply chain pressures seemed to ease heading into the fall of 2020. The second spike occurred in the spring of 2021, following a surge in shipping costs. The cost of bulk shipping,[5] as measured by the Baltic Dry Index, and the cost of container shipping,[6] as measured by the Harpex Index, have increased fourfold and sevenfold in 2021, respectively, from pre-pandemic levels (Figure 1, panel B).

Figure 1. Global supply chain pressures and shipping costs



Sources: Haver Analytics, and IMF staff calculations.
Note: The chart on panel A illustrates the evolution of the Global Supply Chain Pressure Index (GSCPI). In panel B, the blue and yellow lines represent the Baltic Dry Index and the Harpex Index, respectively.

2.2 The inflation outlook in sub-Saharan Africa

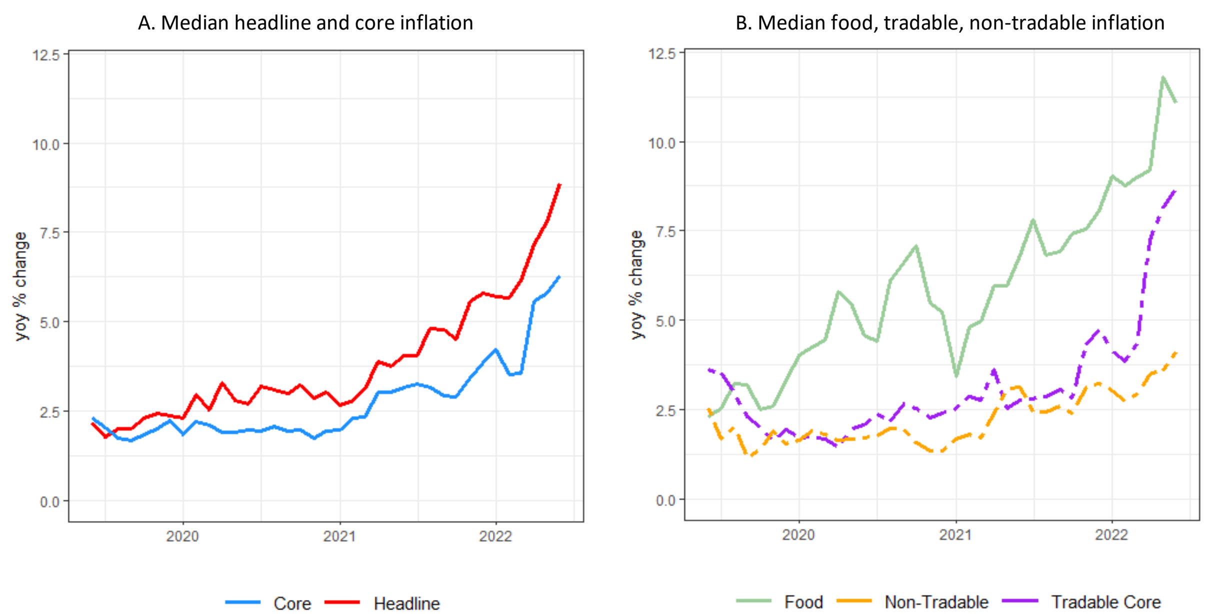
Figure 2 shows the median of different inflation measures in sub-Saharan Africa since 2019. Panel A illustrates the evolution of median headline and core inflation in the region. Throughout 2020, headline inflation remained steady at around 3 percent. Starting from 2021, headline inflation gradually picked up to reach about 8.5 percent in June 2022. Similarly, core inflation gradually increased starting in 2021 and grew at a faster rate in early 2022 to peak at 6.25 percent in June 2022.

Supply chain disruptions have a direct and an indirect impact on inflation. The direct impact is related to the prices of imported goods, which rise as shipping costs increase. The indirect impact is related to an increase in the price of tradable inputs used in the

[5] Goods shipped in bulk are raw materials like steel, coal, and grains.
[6] Goods shipped in containers are any non-bulk goods like clothing, furniture, and electronics.

domestic non-tradable sector. In panel B, we decompose headline inflation into three components: food inflation, tradable core inflation, and non-tradable core inflation. Food, which is typically imported and represents 36 percent of the region's median consumption basket, was the main driver of headline inflation in sub-Saharan Africa during the pandemic, contributing about one-half to inflation.[7] However, the significant heterogeneity across countries suggests that domestic factors such as climate shocks and agricultural yields may also play an important role. The inflation of non-tradable goods remained relatively steady since 2020. One striking fact is the sudden sharp increase in tradable inflation in 2021 and 2022, which we link to global supply chain disruptions in the empirical section of this paper.

Figure 2. Median inflation in sub-Saharan Africa



Sources: Haver Analytics, and IMF staff calculations.
Note: Median inflation is calculated using a sample of 29 sub-Saharan African economies during 2000-22.

[7] The pass-through of food prices to headline inflation is larger compared to advanced and other emerging economies. See Appendix Figure 3.

3. Data

Our panel includes monthly data on 29 sub-Saharan African countries for the period of 2000-22. Table 1 presents the summary statistics for our baseline sample. Appendix Table 1 lists countries included in our sample. Appendix Table 2 reports data sources.

Table 1. Summary statistics

	N	Mean	Std. Dev.	Min	Max
Headline inflation (yoy % chg)	4246	5.80	6.86	-6.24	58.42
Tradable core inflation (yoy % chg)	4246	5.53	7.34	-8.21	60.07
Non-tradable inflation (yoy % chg)	4246	5.07	6.90	-8.54	60.31
Food inflation (yoy % chg)	4246	6.73	8.92	-15.45	76.78
GSPCI	4246	0.36	1.22	-1.52	4.35
Global food price (yoy % chg)	4246	3.70	12.54	-32.23	33.70
Global oil price (yoy % chg)	4246	4.70	38.10	-97.91	98.87
Real GDP growth	4234	3.75	3.87	-14.90	14.60
World output gap	4246	-1.00	1.25	-3.92	1.96
Output gap	4246	-0.02	1.38	-7.74	6.60
Global policy rate	4246	1.07	1.43	0.05	6.54
Monetary policy rates	3164	7.25	3.71	0.25	33.50
VIX Uncertainty Index	4246	19.74	8.13	9.51	59.89
Nominal exchange rates (yoy % chg)	4186	4.31	14.01	-36.89	109.60

Note: All variables are at monthly frequency.

We use the GSCPI as our measure of supply chain pressures. The highly dimensional nature of supply chains makes them hard to measure. The GSCPI, constructed by the Federal Reserve Bank of New York, uses cross-border transportation cost data and survey data from purchasing managers in manufacturing to capture several factors that affect supply chain pressures (Benigno et al 2022).[8] Global transportation costs are measured with the Baltic Dry Index, which measures shipping costs for goods transported in bulk; the Harpex Index,[9] which reflects the costs of shipping goods in containers; and air transport costs from the Bureau of Labor and Statistics. The GSCPI also uses several supply chain-related components from Purchasing Managers' Index (PMI) surveys which include delivery time, backlogs and inventories.[10]

The choice of the GSCPI as our measure of supply chain pressures is twofold. First, the GSCPI is available at monthly frequency from 1997 to 2022, which provides a long panel at a high frequency to study inflation dynamics in sub-Saharan Africa. Second, the

[8] Attinasi et al (2022) propose an alternative indicator: the global sectoral supply chain pressures (GSSP). This indicator is derived from a vector auto-regression (VAR) with global purchasing managers' index (PMI) variables such as output, output prices, and suppliers' delivery times of seven manufacturing sectors. The correlation between the GSCPI and the GSSP is 0.9.

[9] The Harper Petersen Charter Rates Index (Harpex).

[10] PMI surveys manufacturing firms across seven interconnected economies: China, Eurozone, Japan, South Korea, Taiwan, United Kingdom, and United States.

GSCPI, by construction, integrates the two most important dimensions of global supply chain disruptions: goods manufacturing and international transportation.

Our inflation measures come from the Haver Analytics. In particular, we leverage a newly assembled panel of disaggregated consumer price index (CPI) series which include twelve standard components: food, alcohol, housing, furnishing, health, transport, communication, recreation, education, restaurant, and clothing. We construct tradable and non-tradable inflation as a weighted average of the following categories: food (36%), transport (11%), clothing (7%), furnishing (5%) and alcohol (4%) for tradable inflation; and housing (13%), restaurant (6%), communication (5%), health (3%), education (3%), and recreation (3%) for non-tradable inflation (see Appendix Figure 3). A residual component captures the remaining share of the consumption basket.

