Instantaneous Inflation[*]

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Abstract

Current practice to measure inflation for monetary policy uses the average annual inflation rate. When inflation changes fast, whether increasing or decreasing, the annual average rate is biased towards data from too far in the past and conveys the true price level with six months delay. I propose to use instantaneous inflation as a more adequate measure of the price change. The measure trades off noise in the data with the precision of the instantaneous price change. Using the latest inflation numbers up to June 2023, it shows that instantaneous inflation in the US is back to 2.5%, and to 2.6% in the Eurozone, indicating the high inflation period has come to an end. Also US core inflation is declining, currently at 4%. In contrast, inflation remains high and shows no signs of decline in the UK, Japan and Australia.

Keywords. Instantaneous Inflation. Core Inflation. Kernel.

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The inflation rate measures the annualized percentage change in a general price index, typically of a representative consumption basket such as the Consumption Price Index (CPI). Common practice by policy makers at Central Banks and by participants in the public debate is to quote the average price change over the entire year. When prices change fast, this yearlong averaging creates a delay of over 6 months: the data is published the month after collection, and the commonly quoted inflation rate is the average of 12 months. When the inflation increases or decreases, we get on average what happened half a year ago. Of course, when inflation does not change, then averaging out is harmless. But today we are living in different times.

But there is a good reason for quoting the annual average. The price level data is collected and published monthly, and since data is noisy, and bounces around for reasons that do not reflect the inflation rate but rather serendipity of the hand-collected price data: goods might have been on sale on the day of data collection, sellers may temporarily experiment with prices to find out the customer response, there may be weather or seasonal circumstances that lead to unusual price changes, or there may have been an error in collecting the correct data.[1] We can adjust for seasonal factors, but not for noise. This randomness makes it prudent to use an average of multiple monthly observations to reduce the measurement error and to avoid being misled by the statistical inaccuracy.

But now there is a tradeoff between measurement error and instantaneous precision of the measure. In this note I propose kernel-based measure of instantaneous inflation that puts more weight on recent observations and less on observations in the distant past. As with kernel density estimation (see Silverman (1986); Härdle (1990)), the kernel is indexed with a bandwidth parameter that regulates the smoothing of the average.

Based on this measure, I find that the smoothed inflation in the US in June 2023 is at 2.56%, the inflation target (see Figure 1, where $a = 0$ corresponds to the conventional measure and $a = 4$ corresponds to the instantaneous inflation measure with bandwidth parameter 4; the dots are the monthly inflation numbers). The conventional measure of inflation in December instead is 3.09%.

This measurement issue may have profound implications for monetary policy. Monetary authorities crucially take into account the behavior of economic agents such as firms, investors and households, when adjusting the interest rate target to achieve an inflation rate close to 2%. The monetary authority may over or undershoot when the measure used by the public at large has a long lag. It also matters for inflation-indexed contracts, in particular labor market contracts. When conventional inflation is higher than instantaneous inflation, inflation-led wage adjustments may unduly *cause* more inflation when higher wages feed back into higher prices. And in financial markets, inflation-indexed securities will

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[1] Hall (2023) carefully documents the rise in inflation volatility and the implication for the New Keynesian model and the Phillips curve that relates inflation to unemployment. He reaches the same conclusion regarding the trend in inflation.

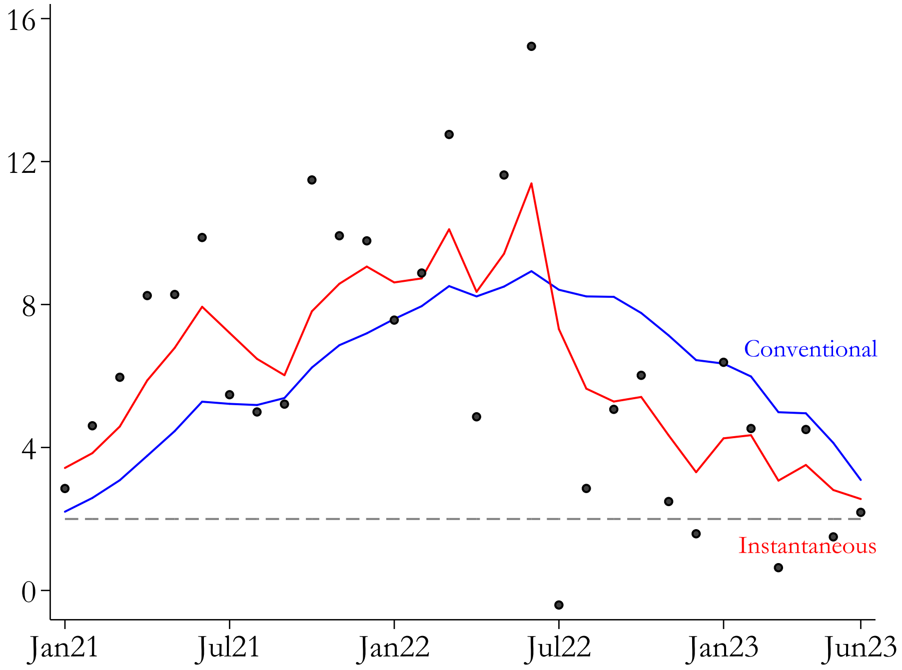

Figure 1: US Inflation: conventional ($a = 0$) and instantaneous ($a = 4$) inflation (Source: BLS)

be biased relative to instantaneous inflation which affects prices and the value of the security.

