Thinking about the Economy, Deep or Shallow?*

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Abstract

We propose a theory of *shallow thinking* to capture people's limited understanding of the long causal chains involved in the propagation of macroeconomic shocks. We conceptualize general equilibrium as a system of causal relations in a directed graph, and our theory predicts that deeper relations—those further from shocks—have less influence on beliefs. Our estimation suggests that, on average, people understand only about three steps of propagation. In a New Keynesian model with shallow thinking, (i) long-term nominal interest rates overreact to monetary policy shocks as agents underperceive a long offset loop, but underreact to cost-push shocks due to underappreciation of propagation; (ii) inflation expectations negatively predict bond excess returns, controlling for yields; (iii) cost-push shocks are more inflationary than under rational expectations, because agents better understand shallow amplifying relations than a deep offsetting one; and (iv) more persistent cost-push shocks lead to higher inflation, contrary to rational expectations. In a real business cycle model, in response to productivity shocks, (i) output displays a hump-shaped, more persistent response; (ii) investment, labor hours, and the stock price show amplified reactions; and (iii) investment negatively predicts stock excess returns.

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1 Introduction

An economy's response to shocks involves causal changes in various prices and quantities, such as inflation, interest rates, and firms' dividends. In general equilibrium models of the economy, prices and quantities emerge from complex causal relations of agents' responses and market outcomes. Expectations of these variables are crucial in macroeconomics and finance because they influence household consumption, firms' pricing and capital investment, asset pricing, and other critical aspects of the economy. How do actual economic agents understand these causal relations when forming their expectations? And how do these expectations, in turn, affect an economy's response to shocks?

The prevailing rational expectations hypothesis amounts to assuming that people fully grasp all causalities in the economy. However, growing evidence suggests that people do not understand the responses of macroeconomic policies to shocks (Bauer, Pflueger and Sunderam, 2024) or the effects of shocks and policy changes on the economy (Andre et al., 2022; D'Acunto, Hoang and Weber, 2022; Coibion et al., 2023*b*). Research from behavioral economics and cognitive psychology further establishes that human reasoning about complex causal systems is limited compared to the benchmark of rationality.[1]

In light of these insights, we propose a theory of *shallow thinking* to model people's limited understanding of the economy as a general equilibrium.[2] We conceptualize a general equilibrium as a system of causal relations in a directed graph. These causal relations capture how one macroeconomic variable depends on other variables, resulting from agents' responses and the determination of prices in competitive markets. The rational expectations hypothesis assumes that agents fully comprehend all causal relations. In contrast, motivated by the aforementioned evidence, we assume that people only understand short chains starting from a shock in the directed graph. As a result, causal relations that are deeper—that is, further removed from shocks—exert less influence on people's beliefs.

We apply our theory to the workhorse New Keynesian and Real Business Cycle (RBC)

[1] People underappreciate how new policies lead to new equilibriums in economic settings (Dal Bó, Dal Bó and Eyster, 2018). They struggle to understand complex causal relations for predictive tasks (Kendall and Oprea, 2024), and make predictions that are insufficiently sensitive to the strengths of causal relations (Rottman and Hastie, 2014). Further, they pay special attention to earlier nodes in causal chains (Ahn et al., 2000), and their knowledge of causally complex systems is sparse and shallow (Rozenblit and Keil, 2002).

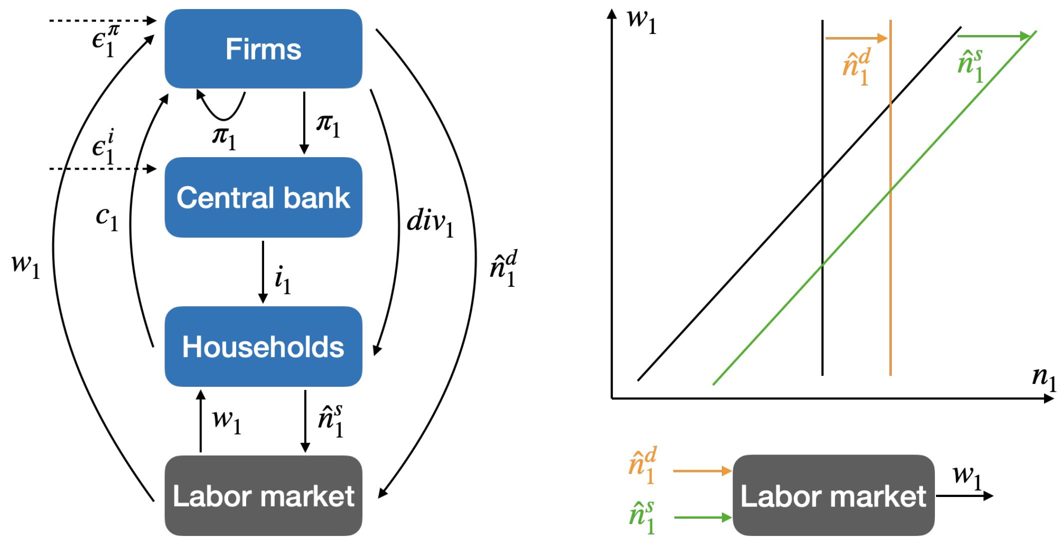
[2] Recent works have relaxed the assumption of full-information rational expectations by removing common knowledge (Angeletos and Lian, 2018) or by modeling agents' limited strategic sophistication (García-Schmidt and Woodford, 2019; Farhi and Werning, 2019) or myopia (Gabaix, 2020), among other notable contributions. However, these studies still assume that agents understand general equilibrium. We will discuss our connection to these works in more detail later.

models and uncover a range of consequences for macroeconomics and finance. We demonstrate that these models feature multiple causal relations that either amplify or offset a shock. By assigning less weight to deeper relations, shallow thinking alters the sign or magnitude of the perceived *net* general equilibrium effect. Consequently, beliefs may over- or underreact to shocks compared to equilibrium outcomes, depending on the specific causal relations involved. We show that, in the New Keynesian model, shallow thinking about future interest rates, inflation and other variables leads to misreactions in long-term interest rates and results in a larger inflation response to cost-push shocks. In the RBC model, shallow thinking amplifies the economy's responses to productivity shocks and implies predictable stock excess returns.

In Section 2, we conceptualize the textbook New Keynesian model à la Woodford (2003*b*) and Galí (2015) as a system of causal relations, and introduce shallow thinking. We study news shocks that are observed in period 0 but only affect the economy in period 1, demonstrating later that the insights hold when generalized to persistent shocks. In period 1, agents observe all variables, respond optimally, and markets clear, making the period-1 economy a static general equilibrium independent of agents' belief formation. However, the period-0 equilibrium depends on agents' beliefs about period-1 outcomes, as households' and firms' decisions are forward-looking. We introduce shallow thinking regarding period-1 outcomes and explore its consequences for the period-0 equilibrium.

Figure 1a illustrates the causal relations among macroeconomic variables of the period-1 economy in a directed graph, subject to shocks ϵ_1. The graph is cyclic, representing the equilibrium as a fixed point. The rational expectations hypothesis assumes that agents take infinite steps in this graph to appreciate the equilibrium as the fixed point.

In contrast to rational expectations, we hypothesize that each individual only foresees a finite number of steps of shock propagation in the graph, which we refer to as their individual "depth of thinking" d, and that d varies across the population. Intuitively, when thinking about a cost-push shock ϵ_1^π, a depth-1 agent acknowledges only the most obvious implication: firms will raise their prices (causing inflation π_1), while overlooking changes in all other variables. A depth-2 agent can further appreciate that the central bank will raise the interest rate i_1 in response to higher inflation, but fails to foresee additional implications. A depth-3 agent understands that a higher interest rate i_1 will discourage household consumption and incentivize labor supply. A depth-4 agent recognizes that changes in household behavior will affect the firms and the labor market. This iteration continues infinitely, and only a depth-∞ (i.e., rational) agent correctly assesses the strength



(a) Directed graph of causal relations (b) Competitive labor market

Figure 1: Causal relations of period-1 New Keynesian economy

Notes: Panel (a) illustrates the causal relations among macroeconomic variables of the period-1 economy in a directed graph, subject to a cost-push shock ϵ_1^π and a monetary policy shock ϵ_1^i. Each node indicates a type of agents or a competitive market, and each arrow is an endogenous variable—either a decision of agents or a price. In the case of a competitive market, we interpret the price as set by a fictitious Walrasian auctioneer to equilibrate supply and demand, as demonstrated in panel (b). The causal relations among variables are embedded by agents' best responses and the determination of prices in markets.

of all loops and accurately forecasts the period-1 equilibrium. This iterative process formally captures the idea that deeper implications are harder to grasp.

Our theory makes a novel prediction about belief heterogeneity, which also allows us to measure the distribution of d across the population. An agent with a low d perceives only a subset of variables that are shallow—i.e., close to the shocks in the directed graph. Thus our theory predicts that deeper variables are understood by fewer people.

For tractability, we assume that the depth of thinking d follows a geometric distribution with continuation rate λ. This parameter λ is the only input required to apply our theory to macroeconomic models. A higher λ means that people think more deeply on average, with $\frac{1}{1-\lambda}$ representing the average depth of thinking, and $\lambda = 1$ nesting the rational expectations hypothesis. The average expectations, which drive the aggregate outcomes in a large class of models (including those analyzed in this paper), is tractably parametrized by λ. They are as if generated by a representative who knows all causal relations in the economy but dampen them by λ. Deeper causal effects are dampened exponentially, as they take more steps to reach, and thus exert less influence on beliefs.

In Section 3, we present our survey to test the prediction that deeper variables are understood by fewer people and measure the parameter λ. We use hypothetical vignettes to investigate people's understanding of the propagation of classic macroeconomic shocks, such as oil shocks and monetary policy shocks. For each shock scenario, we ask respondents to provide directional forecasts of changes in a host of important macroeconomic variables, heresuch as inflation and interest rates. We use the directional responses from the empirical literature as the objectively correct answers. We show that variables deeper relative to shocks are indeed forecasted with correct directions by fewer respondents, as predicted by the theory. This finding is robust to including a rich set of fixed effects which absorb sources of belief heterogeneity that do not correlate with depth.

Leveraging the empirical findings, our estimation indicates that λ is around 0.69 [xx subject to change as we finalize the sample], which implies that the average depth of thinking is only about three—far below infinity (per rational expectations). Furthermore, we find that respondents who better forecast the effects of one shock tend to better understand another shock as well. This suggests that the ability to understand the economy is indeed an individual characteristic, as hypothesized.

In Section 4, we delineate the consequences of shallow thinking for asset prices and aggregate outcomes in the New Keynesian economy under transitory news shocks. The period-0 long-term interest rate *underreacts* to news about period-1 cost-push shocks, consistent with findings by Bauer, Pflueger and Sunderam (2024), because agents underappreciate the monetary policy reaction to inflation in period 1. However, period-0 expectations of period-1 inflation *overreact*. This occurs because multiple causal relations of varying strength and depth are involved in determining period-1 inflation. Among them, the only offsetting relation involves the monetary policy reaction, which is both the strongest and the deepest, while all shallower relations amplify the inflation response. Since agents better understand the shallow relations, they perceive net amplification, even though the true net effect is offset, leading to overreaction of inflation expectations.

Conversely, the period-0 long-term interest rate *overreacts* to news about period-1 monetary policy shocks, aligning with the findings of a large literature (Cochrane and Piazzesi, 2002; Gürkaynak, Sack and Swanson, 2005; Hanson and Stein, 2015). In period 1, all causal relations offset the effects of monetary policy shocks on the interest rate. As they are dampened to varying degrees, shallow agents perceive less offset than the true effect. As a result, period-0 interest rate expectations, and thus the period-0 long-term interest rate, overreact to monetary policy shocks. However, as agents underappreciate the effect of monetary policy on inflation, inflation expectations *underreact*.

Moreover, variables other than current yields predict bond excess returns when multiple shocks impact the economy, as noted by Joslin, Priebsch and Singleton (2014), Cieslak (2018) and others. In the presence of multiple shocks, interest rate expectations (and thus current yields) primarily reflect monetary policy shocks, while other macroeconomic variables load more on other shocks. This leads to the predictability of bond excess returns by macroeconomic variables, controlling for current yields. Taken together, shallow thinking reconciles several bond market puzzles that seem unrelated or even contradictory.

In terms of aggregate outcomes, news about period-1 cost-push shocks is more inflationary and less contractionary in period 0 than under rational expectations. The underlying mechanism is that, upon receiving news about future cost-push shocks, agents overestimate future inflation and underappreciate the future increase in interest rate and the associated economic contraction. Consequently, in period 0, firms price higher in anticipation of higher future inflation, and households consume more as they expect a lower real interest rate, leading to higher inflation and less contraction in output.

In Section 5, we generalize the analysis to persistent shocks in the New Keynesian economy and show that the insights gained from transitory news shocks still hold, while new lessons emerge. A persistent cost-push shock is more inflationary under shallow thinking than under rational expectations, as in the case with transitory news shocks. Additionally, a *more* persistent cost-push shock leads to *higher* inflation under shallow thinking, rather than lower inflation as predicted by rational expectations. In generalizing shallow thinking to accommodate persistent shocks, we focus on causal relations across variables and abstract away from the intertemporal dimension.[3] For example, regarding the dependence of consumption $\{c_t\}_{t\geq 0}$ on interest rates $\{i_t\}_{t\geq 0}$, we assume that if an agent understands how c_t depends on contemporaneous i_t, they also understand how c_t depends on future i_s. With persistent shocks, the causal relations agents underappreciate become the Jacobians of $\{c_t\}_{t\geq 0}$ with respect to $\{i_t\}_{t\geq 0}$, which generalizes the dependence of c_1 on i_1 as a partial derivative in the case of transitory news shocks.

In Section 6, we consider an RBC economy, and demonstrate that shallow thinking amplifies business cycle fluctuations in response to productivity shocks, in a way consistent with return predictability observed in investment boom-bust cycles. In response to

[3]This assumption is for simplicity and generates cross-variable dampening, which complements horizon-dependent dampening in Angeletos and Lian (2018), Farhi and Werning (2019) and Gabaix (2020).

a persistent productivity shock, shallow agents believe that firms will invest more and pay higher dividends in the future, but underappreciate that firms' behavior will push up wages in the economy. Due to this underestimation of future wages, firms invest more and hire more labor compared to the rational expectations equilibrium. This overaccumulation of capital leads to a hump-shaped, persistent boom in output and an amplified response in labor hours. Furthermore, since agents overestimate future dividends and underestimate future interest rates, the stock price becomes more volatile. However, as overly optimistic beliefs prove incorrect, realized stock returns are lower. Thus, higher current investment and earnings in this economy predict lower future stock excess returns, consistent with the findings of Greenwood and Hanson (2015). Our theory makes these predictions in a general equilibrium model that endogenizes interest rates, wages, demand, and misperceptions thereof, generalizing the simple q-theory model in Greenwood and Hanson (2015) with an exogenous demand curve and a fixed interest rate.

1.1 Literature Review

At a high level, our theory enriches prior works by suggesting that, among multiple general equilibrium effects, deeper ones are more dampened. Angeletos and Lian (2023*a*) review recent research that moves beyond full-information rational expectations and highlight a key commonality: in a stylized model with one partial equilibrium effect and one general equilibrium (GE) effect, several prominent theories are equivalent in dampening the GE effect. Building on this insight, we show that workhorse macroeconomic models feature multiple GE effects, sometimes with opposing signs. By assigning less weight to deeper ones, shallow thinking alters the sign or magnitude of the perceived *net* GE effect.

Specifically, our theory concerns rationality in the absence of information frictions, and complements a large theoretical literature that studies information frictions (Lucas, 1972; Gabaix and Laibson, 2001, Mankiw and Reis, 2002; Woodford, 2003*a*; Nimark, 2008; Angeletos and Lian, 2018), rational inattention (Sims, 2003; Maćkowiak and Wiederholt, 2009; Molavi, 2019; Miao, Wu and Young, 2022) and learning (Evans and Honkapohja, 2001; Eusepi and Preston, 2018). Our survey studies understanding of macroeconomic shocks under full information and shows that people fail to even get the directions of impulse responses correct, which provides unique support to our theory.

Our theory broadens an important line of research that considers agents' limited strategic sophistication in macroeconomics (García-Schmidt and Woodford, 2019; Farhi and

Werning, 2019; Iovino and Sergeyev, 2023; Bianchi-Vimercati, Eichenbaum and Guerreiro, 2024) and finance (Greenwood and Hanson, 2015; Bastianello and Fontanier, 2024). These works introduce models of level-*k* thinking (Nagel, 1995; Stahl and Wilson, 1994, 1995; Camerer, Ho and Chong, 2004) and competition neglect (Camerer and Lovallo, 1999) from the experimental and game-theoretical literature to general equilibrium. Level-*k* thinking addresses agents' limited strategic sophistication when lacking experience in analogous games. The aforementioned papers aptly apply it to study unconventional macroeconomic policies (such as forward guidance and quantitative easing) in New Keynesian models. Shallow thinking accounts for agents' underappreciation of non-strategic causal relations (such as the monetary policy rule) and applies to models that are not typically considered strategic (such as the RBC model), as well as to conventional shocks, all driven by a lack of knowledge. Moreover, in our survey, we measure strategic sophistication using the classic "guess 2/3 of the average" game, and find *no* correlation with understanding of macroeconomic shocks. A reasonable interpretation is that shallow thinking reflects limited knowledge about the macroeconomy—a different aspect of bounded rationality from limited strategic sophistication.

Our theory focuses on the dampening of causalities *across variables*, which complements *horizon-dependent* dampening due to bounded rationality (Gabaix, 2020; Farhi and Werning, 2019) or information frictions (Angeletos and Lian, 2018; Angeletos and Huo, 2021). With persistent shocks, we assume that if an agent understands how one variable contemporaneously depends on another variable, they also understand how it depends on future values of the other variable. One could generalize our theory to accommodate horizon-dependent dampening by introducing failure of causal reasoning across time.

Our theory generates belief over- and underreaction in a manner endogenous to the causal relations involved. It implies belief overreaction of a variable to shocks that hit itself, if the very indirect general equilibrium effect is offset, but underreaction otherwise. Hence it adds a layer of richness to theories of overreaction (Barberis, Shleifer and Vishny, 1998; Bordalo et al., 2020; Afrouzi et al., 2023; da Silveira, Sung and Woodford, 2024), in a way that reconciles several bond market puzzles regarding over- and underreaction of long-term interest rates (Hanson and Stein, 2015; Bauer, Pflueger and Sunderam, 2024; Joslin, Priebsch and Singleton, 2014; Cieslak, 2018), as previously discussed.

Last, this paper provides a theory of heterogeneous mental models that connect to a growing literature that uses surveys to measure people's mental models in specific scenarios (Stantcheva 2021, 2023; Andre et al. 2022, 2024; Andre, Schirmer and Wohlfart

2024). In particular, Andre et al. (2022) show that people's level forecasts of unemployment and inflation in response to macroeconomic shocks are highly heterogeneous. Our theory predicts when people can or cannot get the directions correct, bringing some order to their findings of belief heterogeneity. We design a survey to confirm our prediction and calibrate a structural parameter of beliefs that could be used in macroeconomic models. Prior to this paper, Wu (2023) calibrates people's imperfect mental models using existing survey forecasts. This paper develops a theory-informed survey to offer additional evidence in its support, and derives its consequences for macroeconomics and finance.