4. Impact of supply chain pressures on inflation

4.1 Local projections methodology

We use a structural framework to motivate our empirical strategy.[11] We study a set of small open economies, indexed i, with a tradable (T) and a non-tradable (N) sectors. Both sectors use goods from the other sector as intermediate inputs. The headline consumer price index P_{it} takes the form

$$P_{it} = (P_{it}^{T})^{e_T}(P_{it}^{N})^{1-e_T},$$

where e_T is the share of tradable goods in the consumption basket. The country imports a share m_i tradable goods from the rest of the world. We model supply chain disruptions as an increase in the cost $\tau_t^S > 1$ of shipping goods internationally. The change in the price index in response to an exogenous supply chain shock is:

$$d\ln P_{it} = (e_T m_i \ + (1-e_T)\gamma^{NT})d\ln \tau^S + \epsilon_{it}$$

Supply chain pressures affect inflation through two channels. First, as captured in the first term, they directly raise the price of imported goods that are shipped internationally. The second term captures the effect on prices of tradable intermediate inputs by the domestic non-tradable sector, where γ^{NT} is the share of input expenditures on the tradable sector.

[11] The full model is discussed in Annex.

ϵ_{it} acts as a residual that captures global and domestic supply and demand shocks that affect inflation.[12]

The above framework motivates our estimating equation. We estimate the path of inflation after innovations in the GSCPI, following local projections specification in Jordà (2005):

$$\Delta_h y_{it+h} = \alpha_i^h + \sum_{j=0}^{J} \beta_{hj} \Delta C_{t-j} + \sum_{j=0}^{J} \theta_{hj}^G X_{t-j}^G + \sum_{j=0}^{J} \theta_{hj}^D X_{it-j}^D + \sum_{j=0}^{J} \gamma_{hj} \Delta y_{it-j} + \epsilon_{it+h} \ , \quad h = 0, \dots, H,$$

where h is the response horizon in months, $\Delta_h y_{it+h}$ is the year-over-year log change in the inflation variable for country i from period t to $t+h$. α_i^h is a country fixed effect, and ΔC_{it-j} is the GSCPI. X^G is a set of controls that accounts for global factors, including global output gap, year-over-year log change in global food and oil prices. X^D is a set of controls that account for domestic factors, including country i's output gap.

We estimate the local projections for a shock in GSCPI across $h = 0, \dots, H$ monthly horizons, $H = 15$, using the ordinary least squares estimator. In our baseline specification, the number of lags j is set to 12 to control for potential seasonality in the price series. Heteroskedasticity-robust standard errors are clustered at the country level to account for cross-sectional dependence in the error term. We also construct the 90 percent confidence intervals for the IRFs using the standard errors of the β_{hj} coefficients estimated for each horizon. Given the size of the shock to global supply chains during Covid-19 pandemic, our identification mainly relies on empirical variation from this period.

4.2 Results

Table 2 reports the estimates of the impact of a global supply chain pressure shock on domestic price inflation in a sample of 29 sub-Saharan African countries from 2000 to 2022. For each inflation measure, we report the coefficients of GSCPI with three different sets of control variables: (i) no controls, (ii) global oil and food prices, (iii) global oil and food prices, country-specific output gaps, and the world output gap. Left-hand-side charts in Figure 3 illustrate the response of four measures of inflation following a one standard deviation increase in GSCPI, under the third specification with the largest set of controls.

[12] Although we do not model this explicitly, there could also be second-round effects if wages or other input prices are indexed to past inflation. Pricing power of firms, as well as the degree to which inflation expectations are well anchored govern the extent of second-round effects.

To get a sense of the magnitude of this shock, during the pandemic, global supply chain pressures peaked at almost 4.5 standard deviations in late 2022.

The results show a positive, statistically significant, and persistent effect of global supply chain pressures on headline inflation. When no control variables are added, the impact is statistically significant five months after the shock until the twelfth month. Including all control variables shows that the impact is only significant at 10% level from the fifth to the eighth month after the initial shock while the magnitude remains qualitatively unchanged. In particular, a one standard deviation shock in global supply chain pressures increases headline inflation by 0.41 percentage points five months after the shock (Table 2, panel A). This impact is persistent as headline inflation remains elevated until the eighth month after the shock and reverts in the subsequent months.

A one standard deviation shock in global supply chain pressures increases food inflation by 0.54 percentage points five months after the shock while this coefficient is not statistically significant (Table 2, panel B). The magnitude of the impact reflects a high sensitivity of food prices in the region to supply chain pressures. Food accounts for the largest share in the consumption basket in SSA countries.

Panels B and C of Table 2 report the impact of global supply chain pressures on tradable and non-tradable core inflation, respectively. Shocks to tradable core inflation have a weakly significant but non-negligible effect. A one-standard deviation shock of GSCPI increases tradable inflation by 0.49 percentage points after five months with a 10 percent significance level. The impact of GSCPI on tradable core inflation remains elevated through the sixth month and reverts after month seven.

On the other hand, global supply chain pressures have a smaller and delayed effect on non-tradable goods. The response of non-tradable inflation is flat in the first three months. Four months after the shock, inflation gradually increases peaking at seven months after the shock. In contrast to food and tradable inflation, the peak after the initial shock is delayed by two months. Furthermore, the coefficients are smaller in magnitude and are not statistically significant.

We next compare how our four measures of inflation respond to shocks to global oil prices and global food prices, identified as drivers of inflation in the existing literature (right-hand-side charts in Figure 3). Starting with a global oil price shock, the impact on headline inflation materializes in the first three months, plateaus in the subsequent months and only reverts seven months after the initial shock (blue line, panel A, chart B). The impact of a global oil price shock on domestic food inflation materializes in the first three months, persists until month eight and then reverts right after (panel B, chart D). Finally, the impact of a global oil shock on tradable core inflation materializes in the first two months, remains persistent until it peaks at month seven and reverts in the subsequent months (panel C, chart F). The global oil shock increases non-tradable inflation to peak at seven months after the shock, and inflation remains relatively elevated thereafter (panel D, chart H). Overall, a global oil shock has a positive, sizeable, and persistent impact on our different measures of inflation.

Turning to a food price shock, the effect on headline inflation gradually rises before reaching its peak after eight months which is similar in magnitude to an oil shock (red line, panel A, chart B). Food inflation in response to the shock quickly rises until month five and persists until month 12 (panel B, chart D). The food price shock gradually increases tradable inflation until month 8, then inflation starts to come down in the subsequent months (panel C, chart F). The effect of a food price shock on non-tradable inflation is similar in pattern compared to the effect of an oil shock but smaller in magnitude. To sum up, a global food shock also has a positive, sizeable, and persistent impact on our different measures of inflation.

4.3 Robustness checks

We conduct a series of robustness checks. First, we control for additional variables—monetary policy rates, market volatility index and nominal effective exchange rate (NEER). In Figure 4, the solid line is the baseline response of headline inflation, and the dashed line is the response of headline inflation after controlling for monetary policy rates. For this specification, we include measures of global monetary policy rates, proxied by the U.S. Federal Funds rate, and country-specific rates. For the latter, the Central Bank's deposit rate is used.[13] Adding monetary policy rates to the baseline specification allows us to account for responses of monetary authorities to inflation. The impact of a shock to GSCPI on headline inflation disappears when monetary policy rates are controlled for, suggesting that monetary authorities are responding to inflation caused by supply chain disruptions.

We then include the Chicago Board of Options Exchange Market Volatility Index (VIX) in the baseline specification to account for global economic uncertainty. Under this specification, the response of headline inflation to a shock in GSCPI, depicted by the dotted line in Figure 4, follows the same pattern as the baseline. Lastly, we introduce the nominal effective exchange rate as an additional control variable to account for their potential pass-through to domestic inflation. Similar to the specification with VIX, the

[13] Due to missing data, the Central Bank's discount rate is used for Burundi and the lending rate for Malawi.

