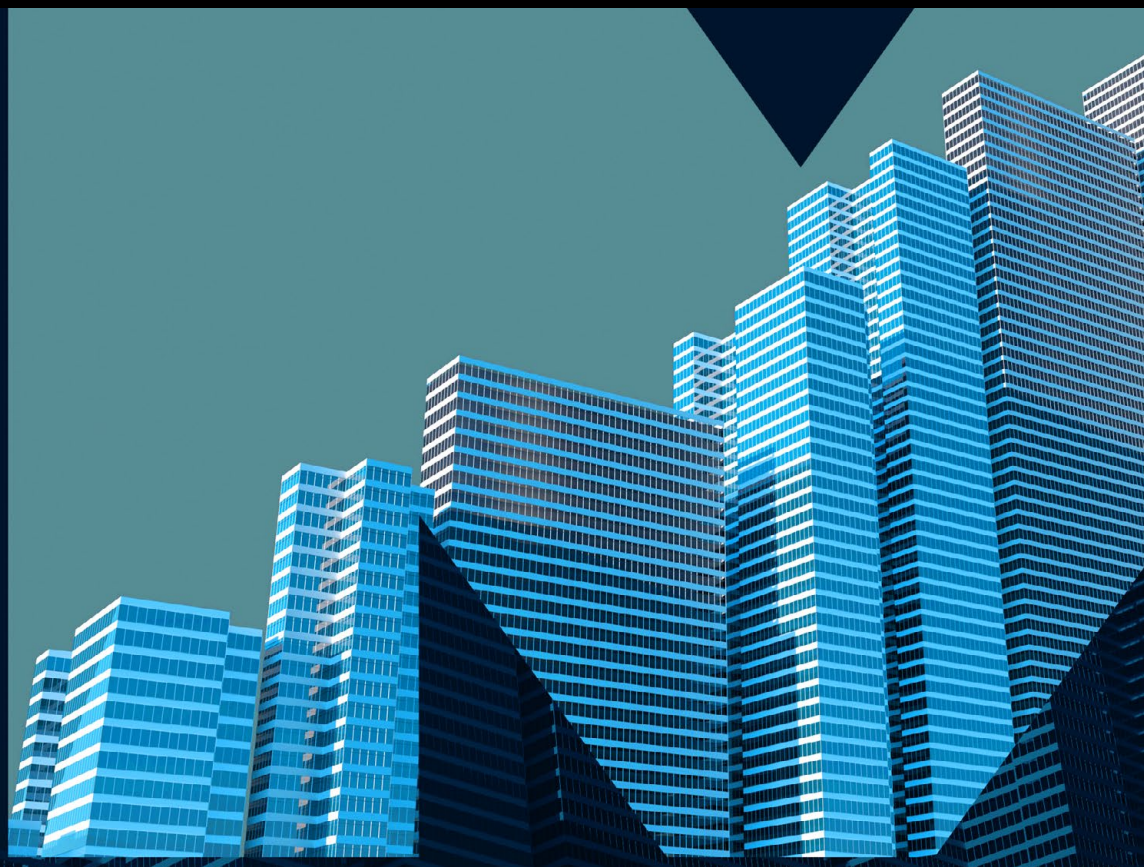

Inflation – What Does the Academic Research Say?

July 2021

Time to read: 104 minutes

We review the state of the scientific literature on various topics on inflations, including: defining and measuring inflation; the causes and consequences of inflation; and trading inflation. Our goal is not to provide answers, but rather to present the past and current debates on these topics.

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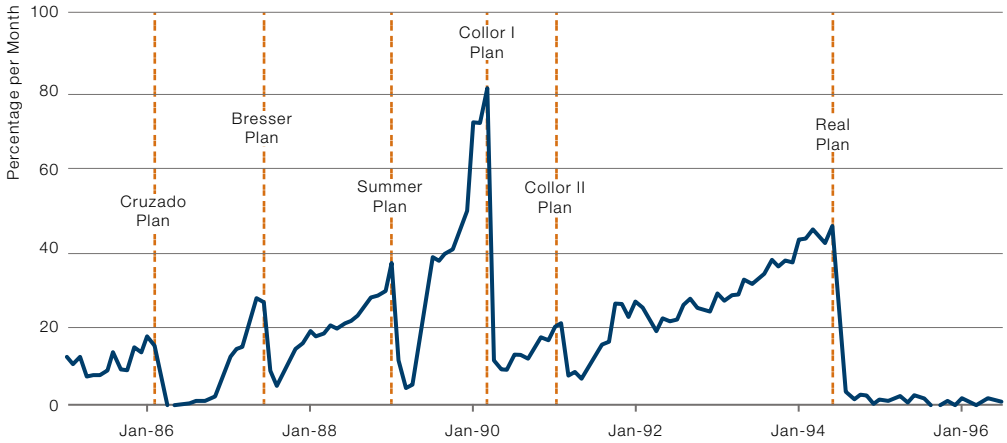
1. Introduction

Economic outcomes are, through changes in the expectations of market participants, a key determinant of asset prices. Inflation is of particular importance, and "has been the bane of central bankers" since World War II, as per the opening words of Ben Bernanke's famous speech (Bernanke B., 2002). Many structural factors are critical in determining the economic climate, such as the rule of law, the strength of – and the trust in – institutions, the quality of infrastructure, the fairness, effectiveness and incentive structure of the tax system and the welfare state, but inflation is a key focus of cyclical policies.

Both deflation and high inflation are likely to create highly unfavourable economic outcomes. Once deflation sets in, typically as a result of a collapse in aggregate demand, it can be hard to escape. Purchases today are postponed in anticipation of lower prices tomorrow, contributing to a spiral of lower economic activity and lower prices. A liquidity trap might follow: cash becomes preferable to debt with virtually no yield, and changes in the money supply do not affect the price level. Debt-deflation periods ensue as rising real debt burdens become increasingly at risk of default when prices and economic activity fall (Fisher I., 1933), (Bernanke B., 2002). Periods of high and volatile inflation lead to bad economic outcomes and tend to persist, too. Periods of hyperinflation, commonly defined as month-on-month inflation over 50% (Cagan, 1956), typically involve money printing to finance government spending, taken to extreme levels. Paper assets lose value rapidly, and in periods of hyperinflation governments print banknotes with ever larger denominations.

Moving from a period of a predictably low and stable inflation to a more volatile environment creates a more uncertain economic future and potentially undermines confidence in nominal assets such as the value of the paper currency. This uncertainty contributes to poor economic performance in economies that are not designed to deal with high and volatile inflation (Fischer, Sahay, & Vegh, 2002), (Cagan, 1956), (Fischer & Modigliani, 1978). Countries experience enormous difficulty in escaping periods of high and volatile inflation. Typically, when a first stabilisation attempt fails, for instance when politicians do not persist with unpopular fiscal austerity policies, confidence in the success of subsequent attempts is lower, thus making the task even more difficult (Vegh, 1992), (Reinhart & Rogoff, 2008). Figure 1, a plot of inflation and stabilisation plans in Brazil, shows the point.

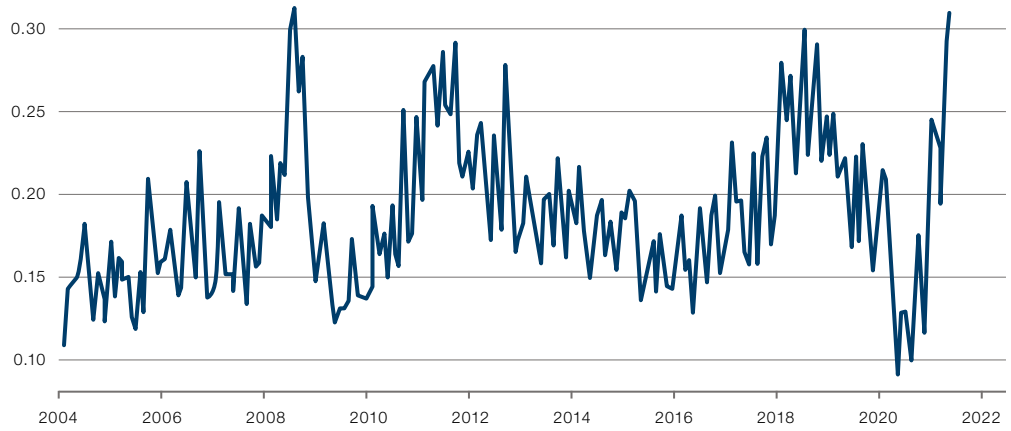
Figure 1. Inflation and Stabilisation Plans in Brazil



Source: Ayres, Garcia, Guillen, & Kehoe, 2019.

The unprecedented stimulus measures that followed the crisis caused by the coronavirus pandemic have cast doubts on the persistence of the stable and moderate inflation prevailing since the mid-1980s. This has generated a renewed interest in the concept of inflation, as shown in Figure 2, showing that the percentage of firms' transcripts mentioning inflation has reached the level of the Global Financial Crisis.

Figure 2. Percentage of transcripts mentioning inflation



Source: Man AHL; as of 8 June 2021.

In this document, we set out to review the state of the scientific literature on the topic from a number of different points of view:

- Defining and measuring inflation:
  - Is there a benefit in considering different inflation measures than the headline?
  - Can temporary and persistent inflation shocks be distinguished ex ante?
  - What is our current understanding of past inflation?
- Causes and consequences of inflation:
  - Besides the monetary environment, are there other causes of inflation?
  - How does inflation impact economic growth?
  - (How) Should policymakers target inflation?
- Trading inflation:
  - How do different financial assets correlate to changes in inflation expectations?[1]
  - How do market participants form and express inflation expectations?
  - What is the state-of-the-art of inflation forecasting?

We remark that the goal of the present work is to represent the past and current debates on these topics, rather than providing answers to the questions above.

1. Despite the importance of this topic, because of the very recent publication of (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021), we only briefly touch on it.

2. Defining Inflation

Inflation is a measure of change in the general price level of an economy. This statement describes an ambiguous concept, and a plethora of different ways of measuring, or rather defining, inflation is available today. This section touches on the following topics:

- A short historical review of the concept of inflation and price indices;
- The definition(s) of the Consumer Price Index;
- Other commonly used inflation measures: PPI, PCE, GDP deflator;
- The concept of core, or steady-state, inflation:
  - What does it add to headline inflation?
  - What is the state-of-the-art of its definition?

2.1. Historical Review of Inflation Definitions

Inflation is the first derivative of a so-called *price index*: a time-series describing the evolution of the price of a certain set of goods over time, which are special cases of *index numbers*.

A first exercise in this direction was a comparison of wages in the English kingdom from the 14th to the 17th century, done in (Vaughan, 1675), whose aim was to distinguish the inflationary effects of currency debasement from the ones originating from the inflow of precious metals from the newly discovered America. Shortly after, (Fleetwood, 1707) constructed a price index with data starting in the 8th century to show and measure the decline of the purchasing power of an annual income of five pounds from the 15th century to his current days (18th century). A last relevant early study is (Carli, 1764), who is often mistakenly attributed to the creation of the first price index, as he used a simple average of relative prices of wheat, wine and oil to examine the price fluctuations occurring in Italy between 1500 and 1750. His calculations were still missing the relative weighting of goods, but the novelty was that he used different commodities for estimating a unique price index. A more formal study of price indices was initiated towards the end of the 19th century in Germany by scholars such as Laspeyres or Paasche. We refer the historically interested reader to (Chance, 1966), (Kendall, 1977), (Diewert, 1988), or (Lippe, 2013), as well as the book (Fischer D. H., 1996).

Developing a suitable price index is generally a complex task: A set of goods and services has to be chosen in the first place, their prices have to be observed and recorded, some of these products naturally change over time, the prices of some of these products feature seasonal or geographical idiosyncrasies, hedonic adjustments may have to be applied so as to reflect the increased utility to the user of an evolving product such as a mobile phone or watch, and even the choice of the algorithm for combining these prices is not a trivial choice. In the words of Angus Deaton (Deaton A. S., 1981):

> *"The theory and measurement of economic index numbers presents side-by-side some of the most difficult and abstruse theory with the most immediately practical issues of everyday measurement."*

A full discussion of the theory of index numbers would be out of place, but for an overview and a detailed discussion of the theorical and practical difficulties of developing price indices in particular we refer the reader to the state-of-the-art manuals (ILO, et al., 2020) and (ILO, IMF, OECD, UNECE & WorldBank, 2004).

2.2. Consumer Price Index

"A Consumer Price Index is a measure of price changes of the goods and services purchased by households in their role as consumers."

– (ILO, et al., 2020).

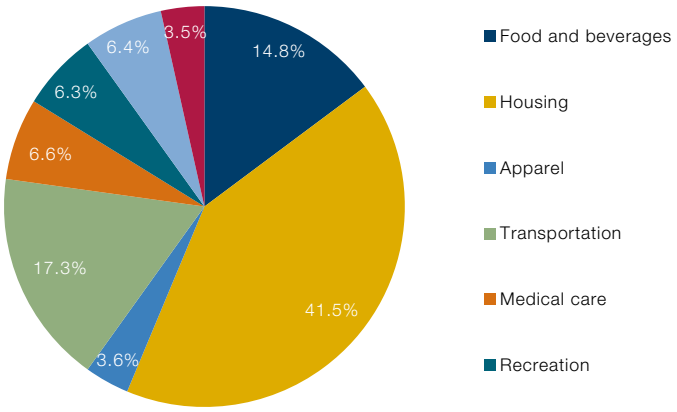
Variations of the Consumer Price Index ('CPI') are the most widely used measures of inflation. The internationally recognised manual just cited provides guidelines and recommendations to the local offices responsible for calculating their own version of the CPI. However, the methods used to compute CPIs differ from country to country, and even in the same country a few different variations might be provided:

- The US Bureau of Labor Statistics computes three **CPIs**: The CPI for All Urban Consumers ('CPI-U'), the CPI for Urban Wage Earners and Clerical Workers ('CPI-W'), and the Chained Consumer Price Index for All Urban Consumers ('C-CPI-U');
- The British Office for National Statistics calculates three **CPIs**: A Consumer Prices Index ('CPI'), a Consumer Prices Index including owner occupiers' housing costs ('CPIH'), and a Retail Prices Index ('RPI'). The latter is not an official statistic in the UK, but there still is a considerable amount of RPI-linked securities due to disappear by 2030. An overview on the topic is given in (Marshall, Merali, & Virij, 2020);
- The Italian Istituto Nazionale di Statistica calculates three **CPIs**: A consumer price index for the whole nation ('NIC'), a consumer price index for blue and white-collar worker households ('FOI'), and a harmonised index of consumer prices calculated according to the EU regulations in force ('HICP');
- Furthermore, some international organisations provide their own harmonised versions of local indices for ease of comparison across countries. For example, the OECD publishes the Harmonised Index of Consumer Prices for member states and selected third countries.

It is important to observe the criticism that the CPI received in the last decades: the index is defined to measure the change in the prices of goods, but it is used to measure changes in the cost of living. Moreover, the heterogeneity of consumers implies that a single price index can only represent a generic average consumer. In the case of the US, (Moulton & Moses, 1997) reports a bias in the CPI exceeding +1% per annum, and mainly coming from not properly accounting for improvements in the quality of goods and for consumers' changing preferences following changes in relative prices. A thorough discussion of the issue of quality change in goods and the biases affecting the CPI can be found in (ILO, et al., 2020).

The composition of a basket of goods is often dynamic, as it has to take into account the changing quality of goods, but also that entirely new products enter the market. For example, the composition of the CPI basket in the US is determined by the spending habits of selected households over the previous years. Figure 3 shows the composition of the CPI as of 2008.

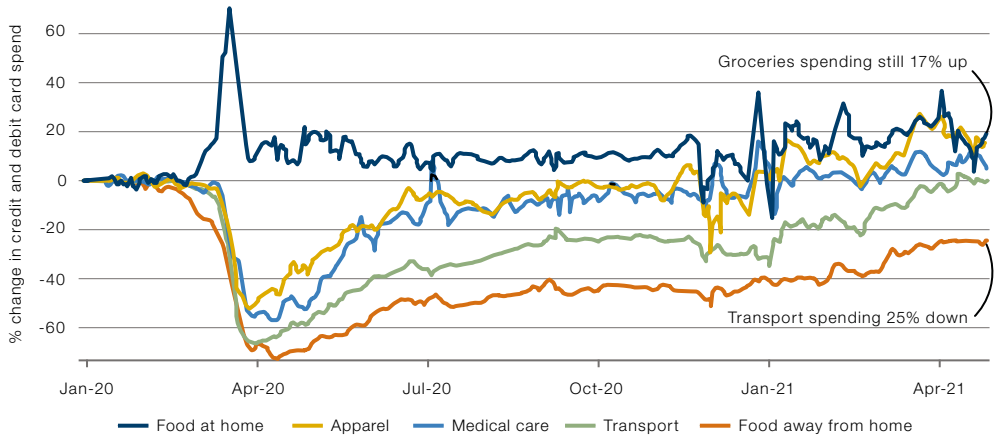
Figure 3. Composition of CPI as of 2008



Source: Table Rock Financial; as of 19 January 2012.