Of course, central bank experts look beyond the conventional inflation number. In its decision making, central banks give consideration to the monthly inflation reading, and they also construct and analyze inflation momentum, which is a three month unweighted average of inflation. All these measures capture different aspects of the notion instantaneous inflation. The main point of this note is that most economists, policy makers, journalists and definitely the broader public do *not* see the nuance of instantaneous inflation. For them, inflation today is 3.09%. And this most certainly affects inflation expectations. If most people (incorrectly) believe that today's inflation is 3.09%, then even if they hold the correct belief that inflation is falling, chances are that their expectations about future inflation are well above 2%. In other words, incorrect information about today's inflation leads to incorrect expectations about future inflation (see for example Mankiw et al. (2003); Coibion et al. (2018a,b); Arioli et al. (2017)).

One of the most daunting challenges in controlling inflation is tenaciously high inflation expectations, which in turn affect firm and household behavior: when inflation expectations are high, firms set high prices and households demand higher wages, resulting in high inflation as well as persistently high inflation expectations. This self-fulfilling prophecy limits the ability of the central bank to bring down inflation. By publicizing instantaneous inflation, the monetary authority may be better able to influence expectations, and thus bring down inflation.

Data and Basic Concepts

Data. We use the official data, published by the relevant authority responsible for collecting price data, in the case of the US, the Bureau of Labor Statistics. We use the average price over the entire basket or goods, or the average price of a subset of the goods (below). Our series for the US is seasonally adjusted.[2] Denote by p_t the price level at month t. Then the month-over-month inflation rate i_t^m is $i_t^m = \frac{p_t - p_{t-1}}{p_{t-1}}$. To annualize this monthly price change ratio, we compound over 12 months to obtain the *annualized monthly inflation rate* i_t^{am} equal to $i_t^{am} = (1 + i_t^m)^{12} - 1$. Basically, i_t^{am} is a rescaling of the monthly rate i_t^m based on one data point from month t (the rate i_t^a itself is of course the difference between the differences of the level of prices p_t and p_{t-1}). This follows common practice to express all changes in annual magnitudes. For example, a 1% monthly inflation rate corresponds to a 12.68% annual inflation rate (more than times 12 due to compounding).

See the Appendix for a list of all data sources used in this note.

Annual average inflation. The conventional measure of inflation is the average inflation rate from 12 monthly inflation readings, calculated as the difference in the current price level and the price level in the same month last year: $i_t^y = \frac{p_t - p_{t-12}}{p_{t-12}}$. We can calculate this every month, always taking the difference with the same month a year earlier.

Now we can write this yearly inflation rate as the chain of all the differences in month-by-month inflation rates, since:

$$\begin{aligned} i_t^y &= \frac{p_t}{p_{t-12}} - 1 && (1)\\ &= \frac{p_t}{p_{t-1}} \times \frac{p_{t-1}}{p_{t-2}} \times \cdots \times \frac{p_{t-11}}{p_{t-12}} - 1 && (2)\\ &= (1 + i_t^m) \times (1 + i_{t-1}^m) \times \cdots \times (1 + i_{t-11}^m) - 1 && (3)\\ &= \prod_{\tau=0}^{11} (1 + i_{t-\tau}^m) - 1 && (4) \end{aligned}$$

Note that the annual inflation rate plus one $(1 + i_t^y)$ is the geometric mean of the annualized monthly inflation rates plus one ($(1 + i_{t-\tau}^{am})^{\frac{1}{12}}$ for $\tau = 0, ..., 11$) since $1 + i_t^y = \prod_{\tau=0}^{11} (1 + i_{t-\tau}^{am})^{\frac{1}{12}}$.

Weighting Kernel. Now we introduce a kernel that gives higher weights to the more recent observations. Denote the kernel by $\kappa(\tau)$ where κ is decreasing in τ: the current period t where $\tau = 0$ has the

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[2] See the Data Appendix for the sources of the data.

highest weight and the period $t-11$ longest in the past where $\tau = 11$ has the lowest weight.[3]

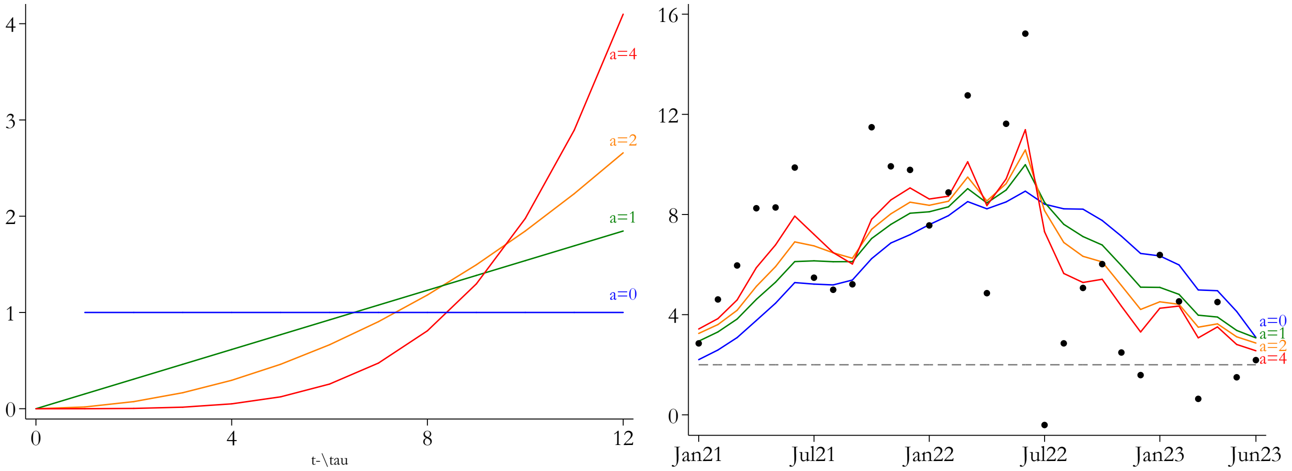
Any kernel function is valid. For simplicity and transparency, here we a polynomial kernel that is governed by one parameter a:

