Sticky Information, Heterogeneity, and Aggregate Demand*

Pascal Meichtry†

February 2025

Abstract

This paper examines how household heterogeneity and information rigidities shape the transmission of monetary policy to aggregate demand. Using U.S. household survey data, I document significant differences in the frequency of information updating across income groups, with constrained households updating less frequently. I develop a two-agent New Keynesian model with heterogeneous households and sticky information, showing that the response of aggregate consumption to monetary policy shocks is driven by an asymmetric interplay of amplification and dampening. While constrained households amplify the effects by responding disproportionately to aggregate income changes, information rigidities slow the diffusion of economic news, attenuating the consumption response and reducing the likelihood of achieving amplification. Additionally, I propose a novel yet simple analytical solution method to handle the infinite state space in sticky-information models, providing a closed-form representation of aggregate-demand effects. These findings enhance our understanding of how household expectations influence macroeconomic dynamics and underscore the critical role of information frictions in shaping the effectiveness of monetary policy.

JEL Classification: E21, E32, E50, E52

Keywords: Heterogeneous Agents, Sticky Information, Aggregate Demand, Monetary Policy, Amplification, Dampening, Hand-to-Mouth

*I am very grateful to Florin Bilbiie for his invaluable guidance and support. I thank Adrien Auclert, Philippe Bacchetta, Kenza Benhima, Aurélien Eyquem, Ricardo Reis, Pascal St-Amour, Andreas Tischbirek, and fellow UNIL Ph.D. students for helpful comments. I am also grateful to seminar participants of the University of Lausanne Research Days and the Bank of England Interns Workshop as well as participants at the 69th Annual Meeting of the French Economic Association, the 2021 Annual Congress of the European Economic Association, the 15th RGS Doctoral Conference in Economics, the RES 2022 Annual Conference, the 26th Spring Meeting of Young Economists, and the 53rd Annual Conference of the Money, Macro and Finance Society.

†University of Lausanne, Switzerland. Email: pascal.meichtry@unil.ch

1 Introduction

Traditional New Keynesian models often assume that households have full up-to-date information at any point in time and can be represented by a single rational-expectations agent. Relaxing these two assumptions has considerable implications for consumption and demand both at the individual household and the aggregate level.

Heterogeneity in terms of income, wealth, or the consumption and saving decisions of households crucially shapes the transmission mechanism of monetary policy. One result of this literature is the appearance of an amplified response of economic aggregates to monetary policy relative to the standard representative-agent New Keynesian (RANK) economy (see, among others, Auclert, 2019; Bilbiie, 2018, 2020; Bilbiie, Känzig, & Surico, 2022; Debortoli & Galí, 2017). A core component to achieve such *amplification* is heterogeneity across agents in terms of the marginal propensity to consume (MPC) out of a transitory income shock. On the other hand, how agents form their expectations is still a much-debated question in macroeconomics. The assumption of full-information rational expectations (FIRE), according to which economic agents are entirely aware of the structure of the economy and can perfectly observe and use all available information at hand to form expectations, has long been the gold standard. However, there is pervasive evidence of large information rigidities across different economic agents (Coibion & Gorodnichenko, 2012, 2015). These frictions cause rational individuals to have only imperfect information about economic conditions and to often underreact in response to macroeconomic shocks. This leads to delayed responses and generates *dampening* at the aggregate level.

Against this backdrop, this paper studies how household heterogeneity and information rigidities impact the transmission of conventional monetary policy to aggregate consumption, or equivalently, aggregate demand. In this context, I explore the relative importance of amplification and dampening arising from the interaction of these two frictions, and their implications for the effectiveness of monetary policy in quantitative models. The target value is the aggregate-demand multiplier, which measures the quantitative effect of a change in the current real interest rate on aggregate consumption.

For this purpose, I build a two-agent New Keynesian (TANK) model with heterogeneity in household income based on Bilbiie (2008), in which households differ in their participation in asset markets. A fraction of agents consume their entire disposable income in each period ("hand-to-mouth households"), while the remaining households are unconstrained and smooth consumption by saving in state-contingent bonds ("savers"). I extend this setup by introducing sticky information, following Mankiw and Reis (2006, 2007), where a portion of households can only occasionally update their information about the state of the economy. Due to these elements, I term the framework a sticky-information two-agent New Keynesian (SI-TANK) model.

The modeling approach is motivated along two lines. First, I provide empirical evidence for information rigidities in household expectations using U.S. survey data. Estimates of the relation between households' inflation forecast errors and their forecast revisions indicate considerable differences in the degree of information rigidity across the income distribution. In particular, lower-income households update their information less frequently than wealthier households. This result serves as the empirical basis for the analytical model and justifies the assumption regarding the information structure. Second, to obtain models that are consistent with both empirical microeconomic and macroeconomic moments, researchers have recently relied on combining heterogeneous households with information frictions (Auclert, Rognlie, & Straub, 2020; Carroll, Crawley, Slacalek, Tokuoka, & White, 2020; Pfäuti & Seyrich, 2022). While existing frameworks successfully match fundamental evidence in the data, it is not always straightforward to isolate the channels at work. A common challenge when deviating from a RANK economy and FIRE is the handling of complex computational methods. By taking a step back, this paper explores what a simplified framework implicates for interactions between the mentioned frictions and about the mechanisms at play. The simplicity of sticky information makes it an appealing choice, as it introduces information rigidity with only a single alternative assumption in the spirit of the well-known Calvo staggered pricing, while retaining rational expectations.

In the first main part of the paper after presenting the SI-TANK model, I analyze its main properties, focusing on the initial impact of a monetary policy shock on aggregate demand. The model combines two important propagation mechanisms of such a shock: amplification and dampening. Amplification means that the effect of real interest rate change on aggregate demand (i.e., the aggregate-demand multiplier) is higher than in a RANK model and increases in the share of hand-to-mouth households in the economy. If that effect is lower, there is dampening.

Therefore, one key component of SI-TANK that changes the size of real effects is the presence of constrained households that live hand-to-mouth, so that the MPC out of their own income is one. This increases the aggregate MPC in the economy relative to RANK. A *force of amplification* then emerges if the income of hand-to-mouth agents reacts more than one-to-one to changes in aggregate income. This condition results in countercyclical income inequality and a reinforced demand response: after an unexpected interest rate cut that implies an initial increase in aggregate demand, hand-to-mouth agents become disproportionately richer, leading to declining inequality between unconstrained and constrained agents together with a further demand boost. The feedback from individual income back to aggregate income is precisely what eventually amplifies the real effects of monetary policy. It is in line with the mechanisms in Bilbiie (2018, 2020) or Bilbiie et al. (2022).

At the same time however, I show that the effects of monetary policy are to a certain extent *dampened* within SI-TANK due to the introduction of information rigidities. In general, there are different ways of departing from the full-information component of

FIRE.[1] The goal of this paper is to keep the analytics tractable and, likewise, the model comparable to the standard RANK model and the recent literature in this field, which is why I adapt the concept of sticky information as in Mankiw and Reis (2002, 2006, 2007) or earlier in Gabaix and Laibson (2002). Among the two household types in the model, only the consumption-smoothing, unconstrained savers are subject to this friction. In each period, a constant fraction of savers update their information about the state of the economy. Based on this, they optimally choose a consumption plan that is just revised at some unknown point in the future. Between two planning dates, the household does not obtain new information and its consumption follows the pre-determined path. As a result, information about economic conditions diffuses slowly through the population. The lag in perception generates a sluggish aggregate-consumption response after a monetary policy shock compared to RANK, because the consumption of savers only adjusts slowly to the arrival of news.

The SI-TANK model combines both of the described features. Household heterogeneity can amplify the initial aggregate-demand response, whereas sticky information attenuates it. By analyzing the IS curve (or aggregate Euler equation), I find that the net propagation effect is largely determined by the two main model parameters: the share of hand-to-mouth agents and the degree of information stickiness. Somewhat less obvious and different from what previous authors have found, dampening might arise even if income inequality is countercyclical. Therefore, the overall effect of a monetary policy shock on aggregate demand may still be attenuated although hand-to-mouth agents' income reacts more than proportionally to aggregate income changes; precisely in the case in which the share of constrained agents (and therefore the amplifying component of SI-TANK) is not high enough compared to the degree of information stickiness. On the other hand, to achieve overall amplification of monetary policy effects, income inequality must be *substantially* countercyclical for a standard calibration of the model.

The magnitudes of the main model parameters are critical for the absolute effects of monetary policy. In a next step, I show that this changes when studying household heterogeneity and sticky information both in isolation and jointly, and relating the respective aggregate-demand multipliers to each other. Considering an unexpected one-time change in the real interest rate, I demonstrate that the propagation of monetary policy shocks is shaped by an asymmetric interaction of amplification and dampening, irrespective of the selected parameter values. Sticky information attenuates the aggregate-consumption response more in a representative-agent model than in a two-agent setting. What is even more striking is that household heterogeneity becomes proportionately more influential in combination with sticky information. Both asymmetries arise from the fact that in a two-agent model the intertemporally optimizing savers alone are affected by the information friction, while this is not the case in an economy where all households are identical. Amplification, in contrast, always involves and works through both types of households.

[1] For a compact overview, see Coibion, Gorodnichenko, and Kamdar (2018).

It is well-known from the heterogeneous-agent literature that hand-to-mouth agents constitute the main element of amplification. On the other hand, my finding about the relative strength of heterogeneity in rigid-information setups indicates that amplification might substantially be driven by the presence of information frictions rather than by high-MPC agents alone. The paper therefore contributes to a better understanding of monetary policy propagation in quantitative models with more than one agent. Furthermore, it points at the importance to differentiate individual frictions and their role.

The second main part of this paper is dedicated to solving the SI-TANK model analytically. Incorporating sticky information in standard macroeconomic models gives rise to an infinite number of lagged expectations and thus an infinite state space. An analytical solution is therefore usually complex or not even possible. To overcome these difficulties, I provide a novel yet simple way to solve a wide range of sticky-information models analytically when one is interested in isolating the aggregate-demand side. It allows me to derive reduced-form expressions for output and inflation that only depend on the monetary policy shock and model parameters. These expressions can then be used to verify the findings obtained from analyzing the effects of the policy shock on the familiar three-equations system of the SI-TANK model.

To complete the analytical part, I simulate impulse responses to an unanticipated monetary policy shock. The graphical representation not only confirms the preceding results about the response of aggregate consumption and output on impact of the shock, but it also facilitates a discussion about the periods subsequent to the shock. Among others, the presence of non-updated savers generates a hump-shaped response as documented in the macroeconomic literature.

Related literature. This work contributes to the growing literature on the effectiveness of monetary policy in heterogeneous-agent models.[2] That field exposes how different assumptions and elements of such models affect the propagation of monetary policy shocks and how they shape amplification and dampening effects. In particular, my analysis draws on the analytical TANK literature that makes simplifying assumptions to identify the driving forces at work in richer models.

The main framework is based on Bilbiie (2008). He builds an analytical TANK model with two types of agents differing in their degree of participation in asset markets as described above. The implied heterogeneity in MPCs changes the sensitivity of aggregate demand to monetary policy and gives room for amplification with respect to RANK. Bilbiie (2020) emphasizes that the net propagation effect hinges on the elasticity of hand-to-mouth households' income to aggregate income: when it is above one, amplification arises; otherwise, there is dampening. While the SI-TANK model in this paper involves comparable effects, the sufficient conditions are different and dampening might arise even

[2] See, among others, Acharya and Dogra (2020); Alves, Kaplan, Moll, and Violante (2020); Auclert (2019); Auclert et al. (2020); Bilbiie (2018, 2020); Bilbiie et al. (2022); Debortoli and Galí (2017); Werning (2015).

if constrained agents react disproportionately to changes in aggregate income.

Second, I build on the large literature that explores deviations from FIRE, in particular about the assumption of sticky information originating from Gabaix and Laibson (2002) and Mankiw and Reis (2002, 2006, 2007). In the context of representative-agent models, sticky information has been first and foremost applied on the part of firms to study price dynamics.[3] The seminal work of Mankiw and Reis (2002) proposes it as an alternative way to model price setting. Related to this and more recently, Bacchetta, van Wincoop, and Young (2022) use a similar Calvo type friction in the context of modeling portfolio decisions and as a way to achieve gradual portfolio adjustment. Other prominent papers incorporate the assumption of sticky information in a fully-fledged DSGE framework to match U.S. business cycle facts or study monetary policy (Mankiw & Reis, 2006, 2007; Reis, 2009a, 2009b). They assume that households, firms, and workers are all subject to inattention when taking decisions. Estimates for the U.S. and the Euro area unveil a different degree of information stickiness to be present in various markets (goods, labor, financial), most notably for consumers. Due to the recent advances in the context of heterogeneous-agent models and the revived interest in aggregate demand, however, it appears appropriate to focus particularly on the implications of sticky information on households within these models.

The literature closest related to this work combines concepts of limited information with household heterogeneity, mostly to match or explain microeconomic and macroeconomic evidence in the data. Similar to this paper, Broer, Kohlhas, Mitman, and Schlafmann (2021) unveil systematic heterogeneity in the macroeconomic expectations of U.S. households. They try to rationalize this in a quantitative heterogeneous-agent New Keynesian (HANK) framework with dynamic information choice. Unlike them, I model information exogenously to focus on its interaction with the pre-determined degree of household heterogeneity and because the way households acquire information is only of second-order importance here. Pfäuti and Seyrich (2022) discuss amplification and dampening channels within a New Keynesian model with household heterogeneity and bounded rationality and study what the interaction of these two elements implies for the IS curve. The model here can be seen as a simplified version of theirs, with an even simpler information friction and without idiosyncratic risk. Instead of explaining empirical facts like they do, I derive sufficient conditions that determine the net propagation effect of monetary policy, focus on the asymmetric interplay of amplification and dampening, and discuss implications for theoretical modeling.

Another strand of this literature combines heterogeneity in household income with sticky expectations about the macroeconomy, assuming that households can perfectly observe their personal circumstances or idiosyncratic shocks, while they perceive information about macroeconomic variables or aggregate shocks only infrequently. Applying this in the

[3] See, for example, Chung, Herbst, and Kiley (2014); Coibion (2006); Dupor, Kitamura, and Tsuruga (2010); Dupor and Tsuruga (2005); Mankiw and Reis (2002); Trabandt (2007).

context of an estimated HANK model, Auclert et al. (2020) achieve realistic MPCs out of a transitory income shock and, at the same time, reproduce the empirical fact that the response of macroeconomic aggregates to monetary policy shocks tends to be hump-shaped. Prior to this, the assumption of sticky expectations was used in Carroll et al. (2020) who succeed in matching aggregate-consumption dynamics in both a micro-founded, small open economy model and a micro-founded HANK model. Unlike these papers, I assume that only part of the households are affected by the information rigidity. As a consequence, these households are eventually the driver of the sluggishness in aggregate consumption, whereas in the mentioned papers it is the imperfect attention to aggregate shocks of all households that counts.

