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Stock price booms from technology news in a HANK model with portfolio choice

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Maximilian Weiß

Research Area B: Inequality and the Business Cycle

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Kaiserplatz 7-9, 4th floor
53113 Bonn

ABSTRACT

News shocks about a temporary rise in capital returns can explain stock price-booms that are succeeded by low returns within a rational expectations framework in a two-asset, heterogeneous agent New Keynesian model. The portfolio choice between liquid assets (like stocks) and illiquid capital is key. Wealthy hand-to-mouth households whose income is dominated by capital rents self-insure with liquid assets after the boom, driving down the real rate. Upon the news, they optimally rebalance their portfolio towards more illiquid capital, exposing themselves to uninsurable income risk. Contrary to models that abstract from either portfolio choice or heterogeneous agents, a policy that raises inflation during the anticipation phase hampers the investment-driven boom.

Maximilian Weiß
Department of Economics
Universität Bonn
maximilian.weiss@uni-bonn.de
PhD student

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JEL classification: E12, E21, E32, G11, G12, G51

Keywords: News shock, stock price booms, time-varying discount rates, HANK

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†PhD student at the Bonn Graduate School of Economics, University of Bonn (maximilian.weiss@gmail.com)

1 Introduction

Can news about future capital returns explain movements in the stock market? Since at least Campbell and Shiller (1988), it has been established that future dividend growth explains only a small part of the variance in stock prices. Instead, they found that future stock returns are predictable, and that most of the price-variation can be attributed to these "discount-factor news" (see also Cochrane (2011)). In this paper, I offer a new explanation of stock market cycles that is in line with these facts[1]: at the onset of a stock market-boom, households receive news about higher future returns on holding capital. Consequently, many households shift from liquid assets to illiquid capital in their portfolios, which causes an investment-driven business cycle boom, as the economy is demand-determined. Since publicly traded firm shares are liquid, their returns rise in the anticipation phase, such that households are restrained from substituting more of future's consumption for today's consumption. At the same time, households expect the increase in capital returns to be temporary, e.g. because it is caused by an ephemeral shift in customer tastes, or by a short-lived acceleration in productivity growth. Then, capital-rich, but liquidity-poor households face falling incomes over the long-run, and since markets are incomplete, they will demand more liquid assets for self-insurance. This extra liquidity demand (predictably) lowers stock returns after the boom, while capital returns remain high; the liquidity premium rises.

The decisive assumption for this result is the distinction between liquid and illiquid assets, which follows the literature that investigates the importance of illiquid household portfolios for central macroeconomic questions (e.g. in Kaplan et al. (2018)). Holding illiquid capital yields a premium, since households face uninsurable labor income risk that they have to self-insure against. In particular, I assume that households that invest in capital are committed to holding it for a random amount of time. The other crucial assumption is that stocks are liquid assets[2]. Then, up to first order, stock returns have to adjust each period to the demand for intertemporal substitution of households (as in, e.g.,

[1]Campbell and Cochrane (1999) provide a model that generates pro-cyclical stock prices by means of countercyclical risk aversion, by incorporating a slow-moving consumption habit in the preferences of a representative agent. Alternatively, Bordalo et al. (2020) propose that low stock returns are caused by the ex-post disappointment of market participants' irrationally optimistic expectations about fundamentals.

[2]In the numerical HANK-model of Kaplan et al. (2018), which allows for wealthy hand-to-mouth households, stocks are modeled as part of the illiquid asset, so that the link between stock prices and self-insurance does not arise there.

Caballero and Simsek (2020)). I abstract from aggregate risk, so that the entire reason for the stock price cycle lies in the time-varying liquidity premium (the effect of a risk premium, as in Campbell and Cochrane (1999), is of second order for the impulse response). When households increase their investment upon the news of future higher returns on capital, they reduce their portfolio liquidity, and thus put themselves more at risk of future labor income shocks. The demand for self-insurance of households whose income is dominated by capital rents - "wealthy hand-to-mouth" households in the terminology of Kaplan et al. (2014) - depresses the stock return after the boom: since their idiosyncratic risk at that point is highest, they become the marginal savers in the economy.

Stock prices are further accompanied by rising real interest rates in the anticipation phase. Whether this amplifies or dampens the stock price increase depends on the slope of the stock dividends: if they fall towards the end of the anticipation phase, then discounting them with increasingly higher rates further amplifies stock prices. In a New Keynesian model, such a dividend-curve arises from a demand shock: a boom is generated through rising marginal costs, which lower the profits of the monopolistically competitive firms, and thus decrease dividends. The literature recently questioned the countercyclical behavior of profits for demand-driven cycles (e.g. Broer et al. (2019)). For stock price cycles, the model implies that procyclical *dividends* may fit the data better[3]: while with countercyclical dividends, the explanatory power of the contemporaneous real rate for the stock price is high, the share of the price-dividend-ratio that is explained by the future (falling) rates is small. Conversely, with procyclical dividends, future rates explain most of the variation in the price-dividend-ratio (as in the data, Cochrane (2011)) during the anticipation phase.

The rising market capitalization in the U.S. in the recent decades has been linked to two observations: the higher capital factor share (Greenwald et al., 2019, Kuvshinov and Zimmermann, 2020), and the increasing importance of IT and intangible capital, complicating the measurement of the capital stock and productivity growth (Hall, 2001, Crouzet and Eberly, 2021). While this literature aims to explain the long-run trend of a higher stock price-dividend ratio, I focus on the comovement of the stock market with the business cycle. Still, I show that the expectation of higher future capital rents, which is the proposed driving force behind the stock price boom, can relatedly be motivated by news about two kinds of "fundamentals": higher total factor productivity (TFP), or a higher

[3]Since the New Keynesian part of the model still implies countercyclical profits, this finding may suggest a dividend policy that dampens, or even reverses, profit swings over the cycle.

capital share in the production process. Importantly, however, these fundamental changes should be (expected to be) *temporary*, since only then investment in the anticipation phase is urgent enough to drive the business cycle[4].

The anticipation of a temporary productivity shock can be motivated by the 1990s "dot-com" boom in the U.S., which was a R&D-investment boom (Brown et al., 2009), and is thought of by many as an anticipation-driven boom (Jermann and Quadrini, 2007, Ben Zeev, 2018)[5]. The anticipation could be interpreted as the expected spillover of returns to the "general purpose" intangible capital that is built up in that time[6]. Since intangible capital, like R&D, depreciates fast (via technological obsolescence and increased competition, c.f. Li and Hall (2020)), the households expect the future TFP increase to dissipate quickly[7]. Alternatively, Karabarbounis and Neiman (2014) find that the decline in the relative price of IT investment goods lowered the labor share in recent decades. In Karabarbounis and Neiman (2019), they argue that the value added was mainly channeled into capital rents, i.e. the capital share of production increased (this is to be distinguished, both in their analysis and in my model, from an increase in firm's profits, or markups). At the same time, they find that the share of value added attributable to IT capital declined after 2000, as the decline in returns outpaced the rate of investment. Market participants might have anticipated this turning point, knowing of the higher depreciation rate of IT capital. Relatedly, Kehrig and Vincent (2021) find in U.S. firm-level data that low labor share-firms massively increased their share of the economy's value added in recent decades. However, the low labor-share status of a firm is quite transitory, lasting for five to six years on average. The authors speculate that fads for certain products, i.e. demand-side effects, could drive these transitory shifts in production shares; through the

[4]The analysis of news about a temporary TFP increase sets this paper apart from the "news literature" that aims to identify news shocks empirically using long-run restrictions, starting with Beaudry and Portier (2006).

[5]McGrattan and Prescott (2010) argue that the 1990's puzzling increase in labor hours (preceding higher wages) can be explained by workers investing "sweat capital", i.e. producing intangibles. They estimate high productivity growth in the intangibles sector, which drives the boom in their model.

[6]The internal memo of Bill Gates to the executive staff at Microsoft, entitled "The Internet Tidal Wave", that he sent out in May of 1995, and in which he predicted the internet to bring both "low cost communication to most businesses and homes within the next decade" and new product markets, illustrates this anticipation (the memo is publicly available on the website of the U.S. Department of Justice, `https://www.justice.gov/atr/`).

[7]Bianchi et al. (2019) also interpret the 1990s boom as driven by R&D investment which provides spillover effects, and interpret the bust after 2000 as a shock to equity financing, as the value of pledgable capital falls. I will offer disappointed expectations, i.e. the spillover (partly) failing to materialize, as an alternative explanation for the bust in section 5.

lense of my model, the 1990s boom could then also be explained from the anticipation of a temporary shift of households' tastes toward more capital-intensive products.

There is a long-standing literature on news-driven business cycles, starting with Beaudry and Portier (2004, 2006)[8]. In a paper most related to this, Christiano et al. (2010) show that the New Keynesian model can generate booms from news shocks when monetary policy follows a naive Taylor rule. The reason is twofold: higher future productivity anchors inflation expectations at a level below steady state, and sufficiently high price stickiness lowers prices already in the anticipation phase. As a consequence, the policy rate falls, which boosts demand.

The mechanism changes in the HANK model with portfolio choice between liquid and illiquid assets. Since government bonds are liquid assets, when households want to rebalance their portfolios toward capital, the government faces pressure to reduce debt. Instead of reducing its balance sheet, however, the government can also induce higher inflation or allow for higher output gaps, thereby raising (inflation) taxes. These policies lower the real rate and decrease profits, which cuts into the income of wealthy households. Since they have the highest marginal propensity to invest, the wish to substitute liquid assets (like bonds) for capital weakens in the aggregate. While this equilibrates the bond market, it prevents the richer households from generating an investment-driven boom during the anticipation phase.

The implication for real rates and profits is thus very different in the model with heterogeneous agents and portfolio choice: It is *higher* real rates during the anticipation phase, and *lower* redistribution from entrepreneurs to workers at its end, that induces the news-driven (stock price and business cycle) boom[9]. The boom will not occur due to less intertemporal substitution of liquid assets, but instead due to more intratemporal substitution *across* assets, towards the (*produced*) illiquid capital. The higher goods-demand from investment is then partly satisfied by the crowding out of government expenditure, and partly by higher labor supply of the households, who earn higher wages and consume increasingly more, which supports the higher real rates in equilibrium.

The structure of my paper is as follows: In section 2, I illustrate the main mechanism to generate a stock price cycle from anticipation in a simple, tractable heterogeneous agent model, making use of the stylized framework developed by Challe and Ragot (2016). In

[8]Beaudry and Portier (2014) give a comprehensive summary.

