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# The inflation game

**Wolfgang Kuhle**[1,2]

[1]Department of Economics, Corvinus University of Budapest, Budapest, Hungary

[2]MEA, Max Planck Institute for Social Law and Social Policy, Munich, Germany

**Correspondence**
Wolfgang Kuhle, Department of Economics, Corvinus University of Budapest, Budapest, Hungary.
Email: wkuhle@gmx.de

## Abstract

We study a game where households buy consumption goods to preempt inflation. This game features a unique equilibrium with high (low) inflation, whenever money supply is high (low). For intermediate levels of money supply, there exist multiple stable equilibria where inflation is either high or low. Equilibria with moderate inflation, however, do not exist, and can thus not be targeted by central banks. That is, depending on agents' equilibrium play, money supply is always either too high or too low for moderate inflation. Finally, we find that inflation rates of durable goods, such as houses, cars, luxury watches, or furniture, are useful leading indicators for changes in overall inflation.

**KEYWORDS**

inflation curve, monetary policy, preemptive demand

> *For it is, so to speak, a game of Snap, of Old Maid, of Musical Chairs a pastime in which he is victor who says Snap neither too soon nor too late, who passed the Old Maid to his neighbor before the game is over, who secures a chair for himself when the music stops. These games can be played with zest and enjoyment, though all the players know that it is the Old Maid which is circulating, or that when the music stops some of the players will find themselves unseated.* (Keynes, 1936, Chapter V)

# 1 | INTRODUCTION

The present paper models large moves in inflation as the outcome of a coordination game, where agents run on shops and retailers, to buy goods before prices increase. In turn, agents' strategic goods purchases move prices, such that inflation is driven by agents' efforts to preempt it.

Our simple model mimics several stylized facts about inflation, which are hard reconcile with standard macroeconomic rational expectations models. First, empirically observed inflation rates tend to lag money supply.[1] Second, changes in inflation, once they do occur, are often drastic rather than gradual.[2] Finally, the timing of such large moves in inflation is extremely hard to forecast.[3]

Even though agents react to changes in money supply, we find that the central bank's ability to steer the economy is limited. If inflation is low, agents are willing to hold cash, such that central banks 'push on a string' while they increase money supply. Likewise, once agents rush to the exit, central banks cannot reduce the quantity of money fast enough to contain a drastic spike in inflation. That is, depending on agents' equilibrium play, the quantity of money that central banks choose is always either too high or too low for moderate inflation. Put differently, relative to a moderate inflation mandate, central banks can only choose between too much or too little inflation.

In Section 4 we extend our model, and assume that consumption goods differ regarding their durability. In turn, we show that agents direct their strategic goods purchases towards durable goods first. Shorter-lived goods are only bought once the prices for durable goods have already started to rise. The extended model thus predicts that the prices of durable goods, such as luxury watches, furniture, or used cars, are a useful leading indicator for increases in the prices of shorter-lived goods such as food items or services. More generally, Section 4 suggests a 'curve' of inflation rates for shorter- and longer-lived consumption goods. In turn, we show that the inflation rates of longer lived goods are a leading indicator for increases in the inflation rates of shorter lived goods, and thus for increases in the economy's overall rate of inflation.

The rest of the paper is organized as follows. Section 2 presents stylized facts that motivate our model. Section 3 contains the baseline model, and Sections 4 and 5 discuss extensions of the framework. Section 6 concludes.

# 2 | STYLIZED FACTS

To motivate our simple game theoretic model, we plot recent US data on money supply, consumer price index (CPI) inflation, and retail sales in Figures 1–4.

Figures 1 and 2 plot the rate of money (M2) growth and CPI inflation for the post war period, and show that large changes in inflation tend to lag money supply. Moreover, changes in inflation, once they do occur, tend to be drastic rather than gradual. Moreover, Figures 1 and 2 also show that this pattern of drastic, lagged, moves in inflation is most visible during the 1940s, 1970s, as well as during the years of the COVID-19 crisis, when monetary policy was relatively loose. On the contrary, periods of tighter monetary policy, such as during the tenure of Paul Volcker, show inflation rates, which are both steady and low.[4]

[1] For example, the increases in money supply after the 2008 financial crisis failed to amplify inflation until 2021. Among others, Del-Negro et al. (2015) argue that such lagged responses are at odds with standard rational expectations models. Fisher (1920) and Kindleberger (2000) discuss such lagged responses in the context of several historical episodes involving 'paper money' and inflation. See also Muth (1961), Blanchard (1979), Blanchard and Fischer (1989), Chapters 4 and 5, and Sargent (1993), for standard models of rational expectations and Walrasian equilibrium, where agents react immediately to policy changes. Lagged responses to changes in money supply are also at odds with the quantity theory of money. Related, see Dimand (1999) and Dimand (2020) for reviews on the early literature on the 'Fisher relation', and the quantity theory of money.