To illustrate the problem of the lack of stationarity of consumer's preferences, we report a breakdown of the changes in spending starting with the pandemic (Figure 4).

Figure 4. Lockdowns Forced Large Changes in US Spending Patterns



Source: Financial Times; as of 7June 2021.

2.3. Other Commonly Used Inflation Measures

The CPI is the most widely used measure of inflation, but it is not the only one. In this section we introduce three other measures that are often considered.

2.3.1. Producer Price Index

"Producer Price Indices measure the rate of change in the prices of goods and services bought and sold by producers."

– (ILO, IMF, OECD, UNECE & WorldBank, 2004).

Exactly as for the CPI, the PPI is a family of price indices following guidelines set out in the manual just cited. It is worth noting that the notion of PPI was pre-dated by the Wholesale Price Index, which measures the rate of change in the prices of wholesale goods. The US changed from the latter to the former in 1978, but in other countries, such as India or the Philippines, this is still used.

It is conventional wisdom that movements in the PPI anticipate or parallel same-direction movements in the CPI, as higher costs are passed from producers to consumers with a delay. The pass-through of PPI into CPI has been vastly tested, but there is no general agreement on a one-way causality between the PPI and the CPI. We review the literature on the topic when examining the causes of inflation.

Personal Consumption Expenditure Price Index

An important measure of inflation is the rate of change of Personal Consumption Expenditure ('PCE') Price Index. Its relevance derives mainly for having been adopted by the Federal Reserve as its primary measure of inflation in place of the CPI (Greenspan, 2000). According to the **Bureau of Economic Analysis**, the main differences with the CPI are:

- The CPI measures the spending by the personal sector, while the PCE measures the spending by and on behalf of the personal sector. The spending of non-profit institutions serving the personal sector is included in the latter but not in the former;
- The algorithms used for computing the price index;
- The weights allocated to each item in the tracked basket of goods.

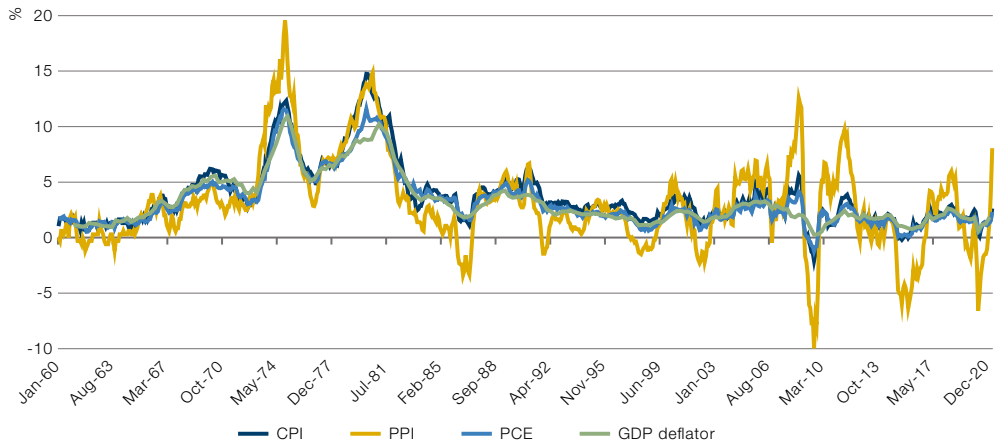
A more detailed analysis of the differences between PCE and CPI can be found in (Johnson, 2017).

2.3.2. GDP Deflator

Another relevant family of inflation measures is the one of GDP deflators. In its most basic form, a GDP deflator is defined as the ratio of nominal GDP and real GDP. The main difference with all the other inflation measures considered so far is that it is not based on a basket of goods and services, but it tracks price changes in the whole economic output of a country. A self-contained work on the details involved in the calculation of a GDP deflator is (Chowdhury, 2008). It must be noted that, being based on the computation of real GDP, a GDP deflator seems from the same drawbacks. As an example, improved terms of trades could be treated as a price phenomenon (Kohli, 2004).

In Figures 5-6, we compare these four different measures in the US since 1960. In Figure 5, we plot their timeseries, and in Figure 6, their correlation. The series of PCE is from the US Bureau of Economic Analysis, the other series are provided by OECD.

Figure 5. Inflation Measures in the US



Source: PCE from US Bureau of Economic Analysis, as of 18 May 2021; other series from OECD, as of 27 April 2021.

Figure 6: Correlation of US Inflation Measures

	CPI	PPI	PCE	GDP Deflator
CPI	1.00	0.86	0.98	0.95
PPI	0.86	1.00	0.85	0.79
PCE	0.98	0.85	1.00	0.97
GDP Deflator	0.95	0.79	0.97	1.00

Source: PCE from US Bureau of Economic Analysis, as of 18 May 2021; other series from OECD, as of 27 April 2021.

Except for the PPI, that is highly volatile, all the other measures are strongly correlated. We further remark that another important measure is acceleration of inflation, as inflation itself is quite sticky. In Figure 7, we report the autocorrelation, with a lag of 12 months to avoid overlaps, for each one of these measures.

Figure 7. Autocorrelation for US Inflation Measures

CPI	PPI	PCE	GDP deflator
0.76	0.37	0.81	0.87

Source: PCE from US Bureau of Economic Analysis, as of 18 May 2021; other series from OECD, as of 27 April 2021.

2.4. Core Inflation

A core inflation measure is a normalisation of the chosen inflation measure, often the CPI, aimed at removing transient effects. Whereas the official core inflation in the US is defined by removing food and energy from the CPI, other – more sophisticated – constructions have been proposed over time.

In (Bryan & Cecchetti, 1994), it is argued that monetary authorities should only aim at controlling aggregate inflation as a monetary phenomenon, thereby disregarding transient shocks such as increased food prices because of poor weather. This view is a generalisation of the analysis done 20 years earlier in (Gordon, 1975), where the large US inflation of 1973-1974 is decomposed into a 'hard-core' inflation inherited from the previous decade and four temporary bubbles. The author's view is that the latter components might have had a permanent effect on the price level, but they did not change inflation *per se*. The core inflation was then defined quantitatively in (Eckstein, 1981) who decomposed the Consumer Price Index into the sum of core inflation, demand-driven inflation, and supply shocks. Eckstein's model has been criticised for the difficulties of its empirical estimation (Parkin, 1984).

The motivation for having a working definition of core inflation is not debated, but achieving this goal is the objective of a substantial number of papers. The working definition of the US Bureau of Labor Statistics consists in a weighted average of the CPI components apart from food and energy since these are the most volatile. (Bradley, Jansen, & Sinclair, 2014) observe that removing food and energy only captures permanent inflation when the latter has order of integration 1 rather than 0. An alternative approach, begun in (Bryan & Cecchetti, 1994) and finalised in (Bryan, Cecchetti, & Wiggins, 1997), consists in estimating the aggregate consumer price inflation using trimmed means of the distribution of price changes. This stems from the observation that the cross-sectional distribution of inflation is not only volatile, but it also has very fat tails. (Cogley, 2002) observes how both measures do not fulfil a crucial requirement for a core inflation, namely that the difference between actual and core inflation should predict subsequent changes in inflation. The author does not try to estimate the noise to be removed from the actual inflation to get the core inflation, but it instead directly estimates the persistent part of inflation. He shows that a simple exponentially weighted average of past inflation is a good estimator under reasonable and loose assumptions.

Which definition of core inflation better captures permanent inflation is still the subject of novel research. A first analysis is done in (Clark, 2001), who compares CPI ex energy and food, CPI ex energy, CPI ex eight selected components, trimmed-mean CPI, and median CPI. The author finds that trimmed-mean CPI and CPI ex energy, but not food, are the best performers in his sample. (Rich & Steindel, 2007) run a comparison of measures of core inflation on equal ground and find that CPI ex food and energy underperforms other statistical normalisations. This was also shown in (Detmeister, 2011), who further finds that core inflation performs better than total inflation, and that all these measures should be averaged over a certain period of time to be most effective, as suggested by (Cogley, 2002). More recently, the outperformance of statistical measures over simply removing energy and food has been confirmed in (Luciani & Trezzi, 2019) but not in (Dolmas & Koenig, 2019). However (Crone, Khettry, Mester, & Novak, 2013) have shown that the outperformance of statistical measures is only valid in the medium term, up to two quarters, and that for longer horizons it is not even clear if the measures of core inflation proposed outperform total inflation as predictors of future inflation.

Once novel and even more sophisticated methods are considered, for example dynamically weighting sectors according to the persistence of their variance (Stock & Watson, 2016) or the k-clustering algorithm proposed in (Carrion, 2018), it is clear that there is not yet agreement on what is the 'right' definition of core inflation. To avoid confusion, we further mention that, when considering core inflation, the standard measure of inflation is referred to as *headline inflation*.

3. Historical Behaviour of Inflation

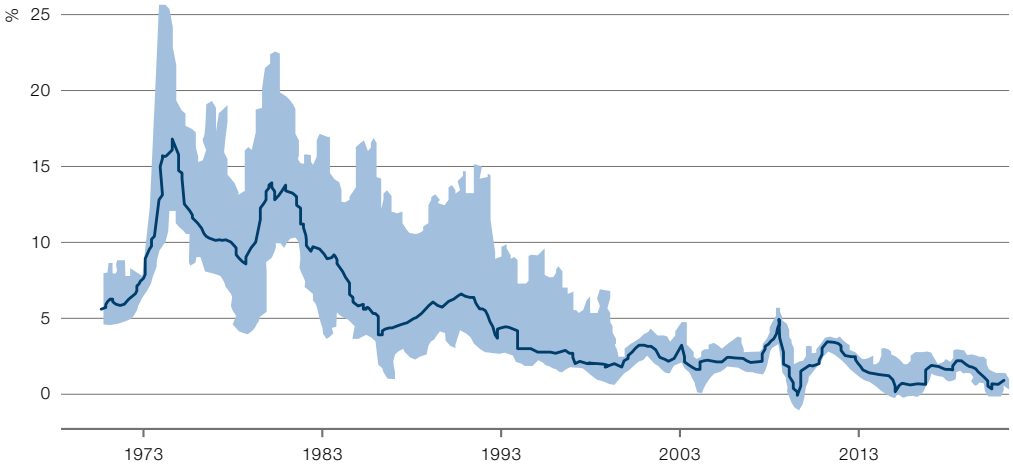
In this section, we present a short historical summary of how it evolved over time in different countries, and a selection of its most extreme examples. Specifically, this section reports on:

- Evolution of inflation in selected countries;
- Definition of Hyperinflation and examples:
  - Germany (1921 – 1923);
  - Israel (1985);
  - Venezuela (2016 – Present);
- Definition of sustained low inflation and examples:
  - Japan (1995 – Present).

3.1. Inflation Time-Series

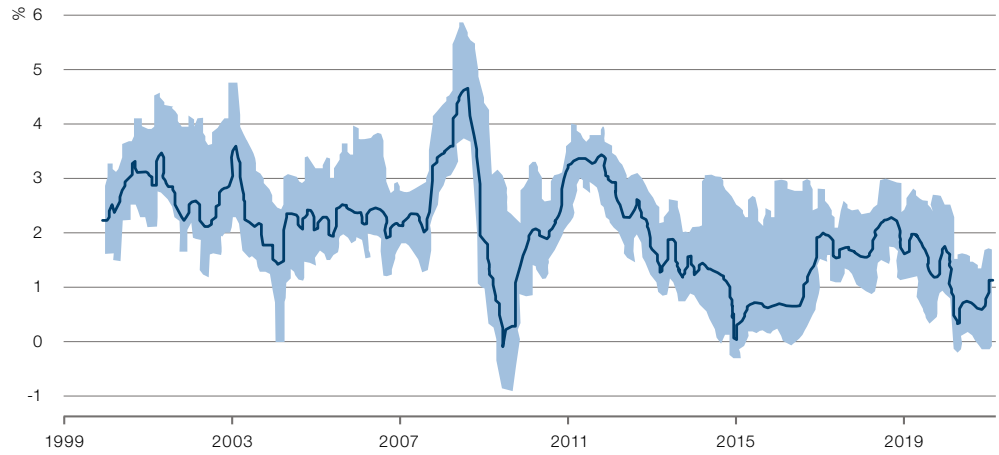
We select the 28 OECD countries for which uninterrupted CPI data since 1971 is provided and plot their median and interquartile range[2], either from 1971 (Figure 8) or from 2000 (Figure 9).

Figure 8. Interquartile Range of Year-on-Year CPI Across Countries (1971-2021)



Source: OECD, as of 27 April 2021.

Figure 9. Interquartile Range of Year-on-Year CPI Across Countries (2000-2021)

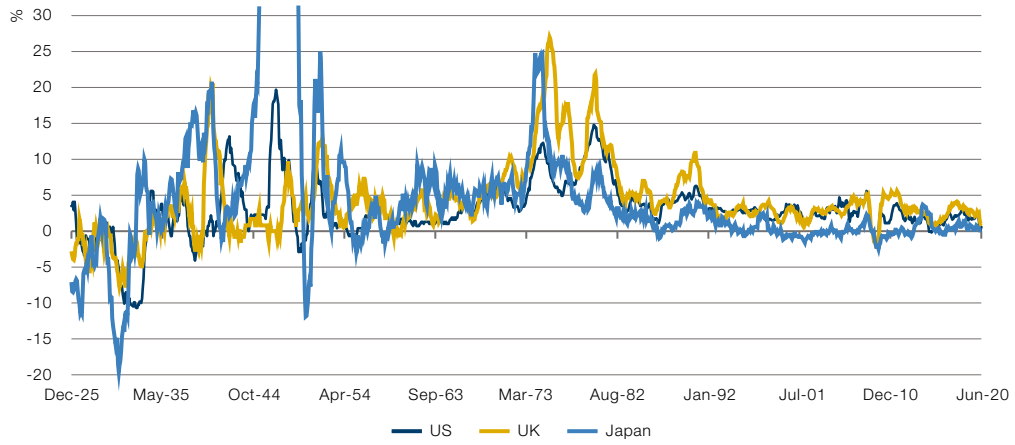


Source: OECD, as of 27th April 2021.

2. The interquartile range is the difference between the 75th and the 25th percentile of a distribution, and it is therefore a measure of dispersion.

For selected countries, it is possible to further extend the time-series of CPI to 1926 using data from Global Financial Data (Figure 10).

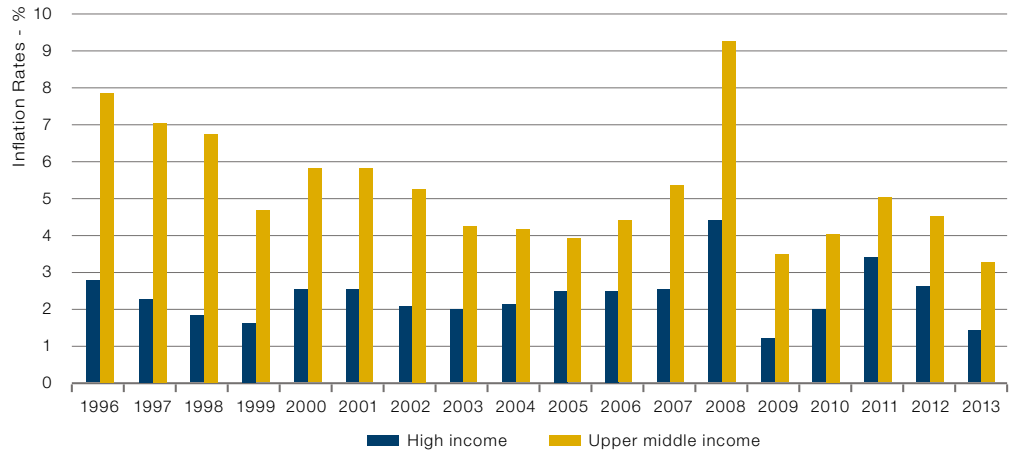
Figure 10. CPI Rates in Selected Countries



Source: Man Group; as of May 2021.

The upper part of Figure 10 is truncated, as the year-on-year inflation in Japan in August 1946 reached 780%. Another interesting evidence piece of evidence is that inflation is higher in low- and middle-income countries than it is in high-income countries. Figure 11 is extracted from (Carvalho, Ribeiro, & Marques, 2017).