2 Shallow Thinking in a New Keynesian Economy

We set up the textbook New Keynesian model in Section 2.1 with transitory news shocks, which are observed in period 0 but only affect the economy in period 1. We conceptualize the period-1 general equilibrium (GE) as a system of causal relations in a directed graph in Section 2.2. This conceptualization of GE is our broader theoretical contribution that nests the New Keynesian model as well as other applications. Based on this causal interpretation of GE, in Section 2.3, we introduce the theory of shallow thinking and present its main testable prediction: deeper variables—those further removed from shocks—are understood by fewer people. Later in the paper, we examine the consequences of shallow thinking for the period-0 equilibrium and generalize to persistent shocks.

2.1 The New Keynesian Economy

We consider the New Keynesian model à la Woodford (2003*b*) and Galí (2015). The economy consists of three types of agents (firms, households, and a central bank) and a competitive labor market. Throughout this paper, we take a log-linear approximation around the steady state for simplicity and use lower-case letters for log-linear deviations.

We study news shocks that are observed in period 0 but only affect the economy in period 1. Since this New Keynesian model is purely forward-looking, the economy returns to its steady state from period 2 onwards. Appendix B.1 develops the infinite-horizon model in full detail. Here, we focus on the period-1 general equilibrium, and conceptualize it as a system of causal relations purposefully as follows: (i) we maintain the structural form of agents' best responses, which express their optimal decisions as functions of decision-relevant variables, and (ii) we interpret price determination in a competitive market as a rule that pins down the price to equilibrate supply and demand, with a fictitious Walrasian auctioneer. These forms are central to our theory.

Firms. There is a continuum of firms indexed by $j \in [0,1]$ that produce using labor to satisfy demand and set prices subject to Calvo rigidity. In period 1, firms choose labor demand, pay dividends, and reset prices if possible, taking as given the aggregate inflation rate π_1, the real wage w_1, and the aggregate demand c_1. Each firm produces a differentiated good, which collectively forms a constant-elasticity bundle that households consume, and charges a markup μ in the steady state.

All firms produce to satisfy demand using the same linear technology in labor, giving rise to the aggregate dividend and labor demand

$$\begin{aligned} div_1 &= c_1 - \frac{1}{\mu - 1} w_1 \\ n_1^d &= c_1 \end{aligned} \tag{1}$$

To anticipate our analysis of the labor market, we interpret labor demand n_1^d as a demand curve $n_1^d = \hat{n}_1^d + E_{n^d w} w_1$, which shifts by

$$\hat{n}_1^d = c_1 \tag{2}$$

and has an elasticity $E_{n^d w}$, which is zero in this model, as firms only use labor in production.

A $(1-\theta)$ share of firms can reset their prices in period 1 to maximize dividends, and each chooses

$$p_{j1}^* = p_0 + (1 - \beta\theta) \left[w_1 + \sum_{k=0}^{\infty} (\beta\theta)^k \pi_1 \right]$$

where β is the household time discount rate, the inverse of which equals the steady-state interest rate. Aggregate inflation results from the pricing behavior of the $(1-\theta)$ share of resetting firms as $\pi_1 = (1-\theta)\left(p_{j1}^* - p_0\right)$. Following the tradition, we consider a cost-push shock ϵ_1^π, and thus inflation is

$$\pi_1 = \theta\kappa w_1 + (1-\theta)\pi_1 + \epsilon_1^\pi \tag{3}$$

with $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$ capturing the slope of the Phillips curve. Importantly, we do not move π_1 on the right-hand side to the left. We intentionally preserve the dependence of π_1 on itself, which encapsulates the within-period complementarity in individual price-setting, as each firm takes the aggregate inflation as given.

Households. There is a continuum of infinitely lived households who maximize their lifetime utility, discounted by β, which is separable in consumption and labor supply. In period 1, households choose consumption and labor supply, taking as given the nominal interest rate i_1, the real wage w_1, and dividend div_1. Their optimal consumption and labor supply decisions are given by

$$\begin{aligned} c_1 &= -\sigma^{-1}\beta i_1 + \frac{(1-\beta)(\mu-1)\nu}{\sigma+\mu\nu} div_1 + \frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu} w_1 \\ n_1^s &= \nu^{-1}\beta i_1 - \frac{(1-\beta)(\mu-1)\sigma}{\sigma+\mu\nu} div_1 + \nu^{-1}\left[1-\sigma\frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu}\right] w_1 \end{aligned} \tag{4}$$

where σ^{-1} is the elasticity of intertemporal substitution, and ν^{-1} is the the Frisch elasticity of labor supply.

Similar to labor demand, we interpret labor supply n_1^s as a supply curve $n_1^s = \hat{n}_1^s + E_{n^s w} w_1$, which shifts by

$$\hat{n}_1^s = \nu^{-1}\beta i_1 - \frac{(1-\beta)(\mu-1)\sigma}{\sigma+\mu\nu} div_1 \tag{5}$$

and has an elasticity $E_{n^s w} = \nu^{-1}\left[1-\sigma\frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu}\right]$.

Central bank. The central bank follows a Taylor rule with a monetary policy shock ϵ_1^i,

$$i_1 = \phi\pi_1 + \epsilon_1^i \tag{6}$$

Competitive labor market. Finally, to close the model, the wage arises from equilibrating labor supply and demand $n_1^s = n_1^d$. We introduce a fictitious labor market auctioneer who determines the wage as the intersection of supply and demand curves,

$$\begin{aligned} \hat{n}_1^s + E_{n^s w} w_1 &= \hat{n}_1^d + E_{n^d w} w_1 \\ w_1 &= \left(E_{n^s w} - E_{n^d w}\right)^{-1}\left(\hat{n}_1^d - \hat{n}_1^s\right) \end{aligned} \tag{7}$$

which prescribes that the wage is higher if labor demand is higher or labor supply is lower, as illustrated in Figure 1b.

2.2 General Equilibrium as a System of Causal Relations

We conceptualize the period-1 general equilibrium (GE) as a system of causal relations, and represent it in a directed graph. This conceptualization of GE is our broader theoretical contribution that nests the New Keynesian model, but also other applications.

The period-1 equilibrium in response to the cost-push shock ϵ_1^π and the monetary policy shock ϵ_1^i is fully characterized by (1-7). We collect all endogenous variables in a vector $V_1 \equiv \left(i_1, \pi_1, div_1, \hat{n}_1^d, c_1, \hat{n}_1^s, w_1\right)'$ and the two shocks correspondingly in $S_1 \equiv \left(\epsilon_1^i, \epsilon_1^\pi, 0, 0, 0, 0, 0\right)'$. While we focus on these two shocks in this paper, it is straightforward to incorporate additional shocks. In addition, we let M be a matrix capturing all the partial derivatives among the endogenous variables from (1-7). We arrive at the following characterization of the period-1 equilibrium.

Proposition 1. (GE as a system of causal relations) *The period-1 equilibrium is characterized by the fixed point to the system of causal relations among all* agents' actions and competitive prices, $V_1 \equiv \left(i_1, \pi_1, div_1, \hat{n}_1^d, c_1, \hat{n}_1^s, w_1\right)'$*, as*

$$\underbrace{V_1}_{\text{variables}} = \underbrace{M}_{\text{causal relations}} V_1 + \underbrace{S_1}_{\text{shocks}} \tag{8}$$

The equilibrium can be solved as a sum of all effects

$$V_1 = (I - M)^{-1} S_1 = \sum_{n=1}^{\infty} M^{n-1} S_1 \tag{9}$$

where each M^{n-1} term is an n-step effect of a shock on a variable via $n-1$ intermediate variables.

Each equation in system (8) describes how an outcome on the left depends on a set of causes on the right, with each element of matrix M (i.e., a partial derivative) representing a *causal relation.* We visualize this causal system as a directed graph in Figure 1a, formally supporting the intuition outlined in the introduction. Each node represents a type of agent (including the fictitious labor market auctioneer), and each arrow indicates an endogenous variable—either an agent's decision or the real wage determined in the labor market.

Formula (9) expresses the solution to (8) as the sum of all effects of varying depth. The 1-step effect S_1 is the direct (or partial equilibrium) effect of shocks, while all subsequent terms represent indirect (or general equilibrium) effects.

As these period-1 shocks are observed in period 0, if agents are rational, they will correctly forecast the period-1 equilibrium, i.e., $\mathbb{E}_0^{rational}[V_1] = V_1$. In this sense, the rational expectations hypothesis assumes that agents can take infinite steps in this graph to converge to the fixed point. Next, we introduce our theory of shallow thinking.

Remarks on representing GE. As alluded to before, we emphasize a specific way of representing the general equilibrium as fixed point. We insist on its structural form, which consists of agents' responses to decision-relevant variables and the determination of prices to equilibrate supply and demand, as captured by (8). There are countless alternative ways to represent a general equilibrium as a fixed point, which amounts to using (8) to express some variables in terms of others. For example, a popular way of representing the textbook New Keynesian model is to only use three variables—inflation π_1, consumption (i.e., output) c_1, and the interest rate i_1. All these alternative representations characterize the same equilibrium, but they alter the meanings of causal relations, which becomes consequential when we introduce beliefs based on the causal representation of GE. For example, expressing inflation π_1 as a function of consumption c_1 already mixes in other relations that *only hold in equilibrium*, and thus no longer reflects firms' best responses.

2.3 Shallow Thinking of General Equilibrium

Motivated by evidence in economics and psychology, we assume that agents only foresee finite steps of shock propagation in the directed graph. We outline the key assumptions and derive the testable prediction that deeper variables are perceived by fewer people.

Assumption 1. Individuals vary in their finite *depth of thinking* $d \in \mathbb{N}^+$, with expectations

$$\mathbb{E}_0^d[V_1] \equiv \sum_{n=1}^{d} M^{n-1} S_1 \tag{10}$$

which implies an iterative formula for $d \geq 1$ as

$$\mathbb{E}_0^d[V_1] = M\mathbb{E}_0^{d-1}[V_1] + S_1 \tag{11}$$

Definition (10) formalizes the idea that a depth-d agent only understands the effects that take no more than d steps. The iterative formula (11) suggests that a depth-d agent can think one step further compared to a depth-$(d-1)$ agent.

For example, in response to a cost-push shock ϵ_1^{π} (Figure 1a), a depth-1 agent acknowledges only the most obvious implication: firms will raise their prices (causing inflation π_1). A depth-2 agent can further appreciate that the central bank will raise the interest rate i_1 in response to higher inflation. A depth-3 agent understands that a higher interest rate i_1 will discourage household consumption and incentivize labor supply. A depth-4 agent recognizes that changes in household behavior will affect the firms and the labor market. This iteration continues infinitely, and only a depth-∞ (i.e., rational) agent correctly assesses the strength of all loops and accurately forecasts the period-1 equilibrium.

This iterative process leads to a prediction about belief heterogeneity, which allows us to measure the distribution of d across the population shortly. We observe that agents with a low d only perceive variables that are shallow—that is, closer to shocks in the directed graph. And the set of variables that they can perceive varies with shocks. By examining people's expectations of various macroeconomic variables in response to different shocks, we can measure the distribution of d, which we formally establish shortly.

For tractability, we make an additional parametric assumption.

Assumption 2. Individual depth of thinking d follows a geometric distribution over $\mathbb{N}^+$ with continuation rate $\lambda \in [0,1]$, i.e.,

$$\mathbb{P}(d \geq n) = \lambda^{n-1}, \; \forall n \in \mathbb{N}^+ \tag{12}$$

We assume that every one can take at least one step. A λ share of them take at least two, a λ^2 share take at least three, and so on. A higher shallow thinking parameter λ means that individuals are deeper on average, with $\frac{1}{1-\lambda}$ representing the average depth of thinking,[4] and $\lambda = 1$ nesting the rational expectations hypothesis. With this parametric assumption, we could aggregate heterogenous beliefs into average beliefs, which will drive the period-0 equilibrium.

Proposition 2. (Average beliefs) *The average beliefs* $\overline{\mathbb{E}}_0[V_1] \equiv \sum_{n=1}^{\infty} \mathbb{P}(d=n) \cdot \mathbb{E}_0^n[V_1]$ *are sums of all effects*

$$\overline{\mathbb{E}}_0[V_1] = \sum_{n=1}^{\infty} \lambda^{n-1} M^{n-1} S_1 \tag{13}$$

[4] The expectation of a geometric distribution is $\mathbb{E}[d] \equiv \sum_{n=1}^{\infty} \mathbb{P}(d=n) \cdot n = \sum_{n=1}^{\infty} \mathbb{P}(d \geq n) = \frac{1}{1-\lambda}$.

and equivalently, as a fixed point

$$\overline{\mathbb{E}}_0\left[V_1\right] = \underbrace{\lambda M}_{\text{average perceived causal relations}} \overline{\mathbb{E}}_0\left[V_1\right] + S_1 \tag{14}$$

Equation (13) is comparable to (9) that expresses the equilibrium as a sum of all effects, but with deeper effects dampened more, since fewer people appreciate them. Equation (14) further suggests that, the average beliefs as a fixed point are formed as if by a representative agent who knows all causal relations in M but underappreciates them by a factor λ, parallel to (8) with the equilibrium as a fixed point. The proof is simple, by summing all n-step effects of shock propagation with decaying weights.

Moreover, equation (14) coincides exactly with the formulation of imperfect mental model in Wu (2023). That paper extracts an empirical moment based on this formula using existing forecasts data and rejects the null of $\lambda = 1$ (rational expectations). The nature of that exercise is *quantitative*, as it compares forecasts to the true conditional expectations. In this paper, we provide *qualitative* evidence to support our theory based on heterogeneity in beliefs being directionally correct, elicited in a customized survey introduced next.

We design a survey to elicit people's understanding of macroeconomic shocks. We recruit a representative sample of respondents indexed by n. We ask each respondent to provide *directional* forecasts of a set of macroeconomic variables v, in response to different hypothetical shocks s, over a 12-month horizon. We get the correct direction of change in each variable v in response to each shock s from the empirical literature, and determine accordingly whether each respondent n's directional forecast is correct.

Definition 1. We define *correct directional belief* 1_{nvs} as one if respondent n correctly forecasts the directional response of variable v to shock s, and zero otherwise.

As discussed earlier, an agent with a low depth of thinking d only perceives causal relations and variables close to shocks. When aggregated across the population, a variable further removed from a shock is understood by fewer people. This is a prediction at the population level, without the need to determine the depth of thinking d for each individual, which facilitates our empirical test.

In order to formally define the depth of a variable relative to a shock for our test, we introduce some additional notations. Notice that beliefs $\mathbb{E}^d\left[V_1\right]$ are linear in the shocks S_1, as determined in (10). With slight abuse of notation, we let $v \in V_1$ be an endogenous variable in our model and $s \in S_1$ be a shock. Thus, $\frac{\partial v}{\partial s}$ is the true sensitivity of variable v to shock s, whereas $\frac{\partial \mathbb{E}^d[v]}{\partial s}$ is the perceived sensitivity by a depth-d individual.

Definition 2. We define the *variable depth D_{vs}* as the minimum d such that $\frac{\partial \mathbb{E}^d[v]}{\partial s}$ has the same sign as $\frac{\partial v}{\partial s}$, for each variable $v \in V_1$ and shock $s \in S_1$.

That is, variable depth D_{vs} corresponds to the depth of the shallowest individual who can correctly perceive the directional response of v to s. In our example with transitory cost-push and monetary policy shocks, D_{vs} equals the depth of the shallowest agent who perceives any change of v in response to s. That is, $\frac{\partial \mathbb{E}^d[v]}{\partial s}$ is zero for all $d < D_{vs}$. Nonetheless, Definition 2 is more general when applied to persistent shocks and other models.

Assumption 3. Model parameters M are such that $\frac{\partial \mathbb{E}^d[v]}{\partial s}$ has the same sign as $\frac{\partial v}{\partial s}$ for all $d \geq D_{vs}$.

Assumption 3 holds true when deeper effects either amplify or offset the impact of the shock, once the correct direction is established, but *do no overturn it.* It facilitates a reduced-form estimation of λ as we establish next. This assumption is generically true in the New Keynesian model. For instance, in response to the cost-push shock ϵ_1^π, the central bank will raise the interest rate i_1 to offset the shock, but does not lead to deflation. That is, $\frac{\partial \mathbb{E}^d[\pi_1]}{\partial \epsilon_1^\pi}$ is positive for all $d \geq 1$. And since $\mathbb{E}^d[i_1] = \phi \mathbb{E}^{d-1}[\pi_1]$ from (11), $\frac{\partial \mathbb{E}^d[i_1]}{\partial \epsilon_1^\pi}$ is positive for all $d \geq 2$. Further, even if it is not true for all variable-shock combinations, as long as there exists a subset of such combinations with varying D_{vs}, our estimation can go through by focusing on this subset.

Proposition 3. (Heterogeneity in correct directional beliefs) *The expectation of correct directional belief 1_{nvs}, conditional on variable depth D_{vs}, in the population is*

$$\mathbb{E}^{pop}[1_{nvs} | D_{vs} = D] = \lambda^{D-1}, \ \forall D \in \mathbb{N}^+ \tag{15}$$

where $\mathbb{E}^{pop}$ denotes the expectation in the population of survey respondents. Consequently,

1. *an ordinary least squares estimation of $1_{nvs} = \gamma D_{vs} + \alpha + \epsilon_{nvs}$ yields a negative slope β;*
2. *a nonlinear least squares estimation of $1_{nvs} = b_1 \cdot b_2^{D_{vs}-1} + b_0 + \epsilon_{nvs}$ identifies λ with b_2.*

We consider both the nonlinear and the linear specifications. The null of $\gamma = 0$ and $b_2 = 1$ includes rational expectations and any other theories of beliefs that do not correlate with variable depth D_{vs}. Our estimation result in Section 3 will show that γ is negative and b_2 is lower than 1, both with high levels of statistical significance.

The nonlinear specification lets us estimate λ from a regression. (15) suggests that, under our three assumptions, the conditional expectation of 1_{nvs}, which is the conditional probability of making correct directional forecasts, is exponentially decaying. Thus a nonlinear least-squares estimation of an exponential function can exactly recover λ. Our Assumption 3 crucially facilitates this estimation. As discussed earlier, if Assumption 3 does not hold for all possible combinations of variables and shocks, as long as one can find a subset of such combinations with varying D_{vs}, one can still estimate λ with the nonlinear regression on this subset. If even that is not possible, one can estimate λ by minimizing distance between the distribution of measured 1_{nvs} and the corresponding theory-implied distribution, as λ parametrizes the latter distribution.

A linear specification is valuable for two reasons: (i) it allows us to empirically control for fixed effects to purge confounding sources of belief heterogeneity, and we will show that our coefficient of interest γ is indeed robust to such controls; and (ii) it does not hinge on the parametric Assumption 2. A negative γ by itself indicates that some agents only understand variables close to shocks. When Assumption 2 does hold, the estimated slope γ will be a weighted average of the local slopes of the nonlinear function λ^{D-1}.

In summary, the idea of shallow thinking is that people understand only limited steps of shock propagation, captured by Assumption 1 as the backbone of our theory. Assumption 2 serves as a convenient aggregator to generate average beliefs. The nature of Assumption 2 is parametric rather than conceptual, akin to how Calvo pricing is a useful parametrization of nominal rigidity but not essential. With these two assumptions, one could generate heterogeneous and average beliefs with one parameter λ in a macroeconomic model. If the model satisfies Assumption 3 in addition, the variable depth D_{vs} can be used as a predictor of belief heterogeneity to test shallow thinking and estimate λ.