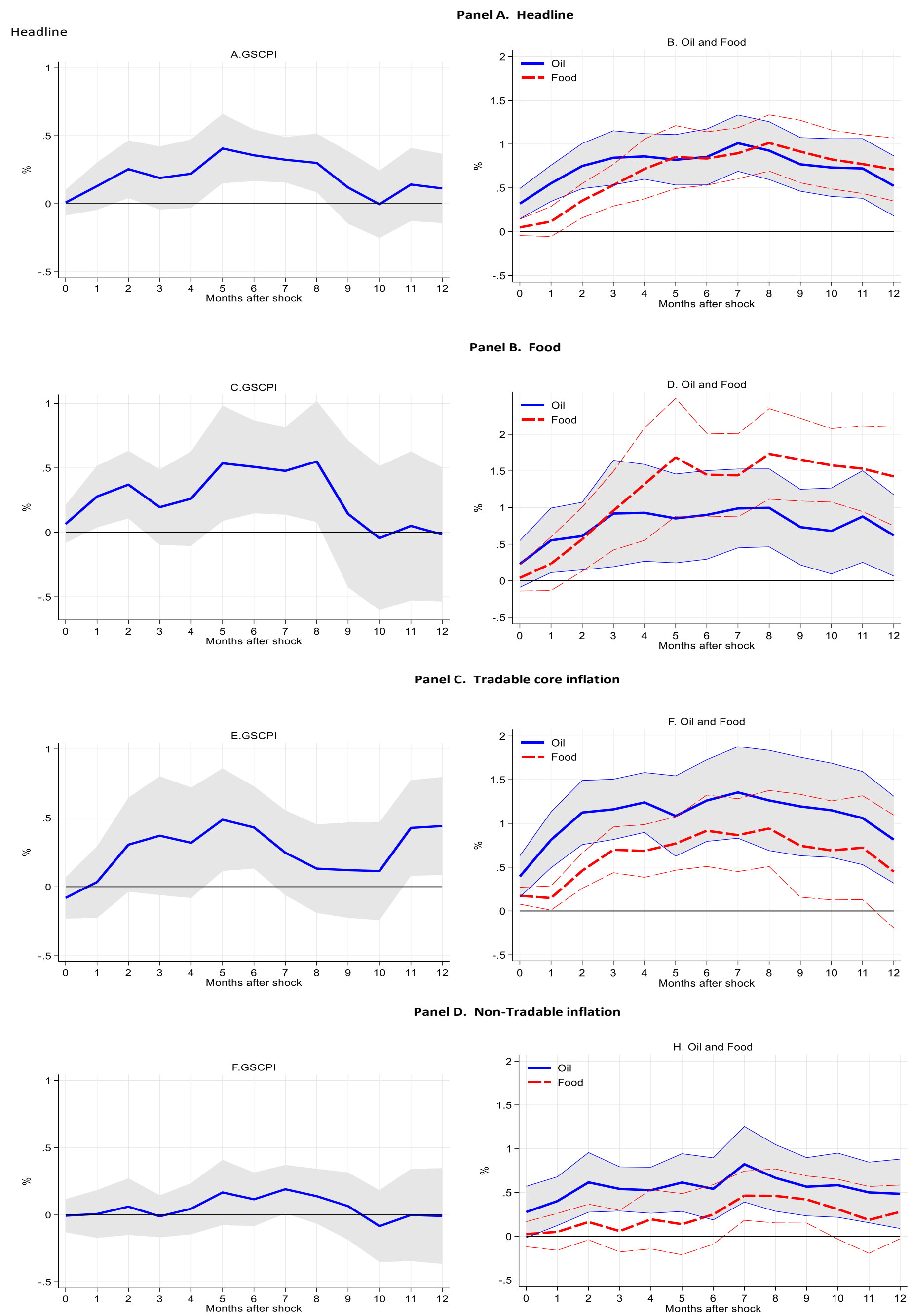
response of headline inflation to a shock in GSCPI, represented by the dash-dotted line in Figure 4, closely follows the baseline response.

Table 2. Local projection estimates

	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8	h = 9	h = 10	h = 11	h = 12
Panel A. Headline inflation													
No controls	0.00	0.13	0.23	0.15	0.19	0.39*	0.41**	0.41***	0.43***	0.33**	0.28*	0.35*	0.38*
	(0.05)	(0.10)	(0.12)	(0.14)	(0.15)	(0.15)	(0.12)	(0.11)	(0.10)	(0.12)	(0.12)	(0.15)	(0.15)
Oil and Food	0.00	0.09	0.22	0.14	0.16	0.35*	0.32**	0.27**	0.24*	0.04	0.08	0.05	0.03
	(0.05)	(0.09)	(0.11)	(0.13)	(0.14)	(0.14)	(0.11)	(0.09)	(0.10)	(0.14)	(0.13)	(0.15)	(0.15)
All controls	0.01	0.13	0.25	0.19	0.22	0.41*	0.36**	0.32**	0.30*	0.12	0.00	0.14	0.11
	(0.06)	(0.11)	(0.13)	(0.14)	(0.15)	(0.15)	(0.12)	(0.10)	(0.13)	(0.16)	(0.15)	(0.16)	(0.15)
Observations	3896	3867	3839	3811	3782	3753	3724	3695	3666	3637	3608	3579	3550
R squared	0.919	0.846	0.769	0.682	0.599	0.511	0.430	0.347	0.274	0.208	0.151	0.111	0.113
Panel B. Food													
	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8	h = 9	h = 10	h = 11	h = 12
No controls	0.03	0.22	0.36*	0.23	0.32	0.62**	0.66**	0.76***	0.87***	0.57*	0.44	0.43	0.45
	(0.07)	(0.15)	(0.15)	(0.17)	(0.20)	(0.22)	(0.19)	(0.18)	(0.17)	(0.23)	(0.24)	(0.26)	(0.25)
Oil and Food	0.04	0.23	0.40*	0.23	0.31	0.57*	0.58**	0.61**	0.70**	0.35	0.23	0.32	0.34
	(0.07)	(0.16)	(0.15)	(0.18)	(0.22)	(0.25)	(0.20)	(0.17)	(0.20)	(0.27)	(0.25)	(0.27)	(0.28)
All controls	0.07	0.28	0.37*	0.20	0.26	0.54	0.51*	0.48*	0.55	0.14	0.05	0.05	0.02
	(0.09)	(0.15)	(0.16)	(0.18)	(0.22)	(0.27)	(0.22)	(0.21)	(0.29)	(0.35)	(0.34)	(0.35)	(0.32)
Observations	3896	3867	3839	3811	3782	3753	3724	3695	3666	3637	3608	3579	3550
R squared	0.897	0.806	0.720	0.633	0.548	0.469	0.397	0.334	0.276	0.224	0.179	0.147	0.152
Panel C. Tradable core inflation													
	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8	h = 9	h = 10	h = 11	h = 12
No controls	0.00	0.15	0.31*	0.24	0.27	0.52**	0.54***	0.56***	0.58***	0.39*	0.35*	0.47*	0.52**
	(0.06)	(0.11)	(0.12)	(0.15)	(0.17)	(0.17)	(0.14)	(0.13)	(0.12)	(0.15)	(0.16)	(0.19)	(0.19)
Oil and Food	0.01	0.14	0.30*	0.20	0.19	0.43*	0.41**	0.31*	0.29*	0.01	0.09	0.06	0.02
	(0.06)	(0.11)	(0.13)	(0.16)	(0.17)	(0.17)	(0.14)	(0.11)	(0.13)	(0.17)	(0.19)	(0.21)	(0.20)
All controls	0.08	0.03	0.31	0.37	0.32	0.49*	0.43*	0.25	0.13	0.12	0.11	0.43	0.44
	(0.09)	(0.16)	(0.21)	(0.26)	(0.24)	(0.23)	(0.18)	(0.19)	(0.20)	(0.21)	(0.22)	(0.21)	(0.22)
Observations	3896	3867	3839	3811	3782	3753	3724	3695	3666	3637	3608	3579	3550
R squared	0.853	0.755	0.654	0.556	0.473	0.395	0.329	0.270	0.212	0.161	0.111	0.077	0.073
Panel D. Non-tradable core inflation													
	h = 0	h = 1	h = 2	h = 3	h = 4	h = 5	h = 6	h = 7	h = 8	h = 9	h = 10	h = 11	h = 12
No controls	0.02	0.06	0.10	0.01	0.07	0.18	0.19	0.26*	0.19	0.15	0.06	0.14	0.21
	(0.06)	(0.09)	(0.08)	(0.07)	(0.09)	(0.10)	(0.10)	(0.11)	(0.11)	(0.14)	(0.18)	(0.22)	(0.20)
Oil and Food	0.02	0.03	0.10	0.04	0.09	0.22	0.19	0.23	0.20	0.14	0.02	0.10	0.13
	(0.07)	(0.10)	(0.12)	(0.10)	(0.12)	(0.16)	(0.13)	(0.12)	(0.14)	(0.15)	(0.13)	(0.16)	(0.15)
All controls	0.01	0.01	0.06	0.01	0.05	0.17	0.12	0.19	0.14	0.07	0.08	0.00	0.01
	(0.08)	(0.11)	(0.13)	(0.10)	(0.12)	(0.15)	(0.12)	(0.11)	(0.12)	(0.15)	(0.16)	(0.21)	(0.22)
Observations	3896	3867	3839	3811	3782	3753	3724	3695	3666	3637	3608	3579	3550
R squared	0.854	0.755	0.667	0.588	0.505	0.421	0.337	0.265	0.202	0.157	0.111	0.076	0.076

