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Inflation: Demand Pull or Cost Push? A Markov switching approach

Abstract: In this paper, we develop a Markov switching method to quantify the relative contributions of cost-push and demand-pull to current inflationary pressures. This approach aids in studying whether the inflation is short-lived or more persistent. We apply this method to Australian data and identify three episodes in the last 25 years when the inflation rate exceeded 4%. All three episodes were primarily driven by cost-push factors. Our results reveal that monetary policy is more effective in controlling demand-pull inflation but less so in controlling cost-push inflation. This observation explains why the episodes of relatively higher inflation were predominantly driven by cost-push factors. Furthermore, we contrast our findings with US inflation drivers.

Keywords: Markov switching models, Inflation, Cost-push and demand-pull

1 Introduction

Understanding the causes of inflation is crucial for policy choices to combat inflation. Cost-push and demand-pull are not only the two most often mentioned causes of inflation, but they are also the two causes that may respond differently to monetary policy measures. As Fed Chair Powell stated in a recent interview, 'What [the Fed] can control is demand; we can't really affect supply with our policies... so the question of whether we can execute a soft landing or not may actually depend on factors that we don't control' (Marketplace, 2022).

In the recent episode of high inflation, monetary expansion through QE measures and liquidity provisions during the Covid-19 period, along with supply-chain bottlenecks due to the impact of Covid-19, add obviously supportive arguments for both demand-pull inflation and cost-push inflation. The effects of monetary policy need to be evaluated.

In the literature, many methods have been developed to differentiate demand-pull inflation from cost-push inflation. Using four aggregate time series data sets: the wholesale price index, the consumer price index, the hourly wage index, and money supply, Barth and Benett [1] applied Sim's unidirectional causality test to identify demand-pull and cost-push factors, respectively. Pasimeni [8] conducted panel regression using business survey data and sectoral price data to quantify the effects of demand-pull and cost-push in EU areas across different industries for the time period of 2019 to 2022. He found that, in the present context, supply factors are the main driver, accounting for at least 80% of the current increase in producer prices in the industry and in each one of the manufacturing sectors experiencing the highest price pressures.

using a moving window regression of categorical-level data, Sharpiro [9] develops a framework to monitor the proportions contributed by demand-pull and cost-push factors, respectively. Sharpiro [10] finds that factors other than demand account for about two-thirds of the recently elevated inflation, highlighting some risks for the economy in the current episode of inflation in the US.

Applying the method of Sharpiro [9], Goncalves and Koester [4] found that the increase in euro area HICPX inflation starting in the third quarter of 2021 was initially mainly supply-driven, but the importance of demand factors has gradually increased over time. In recent months, supply and demand factors have played broadly similar roles in HICPX inflation. Beckers et al. [2] applied three different models to assess

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the relative contribution of supply and demand drivers to current inflation in Australia. These models include the data-driven method by Sharpiro [9], deviations from the RBA's inflation forecast models, and the RBA's DSGE model, which is used to reverse-engineer the demand shock and supply shock to match the observed data. They found that all three approaches suggest that supply factors have accounted for at least half of inflation in Australia over the past year or so.

In this paper, we apply the Markov switching model as a data-driven method to identify the demand-pull regime and the cost-push regime and quantify the contributions of demand drivers and supply drivers to current inflation. We aim to address the following questions: 1) How can we measure/quantify demand-pull inflation? 2) How can we measure/identify cost-push inflation and its respective short-lived or persistent effects? 3) What are the monetary policy implications of these two drivers of inflation?

2 The concept of demand-pull and cost-push

Demand-pull and cost-push are two of the most frequently mentioned causes of inflation, illustrated in many economic textbooks and even on the RBA website. A demand-pull inflation is characterized by a rightward shift of the demand curve (LHS of Fig. 1) while a cost-push inflation results from a leftward shift of the supply curve (RHS of Fig. 1).

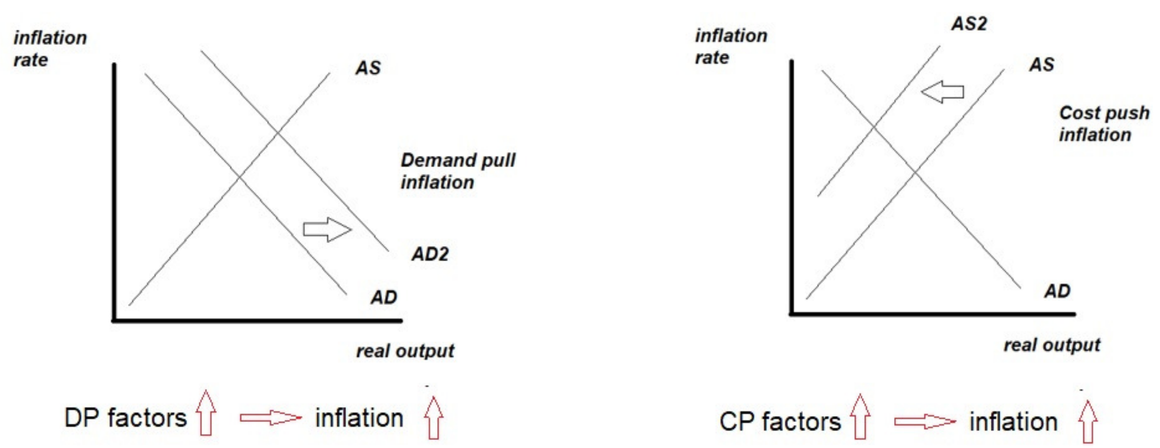

Fig. 1: Conceptual Model

Characteristic of demand-pull inflation is that both the equilibrium quantity and equilibrium price increase simultaneously. In contrast, characteristic of cost-push inflation is that the equilibrium price increases while the equilibrium quantity decreases. These features are explored by Sharpiro [9] using categorical-level data to differentiate between demand-pull inflation and cost-push inflation. Of course, in some circumstances, both the demand curve and the supply curve can shift simultaneously, making it more challenging to dichotomously classify inflation.

2.1 Derivation of the cost-push equation and the demand-pull equation

Suppose that the demand curve and the supply curve display the following linearized functional form. Supply curve:

$$P_t = c_0 + c_1 Q_t + c_2 C_t + c_3 R_t \tag{1}$$

Demand curve:

$$P_t = d_0 - d_1 Q_t + d_2 D_t + d_3 R_t \tag{2}$$

Hereby is: P_t the price, Q_t the quantity, C_t is the cost-push factor, D_t is the demand-pull factor, R_t is the policy variable, c_1 and d_1 are positive representing the upwards sloping of the supply curve and the downwards sloping of the demand curve, and c_2 and d_2 are positive representing the positive effect of the cost-push factor and the demand-pull factor on the price respectively.