3 Measuring Shallow Thinking

We develop a survey to test the theoretical prediction of shallow thinking that deeper variables are understood by fewer people (Proposition 3). We offer further evidence in Section D.3 to suggest that the limited depth of thinking vis-à-vis economic causal relations is an individual characteristic and reflects limited knowledge about the macroeconomy.

Survey design. As previously mentioned, we assess people's understanding of classic macroeconomic shocks by asking them to forecast the directional responses of key macroeconomic variables. We study six shocks in three groups: oil price shocks (oil) and monetary policy shocks (MP) as group 1, government spending shocks (G) and personal income tax shocks (PIT) as group 2, and corporate income tax shocks (CIT) and transfer payment shocks (TP) as group 3. For each shock, respondents provide directional forecasts of a set of macroeconomic variables, choosing from "up," "down," "unchanged," or "I don't know" for each variable.

Table 1 lists the baseline specification with eleven macroeconomic variables, their correct directional responses and their variable depths D_{vs}. The baseline variable depth D_{vs} is generated from enriching our New Keynesian model with decreasing-returns production and Taylor rule dependent on both inflation and unemployment. We consider various robustness versions regarding the selection of variable-shock combinations (v, s) and variable depth D_{vs} in Tables D3 and D4. We randomly allocate half of the respondents into group 1, which has the two shocks we analyze in the model, and allocate a quarter into groups 2 and 3 respectively for additional evidence. Appendix E.1 discusses our survey design in greater detail.

Table 1: Baseline version of variable depth and correct directions

	Group 1 (50%)		Group 2 (25%)		Group 3 (25%)	
	Oil ↑	MP ↑	G ↑	PIT ↑	CIT ↑	TP ↑
Output	3↓	2↓	1↑	2↓	3↓	2↑
Interest rate	2↑	1↑				
Price	1↑	3↓	2↑	3↓		
Unemployment	3↑	2↑	2↓	2↑	3↑	3↓
Labor hours	3↓	2↓	2↑	2↓	3↓	3↑
Durable consumption	3↓	2↓	2↓	2↓	3↓	2↑
Non-durable consumption	3↓	2↓	2↓	2↓	3↓	2↑
Post-tax profits					1↓	1↑
Personal income tax			1↑	1↑		1↑
Corporate income tax			1↑		1↑	1↑
Government borrowing			1↑	1↓	1↓	1↑

Notes: Six shocks are oil price shock (oil), monetary policy shock (MP), government spending shock (G), personal income tax shock (PIT), corporate income tax shock (CIT), and transfer payment shock (TP). The latter four all concern the federal government. Each cell indicates the variable depth D_{vs} and the directional response (up or down) in the baseline specification. The directional responses are from the empirical literature reviewed in Table D2, and robustness versions of selection of variable-shock combinations and variable depth are in Tables D3 and D4.

3.1 Variable Depth Explains Correct Directional Belief

We examine the predictability of correct directional belief 1_{nvs} by variable depth D_{vs} as prescribed by Proposition 3.

Figure 2 shows the expectation of correct directional belief 1_{nvs}, conditional on variable depth D_{vs}, together with the 99.9% confidence interval. The blue dot indicates the conditional expectation. The red diamond represents the conditional expectation, after controlling for individual-by-variable and individual-by-shock fixed effects δ_{nv}, δ_{ns}, the purpose of which we discuss soon. Obviously, the conditional expectation declines in variable depth in both cases.

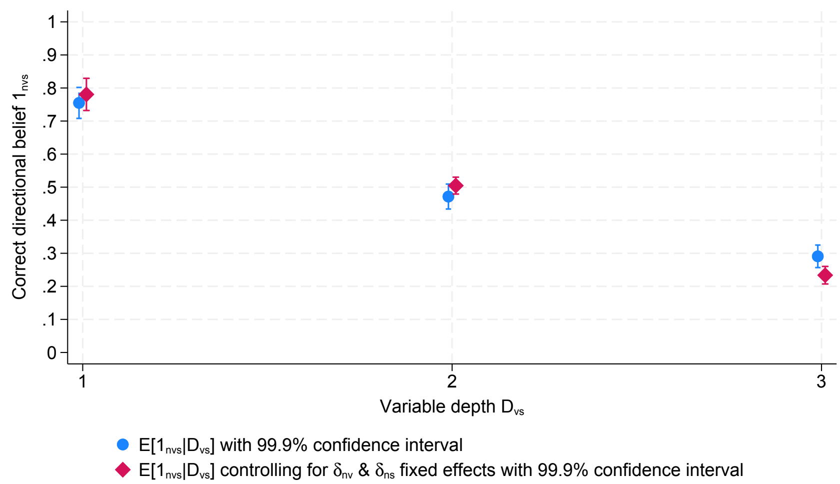


Figure 2: Expectation of correct directional belief 1_{nvs} conditional on variable depth D_{vs}

Notes: This figure shows the expectation of correct directional belief 1_{nvs}, conditional on variable depth D_{vs}, together with the 99.9% confidence interval. The blue dot indicates the conditional expectation. The red diamond represents the conditional expectation, after controlling for individual-by-variable and individual-by-shock fixed effects δ_{nv}, δ_{ns}. Correct directional belief 1_{nvs} equals one if respondent n correctly forecasts the directional response of variable v to shock s, and zero otherwise. Variable depth D_{vs} is derived from a New Keynesian model.

With this visualization, we make two remarks. First, the conditional expectation of 1_{nvs} being low for depth-2 variables and even lower for depth-3 variables suggests that people on average are bad at understanding macroeconomic shocks. They fail to perceive even the true directional responses of important variables. This paper focuses on belief heterogeneity arising from people's shallow understanding of causal relations, but assumes for simplicity that they use the true causal structure and model parameters. Figure 2 suggests that our focus is an important aspect, if not the main one, in the following sense. If people can iterate a model infinitely many times, but they believe in alternative causal models, then these models must be quite wrong, and wrong in a way that correlates with variable depth from the New Keynesian model to produce Figure 2. Another possibility is that people iterate a model infinitely many times, but disagree on the model parameters (such as the slope of the Phillips curve). However, those agents typically do not get the directional responses wrong, which is what Figure 2 finds.

Second, when we run the regressions on variable depth, the key parameter λ will not be solely identified off the comparison of depth-1 variables against other variables. One could intuitively expect such a difference, since depth-1 variables are directly shocked but all other variables are only indirectly affected through general equilibrium effects. Our theory further differentiates among the indirectly affected variables by their depth. This empirical finding substantiates our high-level contribution relative to Angeletos and Lian (2023*a*) that among general equilibrium effects, some are better understood than others.

Table 2 presents various specifications of the linear regression

$$1_{nvs} = \gamma D_{vs} + \alpha + \delta_{nv} + \delta_{ns} + \epsilon_{nvs} \tag{16}$$

and the nonlinear regression

$$1_{nvs} = b_1 \cdot b_2^{D_{vs}-1} + b_0 + \epsilon_{nvs} \tag{17}$$

as prescribed by Proposition 3, where 1_{nvs} is one if individual n's directional forecast of variable v in response to shock s is correct.

The coefficient γ from the linear regression tests for the theory-implied pattern that deeper variables are understood by fewer people.[5] The null of $\gamma = 0$ includes rational expectations and any other theory of beliefs that does not correlate with depth D_{vs}. Further, if respondents are totally clueless about the economy and give random answers in our survey, that will not be reflected in γ. Thus, a negative γ not only implies that people make mistakes, but they do so in a depth-dependent way as predicted by our theory.

Column (1) uses variable depth D_{vs} as the only predictor and finds a statistically significant coefficient with a R^2 of 10%. Column (2) shows that individual fixed effects

[5] Interestingly, in a very different context, using network data of relationships from Indian villages, Breza, Chandrasekhar and Tahbaz-Salehi (2018) show that the knowledge of whether certain pairs of households are linked declines steeply in the pair's network distance to the respondent. The distance in our context is distinct—it is a conceptual one about how easy it is for people to associate a variable to a shock.

Table 2: Regression of correct directional belief 1_{nvs} against variable depth D_{vs}

	OLS					NLS
Correct directional belief 1_{nvs}	(1)	(2)	(3)	(4)	(5)	(6)
Variable depth D	-0.22***	-0.24***	-0.24***	-0.27***		
	(0.01)	(0.01)	(0.01)	(0.01)		
$1_{D=2}$					-0.28***	
					(0.02)	
$1_{D\geq3}$					-0.54***	
					(0.02)	
$b_1 - 1$						-0.23*
						(0.10)
$b_2 - 1$						-0.36***
						(0.06)
Observations	9365	9365	9365	9365	9365	9365
R^2	0.10	0.23	0.29	0.62	0.62	0.10
Individual FE		Yes	Yes	Absorbed	Absorbed	
Variable FE			Yes	Absorbed	Absorbed	
Shock FE			Yes	Absorbed	Absorbed	
Individual-variable FE				Yes	Yes	
Individual-shock FE				Yes	Yes	

Standard errors in parentheses

Standard errors clustered at individual level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table shows the regression results of correct directional belief 1_{nvs} against variable depth D_{vs}, using the ordinary least squares (OLS) specification (16) and the nonlinear least squares (NLS) specification (17). Correct directional belief 1_{nvs} equals one if respondent n correctly forecasts the directional response of variable v to shock s and zero otherwise. Variable depth D_{vs} is derived from a New Keynesian model. The OLS specification tests the null hypothesis that the slope is zero, controlling for individual-by-variable and individual-by-shock fixed effects δ_{nv}, δ_{ns}. The NLS specification identifies λ with b_2, with a null hypothesis of $b_2 = 1$. Hence, we show the estimate $b_2 - 1$ and the associated p-value.

matter too, increasing the R^2 to 24%. That means some people are more likely to be correct than others, as our theory postulates. For all columns, standard errors are clustered at individual level, since they may correlate across all answers submitted by an individual.

Column (3) shows that the estimate of γ and its statistical significance are robust to the inclusion of variable and shock fixed effects. Controlling for these additional fixed effects addresses a concern that people may understand some variables or some shocks better in a way that happens to correlate with depth. For the same variable, it is understood more poorly when it is further away from a shock. A related concern is that some shocks (like monetary policy shocks) may take longer to transmit into the economy or some variables may be slower in responding, and thus people predict no changes in a fixed horizon. These are absorbed by shock and variable fixed effects too.[6]

Column (4) further controls for individual-by-variable or individual-by-shock fixed effects. They absorb belief heterogeneity that is unrelated to depth. For example, if a person believes in a post-pandemic quantity-constrained model of the economy, they will predict that prices respond to all shocks but quantities are fixed. Another person can believe in a price-constrained model, but to the extent that they do not correlate with depth, such heterogeneity is absorbed by individual-by-variable fixed effects. Individual-by-shock fixed effects absorb the possibility that one person only understands monetary policy shocks whereas another person only understands oil shocks.

Column (5) demonstrates that, relative to depth-1 variables (that are directly shocked), depth-2 variables are understood by fewer people, and depth-3-and-above variables by even fewer. This is what we observe from Figure 2, lending further support to the predicted depth-dependent pattern.

Last, column (6) shows the nonlinear estimation and strongly rejects the null hypothesis of $b_2 = 1$. The estimation suggests that $\hat{\lambda} \approx 0.69$ [xx to be settled as we finalize the sample soon]. That means, people on average only understand about three steps, even under our parametric assumption that there is a distribution of people who could reason more than three steps. We will use this value when we apply our theory in workhorse macroeconomic models.

Calibration of shallow thinking parameter λ. We take the estimate from column (6), $\lambda = 0.69$, as our baseline calibration. This is identified from the declining pattern of correct directional belief 1_{nvs} against variable depth D_{vs}. Alternatively, one could infer λ from the average probability of correctly forecasting depth-2 variables, $\mathbb{E}^{pop}\left[1_{nvs}|D_{vs} = 2\right]$, based on (15). That is approximately 0.5, as shown in Figure 2. Under this alternative calibration, on average, people, understand only two steps.

The difference relates to a slight discrepancy between Assumption 2, which assumes that everyone understands depth-1 variables directionally correctly, and the empirical finding in Figure 2, which shows that they mostly, but not always, do. This discrepancy is quantitatively unimportant and may arise from respondents' occasional misunderstanding of or inattention to certain survey questions. We proceed with $\lambda = 0.69$ as our baseline

[6] We also note that most variables we study do have statistically significant impulse responses to shocks at the 12-month horizon we set in the survey.

calibration to err on the side of rationality, but we note that the consequences of shallow thinking are qualitatively similar and quantitatively stronger with a lower λ.

4 Consequences of Transitory News Shocks

We discuss belief over- and underreaction to shocks due to shallow thinking, and the consequences for asset prices and aggregate outcomes in the New Keynesian economy, in the case with transitory news shocks that are observed in period 0 but only affect the economy in period 1, as introduced in Section 2.

We make an important remark on the generality of analyzing transitory news shocks: while we compare shallow thinking against rational expectations regarding news about period-1 shocks, the same comparison holds for persistent shocks that materialize in period 0 and last for two periods. That is simply because in the log-linearized economy, a 2-period persistent shock is equivalent to the sum of a period-0 shock and a period-1 shock that is observed in period 0. The economy's response to a period-0 shock is independent of agents' belief formation. Thus the comparison across theories of expectations regarding any 2-period persistent shock is solely driven by its news shock component.

We follow a standard calibration of the New Keynesian model at quarterly frequency, with all parameters listed in Table 3.

Table 3: Quarterly calibration of the New Keynesian model

Parameter	Description	Value	Estimate/Target
Beliefs			
λ	Continuation rate of depth of thinking	0.69	Our survey evidence
Households			
β	Discount factor	0.99	$r = 4\%$ p.a.
σ^{-1}	Elasticity of intertemporal substitution (EIS)	1	
ν^{-1}	Frisch elasticity of labor supply	0.5	
Firms			
θ	Price stickiness	0.75	Average price duration of 1 year
κ	Phillips curve slope	0.086	$\kappa = \theta^{-1}(1-\theta)(1-\beta\theta)$
μ	Steady state markup	1.1	
Central bank			
ϕ	Taylor rule coefficient	1.5	

4.1 Inflation Expectations and Long-Term Interest Rates

We study belief over- and underreaction in response to news about the cost-push shock ϵ_1^π and the monetary policy shock ϵ_1^i, as well as their consequences for period-0 long-term interest rates. We compare beliefs about period-1 outcomes against the true period-1 equilibrium, which is independent of agents' belief formation. We analyze the two shocks in sequence and present a synthesis afterward.

We assume that the yield of a 2-period bond $y_0^{(2)}$, i.e., the long-term yield, is determined by the expectations hypothesis as[7]

$$y_0^{(2)} = \frac{i_0 + \overline{\mathbb{E}}_0\left[i_1\right]}{2} \tag{18}$$

Cost-push shocks. Proposition 4 characterizes the period-1 equilibrium in response to the cost-push shock ϵ_1^π and beliefs thereof.

Proposition 4. (Period-1 cost-push shock) *The period-1 equilibrium in response to a cost-push shock ϵ_1^π features*

$$\pi_1 = \frac{1}{1 - \underbrace{(1-\theta)}_{\text{pricing complementarity}} + \underbrace{\phi\theta\kappa}_{\text{monetary policy loop}} \cdot \underbrace{\sigma^{-1}\left(\nu+\sigma\right)}_{\text{Keynesian cross}}}\epsilon_1^\pi \tag{19}$$

$$i_1 = \phi\pi_1 \tag{20}$$

whereas the period-0 average expectations upon observing the news about ϵ_1^π are

$$\overline{\mathbb{E}}_0\left[\pi_1\right] = \frac{1}{1-\lambda\left(1-\theta\right)+\lambda^4\phi\theta\kappa K_1\left(\lambda\right)}\epsilon_1^\pi \tag{21}$$

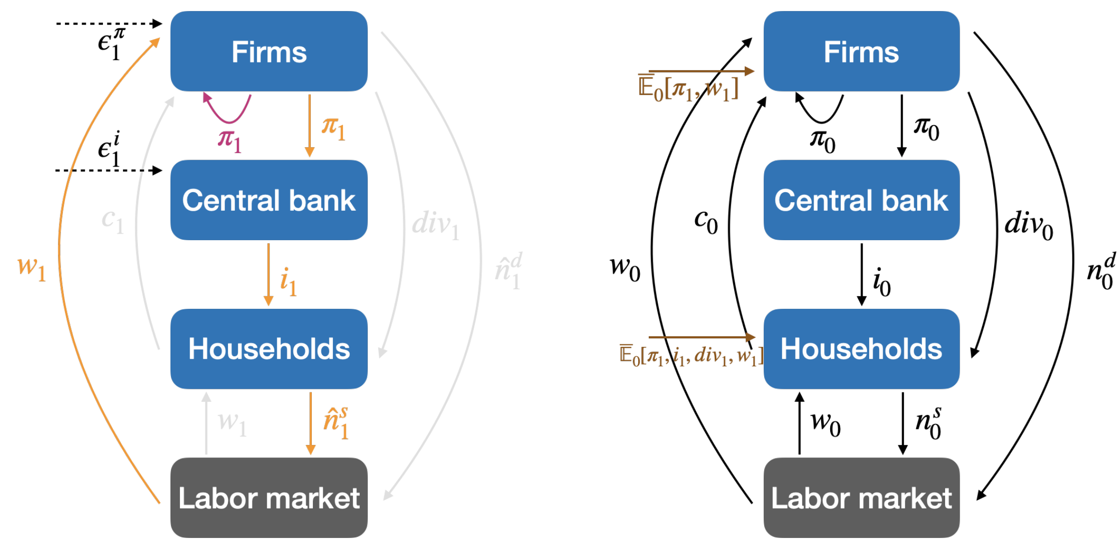
$$\overline{\mathbb{E}}_0\left[i_1\right] = \lambda\phi\overline{\mathbb{E}}_0\left[\pi_1\right] \tag{22}$$

with $K_1(\lambda)$ increasing in λ and $K_1(1) = \sigma^{-1}(\nu+\sigma)$.

To understand these results, we start with equilibrium inflation (19) and the average inflation expectation (21). The period-1 equilibrium is independent of agents' belief formation, as (19) is independent of λ. It coincides with rational expectations, i.e. (21)

[7] To microfound this in our model without aggregate risks, we assume that there is an intermediary who prices the 2-period bond on behalf of all households by averaging their beliefs.

with $\lambda = 1$. Recall that both the equilibrium and the average expectations are sum of all n-step effects, as established in (9) and (13), with deeper effects being dampened more for expectations. We could organize all these effects into three groups that involve different loops, colored distinctively in Figure 3a, and the inflation response π_1 is directly involved in two of them.



(a) Causal relations of period-1 economy

(b) Period-0 equilibrium

Figure 3: New Keynesian economy with transitory news shocks

Notes: Panel (a) illustrates the three loops of causal relations in the period-1 economy in different colors, to accompany the discussion of Propositions 4 and 5. Three loops are the pricing complementarity self-loop (in purple), the monetary policy loop (in orange) and the Keynesian cross (in gray).
Panel (b) demonstrates the period-0 equilibrium in response to news shocks that are observed in period 0 but only impact the economy in period 1, driven by firms' and households' beliefs about period-1 outcomes.

The first loop is a self-loop of *pricing complementarity*, shown in purple. A higher inflation π_1 incentivizes all firms to price higher, thus amplifying itself. This effect has a strength of $(1 - \theta)$. As we sum up the infinite series going through this loop, its strength appears in the denominator of π_1 in (19). It is dampened by λ in $\overline{\mathbb{E}}_0 [\pi_1]$ in (21) since, with each loop, only a λ share of people remain.