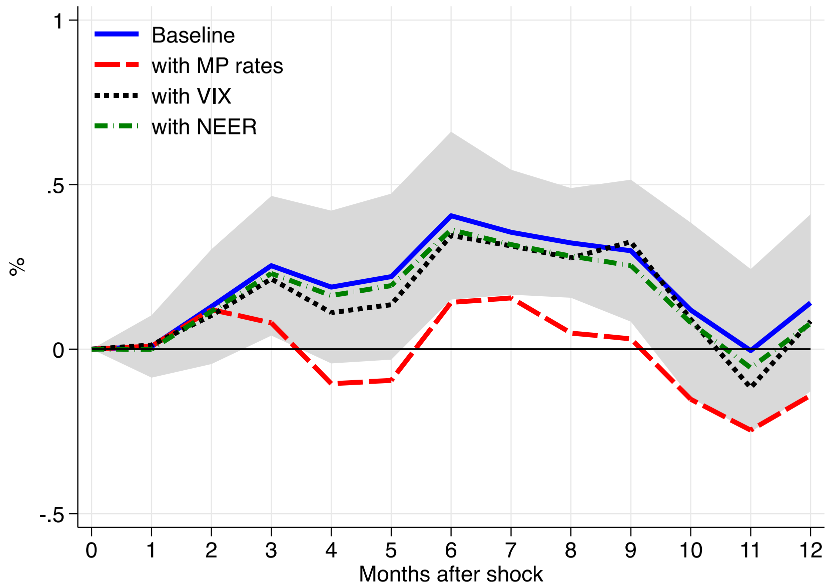
Notes: This table presents the coefficients of GSCPI under three different sets of control variables: (i) no controls, (ii) global oil and food prices, (iii) global oil and food prices, country-specific output gaps, and world output gap. Heteroskedasticity-robust standard errors clustered at the country level are reported in parentheses. ***, **, and * denote statistical significance at 99, 95, and 90 percent levels. Coefficients for the control variables are omitted for brevity and available upon request.

Figure 3. Impact of a one standard deviation shock of GSCPI, oil and food prices on measures of inflation



Notes: Charts on the left present the impact of a one standard deviation shock to GSCPI on domestic measures of inflation in the baseline sample. The solid line is the IRF; the gray shaded region represents the 90 percent confidence band. Control variables include global oil and food prices, country-specific output gaps, and world output gap. $t = 0$ indicates the month of the shock. Charts on the right present the impact of a one standard deviation shock to global oil and food prices, with solid blue and dashed red lines, respectively, on domestic measures of inflation in the baseline sample.

Figure 4. Robustness checks



Notes: The figure presents the impact of a one standard deviation shock of GSCPI to headline inflation after controlling for an additional set of regressors. The blue line represents the IRF under the baseline specification. The red, black, and green lines extend the baseline to include monetary policy rates, economic volatility index (VIX) and nominal effective exchange rate (NEER), respectively.

5. Contributions of supply chain pressures to the surge in inflation

As shown in Section 4, global supply chain pressures have a sizeable and persistent impact on inflation. This section quantifies the contribution of different supply shocks to inflation over the period of 2020-22 in sub-Saharan Africa.

5.1 Methodology

We follow the approach proposed by Benigno et al (2022) and decompose inflation such that:

$$y_t = \sum_{h=1}^{\infty} \hat{\beta}_{GSCPI}^{h} \hat{\epsilon}_{t-h}^{GSPCI} + \sum_{h=1}^{\infty} \hat{\beta}_{food}^{h} \hat{\epsilon}_{t-h}^{food} + \sum_{h=1}^{\infty} \hat{\beta}_{oil}^{h} \hat{\epsilon}_{t-h}^{oil} + \delta_t \ ,$$

where y_t is year-over-year median headline inflation rate in the region. $\hat{\beta}_{GSCPI}^{h}$, $\hat{\beta}_{oil}^{h}$ and $\hat{\beta}_{food}^{h}$ are the estimated coefficients of local projections in which the shock variables were respectively GSCPI, global oil and food prices at horizon h. $\hat{\epsilon}_{t}^{GSCPI}$, $\hat{\epsilon}_{t}^{food}$, $\hat{\epsilon}_{t}^{oil}$ are residuals from regressions of GSCPI, and global oil and food prices on the set of controls. δ_t is a residual term capturing inflation movements unaccounted for by oil and food prices, as well as supply chain pressures. Each contribution term is the sum-product of the coefficient $\hat{\beta}$ and the innovation $\hat{\epsilon}$.

This approach is implemented in two steps. First, we retrieve the estimated β coefficients from the following local projections estimation.

$$\Delta_h y_{t+h} = \alpha_t^h + \sum_{j=0}^{J} \beta_{hj} \Delta W_{t-j} + \sum_{j=0}^{J} \theta_{hj}^{G} X_{t-j}^{G} + \sum_{j=0}^{J} \gamma_{hj} \Delta y_{t-j} + \epsilon_{t+h} \ , \qquad h = 0, \dots, H,$$

where y_t is a year-over-year median inflation rate in SSA, W_t is either GSCPI, oil prices or food prices, X^G is a set of global variables such as global oil prices, global food prices and world output gap. The estimated β_h reflects the response of y_t to one standard deviation in W_t.

Second, we compute the residuals from regressions of GSCPI, global oil prices and global food prices on a set of control variables. The residuals obtained via ordinary least squares regressions are independent innovations to GSCPI, global oil prices and global food prices. The control variables are lags of the global variables and lags of the median inflation rate. We set $p = 12$ to account for any seasonal variation in our monthly series. Appendix Figure 2 presents the residuals.

To sum up, the realized inflation is decomposed into three main contributors: shocks to supply chains, oil and food prices. This approach combines the empirically identified shocks to GSCPI, global oil and food prices with their corresponding impulse response functions. We perform this exercise for headline, food, tradable and non-tradable inflation.

5.2 Results

For ease of reference, our main discussion focuses on Figure 5 which presents the contribution of global supply chain pressure shocks to inflation over the period of 2020-22. As before, we consider four measures of inflation: headline, food, tradable and non-tradable inflation. We focus on median inflation for these measures. We begin by discussing similar patterns observed across these four measures of inflation. Supply chain pressure shocks contributed positively to inflation through the post-2020 period. In the first months of 2020, supply chain pressures gradually increased to peak towards the end of the year. In the first half of 2021, we observe signs of supply chain pressures easing, even though still present. From July 2021 onwards, supply chain pressures gradually increase to reach an all-time high in June 2022, which is the end of sample.

Supply chain pressures contributed to 45 percent of the average median headline inflation rate for sub-Saharan Africa during this period. The contributions for food, tradable and non-tradable inflation are respectively 40, 55, and 40 percent of the average median inflation rate.

While the surge in inflation is mostly due to the positive contribution of supply chain pressures since 2020, oil and food prices have also played an important role. Appendix Figure 1 presents the contribution of the three global supply shocks to inflation: food, oil and supply chain pressures. Oil prices helped keep inflation in check from 2020 up to the last quarter of 2021, before contributing considerably to the rise in headline inflation. Food prices have contributed to lower inflation from 2020 to early 2021. From there on, food prices positively contributed to headline inflation until the beginning of 2022 and negatively in the first half of 2022.

Figure 5. Contributions of GSCPI shocks to inflation (y-o-y percent change)

Note: This figure presents the contributions of supply chain pressures, measured with the GSCPI, to different measures of inflation over the period 2020-22. In each graph, the solid black line indicates the inflation measure, and the red bars are the contributions of supply chain shocks to inflation.

6. Implications for monetary policy

This section examines the appropriate monetary policy response to global supply chain disruptions using a macroeconomic model. We focus on the role of monetary policy timing and the importance of cross-country heterogeneity in the exposure to supply chain disruptions. We exclude food and energy price shocks for simplicity.

Our starting point is the small open economy described in section 3. The structure of the model is relatively standard and in line with the literature on New Keynesian small open economy models.[15] It consists of three equations: (i) a supply curve that links tradable inflation to global shipping supply chain disruptions, (ii) an expectations-augmented Phillips curve that links non-tradable ("core") inflation to the output gap and second-round effects from global supply chain disruptions, and (iii) an intertemporal aggregate demand equation that links the output gap to the real interest rate gap.[16] We provide the full model in Annex II.

In the analysis, we focus on four types of economies.[17] The key features that distinguish these economies is the share of consumption that is tradable and the degree of central bank credibility, which translate into differences in the anchoring of inflation expectations. In the first economy, we assume that tradable goods make up 70 percent of the consumption basket, and the central bank has low credibility such that inflation expectations are fully adaptive.[18] In the second economy, the share of tradable goods is the same but there are no second-round effects from inflation expectations because these are fully anchored to the long-run inflation target. In the third and fourth economy, the tradable share is relatively low at 40 percent.[19] For a given level of pass-through from tradable to non-tradable inflation, the second-round effects of changes in global shipping costs on non-tradable inflation are proportional to the consumption share of tradable

[15] We note that a substantial number of economies in sub-Saharan Africa exhibit limited convertibility and limited interest rate and exchange rate pass-through. This heterogeneity can be reflected in the model calibration.