[2] That is, for example, US inflation accelerated rapidly in the years 2021-2022, even though money supply was no-longer growing.

[3] The June 2021 FED inflation forecast, FED (2021), predicted 3%, 2% and 2% of inflation for the years 2021, 2022, and 2023, respectively. Actual US inflation in 2022 turned out to be over 9%.

[4] Taking these observations together, one may thus argue that Figures 1 and 2 suggest that loose monetary policy is a sufficient condition for a spike in inflation. Our model in Section 3, where large spikes in inflation can only occur if money supply exceeds a certain threshold, is in line with this interpretation.

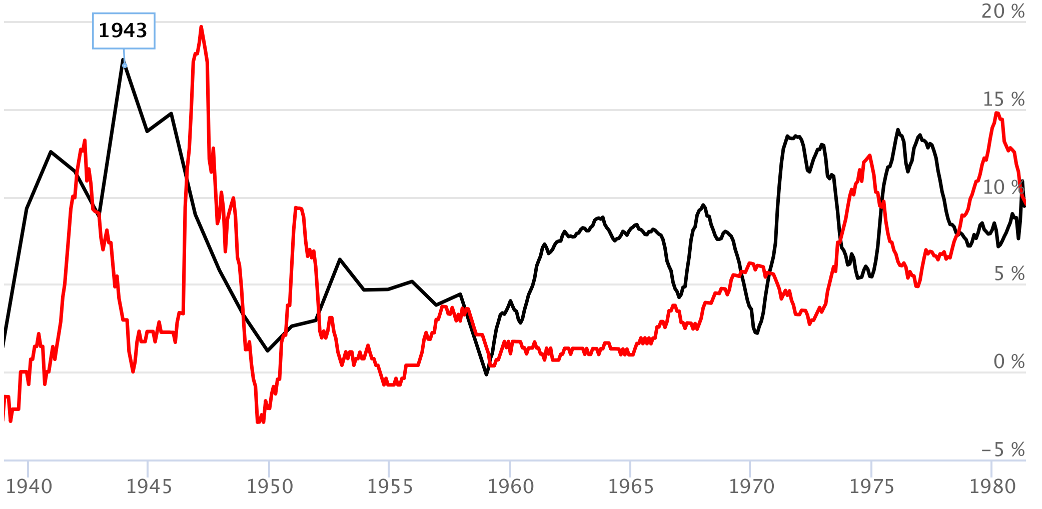


**FIGURE 1** US post war CPI inflation (red) and the rate of money supply M2 (black) for the years 1940–1980. Data provided by Longtermtrends.net.

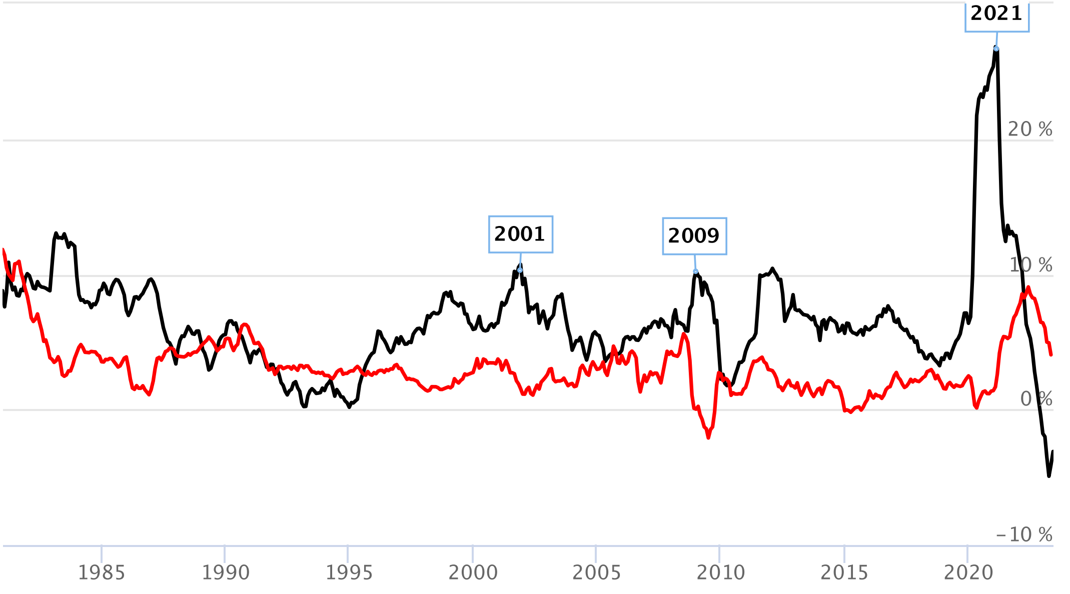


**FIGURE 2** US CPI inflation (red) and the rate of money supply M2 (black) for the years 1980–2023. Data provided by Longtermtrends.net.