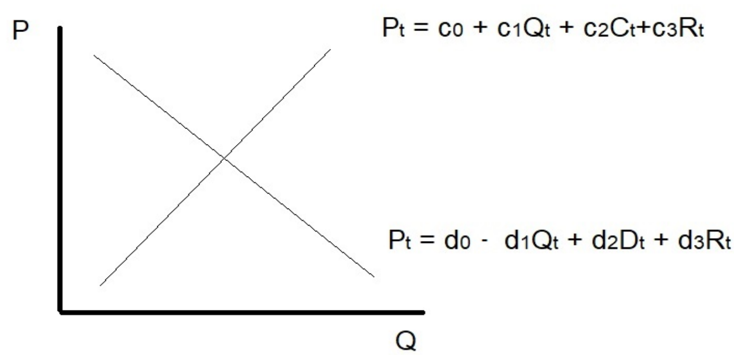

Fig. 2: Conceptual Model

Solving for P_t and Q_t, we obtain the following equilibrium price and equilibrium quantity.

$$\begin{bmatrix} P_t \\ Q_t \end{bmatrix} = \frac{1}{c_1 + d_1} \begin{bmatrix} d_1 & c_1 \\ -1 & 1 \end{bmatrix} \begin{pmatrix} c_0 + c_2 C_t + c_3 R_t \\ d_0 + d_2 D_t + d_3 R_t \end{pmatrix} \tag{3}$$

From the equation above we obtain changes in the equilibrium price as follows.

$$\Delta P_t = \frac{d_1}{d_1 + c_1} (\Delta c_0 + c_2 \Delta C_t + c_3 \Delta R_t) + \frac{c_1}{d_1 + c_1} (\Delta d_0 + d_2 \Delta D_t + d_3 \Delta R_t) \tag{4}$$

From equation (4), it is evident that inflation is driven by both changes in the demand function and the supply function. The first term on the right-hand side of equation (4) represents the contribution of the cost-push factor to inflation, while the second term represents the contribution to inflation by the demand-pull factor. In view of a dichotomous separation of the causes of inflation, we have an equation for cost-push inflation and a separate equation for demand-pull inflation.
Cost-push inflation:

$$\Delta P_t = \frac{d_1}{d_1 + c_1} (\Delta c_0 + c_2 \Delta C_t + c_3 \Delta R_t) + u_{ct} \tag{5}$$

Demand-pull inflation:

$$\Delta P_t = \frac{c_1}{d_1 + c_1} (\Delta d_0 + d_2 \Delta D_t + d_3 \Delta R_t) + u_{dt} \tag{6}$$

Empirical estimation of equation (4) using regression techniques with time series data is feasible. However, this approach would smooth out variations in different drivers of inflation over time, which does not align with our objective of identifying when cost-push is the dominating driver and when demand is the dominating driver. Estimating the cost-push inflation equation (5) and the demand-pull inflation equation (6) separately would require prior knowledge of the time periods of cost-push and demand-pull inflation, making it impractical.

For our purpose, a Markov switching regression model seems to be appropriate because it can be used to infer the contribution of each cause to inflation over time.

$$\Delta P_t = \begin{cases} \frac{d_1}{d_1+c_1}(\Delta c_0 + c_2 \Delta C_t + c_3 \Delta R_t) & \text{for the cost-push regime} \\ \frac{c_1}{d_1+c_1}(\Delta d_0 + d_2 \Delta D_t + d_3 \Delta R_t) & \text{for the demand-pull regime} \end{cases} \tag{7}$$

In the next subsection we discuss the Markov switching regression model in detail.

2.2 Markov switching regression model

A Markov switching regression model is specified as follows:

$$\Delta P_t = \begin{cases} a_o^{(1)} + b_d^{(1)} DD_t + b_c^{(1)} DC_t + c_o^{(1)} Dr_t + u_t^{(1)} & \text{for } s_t = 1 \\ a_o^{(2)} + b_d^{(2)} DD_t + b_c^{(2)} DC_t + c_o^{(2)} Dr_t + u_t^{(2)} & \text{for } s_t = 2 \end{cases} \tag{8}$$

where $s_t = 1$ and $s_t = 2$ denote two different regimes. π_t is the inflation rate, $a_o^{(1)}$ and $a_o^{(2)}$ are the intercepts of the two regimes respectively. DD_t, DC_t, and Dr_t stand for the changes in the demand-pull factor, in the cost-push factor and in the policy variable, respectively. $u_t^{(1)}$ and $u_t^{(2)}$ are assumed to be independent normal residuals for the two regimes.

$$P = \begin{bmatrix} \mathbb{P}(s_t = 1 | s_{t-1} = 1) & \mathbb{P}(s_t = 2 | s_{t-1} = 1) \\ \mathbb{P}(s_t = 1 | s_{t-1} = 2) & \mathbb{P}(s_t = 2 | s_{t-1} = 2) \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}, \tag{9}$$

where p_{ij} $(i, j = 1, 2)$ denote the transition probabilities of $s_t = j$ given that $s_{t-1} = i$. Clearly, the transition probabilities satisfy $p_{i1} + p_{i2} = 1$. This class of models has been well studied in Hamilton [5], Kim [6], and Krolzig [7]. In our model all coefficients are switching.

It's worth noting that the Markov switching regression model (8) is more general than the specification implied by the cost-push and demand-pull model in (7). In equation (8), the right-hand side variables are the same in the two different regimes; we do not impose restrictions on the regression equations to categorize them as a cost-push regime or a demand-pull regime. Instead, we let the data decide whether there is a cost-push regime and a demand-pull regime.

If the concept of demand-pull and cost-push is a proper model explaining inflation, the estimation results should reveal that in one regime, the demand-pull factor is absent, identifying it as the cost-push regime. Conversely, in the other regime, the cost-push factor is absent, identifying it as the demand-pull regime. Specifically, we can formulate the economic theory of demand-pull and cost-push inflation as statistically testable hypotheses:

- For the cost push regime: $H_0 : b_d = 0$, $H_1 : b_d \neq 0$
- For the demand pull regime: $H_0 : b_c = 0$, $H_1 : b_c \neq 0$

2.3 Data and estimation

For our empirical investigation, we use Australian data from 1998Q4 to 2023Q1. The changes of the consumer price index is used to measure inflation. As a measure of the demand-pull factor, the real final consumption expenditure from Australian national accounts is utilized. The wage price index is used as a measure of the cost-push factor. The cash rate of the Reserve Bank of Australia is employed as the policy variable. The sources of the data are given in Tab.1.