[16] In the context of the model, there is no distinction between non-tradable and core inflation. The key feature of the tradable component of the consumption basket is that it is subject to exogenous shocks, including shocks to global supply chains, that are largely beyond the control of domestic policymakers in a small open economy. These shocks do not directly affect the non-tradable component. In practice, this distinction is not always as clear cut.

[17] The four types of economies we consider are: (i) high share of tradables and low credibility, (ii) high share of tradables and high credibility, (iii) low share of tradables and low credibility, and (iv) low share of tradables and high credibility.

[18] The tradable basket includes food, beverages, tobacco, narcotics, clothing, footwear, furniture, household items, and transportation. The non-tradable basket includes housing, health, communication, leisure and culture, education, and restaurants and hotels. In January 2020, there were three countries in sub-Saharan Africa with data on the weights of the CPI basket for which the tradable share exceeded 70 percent: Equatorial Guinea, Ethiopia, and Zambia.

[19] The 40 percent corresponds to the weight of tradable goods in the US CPI basket. In sub-Saharan Africa, South Africa has the lowest share of tradables in the consumption basket at about 50 percent.

goods. As such, economies that consume more tradables face stronger second-round effects and a worse policy trade-off between stabilizing inflation and stabilizing output.

The central bank implements its optimal monetary policy response using changes in the short-term interest rate. The central bank's policy objective is to stabilize the variance of headline inflation and the output gap.[20] After observing a one-time standard deviation shock to global supply chains, the central bank decides to set a path of interest rates to cool inflation. With shocks to global supply chains, a policy trade-off arises because the central bank needs to offset the increase in headline inflation by pushing output below potential.

We consider two policy frameworks. In comparison to a standard policy framework that responds to realized inflation, we allow for the possibility that policymakers anticipate changes in tradable inflation due to global supply chain disruptions and raise the policy rates before the shock has fully passed through into headline inflation.[21] The choice of the framework has important consequences for the conduct of monetary policy and the resilience of the framework to shocks, because responding preemptively to supply chain disruptions is a form of forward-looking monetary policy. For example, given the lagged impact of supply chain shocks on inflation (documented in section 3), not responding to supply chains will mean central banks will have to raise interest rates more once second-round effects pass through to non-tradable inflation.

We now describe how the policy frameworks perform in the four different types of economies following a shock to global supply chains. We first consider the economy with a high share of tradable goods in the consumption basket in which second-round effects are high. We abstract from cyclical factors and set the initial inflation, output, and real exchange rate gaps to zero.[22] The economy is hit by a one-time shock that increases global shipping costs by one standard deviation. We simulate this economy for the two policy frameworks. In both frameworks, the central bank raises its real policy rate (the nominal policy rate less previous month's inflation) in five steps to a peak above the initial neutral rate, and then slowly reverts to its starting level. We interpret the peak of the real rate that maximizes the central bank's objective as a sufficient statistic for the stance of monetary policy. If the central bank of this economy does not immediately respond to supply chain disruptions, we assume it starts tightening policy after nine months, when the shock to supply chains has fully impacted both tradable and non-tradable inflation and

[20] Formally, the central bank minimizes a loss function that consists of the weighted sum of the squared deviations of inflation from the target and the squared output gap. In the baseline, we use equal weights on inflation and the output gap.

[21] We still assign a 50 percent weight to the output gap but allow for a nonzero weight on anticipated tradable inflation. The weight for anticipated inflation and the actual inflation gap adds up to 50 percent.

[22] After estimating key parameters, we calibrate the model to match the impulse response of headline inflation to a one standard deviation shock in global shipping costs as documented in section 3. Annex II provides further detail.

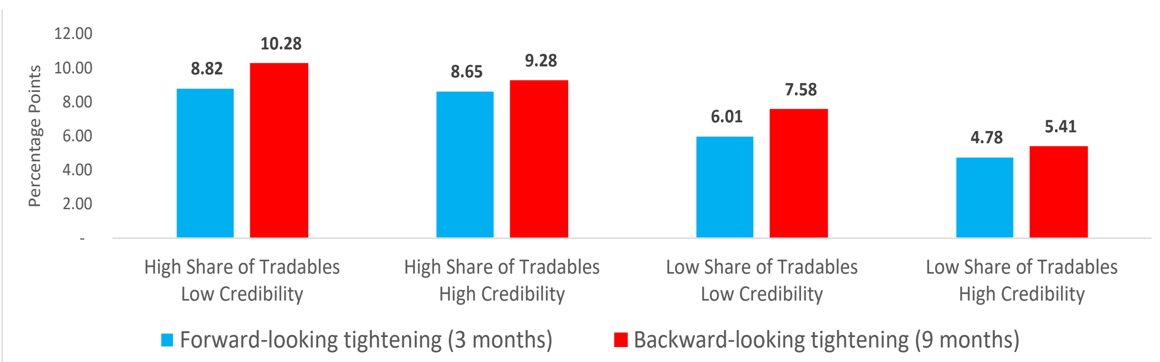
has increased inflation expectations (Appendix Figure 4). We compare the objective function, which the central bank aims to minimize, under (i) a tightening of the real policy rate by one percentage points, and (ii) a constant real policy rate that stays at zero.

Our findings, summarized in Figure 6, are as follows. First, for central banks with low credibility, where inflation expectations are fully adaptive and second-round effects are strong, it is always preferable to increase the real policy rate early. The payoff to tightening early is particularly pronounced for economies where the share of tradables is higher, and the first-round effects from global supply chain disruptions are larger.

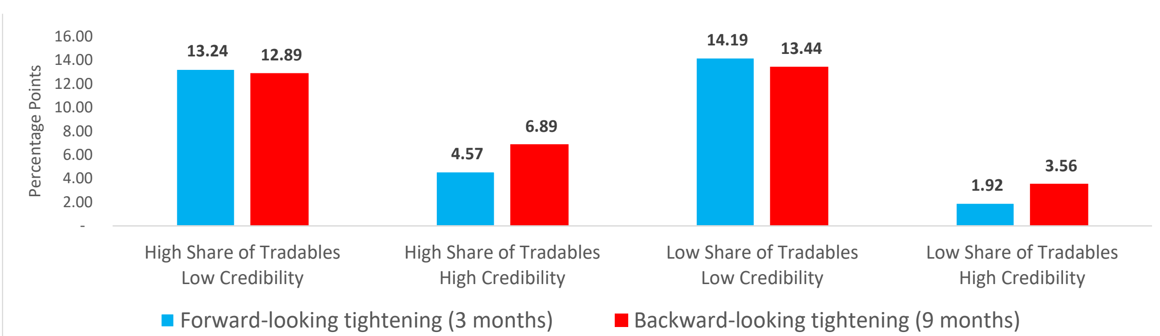
The case of an economy with a high food share but anchored inflation expectations illustrates the benefits of strong monetary policy frameworks for emerging economies and the costs of the elevated pass-through from tradable inflation to the non-tradable sector. In this economy, it is preferable to see through the global supply chain shock and not adjust the real policy rate immediately.

Figure 6. Central Bank objective function

Panel A. Central Bank objective function following a 1% increase in real rate



Panel B. Central Bank objective function following no increase in real rate (0%)



Note: This figure presents the Central Bank's objective function following an increase of one percent in the real rate in Panel A, and no rate increase in Panel B.

7. Conclusions

This paper investigates the inflationary impact of global supply chain pressures in sub-Saharan Africa. We consider four measures of inflation: headline, food, tradable and non-tradable. We show that global supply chain pressures have a sizable, significant, and persistent impact on domestic inflation in sub-Saharan Africa. The impact of supply chain pressures is particularly high for the tradable components of the CPI basket. We also examine the contribution of global supply chain pressures to the surge in inflation in the post-2020 period. Global supply chain shocks contributed positively to inflation and accounted for about half of the level of headline inflation.

Our empirical findings and model simulations imply that central banks can stabilize inflation and output more efficiently by responding to global supply chain disruption in a forward-looking manner. The gains from adjusting policy pre-emptively are particularly large for open economies with outsized second-round effects on the prices of non-tradable goods and services. In these economies, the inflation peaks and output losses from monetary tightening are lower when central banks are forward-looking and tighten pre-emptively after observing global supply chain disruptions. Such a forward-looking path of monetary policy is particularly effective in an environment where the response of output and prices to monetary policy operates with a lag (Fischer 1990).

Our work suggests several avenues for future research on global supply chains and inflation. Although we document second-round effects of global supply chain disruptions on non-tradable inflation in sub-Saharan Africa, we do not study the effect on inflation expectations due to lack of data. Policy trade-offs for emerging economies could worsen further if the recent supply chain-driven inflation spike weakened policy credibility and led to de-anchoring of inflation expectations. Moreover, we do not study the impact of supply chain disruptions on the equilibrium real interest rate. Diversification of supply chains can reduce global economic losses in response to supply chain disruptions (IMF 2022b). Higher investment associated with this diversification process is likely to have a net positive effect on countries' equilibrium real interest rates. We leave these unexplored areas to future research.