Finally, by providing a simple approach to deal with sticky information, I also address the literature on solution methods for this friction. Mankiw and Reis (2007), Meyer-Gohde (2010), and Wang and Wen (2006) draw on infinite moving average representations and the method of undetermined coefficients to efficiently handle the infinite number of lagged-expectation terms. On the other hand, Trabandt (2007) as well as Verona and Wolters (2014) limit those terms to approximate the infinite with a finite state space. My work differs from these papers in its focus on analytical tractability. Although the solution method I propose premises a specific monetary policy rule, it is computationally straightforward and comprehensive enough to elaborate the implications of sticky information in various models, be it in combination with heterogeneous households or not.

Outline. The rest of the paper is organized as follows. Section 2 provides empirical evidence for information frictions across households. Section 3 presents the SI-TANK model and its reduced-form equilibrium conditions. Section 4 analyzes the asymmetric interplay of amplification and dampening after a monetary policy shock. Section 5 provides an analytical and graphical view on the model. Finally, Section 6 discusses practical implications, and Section 7 concludes.

2 Evidence for information rigidities

In order to motivate the model structure below, I start by providing some survey-based evidence for information frictions. A popular data set choice in the literature is the historical forecast data of U.S. consumer price inflation. I will use data from the Michigan Surveys of Consumers (MSC), which asks more than 500 U.S. households on a monthly basis about their consumption attitudes and expectations. Among other aspects, the University of Michigan interviews the participants about the average change in prices they expect over the next 12 months. It also collects information on each household's income which makes it convenient to study differences along the income distribution.

To demonstrate the presence of information rigidities in expectations data, I follow Coibion and Gorodnichenko (2015) and study the relation between the ex-post mean year-ahead inflation forecast errors across agents and the change in the ex-ante mean year-ahead forecast (which I call forecast revision for simplicity):[4]

$$\pi_{t+4,t} - F_t\,\pi_{t+4,t} = \alpha + \beta\,(F_t\,\pi_{t+4,t} - F_{t-1}\,\pi_{t+3,t-1}) + \varepsilon_t\ , \tag{1}$$

where $\pi_{t+4,t}$ denotes the inflation rate between $t+4$ and t, and $F_t\,\pi_{t+4,t}$ is the average forecast across agents at time t. Coibion and Gorodnichenko (2015) argue that the assumption of full information requires $\beta = 0$, but that information frictions are present as soon as $\beta > 0$.[5] The latter case can be visualized, for example, by a slow updating of information in the economy over time. In each period, some agents do not adjust their information set, which is why the average forecast only adjusts gradually and average forecast errors become predictable.

The mean forecast revisions are computed as the difference between the current mean forecast and the mean forecast lagged by one quarter. As the MSC provides one-year-ahead inflation expectations, I define the forecast error in equation (1) as the difference between the actual value of inflation and the average quarterly forecasts across survey respondents. As a first measure of inflation, I use year-on-year changes in the U.S. consumer price index (CPI), taken from the FRED database operated by the Federal Reserve Bank of St. Louis. However, given potential revisions of the realized inflation values, the CPI data might not be directly comparable to the historical consumer expectations. To take this into account, I use as a second measure quarterly real-time data from the first release of the actual personal consumption expenditures (PCE) price index one year ahead. These vintages are available from the Federal Reserve Bank of Philadelphia's real-time data set for macroeconomists.

The time horizons of the forecast data used in equation (1) do not fully overlap across periods. The error term ε_t is therefore not orthogonal to information at time t or earlier and the regression equation cannot be estimated by standard OLS. To overcome that issue, Coibion and Gorodnichenko (2015) propose an instrumental-variable (IV) approach, using the log change in the oil price as the instrument due to its high significance for the course of CPI inflation.

I estimate equation (1) using the average responses for inflation expectations across all households, but also for each of the four equally-sized groups along the income distribution for which the MSC data set provides mean responses. The results for the sample period from 1980-Q1 to 2019-Q4 are shown in Table 1.

The results show that there is evidence for information frictions. The aggregate estimate of $\hat{\beta}$ when using the CPI as the inflation variable implies that an average household

[4] Compared to other surveys, the MSC only provides expectations data for one-year ahead inflation. Revisions in forecasts over identical forecasting horizons (for instance, $F_t\,\pi_{t+4,t} - F_{t-1}\,\pi_{t+4,t}$) can therefore not be computed.

[5] Absent any information frictions, the mean forecast should react to a shock just as much as future inflation. This would imply a zero response of forecast errors.

Table 1: IV estimates of information rigidity in consumer inflation forecasts

	Inflation expectations along the income distribution				
Forecast error	Aggregate	Bottom 25%	Second 25%	Third 25%	Top 25%
CPI					
Forecast revision	0.953***	1.560***	0.691**	0.824***	0.804***
	(0.301)	(0.601)	(0.297)	(0.293)	(0.307)
Constant	−1.112***	−1.969***	−1.331***	−0.852***	−0.395***
	(0.155)	(0.186)	(0.159)	(0.155)	(0.149)
First stage F-statistic	36.32	10.49	40.30	29.85	27.93
Observations	160	160	160	160	160
PCE (real-time)					
Forecast revision	0.546**	1.032**	0.349	0.439*	0.426*
	(0.237)	(0.454)	(0.237)	(0.232)	(0.242)
Constant	−1.531***	−2.391***	−1.749***	−1.271***	−0.812***
	(0.132)	(0.153)	(0.133)	(0.134)	(0.133)
First stage F-statistic	36.32	10.49	40.30	29.85	27.93
Observations	160	160	160	160	160

Notes: Coefficient estimates of the instrumental variable regression equation (1) using MSC data, with Newey-West standard errors in parentheses. The dependent variable is the mean year-ahead forecast error for inflation and the forecast revision is defined as the change in the mean year-ahead forecast. The instrumental variable is the log change in the oil price. The sample period is 1980–2019. The F-statistic reports the first-stage fit and expresses the relevance of the instrument (Kleibergen-Paap rk Wald F-statistic).
* p<0.10, ** p<0.05, *** p<0.01

updates its information set roughly every six months.[6] Almost all estimates with CPI inflation point to a rejection of the null of full information at the one percent level. The point estimates and statistical significance are lower for the PCE data, but still indicate the presence of rigid information.

Analyzing the empirical findings across the income distribution provides strong evidence for a higher degree of information stickiness at the left tail as compared to other parts of the distribution. A representative household in the first quartile shows an average duration of seven to eight months since the last information update, while it is five to six months for higher quartiles of the distribution.[7] In Appendix A.1, I test if the estimated coefficients along the income distribution are statistically different from each other.

The lowest part of the distribution contains, among others, poor agents who are often borrowing-constrained or live hand-to-mouth. The results above suggest that those

[6]Coibion and Gorodnichenko (2015) describe how the regression results can be mapped directly into the degree of information rigidity within a sticky-information model as presented in section 3. If agents update their information sets with probability δ in every period, we can write the degree of information rigidity as a function of the estimated coefficients in equation (1), $1-\hat{\delta} = \hat{\beta}/(1+\hat{\beta})$. From this, the average duration between two updates can be expressed by $1/\hat{\delta} = 1 + \hat{\beta}$.

[7]The instrument for the regression of the lowest quartile seems to be weaker. This could also explain the slightly higher standard errors.

households tend to update their information much less frequently than richer households. I will use this fact for the theoretical model below and, for the sake of simplicity, take the empirical evidence to the extreme by assuming that agents living hand-to-mouth have fully rigid information. This seems intuitive as those agents tend to be much less informed and highly myopic. They undervalue information and therefore do not make an effort to acquire it.[8]

3 Model economy

I propose a model that unifies elements from two different strands of the literature. First, I introduce heterogeneity in a standard representative-agent New Keynesian model with sticky prices and flexible wages by dividing households according to their participation in asset markets. Drawing on the seminal work of Galí, López-Salido, and Vallés (2007) and Bilbiie (2008), I consider two different types of households: intertemporally optimizing savers and constrained agents living hand-to-mouth. Second, I build on Mankiw and Reis (2006, 2007) and assume that only part of the savers are fully informed about economic conditions every period. This assumption is motivated by the empirical evidence provided in the previous section. Savers alone value additional information to make their optimal decisions while agents at their borrowing constraint have no use for it. Following the respective terms used in the literature, I call this economy a sticky-information two-agent New Keynesian (SI-TANK) model.[9]

The model economy is based on a small-scale dynamic general equilibrium model without capital or a government where agents meet in three different markets: the goods market, where firms sell varieties of goods to households; the labor market, where households sell a representative type of labor to firms; and the financial market, where part of the households trade bonds among each other. To close the model, a monetary authority controls the real interest rate. Appendix B contains details on the derivation of the model.

3.1 Households

The economy is populated by a continuum of households indexed by $j \in [0, 1]$. Out of this unit mass, an exogenous share ω has no access to financial markets and thus cannot smooth consumption over time. These households only consume their disposable income such that the marginal propensity to consume out of their own income is equal to one. Following the literature, I call this type of agent hand-to-mouth (H), or constrained, households.

[8] Broer et al. (2021) emphasize that information only becomes valuable when an agent is away from the borrowing constraint. As long as households live hand-to-mouth, they have no benefit from additional information because they do not need to decide about their savings or consumption smoothing. In fact, the authors find empirically that households at low levels of wealth are less well informed.

[9] According to the groups of households present at each point in time (hand-to mouth agents, updated savers and non-updated savers), one might label this framework as a *three*-agent model. Instead, I think of the model as being composed of two types of households, one of which has two subtypes with respect to whether the information set is up-to-date.

The remaining $1-\omega$ households hold all assets in the economy. They can save by trading state-contingent bonds among each other and equally own firms. I follow Bilbiie (2008) and call them savers (S).

In each period, a household decides how many varieties of goods to buy from firms and how many units of labor to provide in order to produce these varieties. Irrespective of its type $o \in \{H, S\}$, a household's period utility function is given by

$$U\left(C_{t,j}^{o}, L_{t}^{o}\right) = \ln C_{t,j}^{o} - \xi \frac{\left(L_{t}^{o}\right)^{1+\eta} + 1}{1+\eta} , \tag{2}$$

where $C_{t,j}^{o}$ is the consumption level of household j at time t, L_{t}^{o} are hours worked by a household, η is the inverse of the Frisch elasticity of labor supply and ξ captures the relative weight of the disutility in labor.

Each household decides on the optimal allocation of spending across the different varieties of goods in the economy.[10] For this, a household of type $o \in \{H, S\}$ has full information and solves the following problem:

$$\min_{\left\{C_{t,j}^{o}(i)\right\}_{i\in[0,1]}} \int_{0}^{1} P_t(i) C_{t,j}^{o}(i) di \quad \text{s.t. } C_{t,j}^{o} = \left(\int_{0}^{1} C_{t,j}^{o}(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di\right)^{\frac{\epsilon_p}{\epsilon_p - 1}} ,$$

where $C_{t,j}^{o}$ is a household's consumption index for different varieties of goods indexed by $i \in [0,1]$, with an elasticity of substitution $\epsilon_p > 1$. $P_t(i)$ is the price of variety i. The solution to this problem is

$$C_{t,j}^{o}(i) = C_{t,j}^{o} \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_p} , \tag{3}$$

where the aggregate price index is defined as $P_t^{1-\epsilon_p} = \int_0^1 P_t(i)^{1-\epsilon_p} di$.

3.1.1 Savers

Each unconstrained household wants to maximize its expected discounted utility drawing on (2) while facing the following period budget constraint:

$$P_t C_{t,j}^{S} + B_{t,j}^{S} = W_t L_t^{S} + \left(1 + i_{t-1}\right) B_{t-1,j}^{S} + \frac{1}{1-\omega} P_t D_t + P_t T_{t,j} ,$$

where P_t is the aggregate price level of goods, $B_{t,j}^{S}$ are nominal bond holdings, W_t is the common flexible nominal wage associated with the representative type of labor supply L_t^{S}, i_{t-1} is the nominal return at time t on a bond purchased in $t-1$, D_t are real dividend payoffs arising from firms' profits and equally distributed to the savers, and $T_{t,j}$ are real lump-sum transfers. Transfers arise from an insurance contract that all these types of households enter to ensure that they start with the same real wealth in every period.

[10] In the terminology of Mankiw and Reis (2006, 2007), this decision is made by the attentive shopper, whereas the decision about total expenditure is made by the inattentive planner.

As seen before, each saver is fully attentive when deciding about how to allocate total spending across differentiated goods. On the other hand, when it comes to the planning of total expenditure and savings, unconstrained households face costs of information that make them prone to being inattentive. They will make decisions only at irregular intervals. I follow Mankiw and Reis (2006, 2007) and assume that savers obtain new information about the current state of the economy with probability $\delta \in [0,1]$ every period, which is constant and independent across households.[11] Based on this information, updating households will choose a consumption plan into the far future. Agents that have not updated their information in a given period continue to make their decisions based on outdated information by following the pre-determined consumption path from when they last updated. Consequently, the mass of savers is divided into a share of δ agents with current information and $\delta(1-\delta)^i$ agents with information as old as i periods, where $i = 1, 2, \ldots$. The case of full information is nested for $\delta = 1$.

Savers only differ in the period in which they last updated their information set. I therefore redefine the index j accordingly: for this part, $C^S_{t,j}$ denotes expenditures at time t for a saver who last updated his information set j periods ago. The optimality conditions of the maximization problem (see Appendix B.1) are then the following:

$$\begin{aligned}
\left(C^S_{t,0}\right)^{-1} &= \beta E_t \left[R_{t+1}\left(C^S_{t+1,0}\right)^{-1}\right] , \\
\left(C^S_{t+j,j}\right)^{-1} &= E_t \left[\left(C^S_{t+j,0}\right)^{-1}\right] , \\
\xi C^S_{t,0}\left(L^S_t\right)^{\eta} &= \frac{W_t}{P_t} ,
\end{aligned}$$

where $R_{t+1} = (1+i_t)\frac{P_t}{P_{t+1}}$ denotes the gross real return on bonds between periods t and $t+1$. These conditions hold for all t and j. The first one is the Euler equation which specifies the optimal intertemporal consumption-savings choice between today and tomorrow of a consumer in an attentive household. The second expression is the Euler equation for an inattentive consumer. It states that the marginal utility of consumption of a saver at any point in time should be equal to the corresponding expectation of the attentive consumer's marginal utility. The last condition determines the labor-leisure choice.

3.1.2 Hand-to-mouth households

Constrained households do not hold assets, but only consume their current disposable income in every period. They maximize their utility $U\left(C^H_t, L^H_t\right)$ subject to

$$P_t C^H_t = W_t L^H_t \, .$$

As agents supply a representative type of labor and prices and wages are common to all agents, consumption will be the same across hand-to-mouth households, $C^H_{t,j} = C^H_t$.

[11] In fact, to derive solutions for the policy experiments further below, I need to assume that $\delta \in (0,1]$.

