BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers

No 733

A risk-centric model of demand recessions and macroprudential policy

by Ricardo J Caballero and Alp Simsek

Monetary and Economic Department

July 2018, revised August 2018

JEL classification: E00, E12, E21, E22, E30, E40, G00, G01, G11

Keywords: Risk gap, output gap, risk-premium shocks, aggregate demand, liquidity trap,"rstar", Sharpe ratio, monetary and macroprudential policy, heterogeneous beliefs, speculation, endogenous volatility

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

A Risk-centric Model of Demand Recessions and Macroprudential Policy

Ricardo J. Caballero and Alp Simsek*

This draft: August 21, 2018

Abstract

We theoretically analyze the interactions between asset prices, financial speculation, and macroeconomic outcomes when output is determined by aggregate demand. If the interest rate is constrained, a rise in the risk premium lowers asset prices and generates a demand recession. This reduces earnings and generates a feedback loop between asset prices and aggregate demand. The recession is exacerbated by speculation due to heterogeneous asset valuations during the ex-ante low-risk-premium period. Macroprudential policy that restricts speculation can Pareto improve welfare. We also provide empirical support for the mechanisms by comparing impulse responses to house price shocks within and outside the Eurozone.

JEL Codes: E00, E12, E21, E22, E30, E40, G00, G01, G11
Keywords: Risk premium shocks, asset prices, aggregate demand, interest rate rigidity, booms and recessions, heterogeneous beliefs, speculation, monetary and macroprudential policy

Dynamic link to the most recent draft:
`https://www.dropbox.com/s/ud0jejruqxsc852/DRSR_37_public.pdf?dl=0`

---

*MIT and NBER. Contact information: caball@mit.edu and asimsek@mit.edu. We thank Chris Ackerman, Jaroslav Borovicka, Gauti Eggertsson, Emmanuel Farhi, Kristin Forbes, Masao Fukui, Mark Gertler, Zhiguo He, Yueran Ma, Jeremy Majerovitz, Plamen Nenov, Zilu Pan, Matthew Rognlie, Martin Schneider, Larry Summers, Jaume Ventura, Olivier Wang, Nathan Zorzi, and participants at the CCBS conference hosted by the Bank of England and MacCalm, Paris School of Economics, the BIS, the Wharton conference on Liquidity and Financial Fragility, the Harvard/MIT Financial Economics Workshop, NBER EFG, NBER AP, 2018 AEA meetings, the Bank of Spain, the FED, Boston College, MIT, Princeton University, the Barcelona GSE Conference on Asset Pricing and Macroeconomics, the Sciences Po Summer Workshop in International and Macro Finance, and the EIEF for their comments. Simsek acknowledges support from the National Science Foundation (NSF) under Grant Number SES-1455319. First draft: May 11, 2017

1. Introduction

Prices of risky assets, such as stocks and houses, fluctuate considerably without meaningful changes in underlying payoffs such as earnings and rents. These fluctuations, which are typically described as the result of a "time-varying risk premium," have been the subject of a large finance literature exploring their scope and causes (see Cochrane (2011); Campbell (2014) for recent reviews). Asset price fluctuations driven by the time-varying risk premium matter not only for financial markets but also for macroeconomic outcomes. Low asset prices are worrisome because they can create or exacerbate recessions. In influential work, Mian and Sufi (2014) demonstrate that the decline in U.S. house prices explains much of the aggregate job losses during the Great Recession. High asset prices also generate concerns because they are often associated with excessive leverage and speculation, which might exacerbate the damage when prices decline. Central banks are aware of these connections between financial markets and macroeconomic outcomes. For example, Cieslak and Vissing-Jorgensen (2017) conduct a textual analysis of 184 FOMC minutes during the 1994-2016 period and find extensive reference to stock market developments, which had significant explanatory power for monetary policy. The Fed's stated rationale for these policy reactions emphasizes the negative impact of severe stock markets declines on aggregate consumption and investment.

There is an extensive literature at the intersection of macroeconomics and corporate finance that highlights a variety of financial frictions and balance sheet mechanisms that capture the connection between asset prices and the macroeconomy. The bulk of the mechanisms in this literature operate through the supply side of the economy, as the tightening of financial constraints reallocates resources from more productive to less productive agents (see Gertler et al. (2010) for a review). With few exceptions, there is no special role for aggregate demand or monetary policy. In this paper, we provide a model that complements this literature by focusing on the role of the aggregate demand channel in causing recessions driven by a rise in the risk premium. We also study the interaction of these recessions with financial speculation and derive the implications for macroprudential policy. In order to isolate our insights, we remove all financial frictions.

Our model is set in continuous time with diffusion productivity shocks and Poisson shocks that move the economy between high and low risk premium states. The supply side is a stochastic endowment economy with sticky prices (which we extend to an endogenous growth model when we add investment). The demand side has risk-averse consumer-investors that demand goods and risky assets. We focus on "interest rate frictions" and "financial *speculation*." By interest rate frictions, we mean factors that might constrain or delay the adjustment of the risk-free interest rate to shocks. For concreteness, we work with a zero lower bound on the policy interest rate, but our mechanism is also applicable with other interest rate constraints such as a currency union or a fixed exchange rate. By financial speculation, we mean the trade of risky financial assets among investors that have heterogeneous valuations of these assets. We capture speculation by allowing investors to have *belief disagreements* with respect to the transition probabilities between high and low risk premium states.

To fix ideas, consider an increase in perceived volatility. This is a "risk premium shock" that

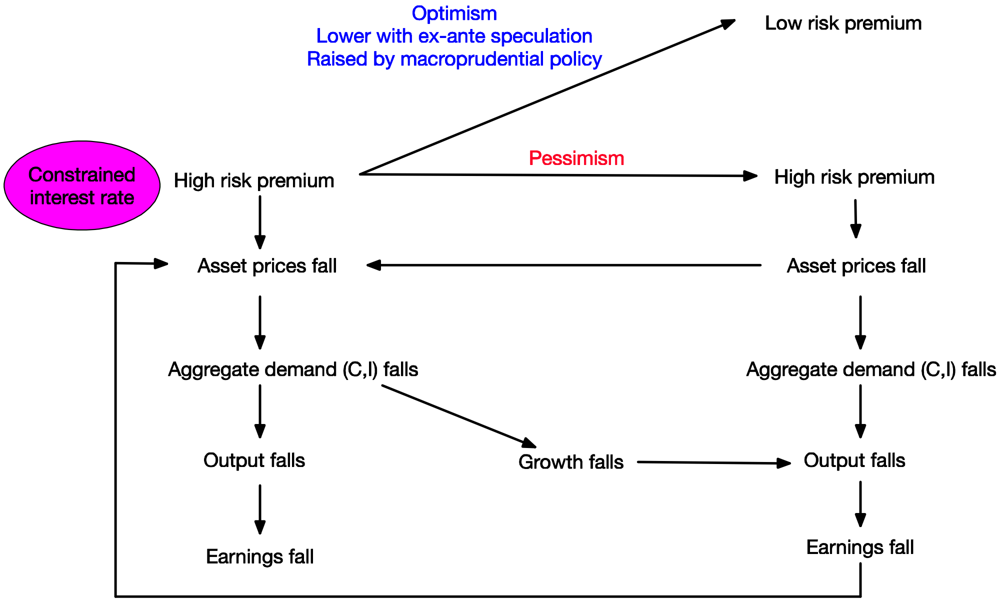

Figure 1: Output-asset price feedbacks during a risk-centric demand recession.

exerts downward pressure on risky asset prices without a change in current productivity (the supply-determined output level). If the monetary authority allows asset prices to decline, then low prices induce a recession by reducing aggregate demand through a wealth effect. Consequently, monetary policy responds by reducing the interest rate, which stabilizes asset prices and aggregate demand. However, if the interest rate is constrained, the economy loses its natural line of defense. In this case, the rise in the risk premium reduces asset prices and generates a demand recession.

Dynamics play a crucial role in this environment, as the recession is exacerbated by feedback mechanisms. In the main model, when the higher risk premium is expected to persist, the decline in future demand lowers expected earnings, which exerts further downward pressure on asset prices. With endogenous investment, there is a second mechanism, as the decline in current investment lowers the growth of potential output, which further reduces expected earnings and asset prices. In turn, the decline in asset prices feeds back into current consumption and investment, generating scope for severe spirals in asset prices and output. Figure 1 provides a graphical illustration of these dynamic mechanisms. The feedbacks are especially powerful when investors are *pessimistic* and interpret the higher risk premium as very persistent. Hence, beliefs matter in our economy not only because they have a direct impact on asset prices but also because they determine the strength of the amplification mechanism.

In this environment, speculation during the low risk premium phase (boom) further exacerbates the recession when there is a transition to the high risk premium phase. With heterogeneous asset valuations, which we capture with belief disagreements, the economy's degree of optimism depends on the share of wealth in the hands of optimists (or high-valuation investors). During recessions, the economy benefits from wealthy optimists because they raise asset valuations, increasing aggregate demand. However, disagreements naturally lead to speculation during booms, which depletes optimists' wealth during recessions. Specifically, optimists take on risk by selling insurance contracts to pessimists that enrich optimists if the boom persists but lead to a large reduction in their wealth when there is a transition to recession. This reallocation of wealth lowers asset prices and leads to a more severe recession.

These effects motivate *macroprudential policy* that restricts speculation during the boom. We show that macroprudential policy that makes optimistic investors behave as-if they were more pessimistic (implemented via portfolio risk limits) can generate a *Pareto improvement* in social welfare. This result is not driven by paternalistic concerns—the planner respects investors' own beliefs, and the result does not depend on whether optimists or pessimists are closer to the truth. Rather, the planner improves welfare by internalizing *aggregate demand externalities.* The depletion of optimists' wealth during a demand recession depresses asset prices and aggregate demand. Optimists (or more broadly, high-valuation investors) do not internalize the effect of their risk taking on asset prices and aggregate demand during the recession. This leads to excessive risk taking that is corrected by macroprudential policy. Moreover, our model supports *procyclical macroprudential policy.* While macroprudential policy can be useful during the recession, by restricting speculation, these benefits can be outweighed by its immediate negative impact on asset prices. This decline can be offset by the interest rate policy during the boom but not during the recession.

While there is an extensive empirical literature supporting the components of our model (see Section 7 for a brief summary), we extend this literature by presenting empirical evidence consistent with our results. We focus on three testable implications. First, our model predicts that negative risk premium shocks generate a more severe demand recession when the interest rate is constrained. Second, the recession reduces firms' earnings and leads to a further reduction in asset prices. Third, the recession is more severe when the shock takes place in an environment with more speculation.

To test these predictions, we assemble a quarterly panel data set of 21 advanced countries between 1990 and 2017, and subdivide the panel into countries that are part of the Eurozone or the European Exchange Rate Mechanism (*the Euro/ERM sample*) and those that have their own currencies (*the non-Euro/ERM sample*). The first group has constrained interest rate with respect to local asset price shocks, since they share a common monetary policy. The second group has less constrained interest rate. We use a local projection method as in Jordà (2005) to estimate impulse responses to surprise house price changes (our risk premium shock variable) separately for each sample. We absorb time and country fixed effects, and include controls for recent output growth and monetary policy. Thus the identification comes from comparing the outcomes in a country that experiences a house price change unrelated to its recent economic activity or monetary policy with the outcomes in countries in the same (Euro/ERM or non-Euro/ERM) sample but do not experience a change.

We find that a negative house price shock in a non-Euro/ERM country is associated with an initial decline in economic activity, followed by a decline in the policy interest rate and output stabilization. In contrast, a similar shock in a Euro/ERM country is associated with no interest rate response (compared to other Euro/ERM countries), which is followed by a more persistent and larger decline in economic activity. This supports our prediction that risk premium shocks generate a more severe demand recession in economies with constrained interest rate. We also find that the house price shock is followed by a larger decline in earnings and stock prices of publicly traded firms in the Euro/ERM sample than in the other sample (although the standard errors are larger for these results). This spillover effect supports our prediction that shocks are amplified due to the endogenous earnings response. Finally, we find that past bank credit expansion is associated with more severe outcomes following the house price shock in the Euro/ERM sample (but not in the other sample). Interpreting bank credit as a broad measure of speculation, both because banks are relatively high-valuation investors (due to their greater capacity and expertise to handle risk) and because they lend to optimists in the housing market, this provides some support for our final prediction that speculation amplifies the severity of the recession.

Literature review. Our paper is part of a large literature that emphasizes the links between asset prices and macroeconomic outcomes. Our model contributes to this literature by establishing a relationship between asset prices and aggregate demand even without financial frictions. This relates our paper to strands of the New-Keynesian literature that emphasize demand shocks that might drive business cycles while also affecting asset prices, such as "noise shocks" (Lorenzoni (2009); Blanchard et al. (2013)), "confidence shocks" (Ilut and Schneider (2014)), "uncertainty shocks" (Basu and Bundick (2017); Fernández-Villaverde et al. (2015)), and "disaster shocks" (Gourio (2012)). Aside from the modeling novelty (ours is a continuous time macrofinance model), we provide an integrated treatment of these and related forces. We refer to them as "risk premium shocks" to emphasize their close connection with asset prices and the finance literature on time-varying risk premia. Accordingly, we also make asset prices the central object in our theoretical and empirical analyses, breaking with convention in the New-Keynesian literature without financial frictions. More substantively, we show that heterogeneity in asset valuation matters in these environments. This heterogeneity matters because it leads to speculation that exacerbates demand recessions and provides a distinct rationale for macroprudential regulation.

The interactions between heterogeneous valuations, risk-premia, and interest rate lower bounds are also central themes of the literature on structural safe asset shortages and safety traps (see, for instance, Caballero and Farhi (2017); Caballero et al. (2017b)). Aside from emphasizing a broader set of factors that can drive the risk premium (in addition to safe asset scarcity), we contribute to this literature by focusing on dynamics. We analyze the connections between boom and recession phases of recurrent business cycles driven by risk premium shocks. Among other things, we show that speculation between "optimists" and "pessimists" during the boom exacerbates a future risk-centric demand recession, and derive the implications for macroprudential policy. In contrast, Caballero and Farhi (2017) show how "pessimists" can create a demand recession in otherwise normal times, and derive the implications for fiscal and unconventional monetary policies. More broadly, our paper is related to an extensive literature on liquidity traps that has exploded since the Great Recession (see, for instance, Tobin (1975); Krugman (1998); Eggertsson and Woodford

(2006); Eggertsson and Krugman (2012); Guerrieri and Lorenzoni (2017); Werning (2012); Hall (2011); Christiano et al. (2015); Eggertsson et al. (2017); Rognlie et al. (2017); Midrigan et al. (2016); Bacchetta et al. (2016)).

At a methodological level, our paper belongs in the new continuous time macrofinance literature started by the work of Brunnermeier and Sannikov (2014, 2016a) and summarized in Brunnermeier and Sannikov (2016b) (see also Basak and Cuoco (1998); Adrian and Boyarchenko (2012); He and Krishnamurthy (2012, 2013); Di Tella (2012); Moreira and Savov (2017); Silva (2016)). This literature seeks to highlight the full macroeconomic dynamics induced by financial frictions. While the structure of our economy shares many similarities with theirs, our model has no financial frictions, and the macroeconomic dynamics stem not from the supply side (relative productivity) but from the aggregate demand side.

Our results on macroprudential policy are related to recent work that analyzes the implications of aggregate demand externalities for the optimal regulation of financial markets. For instance, Korinek and Simsek (2016) show that, in the run-up to deleveraging episodes that coincide with a zero-lower-bound on the interest rate, policies targeted at reducing household leverage can improve welfare (see also Farhi and Werning (2017)). In these papers, macroprudential policy works by reallocating wealth across agents and states so that agents with higher marginal propensity to consume hold relatively more wealth when the economy is more depressed due to deficient demand. The mechanism in our paper is different and works through *heterogeneous asset valuations.* The policy operates by transferring wealth to optimists during recessions, not because optimists spend more than other investors, but because they raise asset valuations and induce *all investors to spend more* (while also increasing aggregate investment).[1]

The macroprudential literature beyond aggregate demand externalities is mostly motivated by the presence of pecuniary externalities that make the competitive equilibrium constrained inefficient (e.g., Caballero and Krishnamurthy (2003); Lorenzoni (2008); Bianchi and Mendoza (2013); Jeanne and Korinek (2010)). The friction in this literature is market incompleteness or collateral constraints that depend on asset prices (see Davila and Korinek (2016) for a detailed exposition). We show that a decline in asset prices is damaging not only because of the reasons emphasized in this literature, but also because it lowers aggregate demand through standard wealth and investment channels.

Our analysis of heterogeneous valuations and speculation via belief disagreements is related to a large finance literature (e.g., Lintner (1969); Miller (1977); Harrison and Kreps (1978); Varian (1989); Harris and Raviv (1993); Chen et al. (2002); Scheinkman and Xiong (2003); Fostel and Geanakoplos (2008); Geanakoplos (2010); Simsek (2013a,b); Iachan et al. (2015)). One strand of this literature emphasizes that disagreements can exacerbate asset price fluctuations by creating endogenous fluctuations in agents' wealth distribution (see, for instance, Basak (2000, 2005); Detemple and Murthy (1994); Zapatero (1998); Cao (2017); Xiong and Yan (2010); Kubler and Schmedders (2012); Korinek and Nowak (2016)). Our paper features similar forces but explores

---

[1] Also, see Farhi and Werning (2016) for a synthesis of some of the key mechanisms that justify macroprudential policies in models that exhibit aggregate demand externalities.

them in an environment where output is not necessarily at its supply-determined level due to interest rate rigidities.

The rest of the paper is organized as follows. In Section 2 we present an example that illustrates the main mechanism and motivates the rest of our analysis. Section 3 presents the general environment and defines the equilibrium. Section 4 characterizes the equilibrium in a benchmark setting with homogeneous beliefs. This section illustrates how risk premium shocks can lower asset prices and induce a demand recession, and how the recession is further exacerbated by feedback loops between asset prices and aggregate demand. Section 5 characterizes the equilibrium with belief disagreements, and illustrates how speculation exacerbates the recession. Section 6 illustrates the aggregate demand externalities associated with optimists' risk taking and establishes our results on macroprudential policy. Section 7 presents our empirical analysis on the relationship between house price shocks and demand recessions, and summarizes other supporting evidence from the related literature. Section 8 concludes. The (online) appendices contain the omitted derivations and proofs as well as the details of our empirical analysis.

2. A stepping-stone example

Here we present a simple (largely static) example that serves as a stepping stone into our main (dynamic) model. We start with a representative agent setup and illustrate the basic aggregate demand mechanism. We then consider belief disagreements and illustrate the role of speculation.

A two-period risk-centric aggregate demand model. Consider an economy with two dates, $t \in \{0,1\}$, a single consumption good, and a single factor of production—capital. For simplicity, capital is fixed (i.e., there is no depreciation or investment) and it is normalized to one. *Potential* output is equal to capital's productivity, z_t, but the actual output can be below this level due to a shortage of aggregate demand, $y_t \leq z_t$. For simplicity, we assume output is equal to its potential at the last date, $y_1 = z_1$, and focus on the endogenous determination of output at the previous date, $y_0 \leq z_0$. We assume the productivity at date 1 is uncertain and log-normally distributed so that,

$$\log y_1 = \log z_1 \sim N\left(g - \frac{\sigma^2}{2}, \sigma^2\right). \tag{1}$$

We also normalize the initial productivity to one, $z_0 = 1$, so that g captures the (log) expected growth rate of productivity, and σ captures its volatility.

There are two types of assets. There is a "market portfolio" that represents claims to the output at date 1 (which accrue to production firms as earnings), and a risk-free asset in zero net supply. We denote the price of the market portfolio with Q, and its log return with,

$$r^m(z_1) = \log \frac{z_1}{Q}. \tag{2}$$

We denote the log risk-free interest rate with r^f.

For now, the demand side is characterized by a representative investor, who is endowed with the initial output as well as the market portfolio (we introduce disagreements at the end of the section). At date 0, she chooses how much to consume, c_0, and what fraction of her wealth to allocate to the market portfolio, ω^m (with the residual fraction invested in the risk-free asset). When asset markets are in equilibrium, she will allocate all of her wealth to the market portfolio, $\omega^m = 1$, and her portfolio demand will determine the risk premium.