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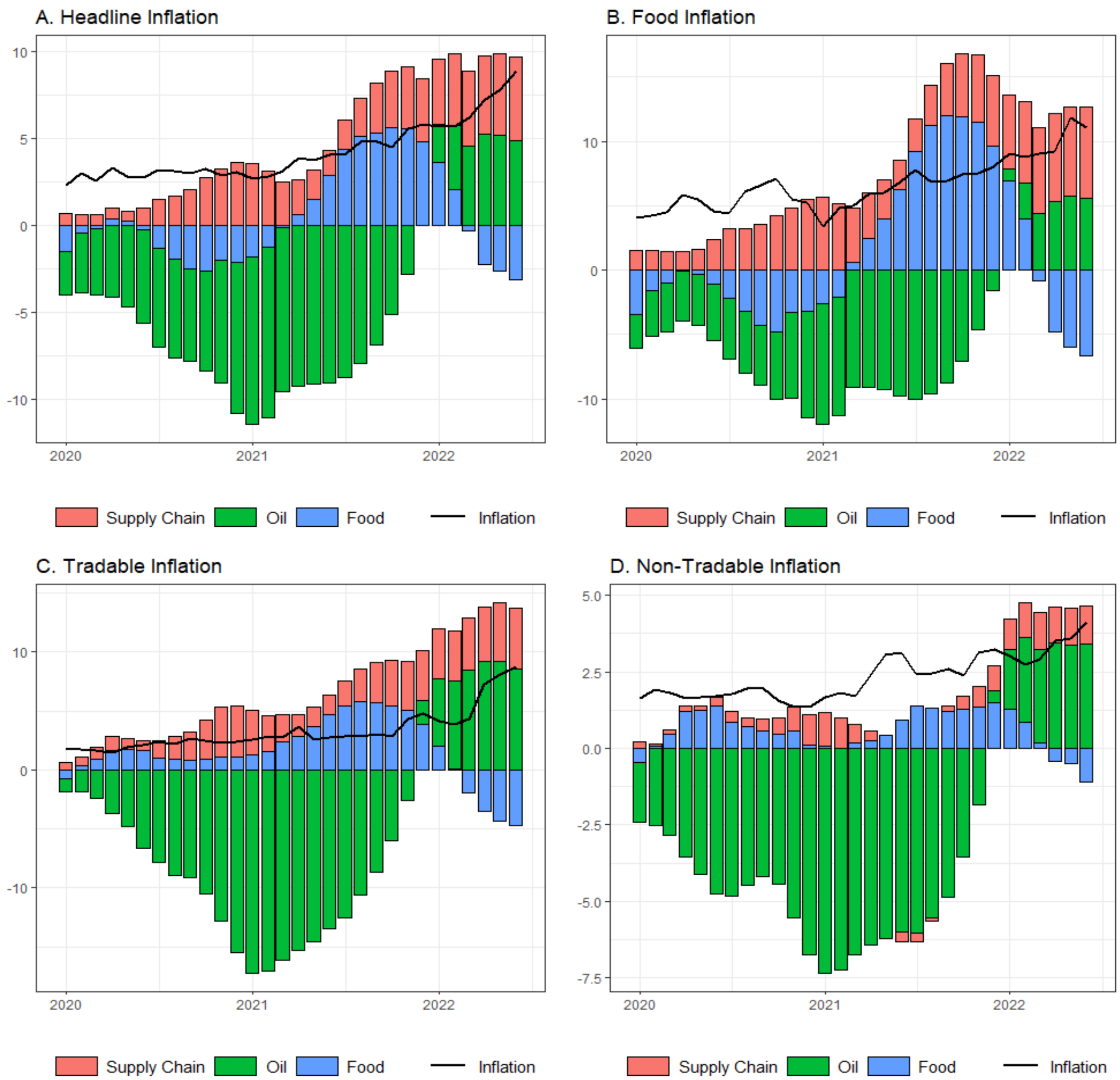
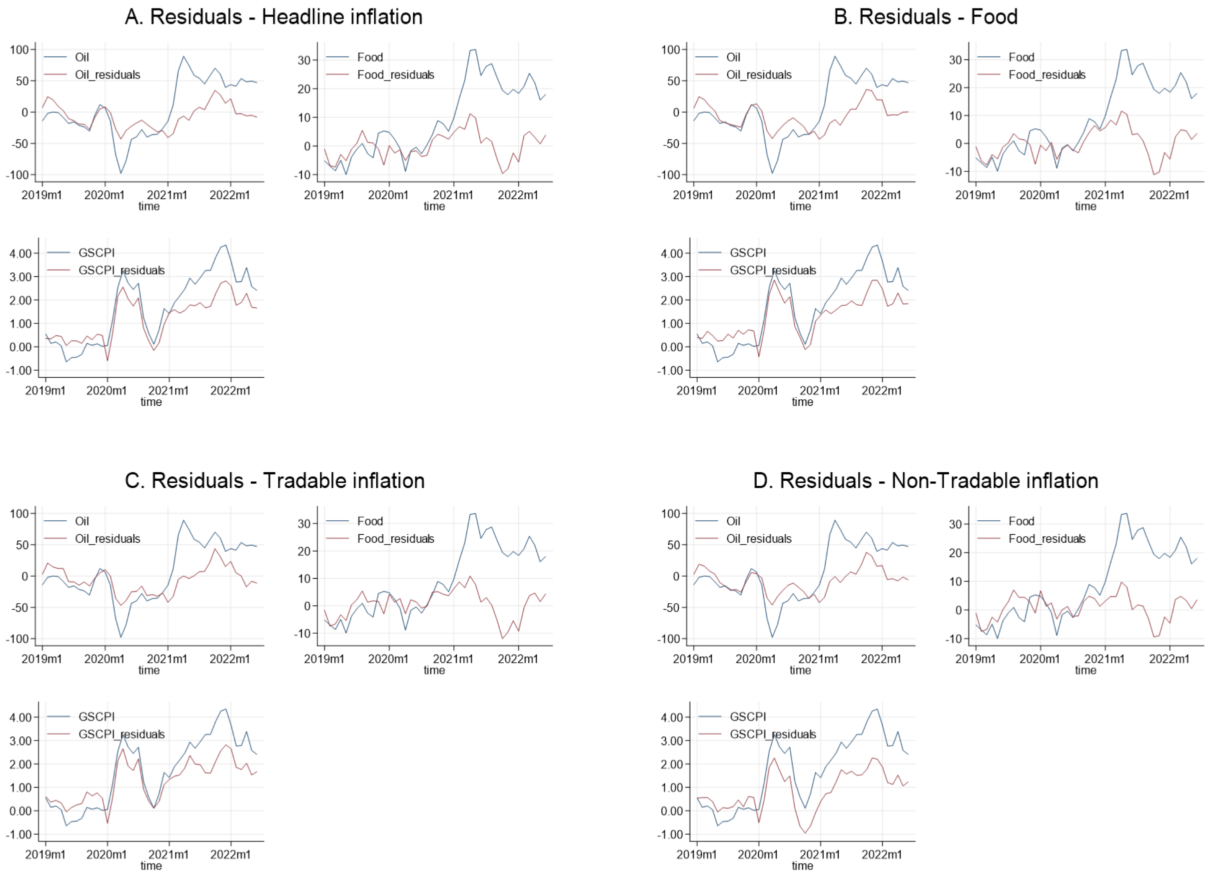
Appendix

Appendix Figure 1. Contribution of global supply shocks to inflation



Note: This figure presents the contributions of global supply shocks to different measures of inflation over the period 2020-22. In each graph, the solid black line indicates the considered inflation measure, the red, blue and green bars are, respectively, the contributions of supply chain shocks, food prices, and oil prices to inflation.

Appendix Figure 2. Residuals



Note: Each panel presents the residuals of global oil prices, global food prices, GSCPI from their respective regressions on a set of control variables.