The resulting optimality condition is

$$\xi C_t^H \left(L_t^H\right)^\eta = \frac{W_t}{P_t} \ .$$

3.1.3 Aggregation

Consumption of household type $o \in \{H, S\}$ is given by $C_t^o = \int_0^1 C_{t,j}^o dj$. Aggregate spending of all households is equal to $C_t = \omega C_t^H + (1-\omega) C_t^S$, whereas total labor supply is $L_t = \omega L_t^H + (1-\omega) L_t^S$. Finally, summing the individual demand for each variety in (3) over all agents of each household type and aggregating up leads to the total demand for variety i:

$$C_t(i) = C_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_p} \ , \tag{4}$$

where $C_t(i) = \omega C_t^H(i) + (1-\omega) C_t^S(i)$.

3.2 Firms

The firm side of the model is kept standard. There is a continuum of monopolistically competitive firms owned by savers, each of which produces one of the differentiated consumption goods i using labor as the only input. They take aggregate prices and wages as given, thereby facing the same market wage W_t.

Each firm minimizes its total variable cost of production $W_t N_t(i)$, given the production function $Y_t(i) = N_t(i)$. This brings along a real marginal cost $MC_t = \frac{W_t}{P_t}$. In addition, each firm maximizes nominal profits $P_t D_t(i) = P_t(i) Y_t(i) - W_t N_t(i)$. Summing over all firms leads to total nominal profits $P_t D_t = P_t Y_t (1 - MC_t)$, which are redistributed to savers by dividend payments. I assume a Calvo (1983) price setting, where each firm can reset the price of its good in every period with probability $1-\lambda$, which is constant and independent across firms. The problem of firm i at time t choosing the reset price that maximizes the current market value of the profits generated over the time that the price remains effective is

$$\begin{aligned}
&\max_{\tilde{P}_t(i)} E_t \sum_{k=0}^{\infty} \lambda^k \left[Q_{t,t+k} \left(\tilde{P}_t(i) Y_{t+k|t}(i) - W_{t+k} N_{t+k|t}(i) \right) \right] \ , \\
&\text{s.t. } Y_{t+k|t}(i) = N_{t+k|t}(i)^{1-\alpha} \ , \\
&\qquad Y_{t+k|t}(i) = \overline{C}_{t+k} \left(\frac{\tilde{P}_t(i)}{P_{t+k}} \right)^{-\epsilon_p} \ ,
\end{aligned}$$

where $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k,0}}{C_{t,0}}\right)^{-\gamma} \frac{P_t}{P_{t+k}}$ is the stochastic discount factor for nominal payoffs in period $t+k$, $\tilde{P}_t(i)$ is the price chosen by a firm that re-optimizes in period t, and $X_{t+k|t}(i)$ is the value of variable X at time $t+k$ for a firm that last reset its price in period t.

All producers face the same production function and the same probability of resetting prices for their goods, which is why all adjusting firms set the same adjustment price

$\tilde{P}_t(i) = \tilde{P}_t$. Hence, $Y_{t+k|t}(i) = Y_{t+k|t}$, $N_{t+k|t}(i) = N_{t+k|t}$ and also $MC_{t+k|t}(i) = MC_{t+k|t}$. The resulting optimality condition for the reset price, written as a function of the real marginal cost, is

$$\tilde{P}_t = \frac{\epsilon_p}{\epsilon_p - 1} \frac{\sum_{k=0}^{\infty} \lambda^k E_t \left[Q_{t,t+k} Y_{t+k|t} P_{t+k} MC_{t+k|t} \right]}{\sum_{k=0}^{\infty} \lambda^k E_t \left[Q_{t,t+k} Y_{t+k|t} \right]} ,$$

where the aggregate price dynamic is governed by

$$P_t = \left[\lambda \left(P_{t-1} \right)^{1-\epsilon_p} + (1-\lambda) \left(\tilde{P}_t \right)^{1-\epsilon_p} \right]^{\frac{1}{1-\epsilon_p}} .$$

3.3 Monetary policy

The central bank strives to fix the real interest rate, where I assume that the Fisher equation holds. The nominal interest rate is determined by

$$i_t = \log \left[E_t \left(\frac{P_{t+1}}{P_t} \right) \right] + \varepsilon_t = \log \left[E_t \left(R_{t+1} \frac{P_{t+1}}{P_t} \right) \right] ,$$

where $\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \nu_t$ is a policy shock with innovation $\nu_t \sim N(0, \sigma_\varepsilon^2)$ and persistence $\rho_\varepsilon \in [0,1]$. This policy rule implies that the real interest rate is exogenously determined by the monetary policy shock. It allows to isolate the mechanisms on the aggregate-demand side by prohibiting interactions with aggregate supply, in particular inflation, as will become evident later.

3.4 Market clearing

In the goods market for each variety $i \in [0,1]$, it holds that $C_t(i) = Y_t(i)$, where total output is defined as $Y_t^{\frac{\epsilon_p - 1}{\epsilon_p}} = \int_0^1 Y_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di$. Using the demand function in (4), it follows that $Y_t = C_t$. Furthermore, labor market clearing requires total labor supply to be equal to total labor demand, $L_t = \int_0^1 N_t(i) di$. This leads to $L_t = N_t$. Finally, financial assets are in zero net supply and so $\int_0^1 B_{t,j}^S dj = 0$.

3.5 Steady state

The model is approximated around a deterministic steady state. From the Euler equations of the saver, one gets $R = \beta^{-1}$ and $C_{\cdot,j}^S = C_{\cdot,0}^S = C^S$, which shows that different information sets do not play a role if variables are constant in steady state.

Assuming zero profits and zero lump-sum transfers in steady state, the budget constraint for both types of households evaluated at steady state collapses to $PC^o = WL^o$ and their labor supply condition becomes $\xi C^o (L^o)^\eta = W/P$, where $o \in \{H, S\}$. Combining these two expressions entails consumption and hours worked being equal across households in steady state, namely that $C^S = C^H = C$ and $L^S = L^H = L$. Moreover, by market clearing, $C = Y$ and $L = N$. Finally, due to zero profits in steady state, total nominal profits become $PY = WN$.

3.6 Equilibrium conditions and reduced-form representation

Table 2 contains the log-linearized equilibrium conditions. Small letters denote the log-linear deviation of the respective uppercase characters from a variable's non-stochastic steady state. Two exceptions are w_t and r_t, which are the log-linear deviations of the real wage $\frac{W_t}{P_t}$ and of the real return $E_t[R_{t+1}]$, respectively. In addition, profits and transfers are defined relative to total income, $d_t = \frac{D_t}{Y}$ and $t_t = \frac{T_t}{Y}$. Finally, inflation is defined as $\pi_t = p_t - p_{t-1}$.

Table 2: Equilibrium conditions for the SI-TANK model

Euler equation, attentive S	$c^S_{t,0} = E_t\left(c^S_{t+1,0} - r_t\right)$
Euler equation, inattentive S	$c^S_{t,j} = E_{t-j}\left(c^S_{t,0}\right)$
Consumption index, S	$c^S_t = \delta\sum_{j=0}^{\infty}(1-\delta)^j c^S_{t,j}$
Labor supply, S	$\eta l^S_t = w_t - c^S_{t,0}$
Budget constraint, S	$c^S_t = w_t + l^S_t + \frac{1}{1-\omega}d_t + t_t$
Labor supply, H	$\eta l^H_t = w_t - c^H_t$
Budget constraint, H	$c^H_t = w_t + l^H_t$
Production function	$y_t = l_t$
Real marginal cost	$mc_t = w_t$
Real profits	$d_t = -mc_t$
Phillips curve	$\pi_t = \beta E_t(\pi_{t+1}) + \frac{(1-\lambda)(1-\lambda\beta)}{\lambda}mc_t$
Monetary policy rule	$i_t = E_t(\pi_{t+1}) + \varepsilon_t$
Fisher equation	$i_t = r_t + E_t(\pi_{t+1})$
Aggregate consumption	$c_t = \omega c^H_t + (1-\omega)c^S_t$
Aggregate labor	$l_t = \omega l^H_t + (1-\omega)l^S_t$
Resource constraint	$y_t = c_t$

In a next step, I present the key log-linearized equilibrium conditions for the demand and supply side of the SI-TANK model. See Appendix B.2 for further details on the derivations. It is important to emphasize that the framework here nests the representative-agent (for $\omega = 0$ and $\delta = 1$) and the basic two-agent (for $\delta = 1$) New Keynesian models.

Aggregate demand. First, the log-linearized Euler equation for savers reads

$$c^S_t = -\delta\sum_{j=0}^{\infty}(1-\delta)^j E_{t-j}\left(R_t\right) \ , \tag{5}$$

where $R_t = E_t\left(\sum_{k=0}^{\infty} r_{t+k}\right)$ is the long-run real interest rate. The consumption of savers is determined by current and past expectations of R_t: lower (expected) real rates encourage consumers to save less and to spend more. The impact of unexpected shocks to these real interest rates is dampened due to the fact that only a share of consumers δ are fully informed.

Second, we can write consumption of hand-to-mouth households as a function of aggregate spending and past expectations of real interest rates:

$$c_t^H = y_t^H = \chi_{\textit{SI-TANK}}\, y_t + \Psi\delta \sum_{j=1}^{\infty}(1-\delta)^j E_{t-j}\left(R_t\right) \ , \tag{6}$$

where $\Psi = \left(\frac{1-\omega}{\omega+(1-\omega)\delta}\right)$ is a composite parameter decreasing in both ω and δ. Moreover, $\chi_{\textit{SI-TANK}}$ is one of the key parameters of this paper. It denotes the elasticity of constrained households' individual income to current aggregate income y_t, disregarding information sets last updated in the past, and is defined as

$$\chi_{\textit{SI-TANK}} = \frac{1+\delta\eta}{\omega+(1-\omega)\delta} \ .$$

A similar expression for individual spending can be derived for savers:

$$c_t^S = \frac{1-\omega\chi_{\textit{SI-TANK}}}{1-\omega} y_t - \big(1-\delta\Psi\big)\delta \sum_{j=1}^{\infty}(1-\delta)^j E_{t-j}\left(R_t\right) \ . \tag{7}$$

The second term of (6) and (7) refers to agents with outdated information sets and becomes relevant when looking at past or anticipated shocks. It captures the spillover of expectations about R formed in the past to the consumption of both household types at time t. Savers expecting interest rates to be lower in the future stimulate spending in the past. By intertemporal substitution, this also increases the current consumption levels of savers and therefore affects hand-to-mouth households.[12]

Finally, the IS curve (or aggregate Euler equation) reads

$$c_t = y_t = -\mu \left\{ \omega R_t + (1-\omega)\delta \sum_{j=0}^{\infty}(1-\delta)^j E_{t-j}\left(R_t\right) \right\} \ , \tag{8}$$

where $\mu = \frac{1-\omega}{1-\omega(1+\eta)}$. The IS curve entails the usual inverse relationship between aggregate consumption (or output) today and expected real interest rates. Different from the standard New Keynesian literature, these expectations are split into two different parts: an undiscounted sum of future real interest rates, also present in RANK models, and a stream of current and past expectations about current and future real rates, emerging from incorporating sticky information. On top of this, the IS curve is shaped by μ, which increases in the share of hand-to-mouth households.

[12] On closer examination of equation (6), it seems that the anticipation of a negative interest rate shock today by agents in the past (second part of the equation) attenuates the increase of c_t^H arising through larger aggregate spending (first part of the equation). However, considering that y_t itself is governed by past expectations, it can be shown that the net effect of this cut in the real rate is positive as long as $\eta > 0$. The consumption of hand-to-mouth households will eventually be higher relative to the case without anticipation of the shock; and likewise the spending of savers.

Aggregate supply. The Phillips curve of the SI-TANK model is given by

$$\pi_t = \beta E_t(\pi_{t+1}) + \kappa y_t - \Theta\Psi \left\{ \delta R_t - \delta \sum_{j=0}^{\infty} (1-\delta)^j E_{t-j}(R_t) \right\}, \tag{9}$$

where $\kappa = \Theta\chi_{SI\text{-}TANK}$ and $\Theta = \frac{(1-\lambda)(1-\lambda\beta)}{\lambda}$. Current inflation depends not only on expected future inflation and output, but also on past expectations of the long-run real interest rate.[13] Just as for the individual consumption levels, the last term is redundant when ignoring past or anticipated shocks. Also note that (9) turns into the standard New Keynesian Phillips curve and becomes independent of the share of hand-to-mouth households ω if agents are fully informed ($\delta = 1$).

4 Amplification and dampening in interaction

The combination of household heterogeneity and sticky information generates dynamics different from standard New Keynesian models. To get a deeper insight into the mechanisms at play within the SI-TANK model, I will now look separately at the impact of an exogenous monetary policy shock that changes the real interest rate. For the time being, I will exclusively focus on the response of aggregate consumption and on the period in which the change in the real rate actually occurs, that is, the *initial* impact of the shock. Further down in section 5, I will also elaborate on potential differences in peak impacts between the models and discuss the response of inflation.

4.1 Aggregate demand under the two frictions

A natural way to investigate the nature of consumption and output responses is through the aggregate Euler equation. Table 3 displays IS curves for different model alternatives, which will be discussed successively in the light of a change in the real interest rate.

The representative-agent New Keynesian (**RANK**) model with full information and the standard consumption-smoothing type of household serves as a benchmark. Output is completely negatively related to the long-run real interest rate R. Higher expected real rates encourage consumers to save more and to spend less, thus depressing aggregate consumption.

Dampening. Assuming imperfect attention to economic events and shocks results in a representative-agent economy with sticky information (**SI-RANK**). Similar to the model described in section 3, households are partly inattentive, meaning that only a fraction of them update their information about the state of the economy in any period. This leads to the case where output in equilibrium is no longer determined by current expectations of

[13] Note that firms' marginal cost and thus inflation depend directly on monetary policy. A higher nominal interest rate affects the cost of working capital and leads to higher prices. This transmission mechanism known as the cost channel in the literature (see, among others, Barth & Ramey, 2002, and Ravenna & Walsh, 2006) entails a mitigated response of inflation after a policy shock.

Table 3: IS curve for various model specifications

	Full information	Sticky information
RANK	$y_t = -R_t$	$y_t = -\delta \sum_{j=0}^{\infty}(1-\delta)^j E_{t-j}(R_t)$
TANK	$y_t = -\mu R_t$	$y_t = -\mu \left\{ \omega R_t + (1-\omega)\delta \sum_{j=0}^{\infty}(1-\delta)^j E_{t-j}(R_t) \right\}$

Notes: The composite multiplier is defined as $\mu = \frac{1-\omega}{1-\omega\chi_{TANK}}$, where $\chi_{TANK} = 1+\eta$. Moreover, $R_t = E_t\left(\sum_{k=0}^{\infty} r_{t+k}\right)$.

R alone, but also by past expectations. This implies a dampening effect as follows. A cut in interest rates encourages updating households to increase their consumption. However, only a share of households are fully informed in each period and learn about news. As a result, aggregate demand will react less to the occurrence of shocks to the real rate relative to RANK. It will only adjust slowly over time, always leaving behind some agents with outdated information sets. That is the result found by Mankiw and Reis (2006, 2007) in its purest form.