We assume the investor has Epstein-Zin preferences with the discount factor, $e^{-\rho}$, and the relative risk aversion coefficient (RRA), γ. For simplicity, we set the elasticity of intertemporal substitution (EIS) equal to 1. Later in this section, we will show that relaxing this assumption leaves our conclusions qualitatively unchanged. In the dynamic model, we will simplify the analysis further by setting RRA as well as EIS equal to 1 (which leads to time-separable log utility).

The supply side of the economy is described by New-Keynesian firms that have pre-set fixed prices. These firms meet the available demand at these prices as long as they are higher than their marginal cost (see Appendix B.1.2 for details). These features imply that output is determined by the aggregate demand for goods (consumption) up to the capacity constraint,

$$y_0 = c_0 \leq z_0. \tag{3}$$

Since prices are fully sticky, the real interest rate is equal to the nominal interest rate, which is controlled by the monetary authority. We assume that the interest rate policy attempts to replicate the supply-determined output level. However, there is a lower bound constraint on the interest rate, $r^f \geq 0$. Thus, the interest rate policy is described by, $r^f = \max\left(r^{f*}, 0\right)$, where r^{f*} is the natural interest rate that ensures output is at its potential, $y_0 = z_0$.

To characterize the equilibrium, first note that there is a tight relationship between output and asset prices. Specifically, the assumption on the EIS implies that the investor consumes a fraction of her lifetime income,

$$c_0 = \frac{1}{1+e^{-\rho}}\left(y_0 + Q\right). \tag{4}$$

Combining this expression with Eq. (3), we obtain the following equation,

$$y_0 = e^{\rho} Q. \tag{5}$$

We refer to this equation as *the output-asset price relation*—generally, it is obtained by combining the consumption function (and when there is investment, also the investment function) with goods market clearing. The condition says that asset prices increase aggregate wealth and consumption, which in turn leads to greater output.

Next, note that asset prices must also be consistent with equilibrium in risk markets. In Appendix A.1, we show that, up to a local approximation, the investor's optimal weight on the market portfolio is determined by,

$$\omega^m \sigma \simeq \frac{1}{\gamma} \frac{E\left[r^m\left(z_1\right)\right]+\frac{\sigma^2}{2}-r^f}{\sigma}. \tag{6}$$

In words, the optimal portfolio risk (left side) is proportional to "the Sharpe ratio" on the market portfolio (right side). The Sharpe ratio captures the reward per risk, where the reward is determined by the risk premium: the (log) expected return in excess of the (log) risk free rate. This is the standard risk-taking condition for mean-variance portfolio optimization, which applies exactly in continuous time. It applies approximately in the two-period model, and the approximation becomes exact when there is a representative household and the asset markets are in equilibrium ($\omega^m = 1$).

In particular, substituting the asset market clearing condition, $\omega^m = 1$, and the expected return on the market portfolio from Eqs. (1) and (2), we obtain the following equation,

$$\sigma = \frac{1}{\gamma} \frac{g - \log Q - r^f}{\sigma}. \tag{7}$$

We refer to this equation as *the risk balance condition*—generally, it is obtained by combining investors' optimal portfolio allocations with asset market clearing and the equilibrium return on the market portfolio. It says that, the equilibrium level of the Sharpe ratio on the market portfolio (right side) needs to be sufficiently large to convince investors to hold the risk generated by the productive capacity (left side).

Next, consider the supply-determined equilibrium in which output is equal to its potential, $y_0 = z_0 = 1$. Eq. (5) reveals that this requires the asset price to be at a particular level, $Q^* = e^{-\rho}$. Combining this with Eq. (7), the interest rate also needs to be at a particular level,

$$r^{f*} = g + \rho - \gamma\sigma^2. \tag{8}$$

Intuitively, the monetary policy needs to lower the interest rate to a low enough level to induce sufficiently high asset prices and aggregate demand to clear the goods market.

Now suppose the initial parameters are such that $r^{f*} > 0$, so that the equilibrium features Q^*, r^{f*} and supply-determined output, $y_0 = z_0 = 1$. Consider a "risk premium shock" that raises the volatility, σ, or risk aversion, γ. The immediate impact of this shock is to create an imbalance in the risk balance condition (7). The economy produces too much risk (left side) relative to what investors are willing to absorb (right side). In response, the monetary policy lowers the risk-free interest rate (as captured by the decline in r^{f*}), which increases the risk premium and equilibrates the risk balance condition (7). Intuitively, the monetary authority lowers the opportunity cost of risky investment and induces investors to absorb risk.

Next suppose the shock is sufficiently large so that the natural interest rate becomes negative, $r^{f*} < 0$, and the actual interest rate becomes constrained, $r^f = 0$. In this case, the risk balance condition is re-established with a decline in the price of the market portfolio, Q. This increases the expected return on risky investment, which induces investors to absorb risk. However, the decline in Q reduces aggregate wealth and induces a demand-driven recession. Formally, we combine Eqs. (5) and (7) to obtain,

$$\log y_0 = \rho + \log Q \text{ where } \log Q = g - \gamma \sigma^2. \tag{9}$$

Note also that, in the constrained region, asset prices and output become sensitive to beliefs about future prospects. For instance, an increase in the expected growth rate, g (optimism)—rational or otherwise—increases asset prices and mitigates the recession.

More general EIS. Now consider the same model with the difference that we allow the EIS, denoted by ε, to be different than one. Appendix A.2 analyzes this case and shows that the analogue of the output-asset price relation is given by [cf. Eq. (5)],

$$y_0 = e^{\rho\varepsilon} \left(R^{CE}\right)^{1-\varepsilon} Q. \tag{10}$$

Here, R^{CE} denotes the investor's certainty-equivalent portfolio return that we formally define in the appendix. The expression follows from the fact that consumption is not only influenced by a wealth effect, as in the baseline analysis, but also by substitution and income effects. When $\varepsilon > 1$, the substitution effect dominates. All else equal, a decline in the attractiveness of investment opportunities captured by a reduction in R^{CE} tends to reduce savings and increase consumption, which in turn increases output. Conversely, when $\varepsilon < 1$, the income effect dominates and a decline in R^{CE} tends to increase savings and reduce consumption and output.

We also show that the risk balance condition (7) remains unchanged (because the EIS does not affect the investor's portfolio problem). Furthermore, we derive the equilibrium level of the certainty-equivalent return as,

$$\log R^{CE} = g - \log Q - \frac{1}{2}\gamma \sigma^2. \tag{11}$$

As expected, R^{CE} decreases with the volatility, σ, and the risk aversion, γ.

These expressions illustrate that a risk premium shock that increases σ or γ affects consumption and aggregate demand through two channels. As before, it exerts a downward influence on asset prices, which reduces consumption through a wealth effect. But in this case it also exerts a downward influence on the certainty-equivalent return, which affects consumption further depending on the balance of income and substitution effects. When $\varepsilon > 1$, the second channel works against the wealth effect because investors substitute towards consumption. When $\varepsilon < 1$, the second channel reinforces the wealth effect.

In Appendix A.2, we complete the characterization of equilibrium and show that the net effect on *aggregate demand* is qualitatively the same as in the baseline analysis *regardless of the level of EIS*. In particular, a risk premium shock that increases γ or σ reduces "rstar" (see Eq. $(A.9)$).[2]

---

[2] The effect of this risk premium shock on Q^* is more subtle (see Eq. $(A.8)$). When $\varepsilon > 1$, Q^* declines, which means that "rstar" does not need to fully accommodate the risk premium shock. The reason is that the substitution effect supports current consumption and reduces the burden on wealth to support aggregate demand. The opposite

When the interest rate is constrained, $r^f = 0$, the shock reduces the equilibrium level of output y_0, as well as the asset price, Q (see Eq. $(A.10)$). When $\varepsilon > 1$, the substitution effect mitigates the magnitude of these declines but it does not overturn them—that is, the wealth effect ultimately dominates. Since the purpose of our model is to obtain qualitative insights, in the dynamic model we assume $\varepsilon = 1$ and isolate the wealth effect.[3]

Belief disagreements and speculation. Let us go back to the baseline case with $\varepsilon = 1$ and illustrate the role of speculation. Suppose that there are two types of investors with heterogeneous beliefs about productivity growth. Specifically, there are optimists and pessimists that believe $\log z_1$ is distributed according to, respectively, $N\left(g^o - \frac{\sigma^2}{2}, \sigma^2\right)$ and $N\left(g^p - \frac{\sigma^2}{2}, \sigma^2\right)$. We assume $g^o > g^p$ so that optimists perceive greater growth. Beliefs are dogmatic, that is, investors know each others' beliefs and they agree to disagree (and it does not matter for our mechanism whether any of them is closer to truth than the other). Optimists are endowed with a fraction α of the market portfolio and of date 0 output (and pessimists are endowed with the remaining fraction). Hence, α denotes the wealth share of optimists. The rest of the model is unchanged.

Following similar steps to those as in the baseline case, we solve for "rstar" as follows (see Appendix A.3),

$$r^{f*} \simeq \alpha g^o + (1-\alpha) g^p + \rho - \gamma\sigma^2. \tag{12}$$

When $r^{f*} < 0$, the interest rate is constrained and $r^f = 0$, so we have a demand recession with,

$$\log y_0 = \rho + \log Q, \text{ where } \log Q \simeq \alpha g^o + (1-\alpha) g^p - \gamma\sigma^2. \tag{13}$$

Hence, equilibrium prices and output depend on optimists' wealth share, α. During the recession, increasing α improves outcomes because optimists increase asset prices, which increases aggregate wealth and *everyone*'s spending. In our dynamic model, α will be endogenous because investors will (ex-ante) speculate on their different beliefs. Moreover, speculation will reduce α during the recession because optimists think the risk premium shock is unlikely. This will exacerbate the recession and motivate macroprudential policy. Next, we turn to a formal analysis of dynamics.

3. Dynamic environment and equilibrium

In this section we first introduce our general dynamic environment and define the equilibrium. We then describe the optimality conditions and provide a partial characterization of equilibrium. In subsequent sections we will further characterize this equilibrium in various special cases of interest. Throughout, we simplify the analysis by abstracting away from investment. In Appendix D.1, we extend the environment to introduce investment and endogenous growth. We discuss additional

---

happens when $\varepsilon > 1$, where the substitution effect is dominated by the income effect. In this case Q^* needs to rise to support aggregate demand, which is achieved by a larger decline in "rstar" following the risk premium shock.

[3] We further simplify the dynamic model by setting $\gamma = 1$ (which leads to log utility), because $\gamma \neq 1$ leads additional dynamic hedging motives that are not central for our analysis.

results related to investment at the end of Section 4.

Potential output and risk premium shocks. The economy is set in infinite continuous time, $t \in [0, \infty)$, with a single consumption good and a single factor of production, capital. Let $k_{t,s}$ denote the capital stock at time t and in the aggregate state $s \in S$. Suppose that, when fully utilized, $k_{t,s}$ units of capital produce $Ak_{t,s}$ units of the consumption good. Hence, $Ak_{t,s}$ denotes the potential output in this economy. Capital follows the process,

$$\frac{dk_{t,s}}{k_{t,s}} = gdt + \sigma_s dZ_t. \tag{14}$$

Here, g denotes the expected productivity growth, which is an exogenous parameter in the main text (it is endogenized in Appendix D.1 that introduces investment). The term, dZ_t, denotes the standard Brownian motion, which captures "aggregate productivity shocks."[4]

The states, $s \in S$, differ only in terms of the volatility of aggregate productivity, σ_s. For simplicity, there are only two states, $s \in \{1, 2\}$, with $\sigma_1 < \sigma_2$. State $s = 1$ corresponds to a low-volatility state, whereas state $s = 2$ corresponds to a high-volatility state. At each instant, the economy in state s transitions into the other state $s' \neq s$ according to a Poisson process. We use these volatility shocks to capture the time variation in the risk premium due to various unmodeled factors (see Section 2 for an illustration of how risk, risk aversion, or beliefs play a similar role in our analysis).

Transition probabilities and belief disagreements. We let $\lambda_s^i > 0$ denote the perceived Poisson transition probability in state s (into the other state) according to investor $i \in I$. These probabilities capture the degree of investors' (relative) optimism or pessimism. For instance, greater λ_2^i corresponds to greater optimism because it implies the investor expects the current high-risk-premium conditions to end relatively soon. Likewise, smaller λ_1^i corresponds to greater optimism because it implies the investor expects the current low-risk-premium conditions to persist longer. We set up the model for investors with heterogeneous beliefs (and in fact, this is the only exogenous source of heterogeneity). We first analyze the special case with common beliefs (Section 4) and then investigate belief disagreements and speculation (Section 5). When investors disagree, they have dogmatic beliefs (formally, investors know each others' beliefs and they agree to disagree).

Menu of financial assets. There are three types of financial assets. First, there is a market portfolio that represents a claim on all output (which accrues to production firms as earnings as we describe later). We let $Q_{t,s}k_{t,s}$ denote the price of the market portfolio, so $Q_{t,s}$ denotes the price per unit of capital. We let $r_{t,s}^m$ denote the instantaneous expected return on the market portfolio

---

[4] Note that fluctuations in $k_{t,s}$ generate fluctuations in potential output, $Ak_{t,s}$. We introduce Brownian shocks to capital, $k_{t,s}$, as opposed to total factor productivity, A, since this leads to a slightly more tractable analysis when we extend the model to include investment (see Appendix D). In the main text, we could equivalently introduce the shocks to A and conduct the analysis by normalizing all relevant variables with $A_{t,s}$ as opposed to $k_{t,s}$.

conditional on no transition. Second, there is a risk-free asset in zero net supply. We denote its instantaneous return by $r_{t,s}^{f}$. Third, in each state s, there is a contingent Arrow-Debreu security that trades at the (endogenous) price $p_{t,s}^{s'}$ and pays 1 unit of the consumption good if the economy transitions into the other state $s' \neq s$. This security is also in zero net supply and it ensures that the financial markets are dynamically complete.

Price and return of the market portfolio. Absent transitions, the price per unit of capital follows an endogenous but deterministic process,[5]

$$\frac{dQ_{t,s}}{Q_{t,s}} = \mu_{t,s}^{Q} dt \text{ for } s \in \{1,2\}. \tag{15}$$

Combining Eqs. (14) and (15), the price of the market portfolio (conditional on *no* transition) evolves according to,

$$\frac{d\left(Q_{t,s}k_{t,s}\right)}{Q_{t,s}k_{t,s}} = \left(g + \mu_{t,s}^{Q}\right) dt + \sigma_s dZ_t.$$

This implies that, absent state transitions, the volatility of the market portfolio is given by σ_s, and its expected return is given by,

$$r_{t,s}^{m} = \frac{y_{t,s}}{Q_{t,s}k_{t,s}} + g + \mu_{t,s}^{Q}. \tag{16}$$

Here, $y_{t,s}$ denotes the endogenous level of output at time t. The first term captures the "dividend yield" component of return. The second term captures the (expected) capital gain conditional on no transition, which reflects the expected growth of capital as well as of the price per unit of capital.

Eqs. $(15-16)$ describe the prices and returns conditional on *no* state transition. If there is a transition at time t from state s into state $s' \neq s$, then the price per unit of capital jumps from $Q_{t,s}$ to a potentially different level, $Q_{t,s'}$. Therefore, investors that hold the market portfolio experience instantaneous capital gains or losses that are reflected in their portfolio problem.

Consumption and portfolio choice. There is a continuum of investors denoted by $i \in I$, who are identical in all respects except for their beliefs about state transitions, λ_s^i. They continuously make consumption and portfolio allocation decisions. Specifically, at any time t and state s, investor i has some financial wealth denoted by $a_{t,s}^{i}$. She chooses her consumption rate, $c_{t,s}^{i}$; the fraction of her wealth to allocate to the market portfolio, $\omega_{t,s}^{m,i}$; and the fraction of her wealth to allocate to the contingent security, $\omega_{t,s}^{s',i}$. The residual fraction, $1 - \omega_{t,s}^{m,i} - \omega_{t,s}^{s',i}$, is invested in the risk-free asset. For analytical tractability, we assume the investor has log utility. The investor then solves a relatively standard portfolio problem that we formally state in Appendix B.1.1.

---

[5] In general, the price follows a diffusion process and this equation also features an endogenous volatility term, $\sigma_{t,s}^{Q} dZ_t$. In this model, we have $\sigma_{t,s}^{Q} = 0$ because we work with complete financial markets, constant elasticity preferences, and no disagreements aside from the probability of state transitions. These features ensure that investors allocate identical portfolio weights to the market portfolio (see Eq. (25) later in the section), which ensures that their relative wealth shares are not influenced by dZ_t. The price per capital can be written as a function of investors' wealth shares so it is also not affected by dZ_t.

Equilibrium in asset markets. Asset markets clear when the total wealth held by investors is equal to the value of the market portfolio before and after the portfolio allocation decisions,

$$\int_I a^i_{t,s} di = Q_{t,s} k_{t,s} \text{ and } \int_I \omega^{m,i}_{t,s} a^i_{t,s} di = Q_{t,s} k_{t,s}. \tag{17}$$

Contingent securities are in zero net supply, which implies,

$$\int_I a^i_{t,s} \omega^{s',i}_{t,s} di = 0. \tag{18}$$

The market clearing condition for the risk-free asset (which is also in zero net supply) holds when conditions (17) and (18) are satisfied.

Nominal rigidities and the equilibrium in goods markets. The supply side of our model features nominal rigidities similar to the standard New Keynesian model. We relegate the details to Appendix B.1.2. There is a continuum of monopolistically competitive production firms that own the capital stock and produce intermediate goods (which are then converted into the final good). For simplicity, these production firms have pre-set nominal prices that never change (see Remark 1 below for the case with partial price flexibility). The firms choose their capital utilization rate, $\eta_{t,s} \in [0,1]$, which leads to output, $y_{t,s} = \eta_{t,s} A k_{t,s}$. We assume firms can increase factor utilization for free until $\eta_{t,s} = 1$ and they cannot increase it beyond this level.

As we show in Appendix B.1.2, these features imply that output is determined by aggregate demand for goods up to the capacity constraint. Combining this with market clearing in goods, output is determined by aggregate consumption (up to the capacity constraint),

$$y_{t,s} = \eta_{t,s} A k_{t,s} = \int_I c^i_{t,s} di, \text{ where } \eta_{t,s} \in [0,1]. \tag{19}$$

Moreover, all output accrues to production firms in the form of earnings.[6] Hence, the market portfolio can be thought of as a claim on all production firms.

Interest rate rigidity and monetary policy. Our assumption that production firms do not change their prices implies that the aggregate nominal price level is fixed. The real risk-free interest rate, then, is equal to the nominal risk-free interest rate, which is determined by the interest rate policy of the monetary authority. We assume there is a lower bound on the nominal interest rate, which we set at zero for convenience,

$$r^f_{t,s} \geq 0. \tag{20}$$

---

[6] In this model, firms own the capital so the division of earnings in terms of return to capital and monopoly profits is indeterminate. Since there is no investment, this division is inconsequential. When we introduce investment in Appendix D, we make additional assumptions to determine how earnings are divided between return to capital and monopoly profits.

The zero lower bound is motivated by the presence of cash in circulation (which we leave unmodeled for simplicity).

We assume that the interest rate policy aims to replicate the level of output that would obtain without nominal rigidities subject to the constraint in (20). Without nominal rigidities, capital is fully utilized, $\eta_{t,s} = 1$ (see Appendix B.1.2). Thus, we assume that the interest rate policy follows the rule,

$$r^f_{t,s} = \max\left(0, r^{f,*}_{t,s}\right) \text{ for each } t \geq 0 \text{ and } s \in S. \tag{21}$$

Here, $r^{f,*}_{t,s}$ is recursively defined as the (instantaneous) natural interest rate that obtains when $\eta_{t,s} = 1$ and the monetary policy follows the rule in (21) at all future times and states.