Figure 3 represents the plots of used time series data. We observe that there is no trend among the data. The time series show episodes of lower variation and episodes of higher variation, indicating there might be structure breaks or regime switchings.

Variable	Code	Names	Transformation	Sources
$DCPI$	A2325846C	Consumer price index (CPI)	$DCPI_t = CPI_t - CPI_{t-1}$	ABS
DD	A2304081W	Final consumption expenditure	$DD_t = (Consumption_t - Consumption_{t-1})$	ABS
DC	A2713846W	Wage Price Index	$DC_1 = WPI_t - WPI_{t-1}$	ABS
Dr	FIRMMCRT	Cash rate (policy interest rate)	$Dr_t = r_t - r_{t-1}$	RBA

Tab. 1: Data from Australia Bureau of Statistics and The Reserve Bank of Australia 1998 Q4 - 2023 Q1

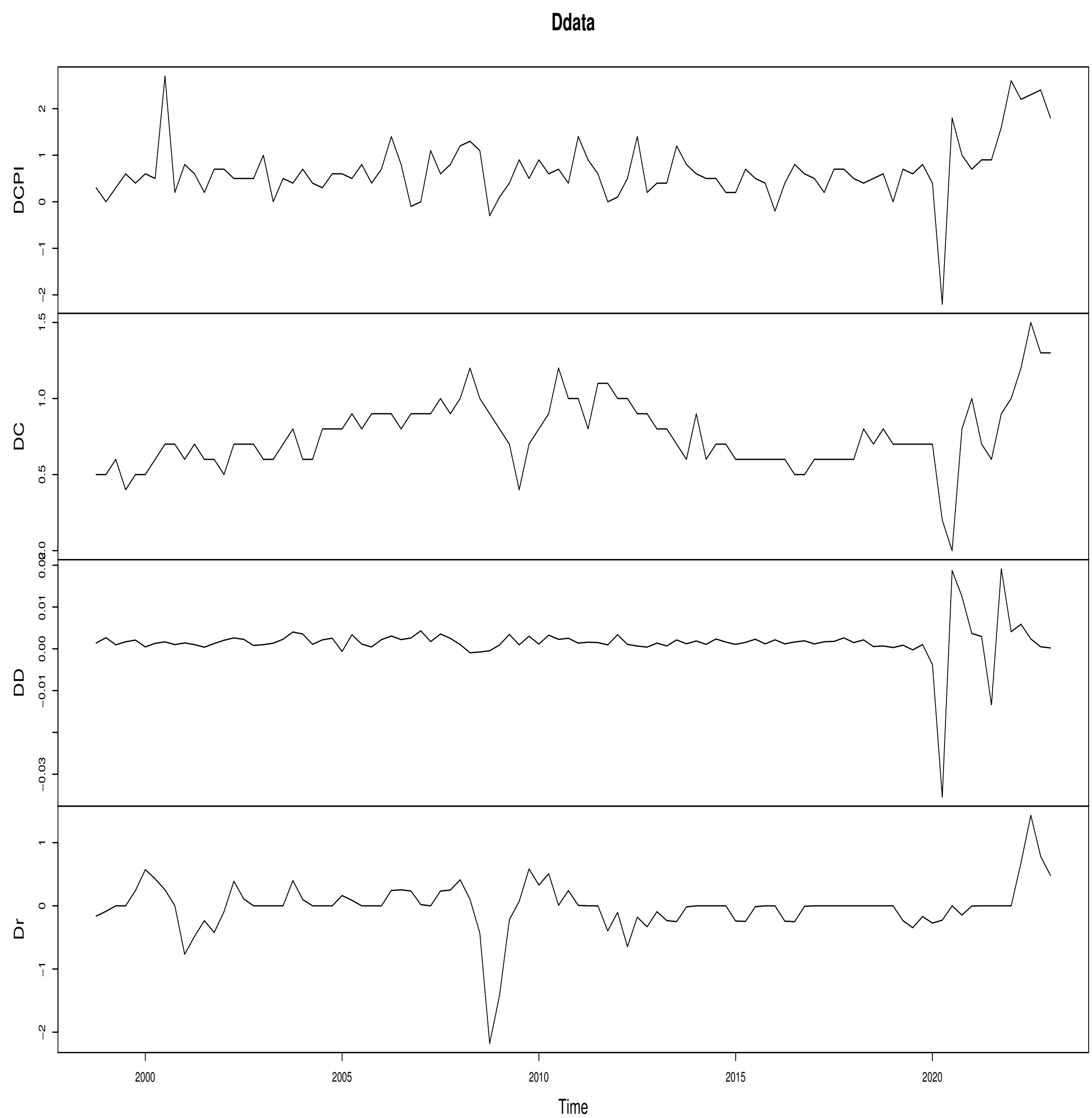

Fig. 3: Plot of the used time series 1998 Q4 - 2023 Q1

We use the R package MSwM to fit a Markov switching model to the data, and the estimation output is shown in the following table. Although in the Markov switching model there are no a priori restrictions that categorize either of the regimes as cost-push or demand-pull regimes, the estimation results yield two regimes that can be interpreted as the cost-push regime and the demand-pull regime, respectively.