The second one is a 4-step loop involving *monetary policy*, shown in orange. As inflation π_1 rises, the central bank raises the interest rate i_1, which encourages labor supply $\hat{n}_1^s$, lowering the real wage w_1. As a lower wage prompts firms to reduce prices, this offsets the inflation response. This loop takes 4 steps to close, meaning that whenever it loops once, only λ^4 share of the people perceive the next loop, resulting in a dampening of λ^4 in

$\overline{\mathbb{E}}_0[\pi_1]$ in (21) relative to π_1 in (19).

The final loop concerns the *Keynesian cross*, shown in gray. As the central bank raises the interest rate i_1, it discourages household consumption c_1, leading firms to lower dividends div_1 and reduce labor demand $\hat{n}^d$, resulting in a lower wage w_1. Consequently, households want to consume even less, triggering additional adjustments by firms. This Keynesian cross strengthens any effect that impacts households, thus compounding the monetary policy loop. Once again, summing the infinite geometric series results in the strength of this loop appearing in the denominator of π_1 in (19), with its dampening for expectations $\overline{\mathbb{E}}_0[\pi_1]$ in (21) captured by $K_1(\lambda)$.

Overall, the average inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ in (21) is modified relative to the true inflation π_1 in (19), with different loops dampened to varying degrees by length.

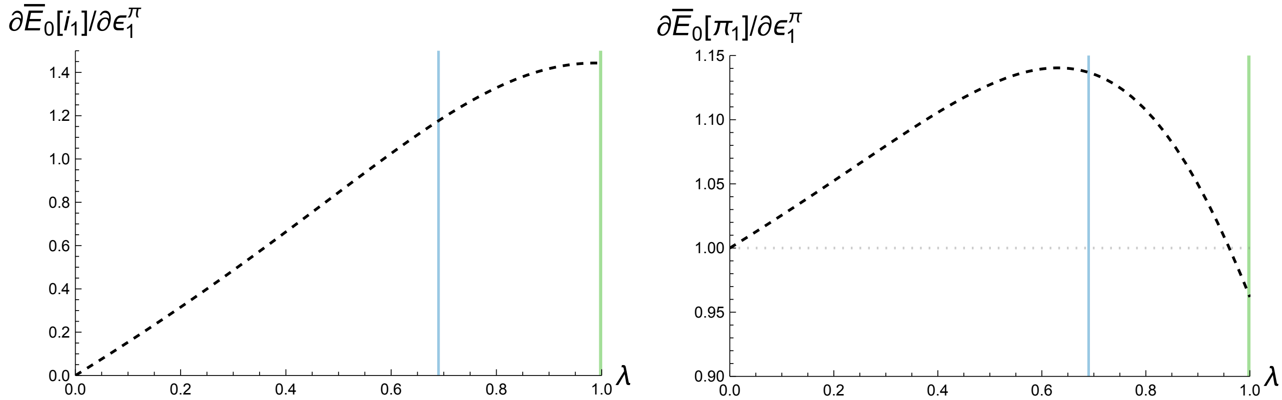
Once we establish the inflation response, the equilibrium interest rate response i_1 in (20) follows directly as the Taylor rule coefficient ϕ times inflation. The average interest expectation $\overline{\mathbb{E}}_0[i_1]$ in (22) is λ times ϕ times the inflation expectation, as it takes one more step for agents to appreciate the response of interest rate to inflation.

In the limit of $\lambda = 0$, shallow agents do not perceive any general equilibrium effects, leading to $\overline{\mathbb{E}}_0[\pi_1] = \epsilon_1^\pi$. In that case, shallow agents do not perceive any change in the interest rate, i.e., $\overline{\mathbb{E}}_0[i_1] = 0$, nor do they perceive any variable other than inflation.

Figure 4 plots the interest rate expectation $\overline{\mathbb{E}}_0[i_1]$ and inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ as functions of λ in dashed black lines, in response to cost-push shock ϵ_1^π. In each graph, the blue vertical line indicates our calibrated λ, whereas the green vertical link corresponds to the rational expectations, which coincide with the true responses i_1, π_1.

Panel 4a implies that $\overline{\mathbb{E}}_0[i_1]$ underreacts to the cost-push shock compared to the true response, because agents underappreciate the Taylor rule. In our economy, the interest rate expectation $\overline{\mathbb{E}}_0[i_1]$ is a forward rate and a component of the long-term yield $y_0^{(2)}$. Thus our theory implies that the long-term yield itself will underreact. This is in line with findings in Bauer, Pflueger and Sunderam (2024) that surprises in the core consumer price index (CPI) led to very little changes in long-term yields until March 2022, when the Fed actually raised the federal funds rate.

Panel 4b suggests that the inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ is non-monotonic in λ. Further, our calibration suggests that the inflation expectation exceeds the size of the direct effect of one, whereas the true inflation response is below one. That is, shallow agents think that the cost-push shock will be amplified, though actually it will be dampened. The underlying reason is that, in determining inflation (19), there is a shorter loop that amplifies the



(a) Interest rate expectation $\overline{\mathbb{E}}_0[i_1]$

(b) Inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$

Figure 4: Average beliefs in response to period-1 cost-push shocks ϵ_1^π

Notes: Panel (a) plots the average interest expectation $\overline{\mathbb{E}}_0[i_1]$ (relative to the size of the shock) as a function of the shallow thinking parameter λ, in response to news about a cost-push shock ϵ_1^π, and panel (b) plots the average inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$. The blue line indicates our calibration of λ, while the green line represents rational expectations ($\lambda = 1$).

cost-push shock and a much longer loop that offsets it. When agents are shallow, they understand the shorter loop relatively better than the longer loop. Thus, on net, they perceive amplification. That can be true even if the longer offset loop is actually stronger than the shorter amplification loop, leading to actual net offset.

In the case with the responses of inflation π_1 and inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ to the cost-push shock, shallow thinking flips the sign of the perceived net general equilibrium (GE) effect from offset to amplification. This occurs because the strong, long offsetting loop is severely dampened by shallow thinkers. The order of operations is key, like the Jensen's inequality. It would be a mistake to first collapse multiple GE effects in a model into a single net effect (which is offset in this case) and then naively dampen that effect. Indeed, when we write down the New Keynesian model, we carefully preserve the structural form of the equations as agents' best responses to decision-relevant variables, without substituting variables using equilibrium relations. For example, households respond to the wage w_1 and dividend div_1. If we had imposed that households respond to their total income, which equals c_1 in equilibrium, and introduced shallow thinking based on that equation, we would be assuming that agents understand that total income equals c_1.

Monetary policy shocks. Proposition 5 characterizes the period-1 equilibrium in response to the monetary policy shock ϵ_1^i and beliefs thereof.

Proposition 5. (Period-1 monetary policy shock) *The period-1 equilibrium in response to a monetary policy shock ϵ_1^π features*

$$i_1 = \left[1 + \frac{\phi\theta\kappa\sigma^{-1}(\nu+\sigma)}{1-(1-\theta)}\right]^{-1}\epsilon_1^i \tag{23}$$

$$\pi_1 = -\frac{\theta\kappa\sigma^{-1}(\nu+\sigma)}{1-(1-\theta)} i_1 \tag{24}$$

whereas the period-0 average expectations upon observing the news about ϵ_1^i are

$$\overline{\mathbb{E}}_0[i_1] = \left[1 + \frac{\lambda^4\phi\theta\kappa K_1(\lambda)}{1-\lambda(1-\theta)}\right]^{-1}\epsilon_1^i \tag{25}$$

$$\overline{\mathbb{E}}_0[\pi_1] = -\frac{\lambda^3\theta\kappa K_1(\lambda)}{1-\lambda(1-\theta)}\overline{\mathbb{E}}_0[i_1] \tag{26}$$

with $K_1(\lambda)$ increasing in λ and $K_1(1) = \sigma^{-1}(\nu+\sigma)$.

These results relate to those regarding the cost-push shocks in Proposition 4, but with a subtle and consequential difference. In this case, *all* general equilibrium effects offset the interest response to a monetary policy shock, differing from the inflation response to a cost-push shock analyzed previously which involves both amplification and offset.

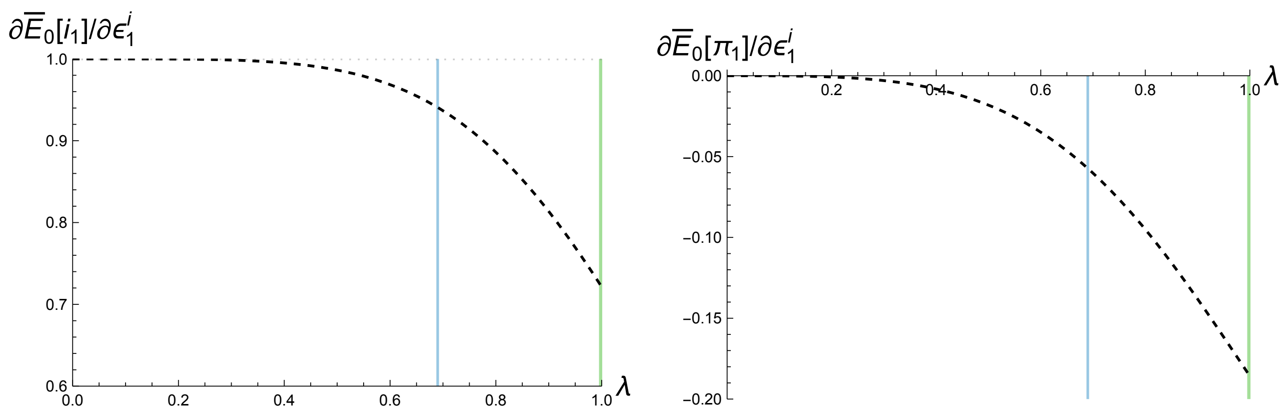
To appreciate that, we analyze the interest rate in (23), which is the sum of all n-step effects, as in (9). These effects belong to three different loops—pricing complementarity, the monetary policy loop, and the Keynesian cross—as previously established and displayed in Figure 3a. Among the three loops, the interest rate response is directly involved in *only one*: the monetary policy loop. This loop offsets the interest rate response to a monetary policy shock in 4 steps: a higher interest rate i_1 encourages labor supply $\hat{n}_1^s$, which then lowers the real wage w_1, leading to lower inflation π_1 through firms' pricing decisions, ultimately prompting the central bank to lower the interest rate i_1 according to the Taylor rule. This 4-step monetary policy offset loop, with a strength $\phi\theta\kappa$, *compounds* with the other two loops—pricing complementarity and the Keynesian cross—which correspond to the $\frac{1}{1-(1-\theta)}$ and $\sigma^{-1}(\nu+\sigma)$ terms in (23). That occurs because pricing complementarity strengthens any effect on inflation, while the Keynesian cross reinforces any effect impacting households.

For the interest rate expectation $\overline{\mathbb{E}}_0[i_1]$ in (25), the 4-step monetary policy loop is dampened by λ^4, the pricing complementarity self-loop is dampened by λ, and the Keynesian cross is also dampened, captured by $K_1(\lambda)$, as in the prior case with cost-push shocks.

The equilibrium inflation response π_1 in (24) depends on the interest rate response i_1. It is compounded by the pricing complementarity $\frac{1}{1-(1-\theta)}$ and the Keynesian cross $\sigma^{-1}(\nu+\sigma)$, as any effect of the interest rate on inflation involves both firms and households. The inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ derives accordingly from the interest rate expectation $\overline{\mathbb{E}}_0[i_1]$, but is dampened by λ^3, since it takes 3 steps for the interest rate to affect the inflation.

In the limit of $\lambda = 0$, shallow agents perceive no general equilibrium effects, and thus $\overline{\mathbb{E}}_0[i_1] = \epsilon_1^i$, $\overline{\mathbb{E}}_0[\pi_1] = 0$.

Figure 5 plots the interest rate expectation $\overline{\mathbb{E}}_0[i_1]$ and inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ as functions of λ in dashed black lines, in response to monetary policy shock ϵ_1^i. As before, the blue vertical line indicates our calibrated λ, whereas the green vertical link corresponds to the rational expectations as well as the true responses i_1, π_1.



(a) Interest rate expectation $\overline{\mathbb{E}}_0[i_1]$

(b) Inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$

Figure 5: Average beliefs in response to period-1 monetary policy shocks ϵ_1^i

Notes: Panel (a) plots the average interest expectation $\overline{\mathbb{E}}_0[i_1]$ (relative to the size of the shock) as a function of the shallow thinking parameter λ, in response to news about a monetary policy shock ϵ_1^i, and panel (b) plots the average inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$. The blue line indicates our calibration of λ, while the green line represents rational expectations ($\lambda = 1$).

Panel 5a indicates that $\overline{\mathbb{E}}_0[i_1]$ overreacts to the monetary policy shock compared to the true response, thus suggesting that the period-0 long-term yield $y_0^{(2)}$ overreacts too. This aligns with a large literature on the excess sensitivity of long-term interest rates to monetary policy shocks (Cochrane and Piazzesi, 2002; Gürkaynak, Sack and Swanson, 2005; Hanson and Stein, 2015). The underlying mechanism is that, all general equilibrium effects offset the interest rate response to a monetary policy shock, and as they are dampened to varying degrees, shallow agents perceive less offset than the true overall effect. In contrast, panel 5b implies that $\overline{\mathbb{E}}_0\left[\pi_1\right]$ underreacts, because agents underappreciate the effect of monetary policy on inflation.

So far, we establish a rich pattern of conditional responses that the long-term interest rate overreacts to monetary policy shocks and underreacts to cost-push shocks, which has further implications for unconditional responses. With multiple shocks, if one runs a univariate regression of the long-term interest rate on the short-term rate, whether it suggests over- or underreaction depends on the mix of shocks. Indeed, Hanson, Lucca and Wright (2021) show that long-term interest rates are overly sensitive to changes in the short-term rates and predictably revert post 2000, suggesting overreaction. But the same pattern does not hold prior to 2000. Through the lens of our theory, one possibility is that there were more inflation shocks (like oil shocks) before 2000, contributing underreaction to the mix and obfuscating overreaction to monetary policy shocks. With multiple shocks, it is natural that one looks at a multivariate regression, which we visit in the next subsection.

Synthesis: strength and depth of GE effects jointly determine belief misreaction. To conclude this subsection, we offer a synthesis of belief misreaction. First consider a model with only one general equilibrium (GE) effect in addition to the partial equilibrium (PE) effect. In that model, if the GE effect amplifies (or offsets) the PE effect, beliefs underreact (or overreact) to shocks, as shallow agents underappreciate the GE effect.

However, our workhorse macroeconomic models feature multiple GE effects, in which case *both* the strength and depth of these GE effects matter for belief misreaction, as suggested by our theory. To understand this point, consider the inflation response to a cost-push shock ϵ_1^π. Under our calibration, shallow agents think that the cost-push shock ϵ_1^π will be amplified, even though it actually will be offset, i.e., $\frac{\partial \overline{\mathbb{E}}_0[\pi_1]}{\partial \epsilon_1^\pi} > 1 > \frac{\partial \pi_1}{\partial \epsilon_1^\pi}$. That occurs because shallow agents underappreciate the long, strong offset loop involving the monetary policy reaction, which is stronger when the Taylor rule coefficient ϕ is larger. We consider alternative values of ϕ in Figure 6.

If, instead, ϕ is of an intermediate value, e.g., $\phi = 1$, the long offset loop is too weak to turn the true net effect into offset. In that case, the true net effect is amplification, but shallow agents perceive even *more* amplification, i.e., $\frac{\partial \overline{\mathbb{E}}_0[\pi_1]}{\partial \epsilon_1^\pi} > \frac{\partial \pi_1}{\partial \epsilon_1^\pi} > 1$, as they overweigh the short amplification loop relative to the long offset loop.

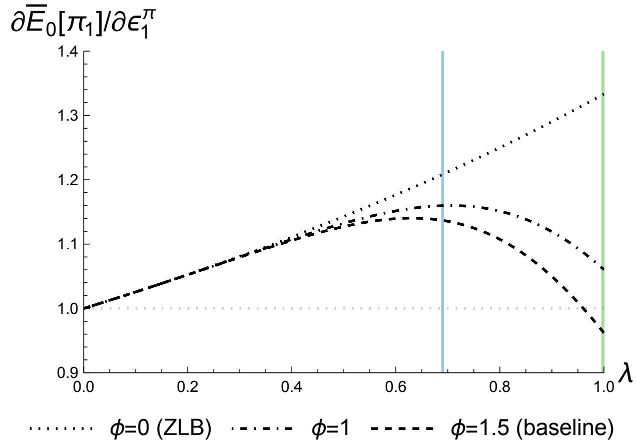


Figure 6: Inflation expectation $\overline{\mathbb{E}}_0\left[\pi_1\right]$ in response to cost-push shock ϵ_1^π, under various ϕ

Notes: This figure plots the average interest expectation $\overline{\mathbb{E}}_0\left[i_1\right]$ (relative to the size of the shock) as a function of the shallow thinking parameter λ, in response to news about a cost-push shock ϵ_1^π, under different values of the Taylor rule coefficient ϕ. The blue line indicates our calibration of λ, while the green line represents rational expectations ($\lambda = 1$).

With an even lower ϕ, for example, if the policy rate is stuck at the zero lower bound (ZLB) with $\phi = 0$,[8] the long offset loop is weak or non-existent, leaving the short amplification loop as the dominant force. In that case, we are almost in a model with only one GE effect, and it amplifies the PE effect. As a result, shallow agents perceive less amplification on net than the true effect, i.e., $\frac{\partial \pi_1}{\partial \epsilon_1^\pi} > \frac{\partial \overline{\mathbb{E}}_0[\pi_1]}{\partial \epsilon_1^\pi} > 1$.

4.2 Predictability of Bond Excess Returns

We show shallow thinking implies that bond excess returns can be predicted by macroeconomic variables other than the current yields, as established empirically by Joslin, Priebsch and Singleton (2014), Cieslak (2018) and others. In this subsection, we consider an economy hit by news about two period-1 shocks, the cost-push shock ϵ_1^π and the monetary policy shock ϵ_1^i, and study the predictability of bond excess returns by macroeconomic variables and expectations thereof.

We consider the excess return of holding a 2-period (i.e., long-term) bond from period

[8] The Taylor principle requires $\phi > 1$ for determinacy of the textbook infinite-horizon New Keynesian model under rational expectations. In our 2-period setting, determinacy is not a concern. With persistent shocks, shallow thinking beliefs are uniquely defined by a formula similar to (10), which helps select an equilibrium. For further discussion on determinacy, which is not the focus of our paper, see Farhi and Werning (2019), Gabaix (2020) and Angeletos and Lian (2023*b*).

0 to period 1, relative to holding a 1-period (i.e., short-term) bond,

$$xr^{(2)}_{0\to 1} \equiv \underbrace{-i_1 + 2y^{(2)}_0}_{\text{return of long-term bond}} - \underbrace{i_0}_{\text{return of short-term bond}} = \overline{\mathbb{E}}_0\left[i_1\right] - i_1 \tag{27}$$

where the equality follows from (18). The intuition is very simple, when the period-0 expectation of period-1 interest rate exceeds its actual value, the long-term bond is undervalued in period 0 and will appreciate in period 1, leading to a positive excess return, and vice versa.