Definition 1. *The equilibrium is a collection of processes for allocations, prices, and returns such that capital evolves according to* (14)*, price per unit of capital evolves according to* (15)*, its instantaneous return is given by* (16)*, investors maximize expected utility (cf. Appendix B.1.1), asset markets clear (cf. Eqs.* (17) *and* (18)*), production firms maximize earnings (cf. Appendix B.1.2), goods markets clear (cf. Eq.* (19)*), and the interest rate policy follows the rule in* (21)*.*

Remark 1 (Partial Price Flexibility)**.** *Our assumption of a fixed aggregate nominal price (or inflation) is extreme. However, allowing nominal price flexibility does not necessarily circumvent the bound in* (20)*. In fact, if monetary policy follows an inflation targeting policy regime, then partial price flexibility leads to price deflation during a demand recession. This strengthens the bound in* (20) *and exacerbates the recession (see Werning (2012); Korinek and Simsek (2016); Caballero and Farhi (2017) for further discussion, and Footnote 10 for a discussion of how partial price flexibility would also strengthen our results with belief disagreements).*

In the rest of this section, we provide a partial characterization of the equilibrium.

Investors' optimality conditions. We derive these optimality conditions in Appendix B.1.1. In view of log utility, the investor's consumption is a constant fraction of her wealth,

$$c^i_{t,s} = \rho a^i_{t,s}. \tag{22}$$

Moreover, the investor's weight on the market portfolio is determined by,

$$\omega^{m,i}_{t,s}\sigma_s = \frac{1}{\sigma_s}\left(r^m_{t,s} - r^f_{t,s} + \lambda^i_s \frac{1/a^i_{t,s'}}{1/a^i_{t,s}} \frac{Q_{t,s'} - Q_{t,s}}{Q_{t,s}}\right). \tag{23}$$

That is, she invests in the market portfolio up to the point at which the risk of her portfolio (left side) is equal to the "Sharpe ratio" of the market portfolio (right side). This is similar to the optimality condition in the two period model (cf. Eq. (6)) with the difference that the dynamic model also features state transitions. Our notion of the Sharpe ratio accounts for potential revaluation gains or losses from state transitions (the term, $\frac{Q_{t,s'}-Q_{t,s}}{Q_{t,s}}$) as well as the adjustment of marginal utility in case there is a transition (the term, $\frac{1/a^i_{t,s'}}{1/a^i_{t,s}}$).[7]

Finally, the investor's optimal portfolio allocation to the contingent securities implies,

$$\frac{p^{s'}_{t,s}}{\lambda^i_s} = \frac{1/a^i_{t,s'}}{1/a^i_{t,s}}. \tag{24}$$

The portfolio weight, $\omega^{s',i}_{t,s}$, is implicitly determined as the level that ensures this equality. The investor buys contingent securities until the price-to-(perceived)probability ratio of a state (or the state price) is equal to the investor's relative marginal utility in that state.

Substituting (24) into (23) shows that investors allocate identical portfolio weights to the market portfolio, $\omega^{m,i}_{t,s} = \omega^m_{t,s}$. Intuitively, investors express their differences in beliefs through their holdings of contingent securities. Combining this observation with Eq. (17), we further obtain that, in equilibrium, these identical portfolio weights are equal to one,

$$\omega^{m,i}_{t,s} = 1 \text{ for each } i. \tag{25}$$

Output-asset price relation. We next show that there is a tight relationship between output and asset prices as in the two period model. Combining Eqs. (22) and (17) implies that aggregate consumption is a constant fraction of aggregate wealth,

$$\int_I c^i_{t,s} di = \rho Q_{t,s} k_{t,s}. \tag{26}$$

Combining this with Eq. (19), we obtain the output-asset price relation,

$$A\eta_{t,s} = \rho Q_{t,s}. \tag{27}$$

As before, full factor utilization, $\eta_{t,s} = 1$, obtains only if the price per unit of capital is at a particular level $Q^* \equiv A/\rho$. This is the efficient price level that ensures the implied consumption clears the goods market. Likewise, the economy features a demand recession, $\eta_{t,s} < 1$, if and only if the price per unit of capital is strictly below Q^*.

Using the output-asset price relation (and $y_{t,s} = A\eta_{t,s}k_{t,s}$), we can rewrite Eq. (16) as,

$$r^m_{t,s} = \rho + g + \mu^Q_{t,s}. \tag{28}$$

In equilibrium, the dividend yield on the market portfolio is equal to the consumption rate ρ.

Combining the output-asset price relation with the interest rate policy in (21), we also summa-

---

[7] The presence of state transitions makes the Sharpe ratio in our model slightly different than its common definition, which corresponds to the expected return in excess of the risk-free rate normalized by volatility.

rize the goods market with,

$$Q_{t,s} \leq Q^*, r^f_{t,s} \geq 0, \text{ where at least one condition is an equality.} \tag{29}$$

In particular, the equilibrium at any time and state takes one of two forms. If the natural interest rate is nonnegative, then the interest rate policy ensures that the price per unit of capital is at the efficient level, $Q_{t,s} = Q^*$, capital is fully utilized, $\eta_{t,s} = 1$, and output is equal to its potential, $y_{t,s} = Ak_{t,s}$. Otherwise, the interest rate is constrained, $r^f_{t,s} = 0$, the price is at a lower level, $Q_{t,s} < Q^*$, and output is determined by aggregate demand according to Eq. (27).

For future reference, we also characterize the first-best equilibrium without interest rate rigidities. In this case, there is no lower bound constraint on the interest rate, so the price per unit of capital is at its efficient level at all times and states, $Q_{t,s} = Q^*$. Combining this with Eq. (28), we obtain $r^m_{t,s} = \rho + g$. Substituting this into Eq. (23) and using Eq. (25), we solve for "rstar" as,

$$r^{f*}_s = \rho + g - \sigma^2_s \text{ for each } s \in \{1, 2\}. \tag{30}$$

Hence, in the first-best equilibrium the risk premium shocks are fully absorbed by the interest rate. Next, we characterize the equilibrium with interest rate rigidities.

4. Common beliefs benchmark and amplification

In this section, we analyze the equilibrium in a benchmark case in which all investors share the same belief. That is, $\lambda^i_s \equiv \lambda_s$ for each i. We also normalize the total mass of investors to one so that individual and aggregate allocations are the same. We use this benchmark to illustrate how the spirals between asset prices and output exacerbate the recession.

Because the model is linear, we conjecture that the price and the interest rate will remain constant within states, $Q_{t,s} = Q_s$ and $r^f_{t,s} = r^f_s$ (in particular, there is no price drift, $\mu^Q_{t,s} = 0$). Since the investors are identical, we also have $\omega^m_{t,s} = 1$ and $\omega^{s'}_{t,s} = 0$. In particular, the representative investor's wealth is equal to aggregate wealth, $a_{t,s} = Q_{t,s}k_{t,s}$. Combining this with Eq. (23) and substituting for $r^m_{t,s}$ from Eq. (28), we obtain the following risk balance conditions,

$$\sigma_s = \frac{\rho + g + \lambda_s \left(1 - \frac{Q_s}{Q_{s'}}\right) - r^f_s}{\sigma_s} \text{ for each } s \in \{1, 2\}. \tag{31}$$

These equations are the dynamic counterpart to Eq. (7) in the two-period model. They say that, in each state, the total risk in the economy (the left side) is equal to the Sharpe ratio perceived by the representative investor (the right side). Note that the Sharpe ratio accounts for the fact that the aggregate wealth (as well as the marginal utility) will change if there is a state transition.[8]

---

[8] To see this, observe that the term, $\frac{Q_{t,s'}-Q_{t,s}}{Q_{t,s'}}$, in the equation is actually equal to, $\frac{Q_{t,s}}{Q_{t,s'}}\frac{Q_{t,s'}-Q_{t,s}}{Q_{t,s}}$. Here, $\frac{Q_{t,s'}-Q_{t,s}}{Q_{t,s}}$ denotes the capital gains and $\frac{Q_{t,s}}{Q_{t,s'}}$ denotes the marginal utility adjustment when there is a representative investor

The equilibrium is then characterized by finding four unknowns, $\left(Q_1, r_1^f, Q_2, r_2^f\right)$, that solve the two equations (31) together with the two goods market equilibrium conditions (29). We solve these equations under the following parametric restriction.

Assumption 1. $\sigma_2^2 > \rho + g > \sigma_1^2$.

In view of this restriction, we conjecture an equilibrium in which the low-risk-premium state 1 features positive interest rates, efficient asset prices, and full factor utilization, $r_1^f > 0, Q_1 = Q^*$ and $\eta_1 = 1$, whereas the high-risk-premium state 2 features zero interest rates, lower asset prices, and imperfect factor utilization, $r_2^f = 0, Q_2 < Q^*$ and $\eta_2 < 1$. In particular, the analysis with common beliefs reduces to finding two unknowns, $\left(Q_2, r_1^f\right)$, that solve the two risk balance equations (31) (after substituting $Q_1 = Q^*$ and $r_2^f = 0$).

Equilibrium in the high-risk-premium state. After substituting $r_2^f = 0$, the risk balance equation (31) for the high-risk-premium state $s = 2$ can be written as,

$$\sigma_2 = \frac{\rho + g + \lambda_2 \left(1 - \frac{Q_2}{Q^*}\right)}{\sigma_2}. \tag{32}$$

In view of Assumption 1, if the price were at its efficient level, $Q_2 = Q^*$, the risk (the left side) would exceed the Sharpe ratio (the right side). As in the two period model, the economy generates too much risk relative to what the investors are willing to absorb at the constrained level of the interest rate. As before, the price per unit of capital, Q_2, needs to decline to equilibrate the risk markets. Rearranging the expression, we obtain a closed form solution,

$$Q_2 = Q^* \left(1 - \frac{\sigma_2^2 - (\rho + g)}{\lambda_2}\right). \tag{33}$$

As this expression illustrates, we require a minimum degree of optimism to ensure an equilibrium with positive price and output.

Assumption 2. $\lambda_2 > \sigma_2^2 - (\rho + g)$.

This requirement is a manifestation of an amplification mechanism that we describe next.

Amplification from endogenous output and earnings. In the two period model of Section 2, the return on the market portfolio is $r^m(z_1) = z_1/Q$ [cf. Eq. (2)], which is decreasing in Q, whereas in the current model the expected return on the market portfolio absent state transitions is, $r^m = \rho + g$ [cf. Eq. (28)], which is constant. Hence, a decline in asset prices does not help to increase the market return any more (aside from state transitions). To see why this happens, note that the dividend yield term in Eq. (32) can be rewritten as $\frac{y_{t,2}}{Q_2 k_{t,2}}$, where $y_{t,2} = \rho Q_2 k_{t,2}$ [cf. (16)]. This illustrates that, if output (and firms' earnings) remained at the first-best level, $y_{t,2}^* = \rho Q^* k_{t,2}$,

---

(see (23)).

then a decline in the price per unit of capital would increase the dividend yield as well as the return on the market portfolio—a stabilizing force as in the two-period model. However, output in this setting is not constant and is increasing in the current price per unit of capital. A lower price reduces output and economic activity, which reduces firms' earnings and leaves the dividend yield constant. Hence, the output-asset price relation overturns an important stabilizing force from price declines and opens the door for amplification of these declines.

In view of this amplification mechanism, one might wonder how the risk market ever reaches equilibrium once the price, Q_2, starts to fall below its efficient level, Q^*. The stabilizing force is captured by the last term in Eq. (32), $\lambda_2\left(1-\frac{Q_2}{Q^*}\right)$. A decline in the price increases the expected capital gain from transition into the recovery state $s=1$, which increases the expected return to capital as well as the Sharpe ratio. Note that the stabilizing force is stronger when investors are more optimistic and perceive a higher transition probability into the recovery state, λ_2. Assumption 2 ensures that the stabilizing force is sufficiently strong to counter the impact of the risk premium shock. If this assumption were violated, a risk premium shock would trigger a downward price spiral that would lead to an equilibrium with zero asset prices and zero output.

Finally, consider the comparative statics of the equilibrium price with respect to the exogenous shifter of the risk premium, σ_2^2 [cf. (30)]. Using Eq. (33), we obtain $\frac{dQ_2}{d\sigma_2^2}=-\frac{1}{\lambda_2}$. Hence, risk premium shocks reduce asset prices (and output) by a greater magnitude when investors are more pessimistic about recovery (lower λ_2). These observations illustrate that beliefs matter in this environment not only because they have a direct impact on asset prices but also because they determine the strength of the amplification mechanism.

Equilibrium in the low-risk-premium state. Following similar steps for the low-risk-premium state $s=1$, we also obtain a closed form solution for the interest rate in this state,

$$r_1^f=\rho+g-\sigma_1^2-\lambda_1\left(\frac{Q^*}{Q_2}-1\right). \tag{34}$$

Intuitively, given the expected return on capital, the interest rate adjusts to ensure that the risk balance condition is satisfied with the efficient price level, $Q_1=Q^*$. For our conjectured equilibrium, we also assume an upper bound on λ_1 which ensures that the implied interest rate is positive.

Assumption 3. $\lambda_1<\left(\rho+g-\sigma_1^2\right)/\left(Q^*/Q_2-1\right)$, where Q^*/Q_2 is given by Eq. (33).

Note also that Eq. (34) implies r_1^f is decreasing in the transition probability, λ_1, as well as in the asset price drop conditional on transition, Q^*/Q_2. Intuitively, interest rates are kept relatively low by the fact that investors fear a recession triggered by an increase in the risk premium and constrained interest rate (an endogenous "disaster").

The following result summarizes the characterization of equilibrium in this section. The testable predictions regarding the effect of risk premium shocks on consumption and output follow from combining the characterization with Eqs. (26) and (27).

Proposition 1. *Consider the model with two states, $s \in \{1, 2\}$, with common beliefs and Assumptions 1-3. The low-risk-premium state 1 features a positive interest rate, efficient asset prices and full factor utilization, $r_1^f > 0, Q_1 = Q^*$ and $\eta_1 = 1$. The high-risk-premium state 2 features zero interest rate, lower asset prices, and a demand-driven recession, $r_2^f = 0, Q_2 < Q^*$, and $\eta_2 < 1$, as well as a lower level of consumption and output, $c_{t,2}/k_{t,2} = y_{t,2}/k_{t,2} = \rho Q_2$. The price in state 2 and the interest rate in state 1 are given by Eqs. (33) and (34).*

Equilibrium with investment and endogenous growth. In Appendix D.1, we extend the baseline environment to incorporate investment. This leads to two main changes. First, the growth rate in (14) becomes endogenous, $g_{t,s} = \varphi(\iota_{t,s}) - \delta$, where $\iota_{t,s} = \frac{i_{t,s}}{k_{t,s}}$ denotes investment rate per capital, $\varphi(\cdot)$ denotes a neoclassical production technology for capital, and δ denotes the depreciation rate. Second, under the simplifying assumption that output accrues to agents in the form of return to capital (i.e., no monopoly profits), optimal investment is an increasing function of the price per unit of capital, $Q_{t,s}$.[9] Moreover, using a convenient functional form for $\varphi(\cdot)$, we obtain a linear relation between the investment rate and the price, $\iota(Q_{t,s}) = \psi(Q_{t,s} - 1)$ for some $\psi > 0$.

In this setting, aggregate demand consists of the sum of consumption and investment. Using the expression for optimal investment, we also generalize the output-asset price relation (27) to,

$$A\eta_{t,s} = \rho Q_{t,s} + \psi(Q_{t,s} - 1). \tag{35}$$

Hence, output is increasing in asset prices not only because asset prices generate a wealth effect on consumption but also because they increase investment through a marginal-Q channel. Substituting optimal investment into the endogenous growth expression, we further obtain,

$$g_{t,s} = \psi q_{t,s} - \delta, \text{ where } q_{t,s} = \log Q_{t,s}. \tag{36}$$

Hence, this setting also features a *growth-asset price relation*: lower asset prices reduce investment, which translates into lower endogenous growth and lower potential output in future periods. The rest of the model is unchanged (see Appendix D.1 for details).

In Appendix D.2, we characterize the equilibrium in this extended environment and generalize Proposition 1. We find that risk premium shocks—captured by a transition to state 2—generate a decline in investment (and endogenous growth) as well as consumption and output as in the baseline version of the model. We test these predictions in Section 7. We also find that the decline in investment generates a second amplification mechanism that reinforces the mechanism we described earlier. Specifically, the recession lowers asset prices further not only by reducing output and earnings but also by reducing investment and growth (in potential output and earnings). Figure 1 in the introduction presents a graphical illustration of the two amplification mechanisms.

---

[9] Without this assumption, investment would be a function of $\tilde{Q}_{t,s} \leq Q_{t,s}$, which represents a claim on the rental rate of capital in future periods (excluding monopoly profits). The difference, $Q_{t,s} - \tilde{Q}_{t,s}$, captures the price of a claim on monopoly profits. Hence, allowing for profits would have a quantitative impact on investment, though we believe it would leave our qualitative results unchanged. We leave an investigation of this issue for future research.

5. Belief disagreements and speculation

Going back to the baseline model, we next investigate the effect of belief disagreements. We show that *speculation* induced by belief disagreements exacerbates recessions and motivates macroprudential policy.

We restrict attention to two types of investors, optimists and pessimists, with beliefs denoted by, $\left\{\left(\lambda_1^i, \lambda_2^i\right)\right\}_{i\in\{o,p\}}$. We normalize the mass of each belief type to one so that $i = o$ and $i = p$ denote, respectively, the representative optimist and pessimist. We assume the beliefs satisfy the following:

Assumption 4. $\lambda_2^o > \lambda_2^p$ and $\lambda_1^o \leq \lambda_1^p$.

When the economy is in the high-risk-premium state, optimists find the transition into the low-risk-premium state relatively likely ($\lambda_2^o > \lambda_2^p$); when the economy is in the low-risk-premium state, optimists find the transition into the high-risk-premium state relatively unlikely ($\lambda_1^o \leq \lambda_1^p$). Hence, optimism and pessimism are *relative*: an optimist is someone who is optimistic relative to a pessimist. In fact, we do not need to specify the "objective distribution" for our theoretical results (including the welfare results). We do, however, need the relative optimism and pessimism to be persistent across the two risk premium states (see Remark 2 at the end of this section).

To characterize the equilibrium, we define the wealth-weighted average transition probability,

$$\overline{\lambda}_{t,s} \equiv \overline{\lambda}_s\left(\alpha_{t,s}\right) \equiv \alpha_{t,s}\lambda_s^o + \left(1-\alpha_{t,s}\right)\lambda_s^p, \text{ where } \alpha_{t,s}^o = \frac{a_{t,s}^o}{k_{t,s}Q_{t,s}}. \tag{37}$$

Here, $\alpha_{t,s}$ denotes optimists' wealth share, and it is the payoff-relevant state variable in this economy. The notation, $\overline{\lambda}_s\left(\alpha_{t,s}\right)$, describes the wealth-weighted average belief in state s as a function of optimists' wealth share, and $\overline{\lambda}_{t,s}$ denotes the belief at time t and state s. This belief is central to the analysis because the following analogue of the risk balance condition (31) holds in this setting (see Appendix B.3),

$$\sigma_s = \frac{1}{\sigma_s}\left(\rho + g + \mu_{t,s}^Q + \overline{\lambda}_{t,s}\left(1 - \frac{Q_{t,s}}{Q_{t,s'}}\right) - r_{t,s}^f\right) \text{ for each } s \in \{1,2\}. \tag{38}$$

In particular, the equilibrium in risk markets is determined according to the wealth-weighted average belief. When $\alpha_{t,s}$ is greater, optimists exert a greater influence on asset prices. Note also that the expected return to the market portfolio features the price drift term, $\mu_{t,s}^Q$ [cf. (28)], which is not necessarily zero in this section because optimists' wealth share is nonstationary.

We must now characterize the dynamics of optimists' wealth share, $\alpha_{t,s}$ (and thus, the dynamics of $\overline{\lambda}_{t,s}$). Eq. (25) implies investors' weights on the market portfolio satisfy $\omega_{t,s}^{m,o} = \omega_{t,s}^{m,p} = 1$. In Appendix B.3, we also solve for investors' weights on the contingent securities,

$$\omega_{t,s}^{s',o} = \lambda_s^o - \overline{\lambda}_{t,s} = \left(\lambda_s^o - \lambda_s^p\right)\left(1-\alpha_{t,s}\right). \tag{39}$$

Thus, investors settle their disagreements on the jump risk by trading the contingent securities.