$$\kappa(\tau, a) = \frac{(T-\tau)^a}{\sum\limits_{\tau=0}^{T-1} (T-\tau)^a} T, \quad \forall a \geq 0$$

We now illustrate some special cases:

1. Uniform kernel: $a = 0$. This is the kernel that the monetary authorities currently use, since for $a = 0$, we get $\kappa(\tau, 0) = 1$ for all τ. In other words, each month, recent or distant, receives an equal weight.
2. Linear kernel: $a = 1$. When $a = 1$ and $T = 12$, then $\kappa(\tau, 1) = (12 - \tau)\frac{12}{78}$, where $\kappa = 1.8$ today when $\tau = 0$ and $\kappa = 0.15$ a year ago when $\tau = 11$.
3. Convex kernel: $a > 1$.
4. Limit kernel: $a \to \infty$, then we approach the monthly reading with all weight on the last observation.

Figure B.1a illustrates the different polynomial kernels. The higher a, the more the kernel is putting weight on recent observations.



(a) Kernel weights $\kappa(\tau; a)$ for different values of a

(b) Instantaneous Inflation for different values of a

Figure 2: Kernel and Instantaneous Inflation US

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[3] In theory one could give lower weights to recent observations and higher weights to observations in the distant past, but this case has little relevance. And we can of course put weights over a period T that is longer or shorter than 12 months. For the remainder of this note, we use examples with a $T = 12$ month window.

In the Appendix we also consider a Gaussian or normal kernel with different bandwidths governed by the standard deviation of the normal distribution. And of course, the entire logic goes through for all other widely used kernel functions such as Epanechnikov, triangular, biweight, triweight,...

Instantaneous Inflation. We write the κ-weighted instantaneous inflation measure as:[4]

$$i_t^{\kappa} = \prod_{\tau=0}^{11} (1 + i_{t-\tau}^{m})^{\kappa(\tau)} - 1$$

Figure 2b illustrates the role of the kernel weights. With uniform weights ($a = 0$), the average inflation is much smoother that for higher a because new information receives relatively less importance in the weighting. The explains why in June 2022 there is hardly any increase for the average inflation when $a = 0$, and there is a notable spike for $a = 4$ to 12.4%. The reason of course is the measured inflation number for June was over 16%. When a is higher, the average series is more susceptible to temporary changes and thus also to measurement error. However, when there is a downward trend, as we have seen starting in July 2022, the conventional measure with $a = 0$ only slowly picks up this trend. Instead, when $a = 4$, the average inflation starts to decline much faster. in other words, the higher a, the more volatile the series and the more exposure there is to noise, but the more responsive the series is to pick up instantaneous changes.

Subcategories of the Consumption Basket. We can apply the same logic of instantaneous inflation to the different subcategories (see Figure 3). Instantaneous core inflation, which excludes food and energy, is falling, but at 4%, it remains higher than the inflation target of 2%. The conventional measure of core inflation is at 4.9%. Instantaneous inflation of food is at 1.9% (with the conventional measure still over 5%). This series has low volatility (especially in recent months) warranting a higher bandwidth coefficient $a = 8$. Then, instantaneous inflation is around 1.53% because the June 2023 reading is at 1.28%.

Inflation of commodities (less food and energy) is falling fast. The conventional measure is at 1.4% but instantaneous inflation has been negative in some of the recent months, reflecting the negative readings that started in September 2022. Finally, services (less energy) inflation of all measures is close to 6%. When prices of services were rising in the first semester of 2022, instant inflation was picking up faster while conventional inflation was increasing much slower. By now, the monthly readings of services inflation have started to fall leading to a temporary coincidence of conventional and instantaneous