[9]The positive relation between real rates and stock prices is also contrary to what Adam and Merkel (2019) find in a model with extrapolative expectations.

section 3, I present the full, quantitative model which expands the estimated HANK model by Bayer et al. (2020)[10] by the inclusion of tradable profit shares and news shocks. In section 4, I show that technology news - either about TFP or factor share shifts - generate a stock-price and business cycle boom, and describe how the hetereogeneous agent and two-asset structure is crucial to obtain this result. In section 5, I show the implications of the time-varying real rates for stock prices in the model, and compare it to facts from the data. Section 6 concludes.

2 Illustration of the stock price cycle

Following Krusell et al. (2011), the analytical literature on asset pricing in heterogeneous agent models often makes two critical assumptions (e.g. Ravn and Sterk (2017), Broer et al. (2019)):

1. The liquid asset is in zero net supply, and its rate is such that the "marginal saver" optimally holds no assets. All other households are constrained.

2. The effect of idiosyncratic risk supersedes the effect of aggregate risk on the budget constraint of the individual, so that the marginal saver can be determined from the stochastic process of idiosyncratic endowments.

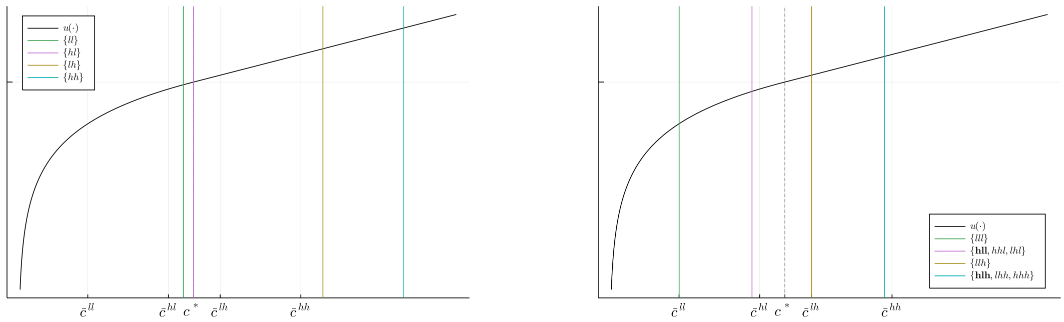
Often, a dichotomy between "capitalists" and "workers" is introduced, where only the latter are subject to idiosyncratic shocks, and thus the "luckiest" worker prices the liquid asset each period. In the analytical HANK-model of Bilbiie (2020, 2019), the roles are reversed: households that receive the returns on capital in the economy price the liquid asset, while the other households do not have access to markets and just consume labor income and transfers. Households switch roles stochastically.

The setting of Bilbiie is closer to my results from the numerical HANK model (described below in section 3): at the peak of the stock price-cycle, the liquid rate is set by (capital)-wealthy households who want to self-insure. The main difference from the (analytically tractable) model of Bilbiie is that there is a heterogeneity among households in the unconstrained state that plays a role over the cycle: Households choose to dissave their liquid asset holdings, as they want to hold on to their capital stock, in anticipation of higher returns. Therefore, more households end up closer to the constrained state,

[10] Bayer et al. (2020) estimate many of the model's parameters by maximizing their full-information likelihood of generating U.S. business cycle and inequality data from the past 60 years, including a host of standard business cycle shocks.

Figure 1: Optimal consumption levels

a. Capital rate increase b. Capital rate decrease



Notes: $\{...y_{t-1}y_t\}$ denotes the history of income shocks at time t, with $y_t \in \{l, h\}$, $l < h$. $\bar{c}^{yy'}$ denote the optimal consumption levels at all possible states $\{yy'\}$ of the ergodic wealth and income distribution.

which makes them more susceptible to income risk. Since stock price fluctuations are an aggregate phenomenon, it appears reasonable that an explanation for co-varying real rates hinges on an aggregate component of income (i.e., the dynamics of capital rents). News about a temporary increase of this income *endogenously* generates time-varying idiosyncratic risk, i.e. exposure to idiosyncratic risk that varies with the (stock price) cycle, due to optimal portfolio choices by households[11].

Applying the technique by Challe and Ragot (2016) to make heterogeneous agent models with a non-degenerate wealth distribution tractable, in this section I illustrate the mechanism how wealthy hand-to-mouth households can drive down the equilibrium real rate. I abstract, however, from portfolio choice between liquid and illiquid assets. Instead, agents face an *exogenous* shortage of liquidity in the anticipation phase, that drives up the interest rate on liquid assets. Also, I analyze a situation in which all households hold little liquid wealth relative to their income risk, i.e. they are poorly insured, while their illiquid wealth is high. In the full model, this situation applies to a small subset of households at the end of the anticipation phase.

Consider a unit mass of households who hold two assets, a liquid bond and a fixed amount of illiquid capital. They can borrow in the liquid bond up to the constraint $\underline{B} < 0$. Their income encompasses interest on the assets they hold, and idiosyncratic income $y \in \{l, h\}$, $l < h$, which follows a stochastic Markov process. They derive utility

[11] In a related paper, Bilbiie et al. (2021) place emphasis on the fact that redistributing capital income to constrained households amplifies demand shocks, as capital income is procyclical. While they model the redistribution exogenously (as fiscal policy by the government), I show that in a model with portfolio choice, anticipation can generate the same kind of "redistribution", but in reverse: households with a large share of capital income choose to become more constrained.

each period from consumption, where the utility function is concave up to point c^*, and has a constant slope afterwards.

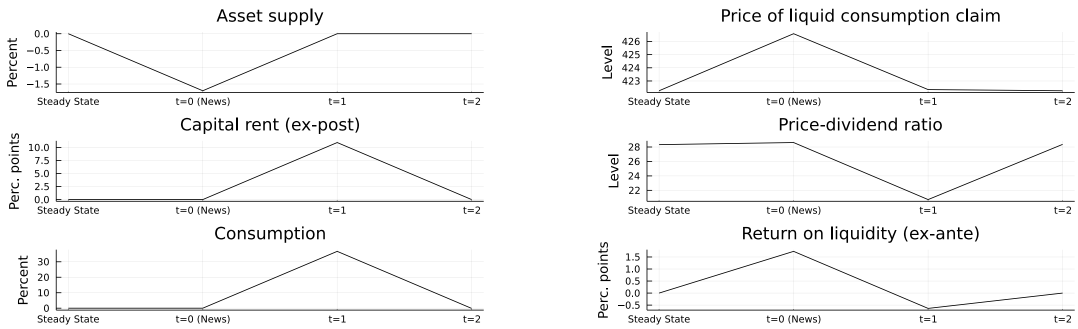
The steady state is calibrated such that all households that receive the low income, l, consume at a level below c^*, which is so low that they like to borrow more than $\underline{B}$. On the other hand, all households that receive income h consume at a level above c^*. They like to self-insurance against the risk of receiving the low income, and hence save $\tilde{b}$ bonds. Since they consume at the linear segment of the utility function, their marginal utilites are all identical, so that $\tilde{b}$ is the optimal saving for all households with high income. The economy has a liquid outside asset at the positive net supply $B = \pi^l \underline{B} + \pi^h \tilde{b}$, where π^l, π^h are the unconditional probabilities of receiving a low or high income.

The grey lines in figure 1 show the steady state consumption allocation in the model. Since all households hold the same (positive) amount of fixed capital, the joint distribution over income and bond wealth has only four mass points in steady state: $(l, \underline{B})$, $(l, \tilde{b})$, $(h, \underline{B})$, and $(h, \tilde{b})$. This renders the model very tractable. In a first step, I consider a surprise, one-period increase of the capital rent. I choose a rent increase such that households who change from the high to the low state, (hl), now optimally consume c^* and save a positive amount b' for self-insurance. In other words, they become unconstrained due to the higher capital income, but since they face lower capital income again in the future, they want to save part of their income gains. Since asset supply is constant, the households who receive high income today have to save less than $\tilde{b}$ this period for the bond market to clear. Equilibrium is obtained with a falling interest rate. For simplicity, I assume the income process to be symmetric[12], so that high-income households will also save the amount $b' < \tilde{b}$. As a result, next period, those households that were lifted out of the constrained state due to the higher capital income are at higher consumption levels than in steady state, while households that received high incomes last period consume slightly less (see figure 1).

In a second step, I consider the case where the capital rent increase is anticipated one period in advance. To keep the solution tractable, I require that the optimal consumption and bond choices stay the same as above, once capital rents change. This implies that unconstrained households decide to fully insure themselves upon the news (since next period, even if they get low income, they will be unconstrained due to higher capital income). Therefore, the equilibrium interest rate has to increase to $1/\beta - 1$ (β being

[12]I choose the conditional probabilites of losing a high income (e.g. job separation) and gaining a high income (e.g. job finding) to be complementary.

Figure 2: Impulse responses



Notes: Responses to a news shock about higher future capital rents, and a *simultaneous* surprise drop in the asset supply, at $t = 0$.

the time discount factor). For this to be an equilibrium outcome, bond supply has to be depressed in the period of the news shock.

Figure 2 shows the responses of the interest rate on liquid assets (ex-ante), the price of a liquid consumption claim (i.e. the "stock" price), and its price-dividend ratio, to this experiment. The price of the consumption claim appreciates so much at the onset of the news, that its higher level in period 1 due to the lower interest rate is barely visible. Similarly, the increase in the price-dividend ratio upon the news is dwarfed by its decrease once the capital rent rises. Still, the result illustrates how anticipation can generate a stock price cycle as seen in the data, i.e. high stock prices followed by low returns. The rates rise in the anticipation horizon due to lower liquid asset supply (caused, in the main model, by portfolio choice), and fall after the increase in capital income due to a higher demand for self-insurance (and constant asset supply).

3 The full model

The model economy consists of heterogeneous households, who are subject to idiosyncratic income shocks and stochastic capital market access, a production sector with intermediate goods producers, who hire workers and rent capital, and final goods producers, who set prices subject to price adjustment costs, and a government sector, where a monetary and a fiscal authority react to business cycle conditions by setting the nominal interest rate and the bond supply according to fixed rules. In the following, I describe each sector individually, before stating the market clearing conditions and giving the definition of the equilibrium of the model[13]. The model is partly calibrated to aggregate data

[13]The model setup, with the exception of the modelling of aggregate shocks and the richer asset structure, is the same as in Bayer et al. (2020). This is a shortened version of their exposition.

of the U.S. economy from 1954 to 2015, and partly estimated by Bayesian methods (see Bayer et al. (2020)). One period denotes one quarter. $\bar{X}$ denotes the steady state value of variable X, and $\hat{X}$ the relative deviation of X from $\bar{X}$.