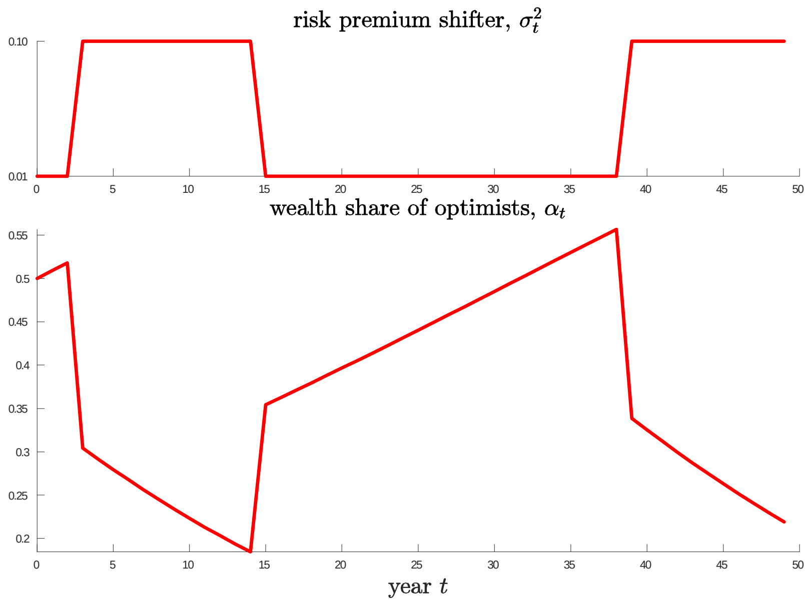

Figure 2: A simulation of the dynamics of optimists' wealth share over time.

Optimists take a positive position on a contingent security whenever their belief for the transition probability exceeds the weighted average belief. This implies that their wealth share evolves according to [cf. Eqs. $(B.13)$ and $(B.14)$],

$$\begin{cases} \dot{\alpha}_{t,s} = \left(\lambda_s^p - \lambda_s^o\right) \alpha_{t,s} \left(1 - \alpha_{t,s}\right), & \text{if there is no state change,} \\ \alpha_{t,s'} / \alpha_{t,s} = \lambda_s^o / \overline{\lambda}_{t,s}, & \text{if there is a state change to } s'. \end{cases} \tag{40}$$

Here, $\dot{\alpha}_{t,s} = \frac{d\alpha_{t,s}}{dt}$ denotes the derivative with respect to time. As long as the economy remains in the boom state, optimists' wealth share drifts upwards (since $\lambda_1^o < \lambda_1^p$), because they make profits from selling insurance—contingent contracts that pay in the recession state. If there is a jump to the recession state, optimists' wealth share makes a downward jump. Conversely, optimists' wealth share drifts downwards in the recession state, and it makes an upward jump if there is a transition to the boom state. Figure 2 illustrates the dynamics of optimists' wealth share for a particular parameterization and realization of uncertainty.

These observations also imply that the weighted average belief in (37) (that determines asset prices) is effectively *extrapolative* in the sense that good realizations increase effective optimism whereas bad realizations reduce it. Specifically, as the boom state persists, optimists' wealth share increases and the aggregate belief becomes more optimistic. After a transition to the recession state, the aggregate belief becomes less optimistic. Similarly, the aggregate belief becomes less optimistic as the recession persists, and it becomes more optimistic after a transition into the boom.

Eq. (40) determines the evolution of optimists' wealth share (and thus, the weighted average belief) regardless of the level of asset prices and output. The equilibrium is determined by jointly solving this expression together with the risk balance condition (38) and the goods market equilibrium condition (29). To make progress, we suppose Assumptions 1-3 from the previous section hold according to both belief types. This ensures that, regardless of the wealth shares, the low-risk-premium state 1 features a positive interest rate, efficient price level, and full factor utilization, $r^f_{t,1} > 0, Q_{t,1} = Q^*, \eta_{t,1} = 1$, and the high-risk-premium state 2 features a zero interest rate, a lower price level, and insufficient factor utilization, $r^f_{t,2} = 0, Q_{t,2} < Q^*, \eta_{t,2} < 1$. We next characterize this equilibrium starting with the high-risk-premium state. In this as well as the next section, we also find it convenient to work with the log of the price level, $q_{t,s} \equiv \log Q_{t,s}$.

Equilibrium in the high-risk-premium state. Consider the risk balance equation (38) for state $s = 2$. Using $\mu^Q_{t,2} = \frac{dQ_{t,2}/dt}{Q_{t,2}} = \dot{q}_{t,2}$, we obtain the following analogue of Eq. (32),

$$\sigma_2 = \frac{1}{\sigma_2}\left(\rho + g + \dot{q}_{t,2} + \overline{\lambda}_{t,2}\left(1 - \frac{Q_2}{Q^*}\right)\right). \tag{41}$$

Combining this with Eq. (40), we obtain a differential equation system that describes the joint dynamics of the log price and optimists' wealth share, $(q_{t,2}, \alpha_{t,2})$, conditional on no transition. In Appendix B.3, we show that this system is saddle path stable: for any initial wealth share, $\alpha_{t,2} \in (0,1)$, there exists a unique equilibrium price level, $q_{t,2} \in [q^p_2, q^o_2)$, such that the solution satisfies $\lim_{t\to\infty} \alpha_{t,2} = 0$ and $\lim_{t\to\infty} q_{t,2} = q^p_2$. Here, q^i_2 denotes the log price level with common beliefs characterized in Section 4 corresponding to type i investors' belief. The system is also stationary, which implies that the price can be written as a function of optimists' wealth share. The price function, $q_2(\alpha)$, is characterized as the solution to the following differential equation in α-domain,

$$q_2'(\alpha)\left(\lambda^o_2 - \lambda^p_2\right)\alpha(1-\alpha) = \rho + g + \overline{\lambda}_2(\alpha)\left(1 - \frac{\exp(q_2(\alpha))}{Q^*}\right) - \sigma_2^2, \tag{42}$$

with boundary conditions, $q_2(0) = q^p_2$ and $q_2(1) = q^o_2$. We further show that $q_2(\alpha)$ is strictly increasing in α. As in the previous section, greater optimism increases the asset price in the high-risk-premium state. The left panel of Figure 3 illustrates the equilibrium price function for a particular parameterization.[10]

Equilibrium in the low-risk-premium state. Following similar steps for the risk balance condition for the low-risk-premium state $s = 1$, we obtain,

$$r^f_1(\alpha) = \rho + g - \overline{\lambda}_1(\alpha)\left(\frac{Q^*}{\exp(q_2(\alpha'))} - 1\right) - \sigma_1^2 \text{ where } \alpha' = \frac{\alpha\lambda^o_1}{\overline{\lambda}_1(\alpha)}. \tag{43}$$

Here, $r^f_1(\alpha)$ denotes the interest rate when optimists' wealth share is equal to α. The term, α', denotes optimists' wealth share after an immediate transition into the high-risk-premium state [cf.

---

[10] Introducing partial nominal price flexibility along the lines discussed in Remark 1 would create a second channel by which increasing optimists' wealth share would increase real asset prices. In that environment, pessimists would perceive lower expected inflation than optimists (because they believe the economy is more likely to stay in recession), which would lead to a greater perceived real interest rate and lower real asset valuations.

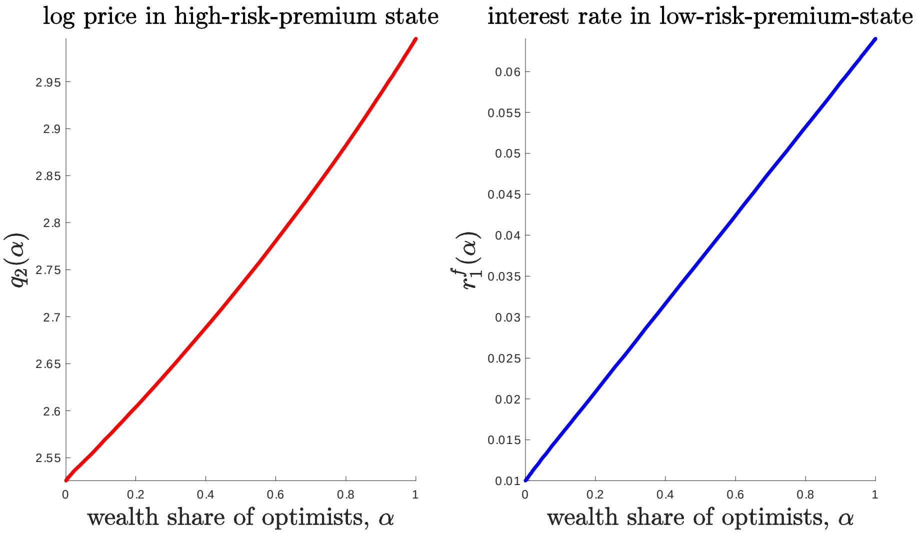

Figure 3: Equilibrium price and interest rate functions with heterogeneous beliefs.

Eq. (40)]. The interest rate depends on (among other things) the weighted average transition probability into the high-risk-premium state, $\overline{\lambda}_1(\alpha)$, as well as the price level that would obtain after transition, $q_2(\alpha')$. It is easy to check that $r_1^f(\alpha)$ is increasing in α, since, as in the previous section, greater optimism increases asset prices. The right panel of Figure 3 illustrates the interest rate function.

The following proposition summarizes the characterization of equilibrium. The last part, which follows by combining the characterization with Eqs. (26) and (27), shows that greater optimists' wealth share in the high-risk-premium state mitigates the severity of the recession.

Proposition 2. *Consider the model with two belief types. Suppose Assumptions 1-3 hold for each belief, and that beliefs are ranked according to Assumption 4. Then, optimists' wealth share evolves according to Eq.* (40)*. The equilibrium log-price and interest rate can be written as a function of optimists' wealth share,* $q_1(\alpha), r_1^f(\alpha), q_2(\alpha), r_2^f(\alpha)$*. In the low-risk-premium state,* $q_1(\alpha) = q^*$*, and* $r_1^f(\alpha)$ *is an increasing function of* α *given by Eq.* (43)*. In the high-risk-premium state,* $r_2^f(\alpha) = 0$*, and* $q_2(\alpha)$ *is an increasing function of* α *that solves the differential equation* (42) *with* $q_2(0) = q_2^p$ *and* $q_2(1) = q_2^o$*. Greater optimists' wealth share in the high-risk-premium state,* $\alpha_{t,2}$*, increases the price per capital,* $Q_{t,2}$*, as well as consumption and output,* $c_{t,2}/k_{t,2} = y_{t,2}/k_{t,2} = \rho Q_{t,2}$*.*

Amplification from speculation. We next illustrate how speculation further amplifies the business-cycle driven by risk premium shocks. To this end, we fix investors' beliefs and simulate the equilibrium for a particular realization of uncertainty over a 50-year horizon. We choose the (objective) simulation belief to be in the "middle" of optimists' and pessimists' beliefs in terms of the relative entropy distance.[11] Figure 4 illustrates the dynamics of equilibrium variables (except

---

[11] This ensures that there is a non-degenerate long-run wealth distribution in which neither optimists nor pessimists permanently dominate, which helps to visualize the destabilizing effects of speculation without taking a stand on

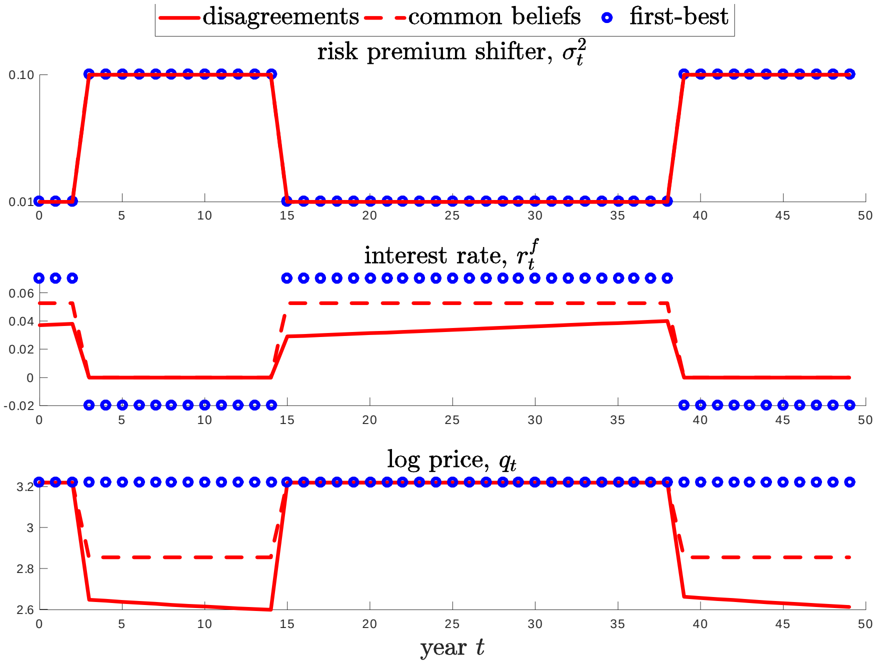

Figure 4: A simulation of the dynamics of equilibrium variables over time with belief disagreements (solid red line), with common beliefs (dashed red line), and the first-best benchmark (circled blue line).

for optimists' wealth share, which we plot in Figure 2). For comparison, the dashed red line plots the equilibrium that would obtain in the common-beliefs benchmark if all investors shared the "middle" simulation belief, and the circled blue line plots the first-best equilibrium that would obtain without interest rate rigidities.

The figure illustrates two points. First, consistent with our baseline analysis in the previous section, the price per unit of capital is more volatile and the interest rate is more compressed than in the first-best equilibrium. In the high-risk-premium state, the interest rate cannot decline sufficiently to equilibrate the risk balance condition, which leads to a drop in asset prices and a demand recession. In the low-risk-premium state, the fear of transition into the recessionary high-risk-premium state keeps the interest rate lower than in the first-best benchmark.

Second, risk-centric recessions are more severe when investors have belief disagreements (and this also leads to more compressed interest rates). The intuition follows from Figures 2 and 3. Speculation in the low-risk-premium state decreases optimists' wealth share once the economy

---

whether optimists and pessimists are "correct." Our welfare results in the next section do not require this assumption since we evaluate investors' expected utilities according to their own beliefs.

Formally, given two probability distributions $(p(\tilde{s}))_{\tilde{s}\in S}$ and $(q(\tilde{s}))_{\tilde{s}\in S}$, relative entropy of p with respect to q is defined as $\sum_{\tilde{s}} p(\tilde{s}) \log\left(\frac{p(\tilde{s})}{q(\tilde{s})}\right)$. Blume and Easley (2006) show that, in a setting with independent and identically distributed shocks (and identical discount factors), only investors whose beliefs have the maximal relative entropy distance to the true distribution survive. Since our setting features Markov shocks, we apply their result state-by-state to pick the simulation belief that ensures conditional transition probabilities satisfy the necessary survival condition for optimists as well as pessimists.

transitions into the high-risk-premium state, as illustrated by Figure 2, which translates into lower asset prices and a more severe demand recession, as illustrated by Figure 3 and Proposition 2. Speculation also increases optimists' wealth share if the boom continues, but this effect does not translate into higher asset prices or output since it is (optimally) neutralized by the interest rate response. The adverse effects of speculation on demand recessions motivates the analysis of macroprudential policy, which we analyze in the next section.

Remark 2 (Interpretatation of Belief Disagreements)**.** *As this discussion suggests, what matters for our results on speculation is* persistent heterogeneous valuations *for risky assets that ensure: (i) during the boom, high-valuation investors absorb relatively more of the recession risks, and (ii) during the recession, greater wealth share of high-valuation investors increases the (relative) price of risky assets. Belief disagreements generate these features naturally, under the mild assumption that optimists and pessimists do not flip roles across booms and recessions,*[12] *but other sources of heterogeneous valuations would lead to similar results. For example, with heterogeneity in risk aversion, more risk tolerant agents take on more aggregate risk (i.e., they insure less risk tolerant agents), which reduces their wealth share and the (relative) price of risky assets following negative shocks to fundamentals (see, for instance, Garleanu and Pedersen (2011); Longstaff and Wang (2012)). From this perspective, belief disagreements can also capture institutional reasons for heterogeneous valuations such as capacity or mandates for handling risk. Investment banks, for example, have far larger capacity to handle and lever risky positions than pensioners and money market funds.*

6. Welfare analysis and macroprudential policy

Since our model features constrained monetary policy, most of the aggregate demand boosting policies that have been discussed in the New Keynesian literature are also effective in our environment. We skip a discussion of these policies for brevity (our results would still apply as long as these policies are imperfect). Instead, we focus on *macroprudential* policy interventions that impose restrictions on risk market participants, which play a central role in our analysis, with the objective of obtaining macroeconomic benefits. In practice, most macroprudential policies restrict risk taking by banks—especially large ones. Interpreting banks as relatively high-valuation investors (see Remark 2) or as lenders to such investors (see Section 7), we capture these policies in reduced form by imposing portfolio risk limits on relatively optimistic investors.

Formally, using the model with two belief types from the previous section, we characterize investors' value functions in equilibrium. This establishes the determinants of welfare and illustrates the aggregate demand externalities. We then show that macroprudential policy that induces optimists to act more pessimistically (via appropriate portfolio risk limits), but that otherwise does not distort allocations, can generate a *Pareto* improvement of social welfare. We focus on macroprudential policy in the boom (low-risk-premium) state and provide a brief discussion of the

---

[12] This assumption is supported by an extensive psychology literature that documents the prevalence of optimism, as well as its heterogeneity and persistence, since it is largely a personal trait (see Carver et al. (2010) for a review).

macroprudential policy in the recession (high-risk-premium) state.

Value function in equilibrium. Because the model is linear, investors' expected utility can be written as (see Appendix B.1.1),

$$V_{t,s}^{i}\left(a_{t,s}^{i}\right)=\frac{\log\left(a_{t,s}^{i}/Q_{t,s}\right)}{\rho}+v_{t,s}^{i}. \tag{44}$$

Here, $v_{t,s}^{i}$ denotes the normalized value function per unit of capital stock. In Appendix C.1, we further characterize it as the solution to the following differential equation system,

$$\rho v_{t,s}^{i}-\frac{\partial v_{t,s}^{i}}{\partial t}=\log\rho+q_{t,s}+\frac{1}{\rho}\left(\begin{array}{c} g-\frac{1}{2}\sigma_{s}^{2} \\ -\left(\lambda_{s}^{i}-\overline{\lambda}_{t,s}\right)+\lambda_{s}^{i}\log\left(\frac{\lambda_{s}^{i}}{\overline{\lambda}_{t,s}}\right)\end{array}\right)+\lambda_{s}^{i}\left(v_{t,s'}^{i}-v_{t,s}^{i}\right). \tag{45}$$

The equilibrium price, $q_{t,s}$, affects investors' welfare since it determines output and consumption [cf. Eqs. (26) and (27)]. Consumption growth, g, and volatility, σ_{s}^{2}, also affect welfare. Finally, speculation affects investors' (perceived) welfare. This is captured by the term, $-\left(\lambda_{s}^{i}-\overline{\lambda}_{t,s}\right)+\lambda_{s}^{i}\log\left(\frac{\lambda_{s}^{i}}{\overline{\lambda}_{t,s}}\right)$, which is zero with common beliefs, and strictly positive with disagreements.