Note that a change in the real interest rate is attenuated as long as there is rigid information and hence lagged expectations, be the change unexpected or not. On the other hand, the more households update their information sets in the current period (higher δ), the more aggregate spending responds to changes in interest rates and the closer the output response to the case without information frictions. In fact, the model nests RANK for $\delta = 1$.

Amplification. Adding hand-to-mouth households to the representative-agent model leads to the simplest version of a two-agent New Keynesian (**TANK**) economy. As Table 3 shows, this model's IS curve differs from the RANK case in μ. This composite parameter is affected by labor market characteristics (captured by the Frisch elasticity of labor supply) and the degree of heterogeneity (captured by the share of hand-to-mouth households). Looking at individual consumption levels, the TANK model is characterized by $c_t^H = \chi_{TANK} y_t$ and $c_t^S = \frac{1-\omega\chi_{TANK}}{1-\omega} y_t$, where $\chi_{TANK} = 1+\eta$ is the elasticity of constrained households' individual income to aggregate income. As a result, the multiplier reads $\mu = \frac{1-\omega}{1-\omega\chi_{TANK}}$.

Amplification requires the effect of a change in the real interest rate on aggregate demand to be higher than in RANK (i.e., $\mu > 1$) and to increase in the share of hand-to-mouth households ω. This is the case if and only if $\chi_{TANK} > 1$, namely when the individual income of constrained households responds more than proportionally to changes in aggregate income.[14] By contrast, the savers' income elasticity will be smaller than one in that case. This implies countercyclical income inequality as analyzed by Bilbiie (2018,

[14] Bilbiie (2008) shows that, depending on the proportion of hand-to-mouth households, the slope of the IS curve may turn positive and reverse the impact of the real interest rate on aggregate demand. In the present case, one needs $\omega < 1/(1+\eta)$ for μ to be positive. This is achieved with empirically plausible values for η and respective estimates of hand-to-mouth shares in empirical studies. I therefore focus only on the common case where $\mu > 0$.

2020), meaning that inequality between unconstrained and constrained agents declines in a period of economic expansion.[15]

The intrinsic mechanism behind the amplification works through the specific distribution of profits I postulated, following Bilbiie (2008). Assume a cut in interest rates that induces an increase in aggregate demand. Even though agents then consume more and work less at a given wage, sticky prices induce firms to increase labor demand. The result is higher wages. This increases the individual income of hand-to-mouth households, which they completely spend for consumption because they cannot intertemporally optimize. Thus, they respond to the initial shock with a higher demand; exactly where $\chi_{TANK} > 1$ is put into effect. This boosts aggregate spending, pushing up wages further, and so on. At the same time, the rise in wages translates into higher marginal costs for firms, shrinking their profits and therefore also each saver's dividend income. As their individual income goes down, savers are willing to bear the required increase in labor supply to meet the higher aggregate demand and work more.

It is apparent that the presence of constrained households that live hand-to-mouth is essential for the real effects of monetary policy to be different from RANK. The MPC out of their own income is one, which increases the aggregate MPC in the economy. In addition, the feedback mechanism from individual back to aggregate income described above is precisely what eventually leads to amplification.

Amplification and dampening. Incorporating household heterogeneity as well as sticky information in the standard RANK economy yields the **SI-TANK** model. The corresponding IS curve unifies amplification and dampening. On the one hand, both types of households react to a change in the real rate, leading to a reinforced impact on aggregate demand as described before. This mechanism is captured by the TANK multiplier μ. At the same time, the response of spending is attenuated because not all agents are aware of the change. However, different from the amplification element, δ just reaches part of the agents. This arises by construction of the model since only a fraction of savers $1-\omega$ is subject to the information friction. Unifying both frictions, the model naturally nests TANK (for $\omega = 0$) as well as SI-RANK (for $\delta = 1$).

While the initial response of output is amplified by the presence of hand-to-mouth agents relative to RANK, information rigidity tempers it relative to TANK. It appears natural to ask under which conditions the propagation of monetary policy shocks takes one or the other direction. To find a sufficient answer, the IS curve can be rewritten as

$$y_t = -\frac{1-\omega}{1-\omega\chi_{SI\text{-}TANK}}\delta R_t - \mu(1-\omega)\delta\sum_{j=1}^{\infty}(1-\delta)^j E_{t-j}\left(R_t\right) \ .$$

Focusing exclusively on real interest rate changes that are unanticipated, the second term

[15] For a complementary analysis within a more complex heterogeneous-agent framework, see the earnings heterogeneity channel in Auclert (2019). Moreover, Patterson (2022) provides estimates for the covariance between MPCs and individual earnings elasticities to GDP.

equals zero because it refers to agents with outdated information sets.[16] The first term consists of two parts. The fraction is characterized by amplification for $\chi_{\textit{SI-TANK}} > 1$, similar to TANK. Thus, disregarding any outdated expectations, the individual income of constrained households has to be more elastic to aggregate income than that of savers. However, this condition is not sufficient to achieve overall amplification in the SI-TANK model: the presence of the stickiness parameter δ might eventually dampen the total effect of a change in real rates. Instead, the following (sufficient) threshold conditions hold:

$$\text{Amplification (on impact):} \quad \chi_{\textit{SI-TANK}} > \frac{1-\delta}{\omega} + \delta \geq 1 \; ;$$
$$\text{Dampening (on impact):} \quad \chi_{\textit{SI-TANK}} < \frac{1-\delta}{\omega} + \delta \; .$$

These expressions point out three things. First and to some extent obvious, what determines the net propagation effect in the SI-TANK model is the relative magnitude of ω as against δ, which in turn both shape $\chi_{\textit{SI-TANK}} = \frac{1+\delta\eta}{\omega+(1-\omega)\delta}$. Appendix C approaches this interplay and the role of the labor supply elasticity graphically. For a given share of hand-to-mouth agents, the probability of getting dampening on impact increases if information becomes stickier. On the contrary, if the degree of information stickiness is fixed, the amplification of aggregate demand is more likely with a higher proportion of constrained households. On top of that, this result does not only hold for the aggregate-demand response on impact, but also for the periods subsequent to the shock. I will elaborate more on this point in the graphical analysis of the model in section 5.3.

Second, amplification calls for countercyclical income inequality, as in Bilbiie (2018, 2020) or Patterson (2022). However, it may require $\chi_{\textit{SI-TANK}}$ to lie considerably above one, meaning that constrained agents' income reacts substantially to changes in current aggregate income.[17] Naturally, this is to outweigh the downward pressure caused by sticky information. The closer the model moves to the full information case, the lower $\chi_{\textit{SI-TANK}}$ will be.

Third, dampening might arise even if income inequality is countercyclical. This result is contrary to Bilbiie (2018, 2020), where attenuated aggregate demand presupposes procyclical inequality.[18] Unlike such a TANK model, a share of savers remain here uninformed about any news in each period. Since, as a result, only a fraction of them react to a monetary policy shock, the response of their spending behavior is relatively weak. This also depresses aggregate consumption relative to a simple TANK model with full information. In fact, the expressions above nest the latter case for $\delta = 1$.

[16] For *expected* changes in the real interest rate, the condition for amplification depends on when the change is announced. However, this case is left out of consideration here.

[17] In comparison to the TANK model, the income elasticity of constrained agents is required to be higher to get amplification in SI-TANK. This can be ascertained by rewriting the threshold condition as $\chi_{\textit{TANK}} > 1 + (1-\delta)\frac{(1-\omega)^2}{\omega} \geq 1$.

[18] Note that in the present simple setup $\chi_{\textit{SI-TANK}} \geq 1$ always holds, independent of the parameter values.

4.2 Multiplier effects after a monetary policy shock

The interplay of amplification and dampening generates effects of various magnitudes. To narrow down the analysis to a common shock, I now consider the effect of an unexpected one-time cut in the current real interest rate on aggregate demand. This impact multiplier can be expressed by

$$\Phi_M = \frac{\partial y_t}{\partial(-r_t)}|_M \ ,$$

where M denotes the respective model specification. Table 4 shows the aggregate-demand multiplier Φ_M for the different cases.

Table 4: Impact of monetary policy on aggregate demand: formal expressions

	Full information	Sticky information
RANK	$\Phi_{RANK} = 1$	$\Phi_{SI\text{-}RANK} = \delta$
TANK	$\Phi_{TANK} = \mu$	$\Phi_{SI\text{-}TANK} = \mu\omega + \mu(1-\omega)\delta$

Notes: Multipliers Φ_M of the effects of an unexpected interest rate cut in the current period on aggregate demand in model specification M. It holds that $\mu = \frac{1-\omega}{1-\omega\chi_{TANK}}$, where $\chi_{TANK} = 1+\eta$.

As before, the starting point is the standard RANK model, which has an aggregate-demand multiplier of 1. Adding sticky information attenuates this multiplier. Not all households perceive the shock so that aggregate spending increases only partly. On the other hand, incorporating hand-to-mouth agents in RANK can induce an amplified response of output provided that income inequality is countercyclical (i.e., $\chi_{TANK} > 1$). Finally, in the SI-TANK model, amplification and dampening clash. We learned in the previous section that the magnitudes of ω and δ are critical to determine which of the two forces eventually prevails. However, by considering the ratios between various multipliers instead of absolute effects, the following proposition states some *universal* results regarding the propagation of monetary policy shocks.

Proposition 1 (Asymmetric effects of dampening and amplification)**.** ***(I)*** *Sticky information dampens the initial aggregate-consumption response associated with an unexpected one-time change in the real interest rate by a higher factor when added to RANK instead of TANK:*

$$\frac{\Phi_{RANK}}{\Phi_{SI\text{-}RANK}} \geq \frac{\Phi_{TANK}}{\Phi_{SI\text{-}TANK}} \ .$$

(II) *Household heterogeneity amplifies the initial aggregate-consumption response associated with an unexpected one-time change in the real interest rate by a higher factor when added to SI-RANK instead of RANK:*

$$\frac{\Phi_{SI\text{-}TANK}}{\Phi_{SI\text{-}RANK}} \geq \frac{\Phi_{TANK}}{\Phi_{RANK}} \ .$$

These asymmetries are independent of the parameter values.

Proof. Follows from the multipliers in Table 4 and $\delta \in [0, 1]$. ■

The impact of neither of the two rigidities is proportional across models. The dampening arising from incorporating sticky information is much less pronounced in a two-agent compared to a representative-agent framework. On the other hand, adding hand-to-mouth agents has a larger relative impact when information frictions are present at the same time.

Even though somewhat mechanical, it seems particularly striking that heterogeneity is proportionately more influential in the presence of information rigidities. Prominent TANK or HANK models show that hand-to-mouth agents are one of the most important elements to achieve amplification. The results above suggest that a lot of these amplifying effects might instead originate from information frictions, implying an overstatement of the importance of heterogeneity in this respect.

Both asymmetries are based on the different channels through which the propagation of the monetary policy shock works. The amplification mechanism in a two-agent economy involves both types of households, meaning that the adjustments in their optimal behavior jointly contribute to the boost in aggregate demand. This holds independent of the presence of information frictions.

It matters, in contrast, whether sticky information comes along with heterogeneous households. While all households are prone to being inattentive in a representative-agent framework, this turns out to be different in SI-TANK. In fact, (limited) inattention to information is intrinsically linked with intertemporal optimization. Not only are hand-to-mouth households unable to shift consumption across periods by saving, they are also not subject to the information friction. These agents are extremely myopic in the sense that they do not care about the future or about how much and which information is revealed at any point in time. In fact, they have no use for additional information and therefore never acquire it. Savers instead benefit from this information to make their optimal decisions, but given the cost to acquire it, they update their information set only infrequently.

The assertions above are best reflected by $\Phi_{SI\text{-}TANK}$ in Table 4. While the TANK multiplier μ that guides amplification reaches both types of households alike, only a share of savers $(1 - \omega)$ are affected by the information stickiness parameter. In SI-RANK, all households are impacted by δ. The respective two fractions for sub-propositions (I) and (II) in Proposition 1 might only be identical if one added some sort of information stickiness on the part of hand-to-mouth households, whatever its source. Otherwise, in the case at hand, the wedge between the ratios becomes wider with a larger share of constrained agents (higher ω) or more stickiness (lower δ). The degree of asymmetry thus becomes more pronounced. See Appendix D for a graphical demonstration in this regard.

4.3 Complementarity between agent types and dynamic effects

Household heterogeneity and information rigidities have been studied so far without considering the potential complementarities between them. In particular, I have assumed that hand-to-mouth agents are fully inattentive to information because they are financially constrained and have no need for information. More in line with the empirical findings of Table 1, we could suppose instead that agents located at the lower end of the income distribution have a particularly high (but not infinite) degree of information rigidity. This would allow us to assess how the interaction of heterogeneity and information drives the dynamics of aggregate demand in the SI-TANK model.

To discuss the interaction between ω and δ, I consider two alternative setups. First, we could assume a third type of household with a very low probability of obtaining new information. It is close to being hand-to-mouth, but able to save a small portion of its income up to a certain limit. Such an intermediate agent is still highly sensitive to changes in its earnings due to the risk of becoming fully financially constrained. If the real wage increases after a cut in interest rates, however, only a small share of the intermediate agents will adjust their optimal behavior while the much larger fraction sticks to outdated consumption plans. Therefore, if we introduce an intertemporal substitution component on the part of households with very infrequent information updates, we lack the strong amplifying effects known from fully constrained agents. Compared to the baseline model, the result is a relatively smaller response of aggregate demand which decreases further with lower δ.

In a second setup, we could start from the idea that constrained agents live hand-to-mouth precisely due to the presence of information frictions, meaning that they consume all their income in each period as long as there is no information update. Following again the results in Table 1 and assuming a low probability that such updates will occur, the response of this type of household to an interest rate cut will be close to the reaction of the baseline hand-to-mouth agents. Only a small fraction will refrain from naively consuming all income gains. Once those agents learn about the shock and its persistence, they will start saving part of their higher individual income as their financial constraints have loosened.[19] Consequently, the amplification coming from hand-to-mouth agents will be slightly weaker due to the small fraction of agents that essentially switch from being fully constrained to a low-savings type. This translates into an aggregate demand response that is only marginally lower, at least as long as the degree of information rigidity of hand-to-mouth agents remains high.

[19] We could assume instead that the degree of information rigidity is state-dependent. For instance, while households at the borrowing constraint do not value additional information, it tends to be very useful when wealth starts to increase because savings mistakes can become costly. As a result, their attentiveness changes. See Broer et al. (2021) for a model that combines incomplete markets with dynamic, heterogeneous information choices.

5 Analytical insights for the effects of monetary policy

Taking advantage of the tractability of the SI-TANK model, this section strives to find an analytical solution for the impact of an unanticipated monetary policy shock, with the aim to isolate the aggregate-demand side. Solving sticky-information models can be tedious due to infinite lagged expectations. I follow hereafter a straightforward approach that leads to simple reduced-form equations for aggregate demand and inflation. Those kinds of solutions provide more insights into how monetary policy works in SI-TANK, but also confirm some of the results that have been found earlier from a different point of view. The section will be completed with a graphical analysis meant to discuss what happens in the periods following the initial occurrence of the policy shock.