Annex I. Data

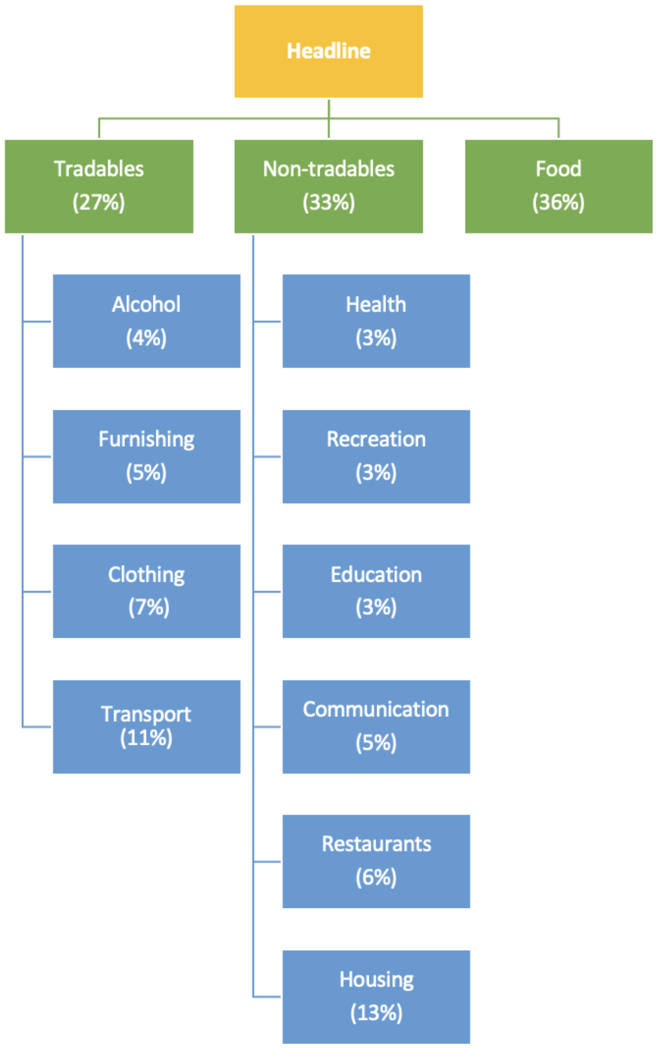
Appendix Table 1. Economies

Country List	
Angola	Mauritius
Benin	Mozambique
Botswana	Namibia
Burkina Faso	Niger
Cameroon	Nigeria
Chad	Republic of Congo
Cote d'Ivoire	Rwanda
Equatorial Guinea	Senegal
Ethiopia	Seychelles
Gabon	South Africa
Ghana	Tanzania
Guinea-Bissau	Togo
Kenya	Uganda
Lesotho	Zambia
Mali	Total = 29

Appendix Table 2. Data sources

Variable	Source	Notes
Headline inflation	Haver	
Tradables inflation	Haver	
Non-tradables inflation	Haver	
Food inflation	Haver	
Output Gap	IMF WEO	Annual frequency
Real GDP	IMF WEO	Annual frequency
GSCPI	Haver	Expressed in standard deviations
Baltic Dry Index	Bloomberg	
Harpex	Haver	Starts in 2001
World Output Gap	IMF WEO	Annual frequency
World Oil Price	IMF Primary Commodity Prices	Crude Oil (petroleum), Dated Brent
World Food Price Index	IMF Primary Commodity Prices	Commodity Food Price Index, 2016 = 100, includes Bananas, Cereal, Citrus-fruit, Dairy Products, Legumes, Meat, Non-citrus fruit, Seafood, Sugar, Vegetables, and Vegetable Oils
VIX Uncertainty Index	Bloomberg	
US Effective Federal Funds rate	Bloomberg	
Monetary policy rate	Bloomberg	Central Banks' deposit rate

Appendix Figure 3. Weight of CPI components



Sources: World Bank, and IMF staff calculations.
Note: Residual component not listed.

Annex II. Structural Model

This section provides the full models used in sections 3 and 4.

Model of section 3

Environment. We study the steady state of small open economy Home (H) that faces the rest of the world, summarized by a large economy Foreign (F). Home is small in the sense that Home variables do not affect foreign aggregates.

Technology and market structure. There are two sectors in Home, the tradable sector (T) and the non-tradable sector (N). Each sector produces a homogeneous good. Labor L_H is supplied inelastically and mobile across sectors. Input and output markets are competitive. Firms are infinitesimal and use a Cobb-Douglas production technology. In the tradable sector, firms produce output q_H^T using labor L_H^T:

$$q_H^T = z_H^T L_H^T,$$

where z_H^T is an exogenous productivity shifter. We write the unit cost function as

$$c_H^T = \chi^T (z_H^T)^{-1} \, w_H,$$

where w_H is the wage, and χ^T is a constant. In the non-tradable sector, firms produce output using labor L_H^j and intermediate inputs N_H^N from the tradable sector:

$$q_H^N = z_H^N \left(L_H^j\right)^{1-\gamma_H^N} (N_H^N)^{\gamma_H^N},$$

where z_H^j are sectoral exogenous productivity shifters and γ_H^N governs the use of intermediate inputs. We write the unit cost function as

$$c_H^N = \chi^N (z_H^N)^{-1} \, (w_H)^{1-\gamma_H^N} (P_H^T)^{\gamma_H^N}.$$

Demand. In the tradable sector, the composite good is produced by an intermediary firm that is an Armington aggregate of domestic output, imports by sea (indexed *S*), and other imports (indexed *O*):

$$Q_H^T = \left[(q_H^T)^{\frac{\sigma-1}{\sigma}} + (q_F^S)^{\frac{\sigma-1}{\sigma}} + (q_F^O)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where q_H^T and q_F^T are domestic output and foreign output. σ is the elasticity of substitution, which also governs the trade elasticity in this model. Wages accrue to a representative household, who has Cobb-Douglas preferences over consumption, with a preference weight ω_H for tradable goods.

Shipping costs. Trade between countries is subject to iceberg trade barriers. It costs τ^S to import from *F*. Exports cost τ^X to ship. Only the tradable sector engages in trade. The value of exports X_H^T by Home takes the form:

$$X_H^T = (\tau^X)^{1-\sigma} \left(\frac{c_H^T}{P_F^T}\right)^{1-\sigma} E_F^T,$$

where E_F^T is expenditure by Foreign on tradables*.* The value of imports by Home takes the form:

$$M_H^T = [(\tau^S)^{1-\sigma}] \left(\frac{c_F^T}{P_H^T}\right)^{1-\sigma} E_H^T.$$

We drop the Home subscript from now on.

Competitive equilibrium. Define the gross revenue of sector *j* as Y^j and the price index as P. The competitive equilibrium of this economy can be represented as the set of solutions for $w, Y^T, Y^N, E,\ P^T, c^T, P^N, c^N$ to the following system of simultaneous equations:

$$wL = Y^T + (1-\gamma^N)Y^N$$

$$E = wL$$

$$(P^T)^{1-\sigma} = (c^T)^{1-\sigma} + (\tau^S\ \ c_F^T)^{1-\sigma}$$

$$P^N = c^N$$

$$c^T = \chi^T (z^T)^{-1}\, w$$

$$c^N = \chi^N (z^N)^{-1}\, (w)^{1-\gamma^N} (P^T)^{\gamma^N}$$

$$Y^T = \left(\frac{c^T}{P^T}\right)^{1-\sigma} (\omega E + \gamma^N Y^N) + (\tau^X)^{1-\sigma} \left(\frac{c_H^T}{P_F^T}\right)^{1-\sigma} E_F^T$$

$$Y^N = (1-\omega)E$$

First-order approximation and mapping to local projections. Normalize $w = 1$. The first-order approximation around $\sigma = 1$ gives:

$$d \ln P^T = m\, d \ln \tau^S$$

$$d \ln P^N = \gamma^N d \ln P^T$$

where m is the share of consumption that is imported. Using the definition of headline inflation gives:

$$d \ln P = (\omega\ s\ + (1-\omega)\gamma^N) d \ln \tau^S,$$

which corresponds to the equation laid out in section 3.

Model of section 4

The model used in section 3 defines a supply curve that links prices of tradable goods to global shipping costs. We now add dynamics and price rigidities. These can be microfounded using the standard New Keynesian machinery, such as the model used in Hazell et al (2022).

We define headline inflation π_t as the weighted average of core tradable inflation π_t^T and non-core inflation π_t^N:

$$\pi_t \equiv (1-\omega)\pi_t^N + \omega\pi_t^T.$$

The model consists of four equations.

1. A supply curve that links tradable inflation π_t^T to global supply chains:

$$\pi_t^T = \lambda\pi_{t-1}^T + \sum_{\tau=0}^{T} \mu_\tau \cdot \Delta C_{t-1-\tau},$$

2. An open economy Phillips curve that relates current non-tradable inflation π_t^N to past and expected non-tradable inflation $E(\pi_t^N)$, the previous period output gap x_{t-1}, and a term that captures the second-round effects from global supply chains to non-tradable inflation:

$$\pi_t^N = \alpha E(\pi_t^N) + \beta x_{t-1} + \epsilon\,\omega\,\pi_{t-1}^T,$$

3. An IS equation that links the output gap to the previous period real interest rate:

$$x_t = \zeta x_{t-1} - \eta(R_t - E(\pi_t) - \bar{r}),$$

Global supply chain disruptions follow an AR(1) process:

$$\Delta C_t = \nu\Delta C_{t-1} + \iota_t.$$

Central bank response. The central bank responds to deviations of headline inflation and the output gap. We assume that the central bank observes the shock first, and then sets the interest rate at the beginning of the period.