Gap value function. To facilitate the policy analysis, we break down the value function into two components,

$$v_{t,s}^{i}=v_{t,s}^{i,*}+w_{t,s}^{i}. \tag{46}$$

Here, $v_{t,s}^{i,*}$ denotes *the first-best value function* that would obtain if there were no interest rate rigidities. It is characterized by solving Eq. (45) with the efficient price level, $q_{t,s}=q^{*}$, for each t,s. The residual, $w_{t,s}^{i}=v_{t,s}^{i}-v_{t,s}^{i,*}$, denotes *the gap value function*, which captures the loss of value due to interest rate rigidities and demand recessions. As we will see below, the first-order impact of macroprudential policy on social welfare depends only on the gap value function. Using Eq. (45), we characterize the gap value function as the solution to the following system,

$$\rho w_{t,s}^{i}=q_{t,s}-q^{*}+\frac{\partial w_{t,s}^{i}}{\partial t}+\lambda_{s}^{i}\left(w_{t,s'}^{i}-w_{t,s}^{i}\right). \tag{47}$$

This illustrates that, in view of the output-asset price relation (27), the gap value function depends on the asset prices relative to the efficient level. Recall also that the equilibrium features $q_{t,1}=q^{*}$ and $q_{t,2}<q^{*}$. Thus, the key objective of policy interventions in this environment is to increase the asset price in the high-risk-premium state (so as to mitigate the demand recession).

Aggregate demand externalities. In Appendix C.1, we show that the gap value function can be written as a function of optimists' wealth share, $w_{s}^{i}(\alpha)$. Combining Eqs. (47) and (40), we also characterize this function as the solution to the following system in α-domain,

$$\rho w_s^i(\alpha) = q_s(\alpha) - q^* - (\lambda_s^o - \lambda_s^p)\,\alpha(1-\alpha)\frac{\partial w_s^i(\alpha)}{\partial \alpha} + \lambda_s^i\left(w_{s'}^i(\alpha') - w_s^i(\alpha)\right), \tag{48}$$

where $\alpha' = \alpha\lambda_s^o/\overline{\lambda}_s(\alpha)$. Recall that the price function in the high-risk-premium state, $q_2(\alpha)$, is increasing in optimists' wealth share [cf. Figure 3]. This leads to the following result.

Lemma 1. *The gap value function satisfies,* $\frac{dw_s^i(\alpha)}{d\alpha} > 0$ *for each* s, i *and* $\alpha \in (0,1)$.

Intuitively, optimists' wealth share is a scarce resource that brings asset prices and output in the high-risk-premium state closer to its first-best level. Thus, the gap value function in the high-risk-premium state is increasing in optimists' wealth share. The gap value function in the other state is also increasing, because the economy can always transition into the high-risk-premium state, where optimists' wealth share is useful (see Lemma 2 below for a ranking of the marginal value of optimists' wealth share across the two states).

The result also illustrates the *aggregate demand externalities.* Optimists' wealth share is an endogenous variable that fluctuates due to investors' portfolio decisions [cf. Figure 2]. Individual optimists that take positions in contingent markets—and pessimists that take the other side of these positions—do not take into account the impact of their decisions on asset prices and social welfare. This leads to inefficiencies that can be corrected by macroprudential policy.

Equilibrium and gap value functions with macroprudential policy. To evaluate the direction of the inefficiency, we consider a constrained policy exercise where the planner can induce optimists to choose allocations as if they have less optimistic beliefs.[13] Specifically, optimists are constrained to choose allocations *as-if* they have the beliefs, $\lambda^{o,pl} \equiv \left(\lambda_1^{o,pl}, \lambda_2^{o,pl}\right)$, that satisfy, $\lambda_1^{o,pl} \geq \lambda_1^o$ and $\lambda_2^{o,pl} \leq \lambda_2^o$. Pessimists continue to choose allocations according to their own beliefs. Throughout, we use $\lambda_s^{i,pl}$ to denote investors' as-if beliefs and λ_s^i to denote their actual beliefs (for pessimists, the two beliefs coincide). We also use $\overline{\lambda}_s^{pl}(\alpha) = \alpha\lambda_s^{o,pl} + (1-\alpha)\lambda_s^p$ to denote the weighted average as-if belief.

In Appendix C.2, we show that the planner can implement this policy by imposing inequality restrictions on optimists' portfolio weights, while allowing them to make unconstrained consumption-savings decisions. Specifically, when the risk premium is low, the policy constrains optimists from taking too negative a position on the contingent security that pays if there is a transition to the high-risk-premium state, $\omega_{t,1}^{2,o} \geq \underline{\omega}_{t,1}^{2,o}$ (restrictions on selling "put options"). When the risk premium is high, the policy constrains optimists from taking too large a position on the contingent security that pays if there is a transition to the low-risk-premium state, $\omega_{t,2}^{1,o} \leq \overline{\omega}_{t,2}^{1,o}$ (restrictions on buying "call options"). Finally, in either state, the policy also constrains optimists' weight on the market portfolio not to exceed the market average, $\omega_{t,s}^{m,o} \leq 1$ (since otherwise optimists start to speculate by increasing their exposure to the market portfolio).

---

[13] For simplicity, we restrict attention to time-invariant policies. The planner commits to a policy at time zero, $\left(\lambda_1^{o,pl}, \lambda_2^{o,pl}\right)$, and implements it throughout.

The characterization of equilibrium with policy is then the same as in Section 5. In particular, Eqs. (40) and (41) still hold with the only difference that investors' beliefs are replaced with their as-if beliefs, $\lambda_s^{i,pl}$. We denote the resulting price functions with $q_s^{pl}(\alpha)$ to emphasize that they are determined by as-if beliefs (as opposed to actual beliefs). On the other hand, the equation system that characterizes the gap value function is given by,

$$\rho w_s^i(\alpha) = q_s^{pl}(\alpha) - q^* - \left(\lambda_s^{o,pl} - \lambda_s^p\right)\alpha(1-\alpha)\frac{\partial w_s^i(\alpha)}{\partial \alpha} + \lambda_s^i\left(w_{s'}^i\left(\alpha'^{,pl}\right) - w_s^i(\alpha)\right) \tag{49}$$

where $\alpha'^{,pl} = \alpha\lambda_s^{o,pl}/\overline{\lambda}_s^{o,pl}(\alpha)$. Comparing this with Eq. (48) illustrates that the macroprudential policy can affect the gap value through two potential channels. First, it might affect the equilibrium asset prices (captured by the term, $q_s^{pl}(\alpha)$). Second, the policy affects the dynamics of optimists' wealth share, which in turn influence the gap value. For example, in the low-risk-premium state $s = 1$, the policy increases $\lambda_1^{o,pl}$, which induces optimists to increase their position on the contingent security that pays if there is a transition into the high-risk-premium state [cf. Eq. (39)]. This increases optimists' wealth share after a transition (captured by the term, $\alpha'^{,pl}$) at the expense of reducing optimists' wealth share in case there is no transition (captured by the term, $-\left(\lambda_s^{o,pl} - \lambda_s^p\right)$).

Planner's Pareto problem. To trace the Pareto frontier, we allow the planner to make a one-time wealth transfer among the investors at time zero. In Appendix C.2, we show that the planner's Pareto problem can then be reduced to,

$$\max_{\lambda^{o,pl}} v_{0,s}^{pl} = \alpha_{0,s} v_{0,s}^o + (1-\alpha_{0,s})\, v_{0,s}^p. \tag{50}$$

Hence, the planner maximizes a wealth-weighted average of investors' normalized values (where the wealth shares correspond to Pareto weights). We also decompose the planner's value function into first-best and gap value components, $v_{0,s}^{pl} = v_{0,s}^{pl,*} + w_{0,s}^{pl}$. A key observation is that, in view of the First Welfare Theorem, the marginal impact of the policy on the planner's first-best value function is zero, $\left.\frac{\partial v_{0,s}^{pl,*}}{\partial \lambda^{o,pl}}\right|_{\lambda^{o,pl}=\lambda^o} = 0$.[14] Thus, the first order impact of the policy is characterized by its impact on the planner's gap value function,

$$w_{0,s}^{pl} = \alpha_{0,s} w_{0,s}^o + (1-\alpha_{0,s})\, w_{0,s}^p. \tag{51}$$

Macroprudential policy in the low-risk-premium state. Now suppose the economy is in the low-risk-premium state $s = 1$. The planner can use macroprudential policy in the current state, $\lambda_1^{o,pl} \geq \lambda_1^o$ (she can induce optimists to act as if transition into the recession is more likely), but not in the other state $\lambda_2^{o,pl} = \lambda_2^o$ (she cannot influence optimists' actions in the recession state).

---

[14] This is because our model features complete markets and no frictions other than interest rate rigidities. Hence, the First Welfare Theorem applies to the first-best allocations that also correct for these rigidities. This implies that the marginal impact on the first-best value must be zero, since otherwise the first-best allocations could be Pareto improved by appropriately changing optimists' as-if beliefs.

Effectively, this policy induces optimists to sell less of the contingent security that pays in case there is a transition to the high-risk-premium state, while also preventing optimists from increasing their position in the market portfolio.

For small changes, this policy does not affect the price function in the current state, $q_1^{pl}(\alpha) = q^*$ (since Assumption 3 continues to hold with as-if beliefs). Hence, the policy affects the gap value only through its impact on optimists' wealth dynamics and the associated aggregate demand externalities. Differentiating Eq. (49) (for $s = 1$) with respect to optimists' as-if beliefs and evaluating at the no-policy benchmark ($\lambda_1^{o,pl} = \lambda_1^o$), we obtain,

$$\left(\rho + \lambda_1^i\right) \frac{\partial w_1^i(\alpha)}{\partial \lambda_1^{o,pl}} = \alpha(1-\alpha)\left[-\frac{\partial w_1^i(\alpha)}{\partial \alpha} + \frac{\lambda_1^i}{\overline{\lambda}_1(\alpha)} \frac{\lambda_1^p}{\overline{\lambda}_1(\alpha)} \frac{\partial w_2^i(\alpha')}{\partial \alpha}\right] + \lambda_1^i \frac{\partial w_2^i(\alpha)}{\partial \lambda_1^{o,pl}}, \tag{52}$$

where $\alpha' = \alpha\lambda_1^o / \overline{\lambda}_1(\alpha)$. Here, the two terms inside the brackets capture the direct impact of the policy on welfare through aggregate demand externalities. The second term illustrates that the policy generates positive aggregate demand externalities—because it increases optimists' wealth share if there is a transition into the high-risk-premium state. On the other hand, the first term illustrates that the policy also generates negative aggregate demand externalities—because it reduces optimists' wealth share in case there is no transition. Eq. (52) describes the balance of these externalities when optimists are required to purchase the contingent security at equilibrium prices.

This illustrates that, in a dynamic setting, macroprudential policy in the low-risk-premium state is associated with some costs as well as benefits. The costs emerge from the fact that the policy prevents optimists from accumulating wealth that could be useful in a *future recession*. However, intuition suggests the benefits should outweigh the costs as long as future recessions are not too different from an imminent recession. The following lemma verifies this for the special case, $\lambda_1^o = \lambda_1^p$.

Lemma 2. *When $\lambda_1^o = \lambda_1^p$, the gap value function satisfies $\frac{dw_2^i(\alpha')}{d\alpha} > \frac{dw_1^i(\alpha)}{d\alpha}$ for each i and $\alpha \in (0,1)$.*

That is, optimists' wealth share increases the gap value more when there is an immediate transition into the high-risk-premium state, in which case the benefits appear immediately. Any delay in such transition reduces the benefits by postponing them. Combining this lemma with Eq. (52) provides a heuristic derivation of our main result in this section (see Appendix C.2 for the proof).

Proposition 3. *Consider the model with two belief types that satisfy $\lambda_1^o = \lambda_1^p$. Consider the macroprudential policy in the boom state, $\lambda_1^{o,pl} \geq \lambda_1^o$ (and suppose $\lambda_2^{o,pl} = \lambda_2^o$). The policy increases the planner's gap value (and thus, also the total value),*

$$\left.\frac{\partial v_1^{pl}(\alpha)}{\partial \lambda_1^{o,pl}}\right|_{\lambda_1^{o,pl}=\lambda_1^o} = \left.\frac{\partial w_1^{pl}(\alpha)}{\partial \lambda_1^{o,pl}}\right|_{\lambda_1^{o,pl}=\lambda_1^o} > 0 \text{ for each } \alpha \in (0,1).$$

In particular, regardless of the planner's Pareto weight, there exists a Pareto improving macroprudential policy.

What happens when we relax the assumption, $\lambda_1^o = \lambda_1^p$? This is largely a technical assumption. We conjecture that Proposition 3 also holds when $\lambda_1^o < \lambda_1^p$ (under appropriate technical assumptions) but we are unable to provide a proof. There are two distinct challenges. First, we cannot generalize Lemma 2, although the ranking is intuitive and should hold unless there are strong nonlinearities in the gap value function.[15] Second, in the more general case pessimists and optimists disagree about the benefits of macroprudential policy (captured by λ_1^i in the bracketed terms of (52)). The planner takes a weighted average of these perceptions, which complicates the analysis.[16] These challenges notwithstanding, we have not yet encountered a counterexample in our numerical simulations.

Figure 5 illustrates the result for our earlier parameterization (that features $\lambda_1^o < \lambda_1^p$). We fix the optimists' wealth share at a particular level ($\alpha = \frac{1}{2}$) and calculate the effect of macroprudential policy on the planner's value function as well as on its components. The policy reduces the planner's first-best value function, since it distorts investors' allocations according to their own beliefs. However, the magnitude of this decline is small (due to the First Welfare Theorem). The policy also generates a relatively sizeable increase in the planner's gap value function. This increase is sufficiently large that the policy increases the actual value function and generates a Pareto improvement. As the policy becomes larger, the gap value continues to increase whereas the first-best value decreases. Moreover, the decline in the first-best value is negligible for small policy changes but it becomes sizeable for large policy changes. The (constrained) optimal macroprudential policy obtains at an intermediate level.

The result is reminiscent of the analysis in Korinek and Simsek (2016), in which macroprudential policy improves outcomes by increasing the wealth of high marginal propensity to consume (MPC) households when there is a demand-driven recession. While both results are driven by aggregate demand externalities, the mechanism here is different and operates via asset prices. In fact, in our setting, all investors have the same MPC equal to ρ. Optimists improve aggregate demand in the high-risk-premium state not because they spend more than pessimists, but because they increase asset prices and induce *all investors* to spend more.

Macroprudential policy in the high-risk-premium state. The analysis so far concerns macroprudential policy in the low-risk-premium state and maintains the assumption that $\lambda_2^{o,pl} = \lambda_2^o$.

---

[15] Specifically, the proof of Lemma 2 establishes,

$$\frac{\partial w_1^i(b_{0,1})}{\partial b} = \frac{\lambda_1^i}{\lambda_1^i + \rho} \int_0^\infty e^{-(\rho+\lambda_1^i)t} \left(\rho + \lambda_1^i\right) \frac{\partial w_2^i(b_{t,2})}{\partial b} dt,$$

where $b_{0,1}$ denotes a transformed version of α at the initial state, and $b_{t,2}$ denotes the same variable after a transition into the high-risk-premium state after a period of length t. When $\lambda_1^o = \lambda_1^p$, we also have $b_{t,2} = b_{0,1}$ (since there is no speculation in the low-risk state), which yields $\frac{\partial w_1^i(b_{0,1})}{\partial b} = \frac{\lambda_1^i}{\lambda_1^i+\rho} \frac{\partial w_2^i(b_{0,1})}{\partial b} < \frac{\partial w_2^i(b_{0,1})}{\partial b}$. When $\lambda_1^o < \lambda_1^p$, the same result holds and the ranking remains unchanged if the value function is linear in the transformed variable b. Hence, the ranking can fail only if there are sufficiently large nonlinearities in the gap value function.

[16] When $\lambda_1^o = \lambda_1^p$, we actually have the stronger result that $\frac{\partial w_1^i(\alpha)}{\partial \lambda_1^{o,pl}} > 0$ for each i, that is, the policy increases the gap value according to optimists and pessimists (see Eq. $(C.18)$). We state the weaker version of the result in Proposition 3 because the stronger version might conceivably fail according to optimists (e.g., if λ_1^o is close to zero).

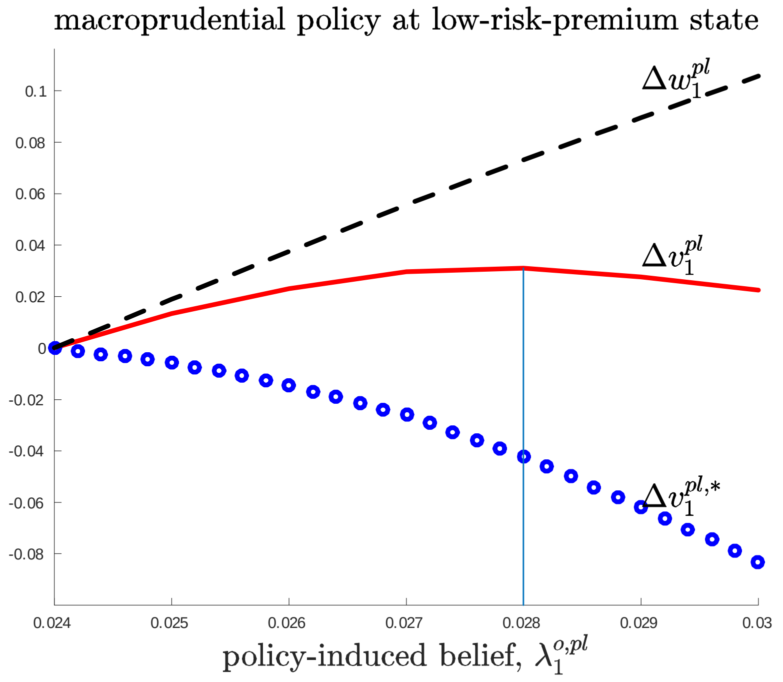

Figure 5: Effect of macroprudential policy in the low-risk-premium state on the planner's value function and its components.

In Appendix C.2, we also analyze the polar opposite case when the economy is in the high-risk-premium state $s = 2$, and the planner can apply macroprudential policy in this state, $\lambda_2^{o,pl} \leq \lambda_2^o$ (she can induce optimists to act as if the recovery is less likely), but not in the other state, $\lambda_1^{o,pl} = \lambda_1^o$. Proposition 4 in the appendix shows that, in contrast to Proposition 3, this policy can reduce social welfare. Consider the two counteracting forces. First, similar to before, macroprudential policy increases the gap value by increasing optimists' wealth share if the economy stays at the high-risk-premium state. However, unlike before, macroprudential policy also reduces current asset prices because the price is below the first-best level, $q_2^{pl}(\alpha) < q^*$, and it is increasing in optimists' as-if optimism, $\lambda_2^{o,pl}$ (see Eq. (33)). This channel reduces the gap value function (see Eq. (49)). When optimists' wealth share is large ($\alpha \to 1$), the latter channel is dominant and macroprudential policy reduces social welfare. Even when the latter channel does not dominate, it suggests that the macroprudential policy in the recession state is less useful than in the boom state (which we verify in numerical simulations).

It is useful to emphasize that macroprudential policy in the low-risk-premium state does not lower asset prices due to the monetary policy response. Specifically, while the asset price in this state is not influenced by policy, $q_1^{pl}(\alpha) = q^*$, the interest rate, $r_1^f(\alpha)$, is decreasing in optimists' as-if pessimism, $\lambda_1^{o,pl}$ (see Eq. (34)). Intuitively, as macroprudential policy reduces the demand for risky assets, monetary policy lowers the interest rate to dampen its effect on asset prices and aggregate demand.

Taken together, our analysis provides support for *procyclical* macroprudential policy. In states where output is not demand constrained (in our model, the boom state $s = 1$), macroprudential policy that restricts high-valuation investors' (in our model optimists') risk taking is desirable. This policy improves welfare by ensuring that high-valuation investors bring more wealth to the demand-constrained states, which increases asset prices and output. In states where output is demand constrained (in our model, the recession state $s = 2$), macroprudential policy is less useful because it has an immediate negative impact on asset prices and aggregate demand.