In Regime 1, the demand-pull factor is insignificant, while the cost-push factor is significant. This makes Regime 1 qualified as the cost-push regime. In Regime 2, the cost-push factor is insignificant while the demand-pull factor is highly significant, qualifying Regime 2 as the demand-pull regime.

```
Regime 1
---------
               Estimate Std. Error t value Pr(>|t|)
(Intercept)(S)  -0.0193     0.3814 -0.0506 0.959644
dcf(S)           1.0095     0.4330  2.3314 0.019732 *
ddf(S)          11.6114    28.3233  0.4100 0.681806
dr(S)            0.6060     0.1887  3.2114 0.001321 **
---
Regime 2
---------
               Estimate Std. Error t value  Pr(>|t|)
(Intercept)(S)   0.4443     0.1289  3.4469 0.0005671 ***
dcf(S)          -0.0545     0.1872 -0.2911 0.7709748
ddf(S)          75.1315     4.9763 15.0979 < 2.2e-16 ***
dr(S)           -0.1671     0.1636 -1.0214 0.3070650
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Transition probabilities:
          Regime 1  Regime 2
Regime 1 0.7743762 0.1790905
Regime 2 0.2256238 0.8209095
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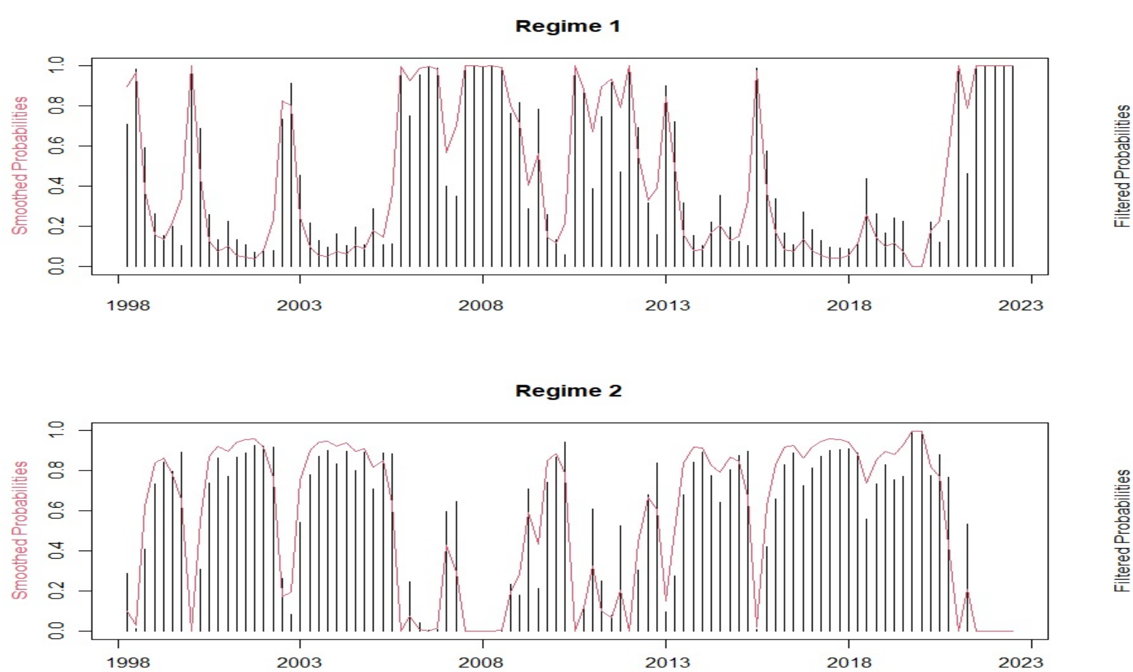

Fig. 4: Filtered and smoothed probability of the two regimes

The information criteria values for the two-regime model are AIC = 117.38 and BIC = 148.40, while the information criteria values for no switching, i.e., the one-regime model, are AIC = 148.54 and BIC = 161.46. Both criteria favour the Markov switching model. The ACF and PACF of the residuals show no serial correlations. Hence, the Markov switching model is appropriate for the data.

2.4 Decomposition of Inflation Drivers

The filtered probability of the two regimes is shown in Figure 4. We observe that most cost-push inflation events are short-lived, except for the episode prior to the 2008-2009 global financial crisis, the period 2012-2014, and particularly the current post-Covid inflation episode after 2020. Demand-pull inflation events are generally more long-lasting. This observation is also reflected in the estimated transition probability matrix. In general the probability to stay in the demand-pull regime is 0.82, while the probability to stay in the cost-push regime is only 0.77.

Using the filtered probability as a measure of the likelihood of each of the two inflation drivers, we can decompose inflation rates at each time point into contributions due to the two different drivers. Figure 5 is the plot of the annualized inflation rate. At each time point, we decompose the inflation rate by the filtered probability and color the cost-push proportion in blue and the demand-pull proportion in red.

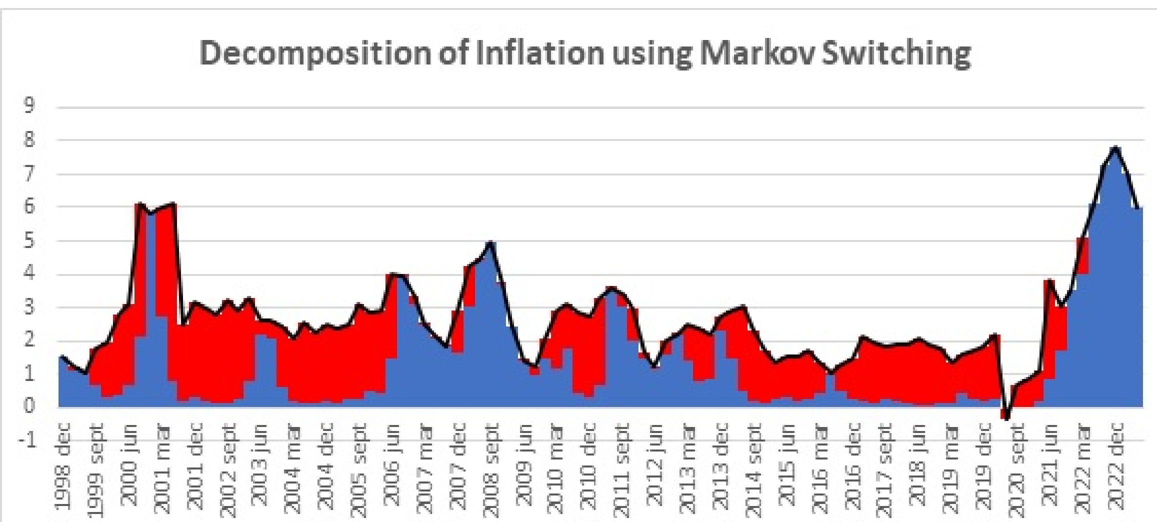

Fig. 5: Decomposition of Inflation. Blue for Cost-Push and Red for Demand-Pull