Figure 11. Inflation Rates in High- Versus Low-Income Countries



Source: Carvalho, Ribeiro, & Marques, 2017.[3]

3.2. Hyperinflation

Hyperinflation is an instance of very high inflation, and acceleration of inflation is often considered a feature of hyperinflation. The closest notion to a shared formal definition of hyperinflation is given in the seminal paper (Cagan, 1956), who defines hyperinflation to be a month-over-month inflation rate larger than 50%. Besides setting such a threshold, the latter paper proposes a model for describing the behaviour of inflation in such extreme scenarios. The conclusion of the paper is that these episodes are driven by two forces: The monetisation of a deficit, and a momentum component caused by individuals' changing inflation expectations. As he wrote a few years later:

> *"Hyperinflation, if driven by rising expectations of inflation rather than rising money growth, can become a self-generating process."*
>
> – (Cagan, 1989)

A substantial work of data cleaning and systematic comparison has been done in (Hanke & Krus, World Hyperinflations, 2013) who computed a table with all the 56 known episodes of Cagan-hyperinflation that occurred up to 2013, to which new entries, such as Venezuela, Zimbabwe or Lebanon, should be added. Figure 12 is an updated and abbreviated version of the table, and the full original table is available in the appendix.

Figure 12. The Hanke-Krus World Hyperinflation Table (Abbreviated)

Rank	Location	Start Date	End Date	Month with Highest Inflation Rate	Highest Monthly Inflation Rate	Time Required for Prices to Double	Currency	Type of price Index
1.	Hungary	Aug. 1945	Jul. 1946	Jul. 1946	4.19×10^{16}%	15.0 hours	Pengö	Consumer
2.	Zimbabwe	Mar. 2007	Mid-Nov. 2008	Mid-Nov. 2008	7.96×10^{10}%	24.7 hours	Dollar	Implied Exchange Rate
3.	Yugoslavia	Apr. 1992	Jan. 1994	Jan. 1994	313000000%	1.41 days	Dinar	Consumer
4.	Republika Srpska	Apr. 1992	Jan. 1994	Jan. 1994	297000000%	1.41 days	Dinar	Consumer
5.	Germany	Aug. 1922	Dec. 1923	Oct. 1923	29500%	3.70 days	Papiermark	Wholesale
15.	France	May. 1795	Nov. 1796	Mid-Aug 1796	304%	15.1 days	Mandat	Exchange Rate
14.	Venezuela	Nov. 2016	Ongoing	Jan. 2019	315%	14.8 days	Bolivar	Exchange Rate
29.	Zimbabwe	Sep. 2017	Oct. 2017	Oct. 2017	185%	20.1 days	Dollars	Implied Exchange Rate
53.	Yugoslavia	Sep. 1989	Dec. 1989	Dec. 1989	59.70%	45.1 days	Dinar	Consumer

Source: Hanke, Steve H., and Erik Bostrom, "Zimbabwe Hyperinflates, Again: The 58th Episode of Hyperinflation in History." Studies in Applied Economics, No. 90(2017). The Johns Hopkins Institute for Applied Economics, Global Health, and the Study of Business Enterprise, 19 Oct. 2018. Web. https://sites.krieger.jhu.edu/iae/files/2018/07/Zimbabwe-Hyperinflates-Again-Hanke-Bostrom-.pdf

In what follows, we review the literature on selected hyperinflation episodes. We do not list any episode more than a century old, because, albeit interesting, the lack of data makes their scientific study harder.

3. Note that the original caption is misleading, as the lighter bars refer to low and middle income.

3.2.1. Germany (1921-1923)

The Weimar Republic had been affected by a severe hyperinflation in the years following WWI, that brought the value of a gold mark from one to a trillion paper marks. The exact interplay of causes that lead to hyperinflation is still a matter of debate, but two crucial facts are at the centre of the debate: the enormous debt inherited by the newly created republic, which was partly due to the borrowing to fund the war and partly coming from the demand for reparations established in the Treaty of Versailles; and a sharp increase in the money supply. As reported in (Kindleberger, 1984), who nicely summarises the history of the analysis on the topic, the two main schools of thoughts are the *balance of payments* view, that considers the former to be the leading the cause, and the *monetarist view*, which considers the latter to be primal factor. (Laidler & Stadler, 1998) summarise the main features of this episode of hyperinflation in four stylised facts:

- An increase in prices in excess of the increase of the money supply from July 1921. But the relationship was reversed in the period 1913-1918;
- A currency depreciation faster than the rise in domestic prices;
- A perceived shortage of money, especially from January 1920, when the Treaty of Versailles became effective;
- An increase in real balances following the stabilisation that ended inflation.

As of today, there is still active research on this topic. For example (Seghezza & Morelli, 2020) argue that the determining factor to determine the hyperinflation was a sudden stop in the foreign capital inflow, an hypothesis not previously considered. For a brilliant account with economic numbers as well as social anecdotes, we refer the reader to the book (Fergusson, 1975).

3.2.2. Israel (1985)

An episode of almost hyperinflation in Israel has been successfully curbed in the summer of 1985 after the annual growth rate reached almost 500%. This was achieved by an agreement between government, labour unions and central bank that curbed prices, wages and the capacity of increasing the money supply all at once. The success of the plan made this an example for subsequent hyperinflationary episodes. Preliminary works on inflation in Israel ahead of the largest spike are (Bruno & Fischer, 1984) and (Bailey & Tavlas, 1985). A detailed account of the economical setting ahead of summer 1985, and of the plan put in practice then can be found in (Bruno M., 1986) and (Charles & Marie, 2019). In summary, the plan consisted of:

- Cut of public spending and tax raises turned a public deficit of 16.8% of GDP in 1984 into a public surplus of 5.8% of GDP in 1986;
- Prices were frozen for three months, and price controls were put in place;
- The institutional indexation mechanism, which could be seen as a systematised inflation expectation mechanism, was dismantled. In particular, the labour unions had to agree to salaries of workers being frozen for three months;
- New deposits indexed to foreign exchange rates were forbidden;
- The central bank undertook a stabilisation plan of the exchange rate to the US dollar, after an initial devaluation to make the former achievable;
- (Blejer & Liviatan, 1987) stress how a crucial role was played by a grant of USD1.5 billion from the US that boosted the confidence in the reforms.

3.2.3. Venezuela (2016-Present)

The origins of the current hyperinflation in Venezuela are usually traced to the high welfare spending initiated at the end of the ’90s, whose sustainment was heavily reliant on high oil prices. The oil crash of 2014 caused a drop in the demand of Venezuelan bolivar, and the government reacted by increasing the money supply.

Since the Banco Central de Venezuela stopped reporting inflation figures in December 2014, and the ones reported since January 2016 are considered unreliable, estimating the current value of inflation is not straightforward. (Hanke & Wu, 2017) leverage on the

economic principle of Purchasing Power Parity to convert the black-market exchange rate to the US dollar into an inflation estimate. According to their computation, in the period finishing in April 2017, the annual inflation rate peaked at about 800%. A more crude but tangible measure is the **Venezuelan Café con Leche Index** published by Bloomberg, which estimates inflation to have been 2,376% in the last year. The **website of the IMF reports** the current annual inflation of 2021 to be about 5,500%, after having peaked at 65,370% in 2018.

Two methods to deal with the situation are proposed in (Hanke & Wu, 2017): dollarisation, which consists in replacing the Venezuelan bolivar with the US dollar as official currency for the country; and the adoption of a currency board system, where the central bank is replaced by a board that holds low-risk assets denominated in a foreign anchor currency and which issues notes that are convertible on-demand into the anchor currency. A survey of the population on the two options showed a support of about 60% for any of the two. However, (Huertas, 2019) argues that the only way to stop hyperinflation is to stabilise the budget without increasing the money supply, which is achieved by a plan of fiscal consolidation combined with strong financial support from the international community. We further observe that cryptocurrencies are widely circulating in Venezuela: Since February 2021, Bitcoin ATMs allow exchanging cash for Bitcoins, and Venezuelans can now buy Stablecoin – a dollar-pegged cryptocurrency managed by the state-owned start-up Glufco – directly through their welfare accounts.

It is also interesting to observe that (Miller, 2019) and (Pittaluga, Seghezza, & Morelli, 2020), besides offering an interesting summary of the current situation, argue that inflation, when considered as a tax to add further revenues for the government, fell on the inefficient side of Laffer curve.[4] This means that the government would have maximised its revenues with a smaller increase of the money supply than what it has done.

3.3. Deflation

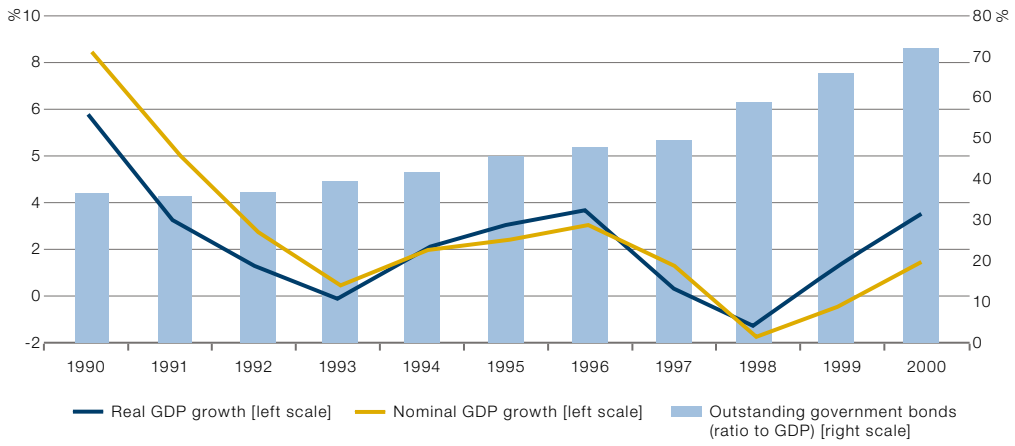
Deflation occurs when the inflation rate becomes negative, and its most immediate effect is the increase of value of currency. The ramified consequences of deflation are examined in more details with the general consequences of inflation. Here we only signal the central paper (Atkenson & Kehoe, 2004) before looking at the most important recent episode of prolonged deflation.

3.3.1. Japan (1990s-Present)

A careful account of the Japanese market bubble that reached its top in 1990 and burst in 1992 and of the economic situation that derived from it is given in (Okina, Shirakawa, & Shiratsuka, 2001), (Ohmi, 2010), and (Herr & Kazandziska, 2010). We briefly summarise it. In the second half of the 1980s, both stock and land prices increased significantly in Japan, and this was accompanied by an expansion of debts and financial assets. Already at the beginning of 1990 the prices of stocks, bonds, and of the yen started lowering, with real estate prices following towards the end of the year. A general increase in bankruptcies was observed in 1990, but only in 1992 did it became clear that the bubble had burst. Between March 1992 and September 1995, seven stimulus packages were introduced by the government. However, alleged inefficiencies of the parliament caused significant obstructions to the speed and breadth of this injection of money into the financial system. As the GDP recovered from the post-bubble recession in 1995-1996, the government increased taxes on consumption and cut public spending. This, when combined with the collapse of a few major banks in November 1997 caused by the large proportion of non-performing loans and by the Asian crisis of 1997, had a detrimental effect on the real economy and caused a new recession. Figure 13, shows the evolution of the GDP and the ratio of debt-to-GDP over the 1990s. It must be noted that outstanding bonds in Japan are domestically held, in contrast to the US where a sizeable part is held by foreigners.

4. The Laffer curve illustrates a relationship between rates of taxation and tax revenues. Intuitively, tax revenues are 0 both when rates of taxation are 0% and 100%, and it attains a maximum for some intermediate value. Therefore, increasing the rates of taxation does not necessarily increase tax revenues.

Figure 13. GDP and Debt in Japan



Source: Ohmi, 2010.

The monetary policy of the Bank of Japan has also been criticised. For example, (Bernanke & Gertler, 2001) argue that the monetary policy was too loose ahead of the burst of the bubble, and too restrictive afterwards. The interest rates were cut to 1% in 1995, and in 1999, the BoJ officially pursued a target of 0%; only to give it up in August 2000 as the economy showed signs of recovery. In 2001, interest rates were brought again down to 0%, and the BoJ further introduced a quantitative easing program. As the situation slightly improved in 2005, the BoJ raised interest rates again, but was forced to decrease them (again!) as the US subprime crisis struck. The lack of response of the Japanese economy to lower interest rates is partially due to deflation itself, which kept real interest rates in positive territory throughout.

The recession, and the large amount of non-performing loans and the monetary policy that followed, had the effect of depressing inflation. An official inflation target of 2% has been adopted by the BoJ only in 2013, which is currently being pursued using a combination of: negative interest rates, quantitative and qualitative monetary easing, yield curve control of the 10-year Japanese government bonds, fiscal stimulus and structural reforms; with the latter two being features of the so-called Abenomics. The CPI since 1958 is shown in Figure 14.

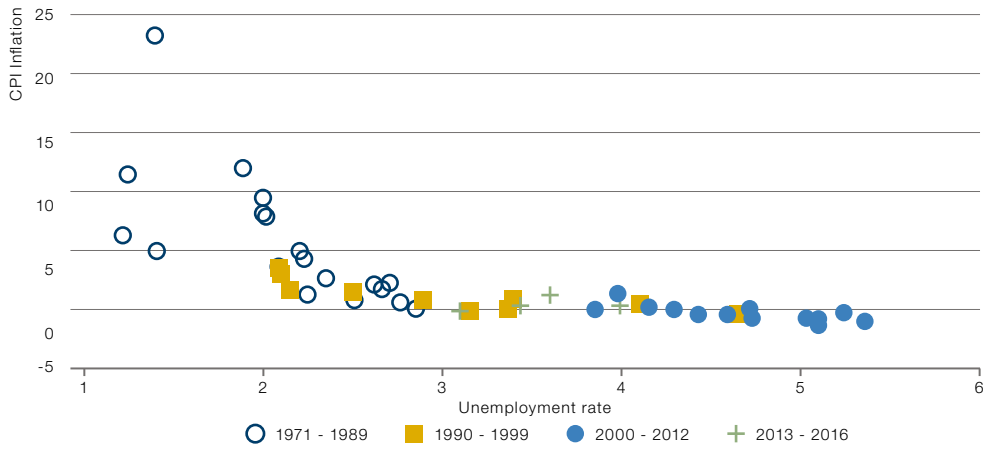
Figure 14. CPI in Japan

Source: Global Financial Data; as of May 2021.

When compared to the deflation that followed the Great Depression in the US, it is clear that the two episodes are very different: the US deflation lasted for about three years and the annual rate has been about -8%; while in Japan, the annual inflation rate since 1995 has been only about -1%, but the deflation lasted, or still lasts, for at least two decades (Watanabe & Watanabe, 2018).

The causes of the prolonged deflation, and its possible solutions, are still debated. Already (Krugman, 1998) speculated that Japan got caught in a liquidity trap. As the reality of this prediction became clear, (Leigh, 2004) found the action of the BoJ to be in line with common sense at the time. (Nishizaki, Sekine, & Ueno, 2012) examined a series of potential causes, such as the zero-lower bound, the public attitude towards the price level, low growth, and central bank communication, and conclude that it is difficult to single out a specific one. Lastly, (Watanabe & Watanabe, 2018) observes that a likely cause for the continuing deflation in Japan is the observed flattening of the Phillips curve[5] (Figure 15).

Figure 15. Phillips Curve in Japan



Source: Watanabe & Watanabe, 2018.

Indeed, a flat Phillips curve implies that acting on the economic variable, such as unemployment or output gap, does not influence inflation. Moreover, they find that as inflation approaches zero, prices become stickier due to menu costs and a strengthened deflationary mindset in the population.

4. Causes of Inflation

Finding the causes of inflation is an exercise as old as measuring inflation itself. Indeed, already (Vaughan, 1675) tried to disentangle the inflation coming from currency debasement from the inflation caused by gold inflow. The distinction of cost-push inflation from demand-driven inflation goes at least as far back as the 'Bullionist Controversy' of the late 18th century (Laidlier, 2000). Another distinction appears in (Wai, 1959), who distinguishes investment-driven inflation from consumer-driven inflation, and declares the former to be less serious and sustained than the latter. Given the vastity of the topic, this section only touches on selected issues, and it is structured as follows:

- A very brief summary of Keynesian and Monetarist views on the topic of inflation, reviewing the debate about inflation being a purely monetary phenomenon;
- Phillips Curves: Genesis, Death and (maybe) Resurrection;
- The pass-through of PPI into CPI;
- A review of the mechanisms generating inflation inertia.

5. The notion of Phillips curve will be properly examined in the next section.

We preliminary observe that inflation has generally been considered a domestic phenomenon, but there is evidence that this assumption is inaccurate. For example, (Ciccarelli & Mojon, 2010) show that a single component accounts for 70% of the variance of the inflation of 22 OECD countries.