We study the predictability of bond excess return $xr^{(2)}_{0\to 1}$ by the average inflation expectation $\overline{\mathbb{E}}_0\left[\pi_1\right]$, as noted by Joslin, Priebsch and Singleton (2014) and Cieslak (2018), controlling for the forward rate $\overline{\mathbb{E}}_0\left[i_1\right]$[9]

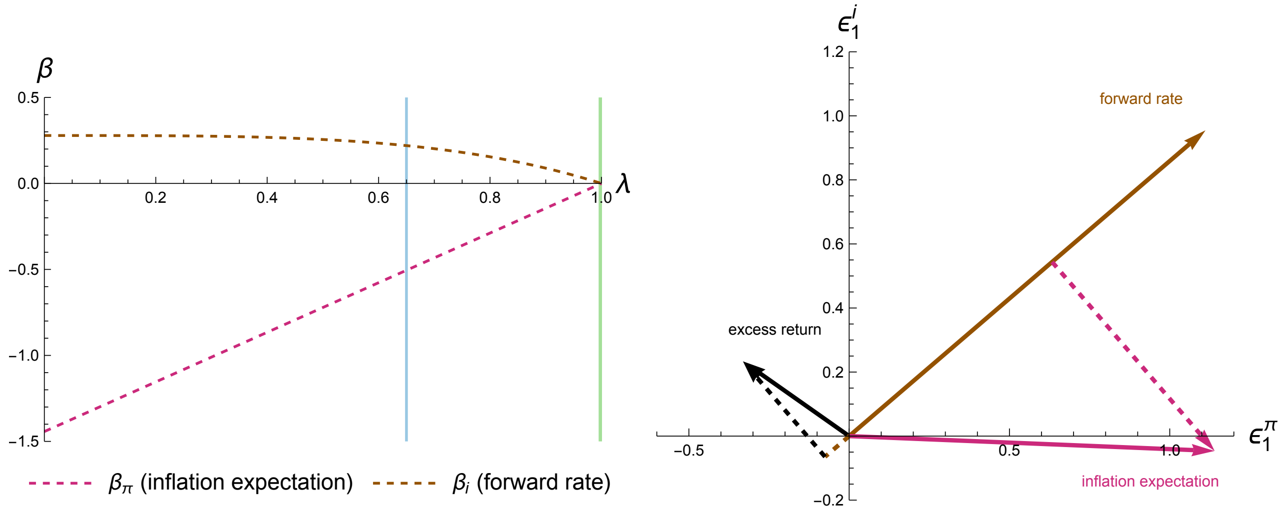
$$\underbrace{xr^{(2)}_{0\to 1}}_{\text{bond excess return}} = \beta_\pi \underbrace{\overline{\mathbb{E}}_0\left[\pi_1\right]}_{\text{inflation expectation}} + \beta_i \underbrace{\overline{\mathbb{E}}_0\left[i_1\right]}_{\text{forward rate}} + \alpha + \epsilon_{0\to 1} \tag{28}$$

Figure 7a illustrates the theory-implied coefficients β_π and β_i as functions of λ, in brown and purple respectively. As long as $\lambda < 1$, our theory predicts a negative β_π, which is what Joslin, Priebsch and Singleton (2014) and Cieslak (2018) found when using inflation expectations or some other macroeconomic variables to predict bond excess returns.

To understand the mechanism, we start by examining the limits of $\lambda = 0$ and 1 and build intuition with shock loadings illustrated in Figure 7b. In the limit of $\lambda = 0$, we have $\overline{\mathbb{E}}_0\left[\pi_1\right] = \epsilon^\pi_1, \overline{\mathbb{E}}_0\left[i_1\right] = \epsilon^i_1$ from Propositions 4 and 5. As the interest rate expectation underreacts to the cost-push shock ϵ^π_1 and overreacts to the monetary policy shock ϵ^i_1, the excess return $xr^{(2)}_{0\to 1}$ loads negatively on the former and positively on the latter, as determined by (27). That is, it lies in the second quadrant (plotted in Figure B1a). Because the forward rate and the inflation expectation are unit vectors along the x- and y-axes in this case, the coefficient β_π is negative and β_i is positive.

In the limit of rational expectations ($\lambda = 1$), $\overline{\mathbb{E}}_0\left[\pi_1\right]$ loads positively on the cost-push shock ϵ^π_1 and negatively on the monetary policy shock ϵ^i_1, placing it in the fourth quadrant (plotted in Figure B1b). $\overline{\mathbb{E}}_0\left[i_1\right]$ loads positively on both shocks, placing it in the first quadrant. However, in this case, and only in this case, the excess return $xr^{(2)}_{0\to 1}$ is zero, as

[9] This regression is equivalent to a bivariate Coibion and Gorodnichenko (2015) regression, and its coefficients reflect the misappreciation of causal relations between variables. See Wu (2023) for a systematic theoretical and empirical analysis of such regressions across many variable pairs.



(a) Coefficients β_π and β_i

(b) Loadings of excess return and predictors on shocks

Figure 7: Predictability of bond excess returns by macroeconomic variables

Notes: Panel (a) plots the theory-implied coefficients β_π and β_i from the predictive regression of bond excess returns $xr^{(2)}_{0\to1}$ in (28) on the inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ and forward rate $\overline{\mathbb{E}}_0[i_1]$, as functions of the shallow thinking parameter λ. The economy is impacted by news about cost-push shocks ϵ_1^π and monetary policy shocks ϵ_1^i that is observed in period 0, but only affect the economy in period 1.The blue vertical line corresponds to our calibration of λ, while the green line represents rational expectations ($\lambda = 1$).
Panel (b) illustrates the loadings of bond excess return $xr^{(2)}_{0\to1}$, inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ and forward rate $\overline{\mathbb{E}}_0[i_1]$ on the cost-push news shock ϵ_1^π (x-axis) and the monetary policy news shock ϵ_1^i (y-axis), as solid vectors. The vectors are determined under our calibration of λ, but their quadrant placements are generically true when $\lambda \in (0,1)$. Figures B1a and B1b show the cases with $\lambda = 0, 1$. The two dashed vectors show the residuals of bond excess return $xr^{(2)}_{0\to1}$ and inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ projected onto the forward rate $\overline{\mathbb{E}}_0[i_1]$. Their opposite directions imply a negative β_π, following the Frisch-Waugh-Lovell theorem.

there is no expectational error. Thus, both coefficients β_π and β_i are zero.

Generically, the inflation expectation $\overline{\mathbb{E}}_0[\pi_1]$ lies in the fourth quadrant, and the forward rate $\overline{\mathbb{E}}_0[i_1]$ is in the first quadrant, as long as $\lambda > 0$ (i.e., some understanding of shock propagation). The excess return $xr^{(2)}_{0\to1}$ is placed in the second quadrant if $\lambda < 1$ (i.e., not fully understanding shock propagation). Figure 7b illustrates these generic placements. It also shows the residual of $xr^{(2)}_{0\to1}$ projected onto $\overline{\mathbb{E}}_0[i_1]$, denoted $xr^{(2)}_{0\to1}|\overline{\mathbb{E}}_0[i_1]$, and the residual $\overline{\mathbb{E}}_0[\pi_1]\,|\overline{\mathbb{E}}_0[i_1]$, both shown as dashed vectors. These two residuals point to opposite directions due to the quadrant placements of the three vectors involved. According to the Frisch-Waugh-Lovell theorem, the coefficient β_π from the bivariate regression (28) equals the univariate regression coefficient of the residual $xr^{(2)}_{0\to1}|\overline{\mathbb{E}}_0[i_1]$ on the residual $\overline{\mathbb{E}}_0[\pi_1]\,|\overline{\mathbb{E}}_0[i_1]$. Opposite directions of these residuals imply a negative coefficient β_π.

In this subsection, we explain an important finding from Joslin, Priebsch and Singleton (2014) and Cieslak (2018) that inflation expectations negatively predict bond excess returns. We illustrate this in an economy with two shocks: one to the interest rate and another macroeconomic shock. In reality, the economy is impacted by multiple shocks. Technically, in a linear model with N shocks, including N independent predictors spans all shocks. However, in practice, the entire yield curve is well captured by the first three principal components. Our theory suggests that other macroeconomic variables may contain additional information about non-monetary-policy macroeconomic shocks, and can therefore predict bond excess returns.

Shallow thinking and bond market puzzles. Taking stock of findings here and in the previous subsection, we conclude that shallow thinking offers a unified rationalization of several bond market puzzles that seem unrelated or even contradictory. These include the underreaction of long-term interest rates (Bauer, Pflueger and Sunderam, 2024), their overreaction (Cochrane and Piazzesi, 2002; Gürkaynak, Sack and Swanson, 2005; Hanson and Stein, 2015), as well as the predictability of bond excess returns (Joslin, Priebsch and Singleton, 2014; Cieslak, 2018).

4.3 Macroeconomic Effects of Cost-Push News Shocks

We establish the consequences of shallow thinking regarding aggregate outcomes in period 0, in response to transitory news shocks. In particular, we show that news about period-1 cost-push shocks are more inflationary and less contractionary than the rational expectations prediction.

Period-0 equilibrium. In period 0, the shocks have not materialized but firms and households are forward-looking. The period-0 equilibrium consists of seven variables $\left\{i_0, \pi_0, div_0, n_0^d, c_0, n_0^s, w_0\right\}$, similar to the period-1 equilibrium. Among these seven variables, three of them (the interest rate i_0, dividend div_0 and labor demand n_0^d) depend only on the contemporaneous values of the other variables. These contemporaneous causal relations are the same as their period-1 counterparts (1, 2, 6). Three variables (the inflation π_0, consumption c_0 and labor supply n_0^s) depend on agents' beliefs about period-1 outcomes, since firms's pricing decisions and households' consumption and labor supply decisions are forward-looking, detailed next. Last, the wage w_0 arises from the labor market clearing condition $n_0^s = n_0^d$.

The period-0 inflation π_0 satisfies

$$\pi_0 = \theta\kappa\left(w_0 + \beta\theta\overline{\mathbb{E}}_0\left[w_1\right]\right) + (1-\theta)\left(\pi_0 + \beta\theta\overline{\mathbb{E}}_0\left[\pi_1\right]\right) \tag{29}$$

which increases in expectations of both future real wage w_1 and inflation π_1, as firms want to front run a higher future marginal cost.

The period-0 consumption c_0 and labor supply n_0^s follow

$$\begin{aligned} c_0 &= -\sigma^{-1}\beta\left(i_0 - \overline{\mathbb{E}}_0\left[\pi_1\right] + \beta\overline{\mathbb{E}}_0\left[i_1\right]\right) + \frac{(1-\beta)(\mu-1)\nu}{\sigma+\mu\nu}\left(div_0 + \overline{\mathbb{E}}_0\left[div_1\right]\right) \\ &\quad + \frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu}\left(w_0 + \overline{\mathbb{E}}_0\left[w_1\right]\right) \end{aligned} \tag{30}$$

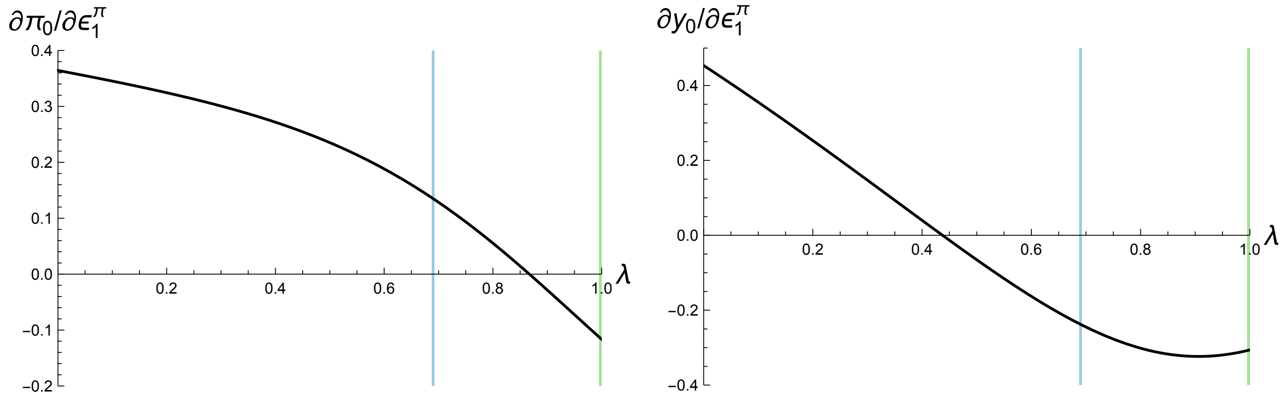
$$\begin{aligned} n_0^s &= \nu^{-1}\beta\left(i_0 - \overline{\mathbb{E}}_0\left[\pi_1\right] + \beta\overline{\mathbb{E}}_0\left[i_1\right]\right) - \frac{(1-\beta)(\mu-1)\sigma}{\sigma+\mu\nu}\left(div_0 + \overline{\mathbb{E}}_0\left[div_1\right]\right) \\ &\quad + \nu^{-1}\left[1 - \sigma\frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu}\right]w_0 - \frac{(1-\beta)(1+\nu)\nu^{-1}\sigma}{\sigma+\mu\nu}\overline{\mathbb{E}}_0\left[w_1\right] \end{aligned} \tag{31}$$

Households react to the future interest rate, dividend, and wage, as well as the future inflation, as a higher inflation lowers the real interest rate from period 0 to period 1.

In determining the period-0 equilibrium, the only decisions-relevant beliefs are about inflation π_1, wage w_1, interest rate i_1 and dividend div_1. Figure 3b illustrates causal system of period-0 equilibrium, where these beliefs act like shocks to firms and households. In particular, the inflation expectation $\overline{\mathbb{E}}_0\left[\pi_1\right]$ serves two roles here: it acts like a cost-push shock for firms as they want to front run future inflation, and it functions as a demand shock for households since a higher inflation lower the real interest rate. This observation will prove useful when we discuss the effects of cost-push shocks next.

Cost-push shocks. Figure 8 illustrates the period-0 equilibrium, in response to period-1 cost-push shock ϵ_1^π, in solid black lines. The period-0 output is simply the consumption c_0. Still the blue line indicates our calibration of shallow thinking λ whereas the green line stands for rational expectations. Unlike the period-1 equilibrium, which is independent of λ, the period-0 equilibrium does depend on λ. Thus the green line represents the rational expectations equilibrium (REE).

Panel 8a suggests that a period-1 cost-push shock is *inflationary* in period 0 under



(a) Period-0 inflation π_0

(b) Period-0 output y_0 (which equals consumption c_0)

Figure 8: Period-0 equilibrium in response to period-1 cost-push shocks ϵ_1^π

Notes: Panel (a) plots the period-0 inflation π_0 in the equilibrium (relative to the size of the shock) as a function of the shallow thinking parameter λ, in response to news about a cost-push shock ϵ_1^π, and panel (b) plots the period-0 output y_0, which equals consumption c_0. The blue line indicates the equilibrium under our calibration of λ, while the green line represents the rational expectations equilibrium with $\lambda = 1$.

shallow thinking, but *deflationary* under rational expectations. It is deflationary under rational expectations because rational agents anticipate that the central bank will raise interest rate i_1 in response to higher inflation π_1, leading to a contraction of the period-1 economy. As a result, households cut back on their consumption today, causing a contract in period 0 as well, as seen in panel 8b. In contrast, in the limit of extremely shallow agents ($\lambda = 0$), they only perceive a change in future inflation, $\overline{\mathbb{E}}_0 [\pi_1] = \epsilon_1^\pi$, but not in any other variable. As we have established with (29-31), inflation expectations act like a cost-push shock for firms and a demand shock for households. As firms price higher and households consume more and work less, this leads to period-0 inflation and output expansion. With an intermediate value of λ, agents somewhat expect a future bust, but not fully. Under our estimated value of λ, period-1 cost-push shocks lead to inflation and a smaller output contraction in period 0.

From transitory news shocks to persistent shocks. So far, we have focused on transitory news shocks, but this is much more informative than it may seem. As we have noted before, comparing theories of beliefs under transitory news shocks is equivalent to comparing them under two-period shocks, since the period-0 equilibrium response to contemporaneous shocks is independent of belief formation. Furthermore, analyzing transitory news shock can help build intuition for persistent shocks. A persistent cost-push shock observed in period 0 is technically a sum of a current shock and a series of future shocks. Shallow thinking implies that a future cost-push shock is inflationary in period 0, whereas rational expectations predict otherwise. This suggests that a persistent cost-push shock is more inflationary under shallow thinking than under rational expectations. Additionally, a *more* persistent cost-push shock is simply a sum of more future shocks. Thus, shallow thinking predicts that a *more* persistent cost-push shock leads to *higher* inflation, contrary to the rational expectations prediction.

Next, we will generalize shallow thinking to persistent shocks to substantiate these two findings. The generalization will fill in one missing piece from the intuitive analysis above: in responding to a persistent shock, agents must think about how the future period-t equilibrium depends on shocks in further periods s.

5 Consequences of Persistent Shocks

We generalize shallow thinking to accommodate persistent shocks in the New Keynesian economy and show that the insights gained from transitory news shocks still hold, while new lessons emerge. We introduce shallow thinking of a dynamic general equilibrium in Section 5.1, by focusing on the cross-variable causal relations and abstracting away from the intertemporal dimension. This will allow us to formally address belief misreaction to persistent shocks and their effects in Section 5.2. Readers who are more interested in the consequences and less interested in the technical details could skip the first subsection.

We consider persistent shocks $\{\epsilon_t\}_{t\geq 0}$ that are observed at time 0^-, and assume that agents form expectations once and for all, i.e., $\overline{\mathbb{E}}_t[\cdot] \equiv \overline{\mathbb{E}}[\cdot]$. This assumption simplifies the analysis, as it nests the rational expectations benchmark and is reasonable for our theory for the following two reasons.

First, an important reason for expectation updates over time is that agents gradually learn about shocks. We focus on the rationality of beliefs in the absence of any information frictions, and our survey design mimics this environment.

Second, expectations can update as agents learn how aggregate variables respond to shocks through repeated experiences, similar to how economists study shock propagation using time series data. We do not explicitly model such learning processes, but we note that in measuring shallow thinking through a survey, we consider conventional shocks, such as oil shocks and monetary policy shocks. These are age-old shocks, so our estimation already incorporates knowledge that people have gained over time. This contrasts with unconventional policy shocks (such as forward guidance or quantitative easing), to which people had no prior exposure until recently. That said, how agents form their mental models through learning and how this interacts with information frictions are promising topics for future research.

5.1 Dynamic General Equilibrium and Shallow Thinking

We conceptualize the dynamic general equilibrium (GE) as a system of causal relations, which can be similarly represented in a directed graph, generalizing Sections 2.2 and 2.3.

The infinite-horizon New Keynesian model is characterized by sequences of seven variables $\left\{i_t, \pi_t, div_t, n_t^d, c_t, n_t^s, w_t\right\}_{t\geq 0}$. We will refer to this collection of variables as $\mathcal{V}$. The first six variables are agents' actions, which we collect as $\mathcal{V}^{action}$, whereas the last is a price formed in the competitive labor market. Note that we start with the labor supply and demand n_t^s, n_t^d in order to reinterpret them as supply and demand curves shortly. In that reinterpretation, with slight abuse of notation, we will use $\mathcal{V}$ and $\mathcal{V}^{action}$ to denote variables of interests with n^s, n^d replaced by $\hat{n}^s, \hat{n}^d$.