3.1 Households

There is a unit mass of ex-ante identical households, indexed by i, who are infinitely lived, discount the future with the factor β, and optimize their (time-separable) preferences of the Constant Relative Risk Aversion (CRRA) type, $u(x) = \frac{1}{1-\xi}x^{1-\xi}$, over consumption, c_{it}, and leisure. Each period t, they choose consumption, labor supply n_{it}, future holdings of liquid assets, b_{it+1}, and non-negative capital goods, k_{it+1}, subject to their budget constraint, the debt limit $\underline{B}$, and capital market participation costs. Their budget is composed of (after tax) labor income, $w_t h_{it} n_{it}$, profit incomes Π_t^F (final goods firms' rents) and Π_t^U (labor union rents), and asset returns. While w_t denotes the aggregate wage rate, their individual productivity h_{it} is determined stochastically according to

$$h_{it} = \frac{\tilde{h}_{it}}{\int \tilde{h}_{it} di}, \tag{1}$$

$$\tilde{h}_{it} = \begin{cases} \exp(\rho_h \log \tilde{h}_{it-1} + \epsilon_{it}^h) & \text{with probability } 1-\zeta \text{ if } \tilde{h}_{it-1} \neq 0, \\ 1 & \text{with probability } \iota \text{ if } \tilde{h}_{it-1} = 0, \\ 0 & \text{else.} \end{cases}$$

$\tilde{h}$ follows a log-AR(1) process, with $\epsilon_{it}^h \sim \mathcal{N}(0, \sigma_{h,t}^2)$, for the times when the household is a worker. Its volatility moves endogenously in response to aggregate hours: $\sigma_{h,t}^2 = \bar{\sigma}_h^2 \exp(\hat{s}_t)$, $\hat{s}_{t+1} = \rho_s \hat{s}_t + \Sigma_Y \hat{N}_{t+1}$. ζ is the probability of becoming an entrepreneur. Entrepreneurs have no labor income ($h_{it} = 0$), but gain a share of the (after tax) profits of the final goods firms, Π_t^F, and raise funds by emitting stock (see section 3.2). With probability ι, they return to being a worker with mean productivity. The average of individual productivity h is normalized to 1. In addition to their wages, workers also receive a lump-sum share of the labor union rent, Π_t^U. The existence of entrepreneurs solves the problem of the allocation of rents that occurs in HANK models. Additionally, it helps the model to match the highly skewed wealth distribution in the data.

The choice of labor supply is greatly simplified by assuming Greenwood-Hercowitz-Huffman (GHH) preferences. They are represented by subtracting the disutility of work,

$G(h_{it}, n_{it})$, from the consumption good *within* the felicity function, i.e. $u(c_{it} - G(h_{it}, n_{it}))$. In this setting, an increase in working hours directly increases the marginal utility of consumption, which offsets the typical consumption-labor tradeoff that arises with separable disutility of labor, namely that more work is only compatible with a smaller consumption level. As a result, optimal labor supply is a function only of the net labor income, independent of consumption[14]. Let $x_{it} = c_{it} - G(h_{it}, n_{it})$ denote the composite demand for consumption and leisure.

Labor income of households is subject to progressive taxation as in Heathcote et al. (2017), i.e. net labor income y_{it} is given by

$$y_{it} = (1 - \tau^L)(w_t h_{it} n_{it})^{1-\tau^P}, \tag{2}$$

where w_t is the aggregate wage rate and τ^L and τ^P are the level and the progressivity of the tax schedule. Assuming that $G(h, n)$ has constant elasticity γ with respect to n, the first-order condition for labor supply yields $G(h_{it}, n_{it}) = y_{it}\frac{1-\tau^P}{1+\gamma}$. Choosing $G(h_{it}, n_{it}) = h_{it}^{1-\tau^P}\frac{n_{it}^{1+\gamma}}{1+\gamma}$ simplifies the problem further, as labor supply then is only a function of the aggregate (after tax) wage rate. This implies that every household works the same number of hours, $n_{it} = N(w_t)$.

Households can have unsecured debt (i.e. negative holdings of the liquid asset) up to the borrowing limit $\underline{B}$. In this case, their payment to the lender consists of the nominal liquid rate, R_t^L, plus a wasted intermediation cost, $\overline{R}$. Each period, a household's chance of participating in the capital market (and adjusting its capital holding) is given by the fixed probability λ. This trading friction renders capital illiquid. The capital good's price in period t is q_t. From holding capital, households earn a dividend r_t. The household's budget constraint sums up to

$$c_{it} + b_{it+1} + q_t k_{it+1} = y_{it} + \mathbb{1}_{h_{it}\neq 0}\Pi_t^U + \mathbb{1}_{h_{it}=0}\Pi_t^F + (q_t + r_t)k_{it} + \left(\frac{R_t^L}{\pi_t} + \mathbb{1}_{b_{it}<0}\frac{\overline{R}}{\pi_t}\right) b_{it}, \tag{3}$$

[14] Jaimovich and Rebelo (2009) propose a class of preferences that nests both King-Plosser-Rebelo (KPR) and GHH preferences, which was then adopted by Schmitt-Grohé and Uribe (2012) and others in their structural estimation of the impact of news shocks. The reason is that GHH preferences, that shut down the wealth effect on labor supply, are helpful in generating booms from news shocks. Hence, having a preference class where this wealth effect enters as a parameter, which can be estimated, gives news shocks a higher chance to fit the data. Schmitt-Grohé and Uribe (2012), as well as Born and Pfeifer (2014) and Bayer et al. (2020) in models without news shocks, find that close to GHH preferences provide the best fit to the data.

where $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ denotes realized inflation. Households maximize the infinite discounted sum of their utility, choosing (composite) consumption, liquid assets, and, if possible, capital holdings subject to the budget constraint and the inequalities $k_{it+1} \geq 0$ and $b_{it+1} \geq \underline{B}$.

The individual household's optimization problem can be written recursively as

$$\begin{aligned} V_t^a(b,k,h;\Theta,\mathcal{P},\Omega) &= \max_{k',b'_a}\{u[x(b,b'_a,k,k',h)] + \beta\,\mathbb{E}_t\,V_{t+1}(b'_a,k',h';\Theta',\mathcal{P}',\Omega')\}, \\ V_t^n(b,k,h;\Theta,\mathcal{P},\Omega) &= \max_{b'_n}\{u[x(b,b'_n,k,k,h)] + \beta\,\mathbb{E}_t\,V_{t+1}(b'_n,k,h';\Theta',\mathcal{P}',\Omega')\}, \quad (4) \\ \mathbb{E}_t\,V_{t+1}(b',k',h;\Theta',\mathcal{P}',\Omega') &= \mathbb{E}_t[\lambda V_{t+1}^a(b',k',h;\Theta',\mathcal{P}',\Omega')] \\ &\quad + \mathbb{E}_t[(1-\lambda)V_{t+1}^n(b',k,h;\Theta',\mathcal{P}',\Omega')], \end{aligned}$$

where Θ stands for the distribution over asset holdings and productivity, $\mathcal{P}$ are equilibrium prices, and Ω denotes an exogenous shock.

3.2 Tradable profit-stocks

Liquid assets consist of government bonds (see section 3.4) and profit-stocks. A fraction of ω^Π of the profits Π_t^F is traded with a unit mass of shares every period at price q_t^Π. A fraction of ι^Π of those shares retire every period and lose value, while new shares are emitted by the entrepreneurs. The real payout to entrepreneurs then becomes

$$(1-\omega^\Pi)\Pi_t^F + \iota^\Pi q_t^\Pi. \tag{5}$$

Ex ante, the expected return on bonds, R_{t+1}^B, has to fulfill the no-arbitrage condition

$$\mathbb{E}_t\,\frac{R_{t+1}^B}{\pi_{t+1}} = \mathbb{E}_t\,\frac{q_{t+1}^\Pi(1-\iota^\Pi) + \omega^\Pi\Pi_{t+1}^F}{q_t^\Pi}. \tag{6}$$

With B_t denoting the total supply of government bonds at time t, the total supply of liquid assets at time t becomes $L_t = B_t + q_{t-1}^\Pi$. The average (ex-post) real return on liquid assets is then given by

$$\frac{R_t^L}{\pi_t} = \frac{B_t}{L_t}\cdot\frac{R_t^B}{\pi_t} + \frac{q_t^\Pi(1-\iota^\Pi) + \omega^\Pi\Pi_t^F}{L_t}. \tag{7}$$

3.3 Production sector

The production sector of the economy is made up of labor unions and labor packers, intermediate goods producers, final goods firms, and capital goods producers. Workers sell their labor at the nominal rate W_t to a continuum of unions (indexed by j), who sell their variety of labor to labor packers (for W_{jt}), which produce and sell the final labor service at the price W_t^F. Since unions have market power, they set a price $W_{jt} > W_t$ subject to the demand curve $n_{jt} = (W_{jt}/W_t^F)^{-\zeta} N_t$, and to a Calvo-type adjustment friction. In a symmetric equilibrium, their optimization yields the wage Phillips curve (linearized around the steady state)

$$\log\left(\frac{\pi_t^W}{\bar{\pi}_W}\right) = \beta\,\mathbb{E}_t \log\left(\frac{\pi_{t+1}^W}{\bar{\pi}_W}\right) + \kappa_w\left(\frac{w_t}{w_t^F} - \frac{1}{\mu^W}\right), \tag{8}$$

where $\pi_t^W = \frac{W_t^F}{W_{t-1}^F}$ is the gross wage inflation, w_t and w_t^F are the real wages for households and firms, $\frac{1}{\mu^W} = \frac{\zeta-1}{\zeta}$ is the target markdown of wages, and κ_w is determined by the probability of wage-adjustment. The homogeneous intermediate good Y is produced with the constant returns to scale production function

$$Y_t = A_t N_t^{1-\alpha_t}(u_t K_t)^{\alpha_t}, \tag{9}$$

where u_t is capital utilization. As is standard, higher capital utilization implies an increased depreciation of capital, $\delta(u_t) = \delta_0 + \delta_1(u_t - 1) + \frac{\delta_2}{2}(u_t - 1)^2$, where $\delta_1, \delta_2 > 0$. A_t and α_t are the level of Total Factor Productivity (TFP) and the capital share, respectively, and follow the stochastic processes

$$\log(A_t) = \rho_A \log(A_{t-1}) + \epsilon_{t-\ell}^{A,\ell} + \epsilon_t^A, \tag{10}$$

$$\alpha_t = (1-\rho_\alpha)\overline{\alpha} + \rho_\alpha \alpha_{t-1} + \epsilon_{t-\ell}^{\alpha,\ell} + \epsilon_t^\alpha, \tag{11}$$

$$\epsilon_t^A \sim \mathcal{N}\left(0, \sigma_A^2\right),\ \epsilon_t^\alpha \sim \mathcal{N}\left(0, \sigma_\alpha^2\right).$$

Here, $\epsilon_{t-\ell}^{A,\ell}, \epsilon_{t-\ell}^{\alpha,\ell}$ denote news shocks (technology news, either about TFP or the capital share) that households receive in period $t-\ell$, and which are added to (the logarithm of) the fundamental process ℓ periods later (as indicated by the superscript). ℓ is called the anticipation horizon of the news. In other words, the capital share and log-TFP follow an ARMA process, where the moving average part is known ℓ periods in advance, and hence interpreted as news. This interpretation is standard in the literature (e.g. Schmitt-Grohé and Uribe (2012), Barsky and Sims (2012)). In particular, I assume the news shock to be iid. from the same distribution as the surprise shocks $\epsilon_t^A, \epsilon_t^\alpha$ (i.e., news are not autocorrelated as in Leeper and Walker (2011)).