Figure 3 plots inflation adjusted retail sales, and shows how demand jumps to a higher level in February 2021. This surge in retail sales aligns with our game theoretic approach, which attributes drastic spikes in inflation to runs on the inventories of shops, retailers and dealerships.

Finally, Figure 4 plots inflation rates for durable and nondurable consumption goods, showing that the inflation rate of durable goods picked up first, while prices for nondurable consumption goods, which are harder to store, followed with a lag. The inflation rate for services, which cannot be stored at all, picked up last. Comparing Figures 3 and 4, we find that the

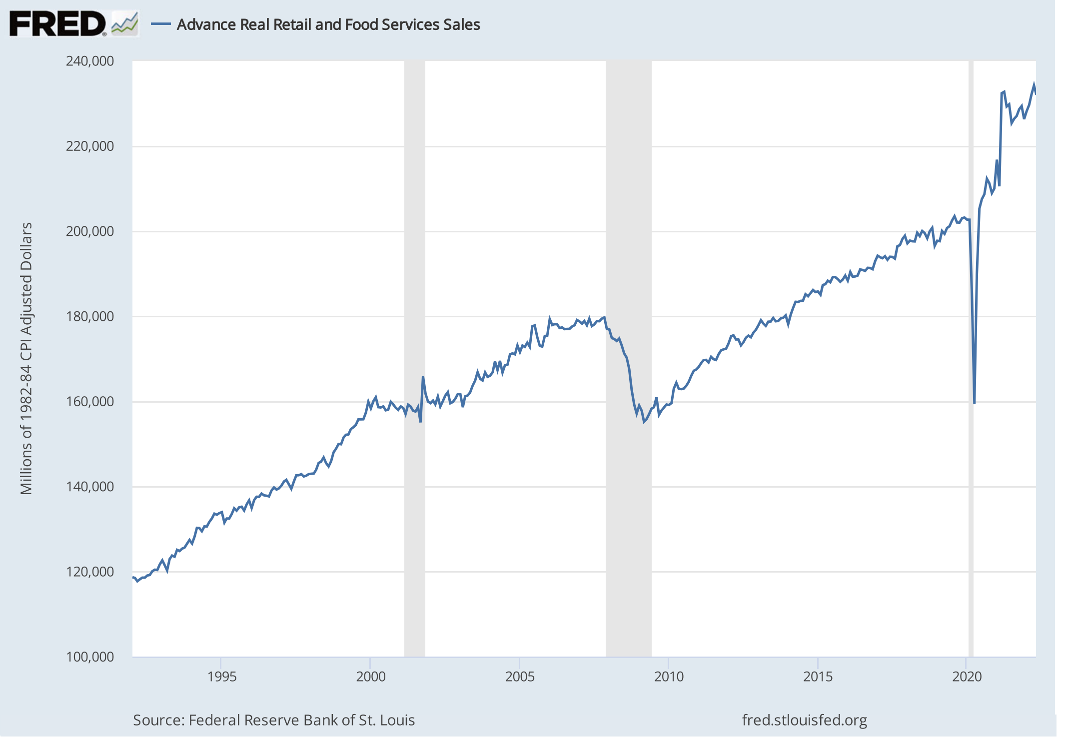


**FIGURE 3** The 2021 run on retailers: Between February and March 2021 real retail sales grew by 10%. Real retail sales between 1992 and the end of 2022 grew at an annual rate of roughly 2.4%.

jump in inflation rates in early 2021 coincides with the increase in real retail sales illustrated in 3. These observations are in line with our extended model in Section 4, where, in their efforts to preempt inflation, agents haven an incentive to buy durable goods first. Put differently, the present model predicts that increases in durable goods inflation should be a leading indicator for nondurable goods inflation as well as for the economy's overall rate of inflation.

## 3 | MODEL

There is a measure-one of agents indexed by $i \in [0, 1]$. Each agent $i$ can choose between two actions $a_i \in \{0, 1\}$. Agents who play $a_i = 1$ buy additional consumption goods, to preempt inflation. Agents who play $a_i = 0$ do not buy additional goods, just to preempt inflation.