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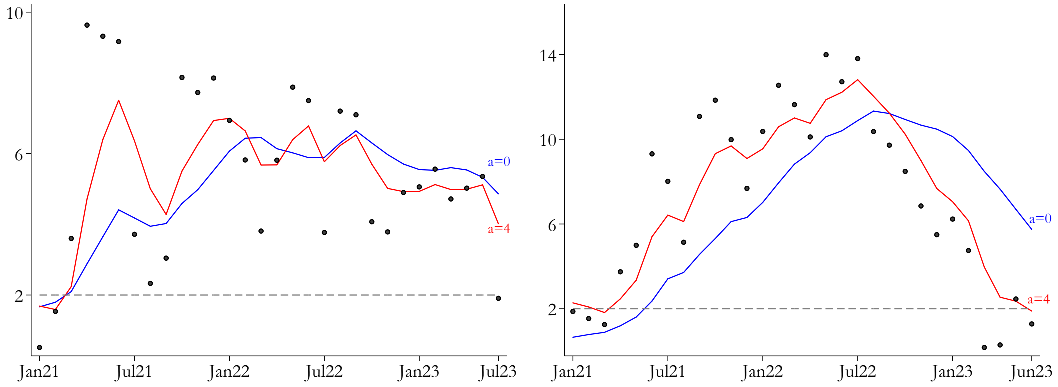
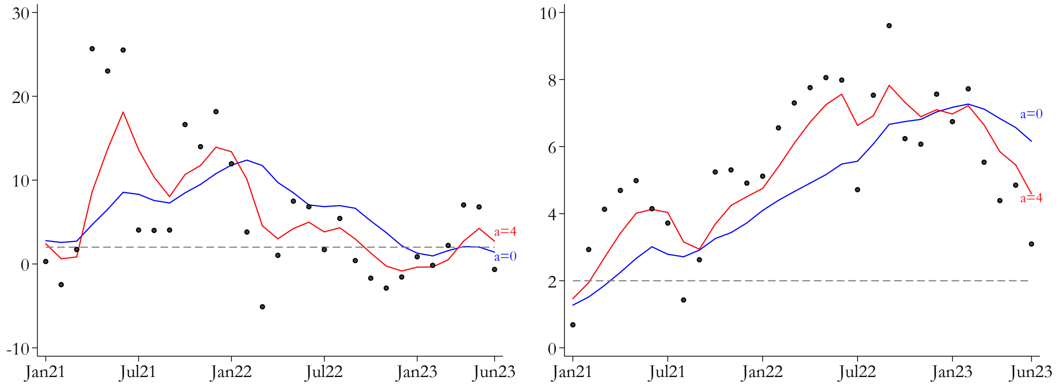
[4] Since for low levels of inflation (i close to zero), $\log(1 + i) \approx i$, in that case we can also approximate the instantaneous inflation as $i_t^{\kappa} = \sum_{\tau=0}^{11} \kappa(\tau) i_{t-\tau}$.



(a) Core inflation: all less food and energy

(b) Food



(c) Commodities less food and energy

(d) Services less energy services

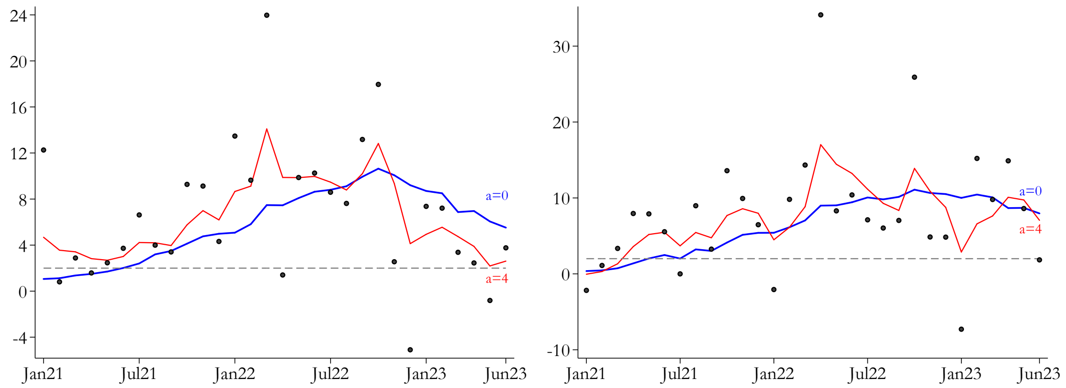
Figure 3: Instantaneous Inflation US for different values of a (Source: BLS)

inflation.

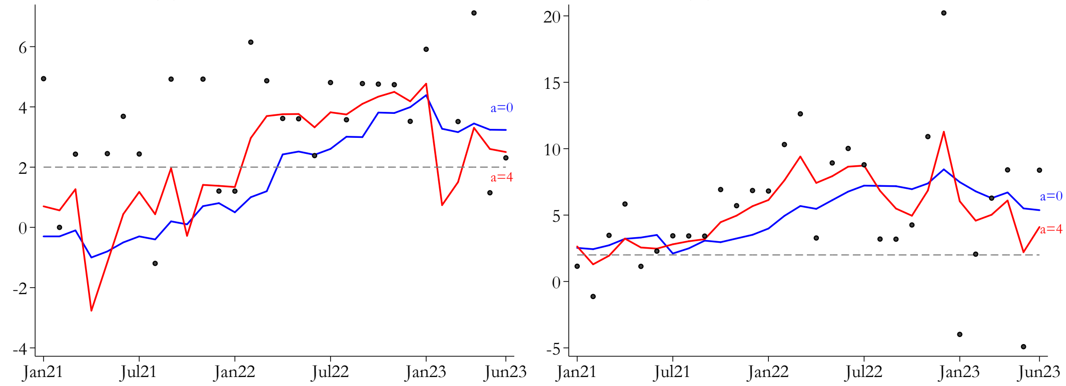
Other countries. Turning to difference currency areas, we see inflation in the Eurozone remarkably mirrors what happens to price in dollars in the United States. The monthly reading for inflation in May 2023 was negative and instantaneous inflation is falling fast. It has not reached 2% yet (it is 2.61 %) but it is substantially lower than the conventional inflation measure which is at 5.5%.