Figure 5 demonstrates that indeed Markov switching regression can be used to quantify the different drivers and their short-lived and persistent of inflation. To assess the validity of our decomposition, we compare it with the cost-push and demand-pull decomposition provided in Beckers et al. [2]. In their work, the authors apply the method developed in Sharpiro [9] to decompose the drivers of inflation into three categories: demand-pull, cost-push, and ambiguous. The decomposition results for the time periods from 2011 to 2023 are shown in Figure 6.

Although due to the difference in their nature these two methods are not directly comparable, their message concerning which one is the dominating driver of inflation across the periods from 2011 to 2023 is very similar. During the time periods from 2011 to 2023, there are two episodes in which the cost-push was the dominating driver of inflation: in the time periods 2011 to 2014 and from 2021 to 2023, cost-push is the dominating driver of inflation. In particular, in the recent post-Covid period from 2021 to 2023, this domination is even more clearly pronounced.

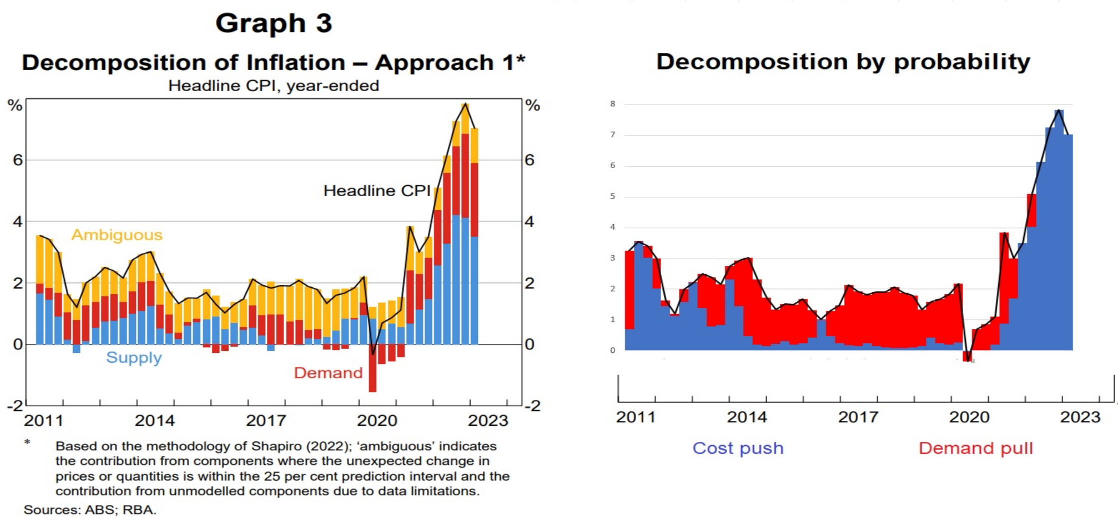

Fig. 6: Comparison of Decomposition

Since the Reserve Bank of Australia (RBA) implemented the inflation targeting policy regime in the early '90s, they have been successful in controlling the inflation rate within a narrow range around the target inflation rate of 2-3% for most periods. Since 1998, there have been only three episodes of relatively higher inflation (>4%): the early 2000s, 2006-2007, and 2021-2023. The decomposition of inflation drivers in Figure 5 reveals that during these three relatively higher inflation episodes, cost-push was the dominating driver.

Is this purely coincidental, or does it stem from any economic rationale? It is widely acknowledged that independent central banks excel at managing demand-pull inflation but are less effective in addressing cost-push inflation. As stated by Fed Chair Paul, 'What [the Fed] can control is demand; we can't really affect supply with our policies.' Consequently, when cost-push inflation becomes the dominant driver, central banks appear to lack the proper tools to combat it effectively, causing the inflation rate to exceed the desired range. This is evident in the three episodes of relatively higher inflation, where cost-push was the dominant driver. To be more precise, the dominance of cost-push inflation made it more challenging for the RBA to control it within the desired range, resulting in the inflation rate exceeding 4%.