Prices react to demand with a lag of one period. That is, if agents run on shops and retailers today, they can buy goods at the current sticker price. In turn, once shelves are empty, prices increase the day after the run.

Formally, there are two points in time. At time $t = 0$ agents choose whether to buy goods at an exogenously given sticker price $P_0$. In turn, there is a second point in time $t = 1$, where retailers choose a new sticker price $P_1$. Accordingly, inflation is given by $\pi := \frac{P_1 - P_0}{P_0}$.

We assume that inflation $\pi$ is a continuously differentiable function of aggregate household demand $A = \int_0^1 a_i di$ and money supply $M$, such that

$$\pi = \pi(A, M), \frac{\partial \pi}{\partial A} > 0, \frac{\partial \pi}{\partial M} > 0. \tag{1}$$

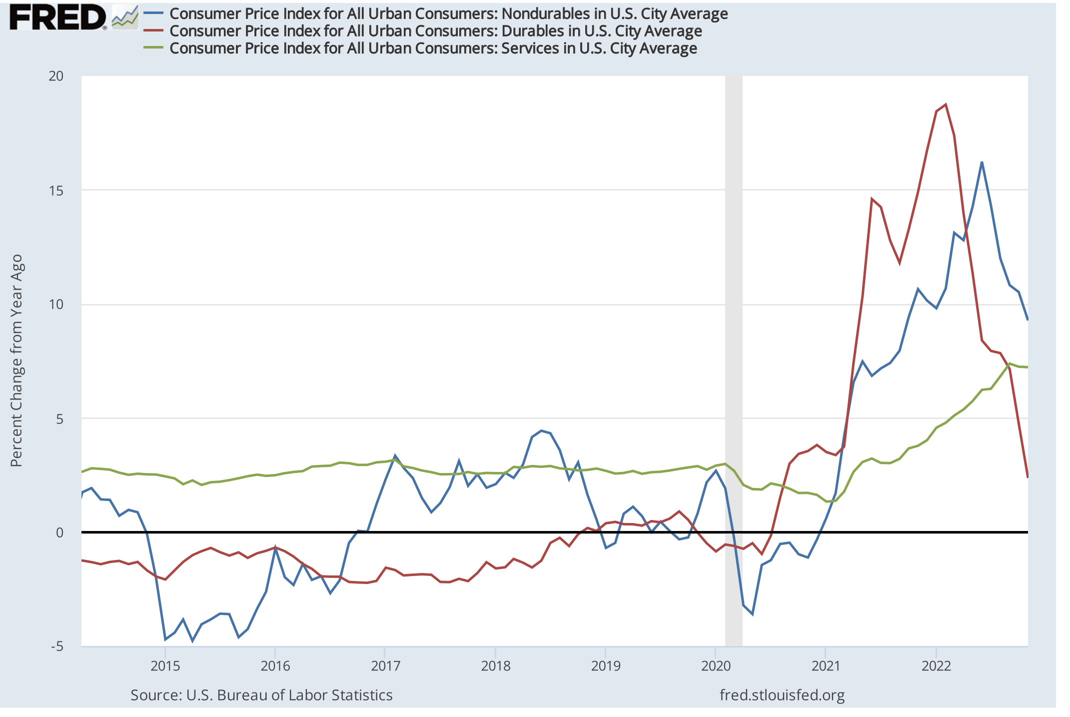


**FIGURE 4** Durable goods inflation leading consumption goods inflation.

In one interpretation, the inflation rate $\pi$ represents the nominal appreciation of durable consumption goods, such as used cars, furniture, or luxury watches. In an alternative interpretation, $\pi$, represents the nominal returns on buying goods today rather than tomorrow. These returns are partially offset by a rate of depreciation $\delta > 0$, which reflects the aging, depreciation or the cost of storing goods. That is, a 5-year-old car, which was stored for a year, can only be sold in the market for 6-year-old cars. In the context of less durable consumption goods, or services, $\delta$ reflects that agents have to rush consumption, to make use of additional goods that were bought to preempt a future price increase.[5]

Paper assets, such as money, checking account balances, or short-term bonds, yield a nominal return $r(M)$, which we may interpret either as a nominal interest rate or as the return on paper assets. This nominal interest rate is assumed to be a continuously differentiable function of aggregate money supply:

$$r = r(M), \frac{\partial r}{\partial M} < 0. \tag{2}$$

Finally, we assume $\lim_{M\to\infty}(\pi(A, M) - \delta - r(M)) > 0$ and $\lim_{M\to 0}(\pi(A, M) - \delta - r(M)) < 0$, which ensures that (i) households use money mainly for transaction purposes as $M \to 0$ and (ii) that discarding money will eventually be a dominant strategy as $M \to \infty$.