4.1. Is Inflation Always and Everywhere a Monetary Phenomenon?

A crucial starting point for discussing the causes of inflation is the point of view of Friedman, nicely summarised by his own quote:

> *"Inflation is always and everywhere a monetary phenomenon."*
>
> – (Friedman M. , 1956)

The fundamental equation of the Quantity Theory of Money asserts that:

$MV = PY$;

where M is the total amount of money, V is the transactions' velocity of money, P is the price level in the economy and Y is the real value of the aggregated transactions. Assuming that V and Y are constant, this implies that changes in the price index are determined by changes in the money supply. The terms of the equation need further specifications:

- The assumption that V and Y are constant is likely too strong, as the velocity of money V is widely considered unpredictable and the real GDP – a proxy for Y – has been variable over time;
- In the previous section on defining inflation, we have seen how there is no such thing as 'the' price level of an economy. Similarly, it must be defined what exactly constitutes money. In the US, various kinds of money are defined as in the next table, and similar definitions are used worldwide:

M0	The total of all physical currency.
MB	M0 + Federal Reserve Deposits
M1	M0 + Checkable deposits
M2	M1 + Savings accounts + Money market accounts + Retail money market mutual funds + Certificates of deposit smaller than $100,000.
M3	M2 + Institutional money market mutual funds + Certificates of deposit larger than $100,000 + Eurodollar deposits + Repurchase agreements
M4	M3 + Commercial Papers + T-Bills

According to the Keynesian view, often seen as opposed to the Monetarist view, in the long run, inflation is purely a monetary phenomenon, but in the short and medium term, both V and Y are influenced by M and inflation is caused by one of:

- Excess of demand over supply, the so-called **demand-driven inflation**;
- The **cost-push inflation**, i.e. the inflation following exogenous shocks: increase in the market power of a domestic monopoly, rising labour cost, shortage of productive resources;
- **Inflation inertia**, where a certain level of inflation standardises practices like raising prices or wages that might carry on even if inflation would be otherwise decreasing.

We refer the reader to (Goodfriend & King, 1997) for a thorough view of the historical arguments.

The relationship indicated by the opening remark of Friedman has been shown to hold in several papers. Two of the most complete are (Barro, 1990), comparing 83 countries over almost 40 years, and (McCandless & Weber, 1995), comparing 110 countries over a period of 30 years and separately looking at M0, M1 and M2. Some more recent papers test the assertion in specific countries with mixed results: (Zhang, 2011) finds the money supply to be the only determinant of inflation in China from 1978 onwards, (Adusei, 2013) looks at the case of South Africa and concludes that inflation is influenced by the money supply but also by international inflation, and (Doyin & Ikechukwu, 2013) partly attribute Nigerian inflation to rigidities in its economy.

However, these studies offer little insight on the lag at which the relationship takes place. However, (Grauwe & Polan, 2005) show that the relationship between inflation and money growth is very strong, but this is only the case because of hyperinflation episodes. Once these are removed the relationship is weak.

According to the Fiscal Theory of the Price Level ('FTPL'), inflation is determined only by the fiscal policy. A clear overview is given in (Bassetto, 2005) and in the upcoming book (Cochrane J. H., 2021). The central idea is that if a government commits – implicitly or explicitly – to not defaulting on its debt, and at the same time it runs a structural deficit, then they will inflate away the debt i.e., reduce its real value. While the FTPL does not completely negate the impact of the monetary policy on inflation, it relegates its role to an indirect one. The FTPL has been highly controversial since its inception: its backers evidence the fact that it is unique in being able to explain inflation in a frictionless economy, i.e. an economy where bonds are as liquid as cash; one of the points of its detractors is that it focuses on the inverse of the government debt rather than on the inverse of the value of money. The FTPL is also connected to the Modern Monetary Theory, which is discussed in the chapter on policymaking.

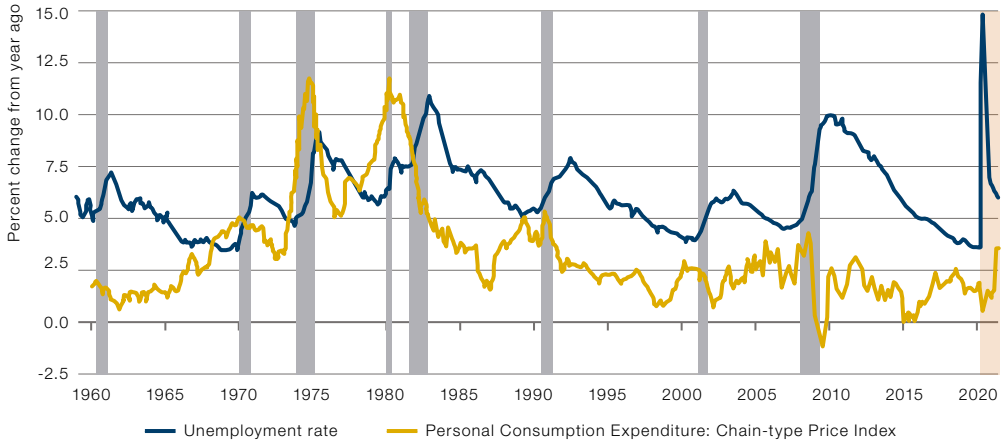
An interesting point, that connects us to the next paragraph, is made in (Mishkin, 1984), who finds that inflation in the US is the result of monetary causes, as predicted by Friedman. However, he goes a step further into trying to understand what has determined the monetary conditions that lead to the observed behaviour of inflation. According to the author, the accommodating monetary policy is geared to achieve a high employment target, along the lines of the Phillips curve.

4.2. Phillips Curves

It is common wisdom that low unemployment causes wage inflation, and in turn, this should fuel higher demand and prompt firms to raise prices. The difference between the current and the natural unemployment rates is a measure of output gap. The relationship connecting this measure (and indeed any other measure of output gap) with wage inflation (or any other measure of inflation) goes under the name of Phillips curve.

The connection between wage inflation and unemployment was already an object of debate at the beginning of the 20th century, and it was first shown by I. Fisher in 1926 (Fisher I., 1973), even though the discovery is usually attributed to Phillips (Phillips, 1958). The theoretical derivation of Phillips curves, i.e. the construction of a reasonable model implying the structure of Phillips curves as an outcome, was put in place in the theory of Money-Wage dynamics of Phelps (Phelps E. S., 1967), (Phelps E. S., 1968), and in (Friedman M., 1968). They both argued that the relationship is only valid in the short run, and Friedman correctly predicted that both unemployment and inflation would have risen during the recession of 1973-1975.

Figure 16. Unemployment and PCE Inflation in the US



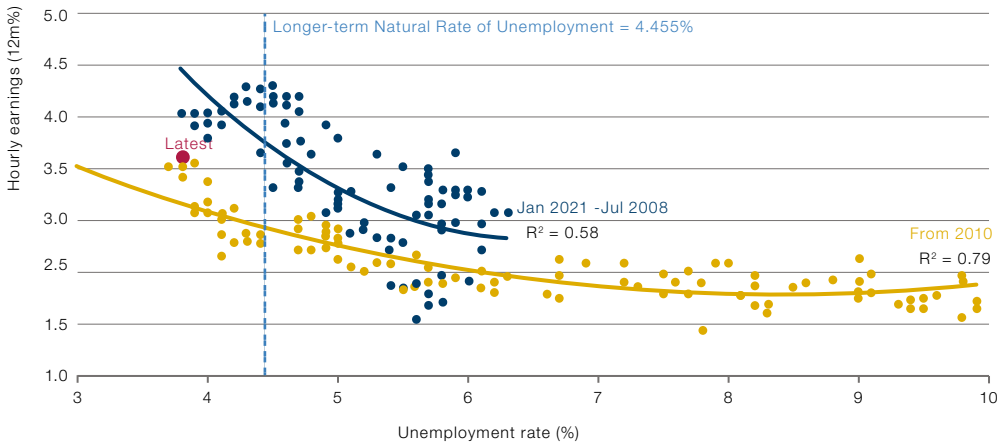
Source: FRED; as of 22 June 2021.

This framework has heavily guided decisions by central bankers, especially since (Modigliani & Papademos, 1975) defined the non-inflationary rate of unemployment ('NIRU') as the threshold above which inflation can be expected to decline; and the definition of the non-accelerating-inflation rate of unemployment ('NAIRU') followed shortly after. A thorough analysis of the concept is carried out in (Ball & Mankiw, 2002), where the authors declare it a useful piece of business cycle theory which is, however, of limited practical value as a policymaking tool.

Mentions of the "death" of the Phillips curve trace at least as far back as (Brinner, 1977). An accurate analysis done in (Niskanen, 2002), for the US, and in (Reichel, 2004), internationally, show that the relationship predicted by the Phillips curve hold in the short term, but it is reversed in the long run. The authors conclude that this makes it useless for policy guidelines. Another issue in this direction is that the output gap itself is often hard to measure. For example, in the 1970s, the output gap was mismeasured, and actually smaller than thought in real-time (Orphanides & Williams, 2011). At least in the US, a change towards a policy more reactionary to observed inflation rather than pre-emptively acting based on the NAIRU is observed under the lead of J. Powell.

Figure 17 shows the comparison of unemployment rate and hourly wages over the last two decades, split into two periods.

Figure 17. Recent Phillips Curve in the US



Source: Man Solutions; as of 14 May 2021.

Recently, (Murphy, 2018) observed how the recent statistical significance of the relationship is weak. For example, disinflation has been 'missing' in the aftermath of the Great Financial Crisis and higher inflation is 'missing' now. However, this is not surprising since the relationship has always been weak. Also (Hazell, Herreno, Nakamura, & Steinsson, 2021) found that the slope of the Phillips curve has been small at least since the beginning of the 1980s, and it did not flatten significantly after that. They attribute the moderate inflation observed in their data to shifting expectations about monetary policy.

Interestingly, using core inflation in place of headline inflation results in a higher statistical significance and explains the 'death' of the Phillips curve (Ball & Mazumder, 2019). Another successful attempt to explain the low statistical significance of the Phillips curve is done in (Stock & Watson, 2019), where the authors look at year-on-year changes in real activity rather than at output gaps, and decompose inflation into a part that is more correlated with real activity, and it is mainly domestic determined, and a part that is less dependent on real activity, and it is mainly internationally determined.

The extent to which the output gap determines future inflation is directly related to its predictive power in forecasting future inflation, therefore, this paragraph partly conflates to the homonym one in the oncoming section about forecasting inflation. In this light, the results of (Stock & Watson, 2008) and (Dotsey, Fujita, & Stark, 2015) can be seen as showing that the existence of the Phillips curve is conditional to high inflationary periods.

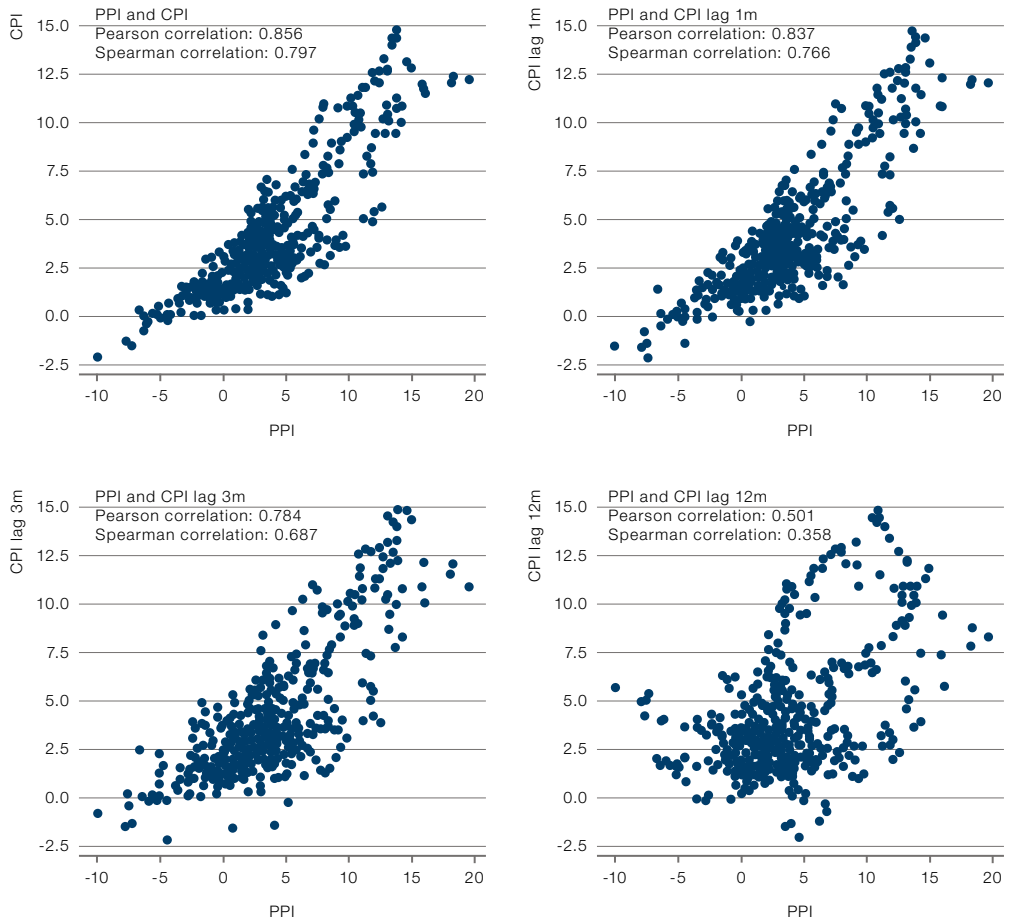
4.3. Pass-Through of PPI Into CPI

It is conventional wisdom that movements in the PPI anticipate or parallel same-direction movements in the CPI, as higher costs are passed from producers to consumers with a delay. Therefore, if the chosen measure of inflation is the CPI, a change in the PPI can be seen as potentially causing a change in inflation.

The **US Bureau of Labor Statistics** observes that this is not always the case primarily because of their different uses: while the PPI is used to measure real growth, the CPI is used to detect changes in the cost of living. The first paper that looked at the lag distribution of CPI and Wholesale Price Index is (Silver & Wallace, 1980), that essentially confirms the lead of wholesale prices on consumer prices. Their results are shown to be potentially biased in (Colclough & Lange, 1982), who provide both empirical evidence and an argument for an inversion of the relationship: if inflation is driven by an increase in demand, then consumer prices should lead wholesale prices. These findings are confirmed in (Jones, 1986), which shows predictability in both directions, and suggests that a bivariate model is the best solution to describe the phenomenon. A more thorough analysis of the underlying pass-through mechanism is done in (Clark, 1995), who finds that changes in the PPI only occasionally lead changes in the CPI. The relationship of the two must take into account the difference of the definitions, the changes in labour and capital costs, and changes in productivity and business decisions. An empirical analysis on data from G-7 countries, rather than US only, is done in (Caporale, Katsimi, & Pittis, 2002), where predictivity from the PPI to the CPI is found. They further find that the previously found causality form CPI to PPI is explained by considering the behaviour of monetary authorities.

More recently, a few papers looked at country-specific lead-lag relationships of CPI and PPI for an indication on the type of inflation that is occurring: a cost-push inflation would imply that the CPI lags the PPI, but if the direction is reversed the inflation is driven by demand. Without claim of completeness we list a few of them: (Gang, Liping, & Jiani, 2009) looked at China, finding that CPI leads PPI to a horizon of 1-3 months; (Tiwari, 2012) uses data from Australia, finding that the PCI leads the PPI in the medium term, but the reverse never happens; the same author applied these techniques to the case of India, and showed in (Tiwari, 2012) that CPI changes Granger cause changes in the Wholesale Price Index at all frequencies; (Tiwari, Suresh, Arouri, & Teulon, 2013) analyse evidence from Mexico and find that CPI leads the PPI in the short term, but the direction is reversed in the long run; (Ulke & Ergun, 2014) find a long-run causality from CPI to PPI in Turkey. We use data from the OECD website to compare monthly year-on-year readings of PPI and CPI with variable lags (either 0, 1, 3, or 12 months) in the US since 1956 (Figure 18).

Figure 18. Comparison of PPI and Lags of CPI



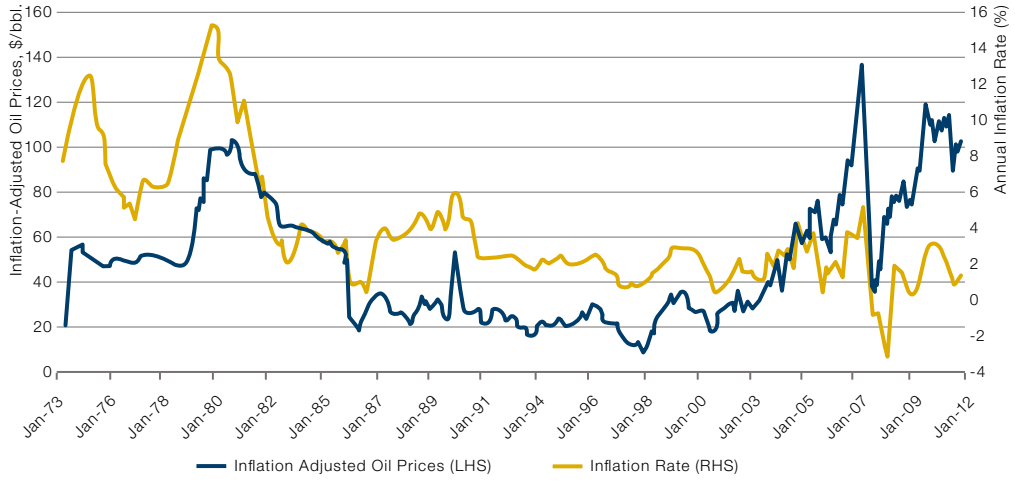
Source: OECD; as of 27 April 2021.