Economists distinguish between demand-pull and cost-push inflation because the effectiveness of monetary policy varies in these scenarios. Our estimated model reflects this distinction. In cost-push inflation (Regime 1), the coefficient of dr is positive, indicating that rate hikes have a significantly positive effect. In other words, monetary tightening and rate hikes may not decrease but rather might increase the inflation rate. This adverse effect can be attributed to a widespread mark-up pricing mechanism. A rate hike tends to reduce supply due to rising financial constraints, increasing production costs, and, given the mark-up, likely leading to higher prices. In a second round, this can result in higher nominal wage rates, either through the minimum wage setting mechanism or wage bargaining (see Chen and Semmler [3]). In contrast, in the demand-pull regime (Regime 2), the coefficient of dr is negative. This suggests that monetary tightening or a rate hike would decrease demand and the inflation rate, although it is not statistically significant at the 5% level. Similar results for the decomposition of cost-push and demand-pull drivers also hold for the US, as presented in the Appendix. However, it's worth noting that there are also other country-specific inflation drivers at play.

3 Concluding Remarks

In this comprehensive exploration of inflation drivers and the effectiveness of monetary policy in the Australian context, we applied a Markov switching model to differentiate between demand-pull and cost-push inflation regimes. We fit a Markov switching model to data from 1998Q4 to 2023Q1, revealing two distinct regimes that align with cost-push and demand-pull classifications. The estimation results, illustrated in figures and tables, showcase the dynamics of inflation drivers over time, with notable episodes of cost-push dominance during periods of relatively higher inflation.

Our findings, supported by filtered probability and decomposition analysis, suggest that while demand-pull inflation events were somewhat persistent in the past, cost-push inflation was tending to be more short-lived, except in the recent period since 2021. The latter requires to refer to specific mechanisms that were set in motion through external drivers of inflation rate such as supply chain bottlenecks, energy and food shortages (see Chen and Semmler [3] and Figure 8). The Markov switching regression model effectively quantifies the contributions of different drivers to inflation, allowing for a nuanced understanding of inflationary episodes. Comparisons with alternative decomposition methods further validate the reliability of our approach.

Notably, our analysis sheds light on the challenges faced by central banks, such as the Reserve Bank of Australia, in managing inflation under distinct drivers. We observed that during episodes of cost-push dominance, the central bank struggled to keep inflation within the desired range, highlighting the limitations of monetary policy in combating cost-push inflation.

Furthermore, the econometric results reveal differential responses to monetary policy measures in cost-push and demand-pull regimes. In the cost-push inflation regime, monetary tightening can exacerbate inflation, while in the demand-pull regime, it has a potential mitigating effect.