5.1 The pitfall of expectations under sticky information

The difficulty in handling models with sticky information arises from the presence of an infinite number of lagged expectations, which leads to an infinite state space. A few papers try to deal with this problem, either by building on infinite moving average representations and the method of undetermined coefficients (Mankiw & Reis, 2007; Meyer-Gohde, 2010; Wang & Wen, 2006), or by implementing restrictions regarding the number of lagged-expectation terms (Trabandt, 2007; Verona & Wolters, 2014). Although these methods are valid from a computational point of view, they reveal the common issue that it is tedious or not possible at all to solve models with sticky information analytically.

In my simple model, I overcome the issue of lagged-expectation terms by the specific choice of the policy rule and by assuming an AR(1) shock process $\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \nu_t$. The former implies that the central bank controls the real interest rate, which makes it possible to abstract from aggregate supply and hence to isolate the aggregate-demand side of the model – equivalently to what could be achieved through postulating fixed prices. The shock process then allows me to solve for the lagged expectations within the IS curve analytically, namely by feeding it directly into the IS curve and transforming the past expectations of future shocks into expressions that are only dependent on past shocks and their persistence.

Combining the monetary policy rule and the Fisher equation yields

$$r_t = \varepsilon_t \ .$$

The real rate in each period is completely determined by the policy shock, and the long-run real interest rate R_t is therefore exogenously determined. Inserting this into the IS curve (8) gives

$$y_t = -\mu \left\{ \omega E_t \left(\sum_{k=0}^{\infty} \varepsilon_{t+k} \right) + (1-\omega)\delta \sum_{j=0}^{\infty} (1-\delta)^j E_{t-j} \left(\sum_{k=0}^{\infty} \varepsilon_{t+k} \right) \right\} \ . \tag{10}$$

It is useful to expand the part with lagged expectations in different ways:

$$
\begin{aligned}
&\delta \sum_{j=0}^{\infty}(1-\delta)^j E_{t-j}\left(\sum_{k=0}^{\infty} \varepsilon_{t+k}\right) \\
&= \delta \sum_{j=0}^{\infty}(1-\delta)^j \Big\{ E_{t-j}\left(\varepsilon_t\right) + E_{t-j}\left(\varepsilon_{t+1}\right) + E_{t-j}\left(\varepsilon_{t+2}\right) + \ldots \Big\} \\
&= \delta E_t\left(\sum_{k=0}^{\infty} \varepsilon_{t+k}\right) + \delta(1-\delta) E_{t-1}\left(\sum_{k=0}^{\infty} \varepsilon_{t+k}\right) + \delta(1-\delta)^2 E_{t-2}\left(\sum_{k=0}^{\infty} \varepsilon_{t+k}\right) + \ldots .
\end{aligned}
$$

The second line emphasizes the role of the policy shocks. The curly brackets enclose a stream of expectations for the current shock, but also for all shocks up to the infinite future, captured by the index k. Compared to this, the third line rewrites the IS curve in a way to stress the presence of current and past information sets of the stream of shocks from time t on, weighted with the respective probabilities to update. This dimension is captured by the index j. As a result, consumption and output are determined by the current and past expectations of current and future policy shocks, resulting in an infinite stream of combinations of information sets and shocks.

5.2 Analytical solution for an unanticipated one-time innovation

To study the dynamics of the model at hand, I will look at an unanticipated one-time innovation that happens at time t, ν_t, and fades out thereafter. To isolate the effects of ν_t, I disregard any future anticipated and any past monetary policy shocks. For a more general solution including past shocks, see Appendix E.

In order to obtain an analytical solution, I start by simplifying the expectation expressions for some $k \geq 0$. Forwarding the AR(1) process that was assumed for the shock gives the common result

$$
\varepsilon_{t+k} = \rho_{\varepsilon}^k \varepsilon_t + \sum_{m=0}^{k-1} \rho_{\varepsilon}^m \nu_{t+k-m} \ ,
$$

which holds for all t. Given that ν is assumed to have mean zero and I rule out future anticipated shocks, one gets $E_{t+i}\left(\varepsilon_{t+i+k}\right) = \rho_{\varepsilon}^k \varepsilon_{t+i}$ for any $i, j \geq 0$. Moreover, disregarding any past shocks means that $\varepsilon_t = \nu_t$ and that $E_{t+i-j}\left(\varepsilon_{t+i+k}\right) = \rho_{\varepsilon}^{j+k} \varepsilon_{t+i-j}$ is only non-zero for $0 \leq j \leq i$. The expectation of an agent with an information set older than time t about shocks at or after t will always be zero, as this agent's best guess would be based on (non-existent) shocks before t. With all this in mind, the latter expression can be simplified to

$$
E_{t+i-j}\left(\varepsilon_{t+i+k}\right) = \rho_{\varepsilon}^{i+k} \nu_t \ ,
$$

where $0 \leq j \leq i$. An agent's best guess of a future unanticipated shock is the last perceived shock, taking into account the persistence across time. From a date $t+i$ perspective, the left-hand side reflects the expectation about a shock k periods in the future of an agent who last updated his information set j periods ago. This expectation is equal to the product of two terms: the one-time policy shock that the agents observe in this experiment and the overall series of persistence coefficients between the date at which the shock happened (t) and the period of the respective future shock ($t+i+k$). Due to $\rho_\varepsilon \in [0,1]$, the weight on ν_t decreases if the time difference between t and the respective future shock increases. Note that apart from ensuring that $i-j \geq 0$, the index j is irrelevant for the final expression as all information sets before time t, where the innovation happens, can be neglected.

Aggregating over all k implies

$$E_{t+i-j}\left(\sum_{k=0}^{\infty}\varepsilon_{t+i+k}\right) = \frac{\rho_\varepsilon^i}{1-\rho_\varepsilon}\nu_t \ . \tag{11}$$

Aggregate demand. Inserting this last expression into the IS curve (10) yields, for all non-negative i,

$$y_{t+i} = -\mu\frac{\rho_\varepsilon^i}{1-\rho_\varepsilon}\left\{\omega\nu_t + (1-\omega)\delta\sum_{j=0}^{i}(1-\delta)^j\nu_t\right\} \ ,$$

which can be further simplified to

$$c_{t+i} = y_{t+i} = -\mu\Big\{1-(1-\omega)(1-\delta)^{i+1}\Big\}\frac{\rho_\varepsilon^i}{1-\rho_\varepsilon}\nu_t \ . \tag{12}$$

Instead of depending on partly unknown elements, aggregate consumption and output are now solely functions of the innovation at date t, whose quantitative impact depends on the two main parameters of the SI-TANK model. More persistent shocks in the past increase the effect of a policy shock. In addition, the larger the share of hand-to-mouth agents (higher ω) and the lower the degree of information stickiness (higher δ), the larger the impact of shocks from the past.

Mirroring earlier results, only the expectations of agents who updated their information set at or after time t determine spending in equation (12). Although the innovation that happened in t affects future consumption and output through the persistence of the shock, the strength of the effect is dampened by the mass of savers who last updated their information sets before the innovation happened. In other words, those savers might have updated $i+1$ periods ago, but clearly remained uninformed since then. Overall, the curly bracket therefore captures the mass of all households that, at time $t+i$, know about the occurred shock. It is exactly this group of agents that is affected by the TANK multiplier μ, amplifying the output response if income inequality is countercyclical. However, since the mass of informed households is smaller than in a model without information rigidities, the amplification effect is lower as well.

Aggregate supply. Using (11) and (12) in (9) leads to

$$\pi_{t+i} = \beta E_{t+i}(\pi_{t+i+1}) - \Theta\Big\{\chi_{\textit{SI-TANK}}\,\mu\Big[1-(1-\omega)(1-\delta)^{i+1}\Big] - (1-\delta)\Psi\Big[1-(1-\delta)^{i}\Big]\Big\}\frac{\rho_\varepsilon^i}{1-\rho_\varepsilon}\nu_t\,.$$

Similar to the IS curve, the response of inflation is in large part determined by the informed households, captured by the first square bracket. If the constrained agents' income elasticity to aggregate income $\chi_{\textit{SI-TANK}}$ and the TANK multiplier μ are considerable above one, that channel generates a strong amplifying effect. The remaining parts within the curly brackets include some counteractive small-sized effects due to the sluggishness coming from non-updating agents.

Solving the last expression forward and simplifying yields

$$\begin{aligned}\pi_{t+i} = -\Theta\Big\{&\chi_{\textit{SI-TANK}}\,\mu\Big[\frac{1}{1-\beta\rho_\varepsilon} - \frac{1}{1-\beta\rho_\varepsilon(1-\delta)}(1-\omega)(1-\delta)^{i+1}\Big] \\ &-(1-\delta)\Psi\Big[\frac{1}{1-\beta\rho_\varepsilon} - \frac{1}{1-\beta\rho_\varepsilon(1-\delta)}(1-\delta)^{i}\Big]\Big\}\frac{\rho_\varepsilon^i}{1-\rho_\varepsilon}\nu_t\,.\end{aligned}$$

The effectiveness of monetary policy in this Phillips curve as before just depends on the model parameters. The response of inflation is reinforced with a higher ρ_ε (more persistent shock), higher ω (more constrained households), or higher δ (less information stickiness). Moreover, as in standard New Keynesian models, a higher share of firms resetting their goods' prices increases Θ and thus the inflation response to the innovation ν_t.

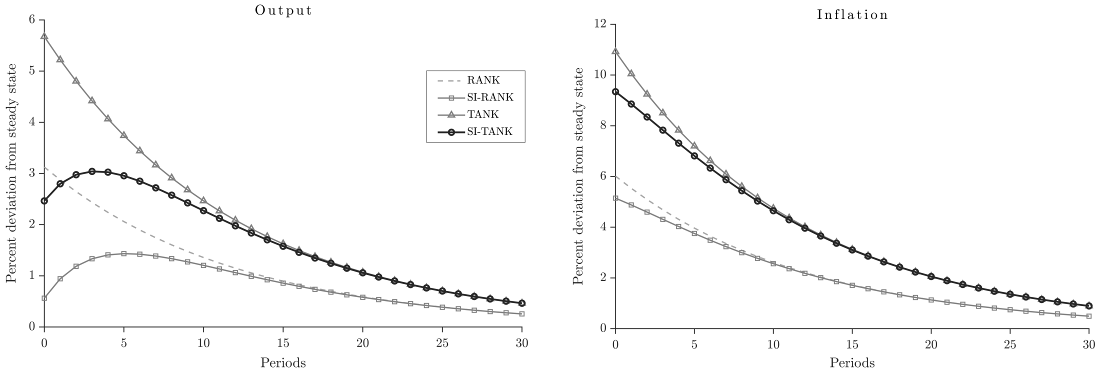
5.3 Graphical insights

With the simple reduced-form expressions at hand, I now move on to a graphical analysis and try to quantify the disproportionate effects of amplification and dampening. The object of study is an unanticipated monetary policy shock of 25 basis points that happens at time t and fades out thereafter. Apart from the benchmark representative-agent economy ($\delta = 1, \omega = 0$) and the SI-TANK model, I am also interested in the individual role of household heterogeneity and sticky information. I isolate each of the two by studying the TANK ($\delta = 1$) and the SI-RANK ($\omega = 0$) models separately.

Figure 1 depicts the impulse responses of output (or, equally, aggregate demand) and inflation after a negative interest rate shock for the different model specifications. Appendix F outlines the calibration of the model parameters. Starting with the left graph, several findings with regard to output arise.

First, sticky information dampens the effect of the monetary policy shock on impact and also for several periods after that. The information friction is therefore able to replicate the inertial, hump-shaped impulse response behavior found in empirical studies. Output in the models without a lag in perception immediately jumps on impact and gradually declines thereafter due to the assumed persistence of the monetary policy shock. By contrast, having information frictions in the model leads to a more delayed response.

Figure 1: Dynamic responses to monetary policy shock



Notes: Impulse response functions of output and inflation to an expansionary monetary policy shock of 25 basis points for different model specifications: representative-agent New Keynesian model without (RANK) or with sticky information (SI-RANK), and two-agent New Keynesian model without (TANK) or with sticky information (SI-TANK).

Only households with an updated information set become aware of the policy shock, as observed in the analytical solution in the previous section. This implies that the maximum impact on output only occurs after a few periods. Once all agents have gotten to know the shock, the output response converges to the model alternative without sticky information.

However, sticky information has a disproportionate effect on output, depending on the underlying model economy. A look at the first row of Table 5 reveals that it attenuates the aggregate-consumption response on impact proportionally more in RANK than in TANK, namely by a factor of $\frac{\Phi_{RANK}}{\Phi_{SI\text{-}RANK}} = 5.6$ as opposed to $\frac{\Phi_{TANK}}{\Phi_{SI\text{-}TANK}} = 2.3$. This confirms the result from Proposition 1: hand-to-mouth agents do not acquire information and are thus not impacted by any information rigidity. As a result, the output response in SI-TANK peaks earlier than in SI-RANK where all households are affected. The aggregate degree of inattention to information in the economy is lower.

Second, adding heterogeneity between households permanently amplifies the response to the policy shock throughout all depicted periods in Figure 1. The cut in the interest rate triggers the mechanism described before: savers adjust their intertemporal consumption and labor supply decisions, which increases the demand of hand-to-mouth households and induces a multiplier effect. Heterogeneity has thereby a stronger relative impact when combined with sticky information. Table 5 implies that it amplifies the output response in RANK in the period of the shock $\frac{\Phi_{TANK}}{\Phi_{RANK}} = 1.8$ times, but in SI-RANK even $\frac{\Phi_{SI\text{-}TANK}}{\Phi_{SI\text{-}RANK}} = 4.4$ times. Although amplification works through both types of households in the two-agent models, it matters for the respective ratio that savers alone are prone to sticky information.

Third, given the current calibration, the output response *on impact* of the shock is lower in SI-TANK compared to RANK. Although $\chi_{SI\text{-}TANK} = 2.72$ and constrained agents' income therefore reacts strongly to changes in aggregate income, the amplifying component seems not to be strong enough and consumption at the aggregate level remains

Table 5: Impact of monetary policy on aggregate demand: dynamics

	Full information		Sticky information	
	RANK	TANK	RANK	TANK
Impact multiplier	1.00	1.82	0.18	0.79
Peak response	3.13	5.67	1.43	3.04
Cumulative response	33.10	60.10	22.98	47.42

Notes: Effects of an unexpected interest rate cut in the current period on aggregate demand. The table contains the multipliers on impact (Φ_M for model specification M), the responses cumulated over time ($\sum_{i=0}^{T} \beta^i y_i$, where y_i is the response of aggregate demand in period i and $T = 1000$), and the magnitude of the peak impact.

attenuated. However, the hump-shaped form makes it still possible to achieve amplification in a later period. The peak effects in RANK and SI-TANK are quantitatively similar in the present case, but a different set of parameters can make amplification more likely. In particular, more frequent updating would mean that a larger fraction of savers adjust their consumption plans in each period and that aggregate demand would therefore react more. This would in turn have implications for both the magnitude and the timing of the peak impact. I show in Appendix G that a larger δ leads to a higher maximum response.[20] Moreover, output then generally peaks earlier in both SI-RANK and SI-TANK, while its inertia in the latter case is comparable for a broad range of δ values.