7. Empirical evidence

Our empirical analysis focuses on three predictions. First, our model predicts that risk premium shocks generate an interest rate reduction when the interest rate is not constrained, and a more severe demand recession when the interest rate is constrained. Second, the recession reduces firms' earnings and leads to a further reduction in asset prices. Third, the recession is more severe when the shock takes place in an environment with more speculation. To test these predictions, we compare the response to house price shocks in Eurozone countries (which have constrained interest rate with respect to national shocks) to the response in non-Eurozone developed countries (which have less constrained interest rate). At the end of the section, we discuss empirical evidence from the recent literature which suggests that similar results apply for price shocks to other asset classes, such as stocks, as well as for other constraints on the interest rate, such as the zero lower bound.

While our model relies on the zero lower bound constraint, the mechanisms are more general, and we find it more convenient to work with the currency-union constraint in our empirical analysis. The zero lower bound has only recently become a practical constraint, generating data limitations, and it calls for an asymmetric specification that requires separate responses to positive and negative price shocks (since the monetary policy can raise the interest rate in response to positive shocks, especially if the economy is close to full capacity utilization). In contrast, individual Eurozone countries have had constrained interest rates (with respect to national shocks) for much longer, and the constraint has been symmetric with respect to the direction of shocks.

A major challenge in this exercise is the identification of the risk premium shock that drives asset prices. As we clarify in Section 2, the exact source of the shock is not important for our mechanisms (e.g., risk, risk aversion, or beliefs have similar effects). Therefore, our strategy is to control for factors that *do not* act as a risk premium shock according to our model. In particular, we attempt to control for supply shocks and monetary policy shocks, and interpret the residual change in asset prices as a plausibly exogenous risk premium shock.

Our model has a single type of capital, which can be interpreted as a value-weighted average of housing, stocks, and other assets. We focus on house prices for two reasons. First, housing wealth is large and its size (relative to output) is comparable between Eurozone and non-Eurozone developed countries (see Table 3 in Appendix E). In contrast, stock markets in Eurozone countries are typically much smaller than in non-Eurozone developed countries, which makes stocks less suitable for our empirical strategy (see Table 4). Second, house prices are less volatile and seem to react to news with some delay (see Figure 15 in Appendix E). These features make it easier to control for other drivers of house prices. Specifically, we control for supply shocks using past realizations of output growth, and for monetary policy shocks using past realizations of policy interest rates.[17] We interpret the residual house price change as a risk premium shock. We also interpret the contemporaneous or future changes in interest rates as the monetary policy response to the shock, which enables us to test a key prediction of our model. This strategy works less well for stocks, because stock prices react to monetary policy news quickly, which might create a correlation between prices and interest rates with the opposite sign (since stock price declines driven by policy-news shocks are typically followed by interest rate *hikes*—the opposite of risk premium shocks).[18]

Data sources. We assemble a quarterly cross-country panel data set of financial and economic variables for advanced economies. We obtain data on house price indices from the quarterly dataset described in Mack et al. (2011). We obtain data on macroeconomic activity such as GDP, investment, and consumption from the OECD. We also obtain financial market data such as the policy interest rate, stock price indices, and earnings (of publicly traded firms) from Global Financial Data (GFD) and the Bank for International Settlements (BIS). Appendix E describes the details of data sources and variable construction.

Sample selection. Our sample covers 21 advanced economies from the first quarter of 1990 until the last quarter of 2017. Our selection of countries is driven by the availability of consistent house price data. We start the sample in 1990 because monetary policy in most advanced economies had shifted from focusing on stabilizing inflation to stabilizing output by this time, as in our model. Our results are robust to alternative sample selections.[19]

To capture interest rate constraints, we divide the data into two categories. The first category, which we refer to as *the Euro/ERM sample*, consists of country-quarters in which the country was a member of the Euro area or the European Exchange Rate Mechanism (ERM) for most of the calendar year. The ERM system, which was introduced as a precedent to the Euro, requires the member countries to keep their exchange rates within a narrow band of a central currency. This system constrains countries' relative policy interest rates (albeit imperfectly) and most member

---

[17] While our controls for supply shocks are imperfect, we also report the differential effects of these shocks in Eurozone countries compared to their effects outside the Eurozone, which provides additional robustness. For example, our model illustrates that permanent supply shocks (e.g., an increase in A) shift asset prices and output regardless of whether the interest rate is constrained (see Sections 3 and 4). This suggests that omitted supply shocks would lead to a similar bias inside and outside the Eurozone that is mitigated by focusing on the differential responses.

[18] Formally, we assume house prices react to monetary policy news with a delay of at least one quarter. Figure 15 in the appendix plots impulse responses to shocks to the policy interest rate and provides support for this assumption. Specifically, a surprise increase in the policy interest rate is followed by a decline in house prices, but the response starts after the first quarter and takes several quarters to complete. The same figure also shows that the assumption is clearly violated for stock prices. A surprise increase in the policy interest rate also reduces stock prices, but all of the response takes place in the same quarter as the shock.

[19] Figures 13 and 14 in the appendix show that starting the sample in 1980 leaves our results (except for the effect on inflation) qualitatively unchanged.

countries eventually adopted the Euro. The countries in the Euro area share the same policy interest rate (determined by the European Central Bank). The second category, which we refer to as *the non-Euro/ERM sample*, consists of the remaining country-quarters. Table 1 in Appendix E describes the Euro/ERM status by country and year.

Empirical specification. To describe how the economy behaves after house price shocks, we follow the local projection method developed by Jordà (2005). In particular, we regress several outcome variables at various horizons after time t on (residual) house price changes at time t. Specifically, we estimate equations of the type,

$$Y^h_{j,t+h} - Y^h_{j,t-1} = \alpha^h_j + \gamma^h_t + \beta^{p,h}\left(-\Delta \log P_{j,t}\right) + \beta^{c,h}\text{controls}_{j,t} + \varepsilon^h_{j,t}, \tag{53}$$

where j denotes the country, t denotes the quarter, h denotes the horizon, Y denotes an outcome variable, P denotes the (real) house price index, and $\Delta \log P_{j,t} = \log P_{j,t} - \log P_{j,t-1}$ denotes its quarterly log change. We include time as well as country fixed effects so our "house price shock" is a decline in house prices in a quarter, after accounting for the average price decline in the sample countries as well as various other controls within the country. Our control variables include 12 lags (3 years) of the first difference of log GDP—to control for supply shocks, and 12 lags of the policy interest rate—to control for recent monetary policy. We also include 12 lags of the first difference of log house prices—to capture the momentum in house prices, and 12 lags of the first difference of the outcome variable—to control for other dynamics that might influence the outcomes. We weight each regression with countries' relative GDP, and estimate (53) for horizons 0 to 12.

To evaluate the responses within and outside the Eurozone, we also include indicator variables for Euro/ERM and non-Euro/ERM status, and we interact all right-hand-side variables (including the fixed effects) with these indicators. We let $\beta^{p,h}_{euro}$ and $\beta^{p,h}_{non}$ denote the coefficient on the interaction of the price shock with the corresponding indicator. Our specification is equivalent to running the regressions separately within the Euro/ERM and non-Euro/ERM samples.[20] We report the sequence of coefficients, $\left\{\beta^{p,h}_{euro}\right\}^{12}_{h=0}$ and $\left\{\beta^{p,h}_{non}\right\}^{12}_{h=0}$, which provide an estimate of the impulse response functions for the respective samples. We also report 95% confidence intervals calculated according to Newey and West (1987) standard errors with a bandwidth of 20 quarters.

Our outcome variables include terms for which our model makes a clear prediction, such as the policy interest rate, the unemployment rate (a proxy for factor underutilization), the logs of GDP, investment, and consumption. We also include the log (core) CPI. Even though it is constant in our model (by assumption), variants of our model predict that it should decline in a demand recession. We also analyze public firms' earnings and log stock prices to investigate spillover and amplification effects, as well as log house prices to investigate the price dynamics following the

---

[20] The point estimates from our regression are identical to those obtained from running separate regressions within each sample. However, because our standard errors account for autocorrelation of the residuals, the joint regression will have slightly different standard errors (for example, the joint regression will account for the fact that residuals are correlated from before and after Greece joined the ERM). The joint regression is preferable to separate regressions, because it uses more data and thus gives more precise standard errors.

initial shock. All relevant variables except for the policy interest rate are adjusted for inflation to focus on real effects, as in our model. For earnings, we use the ratio of earnings to the initial stock price level as our dependent variable (which helps to obtain meaningful units).[21]

Table 2 in Appendix E describes the summary statistics by Euro/ERM status for the variables that enter our regression analysis. The Euro/ERM sample has 821 country-quarters and the non-Euro/ERM sample has 1120 country-quarters.[22] Both samples are unbalanced because a few countries have imperfect data coverage in earlier years (and because a few countries transition between samples). The two samples are comparable except that the non-Euro/ERM sample experienced slightly faster growth over the sample period.

House price shocks and demand recessions. Figure 6 plots the estimated sequences of coefficients by Euro/ERM status (see Figure 10 in Appendix E for the differenced coefficients). The panels at the top two rows illustrate our main empirical findings. The top left panel shows that, in the non-Euro/ERM sample (dashed blue line), a decline in house prices is followed by a sizeable and persistent decline in the policy interest rate. By contrast, in the Euro/ERM sample (solid red line), a decline in house prices does not lead to an additional decline in the country's interest rate relative to other Euro/ERM countries, illustrating the interest rate constraint.[23] The remaining panels in the top two rows illustrate that the shock is followed by a more severe demand recession in an Euro/ERM country than in a non-Euro/ERM country. In fact, the panels on GDP, investment, and consumption suggest that the shock initially leads to similar effects in both samples but is eventually followed by milder outcomes in the non-Euro/ERM sample.

These results are consistent with our prediction that risk premium shocks lead to a more severe demand recession when the interest rate is constrained. From the lens of our model, the interest rate policy mitigates a demand recession driven by a local risk premium shock outside the Eurozone but not within the Eurozone.[24]

---

[21] Earnings sometimes take a negative value (e.g., for Greece in recent years) which makes a log transformation problematic. Instead, we change the specification in (53) slightly so that the dependent variable is $(\text{earnings}_{t+h} - \text{earnings}_{t-1})/(\text{stock price}_{t-1})$. Likewise, we adjust the control variables that feature earnings by dividing them with the stock price at quarter $t-1$.

[22] These are the sample sizes for our baseline regression in which the outcome variable is the policy interest rate and the horizon is 0 (see (53)). For some regressions, the sample size is slightly smaller, because we estimate outcomes at future horizons (that removes some data from the end of the sample period) and because some variables do not have complete coverage.

[23] For the Euro era, the Euro/ERM-wide policy interest rate response is common to all countries and is captured by our time-fixed effects. And during the ERM era, there were severe cross-country monetary policy constraints. Figure 12 in Appendix E illustrates the results from the same regression without time-fixed effects. The figure shows that a negative house price shock in the Euro/ERM sample leads to a decline in the Euro/ERM-wide policy interest rate, but the magnitude of this decline is smaller than in the other sample. This is because house price shocks have a national (or idiosyncratic) component, and the Euro/ERM-wide policy interest rate arguably responds only to the Euro/ERM-wide (or systematic) component of these shocks.

[24] In our model, risk premium shocks generate a less severe recession in unconstrained countries because the interest rate policy response leads to a smaller decline in asset prices. This suggests that asset price changes might provide an inaccurate measure of the underlying shock. We believe our analysis is robust to this concern for three reasons. First, to the extent that this concern is relevant, it biases the empirical analysis against finding support for our mechanisms, because it implies that an equivalent magnitude of asset price decline corresponds to a larger underlying shock if the country has unconstrained interest rate. Second, the concern is less relevant in practice than in our model because the

Spillover effects and amplification. The panels at the bottom row of Figure 6 illustrate the effect of the house price shock on asset markets. The panels on earnings and stock prices establish that there are spillover effects to the stock market: specifically, earnings as well as stock prices decline more in the Euro/ERM sample than in the other sample (although the estimates are imprecise due to the high volatility of earnings and prices). The remaining panel illustrates that, after the initial shock, house prices decline more persistently and by a greater magnitude in the Euro/ERM sample.

These results are consistent with our prediction that the demand recession reduces firms' earnings and leads to a further decline in asset prices. From the lens of the model, stock prices (resp. house prices) decline less in the non-Euro/ERM sample due to the interest rate response, which not only increases the price to earnings ratio (resp. price to rent ratio) but also mitigates the recession and supports earnings (resp. rents).[25]

Speculation and further amplification. We need a proxy for speculation to test the final prediction of our model. We choose a measure of bank credit, which is a major catalyst of speculation in housing markets. First, banks can be thought of as the high-valuation investors ("optimists"), because they have a greater capacity and expertise to handle risk relative to non-institutional investors, and they have real estate exposures through mortgage loans. Under this interpretation, bank credit provides a measure of banks' exposure to the housing market. Second, banks also lend to other high-valuation investors in the housing markets such as optimistic homebuyers that use bank credit to purchase larger homes or second homes. When bank credit is easily available, perhaps because of banks' optimism about house prices, these high-valuation investors wield a greater influence in the housing market (see Simsek (2013a) for a formalization). Thus, bank credit provides a broad proxy for speculation in the housing market.

Our specific measure of bank credit comes from Baron and Xiong (2017), who construct a variable, "credit expansion", defined as the change in the bank credit to GDP ratio in the last three years. They standardize the variable by its mean and standard deviation within each country so that the measure is high when bank credit expansion in a country has been high in recent years relative to its historical trends. They show that their standardized measure predicts the likelihood of a large decline in bank equity prices, and despite the elevated risk, it also predicts lower average returns on bank equity. Their preferred interpretation is that bank equity investors are excessively optimistic or neglect crash risk, which in our framework would translate into greater speculation (by banks or their borrowers).

We use the BIS data on bank credit to households and nonfinancial firms to construct a close analogue of Baron and Xiong's standardized credit expansion variable (see Appendix E for details).

---

interest rate policy affects all assets, which implies that risk-driven price declines in one asset class (such as housing) are partially absorbed by price increases in other asset classes. Third, the concern is also less relevant for house prices because they seem to react to interest rate changes with some delay (see Figure 15 in Appendix E). In fact, the panel of Figure 6 on house prices suggests that the interest rate response only partially stabilizes risk-driven house price changes and with some delay.

[25] We cannot test the predictions on rents because we do not have reliable data.

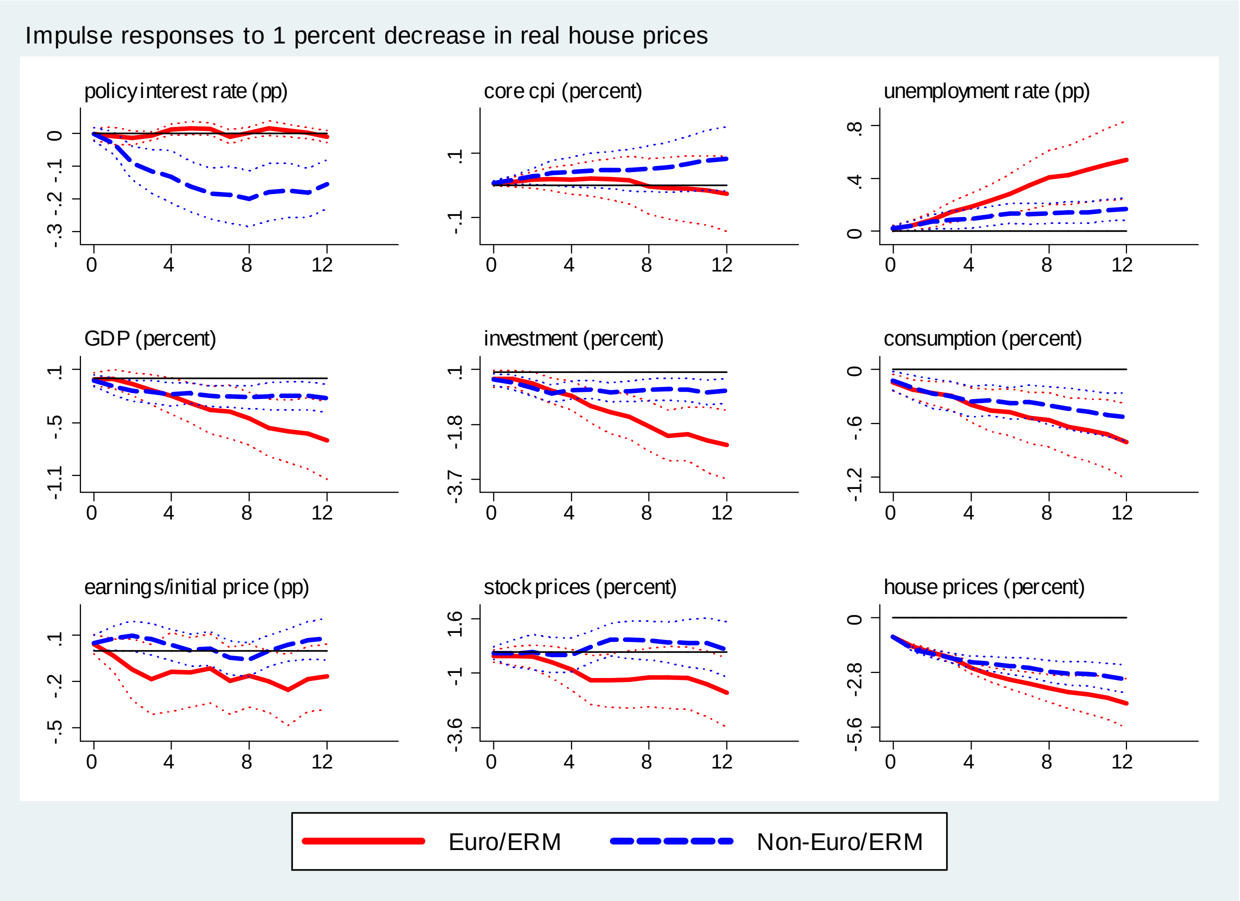

Figure 6: Results from the regression specification in (53) with the addition of the indicator variables for Euro/ERM and non-Euro/ERM status as well as the interaction of all right-hand-side variables with these indicators. The solid red (resp. dashed blue) lines plot the coefficients corresponding to the the negative log house price variable when the Euro/ERM status is equal to 1 (resp. 0). For the units, "percent" corresponds to 0.01 log units (i.e., it is approximate) and "pp" corresponds to percentage points. All regressions include time and country fixed effects; 12 lags of the first difference of log GDP, 12 lags of the level of the policy interest rate, 12 lags of the first difference of log house prices, and 12 lags of the first difference of the outcome variable. The dotted lines show 95% confidence intervals calculated according to Newey-West standard errors with a bandwidth of 20 quarters. All regressions are weighted by countries' PPP-adjusted GDP in 1990. Data is unbalanced quarterly panel that spans 1990Q1-2017Q4. All variables except for those in the top panel are adjusted for inflation. Earnings are normalized by the stock price at the quarter before the shock (see Footnote 21). The sources and the definitions of variables are described in Appendix E.

We then run the same regressions as in (53), but we also include the interaction of the price shock with standardized credit expansion. That is, we estimate,

$$Y^h_{j,t+h} - Y^h_{j,t-1} = \alpha^h_j + \gamma^h_t + \left[\begin{array}{c} \beta^{p,h} \left(-\Delta \log P_{j,t}\right) \\ +\beta^{pc,h} \left(-\Delta \log P_{j,t}\right) \times \text{credit expansion-std} \end{array} \right] + \beta^{c,h} \text{controls}_{j,t} + \varepsilon_{j,t}. \tag{54}$$

In addition to the earlier controls, we include 12 lags of standardized credit expansion to capture its direct impact. As before, we also interact all right-hand-side variables with the Euro/ERM and the non-Euro/ERM status indicators. We let $\beta^{pc,h}_{euro}$ and $\beta^{pc,h}_{non}$ denote the coefficient on the interaction of the shock and credit with these indicators. The sequence of coefficients, $\left\{\beta^{pc,h}_{euro}\right\}^{12}_{h=0}$ and $\left\{\beta^{pc,h}_{non}\right\}^{12}_{h=0}$, provide an estimate of the *additional* effect of the shock when credit expansion has been one standard deviation above average (relative to its baseline effect with average credit).