We observe that both Pearson's and Spearman's correlations decrease as the lag increases, which points to a contemporaneous rather than to a lagged relationship. We remark that this analysis is much rougher than the ones carried in some of the cited articles, as we completely neglected any potential role played by a conditioning variable, and only used data for one country over less than 70 years.

4.3.1. Pass-Through of Energy Prices Into CPI

Changing energy prices contribute to the PPI, but, due to their volatile prices, energies have been the object of specific studies, all of which agree on observing a declined pass-through rate of oil prices into inflation from around 1975. (Chen S.-S., 2009) looks at 19 industrialised countries and suggests that the reason for the decline in oil price pass-through is due to the central banks being more active in the face of inflation changes, a more globalised trade network and to the appreciation of the domestic currency. (Clark & Terry, 2010) confirms that the pass-through rate into core inflation has been lower in the last decades, but observes that this is the case despite monetary policy being less influenced by changes in energy prices than prior to 1985. Finally, (Conflitti & Luciani, 2019) focus on the pass-through of oil prices into consumer prices in both the US and the euro area, and show that oil prices do not change core inflation beyond the impact that they already have on the economy as a whole (Figure 19).

Figure 19. Oil Prices and Inflation



Source: Conflitti & Luciani, 2019.

Interestingly, the difference in pass-through of oil prices into headline or core inflation can be used to set up a trading strategy (Fulli-Lemaire, 2013).

4.4. Inflation Inertia

It is generally accepted that expectation of inflation, either discretionary or due to inflation-adjustment mechanisms built into the economy, is itself a cause of inflation (Carvalho, Ribeiro, & Marques, 2017). For example, (Nishizaki, Sekine, & Ueno, 2012) list lowering inflation expectation as one of the causes leading to deflation in Japan; or we have seen in the paragraph on near hyperinflation in Israel, interrupting automatic wage increases was necessary to curb the oncoming hyperinflation. The ECB created an inflation persistence network to study inflation inertia in the Eurozone in order to adjust the monetary policy accordingly (Geronikolau, Spyromitros, & Tsintzos, 2020). The latest article reviews the literature on the causes identified for inflation persistence: central bank preferences and credibility; robustness of monetary policy; adjustments in wages and price contracts; long memory in inflation due to aggregation of price series; and they further propose progressive taxation and rigidity in the labour market as potential causes for this phenomenon. In Section 6, titled ‘Policymakers and Inflation’, we will further focus on the role played by the credibility of the central bank.

5. The Consequences of Inflation

Has a fully anticipated inflation any effect on the economy? Until as recently as 1949, the answer would have been no (Phelps E. S., 1965). The first objection came in (Friedman M., 1953): if the rate of interest on money is fixed, then inflation will make other financial assets more attractive, and therefore incentivise market participants to reduce their money balance. The opportunity cost of holding less money is now called *shoe leather cost*, referring to the higher shoe consumption deriving from the necessity of more frequent trips to the bank. This section looks at other effects of inflation, and inflation uncertainty. Specifically:

- What is the impact of inflation on economic growth? This is a complex intertwine of macro variables, and the current literature focuses more on correlation than on causation;
- Are inflation and inflation uncertainty related? Do they have similar effects on growth?;
- The *menu cost* causes price dispersion, which in turn generates inefficiencies in the economy. However, the magnitude of this effect has likely been overstated in the past;
- A selection of other inflation consequences;
- What is the optimal inflation target? The answer to this question is a direct consequence of the understanding of costs and benefits of inflation.

5.1. Economic Growth

Inflation can have an impact on economic growth through different channels, such as changing the efficiency of the allocation process (Lach & Tsiddon, 1992), imposing so-called *menu costs* (Devereux & Yetman, 2002) or *shoe-leather costs* (Chadha, Haldane, & Janssen, 1998) on the economy's participants, or speeding up the equilibrium-reaching process of the labour market (Tobin, 1972). Some of these effects will be examined in more details in other paragraphs of this section; in this one, we focus on the overarching question of the effect of inflation on economic growth.

In general, there is no agreement, not only on the magnitude but also on the direction of this phenomenon. Quoting (Friedman M., 1973):

> *"Historically, all possible combinations have occurred: inflation with and without development, no inflation with and without development."*

The literature has been generally on the side of identifying a negative relationship between inflation and economic growth: (Friedman M., 1956) argues for a negative relationship between inflation and economic growth; (Wai, 1959) and (Dorrance, 1963) find a negative correlation, but it is not statistically significant using their limited data. Figure 20 reports the main recent large-panel empirical findings on this relationship. However, we first observe that:

- The table has been mainly populated with information from (Akinsola & Odhiambo, 2017);
- The results refer to an empirical relationship between inflation and economic growth, and there is no claim of causality;
- Many of these studies search for non-linear relationships between inflation and economic growth;
- There is general agreement that 'low' positive inflation is correlated to economic growth, while 'high' inflation is not.

Figure 20. The Relationship Between Inflation and Economic Growth

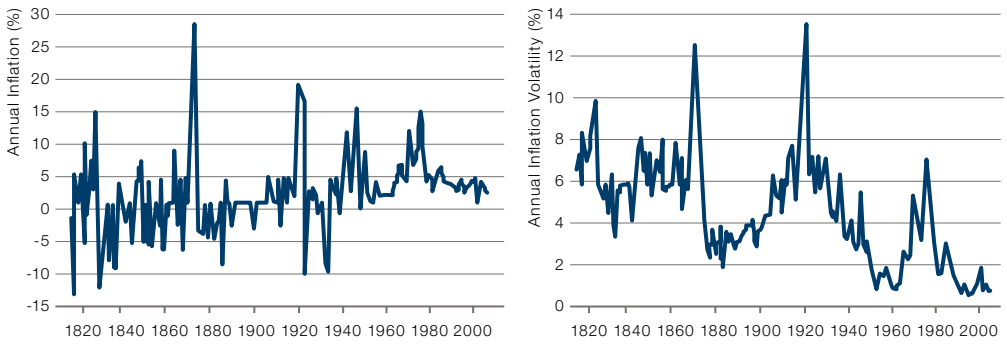
Study	Notes	Findings
(Barro, 1995)	100 countries over 1960 - 1990	Inflation has a negative effect on growth.
(Bruno & Easterly, 1995)	26 countries over 1961 - 1992	Discrete crisis of high inflation retard growth.
(Ghosh & Phillips, 1998)	145 countries over 1960 - 1996	The negative relationship between inflation and growth is valid for very high inflation, and it extends also for single-digit levels of inflation.
(Gylfason & Herbertsson, 2001)	170 countries over 1960 - 1992	10-20% inflation has negative effect on growth.
(Khan & Senhadji, 2001)	140 countries over 1960 - 1998	1-3% inflation positive for industrialised countries, 7-11% positive for developing countries. Higher inflation has negative effect on growth, lower inflation has no effect.
(Atkenson & Kehoe, 2004)	17 countries over 18** - 2000	Deflation and depression are not linked.
(Benhabib & Spiegel, 2009)	17 countries over 1859 - 2004	Inflation below 3.23% is strongly positively correlated to growth. Higher inflation is negatively correlated to growth.
(Kremer, Bick, & Nautz, 2012)	124 countries over 1950 - 2004	Optimal inflation rate is 2% for industrialised and 17% for non-industrialised. Higher inflation has negative effect on growth, lower inflation has no effect.
(Vinayagathasan, 2013)	32 Asian countries over 1980 - 2009	Inflation higher than 5.43% has a negative effect on growth, below this threshold it has no effect.
(Baharumsah, Slesman, & Wohar, 2016)	94 developing countries over 1976 - 2010	Inflation harms growth, but inflation uncertainty promotes growth for inflation in the moderate range of 5.6 – 15.9%.

5.2. Inflation Versus Inflation Uncertainty

Figure 20 illustrates that (Baharumsah, Slesman, & Wohar, 2016) reports separate finding for inflation and inflation uncertainty. In the literature the latter is empirically defined in one of a few ways: either as the standard deviation of realised inflation over the recent period, or by fitting an ARCH model, or as the dispersion of inflation estimates in surveys. The relationship between inflation and inflation uncertainty has been the object of study for some decades: The Friedman-Ball hypothesis (Friedman M., 1977) & (Ball L., 1992) posits that high inflation causes inflation uncertainty, because market agents become unsure about the behaviour of monetary authorities, while the Cukierman-Meltzer hypothesis (Cukierman & Metzer, 1986) asserts that inflation uncertainty leads to an increase in inflation, as central banks prioritise high growth rather than low inflation in the presence of inflation uncertainty. Some authors consider these hypotheses as incompatible, however, despite a general agreement on a positive correlation between inflation and inflation uncertainty, there is no consensus on the direction of causality. For example, (Albulescu, Tiwari, Miller, & Gupta, 2016) apply a wavelet analysis to US data from 1775 to 2014 finding support for the Friedman-Ball hypotheses in the medium and long run, but support the Cukierman-Meltzer hypotheses if the uncertainty of inflation is normalised according to (Chan, Koop, & Potter, 2013). Another recent study is (Zivkow, Njegic, & Pecanac, 2014), which uses data from 11 eastern European countries and confirms both hypotheses for the largest countries with flexible exchange rates, and confutes both hypotheses for smaller economies with a rigid exchange rate regime. A careful and up-to-date literature review on the topic is contained in the introduction of (Jiranyakul, 2020).

We source from (Bredin & Fountas, 2018) plots of inflation and inflation uncertainty – which is calculated by fitting a GARCH model – in the US over a period of 200 years (Figure 21).

Figure 21. Inflation and Inflation Uncertainty in the US



Source: Bredin & Fountas, 2018.

Besides the direction of causality, another interesting question is what the effect of inflation uncertainty on growth is. (Friedman M., 1977) argues that high inflation uncertainty prevents price mechanisms from efficiently allocating resources. (Pindyck, 1991) constructs a model that suggests that a high inflation uncertainty might hamper irreversible investments by increasing the option value of delaying; however, we should note that 30 years later, the option value might be less important as more investments are intangible capital. (Dotsey & Sarte, 2000) construct a model for a cash-in-advance economy, showing that inflation adversely affects growth, but inflation uncertainty has a positive effect on it, as it encourages investment by lower the value of precautionary savings.

Also, the empirical results on the relationship between inflation uncertainty and real economic activity are conflicting. Early results for the US, most of which find a negative relationship, are summarised in (Holland, 1993). (Hayford, 2000) finds analogous results and shows that inflation uncertainty causes lower growth by increasing the uncertainty of economic activities such as employment. (Elder, 2004) quantifies the reduced growth following a shock to inflation uncertainty in 22 basis points over three months. However, (Barro, 1995) empirically shows that inflation uncertainty is not related to reduced growth once other explanatory variables are included, such as life expectation, education spending, or inflation itself. Finally, the already cited (Baharumsah, Slesman, & Wohar, 2016) provides evidence for a positive relation between inflation uncertainty and growth.

5.3. Menu Costs and Price Dispersion

A speculated consequence of high inflation is an increase in the dispersion of prices, which is the variation of prices across sellers of the same item, and it is usually attributed to two effects:

- **Menu costs**: Changing prices has a cost. Therefore, they exhibit a sticky behaviour. Observe that in certain sectors changing prices has no practical costs e.g. when these are set online. However, the fact that the price has changed might still have an impact on the consumer;
- **Imperfect information**: Inflation, and inflation's uncertainty, deteriorate consumers' information about prices. Therefore, consumers are less able to identify products with the best price relative to competitors, and non-competitive market participants can survive as their higher prices – due to relatively inefficient production – are harder to detect.

The latter phenomenon is close in nature to the involuntary saving behaviour described in (Deaton A., 1977): assume that a consumer enters a shop without knowing that a 1% inflation occurred overnight, then every item will look expensive when compared to another shop visited a week prior, and the consumer will end up purchasing less. Observe that the *money illusion*, i.e. the cognitive bias of thinking in nominal, rather than in real, terms, implies that the phenomenon just described is also caused by expected inflation.

Empirically observing price dispersion during times of high inflation is generally hard, because of the heterogeneous nature of items even in small categories. This is a very similar problem to the one faced when defining inflation by looking at the evolution of a price of baskets: if the latest iPhone and the oldest Nokia are on the market at the same time, the dispersion of prices will look enormous, even if it is not. Using price changes dispersion as a proxy for price dispersions, (Lach & Tsiddon, 1992) show that price dispersion increased in Israel during the inflationary period 1978-1984, and upward deviations from the mean are larger than downward ones. On the other hand, (Nakamura, Steinsson, Sun, & Villar, 2018) are able to reconstruct a dataset of single items prices in the US starting in 1997, but do not find evidence of an increase price dispersions during the Great Inflation of the late 1970s. They rather observe a higher frequency of price adjustments, which is in line with the behaviour predicted in (Golosov & Lucas, 2007). (Sheremirov, 2019) similarly observes a *negative* relationship between inflation and price dispersion when examining US data from 2001 to 2011, but the author finds that it can be entirely attributed to sales prices, and for regular prices the relationship between price dispersion and inflation is positive.

Besides the empirical results, in recent times a few studies show how the *menu costs* have been overestimated in the past, and one might argue that technology further lowers the cost of changing prices: (Burstein & Hellwig, 2008) calculate that the welfare loss coming from output inefficiencies stemming from distorted price allocations because of the menu costs are an order of magnitude lower than the loss coming from the opportunity cost of market participants keeping a reduced money balance. In the same direction, (Golosov & Lucas, 2007) construct a menu cost model that is calibrated on, and fits well, international data. One of their findings is that prices that tend to stick are the ones for which stickiness matters the least, i.e. they are the closest to the desired price. In new Keynesian models, price dispersion is usually considered the main cost (Ambler, 2008), however (Hahn, 2018) shows that this is the case because of the standard assumption that firms always satisfy demand. The author shows that relaxing this assumption leads to much smaller estimates for the welfare cost of inflation.

5.4. Other Inflation Consequences

Given the major role played by inflation in the economy, it is not surprising to see several ramified effects. Below, we touch on a few major effects that have not been considered yet:

- **Indexing**: If a cash flow set in a contract, such as a wage or a mortgage, is not indexed to inflation, then its real value will differ from what originally stipulated, generating a distortion. However, it is argued that indexing of contracts systematises an inflation expectation that is itself contributing to generating inflation. See (Fischer S., 1983) for an overview of the problem. This is connected to the actions of the Israeli government in curbing the hyperinflation of 1985. And the general lack of indexing is another consequence of the *money illusion*;
- **Mundell-Tobin effect**: As for the *shoe leather costs*, with higher inflation, market participants will decrease their cash holding and purchase other assets, raising their price and lowering their yield. Therefore, if inflation increases nominal interest rates will rise by less than the same amount (Mundell, 1963), (Tobin, 1965);
- **Seigniorage**: The issuance of new currency is an inflation tax on currency's holder, known as seigniorage, from the Old French for "right of lord to mint money". The more widespread the currency the higher the income from seigniorage, to the degree **that in 2000, the US earned USD25 billion from it**. As for all taxes, seigniorage has a Laffer curve and an optimal rate for maximising revenues, which is affected by currency holders switching to a different currency, as for example Venezuelans do with the US dollar, the Colombian peso or Bitcoin. An analysis of the benefits is carried out in (Fischer S., 1982), and a theoretical study of related concepts is in (Buiter, 2007). Also, some researchers argue that seigniorage is unethical (Howden & Gabriel, 2014)

6. Policymakers and Inflation

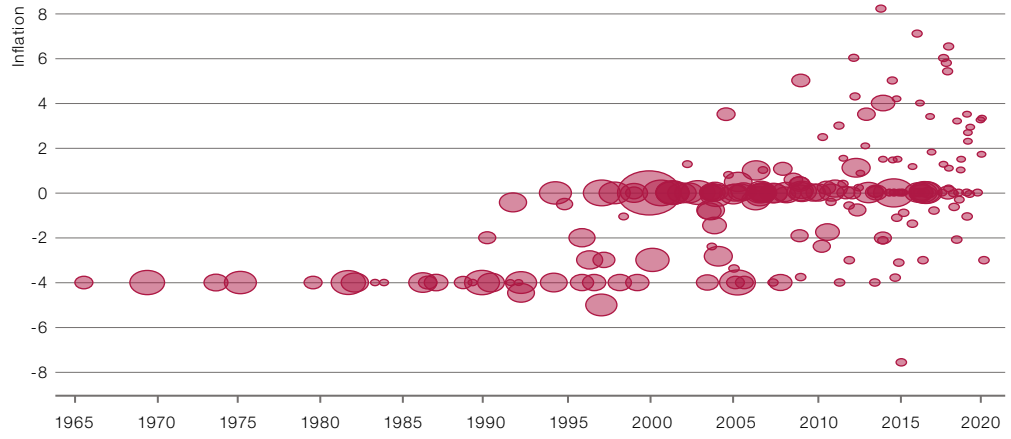
In this section, we review the connection between inflation and policymaking:

- The consensus, and the disagreements, on inflation targeting;
- The role of credibility of policymakers;
- The Taylor rule, a very influential rule for setting interest rates;
- The Modern Monetary Theory, offering a different view on fiscal policies.