Once we normalize the nominal value of each agent's 'paper assets' to one, households maximize:

$$\max_{a_i} U(a_i) = (1 - a_i)r(M) + a_i(\pi(A, M) - \delta), \tag{3}$$

[5]That is, inflation expectations may induce agents to get a haircut a month earlier than necessary, to preempt a price increase. Likewise, a household may change his plans at a cost $\delta$, to go on a cruise today, to preempt inflation. In turn, the household consumes the memories of the experience over time. Finally, the present model does not apply to goods such as a warm meal, which cannot be stored at all.

which yields

$$a_i = \begin{cases} 1 & \pi - \delta > r \\ 0 & \pi - \delta < r. \end{cases} \tag{4}$$

Using (4), we define cutoff values for the quantities of money $M^*$ and $M^{**}$ such that

$$\pi(A = 1, M^*) - \delta = r(M^*), \tag{5}$$

$$\pi(A = 0, M^{**}) - \delta = r(M^{**}). \tag{6}$$

Combining (5) and (6) with our assumptions on the derivatives of $\pi(A, M)$ and $r(M)$, specified in (1) and (2), we have

**Proposition 1.** *There exists a unique low-inflation equilibrium where $A = 0$ as long as $M < M^*$. For $M \in [M^*, M^{**}]$, there exist two stable equilibria, one equilibrium $A = 0$ with low inflation, and the other $A = 1$ with high inflation. Finally, if $M > M^{**}$, a unique high-inflation equilibrium $A = 1$ exists.*

*Proof.* The proof is given in Appendix A. □

Diagram 1 illustrates Proposition 1, and suggests two corollaries:

**Corollary 1.** *The equilibrium inflation rate $\pi(A(M), M)$ is step discontinuous in $M$.*

**Corollary 2.** *There exists no money supply $M$, such that equilibrium inflation $\pi(A(M), M)$ falls into the nondegenerate interval $(\pi(0, M^{**}), \pi(1, M^*))$.*

*Proof.* The proof is given in Appendix A. □

According to Corollary 1, small changes in money supply can lead to disproportionate changes in inflation and goods demand, as illustrated in Diagram 1. In turn, Corollary 2 notes that there exists a nondegenerate range of

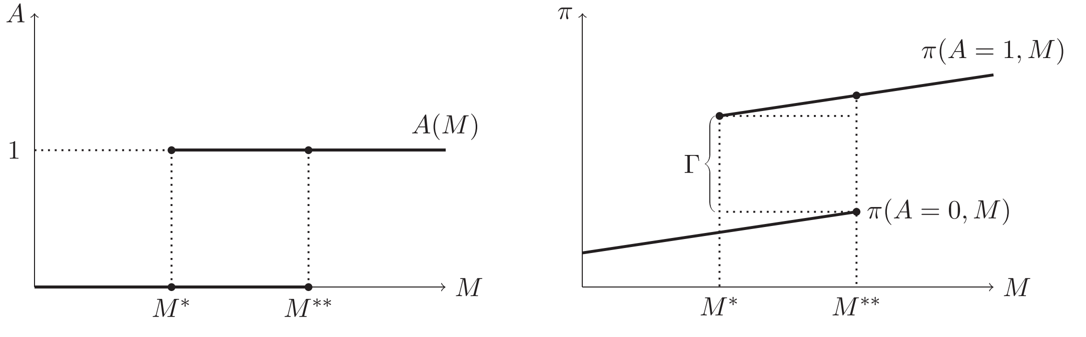


**DIAGRAM 1** Left: Equilibrium aggregate strategic goods demand $A$ as a function of money supply. Right: Inflation rates as functions of money supply $M$ and the level of aggregate strategic goods demand $A$. To simplify the exposition, inflation rates $\pi(1, M)$ and $\pi(0, M)$ are drawn as linear curves. The winged bracket (right diagram) illustrates the set $\Gamma$ of intermediate inflation rates, which cannot be equilibrium outcomes. This set $\Gamma$, as shown in Corollary 2, is nonempty.

intermediate inflation rates that cannot be targeted, even if the central bank was able to choose the equilibrium that agents play for any given level of money supply.