In conclusion, our study contributes valuable insights into the dynamics of inflation, emphasizing the importance of distinguishing between demand-pull and cost-push factors. This understanding is crucial for policymakers facing the challenge of maintaining stable inflation rates, particularly in the context of independent central banks navigating the complexities of monetary policy effectiveness.

4 Appendix

4.1 More estimation results for Australia data

The following autocorrelation function (ACP) and partial autocorrelation function show that there is no significant serial correlation among the residuals of the estimated Markov switching model. Figure 8 suggests that the IMF Global Energy Price (source: FRED ECONOMIC DATA St. Louis) may have significant impact on the Australia domestic inflation, in particular in the current episode of high inflation since 2021.

4.2 Estimation a Markov switching model with US Data

Here we document the estimation results for the inflation in USA using the same method as described in the previous sections. Data are taken from FRED Economic Data, St. Louis Fed.

Figure 9 illustrates the used time series data for the USA. It is evident that there is no discernible trend in the data, and we observe episodes of both lower and higher variation. This suggests the presence of structural breaks or regime switchings.

$$\Delta P_t = \begin{cases} a_o^{(1)} + b_d^{(1)} DD_t + b_c^{(1)} DC_t + c_o^{(1)} Dr_t + u_t^{(1)} & \text{for } s_t = 1 \\ a_o^{(2)} + b_d^{(2)} DD_t + b_c^{(2)} DC_t + c_o^{(2)} Dr_t + u_t^{(2)} & \text{for } s_t = 2 \end{cases} \tag{10}$$

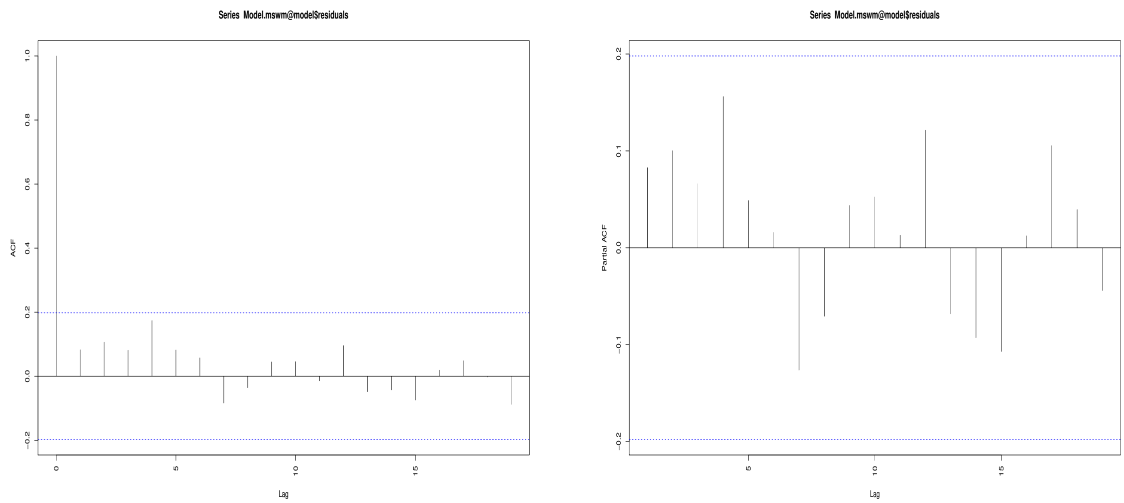

Fig. 7: ACF and PACF of the residuals of the estimated Markov switching model

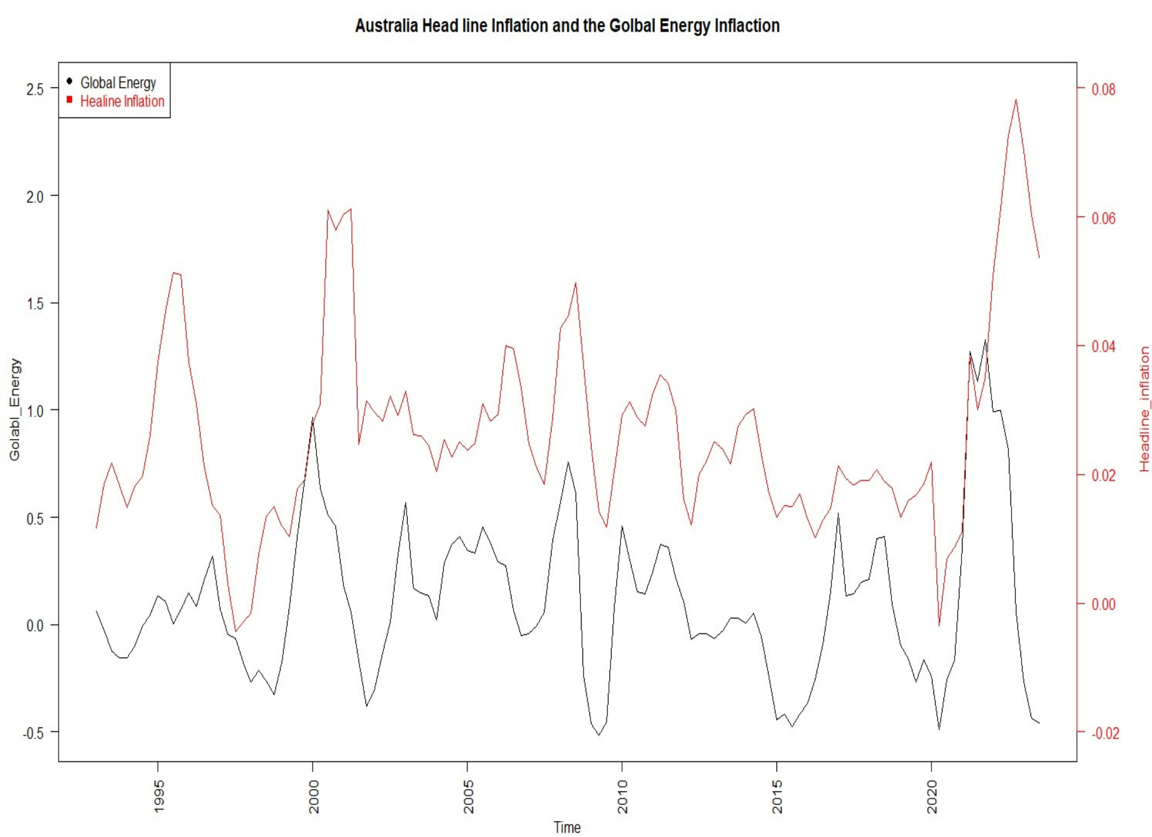

Fig. 8: The head line inflation in Australia and the global energy inflation

We use the nominal wage as the cost-push factor, denoted as DC, while the real personal consumption expenditure serves as the demand-pull factor, represented by DD. The change in the federal funds rate is designated as the policy variable, denoted as Dr. The changes in the headline consumer price index are represented by π. The transformation of the data is outlined in Table 2.

Variable	Code	Names	transformation	Source
$DCPI$	CPIAUCSL	Consumer price index all group(CPI)	$DCPI_t = CPI_t - CPI_{t-1}$	Fed St. Louis
DD	PCECC96	real personal consumption expenditure	$DD_t = Consumption_t - Consumption_{t-1})$	Fed St. Louis
DC	LES1252881500Q	Median usual weekly nominal earnings	$DC_t = W_t - W_{t-1}$	Fed St. Louis
Dr	FEDFUNDS	Fed fund rate	$Dr_t = r_t - r_{t-1}$	Fed St. Louis

Tab. 2: Data from FED ST. LOUIS 1998 Q3 - 2023 Q2

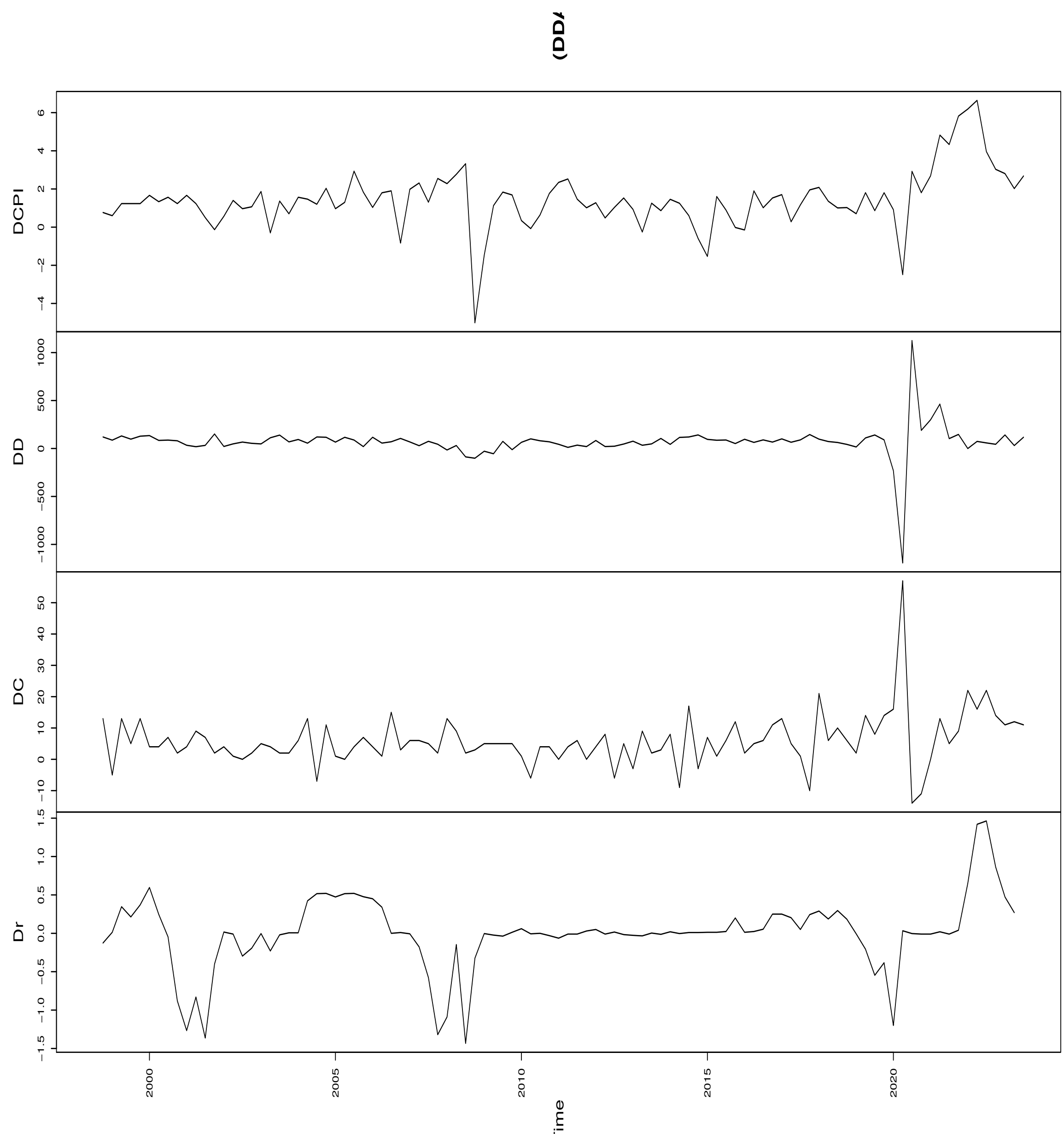

Fig. 9: Plot of used time series USA

The estimation results are presented in the following table.