6.1. Optimal Inflation Targeting

Starting in 1989, about 30 countries around the world adopted a policy of inflation targeting.[6] Given the short history, an assessment of the effectiveness of inflation targeting is still debated, we refer the interested reader to (Ardakani, Kishor, & Song, 2018) or to the recent book (Bernanke, Laubach, Mishkin, & Posen, 2018). The widespread adoption of inflation targeting makes more pressing the question: what is the optimal rate of inflation? A systematic categorisation of optimal inflation targets is presented in (Diercks, 2019), who also maintains **The Reader's Guide to Optimal Monetary Policy**. Figure 22 of optimal inflation targets ordered by year of publication has been obtained using this tool, and the size of each observation is proportional to the number of citations of the paper.

Figure 22. Proposed Inflation Targets in Academic Literature



Source: Various academic research papers; as of 6 May 2021.

Starting with (Phelps E. S., 1965), and until about 1995, the academic literature has been strongly influenced by the Friedman rule (Friedman M., 1969): a nominal interest rate of zero eliminates the opportunity cost of holding money, and it does it at no social cost, since the cost of creating additional money is zero. Therefore, inflation should be negative and have the same absolute value of the real interest rate to make the nominal interest rates zero. However, arguments for a positive inflation rate were already being brought forward: (Tobin, 1972) assumes an asymmetric rigidity of prices, where upward adjustments are more flexible than downward ones, to argue that positive inflation facilitates sectoral adjustments. Moreover, the inflation targets chosen by central banks have never been negative. New Zealand officially started the first program in 1989 with a target range of 0-2%.

An optimal inflation rate of zero is proposed in (Ball & Mankiw, 1994) and then reiterated in the literature review (Clarida, Gali, & Gertler, 1999). The argument is based on menu costs: any inflation rate different from zero implies a cost for adjusting prices, either upward or downward.

Moreover, they do not find empirical evidence for Tobin's assumption of asymmetric price rigidities.

6. The exact number of countries depends on the meaning of "inflation targeting", see for example (Rose, 2006) or (Hammond, 2012).

Since the Global Financial Crisis, there has been a wave of papers advocating positive inflation rates. This is mainly due to the problem of the Zero Lower Bound ('ZLB'): if short-term interest rates are at or near zero, market participants will prefer holding cash rather than purchasing debt, at the same time the monetary authority is unable to further lower interest rates. According to (Ball L., 2014) or (Dordal-i-Carreras, Coibion, Gorodnichenko, & Wieland, 2016), an inflation target of 4% would have dampened the aftermath of 2008 leaving more room for the monetary authority to decrease rates. However, there are alternative options to lowering interest rates in a liquidity trap: One is *helicopter money* (Friedman M., 1969), which consists in a direct transfer from the central bank to the private sector; another one is *quantitative easing* (Werner, 1995), where a central bank buys financial assets raising their prices and lowering the yield, while increasing bank reserves. More recently, estimates for the optimal inflation target that consider different constraints simultaneously are being produce. For example, (Blanco, 2021) considers a model with both medium-scale menu costs and an occasionally binding zero lower bound on interest rates and calculates that the optimal inflation target is 3%.

There are other arguments for keeping a higher inflation target: because of the already-mentioned money illusion, consumers prefer a 2% rise in nominal wages with a 4% inflation to a 2% cut to nominal rates with no effect on inflation (Shafir, Diamond, & Tversky, 1997). Moreover, if a substantial amount of the currency is held abroad, such as is the case of the US dollar, a higher inflation implies a higher revenue from seigniorage. Also, inflation is argued to relax financial constraints for firms, thereby stimulating investment (Finocchiaro, Lombardo, Mendicino, & Weil, 2015).

A recent development, even though it was already advocated in (Nessen & Vestin, 2005), is switching to average inflation targeting rather than spot inflation targeting, thereby allowing inflation to run higher than the target for a period to compensate for a low growth in the price index that might have occurred in the past. This is the same concept of price-level targeting. Recently, (Acuna-Roa & Parra-Polania, 2016) show that average inflation targeting is convenient if a large part of the economy is not indexed to inflation, because of the lower implied macroeconomic volatility. Finally, (Eo & Lie, 2020) argue that the welfare gain of this policy would be minimal, because it is well-approximated by the already well spread practice of interest rates smoothing.

6.2. Policymakers' Credibility

The credibility of a policymaker can be defined, and measured, as the difference between the policymaker's plans and the public's beliefs about those plans. For example (Park, 2018) proposes a numerical measure of central bank credibility based on households' reliance on the central bank's prediction in forming expectations. In Section 3 above, titled 'Causes of Inflation', we have seen how inflation expectations are a leading cause of inflation. It is therefore intuitive that policymakers' credibility is an important tool for controlling inflation. Indeed, (Reddell, 1999) reports that one of the reasons for adopting inflation targeting was to increase the credibility of the policy carried out by the central bank. Perhaps more importantly, credibility was the key goal that Volcker set to reach for controlling the US inflation in the early 1980s, an exhaustive account of which is (Goodfriend & King, 2005).

This is generally confirmed in the literature: (Ball L., 1995) shows that, if credibility is sufficiently low, announcing a disinflation has the effect of reducing the expected output. (Erceg & Levin, 2003) construct a dynamic general equilibrium model derived from microeconomic foundations and show that imperfect information of private agents on central bank's objectives, which depends on the transparency and the credibility of the central bank, generate inflation persistence. (Gibbs & Kulish, 2015) show that the cost of a disinflationary policy, measured in terms of GDP decrease per unit of inflation decrease, is higher when the credibility of the policymaker is low; but that even in this case, pre-announcing the shift in policy does reduce costs. They find that conditioning for credibility yields robust estimates for these costs, which would be weak otherwise.

A more controversial point is how much credibility is needed: for (Schaumburg & Tambalotti, 2007) credibility is the probability of the central bank not reneging on previous commitments, and they find that most of the benefits of credibility already occur at low levels.

6.3. The Taylor Rule

The Taylor rule, proposed in 1992 by J. B. Taylor, the then economic adviser of the US President G. H. W. Bush, and further detailed in (Taylor, 1993), prescribes a change in the federal funds rate to control inflation while taking the output gap into consideration. Specifically, the original formula is:

$$\begin{aligned} \textit{nominal interest rate} &= \textit{measured inflation} \\ &+ \textit{equilibrium interest rate} \\ &+ 0.5 \times (\textit{measured inflation} - \textit{target inflation}) \\ &+ 0.5 \times (\textit{log(real GDP)} - \textit{log(potential output)}) \end{aligned}$$

(Woodford, 2001) analyses the rule from a theoretical perspective, and concludes that, assuming that the output gap is properly defined, it stabilises both inflation and the output gap. (Orphanides, 2003) compares the past monetary policy in the US with the Taylor rule, and finds the latter to be prudent. However, the author thinks that refraining from actively controlling the economy is a better choice.

A number of variations on the Taylor rule have been proposed over time: (Davig & Leeper, 2006) derive a version that allows for stochastic coefficients in the model. (Bunzel & Enders, 2010) modify the rule in such a way that the monetary authority reacts more aggressively to high inflation than to low inflation and show that their model explains past Fed behaviour better than the original Taylor rule. (Chattopadhyay & Daniel, 2018) observe that the Taylor rule cannot be implemented at the zero lower bound, but the problem can be overcome by the monetary authority by setting up a forward policy for interest rates, which consists in setting rates to 0 until a pre-specified date, and applying a time-varying inflation target afterwards.

The rule has also received numerous critiques: (Orphanides, 2003) points out that the rule needs reliable and up-to-date data to be successful, but that this is rarely the case. (Cochrane J. H., 2011) states that the rule is based on old-Keynesian rather than new-Keynesian models, and the application of the rule will generate, at the very least, large inflation movements; moreover, the rule prevents inflation from reaching equilibrium. (Brancaccio & Fontana, 2013) show that the rule is theoretically dependent on the neoclassical theory of growth, and therefore inherits all the critiques to the latter. Furthermore, they show that it is possible to generate an alternative rule, which it is advocated, whose target is not inflation but the solvency of firms and workers.

We further mention that (Molodtsova, Nikolskorzhevskyy, & Papell, 2011) use the Taylor rule to predict slow movements in the EUR/USD exchange rate.

6.4. Modern Monetary Theory

The Modern Monetary Theory ('MMT') is a debated macroeconomics theory, according to which money is created by the government through its fiscal policy. A distinction is drawn between 'vertical transactions' – occurring between the public sector and a private agent, and 'horizontal transactions' – occurring between two private agents; vertical transactions are effectively creating money. In terms of policy recommendations, it is argued that governments do not have any financial constraint and should set their fiscal positions only considering inflation and unemployment. Two main differences with mainstream economics in terms of policy setting should be flagged, as summarised in two Bloomberg articles (Kelton, The Clock Runs Down on Mainstream Keynesianism, 2019), (Kelton, 2019):

- Raising rates is a stimulus for the economy because the increased budget deficit implies more money flowing in the private sector through vertical transactions;
- An expansionary fiscal policy can lower interest rates by increasing bank reserves.

The field is relatively new and gained popularity thanks to the more progressive wing of the US political system, with politicians such as Bernie Sanders and Alexandria Ocasio-Cortez. Slightly different theories can be all regarded as MMT, therefore we point the reader to the overview (Cohan, 2020), the opponent's overview (Mankiw, 2020), and the proponent's overview (Tymoigne & Wray, 2013).

7. Impact of Inflation on Financial Instruments

As mentioned in the introduction, the impact of inflation on financial instruments is a vast and manifold topic, but, because of the very recent publication of an academic paper authored by our Man Group colleagues (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021) on the subject, we only briefly touch on it.

If we were to ignore the existence of non-linear relations, which should not be ignored, then the impact of inflation would be simply measured by the beta to inflation. We use the data of (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021) to compute the beta to vol-normalised inflation of yearly contemporaneous vol-normalised returns in the US. This amounts essentially to a correlation, except that we use rolling and lagged volatility to account for unexpected inflation. We only use data from 1980 for real estate, so that the result is less significant in that case.

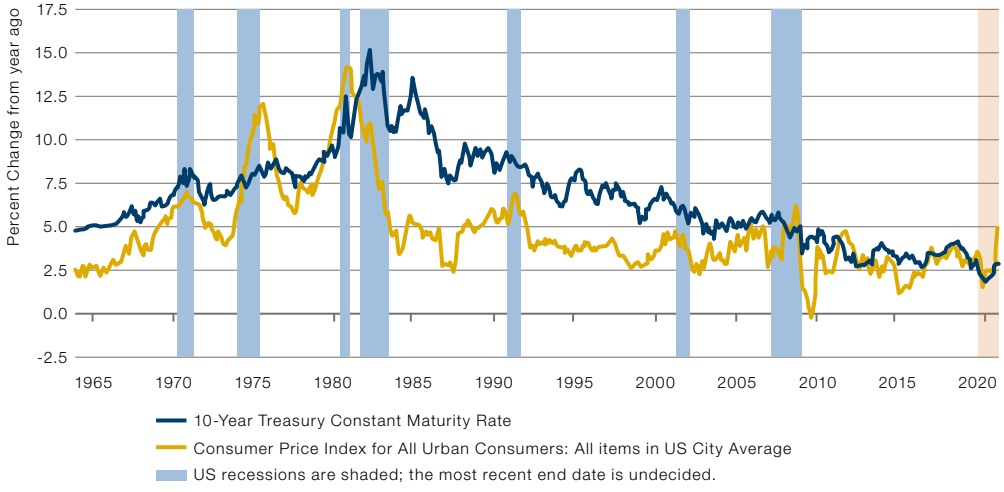
7.1. Fixed Income

Fisher's hypothesis postulates that real interest rates are constant (Fisher I., 1930). Therefore, nominal interest rates vary one-to-one with inflation and fixed income is perfectly hedged against expected inflation. However, we have seen how the Mundell-Tobin effect predicts a change in rates that is smaller than one-to-one with inflation, but if the policymaker were to loyally follow Taylor rule then interest rates would have to change by more than one-to-one with inflation. It is clear that other effects, besides inflation, play a role in determining interest rates. The Fisher effect, which is compatible with Tobin-Mundell and with Taylor rule, predicts that inflation is the major one. In this direction (Mishkin, 1992) finds it to be valid only in the long-run and not in the short-term, so that the effect is more pronounced when both quantities are trending.

A special role is played by inflation-linked bonds, whose cash flow is directly connected to a price index. On the topic, (D'Amico, Kim, & Wei, 2014) points out that there are effects other than inflation that determine their prices, with liquidity being the most prominent. And (Briere & Signori, 2009) observe that they are increasingly correlated to nominal bonds, and therefore suggest that investors do not hold them in their portfolio. However, this is likely the case because of the recent sustained moderate inflation rate. This might be connected to the very low – or negative – yield that these assets exhibit, pointed out in (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021).

Figure 23, which compares the yield on 10-year US Treasuries to the CPI, gives an idea of how volatile the real returns of the former are.[7]

Figure 23. US CPI and Yield of 10-Year Treasuries



Source: FRED; as of 21 May 2021.

7. NOTE: Ideally, we want to extend this plot to the 1920s, to show that in real terms US Treasuries have been flat for over 50 years until the 1980s.

The changing correlation of fixed income and equities returns is examined in (Campbell, Sunderam, & Viceira, 2017), who use both expected and unexpected inflation as explanatory variables. Also, in line with (Ciccarelli & Mojon, 2010), who show inflation to be a global phenomenon, (Gospodinov, 2020) show that US yields respond to international developments, including international inflation.

7.2. Equities

The idea that stock prices are unaffected by inflation because they are connected to the real economy was reported to be well spread in (Danthine & Donaldson, 1986). The authors develop a model that shows how real rates, equities and commodities are all connected, and that the real returns of equities are negatively affected by inflation. However, they argue that stocks offer a hedge against long-term purely monetary inflation. This has been more recently confirmed in (Rapach, 2002).

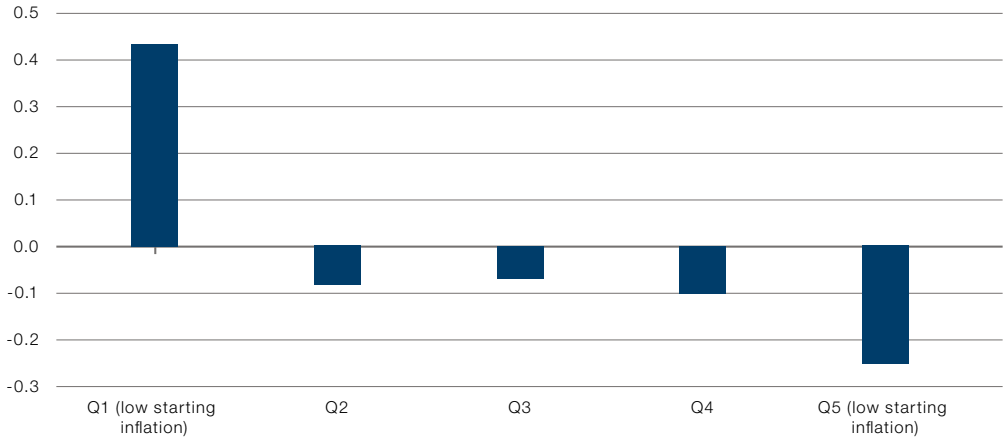
The negative effect of inflation, and of unexpected inflation, was already observed earlier. This is an important distinction, which is clearly spelled out in (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021), and that was already explicitly considered in (Fama & Schwartz, 1977), who finds the effect of unexpected inflation to be weaker than the one of expected inflation. Later, (Fama, 1981) explained the impact of both macro variables on stock returns through their impact on real activity. This view came to be known as the proxy hypothesis.

Another early explanation was provided in (Modigliani & Cohn, 1979), who attribute the negative effect of inflation on stock prices to the money illusion, i.e. the inability of properly discounting inflation from nominal rates, which implies a too large discount rate in the dividend pricing model for stocks. But (Feldstein, 1980) shows that valuation errors are not needed for inflation to have a negative effect on stock prices. Indeed, the tax treatment of depreciation costs and capital gains translates a higher inflation into a higher corporate tax, which in turn justifies lower stock valuations.