The British Pound illustrates the role of noisy observations. While the series over the whole year of 2022 is rather stable, two outliers in April and October with monthly inflation readings at 34% and 25%. These two extreme outliers demand caution using excessive smoothing. While the monthly inflation readings for November and December are around 4% (for June monthly reading is 1.84%), the average inflation measures that we report hover around 10% (7.06%).

Monthly inflation readings in Japan are lower than in the UK, resulting in the reported average inflation measures being around 3-4%, but like the UK, there are are outliers (for example October 2022). In any event, inflation remains 2 percentage points above the 2% target, and there is as of yet, no downward trend.



(a) Euro (Source: ECB) (b) GBP (Source: ONS)



(c) YEN (Source: SBJ) (d) AUS$ (Source: ABS)

Figure 4: Instantaneous Inflation across currency areas for different a

Australia's average inflation measures are all around 5% with little sign of a downward trend. There are some outliers in recent months, especially downward towards 2%. Given such volatility, a higher bandwidth with less smoothing (lower a) is warranted.

In the Appendix I report the same figure for a several individual countries, both those in the Euro area and around the world.

The Optimal Bandwidth. The discussion of the different baskets and the currency areas makes manifest that the bandwidth (the value of a) should change depending on the data. If there is virtually no noise in the data (food prices in the US in 2022 is an example), then the optimal bandwidth should be low (a large) and put a lot of weight on the most recent observations. Clearly, the optimal bandwidth varies in time (for example, in the Summer of 2022, there was substantially more volatility in food prices).

As in the kernel density estimation literature, also here the optimal bandwidth is a function of the variance across different observations. The higher the variance in the data, the higher the bandwidth (the lower a).

Formally different criteria can be used to select the optimal bandwidth. A common one is the mean integrated squared error. Note that the optimal bandwidth can also change over time as the series evolves. A common rule of thumb based on Gaussian basis functions is to use bandwidth that minimizes the mean integrated squared error, where the bandwidth corresponds to the sample standard deviation adjusted for an inverse function of the number of observations (see Silverman (1986)).

Using Inflation Expectations. Price data are published with an average delay of one month. Typically, prices collected throughout the month of December are published mid January. To remedy the bias from the delay, we can use inflation expectations about future inflation. There are multiple ways to measure inflation expectations. Whichever measure we choose, we can use inflation expectations when we don't have published current data yet, or for future data.

We then use a kernel function that is not only backward looking, but also forward looking where observations about inflation expectations in the distant future receive a lower weight than observations in the near future. Now we can use all the standard symmetric kernels used in the kernel density estimation literature – for example the Gaussian kernel. And we can of course use kernels with asymmetric weights on the past data and the future expectations.

Inflation in Real Time. Since data is collected over the duration of a whole month and we aggregate over time anyway, we can now also start dreaming of a real-time measure of inflation. As soon as a good is scanned and is sent to the BLS servers, we can update the average inflation number instantaneously, with the kernel weight moving in real time. Instead of having to wait for the price readings from early December to be reported in mid January, we can report an inflation number on December 1st that has data from December 1st. Of course, real-time inflation will change very slowly, because we use weighted data from a window, but that is precisely the point.

And if over time the noise changes, the bandwidth parameter can be adjusted in real time too, so we can publish a real-time inflation measure in conjunction with the bandwidth to inform about the precision and instantaneity of the inflation number. Stock market tickers are on the screens of many TV channels, but arguable the most important data point is updated once every month and with an average of 6 months delay.

Conclusion

Most often, the information regarding inflation is time-sensitive. The sooner the data is published, and the more informative it is about what happens to prices *now*, the better. This is important for monetary and fiscal policy, for labor and procurement contracts, and for inflation-indexed financial instruments. Moreover, reported inflation data anchor decision makers' beliefs, and inflation expectations of the public are a key variable that affects the effectivity of monetary policy.

The conventional measure of inflation lives in the past: it puts a lot of weight on observations that are 12 months gone. It makes sense to improve inflation the public's perception of inflation and hence inflation expectations by publicizing instantaneous inflation. Because data is noisy, we cannot use the monthly inflation reading, but we can construct an average that puts higher weights on more recent observations. The optimal weight is a function of how much variability there is in the data.