Figure 7 plots these sequences and illustrates our findings (see Figure 11 in the appendix for the differenced coefficients). The panels at the first two rows show that, in the Euro/ERM sample, house price shocks lead to a greater decline in economic activity when credit expansion has been high in recent years. In contrast, credit expansion does not seem to change the effect of the house price shock in the non-Euro/ERM sample. These results support our prediction that risk premium shocks lead to a more severe demand recession (in constrained economies) when they take place in an environment with elevated speculation.

On the other hand, the panels at the bottom row of Figure 7 present largely inconclusive results that do not necessarily support (or refute) our predictions. We do not find meaningful differences for the additional effect of house price shocks on earnings or house prices when credit expansion has been high (in either sample). We do find a negative effect on stock prices for the Euro/ERM sample, but the effect is not statistically significantly different from the other sample. That said, since standard errors are large, we cannot rule out sizeable effects either. Hence, while we tentatively conclude that speculation proxied by credit expansion is associated with deeper risk-centric demand recessions, further empirical research should verify the robustness of this conclusion as well as the precise channels by which speculation affects the recession.

Other supporting evidence. Our mechanisms are supported by a growing empirical literature. Our empirical analysis is related to Mian and Sufi (2014), who use regional data within the U.S. to argue that house price declines explain much of the job losses during the Great Recession. Our results for the Euro/ERM sample suggest that similar results hold in cross-country data. Our results for the non-Euro/ERM sample suggest that monetary policy can mitigate the adverse effects of house price shocks. Moreover, while Mian and Sufi (2014) emphasize household deleveraging as the key channel by which house price declines cause damage, some of our empirical results (e.g., the investment response) suggest this is unlikely to be the only relevant mechanism. As our model demonstrates, house price declines could lower aggregate demand even without household deleveraging or other financial frictions—although these additional ingredients would naturally amplify the effects.

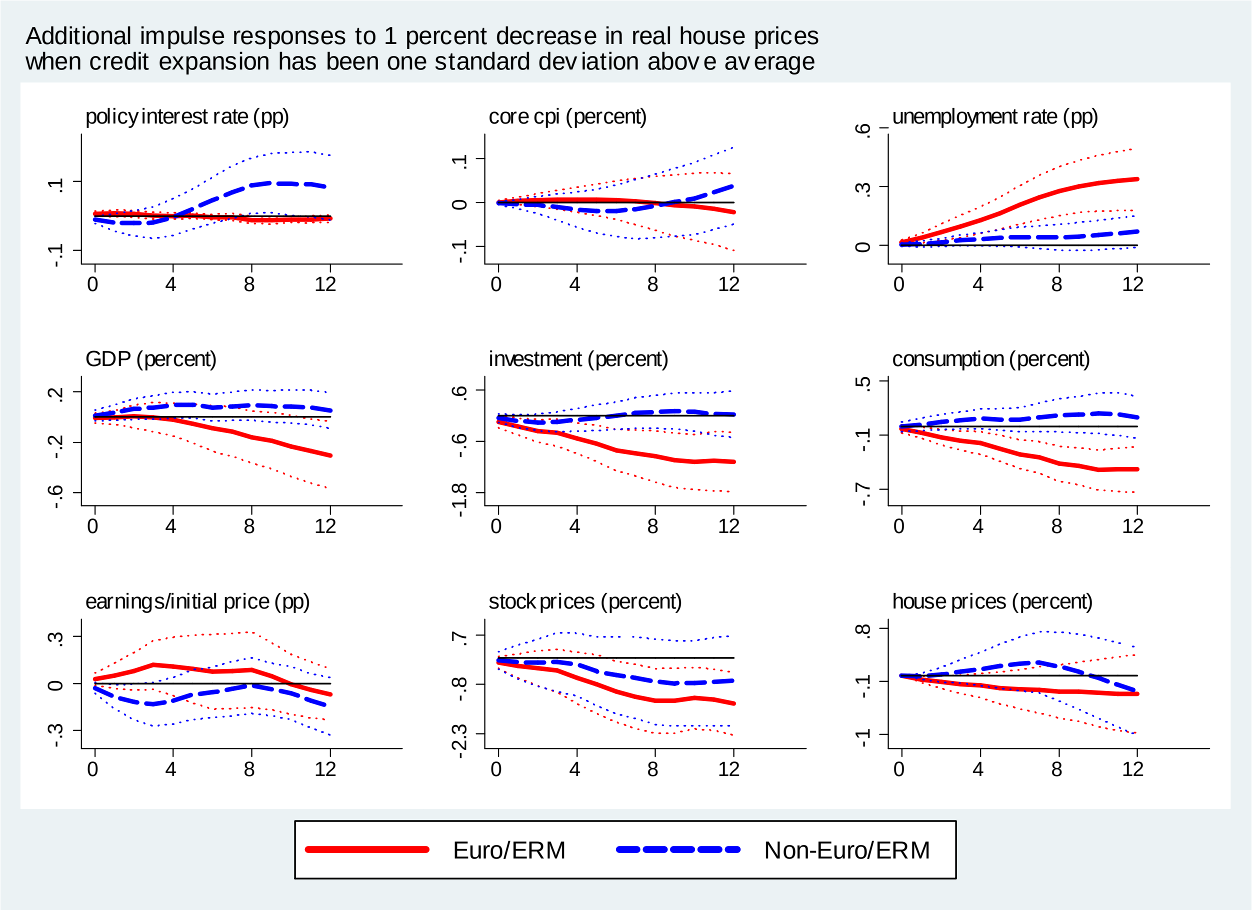

Figure 7: Results from the regression specification in (53) with the addition of the indicator variables for Euro/ERM and non-Euro/ERM status as well as the interaction of all right-hand-side variables with these indicators. The solid red (resp. dashed blue) lines plot the coefficients corresponding to the interaction of the negative log house price and the standardized credit expansion variables when the Euro/ERM status is equal to 1 (resp. 0). For the units, "percent" corresponds to 0.01 log units (i.e., it is approximate) and "pp" corresponds to percentage points. All regressions include time and country fixed effects; 12 lags of the first difference of log GDP, 12 lags of the level of the policy interest rate, 12 lags of the first difference of log house prices, 12 lags of the first difference of the outcome variable, and 12 lags of standardized credit expansion. The dotted lines show 95% confidence intervals calculated according to Newey-West standard errors with a bandwidth of 20 quarters. All regressions are weighted by countries' PPP-adjusted GDP in 1990. Data is unbalanced quarterly panel that spans 1990Q1-2017Q4. All variables except for those in the top panel are adjusted for inflation. Earnings are normalized by the stock price at the quarter before the shock (see Footnote 21). The sources and the definitions of variables are described in Appendix E.

In more recent work, Pflueger et al. (2018) argue that our mechanisms are likely to be relevant for stock prices, too. Specifically, they construct a measure of risk appetite for the U.S. as the price of high (idiosyncratic) volatility stocks relative to low volatility stocks. They show that a decrease in their measure of risk appetite is followed by a slowdown in economic activity as well as a decline in the risk-free rate—similar to our results for the non-Euro/ERM sample. Pflueger et al. (2018) go on to argue that their risk appetite measure explains almost half of the variation of the one year risk-free rate in the U.S. since 1970. This suggests that the time varying risk premium is a quantitatively important driver of the risk-free rate in practice. Likewise, focusing on a value-weighted average of house and stock prices, Jordà et al. (2017) argue that low frequency fluctuations in the risk premium in developed economies have typically been associated with a collapse of the safe rates (as opposed to a spike in risky rates). Focusing on more recent years, Del Negro et al. (2017) provide a comprehensive empirical evaluation of the different mechanisms that have put downward pressure on interest rates and show that risk and liquidity considerations played a central role (see also Caballero et al. (2017a)).

Finally, our mechanisms are supported by a literature that investigates the macroeconomic impact of "uncertainty shocks." Using vector autoregressions (VARs), Bloom (2009) shows that an increase in the volatility index in the U.S. is followed by a slowdown in economic activity. Moreover, although his model does not emphasize monetary policy, his empirical analysis shows that the shock is followed by a decline in the federal funds rate. This response suggests the effects could be more severe if the interest rate is constrained. Recent empirical work verifies this intuition and shows that uncertainty shocks in the U.S. are associated with a greater decline in economic activity when the federal funds rate is close to zero, arguably because of the zero lower bound constraint on the interest rate (see, for instance, Caggiano et al. (2017); Plante et al. (2018)).

8. Final remarks

The key tension in our model is that asset prices must both equilibrate risk markets and support aggregate demand. When these roles are inconsistent, the risk market equilibrium prevails. Interest rate policy takes over the role of equilibrating risk markets, which leaves asset prices free to balance the goods markets. However, if the interest rate is constrained, the dual role problem reemerges and asset prices are driven primarily by risk market equilibrium considerations. An increase in the risk premium lowers asset prices and triggers a demand recession, which further drives down asset prices. Speculation during the ex-ante boom phase exacerbates the recession because it depletes high-valuation investors' wealth once the risk premium rises, which leads to a greater decline in asset prices. Macroprudential policy (in the boom phase) improves outcomes by restricting speculation and preserving high-valuation investors' wealth during the recession. This leads to a Pareto improvement because it forces speculators to internalize aggregate demand externalities.

Interest rate cuts in our model improve the market's Sharpe ratio. From this perspective, any policy that reduces perceived market volatility and prevents sudden asset price drops should have similar effect, rendering support for various policies implemented during the aftermath of the subprime and European crises.

In our model, we use a lower bound constraint as the interest rate friction, but as we stated earlier our mechanisms are also applicable if the interest rate is constrained for other reasons. Also, when the interest rate has an upper bound as well as a lower bound (such as in a currency union or fixed exchange rate regime), our results often become stronger. In this setting, speculation creates damage not only by lowering asset prices during the recession but also by raising asset prices during the boom, when the aggregate demand is stretched above its natural level, which typically exacerbates the inefficiency. Moreover, in this case macroprudential policy during the boom is beneficial not only because it preserves high-valuation investors' wealth for a future recession but also because it immediately contains the excessive rise in asset prices.

In the main text, we did not take a stand on whether optimists or pessimists are right about the transition probabilities. The core of our analysis does not depend on this. For example, we could think of optimists as rational agents and pessimists as Knightian agents (see, e.g., Caballero and Krishnamurthy (2008); Caballero and Simsek (2013)). Absent any direct mechanism to alleviate Knightian behavior during severe recessions, the key point that reducing optimists's risk taking during the boom leads to Pareto improvements survives this alternative motivation.

As we noted earlier, our modeling approach belongs to the literature spurred by Brunnermeier and Sannikov (2014), although our analysis does not feature financial frictions. However, if we were to introduce these realistic frictions in our setting, many of the themes in that literature would reemerge and be exacerbated by aggregate demand feedbacks. For instance, in an incomplete markets setting, optimists take leveraged positions on the market portfolio and induce endogenous volatility in asset prices. In this case, a sequence of negative diffusion shocks that make the economy deeply pessimistic can lead to extreme tail events (we analyze the incomplete markets case in a companion paper).

Finally, while this is mostly an applied theory paper, we also surveyed some of the extensive empirical evidence supporting our analysis, and provided our own evidence by contrasting the local response to risk premium shocks (captured by surprise house price changes) of (constrained) Euro/ERM countries to that of (unconstrained) non-Euro/ERM countries. Our evidence suggests that risk premium shocks lead to more severe recessions when the interest rate is constrained, as in our model. The evidence also supports our model's prediction that recessions reduce firms' earnings and lead to a further reduction in asset prices. Finally, we found some evidence consistent with our prediction that recessions are more severe when the shock takes place in an environment with high speculation (as measured by the size of the bank credit expansion before the shock).

References

Adrian, T., Boyarchenko, N., 2012. Intermediary leverage cycles and financial stability.

Bacchetta, P., Benhima, K., Kalantzis, Y., 2016. Money and capital in a persistent liquidity trap.

Baron, M., Xiong, W., 2017. Credit expansion and neglected crash risk. The Quarterly Journal of Economics 132 (2), 713–764.

Basak, S., 2000. A model of dynamic equilibrium asset pricing with heterogeneous beliefs and extraneous risk. Journal of Economic Dynamics and Control 24 (1), 63–95.

Basak, S., 2005. Asset pricing with heterogeneous beliefs. Journal of Banking & Finance 29 (11), 2849–2881.

Basak, S., Cuoco, D., 1998. An equilibrium model with restricted stock market participation. Review of Financial Studies 11 (2), 309–341.

Basu, S., Bundick, B., 2017. Uncertainty shocks in a model of effective demand. Econometrica 85 (3), 937–958.

Bianchi, J., Mendoza, E. G., 2013. Optimal time-consistent macroprudential policy. Tech. rep., National Bureau of Economic Research.

Blanchard, O. J., L'Huillier, J.-P., Lorenzoni, G., 2013. News, noise, and fluctuations: An empirical exploration. The American Economic Review 103 (7), 3045–3070.

Bloom, N., 2009. The impact of uncertainty shocks. econometrica 77 (3), 623–685.

Blume, L., Easley, D., 2006. If you're so smart, why aren't you rich? belief selection in complete and incomplete markets. Econometrica 74 (4), 929–966.

Brunnermeier, M. K., Koby, Y., 2016. The reversal interest rate: An effective lower bound on monetary policy. Preparation). Print.

Brunnermeier, M. K., Sannikov, Y., 2014. A macroeconomic model with a financial sector. The American Economic Review 104 (2), 379–421.

Brunnermeier, M. K., Sannikov, Y., 2016a. The i theory of money. Tech. rep., National Bureau of Economic Research.

Brunnermeier, M. K., Sannikov, Y., 2016b. Macro, money, and finance: A continuous-time approach. Handbook of Macroeconomics 2, 1497–1545.

Caballero, R. J., Farhi, E., 2017. The safety trap. Review of Economic Studies forthcoming.

Caballero, R. J., Farhi, E., Gourinchas, P.-O., 2017a. Rents, technical change, and risk premia accounting for secular trends in interest rates, returns on capital, earning yields, and factor shares. American Economic Review 107 (5), 614–620.

Caballero, R. J., Farhi, E., Gourinchas, P.-O., 2017b. The safe asset shortage conundrum. The Journal of Economic Perspectives 31 (3).

Caballero, R. J., Krishnamurthy, A., 2003. Excessive dollar debt: Financial development and underinsurance. The Journal of Finance 58 (2), 867–894.

Caballero, R. J., Krishnamurthy, A., 2008. Collective risk management in a flight to quality episode. The Journal of Finance 63 (5), 2195–2230.

Caballero, R. J., Simsek, A., 2013. Fire sales in a model of complexity. The Journal of Finance 68 (6), 2549–2587.

Caballero, R. J., Simsek, A., 2017. Destabilizing speculation and central bank policy puts in a low interest rates environment. MIT Working Paper.

Caggiano, G., Castelnuovo, E., Pellegrino, G., 2017. Estimating the real effects of uncertainty shocks at the zero lower bound. European Economic Review 100, 257–272.

Campbell, J. Y., 2014. Empirical asset pricing: Eugene fama, lars peter hansen, and robert shiller. The Scandinavian Journal of Economics 116 (3), 593–634.

Campbell, J. Y., Viceira, L. M., 2002. Strategic asset allocation: portfolio choice for long-term investors. Clarendon Lectures in Economic.

Cao, D., 2017. Speculation and financial wealth distribution under belief heterogeneity. The Economic Journal.

Carver, C. S., Scheier, M. F., Segerstrom, S. C., 2010. Optimism. Clinical psychology review 30 (7), 879–889.

Chen, J., Hong, H., Stein, J. C., 2002. Breadth of ownership and stock returns. Journal of financial Economics 66 (2), 171–205.

Christiano, L. J., Eichenbaum, M. S., Trabandt, M., 2015. Understanding the great recession. American Economic Journal: Macroeconomics 7 (1), 110–167.

Cieslak, A., Vissing-Jorgensen, A., 2017. The economics of the fed put.

Cochrane, J. H., 2011. Presidential address: Discount rates. The Journal of finance 66 (4), 1047–1108.

Davila, E., Korinek, A., 2016. Pecuniary externalities in economies with financial frictions. The Review of Economic Studies.

Del Negro, M., Giannone, D., Giannoni, M. P., Tambalotti, A., Wu, J. C., 2017. Safety, liquidity, and the natural rate of interest.

Detemple, J., Murthy, S., 1994. Intertemporal asset pricing with heterogeneous beliefs. Journal of Economic Theory 62 (2), 294–320.

Di Tella, S., 2012. Uncertainty shocks and balance sheet recessions. Job Market Paper.

Eggertsson, G. B., Krugman, P., 2012. Debt, deleveraging, and the liquidity trap: A fisher-minsky-koo approach. The Quarterly Journal of Economics 127 (3), 1469–1513.

Eggertsson, G. B., Mehrotra, N. R., Robbins, J. A., January 2017. A model of secular stagnation: Theory and quantitative evaluation. Working Paper 23093, National Bureau of Economic Research.
URL `http://www.nber.org/papers/w23093`

Eggertsson, G. B., Woodford, M., September 2006. Optimal Monetary and Fiscal Policy in a Liquidity Trap. The MIT Press, pp. 75–144.
URL `http://www.nber.org/chapters/c0076`

Farhi, E., Werning, I., 2016. A theory of macroprudential policies in the presence of nominal rigidities. Econometrica 84 (5), 1645–1704.

Farhi, E., Werning, I., 2017. Fiscal unions. American Economic Review forthcoming.

Fernández-Villaverde, J., Guerrón-Quintana, P., Kuester, K., Rubio-Ramírez, J., 2015. Fiscal volatility shocks and economic activity. American Economic Review 105 (11), 3352–84.

Fostel, A., Geanakoplos, J., 2008. Leverage cycles and the anxious economy. The American Economic Review 98 (4), 1211–1244.

Garleanu, N., Pedersen, L. H., 2011. Margin-based asset pricing and deviations from the law of one price. The Review of Financial Studies 24 (6), 1980–2022.

Geanakoplos, J., 2010. The leverage cycle. NBER macroeconomics annual 24 (1), 1–66.

Gertler, M., Kiyotaki, N., et al., 2010. Financial intermediation and credit policy in business cycle analysis. Handbook of monetary economics 3 (3), 547–599.

Gourio, F., 2012. Disaster risk and business cycles. The American Economic Review 102 (6), 2734–2766.

Guerrieri, V., Lorenzoni, G., 2017. Credit crises, precautionary savings, and the liquidity trap. Quarterly Journal of Economics forthcoming.

Hall, R. E., 2011. The long slump. The American Economic Review 101 (2), 431–469.

Harris, M., Raviv, A., 1993. Differences of opinion make a horse race. Review of Financial studies 6 (3), 473–506.

Harrison, J. M., Kreps, D. M., 1978. Speculative investor behavior in a stock market with heterogeneous expectations. The Quarterly Journal of Economics 92 (2), 323–336.

He, Z., Krishnamurthy, A., 2012. A model of capital and crises. The Review of Economic Studies 79 (2), 735–777.

He, Z., Krishnamurthy, A., 2013. Intermediary asset pricing. The American Economic Review 103 (2), 732–770.

Iachan, F. S., Nenov, P. T., Simsek, A., 2015. The choice channel of financial innovation. Tech. rep., National Bureau of Economic Research.

Ilut, C. L., Schneider, M., 2014. Ambiguous business cycles. The American Economic Review 104 (8), 2368–2399.

Jeanne, O., Korinek, A., 2010. Managing credit booms and busts: A pigouvian taxation approach. Tech. rep., National Bureau of Economic Research.

Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. American economic review 95 (1), 161–182.

Jordà, Ò., Knoll, K., Kuvshinov, D., Schularick, M., Taylor, A. M., 2017. The rate of return on everything, 1870–2015. Tech. rep., National Bureau of Economic Research.

Korinek, A., Nowak, M., 2016. Risk-taking dynamics and financial stability.

Korinek, A., Simsek, A., 2016. Liquidity trap and excessive leverage. American Economic Review 106 (3), 699–738.

Krugman, P., 1998. It's baaack: Japan's slump and the return of the liquidity trap. Brookings Papers on Economic Activity 1998 (2), 137–205.

Kubler, F., Schmedders, K., 2012. Financial innovation and asset price volatility. The American Economic Review 102 (3), 147–151.