Let mc_t denote the relative price (compared to the consumption good) at which the intermediate good is sold to final goods firms (which makes it the marginal cost of Y_t for these firms). The intermediate good producers, who operate in a perfect competition environment, set the real wage and the user costs of capital according to the marginal products of labor and capital:

$$w_t^F = (1-\alpha_t) mc_t A_t (u_t K_t/N_t)^{\alpha_t}, \;\; r_t + q_t \delta(u_t) = u_t \alpha_t mc_t A_t (N_t/u_t K_t)^{1-\alpha_t}. \tag{12}$$

Utilization is decided by the owners of the capital goods, who take the aggregate supply of capital services as given, and therefore follow the optimality condition

$$q_t \delta'(u_t) = \alpha_t mc_t A_t (N_t/u_t K_t)^{1-\alpha_t}. \tag{13}$$

Final goods firms (that are owned by the entrepreneurs) differentiate the intermediate good into final goods of the variety j, y_j. In this environment of monopolistic competition, they maximize profits subject to the demand curve $y_{jt} = (p_{jt}/P_t)^{-\eta} Y_t$ and price adjustment frictions. It is assumed that they discount the future at the same rate as the households, β. Then, their optimization yields a symmetric equilibrium that up to first order is determined by the Phillips curve

$$\log\left(\frac{\pi_t}{\bar{\pi}}\right) = \beta\, \mathbb{E}_t \log\left(\frac{\pi_{t+1}}{\bar{\pi}}\right) + \kappa_Y \left(mc_t - \frac{1}{\mu^Y}\right), \tag{14}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ now is defined as the gross inflation rate, $\mu^Y = \frac{\eta}{\eta-1}$ is the target markup, and κ_Y is determined by the probability of price adjustment.

Capital producers transform the investment of consumption goods into capital goods, taking as given the price of capital goods, q_t, and investment adjustment costs. They maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t I_t \left\{ q_t \left[1 - \frac{\phi}{2}\left(\log \frac{I_t}{I_{t-1}}\right)^2\right] - 1 \right\}. \tag{15}$$

Up to first order, the problem reduces to the equation

$$q_t \left[1 - \phi \log \frac{I_t}{I_{t-1}}\right] = 1 - \beta\, \mathbb{E}_t \left[q_{t+1} \phi \log \frac{I_{t+1}}{I_t}\right], \tag{16}$$

which determines q_t from the rates of investment. Since all capital goods producers are symmetric, the law of motion for aggregate capital follows as

$$K_t - (1 - \delta(u_t))K_{t-1} = \left[1 - \frac{\phi}{2}\left(\log \frac{I_t}{I_{t-1}}\right)^2\right] I_t. \tag{17}$$

3.4 Government sector

In the government sector, a monetary authority (the central bank) controls the nominal interest rate on bonds, while a fiscal authority (the government) issues bonds to finance deficits. The monetary policy follows a Taylor rule with interest rate smoothing:

$$\frac{R^B_{t+1}}{\bar{R}^b} = \left(\frac{R^B_t}{\bar{R}^b}\right)^{\rho_R} \left(\frac{\pi_t}{\bar{\pi}}\right)^{(1-\rho_R)\theta_\pi} \left(\frac{Y_t}{Y^*_t}\right)^{(1-\rho_R)\theta_Y}. \tag{18}$$

$\theta_\pi, \theta_Y \geq 0$ govern the severity with which the central bank reacts to deviations in inflation and the output gap, where Y^*_t is defined as the output that would be obtained at steady state markups. The government issues bonds according to the fiscal rule

$$\frac{B_{t+1}}{B_t} = \left(\frac{B_t}{\bar{B}}\right)^{-\gamma_B} \left(\frac{\pi_t}{\bar{\pi}}\right)^{-\gamma_\pi} \left(\frac{Y_t}{Y^*_t}\right)^{-\gamma_Y}. \tag{19}$$

Let $\mathcal{B}_t := \sum_i (w_t n_{it} h_{it} + \mathbb{1}_{h_{it}=0} \Pi^F_t)$ be the tax base for the progressive tax code. The total tax revenue T_t sums up to $T_t = \tau(\mathcal{B}_t + \sum_i \mathbb{1}_{h_{it}\neq 0} \Pi^U_t)$, where the average tax rate τ satisfies

$$\tau \mathcal{B}_t = \mathcal{B}_t - (1 - \tau^L)\mathcal{B}_t^{(1-\tau^P)}. \tag{20}$$

After the fiscal rule determines the government debt, and taxes are collected, government expenditure G_t adjusts such that the government budget constraint is fulfilled in every period: $G_t = T_t + B_{t+1} - B_t \frac{R^b_t}{\pi_t}$. As a simplification, it is assumed that G_t does not provide any utility to households. This implies that in steady state, in which government expenditure is calibrated to be strictly positive, a fraction of physical production is wasted.

3.5 Market clearing and equilibrium

The labor market clears at the competitive wage in (12). The market for liquid assets clears when liquid asset demand, which is given by the households' optimal decisions, $L_t^d = \mathbb{E}[\lambda b^*_{a,t} + (1-\lambda) b^*_{n,t}]$, equals the supply of liquidity $L_{t+1} = B_{t+1} + q_t^{\Pi}$ (as L_t^d is the aggregate over positive and *negative* private liquid asset holdings, the supply of liquid assets is bigger than L_{t+1} in gross terms). Similarly, the price of capital q_t, which is determined by (16), clears the capital market when $K_{t+1} = K_t^d = \mathbb{E}[\lambda k_t^* + (1-\lambda) k_t]$ holds (households that do not adjust capital demand the same amount as last period, k_t). By Walras' law, whenever labor, bonds, and capital markets clear, the goods market also clears.

A *recursive equilibrium* is a set of policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$, value functions $\{V_t^a, V_t^n\}$, prices $\mathcal{P}_t = \{w_t, w_t^F, \Pi_t^F, \Pi_t^U, r_t, q_t, q_t^{\Pi}, \pi_t, \pi_t^W, R_t^B, R_t^L, \tau_t, \tau^L\}$, stochastic state A_t and shocks $\Omega_t = \{\epsilon_t, \epsilon_t^l\}$, aggregate capital and labor supply $\{K_t, N_t\}$, distributions Θ_t over individual asset holdings and productivity, and a perceived law of motion Γ, such that

1. Given the functional $\mathbb{E}_t V_{t+1}$ and $\mathcal{P}_t$, the policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$ solve the households' planning problem, and given the policy functions, $\mathcal{P}_t$, and $\{V_t^a, V_t^n\}$ solve the Bellman equations (4).

2. The labor, the final goods, the bond, the capital and the intermediate good markets clear, and interest rates on bonds are set according to the central bank's Taylor rule.

3. The actual and the perceived law of motion Γ coincide, i.e. $\Theta' = \Gamma(\Theta, \Omega')$.

To solve the model, I use the methods developed by Bayer and Luetticke (2020)[15]. For a short description, see Appendix A.

3.6 Definitions and parameter choice

3.6.1 Classification in liquid and illiquid assets

Illiquid assets, which are assumed to be productive in the model, are equated to all capital goods in the U.S. National Income and Product Accounts (NIPA) tables. By

[15] For the implementation of the methods, I make use of and extend the Julia package "HANKEstim" by Bayer et al. (2020), available on `https://github.com/BenjaminBorn/HANK_BusinessCycleAndInequality`.

Table 1: Calibrations

Targets	Calibration	Data	Source
Mean illiquid assets (K/Y)	11.04	11.44	NIPA
Mean gvmt bonds (B/Y)	0.8	1.58	FRED
Government share (G/Y)	0.18	0.18	FRED
Top10 wealth share	0.68	0.67	WID
Portfolio liquidity upper 80%	0.23	0.21	SCF
Fraction borrowers	0.13	0.16	SCF

their definition, "acquisitions of consumer durable goods by households are treated as consumption expenditures rather than as investment" (U.S. Bureau of Economic Analysis, 2019*a*), which e.g. rules out car wealth as part of the analysis[16]. Housing is an exception, however, as "the ownership of the house [...] is treated as a productive business enterprise" (U.S. Bureau of Economic Analysis, 2019*b*).

From the assets in the Survey of Consumer Finances (SCF), all deposits, money market accounts, and bonds net of credit card debt, and stocks are counted as liquid assets. All other assets, and all non-credit-card debts, are considered illiquid. As the analysis abstracts from consumer durables, car wealth and auto loans are disregarded.

3.6.2 Parameter choice

The portfolio adjustment probability λ is calibrated at 6.5% so that the mean liquidity in households' portfolios matches the data (see also table 1). This adjustment probability implies an average waiting time of almost four years until capital holdings can be adjusted. This is also consistent with the interpretation of capital holdings as investments in projects that include R&D, in the following sense: as noted by Li and Hall (2020), the average gestation lag is two years, and the yearly depreciation of R&D in the late 1990s and early 2000s is between 20% and 60% in most sectors. Fittingly, Adam and Weber (2020) estimate from product data in the UK the median quarterly turnover rate of consumer products as 13.7%. Assuming an initial R&D phase of two years on average, in which intangible capital is produced (while physical capital is pledged as collateral), followed by the phase in which goods are produced using the physical capital and the depreciating

[16]Consumer durables like cars represent a significant share of poorer households' portfolios (e.g. Guiso and Sodini (2013)); however, they are rather evenly distributed across the wealth distribution, so that leaving them out should not hamper the model's ability to describe inequality.

intangible capital, I arrive at an average holding time of physical capital of four years. In line with the interpretation of the TFP news shock as anticipated spill-over from intangible capital, I likewise set the persistence $\rho_A = 1.0 - 2 \cdot 6.5\%$, i.e. log-TFP depreciates at a quarterly rate of 13%. The steady state capital share in production is set as in Bayer et al. (2020), $\overline{\alpha} = 0.32$. For the persistence of the shock to the capital share, $\rho_\alpha = 0,9552$, I use the mean probability for firms of losing the low labor-share status within 5 years, as estimated by Kehrig and Vincent (2021).