There are also results pointing in the other direction: (Ciner, 2015) decomposes inflation into an 'expected' part, persistent and low-frequency shocks that are likely to be a continuation of the trend in inflation, and an 'unexpected' part, high-frequency and transitory shocks. While 'expected' inflation is negatively correlated to stock returns, 'unexpected' inflation is positive correlated to some industries, such as commodity producers and technology. The cross-sectional prediction, but not the directional one, is in line with (Ang, Briere, & Signori, 2012), who show that the beta to inflation of individual stocks is stable, and the combination of stocks with the highest *ex-ante* beta to inflation yields a portfolio with high and significant ex-post beta to inflation, which over weights the energies and technology sectors. Moreover, (Omay, Yuksel, & Yuksel, 2015) attribute the negative relationship often found between stock prices and inflation to flawed statistical methods: Once cross-section dependences are considered, there is a positive relationship between stock prices and goods prices (rather than inflation).

Trying to reconcile the existing evidence, also non-linear relationships between inflation and stock returns have been considered. (Ajaz, Nain, Kamaiah, & Sharma, 2017) and (Alqaralleh, 2020) show that upward inflation has a disproportionately larger effect on stock returns than downward inflation. Also in this direction, (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021) show that increasing inflation is positive for stock returns if the current rate is low – escaping from deflation, while it is negative if the current rate is high – fear of escalating inflation. This result is summarised in Figure 24, which is extracted from the above-mentioned paper and shows the average correlation of contemporaneous 12-month stock returns and 12-month changes in the inflation rate:

Figure 24. Correlation of Contemporaneous 12-Month Stock Returns and 12-Month Changes in Inflation Rate



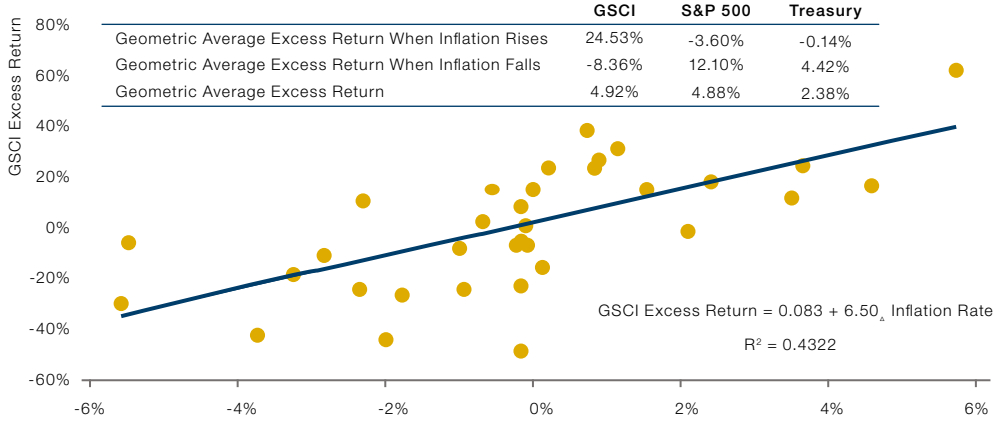
Source: Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021.

7.3. Commodities

The inflation hedging properties of commodities are fairly well understood. (Kat & Oomen, 2006) shows that the returns of commodity futures are positively correlated with unexpected inflation, and the best hedging properties are offered by energies, metals, cattle and sugar. (Zaremba, Umar, & Mikutowski, 2019) compare UK inflation and commodity prices since the 13th century, finding robust hedging properties for agricultural, energy, and industrial commodities at the 4- and 8-year horizons. Much earlier (Bodie Z., 1983) – looking at future prices – and (Bird, 1984) – looking at spot prices – reach similar conclusions, even comparing commodities to other asset classes. The analysis of (Erb & Harvey, 2006) shows that the hedging properties of the Goldman Sachs Commodity Index ('GSCI') to expected inflation are too weak to be significant, while the commodity index is a significant hedge for unexpected inflation, which is proxied by the year-on-year change in inflation (Figure 25).

Figure 25. Distribution of GSCI Excess Returns and 12-Month Changes in Inflation Rate

	GSCI	S&P 500	Intermediate Treasury
Geometric Average Excess Return When Inflation Rises	24.53%	-3.60%	-0.14%
Geometric Average Excess Return When Inflation Falls	-8.36%	12.10%	4.42%
Geometric Average Excess Return	4.92%	4.88%	2.38%



Source: Erb & Harvey, 2006.

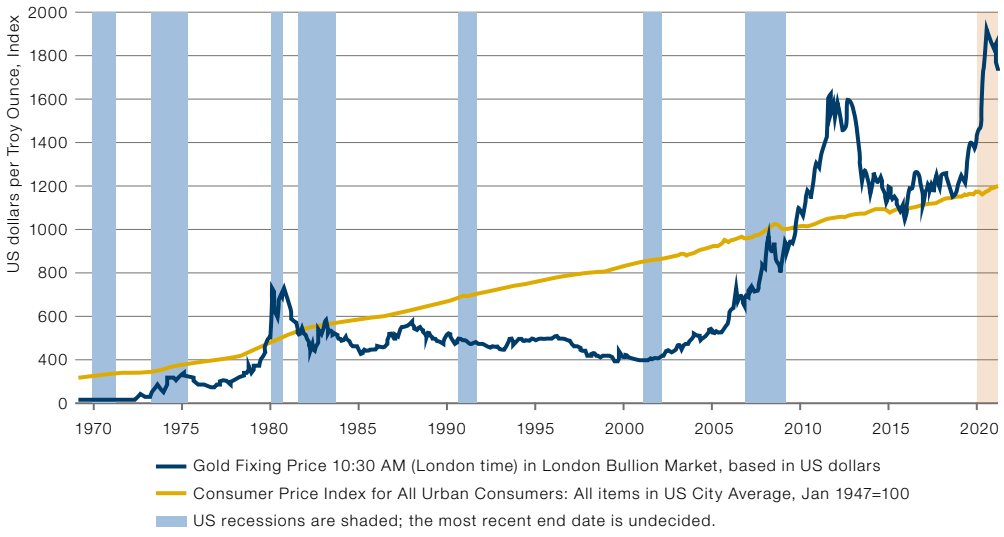
This is further confirmed by the empirical analysis of (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021). We mention that (Erb & Harvey, 2016) decomposes the returns of commodities essentially into price returns and income returns, and finds the latter term to be positive correlated to inflation while the former is not.

The role of gold as inflation hedge is part of the traditional folklore, but various factors could imply that this is not the case, such as changes in the marginal cost of gold extraction, or in the gold usage, for example, as currency reserve. (Ghosh, Levine, Macmillan, & Wright, 2004) empirically observe that gold is an inflation hedge in the long run, but not in the short run. Essentially the same view is expressed in (Beckmann & Czudaj, 2012), where the data is enlarged from the US only to include also the Eurozone, UK, and Japan. This is further confirmed in (Naser, 2017) with more recent US data. And in the analysis of (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021) both gold and silver realise their positive returns in inflationary periods.

However, it has to be noted that, according to (Erb & Harvey, The Golden Dilemma, 2013) or (Batten, Ciner, & Lucey, 2014), once a short period, such as the end of the 1970s and the early 1980s, is taken out of the sample, the hedging properties look much weaker.

A large data analysis for both gold and silver is carried out in (Bampinas & Panagiotidis, 2015), who employ a dataset ranging from 1791 to 2010 in the US and the UK. They show strong hedging properties of gold for headline, core and expected inflation. However, the evidence for silver is very weak or non-existent. On a slightly different note, (Sharma, 2016) successfully predicts gold returns using the CPI in the US and in the UK. Finally (Lucey, Sharma, & Vigne, 2017) push the analysis a step further from inflation to the money supply, and find that gold prices are a partial hedge against inflation because its price is cointegrated with the money supply. The results are robust in the US and in the UK, but do not hold for Japan. More recently (Conlon, Lucey, & Uddin, 2018), run an analysis in US, UK, Switzerland and Japan from 1968 to 2014, where they confirm the hedging properties both for gold futures and gold stocks and both for a short and a long time horizon, and show that gold comoves with both realised and unexpected inflation.

Figure 26. US CPI and Gold Prices



Source: FRED; as of 20 May 2021.

Constructing on this point, from (Erb & Harvey, 2016) one sees that gold is too volatile to be an effective hedge, as the range of 'fair' values of gold given a certain price index level is too broad.

Finally, a mention about cryptocurrencies: the divulgatory paper (Chohan, 2021) argues that the limited supply of Bitcoins provides a natural protection against inflation. On the other hand (Neville, Draaisma, Funnell, Harvey, & van Hemert, 2021) warn about the very limited history available for Bitcoin, and its realised positive beta to the US stock market, which has itself negative to beta to inflation. Both sides of the argument are easily adapted to other cryptocurrencies.

7.4. Real Estate

More than for stocks, real estate should be backed by tangible assets, and therefore act as a hedge against inflation. (Fama & Schwartz, 1977) find empirical evidence for this in the US between 1953 and 1971. (Miles, 1996) reviews the evidence connecting returns on commercial properties in the UK and inflation and finds the former to be an imperfect hedge against inflation. The reason is that letting contracts are often set for a long time and they are not indexed to inflation. The latter phenomenon is another consequence of the money illusion. Returns of different kinds of real estate and REITs are compared in (Gyourko & Linneman, 1988): they determine that the strongest hedge against core inflation is provided by non-residential properties and residential properties are a limited hedge. However, REITs are akin to stocks and their returns are negatively correlated to inflation. More recently (Chang, 2016) specifically look at REITs and confirmed the latter findings.

7.5. Further Remarks

We signal the recent meta-analysis on the evidence of inflation hedging provided in (Arnold & Auer, 2015): Their findings identify an equilibrium in the long term – at least five years – between stocks and inflation, but the same does not happen for gold; fixed income is not a protection, except for inflation-linked securities, that suffer from liquidity problems; and the results for real estate, including the case of REITs, are not conclusive.

Inflation can also be hedged through portfolio construction: (Bodie Z., 1976) observes that the variance on inflation is proxied by the variance of real returns of risk-free long-term bonds, and uses a Markowitz approach to minimise the variance of real returns of a portfolio that combined risk-free long-term bonds with stocks.

Finally, (Bruno & Chincarini, 2011) look at the problem of obtaining reasonable returns, which they quantify as 4.5% p.a., while minimising the inflation risk. They find that the holdings should consist of short-term bonds, longer-term bonds, some gold, some oil, and some emerging market equities. They look at optimal portfolios in both inflationary and deflationary environments.

8. Forecasting Inflation

Given the importance of inflation for both the monetary authority and market participants, it is not surprising that a myriad of inflation forecasting methods has been developed over the years. This section presents an overview of the state-of-the-art of the subject:

- Atheoretical models only rely on the time-series properties of inflation for its forecast, they are the most common benchmark against which to measure other approaches;
- Fundamental models rely on the correlation between inflation and an output gap measure, such as unemployment, to forecast the former knowing the latter. They are only as informative as the Phillips curve is valid;
- Term structure models use the inflation expectation of the market embedded in the term structure of rates to forecast inflation;
- Survey forecasts have historically been the most successful predictors. Their polling sample can be composed of professionals or simple households;
- Finally, we list a few methods that have been published after the reviews we consider: machine learning on big data, information extracted from commodity prices or web-scraping for online prices.

A review and comparison of inflation forecasting methods has been done with abundance of details in (Ang, Bekaert, & Wei, 2007), and subsequently in (Faust & Wright, 2013). Overall, both papers agree on surveys outperforming other methods when using US data, and (Faust & Wright, 2013) finds qualitatively similar results in a brief section on international evidence. We follow the first of these papers in identifying suitable categories for the various forecasting methods that appear in the literature.

Observe that previous-period core inflation could be confused for a forecast of next-period total inflation. Indeed, when comparing different constructions of core inflation, the predictivity on subsequent total inflation was considered a necessary feature. However, this is only because core inflation should best approximate steady-state inflation, which is generally assumed to be stationary. Also having low variance is considered a desirable property of core inflation, but it does not have to be the case for an inflation forecast. Both papers mentioned above consider core inflation to be a target of the forecast, rather than a potential forecasting model. Moreover, it can be argued that permanent inflation changes have the larger impact on the economy and on asset prices, and therefore this is the right target to be forecasted.

8.1. Atheoretical Models

These are models that only use the time-series properties of inflation for its forecast. Standard examples are: an autoregressive model over p periods ('AR(p)'); a parsimonious ('ARMA(1,1)') model; or a regime-switching model ('RGM') to account for lack of stationarity of the series. These are considered natural benchmarks.

8.2. Fundamental Models

A Phillips curve relates inflation to a measure of aggregate economic activity, or generally to a measure of output gap. Historically the first one to be considered is unemployment, but other measures are possible. (Gali & Gertler, 2000) argue that a measure of real marginal costs is theoretically sound and empirically valid in forecasting inflation, especially when compared to output gap measures. But it has to be noted that (Atkenson & Ohanian, 2001) already find Phillips curves to be worse than a simple AR(1) model in forecasting inflation. In their review (Ang, Bekaert, & Wei, 2007) test the predictions implied by Phillips curves on many output gap measures, and confirm that these models underperform both ARMA models and simple random walk estimates. The results in (Faust & Wright, 2013) are also not supportive of the predictive power of Phillips curves, but they observe that using them conditioning on another variable does improve their performance. This was first observed in (Stock & Watson, 2008), who confirm the lack of predictivity in the unconditional case, but show that periods with large deviations of the unemployment gap also corresponds to high predictivity of Phillips curves. But (Dotsey, Fujita, & Stark, 2015) show how the statistical significance of their observations is low.

8.3. Term Structure Models

Extracting an inflation forecast from asset prices consists in gauging the distribution of inflation expectations of market participants. The most straightforward example is the computation of the Treasury Breakeven Inflation ('TBI'), which is obtained by comparing the prices of Treasury Inflation-Protected Securities ('TIPS') to bonds with fixed nominal yield in the US.

Observe that the TBI is a forward curve with non-trivial term structure rather than a single number, therefore changes in its curve can be classified into changes in the expectation of temporary and changes in the expectation of permanent inflation, which we have determined to be an important distinction. A **deck of slides from the US Department of the Treasury** offers a broad overview of the subject. We remark the complication of these securities being linked to the CPI-U, which is itself biased and seasonal.

(Shen, 2006) points out how changes in the yield spread used to compute the TBI can be attributed both to changes in inflation expectations and to changes in liquidity. Following it, (D'Amico, Kim, & Wei, 2014) identify the main non-inflation effects that drive the yield difference between standard treasuries and TIPS: they confirm that liquidity is the most prominent, while the indexation lag and the embedded deflation protection of TIPS are much less important. They propose a method for removing these effects and obtain a cleaner estimate for the expected inflation. A similar exercise can be carried out using zero-coupon inflation swaps (Haubrich, Pennacchi, & Ritchken, 2012), where the authors also develop an affine model of nominal and real term structures that can be solved for expected inflation and should be able to detect mispricing of TIPS.

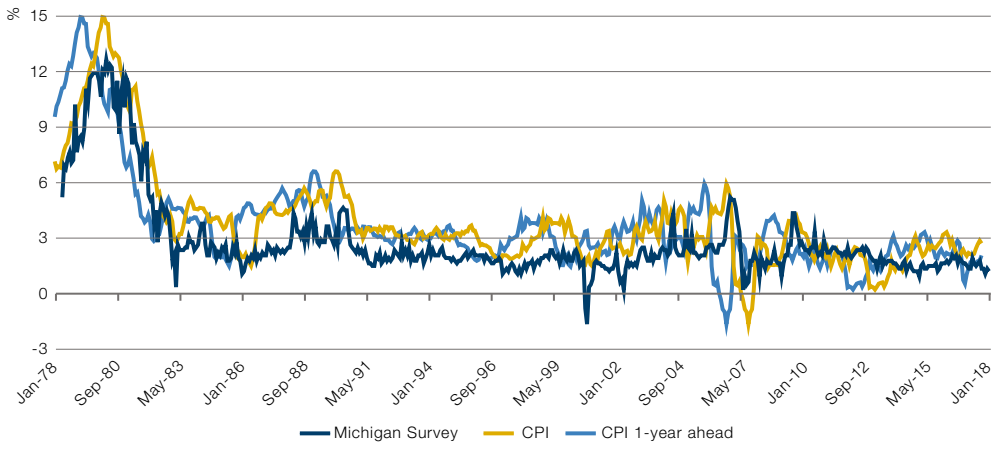
The connection between inflation and term structure of nominal rates can be traced back to (Fama, 1975), who argued that inflation is predictable because real rates are constant. Although the result above was disproven shortly after, see (Nelson & Schwert, 1977) or the author himself (Fama, 2018), this gave rise to a number of papers looking at the interplay of inflation and term structure of rates, see for example (Pelaez, 1989) or (Fama, 1990). In particular, dynamic term structure affine models are used to fit inflation and yields data simultaneously. For an introduction to affine term structure models see (Piazzesi, 2010). Besides the already cited (Haubrich, Pennacchi, & Ritchken, 2012), an interesting example is given in (Ajello, Benzoni, & Chyruk, 2012), where the authors fit such a model on the three 'standard' components of total inflation (core inflation, food, and energy) and on the nominal yield of Treasuries, assuming that the real rate is a linear combination of the considered variables. They find that shocks to core inflation are much more persistent than shocks on the energy component, with food sitting somewhere in the middle. They also claim to outperform survey benchmarks of inflation forecasts.