The winged bracket in Diagram 1 (right) illustrates the range $\Gamma$ of inflation rates which, irrespective of the level of money supply, cannot be equilibrium outcomes. Put differently, depending on agents' equilibrium play, money supply is always either too low or too high for moderate inflation. Taking this view, moderate inflation rates, $\pi(A(M), M) \approx 2\%$, in-line with most central banks' mandates, may thus not be feasible targets.[6]

In one interpretation of our model, Diagram 1 graphs an economy where households are willing to hold cash for as long as $M < M^*$. Increases in money supply thus have only a small impact on inflation rates. Increases in money supply past $M^*$, can then either fail to increase inflation, or, alternatively, can trigger a run on retail inventories, where agents' collective efforts to convert paper assets into consumption goods causes a drastic spike in inflation. Put differently, for money supplies $M \in (M^*, M^{**})$, there exist two equilibria. In one equilibrium the economy is in a liquidity trap, while in the other equilibrium, agents run on retailers, and the economy experiences a spike in inflation. Finally, once $M$ exceeds $M^{**}$, it is a dominant strategy to discard paper assets, resulting in high demand and high inflation.

The functions $\pi(A(M), M)$, $r(M)$, and thus the quantities $M^*$ and $M^{**}$, are likely neither known to policy makers nor to the economy's agents. In the next section, we therefore ask whether there are observable early warning signs, which help both agents and central banks to forecast a move, from a passive $A = 0$ equilibrium, to an inflationary $A = 1$ equilibrium. One way to obtain such early warning signs is by looking at the inflation rates of long- and short-lived consumption goods separately.

## 4 | AN EMPIRICAL IMPLICATION: THE INFLATION CURVE

In our baseline model, variable $\delta$ represented costs, such as aging and depreciation of goods, or, in the context of perishable goods, the inconvenience to rush consumption. Technically, $\delta$ is a hurdle, which makes it less attractive to buy goods, just to preempt inflation. This 'depreciation hurdle' is naturally lower for durable consumption goods, such as furniture, cars, or expensive watches, than for short-lived goods, such as food items and services. Taking these differences into account, we index goods by $j = 1, 2, 3 \ldots N$, and order these goods such that $\delta_{j+1} < \delta_j$. That is, good $j = 1$ is the least durable good, and good $j = N$ is the longest lived good. Once households choose which goods to buy when they discard their cash holdings, we obtain analogues to the households' first order condition (4), which differ regarding the goods' specific depreciation rates $\delta_j$. These conditions, in turn, yield analogues to conditions (5) and (6), which imply cutoffs $M_j^*$ and $M_j^{**}$, for each good $j = 1, 2, 3 \ldots N$. These cutoffs characterize the quantities of money, for which equilibrium inflation in good $j$ is either low, high, or indeterminate. Given that $\delta_{j+1} < \delta_j$, we have $M_{j+1}^* < M_j^*$ and $M_{j+1}^{**} < M_j^{**}$.[7] That is, as money supply grows, agents have an incentive to run on longer-lived goods first. Long-lived goods will thus experience a discontinuous uptick in inflation before shorter-lived goods do. A sudden uptick in the prices of cars, luxury watches, and furniture would thus be followed by increased inflation in shorter-lived goods and services, such as haircuts or food items. Taking this view, the price

[6] We argue that the interval $(\pi(0, M^{**}), \pi(1, M^*))$ is likely large. That is, a change from $A = 0$ to $A = 1$, induces a drastic increase in inflation. To make this argument in the context of the US economy, we note that money supply $M1$ increased more than 10-fold (from 1.4 trillion in 2007 to 18 trillion in mid 2020). At the same time, nominal GDP increased only by 50% (from 14.5 trillion in 2007 to roughly 21 trillion in 2020). This suggests that a coordinated move, from the $A = 0$ equilibrium of the last decade, where inflation was low, to an $A = 1$ equilibrium, in which households discard their (relative to 2007) excessive paper assets, should result in a, using, for example, the quantity equation $PY = Mv$ with $v = f(A)$, $f'() > 0$, quite drastic increase in prices. Taking a slightly different perspective, the interval $(\pi(0, M^{**}), \pi(1, M^*))$ will be nondegenerate in situations where there is a difference between the nominal value of all paper assets on the one hand, and the nominal value of the goods and services that the economy can, now or in the foreseeable future, produce. Taking this perspective, nominal GDP has grown by roughly 50% in the 2009–2020 period while, as mentioned earlier, M1 and the SPY have grown by roughly 1000% and 400% respectively. A move out of financial assets into consumption goods should thus induce considerable price increases.

[7] That is, differentiation of (5) and (6) yields $\frac{dM}{d\delta} = \frac{1}{\pi_M - r_M} > 0$, such that increases in the depreciation rate increase thresholds $M^*$ and $M^{**}$.

movements in durable consumption goods[8] are a leading indicator for an economy-wide increase in inflation as in Figure 4.