```
Regime 1
---------
               Estimate Std. Error t value  Pr(>|t|)
(Intercept)(S)   1.0220     0.1267  8.0663 6.661e-16 ***
C(S)             0.0023     0.0006  3.8333 0.0001264 ***
nominalw(S)      0.0012     0.0130  0.0923 0.9264597
Rq(S)            0.2188     0.2129  1.0277 0.3040910
---

Regime 2
---------
               Estimate Std. Error t value Pr(>|t|)
(Intercept)(S)  -0.5169     0.9523 -0.5428 0.587268
C(S)             0.0075     0.0039  1.9231 0.054467 .
nominalw(S)      0.2636     0.0934  2.8223 0.004768 **
Rq(S)           -0.5573     0.8300 -0.6714 0.501966
---

Transition probabilities:
           Regime 1  Regime 2
Regime 1 0.96343236 0.1461543
Regime 2 0.03656764 0.8538457
```

Here, we can identify Regime 1 as the demand-pull regime and Regime 2 as the cost-push regime. This distinction arises from the fact that the cost-push factor *nominalw* is found to be insignificant in Regime 1, while the demand-pull factor C_t is insignificant in Regime 2. The probability of remaining in the demand-pull regime is 0.96, whereas the probability of staying in the cost-push regime is 0.86.

The filtered probability, as depicted in Figure 10, highlights three episodes where cost-push was the predominant driver of inflation.

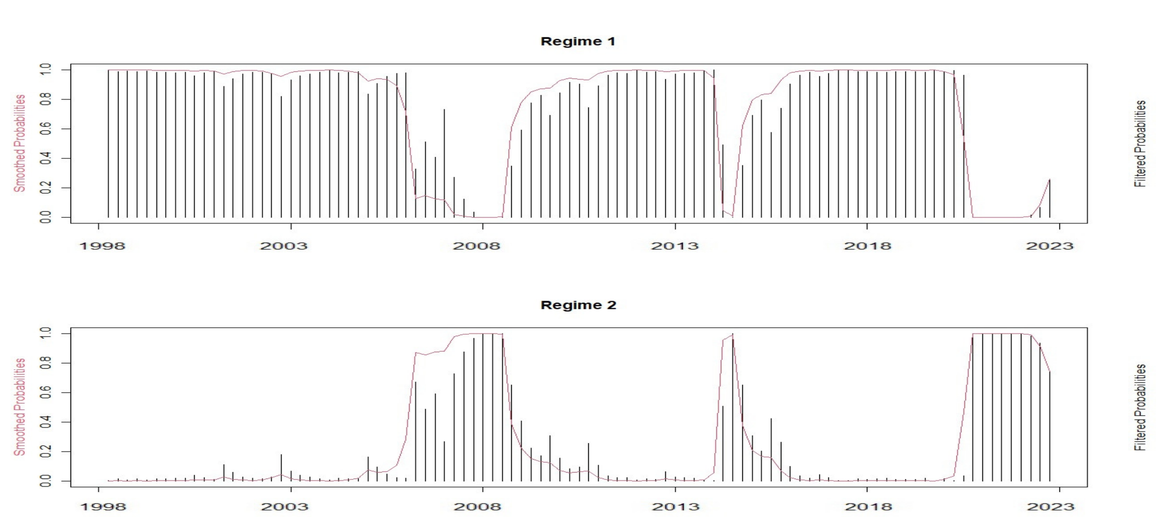

Fig. 10: Filtered and smoothed probability of the two regimes in USA

Using the filtered probabilities as a measure of the likelihood of demand-pull and cost-push drivers, respectively, we can decompose headline inflation into proportions driven by demand-pull and cost-push factors. In Figure 11, we observe two episodes of relatively high headline inflation (>4%): one in 2007-2008, prior to the global financial crisis, and the current episode starting from 2021. In both of these episodes, the cost-push driver played the dominant role, confirming our findings in the Australia case. Specifically, the central bank appears to be less effective in managing cost-push inflation, allowing the cost-push driver to push the inflation rate beyond the desired inflation targeting range.

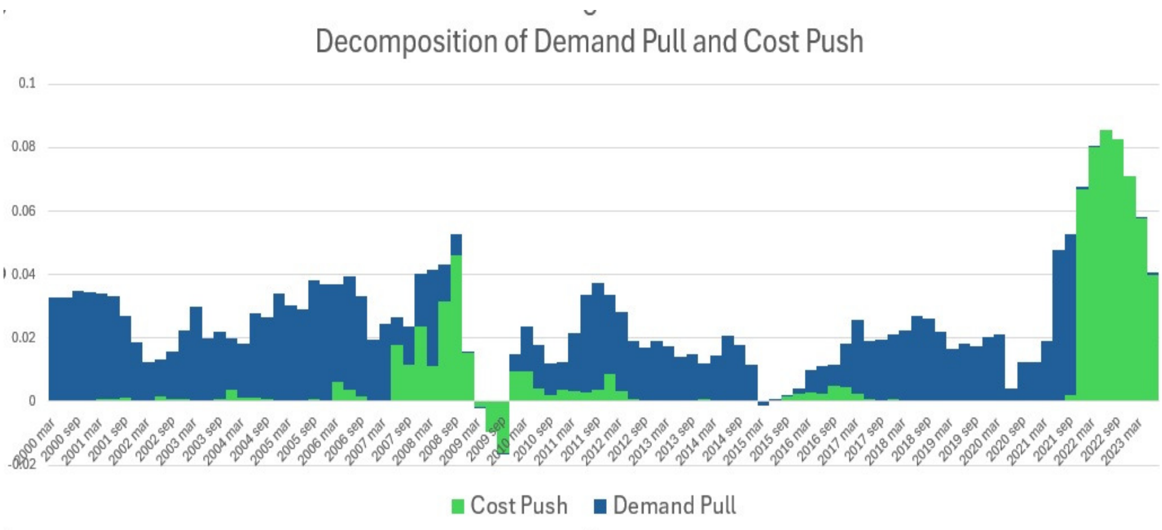

Fig. 11: Decomposition of Inflation. Green for Cost-Push and Blue for Demand-Pull

Figure 11 illustrates that the current period of cost-push inflation, starting in 2021, is notably more prolonged compared to previous episodes. In the current situation, external factors such as supply chain bottlenecks and shortages in energy and food supplies may contribute to the long-lasting high inflation episode. Notably, the global energy price appears to be a significant driver of domestic inflation, as depicted in Figure 12, though there are also country specific drivers to be considered. We plan to delve deeper into this aspect in our future research.

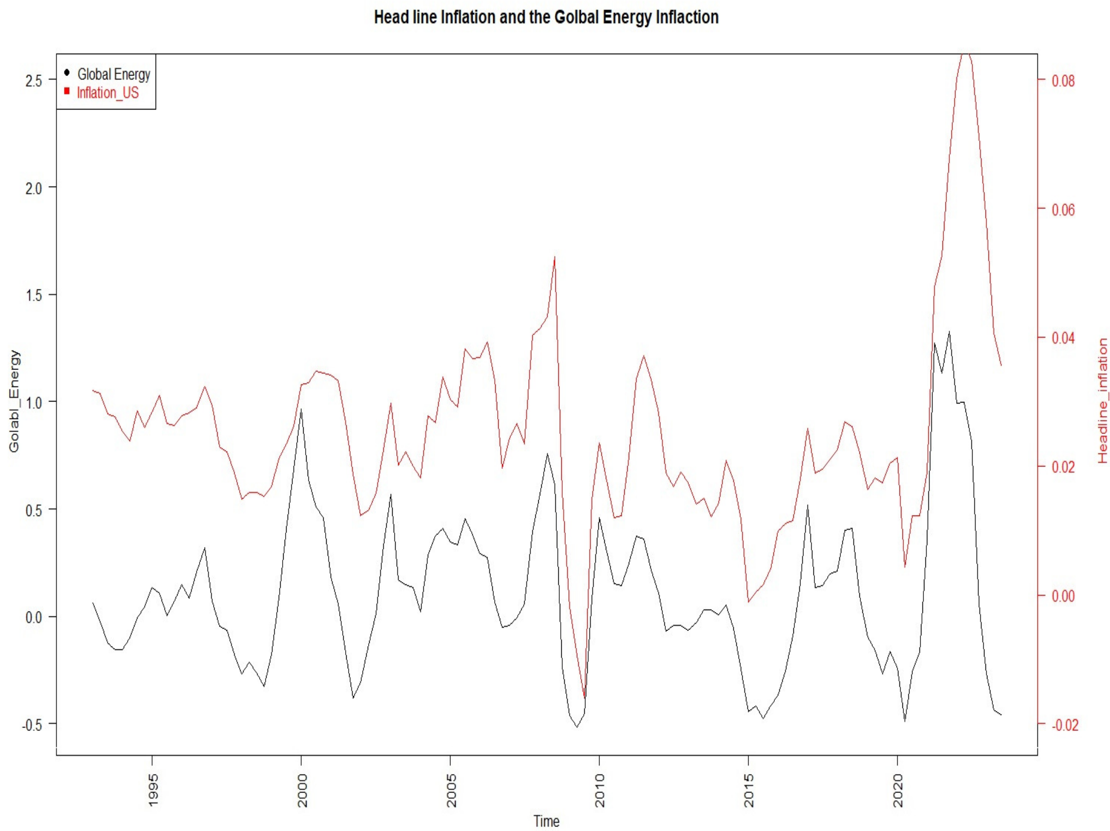

Fig. 12: The head line inflation in USA and the global energy inflation

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