The size of both of the news shocks will be two times the standard deviations of the surprise shocks (see table 2). For TFP, this is the estimated value from Bayer et al. (2020). For the capital share, I calibrate the size of the news shock to fit to the increase of the capital share from the mid 1990s to 2000. To get an estimate of the capital share, I use the NIPA table 1.12 (National Income by Type of Income) and attribute the components to either profit income ($(1 - mc)Y$ in the model), wage income (wN in the model), or capital income (rK in the model). Importantly, corporate profits do not enter into capital income (in the model, profit income and capital income are different), while proprietors' income counts towards capital income. While the concrete estimates differ, this exercise is close in spirit to Karabarbounis and Neiman (2019). I find that, between 1995 and 2000, the capital share increased by about 1 percentage point.

The fractions ω^{Π} and ι^{Π} are calibrated to yield a share of liquid assets held in stocks of 39%[17], which implies $\omega^{\Pi} = 15\%$ and $\iota^{\Pi} = 1.6\%$. I set $\bar{\eta} = 13.5$ and $\bar{\zeta} = 11$, which implies price and wage markups of 8% and 10%, respectively. The real liquid rate is chosen to be 2.5% p.a., while the borrowing penalty $\bar{R}$ is set to 7.5% p.a. in order to roughly match the share of borrowers with the data. The steady state capital rent is $\bar{r} = 3.7\%$ p.a., implying a steady state liquidity premium of 1.2% p.a. Since the model abstracts from long-run technological growth, 2% yearly growth should be substracted from the couterparts of the liquid and the illiquid rate in the data. Additionally, one should account for the cost of financial intermediation, which Philippon (2015) estimates to be 1.5-2.0% yearly, when comparing the capital rent, and part of the liquid asset yield (the model liquid asset is composed both of government bonds, and more risky equity) to the data. Taking S&P returns and 10 year real bond returns from Robert Shiller, I compute average yearly returns of 9.5% and 5.5%, respectively, over the period of 1983 to 2013. Over that time

[17] From estimations by Saez and Zucman (2016), when defining bonds as fixed income assets plus net deposits and currency, and stocks as equities (other than S corporations), I get a stockshare of 45% in 1995. From the SCF wave of 1995 (see e.g. Guiso and Sodini (2013)), when defining bonds as cash and fixed income, and stocks as directly held equity, I compute a stockshare of 30%.

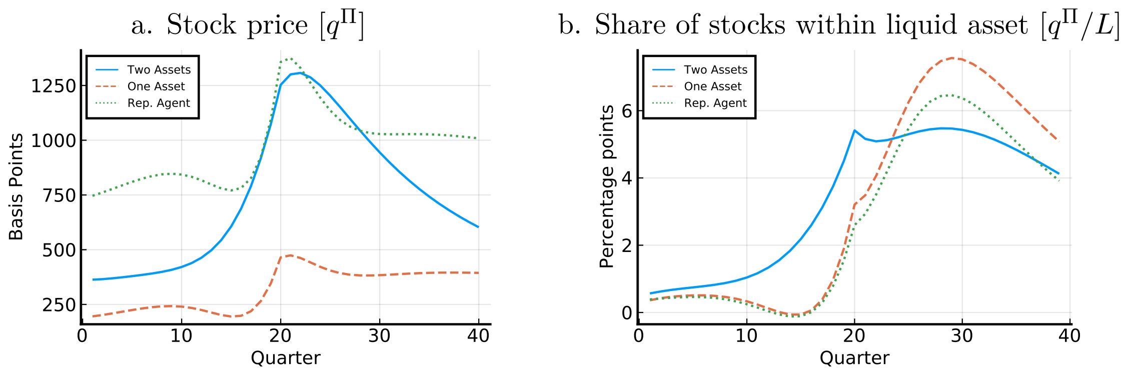
Table 2: Estimated parameters (selected)

Parameter	Description	Value
ϕ	Capital adj. costs	0.218
κ	Price stickiness	0.105
κ_w	Wage stickiness	0.133
ρ_R	R^B autocorr.	0.803
θ_π	Taylor: inflation	2.614
θ_Y	Taylor: output gap	0.078
γ_B	Fiscal: smoothing	0.157
γ_π	Fiscal: inflation	8.15
γ_Y	Fiscal: output gap	3.01
σ_A	TFP std. dev.	0.00608
σ_α	capital share std dev.	0.005

span, the federal funds rate implies an average real yearly return on quarterly bonds of 1.5%. The liquid rate in the model should be considered as a (weighted) average of these rates. As estimate for the capital rent, I take the series by Gomme et al. (2011) (including housing, without capital gains), which has an average yearly return of 8% over the same time.

Tax progressivity $\tau^P = 0.18$ is taken from Heathcote et al. (2017), while the tax level $\tau^L = 0.1$ is set to achieve a government share of rougly 18%. With respect to the parameters that Bayer et al. (2020) estimated, I choose those estimates where inequality data was included in the estimation (the HANK* specification). Importantly, I deviate with respect to the fiscal rule, where I estimate γ_π and γ_Y so that the ratio of the magnitude of the profits- and the magnitude of the bonds-response in the anticipation phase of the news shock matches the respective ratio in the late 1990s[18]. Table 2 lists the chosen values for a selection of parameters in the model.

Figure 3: Response of stocks across model classes



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).

4 A news-induced stock price boom

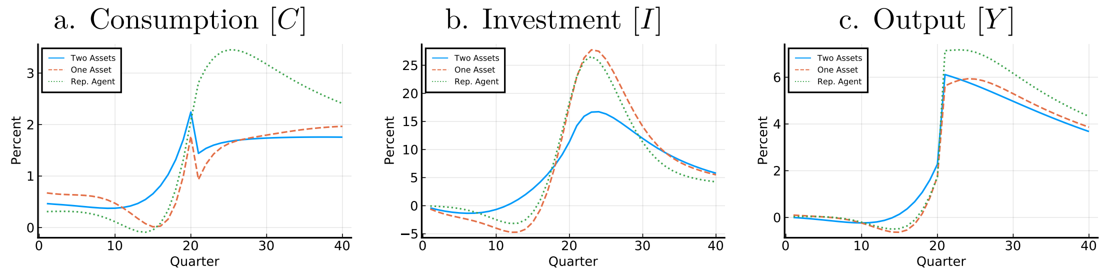
I consider the following experiment: with an anticipation horizon of 5 years ($\ell = 20$)[19], households become aware that the capital share will increase (by two times its standard deviation). As outlined in the introduction, one can interpret the capital share increase as caused by more firms employing IT capital, which changes the production process, or a temporary taste shock towards more capital-intensive products. In section 4.2, I show that I obtain almost the same impulse responses if the news is instead about a temporary increase in TFP. The reason is that for both news shocks, the expectation of a higher future return on holding capital is identical, which is the decisive impulse to cause the investment-driven boom. The higher expected life-time income that induces households to increase their consumption in the anticipation phase is mainly produced by the higher capital stock, which is accumulated in both scenarios when households rebalance their portfolio towards the productive asset.

Figures 3 and 4 present the response of the stock price and business cycle variables across three model variants: *Two Assets* denotes the baseline model with heterogeneous agents and portfolio choice between liquid and illiquid assets. *One Asset* retaines the market incompleteness, but takes away the portfolio choice: every household holds a

[18] I define the magnitude of the impulse response as the distance between the maximum and the minimum of the percent deviations in the anticipation phase. I constrain both γ_π and γ_Y to the interval $[-10.0, -0.01]$, and search for a global minimum using a Simulated Annealing-algorithm. The estimated bond supply is much more elastic, i.e. the government stabilizes inflation and the output gap more aggressively, than what was estimated by Bayer et al. (2020) for the whole period since 1960. The reason is that in the late 1990s, the U.S. government strongly reduced their debt.

[19] I choose an anticipation horizon of five years to be close to the dotcom-boom example: Karnizova (2012) estimates increased "productivity prospects" around 1995, while in 2000, the NASDAQ peaks.

Figure 4: Response of the business cycle across model classes



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).

representative portfolio, which is determined by the bond supply rule and the ex-ante liquidity premium being fixed at a steady state level of zero[20]. This implies that capital becomes liquid in this setting. *Rep. Agent* additionally takes away market incompleteness, and is thus a model of the RANK variety.

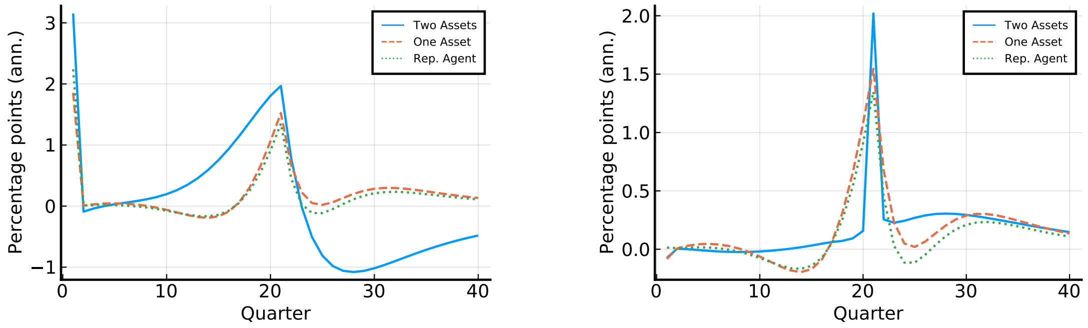
While all model varieties exhibit a peak in the stock price one quarter before the capital share increase (quarter 20), only the HANK model with portfolio choice generates the uniformly accelerating stock price growth that is typical for stock price booms. It is clear that the decisive difference for whether the news drives the business cycle is the portfolio choice. In the full HANK model, richer households start shifting their portfolio towards the illiquid capital after around 2.5 years. This crowds out government bonds (which increases the share of stocks within liquid assets) and thus government expenditures. The higher goods-demand increases wages (since prices are sticky) and lowers the negative labor gap (since wages are sticky), so that households increase their labor supply. Aggregate consumption rises on impact as households expect to have a higher lifetime income, and increases gradually with higher incomes. This gradual consumption increase (by most households) supports a higher real interest rate in equilibrium.