## 5 | LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The present model is highly stylized and thus abstracts from several aspects that may otherwise be of importance.

### 5.1 | Common knowledge

Our model attributes drastic increases in inflation to coordinated changes in agents' behaviour, rather than to incremental variations in fundamentals, such as the level of money supply. To emphasize this mechanic, we assumed that agents have common knowledge over the game that they play. Under common knowledge, agents can of course coordinate perfectly, and pure strategy equilibria are either associated with an aggregate action/demand $A = 0$ or $A = 1$. One way to relax the assumption of common knowledge and perfect coordination, is to incorporate asymmetric information over the game's payoff coefficients. For example, agents might have asymmetric information over the magnitude of the price increase, which is caused by a run on retailers.[9] Monderer and Samet (1989), Carlsson and van Damme (1993), Rubinstein (1989). Recently, Morris and Shin (2004), Angeletos and Werning (2006), Grafenhofer and Kuhle (2016) and Grafenhofer and Kuhle (2022) discuss such models in the context of bank-runs, and show that multiple equilibria exist under fairly general conditions. That is, assymmetric information, respectively, a lack of common knowledge, would still give rise to multiple equilibria. Coordination, however, would no-longer be perfect. That is, there would be high-inflation equilibria where $A \in (0, 1)$ is sufficiently high, and low inflation equilibria where $A \in (0, 1)$ is low. In turn, the jumps in inflation, though less drastic, would carry over.

Another way to argue for agents' ability to coordinate is the plot in retail sales in Figure 3. The 10% jump in sales in February 2021 shows that agents' buying decisions were well coordinated. That is, the step function in retail sales, as well as the step function in rate of inflation in Figure 2, are akin to the two step functions drawn in Diagram 1.

### 5.2 | Substitutes and complements

In Section 4, we argued that agents direct their preemptive purchases towards longer-lived goods first. This would make durable goods inflation a useful leading indicator for increases in overall inflation rates. One way to extend this argument further is to take into account that certain shorter-lived goods are complements to long-lived goods. That is, the purchase of a house may coincide with an increase in demand for garden furniture, or home appliances. Incorporating substitution, income and wealth effects,[10] may thus offer

[8]We could extend the current argument to include assets like farm-land, real estate, and stocks, i.e. claims on future consumption. In this interpretation, stocks would be the first asset class/good, that moves to an equilibrium with high (asset price) inflation. In turn, long-lived consumption goods follow. Finally, as long-lived, cheaply priced, investment opportunities become scarce, inflation reaches nondurable consumption goods.

[9]That is, the inflation rate might have the following functional form $\pi(A, M, \theta) = \alpha A + \beta M - \theta, \alpha > 0, \beta >$, where $\theta$ represents an unobservable variable that governs the suppliers' price response to increased demand. Once we assume that each agent $i$ receives a noisy private signals $x_i = \theta + \xi_i, \xi_i \sim \mathcal{N}(0, 1)$, over this unknown supply response, the game's payoff structure is no-longer common knowledge. Players who receive high (low) signals $x_i$ will expect that inflation is low (high). Accordingly, agents with low realizations will run on retailers, while agents, who receive high realizations $x_i$, will expect that the supply response is strong, respectively that inflation will be low, and will thus abstain from the run on retailers.

[10]In the case of housing, wealth and income effects may also play a role. That is, a run on the housing market will improve the wealth of those who already own a house, which may induce demand for other goods and services.

another direction for future research. Likewise, and similar to the aspect of asymmetric information, we may use the present continuum of agents model, to endow agents with heterogeneous tastes and (time) preferences. One may conjecture that such heterogeneity, will, once again, make coordination harder. That is, the thresholds of money supply, which are sufficient for a run on retailers to occur, would likely increase if different agents would prefer to target different goods categories first.

## 6 | DISCUSSION

We present a simple coordination game, where inflation is driven by agents' efforts to preempt it.

This simplistic model mimics a number of stylized facts on money and inflation, which are hard to reconcile with standard macroeconomic rational expectations models. First, increases in money supply often fail to amplify inflation for extended periods of time. In turn, due to agents' strategic goods purchases, these periods of calm end with drastic, rather than gradual, changes in inflation. Third, the present model predicts that there exists a range of intermediate inflation rates, which are not consistent with any equilibrium. That is, depending on agents' equilibrium play, money supply is always either too high or too low for moderate inflation. Put differently, if moderate inflation rates are socially desirable, then the present model predicts that central banks can only choose among equilibria that have either too much or too little inflation.