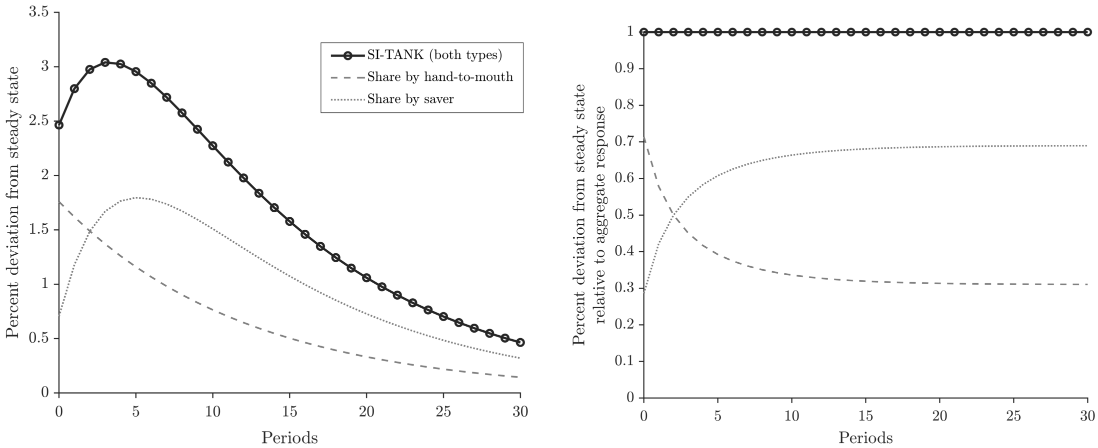
Fourth, even if output moves less on impact, the *cumulative* response can show a different picture. The second row of Table 5 illustrates that the present discounted value is much higher in SI-TANK (47.42) compared to RANK (33.10). Note further that Proposition 1 holds in cumulative terms as well. For instance, adding heterogeneity to RANK amplifies the output response by a factor of $\frac{60.10}{33.10} = 1.8$, but by $\frac{47.42}{22.98} = 2.06$ when combined in addition with sticky information. These two findings hold even for extreme calibration values.[21]

Turning to the price response, the right graph of Figure 1 reveals some features for the course of inflation after the expansionary monetary policy shock. Compared to aggregate demand, the implications of the considered frictions are rather modest. The already substantial degree of information stickiness has only a limited impact given the strong counteractive amplification effects; as was indicated in the analytical solution for the Phillips curve. Moreover, due to missing information frictions on the part of firms, there is no delayed reaction of inflation. At the same time, asymmetric effects across models are absent: Sticky information dampens the initial inflation response by the same (minor) factor when added to RANK and TANK, respectively, and household heterogeneity amplifies that response similarly when incorporated in RANK or SI-RANK.

[20] Likewise, more hand-to-mouth agents (a higher ω) would lead to a higher peak impact by reinforcing the amplification channel. These conclusions can be checked by means of the analytical solution for the IS curve (12).

[21] See Table G.1 in Appendix G for a sensitivity analysis with respect to δ.

Figure 2: Unequal shares of household types in output response



Notes: Impulse responses of output to an expansionary monetary policy shock of 25 basis points for the SI-TANK model. Subfigures show absolute (left) and relative (right) shares of each type of household.

Shifting the focus back on the demand side, one might be interested in the individual contribution of each household type to the aggregate impulse response within SI-TANK. Figure 2 reveals that it varies over the periods following the monetary policy shock. The left graph displays the split of the aggregate into individual responses. Savers only gradually adjust consumption, while the peak impact for constrained households is in the period in which the shock happens. As one might expect, the sluggishness in aggregate consumption therefore originates alone from the behavior of the intertemporal optimizers who are subject to information frictions. In addition, the relative shares in the right graph indicate that hand-to-mouth agents significantly drive the output response in the periods right after the shock, because only part of the savers are already aware of the latter. The remaining share of savers still acts according to their outdated information sets. If time passes and more savers learn about the shock, the relative contribution of each household type converges to the calibrated value for the agent's share in the population.

6 Implications for policymaking and theoretical modeling

The findings of the SI-TANK model reveal some implications for policymaking and the fine-tuning of aggregate demand in practice. Briefly speaking, empirical evidence for constrained households and the degree of information frictions in an economy should be considered together in the design of policy measures. Understanding their interaction is important due to the implications for the transmission and effectiveness of monetary policy and to avoid misleading policy recommendations.

The macroeconomic impact of information frictions and household heterogeneity should not be studied in isolation. As seen in section 4.1, the (absolute) impact of the propagation of a policy shock relative to a benchmark RANK model eventually hinges on the magnitude of the two main model parameters in SI-TANK. Various countries may therefore draw different conclusions for policymaking when using such a framework. Building on the figures estimated by Kaplan, Violante, and Weidner (2014), the SI-TANK model indicates that amplification is more likely if it is applied to countries with high shares of hand-to-mouth households such as the U.S., Canada, or the United Kingdom (above 30 percent). It is instead less likely for Euro area countries such as France, Italy, or Spain with smaller shares (around 20 percent), which, all else equal, require a larger monetary policy impulse to achieve a comparable response of aggregate demand. At the same time, a lower degree of information stickiness on the part of households may by conducive to amplification: if a central bank tries to stimulate aggregate spending by cutting interest rates, more widespread updating of the information sets of households can help.

This paper also opens room for the question of how to precisely model information frictions in macroeconomics. For instance, Auclert et al. (2020) and Carroll et al. (2020) assume that all households are subject to the same amount of stickiness. Each household adjusts its expectations about macroeconomic variables only sluggishly. The SI-TANK model postulates instead that savers alone are affected by sticky information. This builds on the view that the economy is in part made up of a group of (hand-to-mouth) households that are always at their borrowing constraint and cannot shift consumption across periods by saving. As a consequence, these constrained agents are assumed to be overly short-sighted and ignore any kind of information regarding the state of the economy. Their degree of information rigidity should thus be much different in the data. Unfortunately, to the best of my knowledge, no study so far regards hand-to-mouth agents' degree of inattention separately. There is only evidence of large information rigidities for consumers as a whole (Coibion & Gorodnichenko, 2012, 2015; Mankiw & Reis, 2007; Reis, 2009a, 2009b). The findings I present in section 2 are a first rough attempt for a more detailed analysis, but further work in this direction would be needed to show empirically significant differences in the degree of information stickiness for precisely identified household groups.

It is only safe to say that the way of incorporating information frictions into macroeconomic models will influence the evaluation of monetary policy transmission in practice. My findings for the SI-TANK model point at the potential asymmetric interaction of amplification and dampening effects. The impact of monetary policy at the individual-household level will therefore depend on whether a specific group of households updates its information set at all and if so, how often.[22] As seen in the graphical analysis, intertemporal optimizers only get to know new information slowly, while constrained agents are those who drive the output response right after a monetary policy shock.

Finally, to influence the behavior of the public effectively, the way a monetary authority communicates is key. Likewise, it is important how economic agents react to the information provided to them and how they adjust their views about the (future) state

[22]It remains to be verified whether the revealed asymmetry also arises in setups where all households are affected by information frictions.

of the economy accordingly. In fact, expectation formation is intrinsically linked to communication by nature and affects the formulation of optimal monetary policy. On the other hand, differences in MPCs, labor income or also the degree of information frictions induce households to form distinct expectations as a response to specific policy measures. Given the implications of these elements for aggregate demand, policymakers might actively investigate how to tackle them in the context of communication. Shaping the timing or simplicity of published content and especially the channels through which the public acquires information is clearly of high importance. As an example, reducing the costs of households to gather information can make it easier for a central bank to boost aggregate spending during a recessionary period.

7 Conclusion

The literature on macroeconomic models increasingly tries to follow recent empirical evidence and relax the traditional assumption of a representative household with full information. This paper studies the transmission of monetary policy to aggregate demand when incorporating sticky information into a TANK model with heterogeneity in household income. The resulting SI-TANK framework features specific propagation characteristics of a monetary policy shock: the presence of constrained hand-to-mouth households with a high MPC amplifies the impact of a change in the real interest rate with respect to RANK, while the information friction attenuates it.

Focusing on the net response of aggregate consumption on impact of the shock, I find that the effects of monetary policy might be dampened even if income inequality is countercyclical, which is different from recent findings in the literature. As a consequence, amplification only arises if constrained agents' income reacts substantially more than one-to-one to changes in aggregate income. Even more essential, the interaction of sticky information and household heterogeneity generates asymmetric effects on demand. The former attenuates the aggregate-consumption response more in a model without heterogeneous households, while the latter is proportionately more influential in combination with sticky information.

As already shown by some recent work (Auclert et al., 2020; Carroll et al., 2020; Pfäuti & Seyrich, 2022), combining heterogeneous households and information frictions is a convenient way to match both microeconomic and macroeconomic evidence in the data. When using such models for policy analysis, my findings point at the importance to locate the exact source of amplification and how the asymmetry between the two frictions changes the effectiveness of monetary policy. Policymakers need to consider this in the design of policy measures and communication to the public. In addition, it remains crucial to further explore various approaches to incorporate information frictions in macroeconomic models and to determine whether they are supported in the data.

References

Acharya, S., & Dogra, K. (2020). Understanding HANK: Insights from a PRANK. *Econometrica*, *88*(3), 1113–1158.

Alves, F., Kaplan, G., Moll, B., & Violante, G. L. (2020). A Further Look at the Propagation of Monetary Policy Shocks in HANK. *Journal of Money, Credit and Banking*, *52*(S2), 521–559.

Auclert, A. (2019). Monetary Policy and the Redistribution Channel. *American Economic Review*, *109*(6), 2333–2367.

Auclert, A., Rognlie, M., & Straub, L. (2020). *Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model* (NBER Working Paper No. 26647). National Bureau of Economic Research.

Bacchetta, P., van Wincoop, E., & Young, E. R. (2022, January). *Infrequent Random Portfolio Decisions in an Open Economy Model* (Research Paper No. 22-10). Swiss Finance Institute.

Barth III, M. J., & Ramey, V. A. (2002, January). The cost channel of monetary transmission. In *NBER Macroeconomics Annual 2001, Volume 16* (pp. 199–256). MIT Press.

Bilbiie, F. O. (2008). Limited Asset Market Participation, Monetary Policy and (Inverted) Aggregate Demand Logic. *Journal of Economic Theory*, *140*(1), 162–196.

Bilbiie, F. O. (2018). *Monetary Policy and Heterogeneity: An Analytical Framework* (CEPR Discussion Paper No. 12601). Centre for Economic Policy Research.

Bilbiie, F. O. (2020). The New Keynesian Cross. *Journal of Monetary Economics*, *114*, 90–108.

Bilbiie, F. O., Känzig, D. R., & Surico, P. (2022). Capital and Income Inequality: an Aggregate-Demand Complementarity. *Journal of Monetary Economics*, *126*, 154–169.

Broer, T., Kohlhas, A., Mitman, K., & Schlafmann, K. (2021, March). *Information and Wealth Heterogeneity in the Macroeconomy* (CEPR Discussion Paper No. 15934). Centre for Economic Policy Research.

Calvo, G. A. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics*, *12*(3), 383–398.

Carroll, C. D., Crawley, E., Slacalek, J., Tokuoka, K., & White, M. N. (2020). Sticky Expectations and Consumption Dynamics. *American Economic Journal: Macroeconomics*, *12*(3), 40–76.

Chung, H., Herbst, E., & Kiley, M. T. (2014, June). Effective Monetary Policy Strategies in New Keynesian Models: A Reexamination. In *NBER Macroeconomics Annual*

2014, Volume 29 (pp. 289–344). University of Chicago Press.

Coibion, O. (2006). Inflation Inertia in Sticky Information Models. *Contributions In Macroeconomics*, *6*(1), 1–29.

Coibion, O., & Gorodnichenko, Y. (2012). What Can Survey Forecasts Tell Us about Information Rigidities? *Journal of Political Economy*, *120*(1), 116–159.

Coibion, O., & Gorodnichenko, Y. (2015). Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts. *American Economic Review*, *105*(8), 2644–2678.

Coibion, O., Gorodnichenko, Y., & Kamdar, R. (2018). The Formation of Expectations, Inflation, and the Phillips Curve. *Journal of Economic Literature*, *56*(4), 1447–1491.

Debortoli, D., & Galí, J. (2017). *Monetary Policy with Heterogeneous Agents: Insights from TANK models* (Economics Working Paper No. 1686). Universitat Pompeu Fabra.

Dupor, B., Kitamura, T., & Tsuruga, T. (2010). Integrating Sticky Prices and Sticky Information. *The Review of Economics and Statistics*, *92*(3), 657–669.

Dupor, B., & Tsuruga, T. (2005). Sticky Information: The Impact of Different Information Updating Assumptions. *Journal of Money, Credit and Banking*, *37*(6), 1143–1152.

Gabaix, X., & Laibson, D. (2002, January). The 6D Bias and the Equity-Premium Puzzle. In *NBER Macroeconomics Annual 2001, Volume 16* (pp. 257–330). MIT Press.

Galí, J., López-Salido, J. D., & Vallés, J. (2007). Understanding the effects of government spending on consumption. *Journal of the European Economic Association*, *5*(1), 227–270.

Kaplan, G., Violante, G. L., & Weidner, J. (2014). The Wealthy Hand-to-Mouth. *Brookings Papers on Economic Activity*, *45*(Spring), 77–153.

Mankiw, N. G., & Reis, R. (2002). Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve. *The Quarterly Journal of Economics*, *117*(4), 1295–1328.

Mankiw, N. G., & Reis, R. (2006). Pervasive Stickiness. *American Economic Review*, *96*(2), 164–169.

Mankiw, N. G., & Reis, R. (2007). Sticky Information in General Equilibrium. *Journal of the European Economic Association*, *5*(2-3), 603–613.

Meyer-Gohde, A. (2010). Linear Rational-Expectations Models with Lagged Expectations: A Synthetic Method. *Journal of Economic Dynamics and Control*, *34*(5), 984–1002.

Patterson, C. (2022, June). *The Matching Multiplier and the Amplification of Recessions* (Working Paper No. 22-20). Center for Economic Studies, U.S. Census Bureau.

Pfäuti, O., & Seyrich, F. (2022). *A Behavioral Heterogeneous Agent New Keynesian*

Model. (Mimeo)

Ravenna, F., & Walsh, C. E. (2006). Optimal Monetary Policy with the Cost Channel. *Journal of Monetary Economics*, *53*(2), 199–216.

Reis, R. (2009a). Optimal Monetary Policy Rules in an Estimated Sticky-Information Model. *American Economic Journal: Macroeconomics*, *1*(2), 1–28.

Reis, R. (2009b). A Sticky-Information General-Equilibrium Model for Policy Analysis. In K. Schmidt-Hebbel & C. E. Walsh (Eds.), *Monetary Policy under Uncertainty and Learning* (Vol. 13, pp. 227–283). Central Bank of Chile.