Figure 5 shows the response of the (ex-post) returns to the two asset classes across the model varieties. It is clear that without a time-varying liquidity premium, the expected returns are the same between asset classes (the liquid asset return jumps up at the onset of the news, as the stock appreciates unexpectedly). In contrast, with illiquid capital, the liquidity premium declines during the anticipation period (the real rate increases) and rises after the stock price-peak (the real rate falls). The increasing real interest rate in the anticipation period does not depress the economy; to the contrary, it stabilizes the

[20]The ex-ante liquidity premium is defined up to first order as the difference between the expected return on capital and the expected return on liquid assets, $\frac{\mathbb{E}_t(q_{t+1}+r_{t+1})}{q_t} - \frac{R_t^b}{\mathbb{E}_t\,\pi_{t+1}}$.

Figure 5: Response of *ex-post* returns across model classes

a. Liquid return b. Illiquid return (including capital gains)



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).

income of the top half of the wealth distribution (figure 6), which enables the middle class (households in between median wealth and the highest wealth decile) to invest in capital, inducing the boom. Is the investment boom driven by the middle class? Households in the top 10% of the wealth distribution own 70% of the capital stock in the economy, so that their incentive to invest in new capital is low. However, if the profit losses of entrepreneurs were higher, or interest income lower, more of the richest household would sell capital to offset their income losses, thereby depressing aggregate investment.

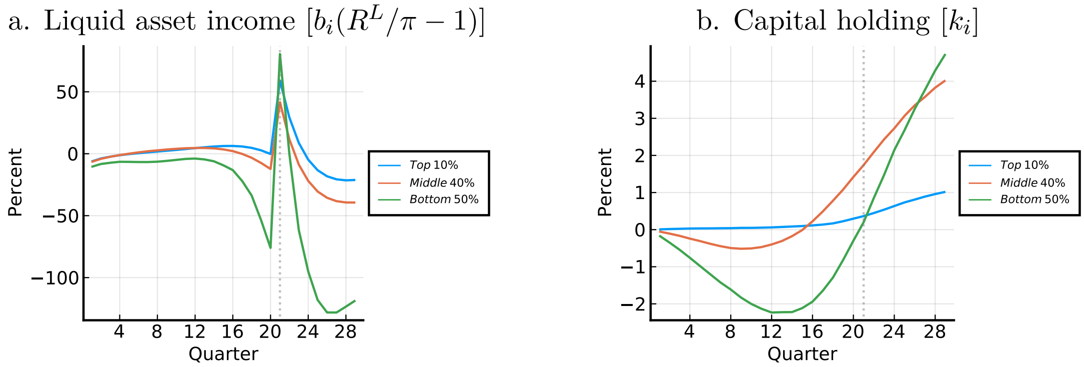
4.1 Comparison to the dotcom-boom

Since both the capital share shock as well as several parameters were calibrated to the 1990s in the U.S., I can make a quantitative comparison of the shock responses to the aggregate observations from 1995 to 2000[21]. In terms of real business cycle variables, the model exactly replicates the 6% rise in output and the 15% increase in investment, while it only accounts for one third to one half of the observed increase in consumption. As noted above, I calibrate the fiscal rule so that the model responses match the ratio of the decline in U.S. government debt to the decline in corporate profits during the late 1990s. In absolute size, the model explains about 75% of the observed declines in government bonds and profits (notably, federal debt held by the public declined by 20% during that time).

The shortcoming with respect to aggregate consumption may be due to the fixed debt limit in the model, while in reality, financial innovation related to collateral borrowing

[21] I detrend all time series by a constant growth rate of 2%, following McGrattan and Prescott (2010), and deflate nominal series with the GDP deflator [GDPDEF].

Figure 6: Response of income and investment over the wealth distribution



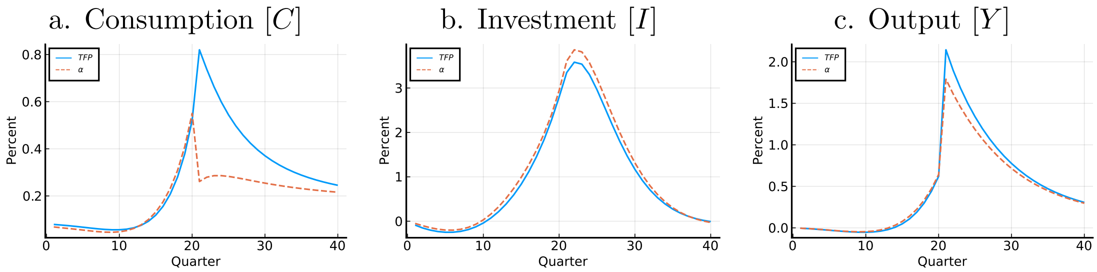
Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).

might have allowed households to consume more. Considering only unsecured borrowing, I find that the model accounts for half of the 30% increase in consumer credit. In the model, the increase in borrowing, mostly by the bottom 50% of households, contributes to the overall increase in wealth inequality during the anticipation period. From the World Inequality Database, the Gini index of wealth increased by 1.25% in that time span; the model explains about half of this increase. Finally, with respect to the share of stocks within the liquid asset class, using the estimates by Saez and Zucman (2016), during the dotcom boom this share increased by 20 percentage points. The model accounts for around a 25% of this increase. This highlights that institutional changes likely played a major role in increasing the stock share up to the 2000s.

4.2 Alternative news shock

Figure 7 compares the response of the business cycle to news about a temporary TFP-increase with the response to the capital share-news (I adjust size and persistence of the shocks to make them comparable). The responses are virtually identical in the anticipation phase. This shows that the portfolio rebalancing towards capital, which is incentivized in both cases by the expectation of higher future returns on holding capital, drives the boom also in consumption and output. Differences only occur once the fundamental shock realizes: a higher capital share redistributes from households with a high marginal propensity to consume to those with a low propensity, so that consumption falls, while higher TFP implies more income for all households. Therefore, output also rises a little less in the case of the capital share increase. Still, in the long run, the levels of consumption and output converge across the two shock responses. The reason is that, when the direct

Figure 7: Response of business cycle to alternative news shock



Notes: Model impulse responses are to news about a temporary TFP-increase in 5 years, and to news about a temporary capital share-increase in 5 years (both quarter 21). The size of the capital share-impulse is scaled to fit to the TFP news shock (given by two times σ_A). For comparability, the persistence of the capital share-process is adjusted to ρ_A.

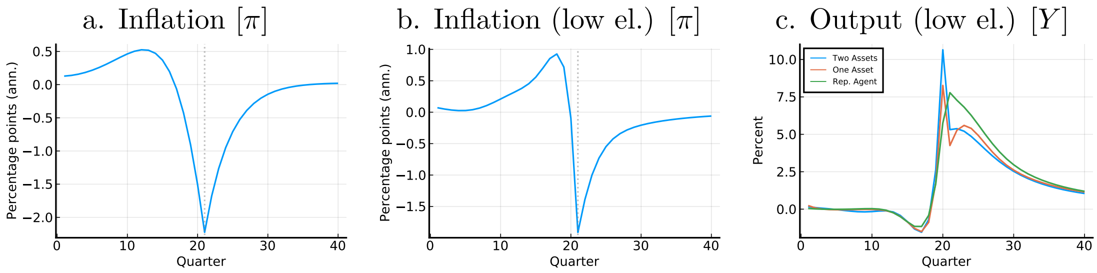
effect of the transitory shocks subsides, the indirect effect of the higher capital stock, built up during the identical anticipation phase, dominates.

In a further clarifying exercise, I also shock the model economy with news about future transitory increases in the markup μ (i.e., market power), and news about future increases in investment-specific technology productivity, which increases the marginal productivity of the transformation from consumption to capital goods. Both variables are prominent candidates in the literature to explain the secular decline (increase) in the labor (capital) share (e.g. in Karabarbounis and Neiman (2014), Greenwald et al. (2019)). I find that both news shocks depress the economy in the anticipation phase. The markup shock implies an expected redistribution from capital to profit income, which disincentivizes the holding of capital, so that investment falls. On the other hand, the investment-specific technology shock increases the capital rent, but it lowers the cost of capital; therefore, households wait with the investment until capital becomes cheap. This illustrates how only the anticipation of high rents *and* returns for capital causes an investment-driven business cycle and stock price boom in the model.

4.3 Importance of the fiscal rule

The investment boom is enabled by an elastic bond supply and a government that is willing to temporarily reduce its expenditure. To illustrate this point, I compare the response of inflation in the baseline model with the impulse responses in an alternative environment (*low el.*), where the government does not stabilize the output gap, and stabilizes inflation less strongly (figure 8). With the alternative fiscal rule that allows for higher inflation during the anticipation phase, middle class households do not invest enough to start a boom. The reason is that inflation depresses the liquid asset return and magnifies

Figure 8: Responses of government expenditure and output for different fiscal rules.



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).
The changed fiscal rule parameters of the *low elasticity* specification are $\gamma_Y = 0.007, \gamma_\pi = 6.58$.

the increase in the marginal costs of firms (affecting the entrepreneurs) and of unions (affecting the workers) late in the anticipation phase. The expectation of being exposed to these income losses discourages the households' capital investment earlier in the cycle. As a result, even in the model with portfolio choice, government expenditure is crowded out too late to drive the boom, and therefore all three model variants exhibit roughly the same output-response (as well as consumption-response) to the news shock.