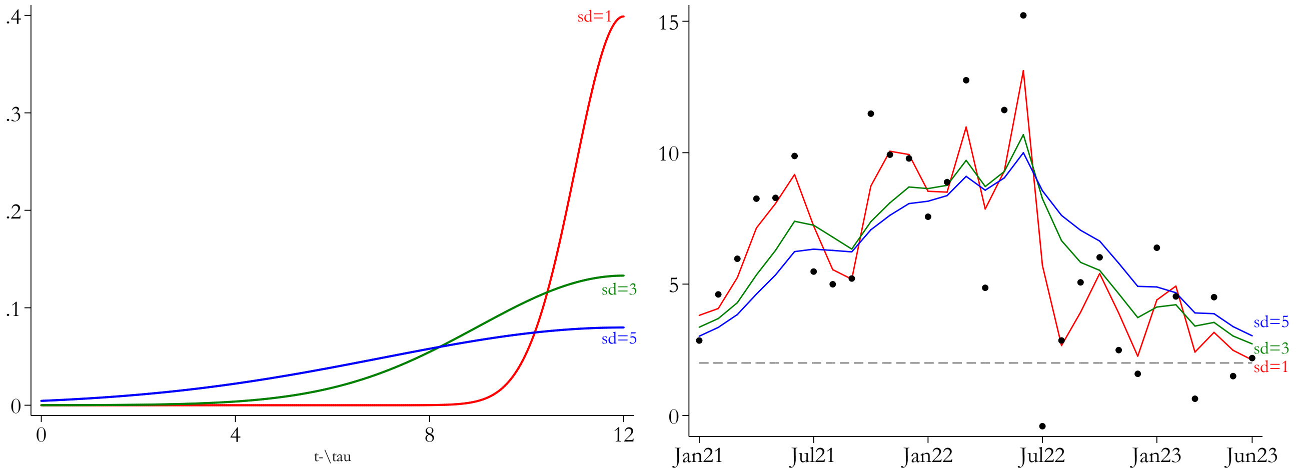
Appendix

Appendix A Data Sources

1. Figures 1 and 2b. Data source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [series id: CUSR0000SA0]; https://beta.bls.gov/dataViewer/view/timeseries/CUSR0000SA0, July 13, 2023.
2. Figure 3a. Data source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average [series id: CUSR0000SA0L1E]; https://beta.bls.gov/dataViewer/view/timeseries/CUSR0000SA0L1E, July 13, 2023.
3. Figure 3b. Data source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: Food in U.S. City Average [series id: CUSR0000SAF1]; https://beta.bls.gov/dataViewer/view/timeseries/CUSR0000SAF1, July 13, 2023.
4. Figure 3c. Data source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: Commodities Less Food and Energy Commodities in U.S. City Average [series id: CUSR0000SACL1E]; https://beta.bls.gov/dataViewer/view/timeseries/CUSR0000SACL1E, July 13, 2023.
5. Figure 3d. Data source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: Services Less Energy Services in U.S. City Average [series id: CUSR0000SASLE]; https://beta.bls.gov/dataViewer/view/timeseries/CUSR0000SASLE, July 13, 2023.
6. Figure 4a. Data source: European Commission (Eurostat) and European Central Bank calculations based on Eurostat data, Indices of Consumer prices, Overall index, Euro Area (changing composition), [series id: ICP.M.U2.Y.000000.3.INX] https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=122.ICP.M.U2.Y.000000.3.INX, July 26, 2023.
7. Figure 4b. Data source: Office for National Statistics, Consumer Price Index: All Items [series id: D7BT] https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7bt/mm23, July 26, 2023.
8. Figure 4c. Data source: Statistics Bureau of Japan, Consumer Price Index, All items [series id: 901], https://www.e-stat.go.jp/en/stat-search/files?stat_infid=000032103846, July 26, 2023.

9. Figure 4d. Data source: Australian Bureau of Statistics, The monthly Consumer Price Index, All groups [series id: A128478317T], `https://www.abs.gov.au/statistics/economy/price-indexes-and-infla` `monthly-consumer-price-index-indicator/nov-2022#data-downloads`, July 26, 2023.