With persistent shocks, we distinguish between two sets of equations that jointly determine the equilibrium outcomes, similar to García-Schmidt and Woodford (2019). The first set corresponds to relations among economic variables that arise from optimal decisions of economic agents, given the current realizations and their expected future values of variables that directly affect them. We call these temporary equilibrium relations. Based on these temporary equilibrium relations, we will define the second set of equations that characterizes expectations, which generalizes Assumption 1.

In terms of the temporary equilibrium relations, three variables i_t, div_t, n_t^d only depend on contemporaneous values of other variables, laid out in (B1, B2, B6). Three variables π_t, c_t, n_t^s are forward-looking. Inflation π_t is a linear function in w_t, π_t and $\left\{\overline{\mathbb{E}}_t\left[w_{t+k}\right], \overline{\mathbb{E}}_t\left[\pi_{t+k}\right]\right\}_{k\geq 1}$, and consumption and labor supply c_t, n_t^s are linear functions in i_t, div_t, w_t and $\left\{\overline{\mathbb{E}}_t\left[i_{t+k}\right], \overline{\mathbb{E}}_t\left[\pi_{t+k}\right], \overline{\mathbb{E}}_t\left[div_{t+k}\right], \overline{\mathbb{E}}_t\left[w_{t+k}\right]\right\}_{k\geq 1}$, detailed in (B3-B5). The last variable w_t arises from equilibrating labor supply n_t^s and demand n_t^d. These seven equations completely characterize the equilibrium, given beliefs.

To determine shallow thinking beliefs, we start by characterizing the rational expectations equilibrium (REE) and causal relations thereof. By replacing each expectation $\overline{\mathbb{E}}_t\left[v_\tau\right]$ with the true outcome v_τ under rational expectations, the six variables in $\mathcal{V}^{action}$ that agents choose can be represented in the sequence space, following Farhi and Werning (2019) and

Auclert, Rognlie and Straub (2024), as

$$\mathbf{v}^{REE} = \sum_{\mathbf{u}\in\mathcal{V}} \mathbf{J}_{\mathbf{vu}}\mathbf{u}^{REE} + \boldsymbol{\epsilon}^{v},\ \forall \mathbf{v} \in \mathcal{V}^{action} \tag{32}$$

where

$$(\mathbf{J}_{\mathbf{vu}})_{ts} \equiv \begin{cases} \frac{\partial v_t}{\partial u_s} & s \leq t \\ \frac{\partial v_t}{\partial \overline{\mathbb{E}}_t[u_s]} & s > t \end{cases} \tag{33}$$

is the Jacobian of the sequence of one variable $\mathbf{v} \equiv (\{v_t\}_{t\geq 0})'$ with respect to the sequence of another variable $\mathbf{u} \equiv (\{u_t\}_{t\geq 0})'$, and $\boldsymbol{\epsilon}^v \equiv \left(\left\{\epsilon_t^v\right\}_{t\geq 0}\right)'$ denotes the sequence of a structural shock. The first term in the parenthesis captures best response to current and past realizations, and the second term embeds the best response to beliefs about future outcomes. The Jacobians $\mathbf{J}_{\mathbf{vu}}$ are upper triangular matrices in this New Keynesian model which is purely forward-looking with no state variable, but the formulation (32) is general to accommodate models with state variables that depend on the past, such as the RBC model.

For labor supply and demand $\mathbf{n}^s, \mathbf{n}^d$, by separating their dependence on the wage $\mathbf{w}$ from the rest, we interpret them as supply and demand curves in the sequence space

$$\mathbf{n}^{s,REE} = \mathbf{J}_{\mathbf{n}^s\mathbf{w}}\mathbf{w}^{REE} + \hat{\mathbf{n}}^{s,REE}, \quad \mathbf{n}^{d,REE} = \mathbf{J}_{\mathbf{n}^d\mathbf{w}}\mathbf{w}^{REE} + \hat{\mathbf{n}}^{d,REE}$$

with elasticities $\mathbf{J}_{\mathbf{n}^s\mathbf{w}}, \mathbf{J}_{\mathbf{n}^d\mathbf{w}}$ and shifters $\hat{\mathbf{n}}^{s,REE}, \hat{\mathbf{n}}^{d,REE}$ defined as

$$\hat{\mathbf{n}}^{s,REE} = \sum_{\mathbf{u}\in\mathcal{V}^{action}} \mathbf{J}_{\mathbf{n}^s\mathbf{u}}\mathbf{u}^{REE} + \boldsymbol{\epsilon}^{n^s}, \quad \hat{\mathbf{n}}^{d,REE} = \sum_{\mathbf{u}\in\mathcal{V}^{action}} \mathbf{J}_{\mathbf{n}^d\mathbf{u}}\mathbf{u}^{REE} + \boldsymbol{\epsilon}^{n^d} \tag{34}$$

Demand elasticity $\mathbf{J}_{\mathbf{n}^d\mathbf{w}}$ is a matrix of zeros in this model since firms only use labor inputs, but, more generally (such as in the RBC model), it does not have to be. Supply elasticity $\mathbf{J}_{\mathbf{n}^s\mathbf{w}}$ is a upper triangular matrix, as households' labor supply responds to future wages. To specify beliefs, we reason with $\hat{\mathbf{n}}^{s,REE}, \hat{\mathbf{n}}^{d,REE}$ instead of $\mathbf{n}^{s,REE}, \mathbf{n}^{d,REE}$ in $\mathcal{V}$ and $\mathcal{V}^{action}$.

By equalizing $\mathbf{n}^{s,REE} = \mathbf{n}^{d,REE}$, we can interpret the wage $\mathbf{w}^{REE}$ as resulting from

$$\mathbf{w}^{REE} = (\mathbf{J}_{\mathbf{n}^s\mathbf{w}} - \mathbf{J}_{\mathbf{n}^d\mathbf{w}})^{-1}\left(\hat{\mathbf{n}}^{d,REE} - \hat{\mathbf{n}}^{s,REE}\right) \tag{35}$$

This rule of price determination generalizes its counterpart in the period-1 economy (7) and incorporates the response of time-t wage on time-s demand and supply shifts.

Taking stock of the rational expectations equilibrium, (32) describes all agents' actions

$\mathcal{V}^{action}$ and (35) characterizes the wage from the competitive labor market. We stack the sequences of outcomes to form a long vector $\mathbf{V} \equiv \left(\{\mathbf{v}'\}_{v\in\mathcal{V}}\right)'$, sequences of shocks as $\mathbf{S} \equiv \left(\left\{\boldsymbol{\epsilon}^{v'}\right\}_{v\in\mathcal{V}}\right)'$, and correspondingly stack the Jacobians as a giant matrix $\mathbf{M} \equiv \left(\{\mathbf{J}_{\mathbf{vu}}\}_{v,u\in\mathcal{V}}\right)$.

Proposition 6. (Dynamic GE as a system of causal relations in the sequence space) *The rational expectations equilibrium is characterized by the fixed point to the system of causal relations in the sequence space among all* agents' actions and competitive prices, $\mathbf{V} \equiv \left(\mathbf{i}', \boldsymbol{\pi}', \mathbf{div}', \hat{\mathbf{n}}^{d'}, \mathbf{c}', \hat{\mathbf{n}}^{s'}, \mathbf{w}'\right)'$, *as*

$$\underbrace{\mathbf{V}^{REE}}_{\text{sequence of variables}} = \underbrace{\mathbf{M}}_{\text{sequence-space causal relations}} \mathbf{V}^{REE} + \underbrace{\mathbf{S}}_{\text{sequence of shocks}} \tag{36}$$

The rational expectations equilibrium can also be solved as a sum of all effects

$$\mathbf{V}^{REE} = (\mathbf{I} - \mathbf{M})^{-1}\,\mathbf{S} = \sum_{n=1}^{\infty} \mathbf{M}^{n-1}\mathbf{S} \tag{37}$$

where each $\mathbf{M}^{n-1}$ *term is an n-step effect of the sequence of a shock on the sequence of a variable via sequences of* $n-1$ *intermediate variables.*

This generalizes Proposition 1 to the case of persistent shocks. With this representation of a dynamic general equilibrium model in the sequence space, we could generalize Assumption 1 as follows.

Assumption 1'. Individuals vary in their finite *depth of thinking* $d \in \mathbb{N}^+$, with expectations

$$\mathbb{E}^d\left[\mathbf{V}\right] \equiv \sum_{n=1}^{d} \mathbf{M}^{n-1}\mathbf{S} \tag{38}$$

which implies an iterative formula for $d \geq 1$ as

$$\mathbb{E}^d\left[\mathbf{V}\right] = \mathbf{M}\mathbb{E}^{d-1}\left[\mathbf{V}\right] + \mathbf{S} \tag{39}$$

Parallel to Assumption 1, (38) and (39) embed the idea that a depth-d agent only understands effects that take no more than d steps and they think one step further than a depth-($d-1$) agent.

Remarks on cross-variable causal relations vs. intertemporal relations. As briefly mentioned in the introduction, we focus on the causal relations across variables and abstract away from the intertemporal dimension. We assume that if agents understand how consumption c_t depends on the contemporaneous interest rate i_t, they also understand how c_t depends on future i_s. This reflects in (39), where the dependence of $\mathbb{E}^d[c_t]$ on $\mathbb{E}^{d-1}[\mathbf{i}]$ is mediated via the causal relations $\mathbf{M}$, which collects all the Jacobians $\mathbf{J_{vu}}$ in (33) that characterize the rational expectations equilibrium. This assumption simplifies the analysis and generates dampening of cross-variable relations in beliefs, complementing horizon-dependent dampening in Angeletos and Lian (2018), Farhi and Werning (2019) and Gabaix (2020). One could further generalize our theory to introduce additional dampening across periods, by modifying $\mathbf{M}$ in (38) and (39).[10]

Assumptions 1′ and 2 jointly lead to the following characterizations of the average beliefs, generalizing Proposition 2.

Proposition 7. (Average beliefs of dynamic GE) *The average beliefs $\overline{\mathbb{E}}[\mathbf{V}]$ are sums of all effects*

$$\overline{\mathbb{E}}[\mathbf{V}] = \sum_{n=1}^{\infty} \lambda^{n-1}\mathbf{M}^{n-1}\mathbf{S} \tag{40}$$

and equivalently, as a fixed point

$$\overline{\mathbb{E}}[\mathbf{V}] = \lambda\mathbf{M}\overline{\mathbb{E}}[\mathbf{V}] + \mathbf{S} \tag{41}$$

Given the average beliefs $\overline{\mathbb{E}}[\cdot]$, the equilibrium $\left\{i_t, \pi_t, div_t, n_t^d, c_t, n_t^s, w_t\right\}_{t\geq 0}$ is characterized by temporary equilibrium relations (B1-B6) as well as the labor market clearing condition $n_t^s = n_t^d$.

5.2 Macroeconomic Effects of Persistent Cost-Push Shocks

We consider responses of beliefs and equilibrium to a persistent cost-push shock $\epsilon_t^{\pi} = \rho^t \epsilon^{\pi}$. In particular, we show that a more persistent (higher ρ) cost-push shock leads to higher inflation under shallow thinking, contrary to the prediction of rational expectations.

[10] For example, by replacing $(\mathbf{J_{vu}})_{ts}$ with $m^{s-t}(\mathbf{J_{vu}})_{ts}$ for $s > t$ with a factor $m < 1$ and adjusting $\mathbf{M}$ accordingly in (38) and (39), we can allow for the possibility that agents underappreciate the dependence of one variable on future variables relative to its dependence on contemporaneous variables, à la Gabaix (2020).

In response to such an exponentially decaying shock, both beliefs and equilibrium outcomes decay exponentially at the same rate. Proposition 8 establishes the rational expectations equilibrium and shallow thinking beliefs, characterizing their time-t values relative to the time-t size of the shock ϵ_t^π.

Proposition 8. (Persistent cost-push shock) *The rational-expectations equilibrium (REE) response to a persistent cost-push shock $\epsilon_t^\pi = \rho^t \epsilon^\pi$ features*

$$\pi_t^{REE} = \left[1 - \frac{(1-\theta) + \left(\rho - \phi\right)\theta\kappa\frac{\sigma^{-1}(\nu+\sigma)}{1-\rho}}{1-\beta\theta\rho}\right]^{-1} \epsilon_t^\pi \tag{42}$$

$$i_t^{REE} = \phi\pi_t^{REE} \tag{43}$$

whereas the average expectations under shallow thinking are

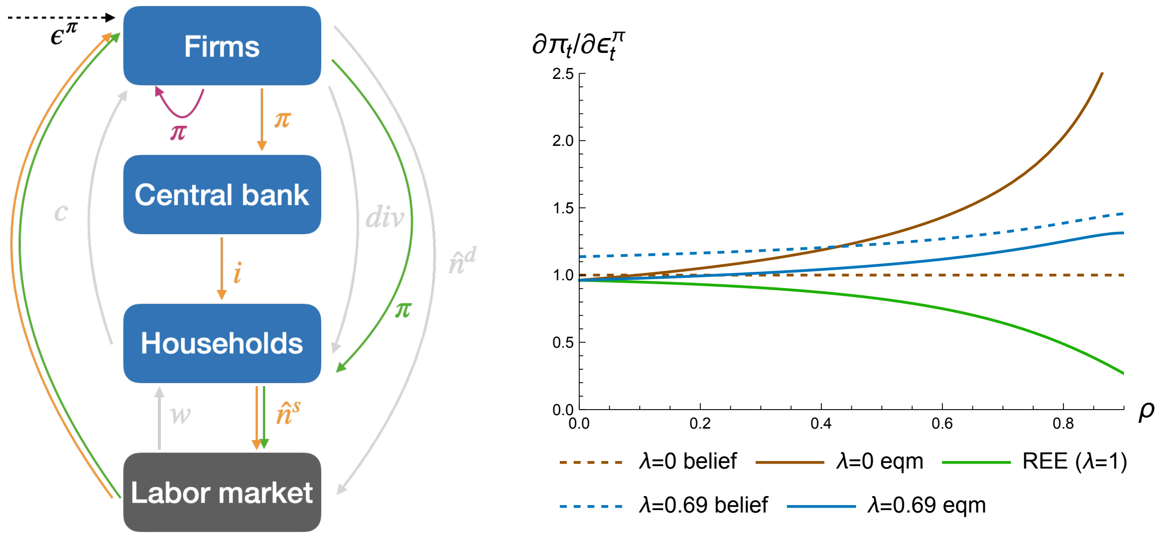
$$\overline{\mathbb{E}}\left[\pi_t\right] = \left[1 - \frac{\lambda\left(1-\theta\right) + \left(\lambda^3\rho - \lambda^4\phi\right)\theta\kappa K\left(\lambda,\rho\right)}{1-\beta\theta\rho}\right]^{-1} \epsilon_t^\pi \tag{44}$$

$$\overline{\mathbb{E}}\left[i_1\right] = \lambda\phi\overline{\mathbb{E}}_0\left[\pi_1\right] \tag{45}$$

with $K\left(\lambda,\rho\right)$ increasing in λ and ρ and $K\left(1,\rho\right) = \frac{\sigma^{-1}(\nu+\sigma)}{1-\rho}$.

This proposition shows how exactly the persistence of shock ρ matters, nesting Proposition 4 with $\rho = 0$. A positive ρ gives rise to new terms and modifies existing terms, which we dissect in order by analyzing REE inflation (42) and shallow expectations (44).

Regarding new terms, four general equilibrium loops across sequences of variables are involved, instead of three, displayed in Figure 9a. Relative to the case with period-1 shocks (Figure 3a), persistent shocks give rise to new causal relations—the responses of household consumption and labor supply to inflation π, plotted in green. This results in the fourth loop, the *inflation-on-households loop* (in green), in addition to pricing complementarity (in purple), the monetary policy loop (in orange), and the Keynesian cross (in gray). This loop takes three steps to close and amplifies the inflation response to cost-push shocks, since a higher inflation π simultaneously encourages consumption c and discourages labor supply $\hat{n}^s$, which leads to a higher wage w, feeding into inflation π. As a result, this loop is dampened by λ^3 in expectations (44). Further, the strength of this loop is proportional to ρ, meaning that it only exits when $\rho > 0$ and is stronger when ρ is higher. That occurs because only future inflation impacts household behavior by changing the real interest rate, and the expected inflation decays with rate ρ.



(a) Causal relations in the sequence space

(b) Inflation π_t in response to cost-push shock ϵ_t^π

Figure 9: New Keynesian economy with persistent shocks

Notes: Panel (a) illustrates the four loops of causal relations across sequences of variables in the New Keynesian economy in different colors, to accompany the discussion of Proposition 8. Four loops are the pricing complementarity self-loop (in purple), the inflation-on-households loop (in green), the monetary policy loop (in orange) and the Keynesian cross (in gray).
Panel (b) plots the equilibrium inflation π_t and the average expectation thereof (relative to the size of the shock) in response to a persistent cost-push shock $\epsilon_t^\pi = \rho^t \epsilon^\pi$, as functions of the persistence ρ, under different values of λ. The dashed lines indicate expectations and the solid lines represent the equilibrium. Different colors stand for different λ, with $\lambda = 0$ in brown, $\lambda = 0.69$ in blue (our calibration), and $\lambda = 1$ (rational expectations) in green. In the case with rational expectations, the beliefs coincide with the equilibrium.

Concerning the strength of these terms, a positive ρ does two things, in addition to activating the inflation-on-households loop. First, it strengthens all loops by $\frac{1}{1-\beta\theta\rho}$, because firms' pricing decisions are forward-looking and respond to a sum of future changes discounted by $\beta\theta$. Second, it further boosts the Keynesian cross via $K(\lambda, \rho)$. This additional boost occurs because households' decisions are forward-looking as well. Since the Keynesian cross reflects the feedback between firms and households, the persistence of shocks is compounded. As ρ increases, all loops get stronger, but the inflation-on-households and monetary policy loops become even stronger relative to the pricing complementarity self-loop, which has important consequences, as we will discuss next.

Figure 9b plots the average inflation expectation $\overline{\mathbb{E}}[\pi_t]$ and the equilibrium inflation π_t, both relative to the time-t size of the shock, as functions of persistence ρ. The dashed lines indicate expectations and the solid lines represent the equilibrium. Different colors stand for different values of λ, with $\lambda = 0$ in brown, $\lambda = 0.69$ in blue (our calibration of shallow thinking), and $\lambda = 1$ (rational expectations) in green. In the case with rational expectations, the beliefs coincide with the equilibrium.

We note from Figure 9b that two insights obtained with transitory news shocks extend here, and a new lesson emerges regarding persistence. First, inflation expectations exceed their equilibrium values under shallow thinking, as the dashed blue line lies above the solid blue line. Second, cost-push shocks are more inflationary under shallow thinking than under rational expectations, since the solid blue line lies above the solid green line. These two findings generalize the previous results from transitory news shocks. Last, a persistent cost-push shock leads to higher inflation under shallow thinking, but lower inflation under rational expectations, since the solid blue line increases in ρ while the solid green line decreases in ρ.[11]

To understand this new lesson regarding persistence, we start with the limit case of $\lambda = 0$ and $\lambda = 1$ (rational expectations). In the limit of $\lambda = 0$, inflation expectations always have the same size as the shock, with the dashed brown being flat. Inflation expectations change agents' behavior by acting like a cost-push shock for firms and a demand-shock for households. As their decisions are forward-looking and depend on discounted sums of future disturbances, a more persistent shock leads to larger changes in their behavior in any period, thus resulting in higher inflation.