Finally, we illustrate our model using recent data on inflation, money supply and retail sales. These data were in-line with the present model's predictions. Namely, the post 2008 increases in money supply did not lead to higher inflation for a long time. This period of calm was followed by a spike in inflation, which coincided with a discontinuous increase in retail sales. Moreover, durable goods inflation indeed increased first, while non-durable goods and services inflation followed with a lag. Taking this view, the present model predicts that increases and decreases in durable goods inflation are a useful leading indicator for a coming increases and decreases in the overall rate of inflation.

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### CONFLICT OF INTERESTS STATEMENT

The author declares no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study were taken from 'Fred Economic Data St Louis FED', and are openly available at https://fred.stlouisfed.org/data was also taken from Longtermtrends.net at https://www.longtermtrends.net/m2-money-supply-vs-inflation/.

### ETHICS STATEMENT

The author followed the required ethical standards.

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## NON-TECHNICAL SUMMARY

This paper studies games, where households buy consumption goods to preempt inflation. For these games, increases in money supply often fail to amplify inflation for extended periods of time. In turn, due to agents' preemptive goods purchases, these periods of calm end with drastic, rather than gradual, changes in inflation. Finally, the present model predicts that there exists a range of intermediate inflation rates, which are not consistent with any equilibrium. That is, depending on agents' equilibrium play, money supply is always either too high or too low for moderate inflation. We present recent data to illustrate our model's predictions.

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## APPENDIX A: PROOF OF PROPOSITION 1 AND COROLLARY 2

The proof of Proposition 1 consists of two main steps. First, we establish the existence and uniqueness of cutoffs $M^* > 0$ and $M^{**} > 0$. In a second step, we show that $M^* < M^{**}$. Finally, we prove that $\pi(0, M^{**}) < \pi(1, M^*)$, which establishes that the interval $(\pi(A = 0, M^{**}), \pi(A = 1, M^*))$ in Corollary 2 is nondegenerate.

**Step 1:** To show existence and uniqueness of $M^* > 0$ and $M^{**} > 0$, we rewrite (5) and (6) such that

$$\pi(A = 1, M^*) - \delta - r(M^*) = 0, \tag{A1}$$

$$\pi(A = 0, M^{**}) - \delta - r(M^{**}) = 0. \tag{A2}$$

It then follows from our assumptions $\lim_{M\to\infty}(\pi(A, M) - \delta - r(M)) > 0$ and $\lim_{M\to 0}(\pi(A, M) - \delta - r(M)) < 0$ that (A1) has at least one solution $M^* > 0$ and (A2) has at least one solution $M^{**} > 0$. Taking into account that inflation

$\pi(A, M)$ is increasing in money supply, and that the interest rate $r(M)$ is decreasing in money supply, the left-hand-sides in (A1) and (A2) are monotonous in $M$, such that the respective solutions $M^* > 0$ and $M^{**} > 0$ must be unique.

**Step 2:** Given that $M^* > 0$ and $M^{**} > 0$ exist, we can now show by contradiction that $M^* < M^{**}$. That is, we consider the three possible cases $M^* = M^{**}$, $M^* > M^{**}$, $M^* < M^{**}$, and show that $M^* = M^{**}$ and $M^* > M^{**}$ each yield contradictions.

- Suppose $M^* = M^{**}$, then it follows that $r(M^*) = r(M^{**})$, which, together with (A1) and (A2) implies that $\pi(A = 1, M^*) = \pi(A = 0, M^{**})$, which, given our assumption that inflation is an increasing function of demand $A$, cannot be true.
- Suppose $M^* > M^{**}$: Given that the interest rate is falling in $M$, this implies that $r(M^*) < r(M^{**})$. Combining this with (A1) and (A2), implies that $\pi(A = 1, M^*) < \pi(A = 0, M^{**})$. At the same time, given that inflation is increasing in $A$ and $M$, we should have $\pi(A = 1, M^*) > \pi(A = 0, M^{**})$, as long as $M^* > M^{**}$. Hence, our assumption $M^* > M^{**}$ yields a contradiction.

Taken together, we have thus shown that $M^* > 0$ and $M^{**} > 0$ exist, and that $M^* < M^{**}$.

*Proof of Corollary* 2. If $M^* < M^{**}$, then $r(M^*) > r(M^{**})$. Together with (A1) and (A2), this implies that $\pi(A = 0, M^{**}) < \pi(A = 1, M^*)$. Accordingly, the interval $(\pi(A = 0, M^{**}), \pi(A = 1, M^*))$ is nondegenerate. □