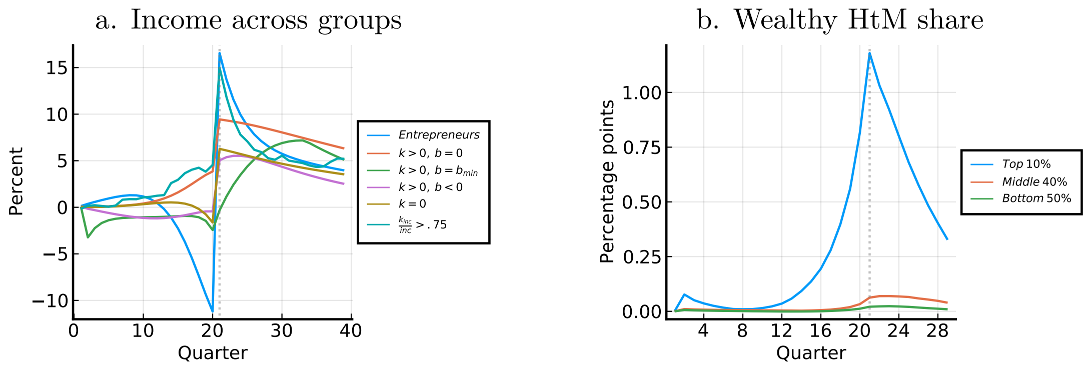
4.4 Wealthy hand-to-mouth households

Following Kaplan et al. (2014), wealthy hand-to-mouth households are households that have non-zero wealth in the illiquid asset ($k_i > 0$), while being at a kink in the budget set: either at zero liquid savings ($b_i = 0$), or at the borrowing limit ($b_i = \underline{B}$). Motivated by my numerical findings, I concentrate on the case when households hold the illiquid asset, while being at the borrowing constraint. Kaplan et al. propose a stylized 3-period life-cycle model without uncertainty to highlight the conditions under which it is optimal for households to be wealthy hand-to-mouth: Suppose that in the first period, households allocate their initial endowment between the liquid and the illiquid asset. Next period, they receive income and can sell their liquid asset (or borrow) to increase their consumption, but can not sell the illiquid asset until the third (and last) period, where they consume their income and the return to all asset holdings.

In this setup, households are more likely to be wealthy hand-to-mouth at the end of the second period if:

1. the capital rent and price in the last period are high relative to the borrowing rate,
2. their initial endowment is high, and both capital rent and their income are increasing from the second to the last period.

Figure 9: Response of income and shares of wealthy hand-to-mouth



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).

The news shock raises the expected capital rent and prices in the future. As I argued in section 4.3, extreme profit swings towards the end of the cycle depress investment. Part of the reason is that a big output gap late in the cycle requires monetary policy to hike the nominal rate, so that the real rate spikes in the last quarter before the TFP increase. This makes it more expensive to finance illiquid asset holdings with debt accumulated over the anticipation period, so that more households will refrain from doing so (as discussed above, higher real rates *earlier* in the cycle instead are beneficial for investment).

While the income of the average household in the upper half of the wealth distribution rises during the stock price boom, the most income gains are incurred by households whose income is dominated by capital rents (see figure 9a). While entrepreneurs, who receive the profit income, experience the largest income rise at the onset of the capital share increase, they lose in the anticipation period, and are therefore less likely to become wealthy hand-to-mouth households[22]. Hence, by virtue of capital rents, holding (a high amount of) the illiquid asset and experiencing income gains reinforces each other, making point 2) more likely to hold.

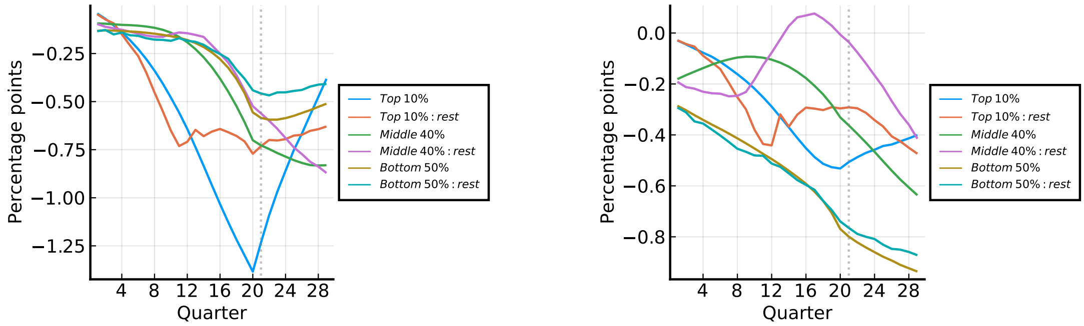
For these reasons, it is mostly households at the top of the wealth distribution who become wealthy hand-to-mouth households during the anticipation phase (see figure 9b). In steady state, only 0.2% of households are wealthy hand-to-mouth (at the borrowing limit). 73% of those households are in the top 10% of the wealth distribution. I find that during the stock price boom, the share of wealthy hand-to-mouth households among the wealthiest households grows by 10%. Hence, by far the largest inflow into this group comes

[22] What is more, entrepreneurs hold much larger liquid asset stocks than workers, as they face the largest idiosyncratic risk (becoming a worker).

Figure 10: Response of the saving rate across groups of households

a. Short-lived capital share (baseline)

b. Long-lived TFP ($\rho_A = 0.992$)



Notes: The saving rate is defined as $1 - c_{it}/\{\text{cash at hand}_{it}\}$, where

$$\text{cash at hand}_{it} = y_{it} + b_{it}R_t^L/\pi_t + k_{it}(r_t + \mathbb{1}_{\{k \text{ adjustable}\}}q_t) - \underline{B}.$$

rest denotes households who, in period t, have *not* been wealthy hand-to-mouth in period s *and* became unconstrained in $s+1$, at some time $s < t-1$ (since the news shock).

from capital-wealthy households, who optimally choose to get at or near the borrowing constraint so that they can hold on to the capital a little longer.

4.5 Marginal savers

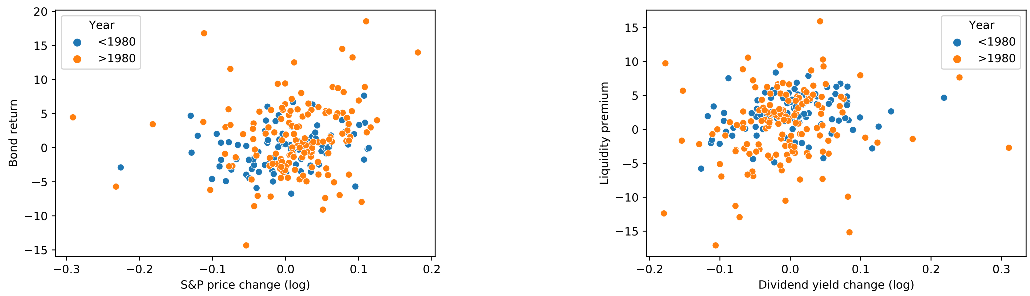
How can it be known whether the mechanism highlighted in section 2 is at work in the full HANK model? To show this, I split up households into those that were wealthy hand-to-mouth at some period s after the news shock, and became unconstrained at the subsequent period $s+1$, and the *rest*. The idea is that it should be the saving behavior of the first group, and not of the *rest* of households, that explains the rates during the cycle. Figure 10 reports the response of the households' saving rate (defined as the fraction that is saved of all funds available to the household in a given period) to the news shock across the wealth distribution. I show for each wealth group the average response of all households, and only that of the *rest* in that group. Panel a) shows that the biggest divergence between all households and the *rest* can be seen in the top wealth decile. There, wealthy hand-to-mouth households save less during the anticipation period, and save more after the capital share increase. In particular, it is the only group of households where the saving rate is trending upwards strongly after the 5th year, which indicates that these households drive down the real rate.

One may be worried that, since aggregate consumption also decreases after the temporary shock to the capital share, the lower rates are due to a general decline in consumption.

Figure 11: Contemporaneous correlations among asset returns

a. Bond return and S&P price change <1980: r=0.27, >1979: r=0.17

b. Liqu. Premium and Dividend yield change <1980: r=0.23, >1979: r=0.15



Notes: Data by Robert Shiller (S&P and 10 year treasury bond) and Gomme et al. (2011) (capital return). All returns are ex-post (realized) quarterly observations from 1947.Q1 to 2014.Q4. Lower maturity-bonds have a weaker correlation with stock prices: the respective correlation coefficients for the real federal funds rate are 0.11 (<1980) and 0 (>1979, after excluding outlier 2008.Q3).

In panel 10b, I plot the saving rates of households who react to a news shock about a very persistent TFP increase. The dynamic of the real rate over the cycle in response to such a shock is the same: real rates also decline after the TFP increase[23]. However, in that scenario, almost all households in the economy *decrease* their savings after the TFP increase, as their incomes continue to rise (and aggregate consumption rises as well). Only the wealthy hand-to-mouth households within the top decile of the wealth distribution increase their savings, as their main source of income, capital income, is trending downwards. This depresses the real rate in equilibrium.

5 Time-varying real rates and stock prices

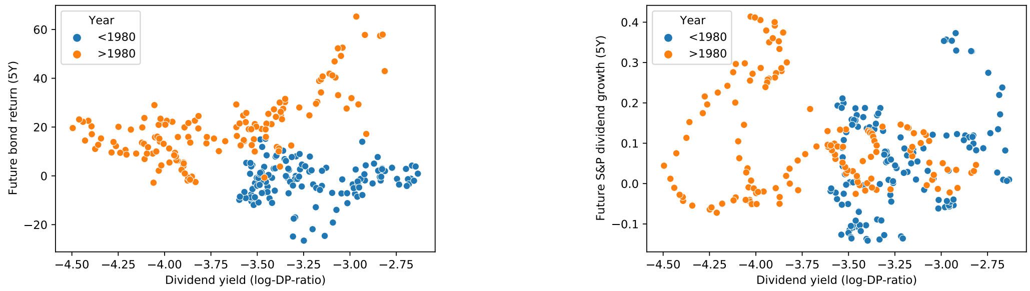
In this section, I provide some empirical evidence for the relation between liquid assets and stocks, and compare these to the Campbell-Shiller decomposition of the model stock price. First, the theory implies that the expected real rate on a liquid asset is positively correlated with the expected stock price change. Relatedly, the expected liquidity premium should covary positively with the expected change in the dividend yield (the inverse of the price-dividend ratio). Figure 11 shows that ex-post returns in the data provide weak evidence for these links, where the first relation is driving the second relation (bond returns and stock prices are more volatile than capital returns and stock dividends). The empirical noise can be due to, first, surprise events that change the returns differently,

[23] The results are available from the author upon request.

Figure 12: Decomposition of the dividend yield: Correlations

a. Future bond return
<1980: r=0.05, >1979: r=0.64

b. Future S&P dividend growth
<1980: r=0.31, >1979: r=-0.16



Notes: Data by Robert Shiller (S&P and 10 year treasury bond) and Gomme et al. (2011) (capital return). Quarterly observations (1947.Q1 - 2014.Q4)

and second, a co-varying risk premium (that is abstracted from in the model).