Trabandt, M. (2007). *Sticky Information vs. Sticky Prices: A Horse Race in a DSGE Framework* (Working Paper No. 209). Sveriges Riksbank.

Verona, F., & Wolters, M. H. (2014). Sticky Information Models in Dynare. *Computational Economics*, *43*(3), 357–370.

Wang, P., & Wen, Y. (2006, May). *Solving Linear Difference Systems with Lagged Expectations by a Method of Undetermined Coefficients* (Working Paper No. 2006-003C). Federal Reserve Bank of St. Louis.

Werning, I. (2015). *Incomplete Markets and Aggregate Demand* (NBER Working Paper No. 21448). National Bureau of Economic Research.

A Empirical analysis

A.1 Test for the equality of regression coefficients

One can test for the statistical significance of differences between the coefficients of Table 1. To do so, I append the data on forecast errors and revisions related to the first quartile of the income distribution separately to the data for each of the other quartiles. I then define a dummy variable that equals 0 for data points from the first quartile and 1 otherwise. With this, we can estimate the following regression for each pair of quartiles:

$$\pi_{t+4,t} - F_t\, \pi_{t+4,t} = \alpha + \beta_1\, d_t + \beta_2\, (F_t\, \pi_{t+4,t} - F_{t-1}\, \pi_{t+3,t-1}) \\ + \beta_3\, d_t\, (F_t\, \pi_{t+4,t} - F_{t-1}\, \pi_{t+3,t-1}) + \varepsilon_t\ , \tag{A.1}$$

where d_t is the dummy variable. Note that β_3 is the coefficient on an interaction term between the dummy and the forecast revision. With this specification, $\hat{\beta}_2$ and $\hat{\alpha}$ are going to equal the estimated coefficients for the bottom 25% in Table 1, whereas $\hat{\beta}_2 + \hat{\beta}_3$ and $\hat{\alpha} + \hat{\beta}_1$ are going to be consistent with the estimates for the respective other group.

Similar to Section 2, we follow Coibion and Gorodnichenko (2015) and estimate equation (A.1) using log changes in the oil price as an instrument to account for the correlation between the error term ε_t and variables at time t. The results are shown in Table A.1.

The coefficient of interest is β_3. Its estimates are negative for all specifications, but never significantly different from zero. For example, focusing on the Bottom|Top 25% specification with CPI inflation, the p-value of the mentioned coefficient equals 0.263. This value suggests that the estimates of the coefficients on the forecast revision of these two groups in Table 1 (1.560 and 0.804) are statistically different from each other with only a low probability. This finding is also reflected in the 95% confidence bands of the two estimates, which overlap in large part ($[0.382, 2.737]$ for the first quartile and $[0.203, 1.406]$ for the fourth quartile). The estimation results should therefore be treated with caution and only be seen as a rough guidance for the structure of the theoretical model.

Table A.1: IV estimates of information rigidity in consumer inflation forecasts

	Inflation expectations for quartile pairs of income distribution		
Forecast error	Bottom|Second 25%	Bottom|Third 25%	Bottom|Top 25%
CPI			
Forecast revision	1.560***	1.560***	1.560***
	(0.601)	(0.601)	(0.601)
Interaction term	−0.869	−0.736	−0.756
	(0.670)	(0.668)	(0.674)
Dummy	0.638***	1.117***	1.575***
	(0.244)	(0.242)	(0.238)
Constant	−1.969***	−1.969***	−1.969***
	(0.186)	(0.186)	(0.186)
Observations	320	320	320
PCE (real-time)			
Forecast revision	1.032**	1.032**	1.032**
	(0.454)	(0.454)	(0.454)
Interaction term	−0.683	−0.593	−0.607
	(0.513)	(0.510)	(0.515)
Dummy	0.642***	1.120***	1.579***
	(0.203)	(0.203)	(0.202)
Constant	−2.391***	−2.391***	−2.391***
	(0.153)	(0.153)	(0.153)
Observations	320	320	320

Notes: Coefficient estimates of the instrumental variable regression equation (A.1) using MSC data, with Newey-West standard errors in parentheses. The dependent variable is the mean year-ahead forecast error for inflation and the forecast revision is defined as the change in the mean year-ahead forecast. The instrumental variable is the log change in the oil price. The sample period is 1980–2019.
* p<0.10, ** p<0.05, *** p<0.01

B Model derivations

B.1 Saver's optimization problem

Each saver has utility from consumption and leisure, $U\left(C_{t,j}^S, L_t^S\right) = \ln C_{t,j}^S - \xi \frac{(L_t^S)^{1+\eta}+1}{1+\eta}$, and is subject to the following budget constraint:

$$C_{t,j}^S + \frac{B_{t,j}^S}{P_t} = \frac{W_t}{P_t} L_t^S + (1+i_{t-1}) \frac{B_{t-1,j}^S}{P_t} + \frac{1}{1-\omega} D_t + T_{t,j} \,. \tag{B.1}$$

Since transfers make sure that all savers start into a period with the same level of real wealth, we can define the right-hand side as $X_{t,j}^S = X_t^S$. From this, rewriting the flow of budget constraints, the intertemporal optimization problem of an inattentive saver j

choosing a plan for current and future consumption (with $i = 0, 1, 2, \ldots$) at time t is

$$
\begin{aligned}
V\left(X_t^S\right) = \max_{\left\{C_{t+i,i}^S,\, L_{t+i}^S\right\}} & \left\{ \sum_{i=0}^{\infty} \beta^i (1-\delta)^i \left[\ln C_{t+i,i}^S - \xi \frac{\left(L_{t+i}^S\right)^{1+\eta} + 1}{1+\eta} \right] \right. \\
& \left. + \beta\delta \sum_{i=0}^{\infty} \beta^i (1-\delta)^i E_t \left[V(X_{t+1+i}^S) \right] \right\} , \\
\text{s.t. } X_{t+1+i}^S = & \frac{W_{t+1+i,.}}{P_{t+1+i}} L_{t+1+i,.}^S + R_{t+1+i} \left(X_{t+i}^S - C_{t+i,.}^S \right) + D_{t+1+i} + T_{t+1+i,.} ,
\end{aligned}
$$

where $V(.)$ denotes the agent's value function conditional on date t being a planning date, $R_{t+1} = (1+i_t)\frac{P_t}{P_{t+1}}$ is the gross real return on bonds between periods t and $t+1$, $\beta \in (0, 1)$ is the discount factor, and $C_{t,j}^S$ denotes individual consumption at time t of a saver who last updated his information set j periods ago. The j-subscripts in the budget constraint were replaced by dots, indicating that all savers arrive in period t with the same real resources, regardless of when they last updated.

The value function consists of two parts. The first term captures the expected discounted utility that the saver gets if he does not update his information set in any period from time t on.[23] The second part contains the continuation value functions for the potential case in which the household updates again at some point in the future. This can happen with probability $\delta(1-\delta)^i$ in each period.

The optimality conditions (for $i = 0, 1, 2, \ldots$) are given by

$$
\begin{aligned}
\beta^i (1-\delta)^i \left(C_{t+i,i}^S\right)^{-1} &= \beta\delta \sum_{k=i}^{\infty} \beta^k (1-\delta)^k E_t \left[V'(X_{t+1+k}^S) \overline{R}_{t+i,t+1+k} \right] , \\
\beta^i (1-\delta)^i \xi \left(L_{t+i}^S\right)^{\eta} &= \beta\delta \sum_{k=i}^{\infty} \beta^k (1-\delta)^k E_t \left[V'(X_{t+1+k}^S) \overline{R}_{t+i,t+1+k} \right] \frac{W_{t+i}}{P_{t+i}} , \\
V'(X_t^S) &= \beta\delta \sum_{k=0}^{\infty} \beta^k (1-\delta)^k E_t \left[V'(X_{t+1+k}^S) \overline{R}_{t,t+1+k} \right] ,
\end{aligned}
$$

with $\overline{R}_{t+i,t+1+k} = \prod_{z=t+i}^{t+k} R_{z+1}$ being the compound return between two periods $t+i$ and $t+1+k$. Setting the first condition for $i = 0$ equal to the envelope condition yields $V'(X_t^S) = \left(C_{t,0}^S\right)^{-1}$. Inserting this result into the three optimality conditions gives the Euler equations for both attentive and inattentive households and the usual intratemporal

[23] Strictly speaking, the information friction exclusively affects the consumption decision. How many hours to work is decided without considering when information was last updated because all savers choose the same labor supply in each period. As a result, regardless of whether the problem of consumers and workers are separated as in Mankiw and Reis (2006, 2007), or combined into a single problem, the log-linearized equilibrium will be equal for the model specification here.

condition:

$$1 = \beta E_t \left[R_{t+1} \left(\frac{C^S_{t+1,0}}{C^S_{t,0}} \right)^{-1} \right] ,$$

$$1 = E_t \left[\left(\frac{C^S_{t+j,0}}{C^S_{t+j,j}} \right)^{-1} \right] ,$$

$$\frac{W_t}{P_t} = \xi C^S_{t,0} \left(L^S_t \right)^{\eta} .$$

B.2 Derivation of the reduced-form model representation

The non-linear model is approximated around a non-stochastic steady state as described in section 3.6. The resulting log-linearized model conditions are the following:

$$c^S_{t,0} = E_t \left(c^S_{t+1,0} - r_t \right) \tag{B.2}$$

$$c^S_{t,j} = E_{t-j} \left(c^S_{t,0} \right) \tag{B.3}$$

$$c^S_t = \delta \sum_{j=0}^{\infty} (1-\delta)^j c^S_{t,j} \tag{B.4}$$

$$\eta l^S_t = w_t - c^S_{t,0} \tag{B.5}$$

$$\eta l^H_t = w_t - c^H_t \tag{B.6}$$

$$c^H_t = w_t + l^H_t \tag{B.7}$$

$$c^S_t = w_t + l^S_t + \frac{1}{1-\omega} d_t + t_t \tag{B.8}$$

$$y_t = l_t \tag{B.9}$$

$$mc_t = w_t \tag{B.10}$$

$$d_t = -mc_t \tag{B.11}$$

$$\pi_t = \beta E_t(\pi_{t+1}) + \Theta mc_t, \ \Theta = \frac{(1-\lambda)(1-\lambda\beta)}{\lambda} \tag{B.12}$$

$$i_t = E_t(\pi_{t+1}) + \varepsilon_t \tag{B.13}$$

$$i_t = r_t + E_t(\pi_{t+1}) \tag{B.14}$$

$$c_t = \omega c^H_t + (1-\omega) c^S_t \tag{B.15}$$

$$l_t = \omega l^H_t + (1-\omega) l^S_t \tag{B.16}$$

$$y_t = c_t \tag{B.17}$$

Using these conditions, I can derive the aggregate demand (IS curve) and aggregate supply (Phillips curve) equations in reduced form.

Aggregate demand. I start by iterating equation (B.2) forward. In the limit as time goes to infinity, all agents will be fully informed. Therefore, $\lim_{i\to\infty} E_t(r_{t+i}) = \lim_{i\to\infty} E_t\left(r^n_{t+i}\right) = 0$ and $\lim_{i\to\infty} E_t\left(c^S_{t+i,0}\right) = \lim_{i\to\infty} E_t\left(y^{S,n}_{t+i}\right) = 0$, where the superscript n is used to denote the natural equilibrium without any frictions such that all agents are attentive. This leaves us with $c^S_{t,0} = -R_t$, where $R_t = E_t\left(\sum_{k=0}^{\infty} r_{t+k}\right)$. Inserting this expression into (B.3), combining the result with (B.4) and using (B.17) leads to the Euler equation (5) of the main text that governs the bond holding decision of savers.

To derive an aggregate Euler equation, first note that the labor supply of hand-to-mouth households is fully inelastic because I assumed unity for the intertemporal elasticity of substitution, as shown in Bilbiie (2008). In other words, their hours worked are constant, such that $l^H_t = 0$. Combining (B.5), (B.7), (B.9) and (B.16) yields

$$c^H_t = \eta \frac{1}{1-\omega} y_t + c^S_{t,0} \,. \tag{B.18}$$

By (B.4), one gets $c^S_t = \delta c^S_{t,0} + \delta \sum_{j=1}^{\infty}(1-\delta)^j E_{t-j}\left(c^S_{t,0}\right)$. Combined with (B.15) and replacing $c^S_{t,0}$ in (B.18) leads to equation (6) of the main text, the consumption of constrained agents as a function of aggregate output and real interest rates.

Finally, using (6) together with (B.17) in (B.15) gives us an expression for c^S_t that can be combined with the Euler equation of savers to find the IS curve (8) of the SI-TANK model.

Aggregate supply. By (B.6) and (B.10), we get $mc_t = c^H_t$. Using (6) and replacing the real marginal cost in (B.12) results in the Phillips curve (9) of the SI-TANK model.

C Dependence of shock propagation on main parameters

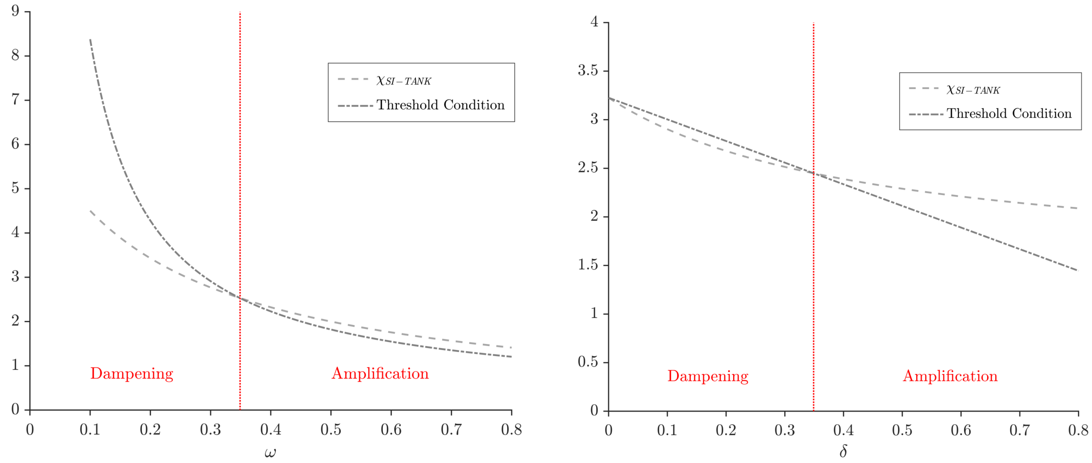
The key driver for the propagation of monetary policy shocks in the SI-TANK model is the relative proportion between the share of hand-to-mouth agents (ω) and the degree of information stickiness $(1-\delta)$. Focusing on the *initial* consumption and output responses on impact of the shock, in order to get amplification of the effects of a change in real interest rates, the following threshold condition must hold:

$$\chi_{\textit{SI-TANK}} > \frac{1-\delta}{\omega} + \delta \geq 1 \,,$$

where $\chi_{\textit{SI-TANK}} = \frac{1+\delta\eta}{\omega+(1-\omega)\delta}$. Otherwise, there is dampening. See section 4.1 for more details.