Appendix B Gaussian Kernel



(a) Kernel weights $\kappa(\tau; \sigma)$ for different values of σ

(b) Instantaneous Inflation for different values of a

Figure B.1: Gaussian Kernel and Instantaneous Inflation US

Appendix C Individual Countries

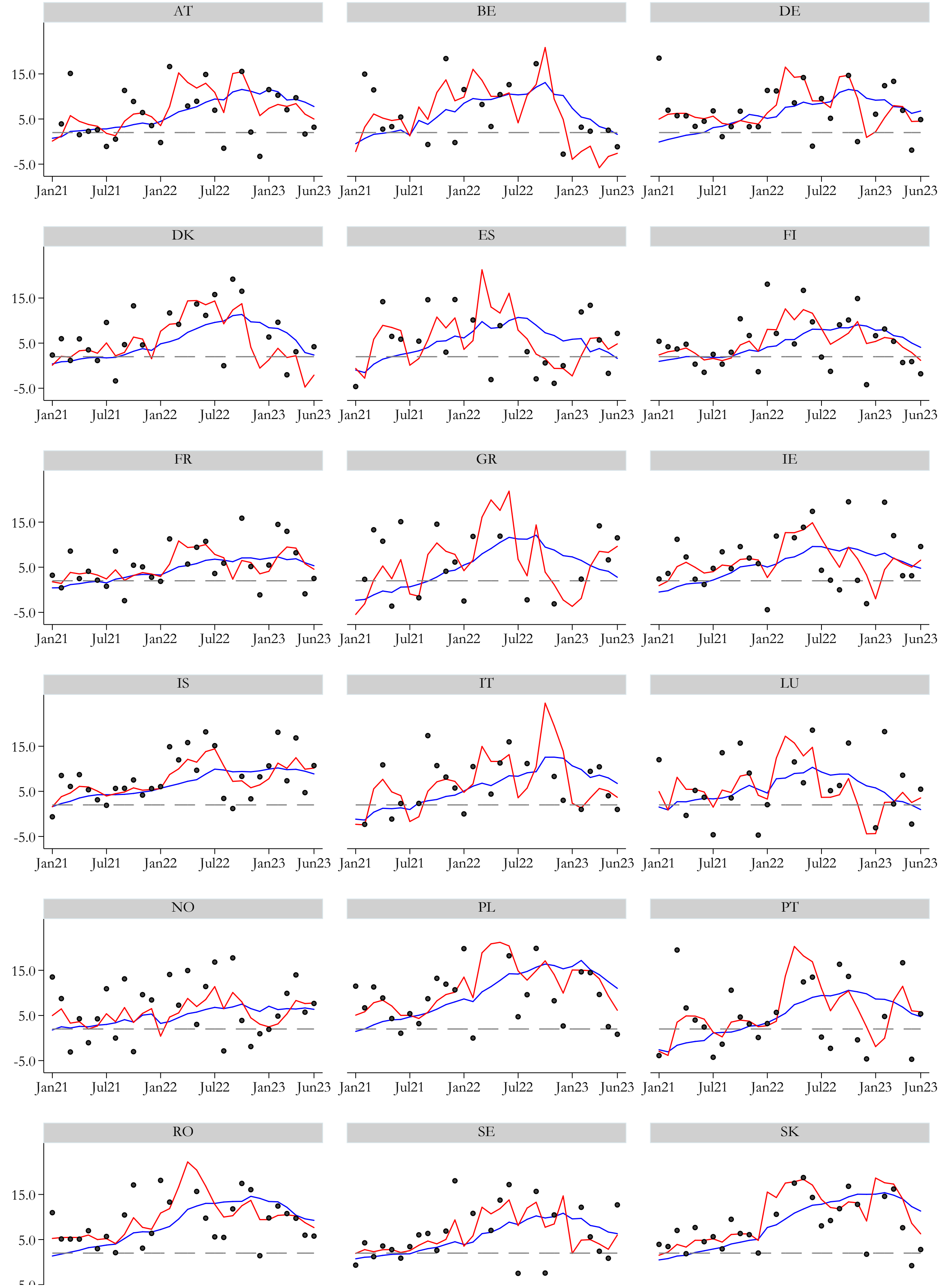


Figure C.2: Europe – part 1

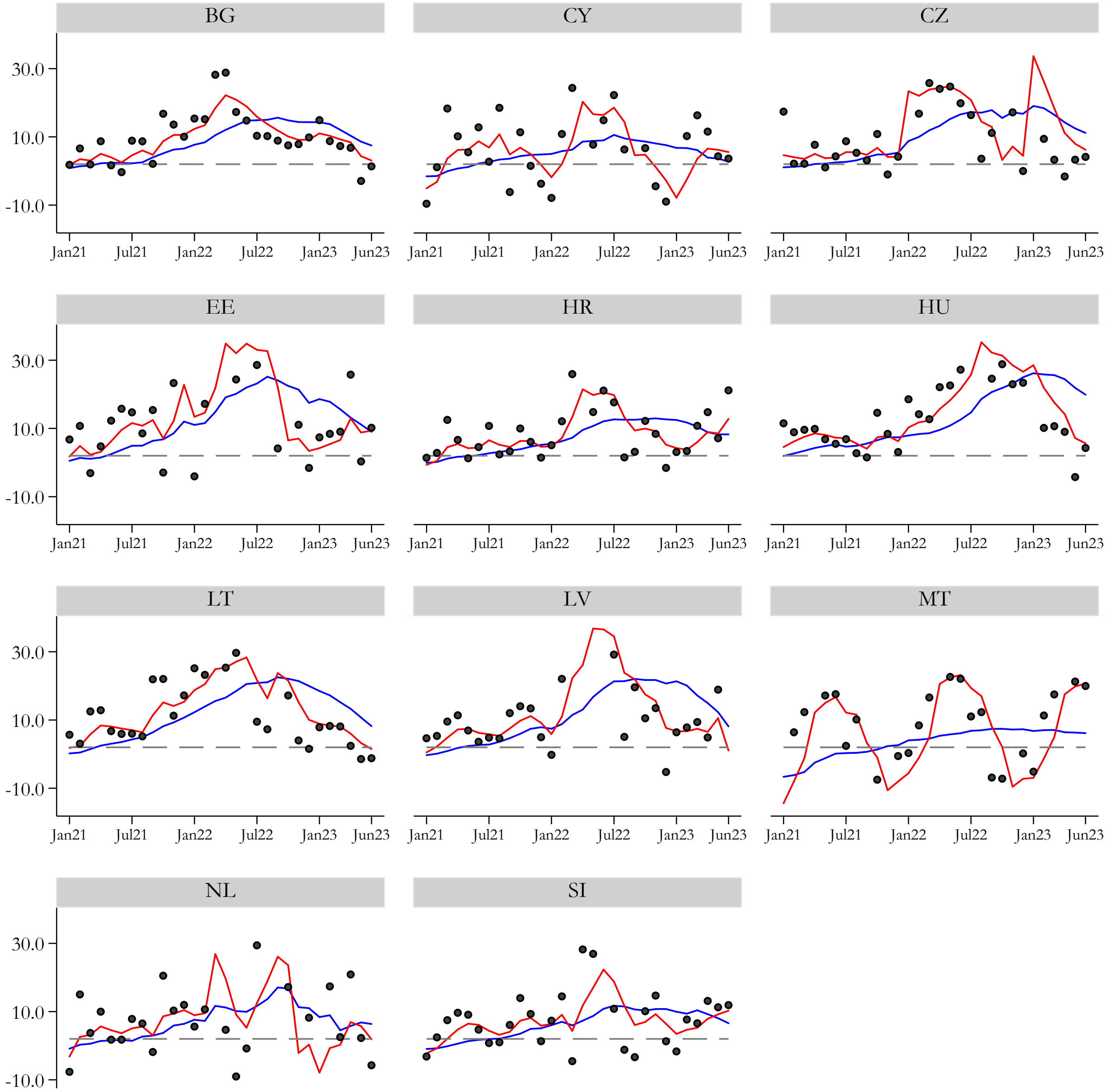


Figure C.3: Europe – part 2

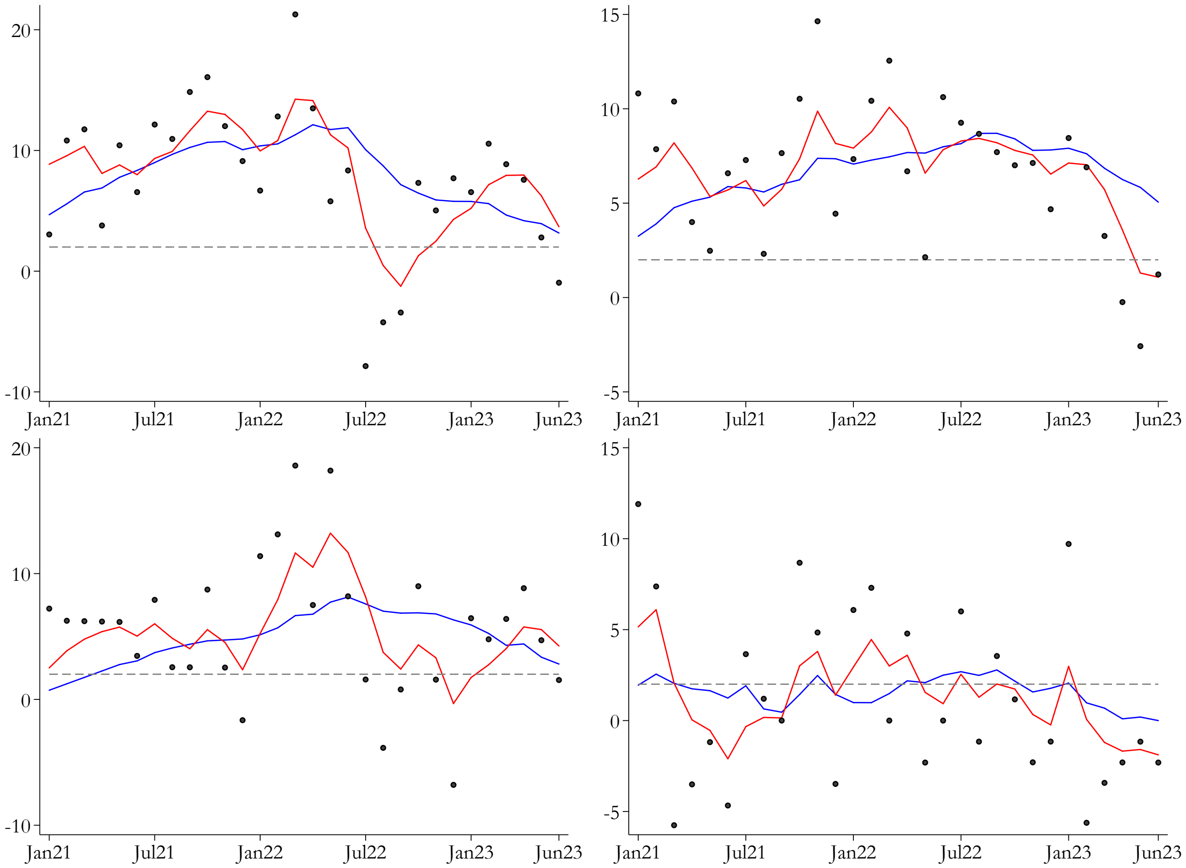


Figure C.4: Brasil, Mexico, Canada, China

References

ARIOLI, R., C. BATES, H. DIEDEN, I. DUCA, R. FRIZ, C. GAYER, G. KENNY, A. MEYLER, AND I. PAVLOVA (2017): “EU consumers’ quantitative inflation perceptions and expectations: an evaluation,” Tech. rep., ECB Occasional Paper.

COIBION, O., Y. GORODNICHENKO, AND R. KAMDAR (2018a): “The formation of expectations, inflation, and the phillips curve,” *Journal of Economic Literature*, 56, 1447–1491.

COIBION, O., Y. GORODNICHENKO, AND S. KUMAR (2018b): “How do firms form their expectations? new survey evidence,” *American Economic Review*, 108, 2671–2713.

HALL, R. (2023): “A Major Shock Makes Prices More Flexible and May Result in a Burst of Inflation,” Stanford mimeo.

HÄRDLE, W. (1990): *Applied nonparametric regression*, Cambridge University Press.

MANKIW, N. G., R. REIS, AND J. WOLFERS (2003): “Disagreement about inflation expectations,” *NBER macroeconomics annual*, 18, 209–248.

SILVERMAN, B. (1986): *Density Estimation for Statistics and Data Analysis*, Chapman & Hall.