8.4. Survey Forecasts

Another natural inflation forecast is given by using surveys. A, slightly outdated, review and description of the most important ones for the US is given in (Lloyd, 1999), which compares the Livingston Survey of professional economists conducted by the Federal Reserve Bank of Philadelphia, the Survey of Professional Forecasters conducted by the same bank, and the survey of households conducted by the Institute for Social Research at the University of Michigan. These are the same surveys compared first in (Mehra, 2002) and then considered in (Ang, Bekaert, & Wei, 2007), but not the same of (Faust & Wright, 2013). The latter uses the Survey of Professional Forecasters, together with the Fed staff's Greenbook forecast, and the Blue Chip survey conducted by Aspen Publishers.

When comparing them, (Lloyd, 1999) finds the Michigan survey of households to be the most predictive. However, (Bryan & Venkatu, 2001) show that it suffers from meaningful and persistent demographic biases, and a deep analysis of its biases from a household-level perspective is done in (Souleles, 2004). Surveys of professionals are also biased: the Blue Chips survey has been the object of a study on rational biases for professional forecasters (Laster, Bennett, & Geoum, 1999), while (Mehra, 2002) compares the biases of the three survey whose predictivity it compares. This is why, when comparing them to other standard inflation forecasts, (Ang, Bekaert, & Wei, 2007) do remove long-term biases from these measures. In Figure 27, we combine the 1-year ahead consensus of the Michigan households' survey with the CPI data from the OECD database, either the current or the 1-year ahead.

Figure 27. US CPI and Michigan Households Survey



Source: Institute for Social Research at the University of Michigan, as of 18 May 2021; OECD as of 27 April 2021.

The Michigan survey is highly correlated to the current CPI, but it is a better predictor of next year CPI than the current CPI is. Another comparison of survey forecast to standard measures has been published by the Fed using data from 1999 to 2020 (Figure 28).

Figure 28. Fed Comparison of Survey Forecast to Standard Inflation Measures

	SPF (10y PCE)	SPF (10y CPI)	TIPS Breakeven (5-10y CPI)	Blue Chip (7-11y 75th pct)	Michigan (5-10y 75th pct)	Michigan (5-10y Prices)	Michigan (1y Prices)	Blue Chip (1y CPI)	SPF (1y Core PCE)
SPF (10y PCE)	1								
SPF (10y CPI)	0.82	1							
TIPS Breakeven (5-10y CPI)	0.63	0.62	1						
Blue Chip (7-11y CPI)	0.62	0.70	0.31	1					
Michigan (5-10y 75th pct)	0.57	0.60	0.72	0.48	1				
Michigan (5-10y Prices)	0.51	0.60	0.66	0.46	0.94	1			
Michigan (1y Prices)	0.46	0.17	0.41	-0.17	0.48	0.59	1		
Blue Chip (1y CPI)	-0.17	0.34	-0.19	0.33	0.08	0.23	0.10	1	
SPF (1y Core PCE)	-0.26	-0.12	-0.41	-0.49	-0.40	-0.22	0.17	0.65	1

Source: Federal Reserve Board, University of Michigan Surveys of Consumers, Federal Reserve Bank of Philadelphia, Wolters Kluwer Legal and Regulatory Solutions US, Blue Chip Economic Indicators; Between 1999 and 2020.

8.5. Alternative Methods

There are a few methods that have not been considered in the two main comparison articles we looked at.

- (Groen, Paap, & Ravazzolo, 2013) propose a Bayesian Model Averaging of different methods to improve the performance of the prediction;
- (Chen, Turnovsky, & E. Zivot, 2014) show that commodity prices can be used to forecast the inflation of an exporting country, assuming that its central bank engages in inflation targeting;
- (Medeiros, Vasconcelos, Veiga, & Zilberman, 2019), extending to the US results previously obtained for Brazil in (Garcia, Medeiros, & Vasconcelos, 2017), run a comparison of a battery of machine learning predictors a la (Gu, Kelly, & Xiu, 2018) using the library of monthly macro factors constructed in (McCracken & Ng, 2016). They find that combining the observations using a Random Forest algorithm yields better predictions that using other machine learning algorithms or using surveys. Moreover, the algorithm can also be used to assign an importance to features, and the authors report that the preferred features by the algorithm are disaggregated prices, interest-exchange rates, employment, and housing;
- (Aparicio & Bertolotto, 2019) show how web-scraping for prices can beat surveys. However, we note that one of the authors is affiliated with PriceStats, a popular vendor of online prices data.

We further observe that a variation of the problem of forecasting inflation consists in nowcasting inflation i.e., estimating the inflation of the current period, or even of a past period for which official data is not yet available. To give an idea of the timeline, observe that both CPI and PCE numbers are reported in the US with a few weeks' delay. (Knotek & Zaman, 2017) reviews the literature on the topic and claims to be providing a valid model.

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Appendix: Hanke-Krus Hyperinflation

Location	Start Date	End Date	Month with Highest Inflation Rate	Highest Monthly Inflation Rate	Equivalent Daily Inflation Rate	Time Required for Prices to Double	Currency	Type of Price Index
Hungary[1]	Aug. 1945	Jul. 1946	Jul. 1946	4.19×10^{15}%	207%	15.0 hours	Pengö	Consumer
Zimbabwe[2]	Mar. 2007	Mid-Nov. 2008	Mid-Nov. 2008	7.96×10^{10}%	98.0%	24.7 hours	Dollar	Implied Exchange Rate*
Yugoslavia[3]	Apr. 1992	Jan. 1994	Jan. 1994	313,000,000%	64.6%	1.41 days	Dinar	Consumer
Republika Srpska†[4]	Apr. 1992	Jan. 1994	Jan. 1994	297,000,000%	64.3%	1.41 days	Dinar	Consumer
Germany[5]	Aug. 1922	Dec. 1923	Oct. 1923	29,500%	20.9%	3.70 days	Papiermark	Wholesale
Greece[6]	May. 1941	Dec. 1945	Oct. 1944	13,800%	17.9%	4.27 days	Drachma	Exchange Rate ‡
China§[7]	Oct. 1947	Mid-May 1949	Apr. 1949	5,070%	14.1%	5,34 days	Yuan	Wholesale for Shanghai
Free City of Danzig[8]	Aug. 1922	Mid-Oct. 1923	Sep. 1923	2,440%	11.4%	6.52 days	German Papiermark	Exchange Rate**
Armenia[9]	Oct. 1993	Dec. 1994	Nov. 1993	438%	5.77%	12.5 days	Dram & Russian Ruble	Consumer
Turkmenistan ††[10]	Jan. 1992	Nov. 1993	Nov. 1993	429%	5.71%	12.7 days	Manat	Consumer
Taiwan[11]	Aug. 1945	Sep. 1945	Aug. 1945	399%	5.50%	13.1 days	Yen	Wholesale for Taipei
Peru[12]	Jul. 1990	Aug. 1990	Aug. 1990	397%	5.49%	13.1 days	Inti	Consumer
Bosnia and Herzegovina[13]	Apr. 1992	Jun. 1993	Jun. 1992	322%	4.92%	14.6 days	Dinar	Consumer
France[14]	May 1795	Nov. 1796	Mid-Aug. 1796	304%	4.77%	15.1 days	Mandat	Exchange Rate
China[15]	Jul. 1943	Aug. 1945	Jun. 1945	302%	4.75%	15.2 days	Yuan	Wholesale for Shanghai
Ukraine[16]	Jan. 1992	Nov. 1994	Jan. 1992	285%	4.60%	15.6 days	Russian Ruble	Consumer
Poland[17]	Jan. 1923	Jan. 1924	Oct. 1923	275%	4.50%	16.0 days	Marka	Wholesale
Nicaragua[18]	Jun. 1986	Mar. 1991	Mar. 1991	261%	4.37%	16.4 days	Cordoba	Consumer
Congo (Zaire)[19]	Nov. 1993	Sep. 1994	Nov. 1993	250%	4.26%	16.8 days	Zaire	Consumer
Russia†† [20]	Jan. 1992	Jan. 1992	Jan. 1992	245%	4.22%	17.0 days	Ruble	Consumer
Bulgaria[21]	Feb. 1997	Feb. 1997	Feb. 1997	242%	4.19%	17.1 days	Lev	Consumer
Moldova[22]	Jan. 1992	Dec. 1993	Jan. 1992	240%	4.16%	17.2 days	Russian Ruble	Consumer
Russia/ USSR[23]	Jan. 1922	Feb. 1924	Feb. 1924	212%	3.86%	18.5 days	Ruble	Consumer
Georgia[24]	Sep. 1993	Sep. 1994	Sep. 1994	211%	3.86%	18.6 days	Coupon	Consumer
Tajikistan††[25]	Jan. 1992	Oct. 1993	Jan. 1992	201%	3.74%	19.1 days	Russian Ruble	Consumer
Georgia[26]	Mar. 1992	Apr. 1992	Mar. 1992	198%	3.70%	19.3 days	Russian Ruble	Consumer
Argentina[27]	May 1989	Mar. 1990	Jul. 1989	197%	3.69%	19.4% days	Austral	Consumer
Bolivia[28]	Apr. 1984	Sep. 1985	Feb. 1985	183%	3.53%	20.3 days	Boliviano	Consumer
Belarus††[29]	Jan. 1992	Feb. 1992	Jan. 1992	159%	3.22%	22.2 days	Russian Ruble	Consumer
Kyrgyzstan ††[30]	Jan. 1992	Jan. 1992	Jan. 1992	157%	3.20%	22.3 days	Russian Ruble	Consumer
Kazakhstan ††[31]	Jan. 1992	Jan. 1992	Jan. 1992	157%	3.20%	22.3 days	Russian Ruble	Consumer
Austria[32]	Oct. 1921	Sep. 1922	Aug. 1922	129%	2.80%	25.5 days	Crown	Consumer
Bulgaria[33]	Feb. 1991	Mar. 1991	Feb. 1991	123%	2.71%	26.3 days	Lev	Consumer
Uzbekistan[34]	Jan. 1992	Feb. 1992	Jan. 1992	118%	2.64%	27.0 days	Russian Ruble	Consumer
Azerbaijan[35]	Jan. 1992	Dec. 1994	Jan. 1992	118%	2.63%	27.0 days	Russian Ruble	Consumer
Congo(Zaire)[36]	Oct. 1991	Sep. 1992	Nov. 1991	114%	2.57%	27.7 days	Zaire	Consumer
Peru[37]	Sep. 1988	Sep. 1988	Sep. 1988	114%	2.57%	27.7 days	Inti	Consumer

Taiwan[38]	Oct. 1948	May 1949	Oct. 1948	108%	2.46%	28.9 days	Taipi	Wholesale for Taipei
Hungary[39]	Mar. 1923	Feb. 1924	Jul. 1923	97.9%	2.30%	30.9 days	Crown	Consumer
Chile[40]	Oct. 1973	Oct. 1973	Oct. 1973	87.6%	2.12%	33.5 days	Escudo	Consumer
Estonia††[41]	Jan. 1992	Feb. 1992	Jan. 1992	87.2%	2.11%	33.6 days	Russian Ruble	Consumer
Angola[42]	Dec. 1994	Jan. 1997	May 1996	84.1%	2.06%	34.5 days	Kwanza	Consumer
Brazil[43]	Dec. 1994	Jan. 1997	May 1996	82.4%	2.02%	35.1 days	Cruzado & Cruzeiro	Consumer
Democratic Republic of Congo[44]	Aug. 1998	Aug. 1998	Aug. 1998	78.5%	1.95%	36.4 days	Franc	Consumer
Poland[45]	Oct. 1989	Jan. 1990	Jan. 1990	77.3%	1.93%	36.4 days	Zloty	Consumer
Armenia††[46]	Jan. 1992	Feb. 1992	Jan. 1992	73.1%	1.85%	38.4 days	Russian Ruble	Wholesale
Tajikistan[47]	Oct. 1995	Nov. 1995	Nov. 1995	65.2%	1.69%	42.0 days	Tajikistani Ruble	Wholesale
Lativa[48]	Jan. 1992	Jan. 1992	Jan. 1992	64.4%	1.67%	42.4 days	Russian Ruble	Consumer
Turkmenistan ††[49]	Nov. 1995	Jan. 1996	Jan. 1996	62.5%	1.63%	43.4 days	Manat	Consumer
Philippines[50]	Jan. 1944	Dec. 1944	Jan. 1944	60.0%	1.58%	44.9 days	Japanese War Notes	Consumer
Yugoslavia[51]	Sep. 1989	Dec. 1989	Dec. 1989	59.7%	1.57%	45.1 days	Dinar	Consumer
Germany[52]	Jan. 1920	Jan. 1920	Jan. 1920	56.9%	1.51%	46.8 days	Papiermark	Wholesale
Kazakhstan[53]	Nov. 1993	Nov. 1993	Nov. 1993	55.5%	1.48%	47.8 days	Tenge & Russian Ruble	Consumer
Lithuania[54]	Jan. 1992	Jan. 1992	Jan. 1992	54.0%	1.45%	48.8 days	Russian Ruble	Consumer
Belarus[55]	Aug. 1994	Aug. 1994	Aug. 1994	53.4%	1.44%	49.3 days	Belarusian Ruble	Consumer
Taiwan[56]	Feb. 1947	Feb. 1947	Feb. 1947	50.8%	1.38%	51.4 days	Taipi	Wholesale for Taipei

Source: Steve H. Hanke and Nichola Krus (2012) "World Hyperinflation" Cato Working Paper no. 8 August 15 . *Forthcoming in*: Randall Parker and Robert Whaples (eds.) (2013) *The Handbook of Major Events in Economic History*, London: Routledge Publishing. (expected publication date: Summer 2013).

Notes:

- When a country experience periods of hyperinflation that are broken up by 12 or more consecutive months with a monthly inflation rate below 50% the periods are defined as separate episodes of hyperinflation.

- The currency listed in the chart is the one that in a particular location, is associated with the highest monthly rate of inflation. The currency may not have been the only one that was in circulation, in that location, during the episode.

- We are aware of one other case of hyperinflation: North Korea. We reached this conclusion after calculating inflation rates using data from the foreign exchange black market, and also by observing changes in the price of rice. Based on our estimates this episode of hyperinflation most likely occurred from December 2009 to mid January 2011. Using black-market exchange-rate data, and calculations based on purchasing power parity, we determined that the North Korean hyperinflation peaked in early March 2010, with a monthly rate of 496% (implying a 6.13% daily inflation rate and a price-doubling time of 11.8 days). When we used rice price data we calculated the peak month to be mid-January 2010 with a monthly rate of 348% (implying a 5.12% daily inflation rate and a price-doubling time of 14.1 days). All of these data were obtained August 13, 2012 from Daily NK an online newspaper that focuses on issue relating to North Korea.

(http://www.dailynk.com/english/market.php). We also acknowledge that our investigation was aided by reports from Good Friends USA a Korean-American advocacy and research organization, as well as from Marcus Noland at the Peterson Institute for International Economics.

(*) The authors calculated Zimbabwe's inflation rate, from August to November 2008, using changes in the price of the stock, Old Mutual, which was traded both on the Harare and London stock exchanges. The stock prices yielded an implied exchange rate for Zimbabwe dollars, under purchasing power parity.

(†) The Republika Srpska is a Serb-majority, semi-autonomous entity within Bosnia and Herzegovina. From 1992 until early 1994, the National Bank of Republika Srpska issued its own unique currency the Republika Srpska dinar.

(‡) Greece's inflation rate was estimated by calculating the drachma / gold sovereign exchange rate.

(§) The peak monthly inflation rate listed for China in the table differs from that presented in one of the authors' previous pieces on hyperinflation (Hanke and Kwok, 2009). This revision is based on new data from a number of sources, which were recently obtained from the Library of Congress in Washington D.C.

(**) We calculated the Free City of Danzig's inflation rate using German inflation data, since the German papiermark was in circulation in Danzig during this time. It is worth noting that Germany and Danzig experienced different peak month of hyperinflation. This is case because the last full month in which the German papiermark circulated in the Free City of Danzig was September 1923. Germany continued to circulate the papiermark beyond this point, and subsequently experienced its peak month of hyperinflation (October 1923).

(††) The data for many of the post-Soviet countries were only available in the World Bank's Statistical Handbook: States of the Former USSR. In this publication, the authors stated that the data should be viewed with an extra degree of caution because the statistics were taken from the corresponding official internal government source and not independently reviewed by the World Bank. However these statistics are official and are the only source of data available for the corresponding time periods for each country.

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