In contrast, in the limit of $\lambda = 1$ (rational expectations), as analyzed based on Proposition 8, a higher ρ strengthens all general equilibrium effects and, further, boosts the inflation-on-households and monetary policy loops relative to the pricing complementarity self-loop. The monetary policy loop offsets the inflation response, whereas the other two amplifies it. As the monetary policy loop is the strongest among them and rational agents appreciate that, a higher ρ strengthens the offset and leads to a lower inflation. That is, facing a more persistent shock, rational agents anticipate that the monetary policy reaction will offset it more by acting on the Keynesian cross between firms and households, and their beliefs coincide with the rational expectations equilibrium.

Under our calibrated value $\lambda = 0.69$, shallow agents' inflation expectations increase in ρ. The mechanism is that, while the monetary policy offset loop is objectively the strongest, it is also the longest and gets dampened more in expectations. Thus, shallow agents believe that a more persistent shock leads to more amplification, as they better

[11]The equilibrium under $\rho = 0$ is independent of belief formation (i.e., λ) since agents observe all period-0 variables when making decisions in response to such a purely transitory shock.

understand the shorter amplification loops than the monetary policy offset loop. As a result, the equilibrium inflation is higher when ρ is higher. That increasing relationship is less drastic than in the extreme case of $\lambda = 0$, as shallow agents partially understand the monetary policy reaction and its effects on the economy.

6 Consequences in an RBC Economy

6.1 Shallow Thinking in an RBC Economy

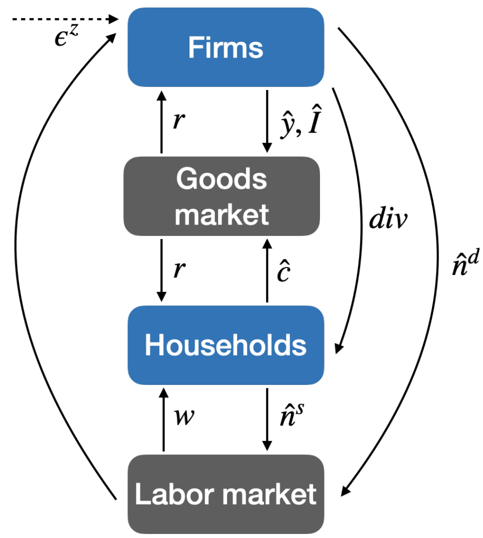


Figure 10: Causal relations of RBC economy in the sequence space

6.2 Effects of Productivity Shocks on Macroeconomy and Asset Prices

7 Conclusion

This paper develops a theory of *shallow thinking* as the structure of belief formation, supports its empirical content using a customized survey, and illustrates its consequences for macroeconomics and finance.

The key implication of our theory is that deeper causal relations have less influence on beliefs, meaning both the strength and depth of these relations matter. Our estimation suggests that the average depth of thinking is only about three—far below infinity assumed by rational expectations. We also provide evidence that this limited depth of thinking reflects people's limited knowledge about the macroeconomy. While our primary contribution is to develop a psychologically grounded model of expectations for macroeconomic analysis, our study of perceived macroeconomic shock propagation also advances the causal reasoning literature (Waldmann, 2017). These works typically present participants with simple examples in short experiments, whereas we examine a real-world domain that involves many variables and long-term data accumulation.

Our theory leads to a host of consequences for macro and finance. In a New Keynesian model, long-term nominal rates overreact to monetary shocks and underreact to cost-push shocks, as agents underappreciate offsetting loops and the propagation of shocks. This insight reconciles multiple bond market puzzles. Additionally, cost-push shocks are more inflationary than predicted under rational expectations, and more persistent cost-push shocks lead to higher inflation—contrary to rational expectations' predictions. That occurs because shallow agents better understand shallow general equilibrium effects, which amplify cost-push shocks. In a real business cycle model, shallow thinking amplifies fluctuations in response to productivity shocks, in a way consistent with observed return predictability over investment boom-bust cycles.

At a high level, we acknowledge the immense complexity of the economy. If it has taken decades for our best economists to understand how it works—or if they are still figuring it out—we must carefully consider how much the average person understands. Our theory of shallow thinking in general equilibrium may be fruitfully applied elsewhere, and we hope that this research agenda can make meaningful contributions to economics.

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Online Appendix for

"Thinking about the Economy, Deep or Shallow?"

Pierfrancesco Mei Lingxuan Wu

October 19, 2024

A Derivations and Proofs

Proof of Proposition 2. Assumptions 1 and 2 imply that the average beliefs are

$$\begin{aligned}\overline{\mathbb{E}}_0\left[V_1\right] &\equiv \sum_{d=1}^{\infty} \mathbb{P}\left(d=n\right) \mathbb{E}_0^d\left[V_1\right] \\ &= \sum_{d=1}^{\infty} \mathbb{P}\left(d=n\right) \sum_{n=1}^{d} M^{n-1} S_1 = \sum_{n=1}^{\infty} \mathbb{P}\left(d \geq n\right) M^{n-1} S_1 = \sum_{n=1}^{\infty} \lambda^{n-1} M^{n-1} S_1\end{aligned}$$

which can be recast as (14).□

Proof of Proposition 3.

Proof of Propositions 4 and 5.

Proof of Proposition 8.

B Details of the New Keynesian Economy

[This whole section is to be cleaned up.]

B.1 The Infinite-Horizon New Keynesian Model

Firms. There is a continuum of firms indexed by $j \in [0,1]$ in this economy subject to Calvo price rigidity. Each firm chooses labor demand N_{jt}^s, pays dividend DIV_{jt}, and sets price P_{jt}^* when it can, taking as given the aggregate inflation rate π_t, the real wage W_t, and the aggregate demand C_t. They agree on the steady state of the economy but may have heterogeneous beliefs about the economy's response to shocks.

Each firm produces a differentiated good, using the same constant-returns production technology using labor hours $Y_{jt} = N^d_{jt}$, which together forms a bundle with constant elasticity ε of substitution (CES) that the households consume. At the steady state, they each charge a markup $\mu \equiv \frac{\varepsilon}{\varepsilon-1}$. The log-linearized real dividend and aggregate labor demand are

$$div_t = c_t - \frac{1}{\mu - 1} w_t \tag{B1}$$

$$n^d_t = c_t \tag{B2}$$

Each firm resets its price with independent probability $1-\theta$ in any period and fulfills its demand period by period. Firms that can reset prices choose

$$p^*_{jt} = p_{t-1} + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \, \mathbb{E}_{it} \left[\sum_{l=0}^{k} \pi_{t+l} + w_{t+k} \right]$$

We assume that the average belief of firms is the same as that of the households $\overline{\mathbb{E}}_t$. Aggregate inflation emerges from the pricing behavior of the $(1-\theta)$ share of resetting firms as $\pi_t = (1-\theta)\left(p^*_{jt} - p_{t-1}\right)$. Following the tradition, we consider a cost-push shock ϵ^π_t for inflation

$$\pi_t = \theta\kappa w_t + (1-\theta)\,\pi_t + \sum_{k=1}^{\infty} (\beta\theta)^k \, \overline{\mathbb{E}}_t \left[w_{t+k} \right] + (1-\theta) \sum_{k=1}^{\infty} (\beta\theta)^k \, \overline{\mathbb{E}}_t \left[\pi_{t+k} \right] + \epsilon^\pi_t \tag{B3}$$

with $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$ capturing the slope of the Phillips curve. Importantly, we do not move π_t on the right-hand side to the left. We intentionally preserve the dependence of π_t on itself, which encapsulates the within-period complementarity in individual price setting as each firm takes the aggregate inflation as given.

Households. There is a continuum of infinitely lived households indexed by $h \in [0,1]$. Each household chooses consumption C_{ht} and labor supply N^s_{ht}, taking as given the gross nominal interest rates R_{t-1}, the inflation rate $\pi_t \equiv P_t/P_{t-1} - 1$, the real wage W_t, and the real dividend DIV_t. They agree on the steady state of the economy but may have heterogeneous beliefs about the economy's response to shocks.

They each maximize

$$\max_{\{C_{ht},N^s_{ht}\}_{t\geq 0}} \mathbb{E}_{h,t=0} \sum_{t=0}^{\infty} \beta^t \left(\frac{C_{ht}^{1-\sigma}-1}{1-\sigma} - \frac{\left(N^s_{ht}\right)^{1+\nu}}{1+\nu} \right)$$

subject to the budget constraint

$$C_{ht} + A_{ht} = \frac{R_{t-1}}{1+\pi_t} A_{h,t-1} + W_t N^s_{ht} + DIV_t$$

where C_{ht} is a CES bundle of goods in the economy, A_{ht} is the period-t saving.

Around the steady state with zero savings, the familiar log-linearized aggregate consumption and labor supply functions are (Appendix B contains all derivations)

$$\begin{aligned} c_t = & -\sigma^{-1}\beta i_t - \sigma^{-1}\beta \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\left[i_{t+k}\right] + \sigma^{-1} \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\left[\pi_{t+k}\right] + (1-\beta) \left[\frac{(\mu-1)\,\nu}{\sigma+\mu\nu} div_t + \frac{(1+\nu)}{\sigma+\mu\nu} w_t \right] \\ & + (1-\beta) \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\Big[\frac{(\mu-1)\,\nu}{\sigma+\mu\nu} div_{t+k} + \frac{(1+\nu)}{\sigma+\mu\nu} w_{t+k} \Big] \end{aligned} \tag{B4}$$

$$\begin{aligned} n^s_t = & \ \nu^{-1}\beta i_t + \nu^{-1}\beta \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\left[i_{t+k}\right] - \nu^{-1} \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\left[\pi_{t+k}\right] - (1-\beta) \frac{(\mu-1)\,\sigma}{\sigma+\mu\nu} div_t + \nu^{-1} \left(1 - \sigma \frac{(1-\beta)(1+\nu)}{\sigma+\mu\nu} \right) w_t \\ & - (1-\beta) \sum_{k=1}^{\infty} \beta^k \overline{\mathbb{E}}\Big[\frac{(\mu-1)\,\sigma}{\sigma+\mu\nu} div_{t+k} + \frac{(1+\nu)\,\sigma\nu^{-1}}{\sigma+\mu\nu} w_{t+k} \Big] \end{aligned} \tag{B5}$$

where $\overline{\mathbb{E}}_t[\cdot]$ denotes the average expectations of households, the lower-case variables denote the log deviation from the corresponding steady-state values, and $\mu = \frac{C}{WN^s}$ denotes the ratio of consumption to labor income at the steady state (which equals firms' markups as introduced next).

Monetary policy. The central bank a Taylor rule with a monetary policy shock ϵ^i_t,

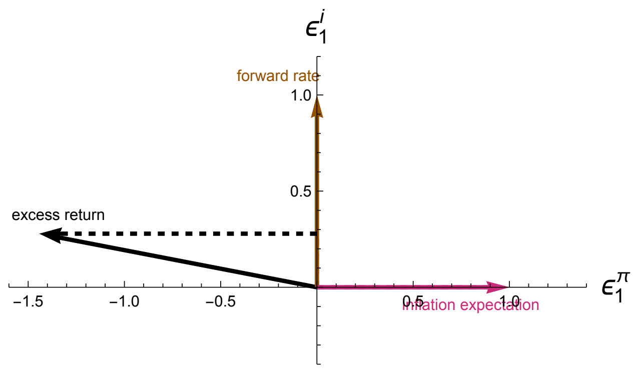
$$i_t = \phi\pi_t + \epsilon^i_t \tag{B6}$$

Competitive labor market. Last, to close the model, the wage arises by equilibrating labor supply and demand

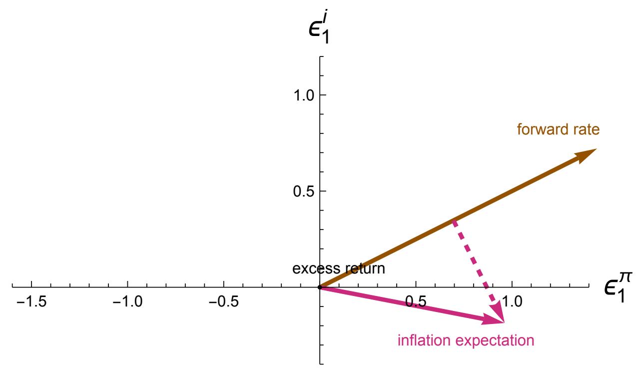
$$n_t^s = n_t^d \tag{B7}$$

B.2 Derivations

B.3 Additional Results



(a) $\lambda = 0$



(b) $\lambda = 1$

Figure B1: Loadings of excess return and predictors on shocks with $\lambda = 0, 1$

C Details of the RBC Economy

D Supplements to Survey

D.1 Tables for the Forecast Part of the Survey

Table D1: Variables elicited in forecast part of our survey

Variable	Abbrev.	Group 1 Oil ↑	Group 1 MP ↑	Group 2 G ↑	Group 2 PIT ↑	Group 3 CIT ↑	Group 3 TP ↑
Firms-related	**bus**						
Nominal marginal cost	mc	✓	✓	✓	✓	✓	✓
Demand	Y	✓	✓	✓	✓	✓	✓
Interest rate	i	✓	✓	✓	✓	✓	✓
Corporate income tax rate	CIT	✓	✓	✓	✓	✓	✓
Prices	p	✓	✓	✓	✓	✓	✓
Intermediate inputs	x	✓	✓	✓	✓	✓	✓
Investment	I	✓	✓	✓	✓	✓	✓
Total hours	N	✓	✓	✓	✓	✓	✓
Unemployment rate	u	✓	✓	✓	✓	✓	✓
Post-tax profits	d	✓	✓	✓	✓	✓	✓
Households-related	**hh**						
Interest rate	i	✓	✓	✓	✓	✓	✓
Prices	p	✓	✓	✓	✓	✓	✓
Hours	N	✓	✓	✓	✓	✓	✓
Personal income tax rate	PIT	✓	✓	✓	✓	✓	✓
Pre-tax nominal wage	W	✓	✓	✓	✓	✓	✓
Durable consumption	D	✓	✓	✓	✓	✓	✓
Non-durable consumption	ND	✓	✓	✓	✓	✓	✓
Central-bank-related	**fed**						
Unemployment rate	u	✓	✓	✓	✓	✓	✓
Inflation	p	✓	✓	✓	✓	✓	✓
Interest rate	i	✓	×	✓	✓	✓	✓
Government-related	**gov**						
Borrowing/repayment	B	✓	✓	✓	✓	✓	✓
Tax revenue	TR	✓	✓	✓	✓	✓	✓

Table D2: Literature review of directional impulse responses

		Oil price ↑	Monetary policy (MP) ↑	Transfer payment (TP)‡ ↑
Output	Y	Down (Känzig)	Down (Ramey)	Up (Pennings)
Interest rate	i	Up (Känzig)	Up (Ramey, as shock itself)	
Price	p	Up (Känzig)	Down (MAR), insignificant or up (Ramey, classic price puzzle)	
Unemployment	u	Up (Känzig)	Up (Ramey)	Down (MMNPF)
Labor hours	N	Down (BG)	Down (MAR)	
Nonresidential investment	I	Down (Känzig)	Down (BKM)	
Durable consump.	D	Down (Känzig)	Down (BKM)	Up (EHMNW)
Nondurables & services	ND	Down (Känzig)	Down (BKM)	Up (EHMNW)
Nominal wage	W	Up (BG)	Down (OT, as real wage and price both down), insignificantly down (MAR)	Up (EHMNW)
Business post-tax profits	div			Up (EHMNW)
References		Känzig (2021, figs 8-10/A.7) Blanchard and Galí (2010, fig 7.6.A)	Ramey (2016, figs 2-3) Miranda-Agrippino and Ricco (2021, fig 7) Boivin, Kiley and Mishkin (2010, fig 4, post-84) Olivei and Tenreyro (2007, figs 10-14)	Pennings (2021, tab 1) Mendes et al. (2024, tab 5) Egger et al. (2022, tabs 1, 3)

		Government spending (G) ↑	Personal income tax (PIT) ↑	Corporate income tax (CIT) ↑
Output	Y	Up (Ramey16)	Down (MR)	Down (MR)
Interest rate	i	Insignificant (Ramey11)	Insignificant (MR)	Insignificant (MR)
Price	p	Up (Ramey16 unreported result)	Down (CMMS23), insignificantly down (MR)	Insignificantly up (CMMS23, MR)
Unemployment	u	Down (Ramey13*)	Up (MR)	Up (CKS), insignificantly up (MR)
Labor hours	N	Up (Ramey11*)	Down (CMMS24, MR)	Insignificantly down (CMMS24), insignificant (MR)
Nonresidential investment	I	Down (Ramey11)	Down (MR)	Down (MR)
Durable consump.	D	Down (Ramey11**)	Down (MR)	Down (CMMS24†), insignificantly up (MR)
Nondurables & services	ND	Down (Ramey11**)	Down (CMMS24†), insignificantly down (MR)	Down (CMMS24†), insignificantly up (MR)
Nominal wage	W	Up (Ramey11)	Down (CMMS24, as real wage and price both down)	Down (CMMS24, as real wage down and price insignificant)
Business post-tax profits	div			Down (if measured by dividend, CKS)
Personal income tax rate	PIT	Up (Ramey11)	Up (MR, as shock itself)	Insignificantly down (MR)
Corporate income tax rate	CIT	Up (Ramey16***)	Insignificantly down (MR)	Up (MR, as shock itself)
Tax revenue	TR		Up (CMMS24‡, MR)	Up (CMMS24††), insignificant (MR)
Government spending	G	Up (Ramey16, as shock itself)	Insignificant (MR)	Insignificant (MR)
Government debt	B	Up (CMM)	Down (CMMS24, MR)	Insignificant (CMMS24, MR)
References		Ramey (2016, fig 5) Ramey (2011, fig X) Ramey (2013, figs 1.11-17) Corsetti, Meier and Müller (2012, fig 1)	Mertens and Ravn (2013, figs 2-4/9/10) Cloyne et al. (2023, fig 1) Cloyne et al. (2024, figs 1-2/B.1/H.8) Cloyne, Kurt and Surico (2023, figs 2/3B)	

Notes: This table lists directional impulse responses at about 1-year horizon across variables to shocks. Shocks considered are oil shocks, contractionary monetary policy (MP) shocks, transfer payment (TP) shocks, government spending (G) shocks, and positive shocks in personal income tax (PIT) rate and corporate income tax (CIT) rate. As we are only interested in the directions rather than the magnitudes of responses, we only impose a weak assumption that each variable responds to positive and negative shocks with opposite signs. This is weaker than assuming that the multipliers are the same for positive and negative shocks. Nonetheless, it is worth noting that while some earlier papers advocate for asymmetric multipliers, more recent papers argue that the evidence is weak (e.g., Kilian and Vigfusson (2011) for oil shocks and Ben Zeev, Ramey and Zubairy (2023) for government spending shocks). The abbreviation in parentheses indicates the main reference, usually the most recent or most cited paper. All references are listed at the bottom of each column.

‡ For the transfer payment shock, Pennings (2021) and Mendes et al. (2024) provide cross-sectional estimates instead of aggregate ones, in the US and Brazil respectively. Egger et al. (2022) study transfers in Kenya, but these transfers are funded from outside the economy. We drop this shock in a robustness version in Table D3.

* Ramey (2013) shows that the unemployment rate falls in response to government spending shocks. It is mainly driven by government employment, with the response of private employment either insignificant or negative in different specifications. We drop this variable in a robustness version in Table D3, since we elicit participants' opinions about private businesses.

** Ramey (2011, 2016) discusses extensively potential issues with previous works (e.g., Blanchard and Perotti, 2002; Galí, López-Salido and Vallés, 2007) that find a positive consumption response to government spending shocks. We drop this variable in a robustness version in Table D3.