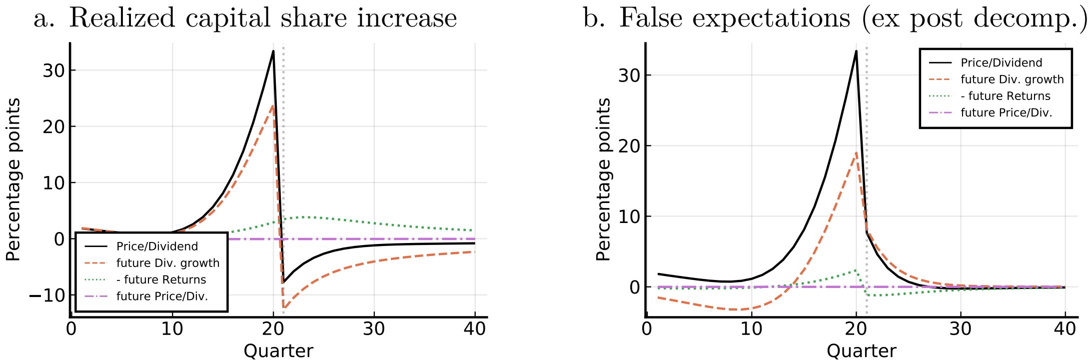
The Campbell and Shiller (1988) decomposition is a log-linear approximation of the price-dividend ratio around its (proposed) stationary value, and is given by

$$\log(q_t^{\Pi}/\Pi_t^F) = c + \mathbb{E}_t \sum_{j=0}^{\infty} \rho^j \left[\underbrace{\hat{\Pi}_{t+1+j}^F}_{\text{dividend growth news}} \underbrace{-r_{t+1+j}^L}_{\text{discount rate news}} \right], \tag{21}$$

where c and ρ are constants that are computed from long-run averages, and $r_t^L = R_t^L/\pi_t - 1$ is defined as the net real rate on the liquid asset (where I assume that the no-arbitrage condition holds up to first order, i.e. r^L is also the expected net return on the stocks). The composition shows that the contemporaneous price-dividend ratio is determined by dividend growth news and negative “discount rate” news up to first order (in the formula with a finite horizon, a future price-dividend ratio also enters). In a regression exercise, Cochrane (2011) shows that discount rate news, rather than dividend growth news, explain most of the variation in the price-dividend ratio.

To illustrate these results, in figure 12 I show the scatter plots of the log-dividend yield of the S&P with future bond return and future S&P dividend growth (the future variables are computed as discounted sum over the next five years). While before 1980, the relation between the dividend yield and discount rate news is zero, in the later sample the relation is strongly positive. On the other hand, the relation between the dividend yield and dividend growth news is positive before 1980 (i.e., it has the wrong sign), and only weakly negative in more recent decades. Overall, the discount rate news component of the Campbell-Shiller decomposition seems to have more support from the data.

Figure 13: Campbell-Shiller decomposition with countercyclical dividends (model)

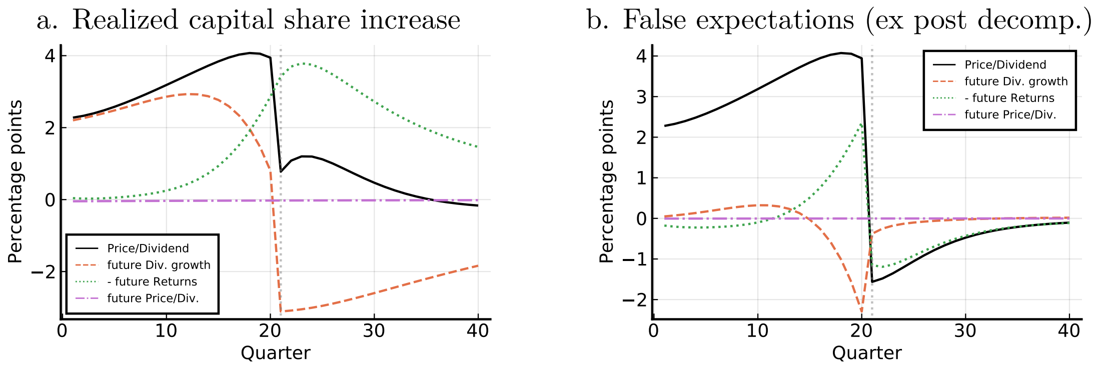


Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).
In b), the news is offset by a negative capital share surprise shock in quarter 21.

In a next step, I decompose the stock-price response to a news shock in the model into the components *future dividend growth*, - *future returns*, and *future price/dividend* (as in the data, the horizon of future variables is five years). Since the response to the news shock is solved up to first order, the Campbell-Shiller decomposition exactly holds. In panel a) of figure 13, one can see that most of the price-dividend ratio is explained by future dividend growth. The reason is that dividends are strongly countercyclical in the model, so that they dominate the future returns component over the cycle (the latter slightly increases the stock price). In panel b), I consider the possibility that households systematically expect productivity growth that does not materialize. Specifically, the contemporaneous price-dividend ratio, which up to the 21st quarter is driven by the wrong expectation of a capital share increase, is plotted together with the true future components that are known ex-post. Now, of course, the Campbell-Shiller decomposition does not hold in the anticipation period, as the price is based on a wrong expectation. Indeed, as the real rate also falls after the news-disappointment in the model, the future returns-component can "rationalize" some of the excess price-dividend ratio relative to future dividend growth. Still, the swings in profits "explain" most of the variation over the cycle, as profits fall strongly in the anticipation period, and revert to the steady state value after the news-disappointment.

Since it is not clear that firms pass on their profits to shareholders one-to-one, and countercyclical dividends may appear unreasonable, I also compute the Campbell-Shiller decomposition for an alternative asset, where the dividend is simply given by a fraction of output (see figure 14). For this type of stock, the future returns-component explains most of the increase of the price-dividend ratio in the anticipation phase. The reason is that,

Figure 14: Campbell-Shiller decomposition with procyclical dividends



Notes: Model impulse responses are to news about a temporary capital share-increase in 5 years (quarter 21).
In b), the news is offset by a negative capital share surprise shock in quarter 21.
The hypothetical asset yields dividends $\omega^{\Pi} Y$.

from the future dividend growth-component alone, a forward-looking price would already incorporate the future expected decline in output. However, since the future output will also be discounted less as the demand for liquidity will rise, the high price-dividend ratio can be rationalized. If the capital share-increase materializes, the high output level and subsequent output decline again explain most of the price-dividend ratio in the second half of the cycle. If the capital share-expectation is disappointed, however, the future returns (which increase quickly after the news-disappointment, as the price level shoots up and then declines slowly) explain most of the subsequent lower stock price. Based on these results alone, the model can generate a stock price-dividend ratio which is driven by the "discount rate" news component, if the stock dividend is mostly procyclical, and positive capital return expectations are systematically disappointed.

6 Conclusion

High stock prices are positively correlated with lower future returns. This fact can be explained by modelling households that are subject to a consumption-habit (Campbell and Cochrane, 1999), or that form extrapolative expectations (Bordalo et al., 2020). I offer an alternative, rational expectations framework to think about the relation between stock prices and future returns. Concretely, I show that a HANK model with portfolio choice generates a stock price cycle from the expectation of a temporary increase in the return on holding capital (a news shock). Although the households receive no additional information after the news, the price of the stock, which is perfectly forward looking, fluctuates over the business cycle. The reason is that publicly traded stocks are liquid assets, and are therefore useful to households for intertemporal substitution and self-insurance against bad income shocks.

I show that the former motive drives the accelerating stock price growth in the anticipation phase, while higher demand for self-insurance leads to a gradual decline in stock prices once the increase in capital returns subsides. As a result, stock prices appear to follow GDP over the cycle, which cannot be generated in model varieties that abstract from either market incompleteness or portfolio choice. First, portfolio choice is essential for investment to crowd out government expenditure during the boom, which is supported by rising real rates due to heterogeneity in the propensity to invest accross the wealth distribution. Investment-driven stock price booms like the 1990s dot-com boom provide support for this part of the theory. Second, the exposure to idiosyncratic risk varies over the cycle, which arises endogenously as capital-wealthy households become constrained during the anticipation phase. Hence, I find that the mechanism that generates amplification of business cycles in heterogeneous agent models (e.g. Ravn and Sterk (2017)), can also amplify stock price fluctuations over the cycle.

An obvious next step is to incorporate aggregate risk into the business cycle model. This would allow me to quantify the effect of time-varying risk premia for my results, as those are the leading candidate for explaining stock price fluctuations in the literature. This paper shows that already up to first order, liquid stocks, when embedded in a model with households who face idiosyncratic risk and rebalance their portfolios upon news shocks, can account for salient features of stock prices.

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A Numerical implementation

The heterogeneous agent model that is discussed in this paper poses the dynamic planning problem (4) to the households. As this problem includes the infinite dimensional object Θ_t, it cannot be solved without discretization. The idiosyncratic productivity process is approximated by a discrete Markov chain with n_h states. The household's policy functions are solved for by applying an endogenous grid method developed by Carroll (2006), and extended by Hintermaier and Koeniger (2010), on a grid of n_b bond-states and n_k capital-states.

To solve for the economy's responses to an aggregate shock like the news shock, a first-order perturbation around the stationary equilibrium, as proposed by Reiter (2009) and extended by Bayer and Luetticke (2020), is applied. The extension aims at reducing the state space, which includes the two- or three-dimensional distribution Θ as well as the value function and its derivatives. This is done by approximating Θ by a distribution with a fixed copula, but time-varying marginal distributions, and by applying the discrete cosine transformation to approximate the (marginal) value functions by a sparse polynomial around the stationary equilibrium. The first-order responses are obtained by computing the first derivatives of the system, as in Schmitt-Grohé and Uribe (2004).

In order to generate the policy responses conditional on the initial wealth position, I simulate a panel of N households per wealth position (i.e. $N \times n_b \times n_k$ different households), that are subject to idiosyncratic income shocks (generated by the Markov chain) as well as the aggregate shocks (news and news reversal). I simulate a second panel that is subject to the same income shocks, but faces no aggregate shocks. The average difference between the first and the second panel is taken as the response to the aggregate shocks (this procedure is necessary, as households move between wealth positions also in the steady state, which should be abstracted from). This method allows me to track the household's responses to a *sequence* of aggregate shocks (like in the case of the news reversal). To conduct the simulation, in every period I compute a transition matrix between this and next period's asset and productivity tuples (b, k, h), that is filled (sparsely) with weights that are taken from the computations for solving for the policy functions via the endogenous grid method.

The model is solved with $n_h = 22$ productivity, $n_m = 80$ bond, and $n_k = 80$ capital states. For the panel, I set $N = 1000$.