Monetary policy objectives. The central bank's objective function is

$$\sum_t \xi x_t^2 + (1-\xi)(\pi_t - \bar{\pi})^2.$$

Inflation expectations. We impose a mix of anchored and adaptive expectations, such that

$$E(\pi_t^N) = \gamma\,\bar{\pi} + (1-\gamma)\pi_{t-1}^N.$$

- $\gamma = 0$ – adaptive expectations, low credibility
- $\gamma = 0.5$ – anchored expectations, high credibility

Calibration. We summarize our calibration strategy in Appendix Table 3.

1. Estimate (1) and (2) as ‘local projections’, recover parameters.
2. Take external parameters from the literature.
3. Solve the model using:

    a. For a given framework, increase ΔC_t by $\iota_t = 1\,sd$

    b. Compute π_t^T and π_t^N, compute π_t

    c. Central bank sets R_{t+1} after observing ΔC_t and π_t^T and π_t^N

    d. $\Delta C_{t+1} = 0$

    e. Compute π_{t+1}^T and π_{t+1}^N, x_{t+1}

    f. Central bank sets R_{t+2} after observing ΔC_{t+1} and π_{t+1}^T and π_{t+1}^N

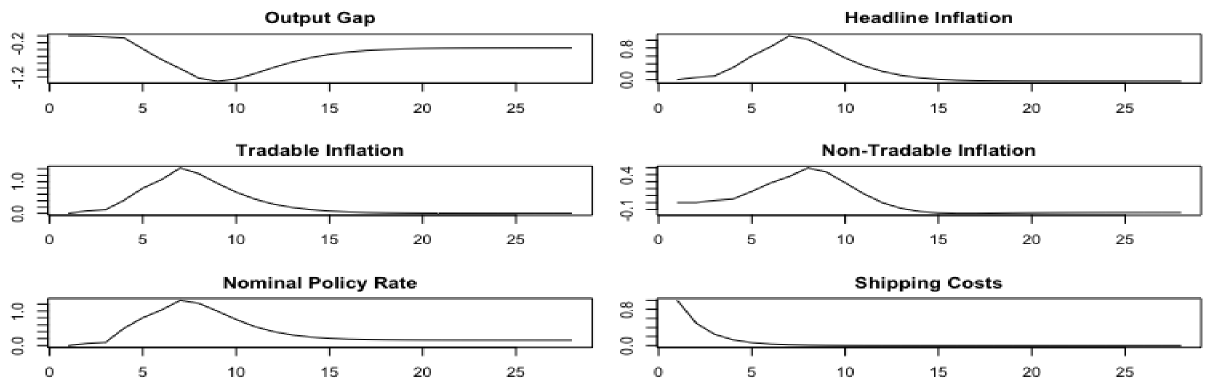
    etc. until no further changes

Appendix Table 3. Calibration

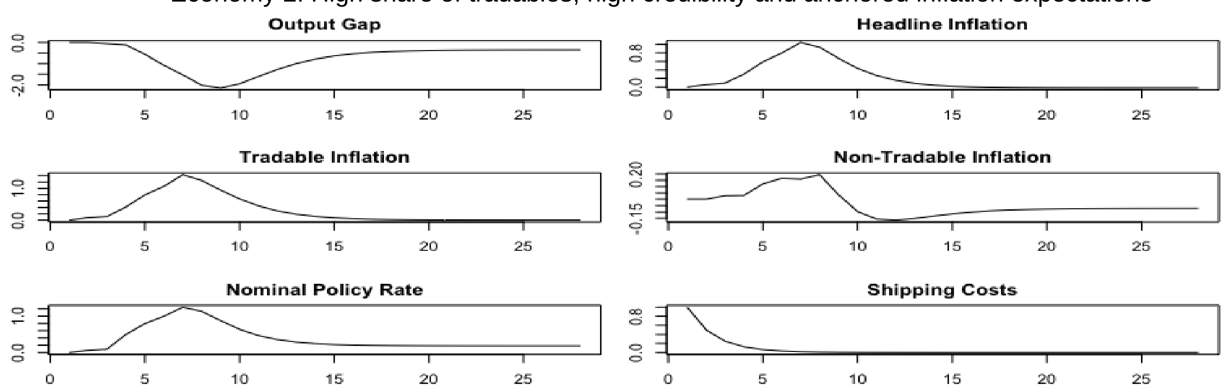
Parameter	Meaning	Source/target	Value
ω	Share of tradable goods in consumption basket		0.4 or 0.7
λ	Persistence of tradable inflation		0.5
μ	Elasticity of tradable inflation to global supply chain disruptions	Local projections	
α	Persistence of non-tradable inflation	Gali (2015)	0.99
β	Slope of core Phillips curve for non-tradable inflation	Stock and Watson (2020)	0.2 (annual)
ϵ	Second-round effects of global shipping costs on non-tradable inflation	Local projections	0.5
ζ	Persistence of output gap		0.5
η	Elasticity of output gap to real policy rate	Gali (2015)	1 (annual)
ν	Persistence of shock to global shipping costs		0 or 0.5
ξ	Weight of output gap in the central bank's objective function		0.5

Appendix Figure 4. Stylized economy responses to supply chain shock (backward-looking central bank)

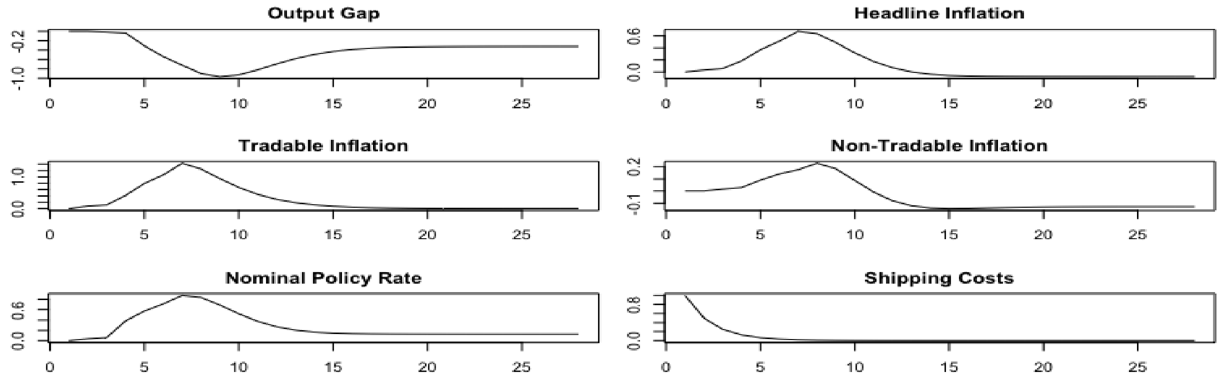
Economy 1: High share of tradables, low credibility and fully adaptive inflation expectations



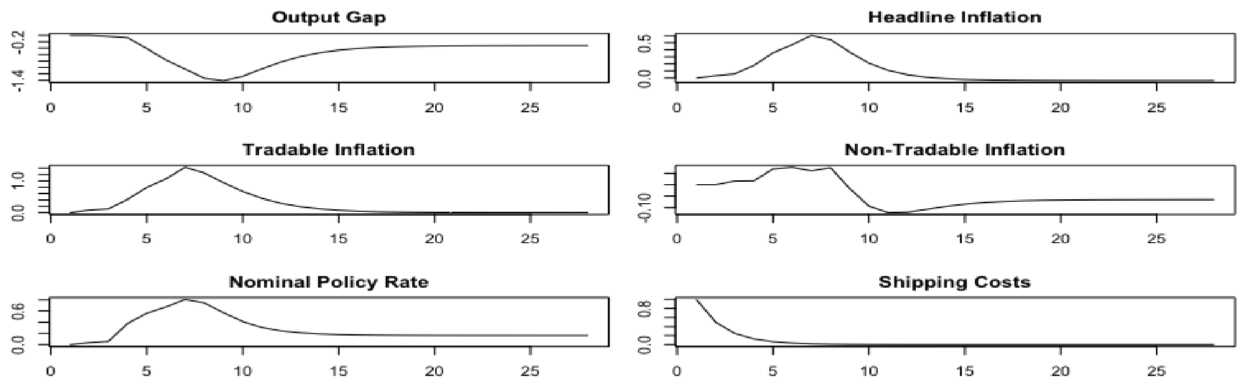
Economy 2: High share of tradables, high credibility and anchored inflation expectations



Economy 3: Low share of tradables, low credibility and fully adaptive inflation expectations



Economy 4: Low share of tradables, high credibility and anchored inflation expectations



Note: Central bank raises real policy rate after nine months.

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