*** Ramey (2016, fig 5) suggests that the average tax rate goes up in response to government spending shocks, calculated as federal current receipts divided by nominal GDP.

† Cloyne et al. (2024, fig 2) show positive consumption responses to decreases in PIT and CIT, but do not split into durables vs. nondurables.

†† Cloyne et al. (2024, fig H.8) show negative primary surplus response (tax revenue minus government spending) to decreases in PIT and CIT.

Table D3: Correct directional responses with robustness versions

	Oil $\uparrow$			MP $\uparrow$			G $\uparrow$			PIT $\uparrow$			CIT $\uparrow$			TP $\uparrow$		
Version	Va	Vb	Vc	Va	Vb	Vc	Va	Vb	Vc	Va	Vb	Vc	Va	Vb	Vc	Va	Vb	Vc
Y	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$
i	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$			$\uparrow$			$\downarrow$			$\downarrow$			$\uparrow$
p	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$		$\downarrow$	$\uparrow$		$\uparrow$	$\downarrow$		$\downarrow$			$\downarrow$			$\uparrow$
u	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$		$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$		$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$
N	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$		$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$
I	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$			
D	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$		$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$		$\downarrow$	$\uparrow$		$\uparrow$
ND	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$		$\downarrow$	$\downarrow$		$\downarrow$	$\downarrow$		$\downarrow$	$\uparrow$		$\uparrow$
W	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$		$\uparrow$
div			$\downarrow$			$\downarrow$			$\uparrow$			$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$		$\uparrow$
mc			$\uparrow$			$\downarrow$			$\uparrow$			$\downarrow$			$\downarrow$			$\uparrow$
PIT							$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$						$\uparrow$
CIT							$\uparrow$		$\uparrow$				$\uparrow$	$\uparrow$	$\uparrow$			$\uparrow$
TR									$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$		$\uparrow$			$\uparrow$
B							$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$		$\downarrow$			$\uparrow$

Notes: Three versions are constructed as follows. Version a is the baseline specification in Table 1.
Version a is most closely based on most up-to-date empirical estimates with clear directions.
Version b drops from Version a variables for which estimates are noisy or controversy exists. A few noteworthy choices are price response to monetary shocks (classic price puzzle), unemployment and consumption responses to government spending shocks (as discussed in the notes of Table D2).
Version c makes additional predictions based on theoretical predictions, relative to Version a.

Table D4: Model-implied variable depth with robustness versions

	Oil			MP			G			PIT			CIT			TP		
Model	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Y	3	3	3	2	2	2	1	1	1	2	2	2	3	3	3	2	2	2
i	2	2	2	1	1	1	5	3	3	5	3	4	6	4	3	5	4	3
p	1	1	1	4	3	4	4	2	2	4	3	3	5	4	2	4	3	2
u	3	3	3	2	2	2	2	2	2	2	2	2	3	3	2	2	3	2
N	3	3	3	2	2	2	2	2	2	2	2	2	3	3	2	2	3	2
I			3			2			2			3			2			2
D	3	3	3	2	2	2	2	2	2	2	2	2	3	3	3	2	2	2
ND	3	3	3	2	2	2	2	2	2	2	2	2	3	3	3	2	2	2
W			2			3			3			3			3			3
div	4	4	3	3	3	3	2	2	2	3	3	3	2	2	2	2	2	2
mc	1	1	1	3	3	3	3	2	2	3	3	3	4	4	2	3	3	2
PIT							1	1	1	1	1	1				1	1	1
CIT							1	1	1				1	1	1	1	1	1
B							1	1	1	1	1	1	1	1	1	1	1	1

Notes: Three sets of depths are constructed as follows, with the oil price shock interpreted as a cost-push shock. Model 2 is the baseline specification in Table 1.
Model 1 is the textbook New Keynesian model in the main text of this paper.
Model 2 extends Model 1 to feature decreasing-returns production (so that the marginal cost is increasing in quantity) and a Taylor rule of monetary policy that depends on both inflation and unemployment.
Model 3 extends Model 1 with capital investment by firms, price and wage rigidity (via a labor union instead of a competitive labor market).

D.2 Additional Results for the Predictability of Correct Directional Belief

D.3 Depth of Thinking is Individual Characteristic and Domain-Specific

We further show that the ability to understand shock propagation is indeed an individual characteristic and does not correlate with a classic measure of strategic sophistication.

The previous fact that individual fixed effects matter for correct beliefs already suggests that some people get more variables correct than others. To further investigate this, we measure individual n's overall understanding of shock s by a *total depth score (TDS)* as

$$TDS_{ns} \equiv \sum_{v} D_{vs} \cdot 1_{nvs} \tag{D1}$$

To receive a higher TDS, a respondent needs to get more variables correct and especially deeper variables correct.[12]

To the extent that depth is an individual characteristic as we postulate, we expect each respondent's TDSs to correlate strongly across shocks. To test this, we rank the TDSs from the lowest to the highest for each shock, and correlate the two TDS rank measures across individuals in Table D5. Column (1) confirms this prediction.

In contrast, column (2) suggests that TDS does not correlate with a classic measure of strategic sophistication (level k), via a "guess 2/3 of the average" game we play with survey respondents. This connects to findings in the macroeconomic literature that the measured level k does not predict differential consumption response to inflation news by Dutch households (Coibion et al., 2023*a*) or first- and higher-order inflation expectations of New Zealand firm managers (Coibion et al., 2021).[13] We remark that shallow thinking likely reflects people's limited knowledge about the macroeconomy, a distinct aspect of bounded rationality from limited strategic sophistication. After all, a chess master who could anticipate opponents well may not know macroeconomics, and vice versa.

The rest of the columns suggest that a measure of financial literacy, following Lusardi

[12]This TDS is a more robust measure to noise than the depth of the deepest variable that is understood correctly, as we have several variables for each depth and respondents may coincidentally get some correct.

[13]In the experimental literature, Dal Bó, Dal Bó and Eyster (2018) show that voters prefer policy changes that bring in direct benefits but induce larger indirect costs, but their voting behavior is not correlated with level k. Georganas, Healy and Weber (2015) study stability of level k using two families of games: beauty contest games à la Nagel (1995) and undercutting games similar to Arad and Rubinstein (2012). They find that the participants' levels are consistent within the beauty contest family, but do not correlate within the undercutting game family or across two families.

Table D5: Total depth score of one shock against that of the other shock

Total depth score of 2nd shock (rank)	(1)	(2)	(3)	(4)	(5)	(6)
Total depth score of 1st shock (rank)	0.22***					0.19***
	(0.05)					(0.04)
Level k (rank)		-0.02			-0.01	0.01
		(0.04)			(0.04)	(0.04)
Financial literacy score (rank)			0.21***		0.20***	0.17***
			(0.04)		(0.04)	(0.04)
Education (rank)			0.01		-0.03	-0.04
			(0.04)		(0.05)	(0.05)
Net asset (rank)				0.11*	0.11*	0.11*
				(0.05)	(0.05)	(0.05)
Income (rank)				0.02	0.02	0.02
				(0.05)	(0.05)	(0.05)
Constant	0.39***	0.53***	0.39***	0.45***	0.35***	0.26***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)
Observations	529	529	529	529	529	529
R^2	0.05	0.00	0.05	0.02	0.06	0.10

Standard errors in parentheses
Standard errors are heteroscedasticity-consistent
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

and Mitchell (2011), but not general education, correlates with TDS. Households' net asset positions also correlate with TDS. The former finding corroborates the idea that shallow thinking reflects people's economic knowledge, for which general education may be too noisy a proxy. These individual characteristics that correlate with TDS remain significant when analyzed together.

E Survey Design

E.1 Survey Structure and Sample

We design our survey to elicit the general public's directional beliefs about changes in a host of macroeconomic variables (such as prices, hours, and interest rates) in response to a set of hypothetical macroeconomic shocks (such as oil shocks and monetary policy shocks).

Our survey builds on Andre et al. (2022), which ask respondents to forecast changes (in levels) of inflation and unemployment rate in response to hypothetical macroeconomic shocks.[14] Grounded in our theory, two innovative features of our design are to inquire a number of major macroeconomic variables and to only elicit beliefs about the directional responses. Inquiring a host of macro variables traces out the path of shock propagation and tests if perception fails sequentially as suggested by our theory. For example, one of our questions concerns labor hours and asks respondents whether the average worker will work for more, fewer, or the same amount of hours during a typical week in response to shocks. Comparing people's beliefs of labor hours to those of aggregate demand sheds light on their understanding of firms' input choice. Eliciting directional assessments instead of level forecasts lowers the cognitive strain and lets us focus on the qualitative aspect of people's mental models. For instance, their responses of directional price change reveal whether participants understand the Phillips curve, rather than their potentially different perceptions about its slope.[15]

Respondents are randomized into three groups with probability one half, one quarter and one quarter, each receiving two shock scenarios in random order. Groups 1, 2, and 3 receive the following pairs of shocks respectively: oil shock and monetary policy shock, government spending shock and personal income tax shock, transfer payment shock and corporate income tax shock. In each scenario, we introduce a shock that realizes now and persists for 12 months (except for the transfer payment shock), and then elicit respondents' beliefs about changes in the economy over the next 12 months. We stress the exogeneity of the shock and state clearly that the shocks are publicly announced/broadcasted and are

[14] Haaland, Roth and Wohlfart (2023) discuss the potential and limitations of hypothetical vignettes.

[15] Andre et al. (2022) further ask participants to select the relevant ones from a list of potential channels and show that the selected channels predict their forecasts. For example, one channel in the oil shock vignette is "due to lower incomes or job loss, households cut back on their spending." We simply ask for directional assessments for a set of variables, without showing them any directional statement that is objectively true or false, which may influence their responses.

common knowledge to everyone in the US.

Our questions cover a large set of macroeconomic variables, divided into four blocks presented in random order, each on a separate page. The four blocks correspond to firms, households, the Fed, and the federal government's fiscal policy. We ask people's opinions about the average US business and household, to avoid any potential peculiarity of their own situations. Each block contains variables that the block either responds to (inputs) or decides on (outputs), summing up to 12 to 16 distinct variables for each shock scenario, listed in Table D1. Several key variables, such as price and total labor hours, are included in more than one block as both inputs and outputs, resulting in a total of about 22 questions for each shock scenario. For each question, respondents select among "up," "down," "unchanged," or "I don't know" to indicate their perceived directional changes of the specific variable in response to the shocks. The directional responses of most variables we elicit to these shocks are well-established in the empirical literature, as surveyed in Table D2.

In addition, to contrast our depth of thinking against level-k thinking in the game theoretical literature, we play the popular game of "guess 2/3 of the average" à la Nagel (1995) to measure respondents' game theoretical sophistication. Each respondent selects a number between 0 and 100, and they are informed that the number closest to the 2/3 of the average wins the game. Based on each respondent's answer g_i, we compute her level-k as $k_i \equiv \log\left(\frac{g_i}{50}\right)/\log\left(\frac{2}{3}\right)$, assuming that a level-0 player randomly selects a number.

We also assess respondents' financial literacy and collect other information, including gender, age, race, ZIP code, household composition, education, main occupation and additional employment, political affiliation, household income, assets, and debts.

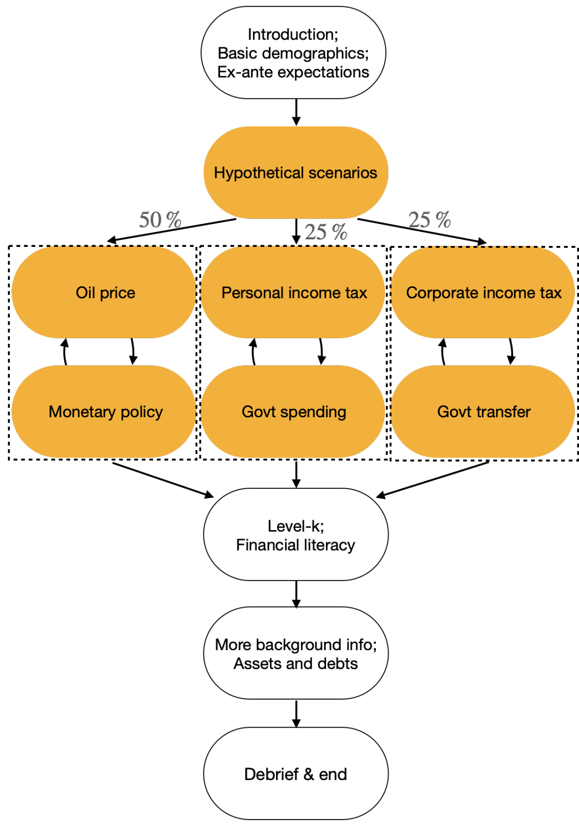


Figure E1: Survey structure

Sample. We conduct an online survey of around 1000 [xx] US households in June and October 2024. The survey was distributed through LUCID Marketplace, a platform that is widely used for research and is made up of hundreds of suppliers with a diverse set of recruitment methodologies, ensuring that the sample does not overweigh any particular segment of the population. The vast majority are double opt-in suppliers. Suppliers incentivize their respondents with loyalty reward points or gift cards or cash payments. The median completion time for our survey is 13.5 minutes.

We focus on US residents who are in the labor force at the time of the interview, and are aged between 25 and 65. Conditional on these characteristics, the survey is constrained through quotas to be representative of the US population along the dimensions of gender, age, total gross household income, and race, based on the Annual Social and Economic Supplement data of the Current Population Survey in 2022. Table E1 in the Appendix compares the distributions of the targeted characteristics in the US population and in our sample.

We drop people who fail the attention checks placed in our survey or spend too much or too little time completing the survey to form our main sample. Our results are robust to various sample selection criteria.

Table E1: Targeted respondents' characteristics

	US Population	Survey
Gender		
Male	.53	
Age		
25-29 years old	.13	
30-39 years old	.28	
40-49 years old	.25	
50-59 years old	.24	
60-65 years old	.10	
Household income		
\$0-\$19,999	.04	
\$20,000-\$39,999	.11	
\$40,000-\$69,999	.20	
\$70,000-\$124,999	.29	
\$125,000+	.36	
Race		
White	.61	
Black/African-American	.12	
Hispanic/Latino	.18	
Asian/Asian-American	.07	
Employment status		
Full time employed	.78	
Part time employed	.09	
Self-employed	.10	
Unemployed	.03	

E.2 Hypothetical Vignettes

Group 1.

Oil shock. *"Since the beginning of 2024, the average price for one barrel of WTI crude oil, which is a major benchmark for oil prices in the US, has been around \$80.*

Now, imagine that the price of crude oil unexpectedly increases due to production problems in the Middle East. For the next 12 months, the price for one barrel of crude oil will be, on average, \$20 higher than its current level.

This price increase is publicly broadcasted by major news outlets and is common knowledge to everyone in the US.

We will now ask you a few short questions to understand how you think the US economy would be affected by such an increase in oil price."

Monetary policy shock. *"The Federal Reserve, often referred to simply as "the Fed," is the central bank of the United States that conducts the nation's monetary policy to help regulate the economy. It sets a key interest rate known as the Federal Funds Rate. This is the rate at which banks lend to each other, and it affects the economy in many ways. The Federal Funds Rate influences the interest rates for savings accounts, credit card balances, mortgages, loans, and others. As of now, the Federal Funds Rate set by the Federal Reserve is 4.75%.*

Now, imagine that the Federal Reserve unexpectedly raises the Federal Funds Rate by 0.5 percentage points, changing it to 5.25%, and announces that it will maintain this rate for the next 12 months.

This interest rate raise is publicly announced and is common knowledge to everyone in the US. The Federal Reserve clarifies that this decision is made with no changes in their assessment of economic conditions.

We will now ask you a few short questions to understand how you think the US economy would be affected by this raise in the interest rate."

Group 2.

Government spending shock. *"Since 2000, US federal government spending has averaged about 25% of the US Gross Domestic Product (GDP), which is the total value of all goods and services produced in the country.*

Now, imagine that the US federal government unexpectedly announces a new defense program, leading to an increase in federal government spending over the next 12 months. And the additional spending will be directed domestically. Specifically, federal government spending relative to US GDP will increase by about 2% over the next 12 months.

This increase is publicly announced and is common knowledge to everyone in the US. The government clarifies that this change is temporary and occurs without any alterations in its *assessment of national security or economic conditions.*

We will now ask you a few short questions to understand how you think the US economy would be affected by this increase in federal government spending."

Personal income tax shock. *"In 2023, a typical household earning the median income is subject to a 12% federal personal income tax rate. Collectively, all households paid about 2.2 trillion dollars in federal personal income taxes in 2023, which is about 8% of the US Gross Domestic Product (GDP), the total value of all goods and services produced in the country.*

Now, imagine that the US federal government unexpectedly announces a 2% increase in the federal personal income tax rate over the next 12 months.

This increase is publicly announced and is common knowledge to everyone in the US. The government clarifies that the change is temporary and occurs without any changes in its assessment of economic conditions.

We will now ask you a few short questions to understand how you think the US economy would be affected by this increase in the federal personal income tax rate."

Group 3.

Transfer payment shock. *"Imagine that today the US federal government unexpectedly announces that each taxpayer will receive a one-time transfer payment worth, on average, $1,200. This one-time payment, which will not be taxed, will be available in bank accounts or as a check in mailboxes within three months.*

Taking into account that around 200 million US taxpayers will receive the payment, the total payments disbursed will be approximately 240 billion dollars, which is about 1% of the US Gross Domestic Product (GDP), the total value of all goods and services produced in the country.

The payment is publicly announced and is common knowledge to everyone in the US. The government clarifies that the payment is a one-time event and occurs without any changes in its assessment of economic conditions.

We will now ask you a few short questions to understand how you think the US economy would be affected by this transfer payment by the federal government"

Corporate income tax shock. *"Since 2017, there has been a 21% federal corporate income tax rate in place. The taxable income is a business's revenue minus expenses. In 2023, all* *corporations together paid about 420 billion dollars, which is about 1.5% of the US Gross Domestic Product (GDP), the total value of all goods and services produced in the country.*

Now, imagine that the US federal government unexpectedly announces a 2% increase in the federal corporate income tax rate over the next 12 months.

The increase is publicly announced and is common knowledge to everyone in the US. The government clarifies that the change is temporary and occurs without any changes in its assessment of economic conditions.

We will now ask you a few short questions to understand how you think the US economy would be affected by the increase in federal corporate income tax rate."

E.3 Other Questions

Financial literacy. Three questions are asked for each respondent, following Lusardi and Mitchell (2011).

1. *"Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?: more than today; less than today; exactly the same; don't know."*

2. *"Do you think that the following statement is 'true' or 'false'? Buying a company stock usually provides a safer return than a stock mutual fund.: true; false; don't know."*

3. *"Suppose you had $100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?: more than $102; less than $102; exactly the same; don't know."*

Incentivized level-*k* ("guess 2/3 of the average"). *"Imagine you are playing a game with about 300 other people chosen randomly from across the United States.*

Please choose a number between 0 and 100, inclusive.

We will take your number, as well as the numbers chosen by other participants, to calculate the average number. The winning number will be the number that is closest to two-thirds (2/3) of the average number. Specifically, we sum the chosen numbers by everyone and divide by the number of participants. Multiply the result by 2/3. The winning number is the one closest to the last result.

The winner will get an electronic gift card at any popular merchant worth $30, which will be split when there are multiple winners. The winner will be contacted in a few days at the conclusion of this study, using the email provided below."