Assuming conventional parameter values (see Table F.1), Figure C.1 shows how likely amplification arises relative to dampening. Given the baseline values of $\omega = 0.31$ and $\delta = 0.18$, respectively, the particular other parameter has to be relatively high to achieve amplification of monetary policy effects on impact. However, regarding the absolute values, one needs to consider the simplicity of the model at hand. An extended model including, for example, fiscal redistribution as in Bilbiie (2020) might narrow the dampening region. Moreover, as discussed in the graphical analysis in section 5.3, one also needs to consider the further course of the response. Even if the effect of the policy shock was attenuated on impact, the sticky-information assumption and the resulting hump-shaped behavior of output would still allow to get amplification in subsequent periods.

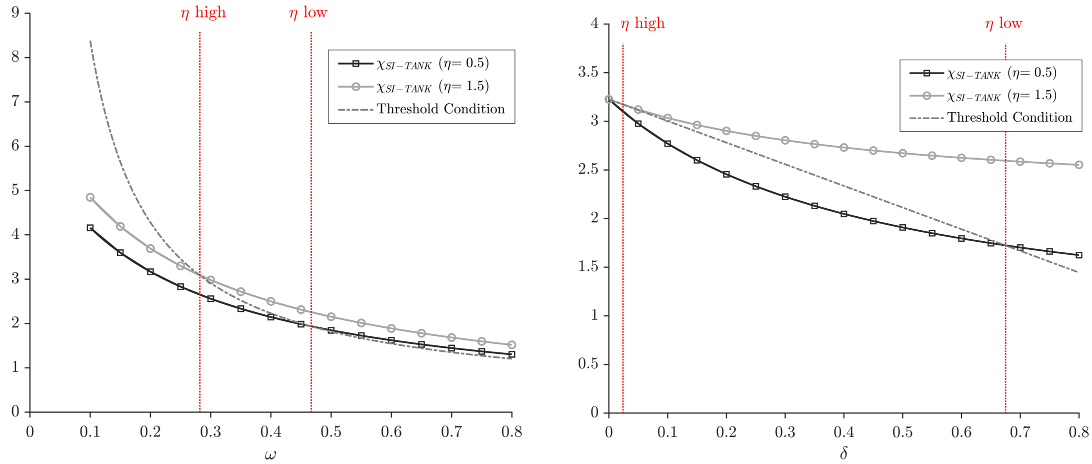
Figure C.1: Impact of main model parameters on the propagation of monetary policy



Notes: Propagation regions along the distribution of the share of hand-to-mouth households ω (left graph; $\delta = 0.18$) or of the information stickiness parameter δ (right graph; $\omega = 0.31$). Labor supply elasticity is set to $1/\eta = 1$. The amplification region is characterized by the constrained agents' income elasticity to aggregate income $\chi_{SI\text{-}TANK}$ being larger than the threshold condition $\frac{1-\delta}{\omega} + \delta$. Left graph: The lowest part of the distribution is not depicted because the threshold condition is exploding for very small values of ω.

Another parameter that determines the propagation regions is η, the inverse of the Frisch elasticity of labor supply. As Figure C.2 shows, the higher its value, the lower is the threshold between dampening and amplification along the distributions of both ω and δ. Thus, a more inelastic labor supply elasticity (i.e., a lower $1/\eta$) compared to the benchmark case in Figure C.1 implies that amplification becomes more likely to arise in economies with even a low amount of hand-to-mouth households and a high degree of information stickiness, respectively.

Figure C.2: Impact of labor supply elasticity on the propagation of monetary policy



Notes: Propagation regions along the distribution of the share of hand-to-mouth households ω (left graph; $\delta = 0.18$) or of the information stickiness parameter δ (right graph; $\omega = 0.31$), given alternative values for the inverse of the Frisch elasticity of labor supply. Left graph: The lowest part of the distribution is not depicted because the threshold condition is exploding for very small values of ω.

D Dependence of multiplier wedges on main parameters

The degree of asymmetry regarding the *initial* impact of monetary policy shocks on aggregate consumption and output in the SI-TANK model is significantly influenced by the share of hand-to-mouth agents (ω) and the degree of information stickiness ($1 - \delta$). Assuming conventional parameter values (see Table F.1), Figure D.1 shows how the wedge between the ratios of different aggregate-demand multipliers varies with these two parameters.

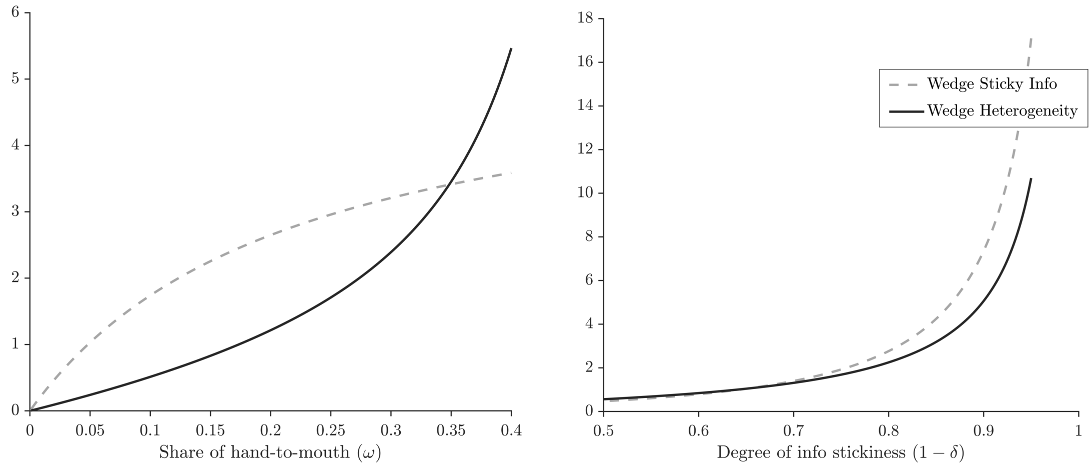
The ratios in question arise from Proposition 1. In particular, I define two wedges:

(i) Wedge from sticky information: $\frac{\Phi_{RANK}}{\Phi_{SI\text{-}RANK}} - \frac{\Phi_{TANK}}{\Phi_{SI\text{-}TANK}} \geq 0$

(ii) Wedge from heterogeneity: $\frac{\Phi_{SI\text{-}TANK}}{\Phi_{SI\text{-}RANK}} - \frac{\Phi_{TANK}}{\Phi_{RANK}} \geq 0$

where Φ_M is the aggregate-demand multiplier on impact of a monetary policy shock. A larger difference between any two fractions indicates a higher degree of asymmetry, which is equivalent to a more pronounced inequality between the ratios in sub-propositions (I) and (II) of Proposition 1. As Figure D.1 shows, the differences increase in both ω and $1 - \delta$. A higher share of hand-to-mouth households results in stronger amplification, whereby the latter is relatively more influential in SI-TANK compared to TANK. Similarly, stickier information translates into a more dampened output response in SI-TANK, but even more attenuation in SI-RANK.

Figure D.1: Impact of the main model parameters on the multiplier ratios



Notes: Differences in ratios between aggregate-demand multipliers of various model specifications. Left graph: wedges along the distribution of ω with information stickiness set to $\delta = 0.18$. Right graph: wedges along the distribution of δ with a share of hand-to-mouth households of $\omega = 0.31$.

E General analytical solution of lagged expectations

For the general solution of the expectation expressions, I only rule out future anticipated shocks, but shocks in the past (i.e., before t) are considered. Using the forwarded AR(1) process for the shock and the assumption that the innovation ν has mean zero, one gets $E_t\left(\varepsilon_{t+k}\right) = \rho_\varepsilon^k \varepsilon_t$, $E_{t-1}\left(\varepsilon_{t+k}\right) = \rho_\varepsilon^{k+1}\varepsilon_{t-1}$, etc. More general, for any $j \geq 0$ and $t = t + i$ with $i \geq 0$,

$$E_{t+i-j}\left(\varepsilon_{t+i+k}\right) = \rho_\varepsilon^{j+k}\varepsilon_{t+i-j} \; .$$

An agent's expectation at any point in time of current and future policy shocks is equal to the product of the shock that the agent observed at the time he last updated and the overall series of persistence coefficients since then. The latter accumulate over $(t+i+k) - (t+i-j) = j+k$ periods.

Summing over all $k \geq 0$,

$$E_{t+i-j}\left(\sum_{k=0}^{\infty} \varepsilon_{t+i+k}\right) = \frac{\rho_\varepsilon^j}{1-\rho_\varepsilon}\varepsilon_{t+i-j} \; .$$

Combined with the IS curve yields, for all non-negative i,

$$c_{t+i} = y_{t+i} = -\frac{\mu}{1-\rho_\varepsilon}\left\{\omega\varepsilon_{t+i} + (1-\omega)\delta\sum_{j=0}^{\infty}(1-\delta)^j\rho_\varepsilon^j\varepsilon_{t+i-j}\right\} \; .$$

Aggregate consumption and output are not anymore functions of expectation expressions and future policy shocks shocks that are partly unknown, but only depend on current and past shocks that were observed by an agent being in period $t + i$. Spending after time t

thereby reacts more with a larger persistence of the shock (higher ρ_ε), more hand-to-mouth households (higher ω), and stickier information (smaller δ).

F Parameterization for the graphical analysis

Table F.1 shows the calibration of the model parameters used for the analysis in section 5.3. I take the baseline value for the information stickiness parameter from the estimates for the United States in Mankiw and Reis (2007). The value implies that consumers update their information on average about every 16 months.[24] The baseline value for the share of hand-to-mouth households, taken from Kaplan et al. (2014), is an average value for the United States over the period 1989-2010. I assume a Calvo stickiness parameter of 0.75, implying average price duration of four quarters. Labor supply elasticity is set to one. Finally, the persistence of the policy shock is assumed to be 0.92, just as in Mankiw and Reis (2006).

Table F.1: Calibration

Parameter	Value	Description
δ	**0.18**, 1.0	Probability of updating information set
ω	0, **0.31**	Share of hand-to-mouth households
λ	0.75	Probability of not resetting price
β	0.99	Household discount factor
$1/\eta$	1	Frisch labor supply elasticity
ρ_ε	0.92	Persistence of monetary policy shock

Note: Baseline values in bold.

G Sensitivity analysis for information stickiness

Information frictions are an important driver of the dynamic effects of a monetary policy shock. Table G.1 lists different response measures for alternative values of the information stickiness parameter δ. We can draw several conclusions from it. First and intuitively, changes in δ leave the impact, cumulative, and peak responses under full information all unaffected. Second, more frequent information updating makes a larger fraction of savers aware of the policy shock and thus implies higher values for all listed responses of the SI-RANK and SI-TANK models. This result is also visible in Figure G.1. Third, an increase in δ also leads to earlier peaks of output in SI-RANK, while the period of the maximum impact is less variable in SI-TANK due to the smaller group of households for which the information frictions matter. The only exception is the case where savers are almost fully inattentive to information (i.e., $\delta = 0.01$) and overall updating in the economy is very

[24] Reis (2009a, 2009b) confirms the relatively high inattentiveness to information of consumers. He estimates $\delta = 0.08$ for the U.S. and $\delta = 0.21$ for the Euro area. A slightly more moderate value of $\delta = 0.25$ is found by Mankiw and Reis (2006), which indicates that consumers update their information on average once a year.

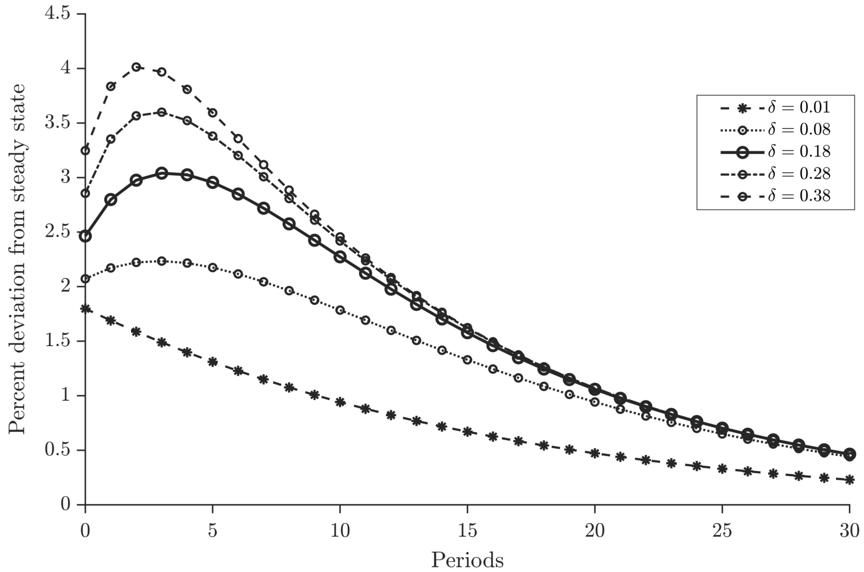
slow, which is why the peak occurs already on impact of the shock. See also Figure G.1. Fourth, comparing the ratios between various responses implies that Proposition 1 not only holds for initial aggregate-consumption responses, but also at the cumulative level.

Table G.1: Impact of monetary policy on aggregate demand: sensitivity of dynamics

		Full information		Sticky information	
		RANK	TANK	RANK	TANK
$\delta = 0.01$	Response on impact	3.13	5.67	0.03	1.80
	Cumulative response	33.10	60.10	2.90	22.27
	Peak response	3.13	5.67	0.14	1.80
	Peak period	1	1	11	1
$\delta = 0.08$	Response on impact	3.13	5.67	0.25	2.07
	Cumulative response	33.10	60.10	15.43	37.97
	Peak response	3.13	5.67	0.85	2.23
	Peak period	1	1	8	4
$\delta = 0.18$	Response on impact	3.13	5.67	0.56	2.46
	Cumulative response	33.10	60.10	22.98	47.42
	Peak response	3.13	5.67	1.43	3.04
	Peak period	1	1	6	4
$\delta = 0.28$	Response on impact	3.13	5.67	0.88	2.86
	Cumulative response	33.10	60.10	26.56	51.91
	Peak response	3.13	5.67	1.81	3.60
	Peak period	1	1	5	4
$\delta = 0.38$	Response on impact	3.13	5.67	0.88	2.86
	Cumulative response	33.10	60.10	28.65	54.52
	Peak impact	3.13	5.67	2.07	4.01
	Peak period	1	1	4	3

Notes: Effects of an unexpected interest rate cut in the current period on aggregate demand. The table contains the responses both on impact and cumulated over time ($\sum_{i=0}^{T} \beta^i y_i$, where y_i is the response of aggregate demand in period i and $T = 1000$), and the magnitude and period of the peak impact.

Figure G.1: Dynamic response of output to monetary policy shock



Notes: Impulse response function of output in thhe SI-TANK model to an expansionary monetary policy shock of 25 basis points for alternative values of the information stickiness parameter δ. A lower value of δ denotes a smaller probability of obtaining new information and thus more rigid information.