Lintner, J., 1969. The aggregation of investor's diverse judgments and preferences in purely competitive security markets. Journal of financial and quantitative analysis 4 (04), 347–400.

Longstaff, F. A., Wang, J., 2012. Asset pricing and the credit market. The Review of Financial Studies 25 (11), 3169–3215.

Lorenzoni, G., 2008. Inefficient credit booms. The Review of Economic Studies 75 (3), 809–833.

Lorenzoni, G., 2009. A theory of demand shocks. The American economic review 99 (5), 2050–2084.

Mack, A., Martínez-García, E., et al., 2011. A cross-country quarterly database of real house prices: a methodological note. Globalization and Monetary Policy Institute Working Paper 99.

Mian, A., Sufi, A., 2014. What explains the 2007–2009 drop in employment? Econometrica 82 (6), 2197–2223.

Midrigan, V., Philippon, T., Jones, C., et al., 2016. Beyond the liquidity trap: the secular stagnation of investment. In: 2016 Meeting Papers. No. 1429. Society for Economic Dynamics.

Miller, E. M., 1977. Risk, uncertainty, and divergence of opinion. The Journal of finance 32 (4), 1151–1168.

Moreira, A., Savov, A., 2017. The macroeconomics of shadow banking. The Journal of Finance forthcoming.
URL `http://dx.doi.org/10.1111/jofi.12540`

Newey, W. K., West, K. D., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55 (3), 703–708.

Pflueger, C., Siriwardane, E., Sunderam, A., 2018. A measure of risk appetite for the macroeconomy. Tech. rep., National Bureau of Economic Research.

Plante, M., Richter, A. W., Throckmorton, N. A., 2018. The zero lower bound and endogenous uncertainty. The Economic Journal 128 (611), 1730–1757.

Rognlie, M., Shleifer, A., Simsek, A., 2017. Investment hangover and the great recession. American Economic Journal: Macroeconomics forthcoming.

Romer, C. D., Romer, D. H., 2018. Phillips lecture–why some times are different: Macroeconomic policy and the aftermath of financial crises. Economica 85 (337), 1–40.

Scheinkman, J. A., Xiong, W., 2003. Overconfidence and speculative bubbles. Journal of political Economy 111 (6), 1183–1220.

Schularick, M., Taylor, A. M., 2012. Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. American Economic Review 102 (2), 1029–61.

Silva, D. H., 2016. The risk channel of unconventional monetary policy.

Simsek, A., 2013a. Belief disagreements and collateral constraints. Econometrica 81 (1), 1–53.

Simsek, A., 2013b. Speculation and risk sharing with new financial assets. The Quarterly journal of economics 128 (3), 1365–1396.

Tobin, J., 1975. Keynesian models of recession and depression. The American Economic Review 65 (2), 195–202.

Varian, H. R., 1989. Differences of opinion in financial markets. In: financial Risk: Theory, Evidence and implications. Springer, pp. 3–37.

Werning, I., 2012. Managing a liquidity trap: Monetary and fiscal policy. Tech. rep., National Bureau of Economic Research.

Xiong, W., Yan, H., 2010. Heterogeneous expectations and bond markets. Review of Financial Studies 23 (4), 1433–1466.

Zapatero, F., 1998. Effects of financial innovations on market volatility when beliefs are heterogeneous. Journal of Economic Dynamics and Control 22 (4), 597–626.

Comments by Mohamed A El-Erian[1]

It is such a pleasure and honour to be here. Huge thanks to Claudio, Jaime, Hyun Song and other BIS colleagues for inviting me to this wonderful event. I greatly appreciate the opportunity to participate in such a stimulating conference. It is also a privilege to be asked to provide some comments in this session on Ricardo Caballero's three interesting papers.

My remarks will be organised around the what, why, and so what of relating to – and here I am quoting Ricardo – "the world economy experienced a prolonged period of risk intolerance". I will approach this from the perspective of a capital market observer and participant who has followed closely the impact of unconventional monetary policies, including large-scale asset purchases by systemically important central banks.

My particular interest today is in the issue, and again I quote, that "the key tension that asset prices have the dual role of equilibrating financial markets and supporting aggregate demand". Moreover, given the forward-looking spirit of this gathering, I will also pose the question of what may happen if we run the current policy regime forward – with particular emphasis on cumulative effects and feedback loops which, I believe, are taking some economies closer to tipping points. Indeed, rather than signal a generalised increase in risk intolerance, as Ricardo suggests, we could well be in the midst of a new period of excessive risk-taking – one in which high financial risk-taking has become dangerously decoupled from economic risk-taking, opening up two potential outcomes depending on the policy response beyond the world of central banking. They carry similar probabilities but very different outcomes when it comes to economic, financial, institutional, political and social factors.

The What

When it comes to the what, Ricardo's work documents:

- The secular decline in real interest rates to persistently negative real levels and, in some cases, nominal too;
- Shows that it has been generalised across maturities and advanced economy jurisdictions – the so-called Triffin dilemma for fixed income securities that serve, or are perceived to serve as a true "store of value";
- That it is part of what he suggests "may well be a recurrent global safety traps environment", reflecting both supply and demand influences that have reduced

---

[1] Allianz.

the availability of safe assets around the world, and in advanced economies in particular; and

- That the phenomenon has both a public and private component.

Given my own perspective, I find it interesting that the analysis places a lot less weight on the information content of spreading contradictions on the ground, especially if we consider the dramatic changes in traditional historical correlations. There are, in my opinion, signals rather than noise and they include:

- The behaviour of both the term premium on government bonds and the flattening of the yield curve versus the valuation of stocks;
- The decoupling of financial risk-taking (high) from economic risk-taking (low);
- The promise of ample liquidity inherent in the proliferation of ETFs in traditionally less liquid asset classes (such as high-yield corporates and emerging markets) versus experience, particularly at times of change in the paradigms governing the general market behaviour;
- The discrepancy between soft and hard data;
- The unusual uncertainty in national politics and cross-border economic relations versus notably low actual and implied market volatility;
- The persistence of negative interest rates in systems that are now struggling to provide longer-term financial protection products to households (such as life insurance and retirement); and, more generally and linking to the earlier sessions; and
- The step decline in r* in a system built on the presumption of a notably higher level.

The Why

On the why, Ricardo's emphasis is primarily on structural and secular issues such as demographics and regulation that, in his analytical framework, have resulted in the supply of safe assets not keeping up with global demand. There is little discussion of the role of policy issues and choices, including the earlier pursuit by emerging economies of high self-insurance and, since the global financial crisis, central banks being de facto forced into a prolonged period of "being the only game in town" policy-wise. The latter has led to unprecedented policy experimentation, with both rates and balance sheets, turning quite a few previous improbables and unthinkables into reality.

With that, I wonder whether the analysis may underplay the role of policy choices that have accentuated the structural and secular factors that are correctly identified. These policy issues speak not only to trade-offs within the direct scope of monetary policy as mentioned by Jamie in his introductory remarks but also, and more importantly, the excessive reliance on central banks when compared to other policymaking entities that can pursue structural reform, more responsive fiscal policies, targeted debt reduction measures and greater global policy coordination.

The So What

All of which takes us to the so what.

Ricardo shows that the "volatility stabilisation" of financial assets has coincided with a period of increasing return on capital and, more importantly, that the actual and potential consequences are a mix of benign, concerning and damaging. It is a mix that gets more worrisome the closer we get to, and stay at, the effective lower bound. There, "any further intensification in the shortage of safe assets has destabilising macroeconomic consequences" – including pushing the global economy further away from its potential.

In terms of solution, Ricardo's work identifies four channels:

- through the exchange rate mechanism;
- through greater issuance of public debt;
- through the production of private safe assets; and
- through changes in the regulatory framework.

Ironically, I get to some of Ricardo's policy prescriptions, and add a few, but using a different route that involves some reverse causality compared with his analytical framework. Importantly, rather than reflect a "natural" process driven just by secular and structural factors, what Ricardo identifies may well also involve the impact of a prolonged phase of non-commercial activities in financial markets: directly through interest rate-setting and balance sheet management, and indirectly through forward guidance.

A notable part of what Ricardo picks up is the persistent use of a partial instrument for desirable growth and economic well-being objectives, and doing so for a long time and in such a way that Ben Bernanke's characterisation of the "benefits, costs and risks" have gradually evolved in a more worrisome fashion. In sum, rather than serve as the bridge to more comprehensive policies, as originally intended, unconventional monetary policy has become too much of a destination.

Considered through this prism, the shortage of safe assets is not just an outcome but also part of the transmission mechanism of central banks' policies. And it has unintended consequences, together with collateral damage.

All this speaks to the urgent importance of a policy hand-off: from prolonged excessive reliance on central banks to a broader policy response that deploys pro-growth structural reforms, more active fiscal policy where there is room, targeted debt reduction, and better regional and global economic architecture and cooperation.

If the hand-off occurs in a timely fashion, the "Triffin Dilemma" that Ricardo identifies would be solved in an orderly fashion as low growth and insufficiently inclusive growth gives way to high and more inclusive growth, as artificial financial stability becomes genuine, and as the scope for a “beautiful normalisation” (to adapt Ray Dalio’s term) becomes more of a reality.

However, if the hand-off remains elusive, low growth would risk turning into periodic recessions, artificial financial stability would give way to unsettling volatility, the effective lower bound would become more of a binding constraint, and central bank effectiveness would erode further.

Conclusion

The data on government yields may be seen by some to reflect a period of risk intolerance which is supported by a decline in the supply of safe assets and an increase in demand. But the underlying influences go beyond that, reflecting an unbalanced policy mix that has put way too much of the burden on unconventional monetary policy. The result is another period of excessive financial risk-taking that is continuously fuelled by the liquidity trade.

It is a configuration that speaks to the contradictions that I mentioned at the start of my presentation. And the longer it persists, the greater the likelihood that, for central bank policy, what Ricardo labels the “safe assets shortage conundrum” risks going from being an outcome to becoming a notable problem in itself.

Thank you very much.

Comments by David Laidler[2]

To a retired professor of monetary economics and its history, the topic of this session is irresistible. As a retiree, he is a member of a rentier class currently undergoing euthanasia by persistently low interest rates; as a monetary economist he is intellectually challenged by the efforts of economists like Ricardo Caballero to understand this phenomenon; and as a historian he is fascinated by certain similarities between the fruits of those efforts, and ideas that were current in earlier years.

Caballero's message

Professor Caballero's central message is that a growing concern with "risk" and a concomitant rise in the demand for "safe" stores of value has been the main driver of the world-wide fall in interest rates on high-quality bonds that began even in the 1990s, but gathered particular momentum after 2008. And this message has a corollary: that because growing antipathy to risk seems to be a structural phenomenon, and because rates have now reached rock bottom, other mechanisms – constricted aggregate demand for goods and services, sluggish output growth, or even outright contraction etc – are replacing further interest rate falls as means of equilibrating a potentially ever-growing demand for safe assets with an inadequate supply. Or to put it in traditional terms: those "dark forces of time and ignorance" as John Maynard Keynes called them, with which economic agents must always cope as they plan for their future, having seemed to be manageable since the Great Depression and the war which followed it, have recently begun once again to wreak havoc with orderly economic progress.

Caballero's message is intriguing and plausible, and historians of monetary thought will find it particularly attractive because within it are embedded new variations on certain ideas left over from the literature generated by that Great Depression, something of a rarity in today's economics.

Here I am referring first of all to the insight that output variations might take over as equilibrating mechanisms when other variables become stuck, an idea that underpinned the Richard Kahn (1931) – Jens Warming (1932) – Keynes (1936) multiplier (see David Laidler (1999, pp 172–177, 250–253)) and lay at the very heart of the so-called Keynesian Revolution; but second, and to my mind more importantly, to the significance which Caballero attaches to the interactions of the supply and demand for a particular subset of available stores of value that have the capacity to help agents to deal with the challenges posed by those above-mentioned

---

[2] University of Western Ontario. These comments are based on Caballero's paper "On the Macroeconomics of Risk Intolerance", that was also included in Caballero's presentation at the 16th BIS Annual Conference.

"dark forces", a focus that recalls the theory of what in the 1930s was often called "liquidity preference".

Safe assets and liquidity preference

To be sure, Caballero's "safe" asset – "a simple debt instrument that is expected to preserve its value during adverse systemic events" – at first sight differs quite a bit from the currency and bank deposits whose capacities to provide protection against risk were analysed in the inter-war years by, among others, Frederick Lavington (1921), John Hicks (1935) and, once more Keynes (1930, 1936) (see Laidler (1999, pp 139–42)). The instruments that fit Caballero's definition best, high-quality bonds, are less immediately negotiable and hence, in uncertain times are less useful to ordinary agents – firms households and the like – than currency and deposits, even if they are more likely to remain valuable in the face of shocks to the financial system overall. But Caballero's broader ideas about safety are easily extended to give some weight to immediate acceptability, while expectations about value preservation can never be held with certainty, as his own informal discussion makes clear. It is no surprise, then, that his story of how the demand for safe assets is prone to rise in uncertain times bears more than a passing resemblance to the above-mentioned older accounts of the role of "liquidity preference" (sometimes, in simplified discussions, but not always, synonymous with the "demand for money" (see Laidler (1999, pp 283–7)) in the mechanics of depression and stagnation.

Basically, agents hold stocks of safe assets to enable them to meet their "survival constraints" – to borrow Hyman Minsky's (1954) phrase – in the face of unforeseen adverse economic shocks. And the more agents fear such events, the larger will be the quantities of such assets that they wish to hold. As Caballero himself is careful to point out, these shocks take different forms at different times and for different agents, so fear of them gives rise to demands for assets with characteristics vis-à-vis price predictability, marketability, rate of return etc, that are also different. "Safety" is not just a matter of the objective characteristics possessed by an asset. It also has to do with how these characteristics match up to the specific risks that particular agents believe they face, and the availability to them of other means of dealing with them. Not all of these risks are systemic, but they all give rise to what are fundamentally precautionary demands for assets of various sorts. Which specific assets fill the bill best is a matter of particular situations.

So how do those safe securities issued by a select few governments on which Caballero focuses fit in to this broader picture? Large financial institutions certainly like them, particularly those heavily engaged in international transactions, because their market is deep and active, and for large participants they are easily disposed of at short notice. Crucially, non-reserve currency central banks, on whom domestic institutions rely to provide lender of last resort services, will also want to hold them, particularly in a world lacking a reliable international "central bankers' central bank" on which they can count for support when their own survival constraints start to bind. In short, because of the precautionary services they can provide to internationally significant private institutions and central banks, Caballero's safe securities contribute to the liquidity and stability of the international financial system, and hence, crucially, of the national financial systems that are linked to it.

It is thus possible to link traditional discussions of the monetary experiences of national economies to the issues that particularly concern Caballero, and he is right to note that, in the 1960s, debates about the role of the so-called Triffin dilemma in the workings of the Bretton Woods system, did precisely that; though I would argue that in this case he perhaps overemphasises the international element in the causes of the monetary problems of that time. In my view, the final demise of the gold exchange standard in the early 1970s had more to do with the destructive domestic fiscal and monetary policies pursued by the United States as it tried to finance two wars – one on poverty and the other in Vietnam – than with the stresses created within the Bretton Woods system by limits on the stock of monetary gold. In a similar vein I would also be inclined nowadays to put more stress than does Caballero on the effects of the domestic monetary policies pursued by, among others, the Fed, the ECB and the Bank of England on the economic performance of national economies, than on problems within the international financial system per se.

Further issues

Even so, the currently high prices of Caballero's "safe" securities are a conspicuous feature of the financial landscape and they do pose questions that are intellectually interesting and policy-relevant in their own right, so his analysis should certainly command careful attention. He argues that, without policy attention, rock-bottom interest rates are likely to persist because their underlying causes are structural. First, the demand for safe assets even in normal times grows roughly proportionally with the world economy – see in particular Caballero et al (2017b); second, and crucially, agents in that economy have become, and continue to become, more risk averse, significantly exacerbating the effects of this normal growth in demand – see in particular Caballero et al (2017a); and, finally, these forces are at play in an economy where, if anything, the capacity of the supply of safe assets to respond to growing demand is seriously limited by various institutional and political constraints. This case is well made and coherent, but it does raise a few further issues.

First, if I read Caballero et al (2017b) correctly, some of its argument is based – either for analytical simplicity or because the authors believe it to be true – on the proposition that the demand for "safe" assets grows roughly proportionally with the overall level of activity in the world economy. I wonder about this, because if, as I have argued above, this demand is fundamentally precautionary, then surely one would expect it to be subject to economies of scale – see Francis Edgeworth (1888), Knut Wicksell (1898) and a myriad others. There are many obvious reasons why the precautionary demand for safe assets might have grown over the last couple of decades not just from movements along, but also upward shifts of, its demand function, so perhaps its upward trend in future might become more subdued than in the past as the economic environment becomes more stable, and thus lessen the stresses to which Caballero points.

Second, the analysis seems to neglect another important feature of certain older treatments of the demand for precautionary assets. The risks that matter for this demand are those that agents perceive, and these are not independent of the time, effort and other resources that they devote to gathering and processing relevant information about the likely future course of events. Holding stocks of precautionary assets is thus, on the margin, a substitute for engaging in such activities, because doing so reduces the costs incurred when adverse shocks are encountered. Interactions between risk and the demand for "safe" assets thus run in two directions, not one. This consideration too would tend to make the effects of constraints on the supply of safe assets less acute.

Two questions also arise concerning the evidence presented in Caballero et al (2017a) about the intensity of risk aversion and its growth in recent years, findings that provides an important empirical basis for the rest of his analysis.

To begin with, the four series presented there on ex ante real yields on US Treasury securities (90-day, three-year, five-year and 10-year) do not measure truly "safe" real interest rates. These data have been constructed by subtracting estimates of the expected inflation rate from ex ante *nominal* yields to maturity, and the estimates in question come from the Michigan Survey of Consumers, by way of FRED (See Caballero et al (2017a), fig. 1 panel a, fn.). Now the Michigan Survey itself provides data based on questions about inflation expectations over two time horizons, the next year, and the next five to 10 years, but FRED publishes only the first of these. So: just how reliable, and hence safe, are estimates of ex ante real rates over three months, three, five and 10 years when they are constructed by subtracting inflation expectations over one year from the safe nominal yields to these various maturities? Furthermore, Michigan's published estimates of expected inflation are the *median* values of individual responses to their monthly questionnaire. These responses are subject to a great deal of dispersion around measures of central tendency in any month, and to volatility in that dispersion over time too. So, just how risk-free are real interest rates that are estimated using such a series? And has the element of risk that remains attached to them been constant over time?

Finally, we should be uncomfortable with the fact that an aggregate production function and estimates of the aggregate stock of capital play major inter-related roles in generating this paper's key empirical findings. To be sure, these are ubiquitous features of today's macroeconomics, not least in research on the determinants of that elusive variable r*, much discussed in other sessions of this conference, and much discussed in the older literature too – see Laidler (1999, pp 29–31, 53–57). But we all know (or ought to know) that the conditions under which these entities exist are vanishingly unlikely. Joan Robinson (1953–4) was right about this point during the so-called "Cambridge controversies" – see Avi Cohen and Geoffrey Harcourt (2003) for a retrospective survey – and her arguments had the backing of many others, including Wicksell (1893), Gustav Cassel (1918), and their Swedish successors, as well as a pair of Fishers – Irving (1907) and Franklin (1969).

But evidently economists cannot do without these constructs and have mostly been inclined to ignore her.

In some respects this is fair enough: we do have to get on with our economics, and if our starting points are not always quite right, perhaps it is still permissible to assume that the world behaves more or less "as if" they were, and then proceed. But the "as if" defence can be treacherous: it might be reasonable to analyse the behaviour of Milton Friedman's "expert billiard player" at the pool table "as if" this person was indeed a competent mathematician – see Friedman (1953) – but I'm not so sure that I would have much confidence in predicting that same agent's performance in a calculus test using this assumption.

By analogy, analysis deploying an aggregate production function probably is adequate when, for example, pinning down the supply side of output gap measures in empirically based monetary policy models; it is surely better than fitting simple time trends as people used to do in the 1970s. But the basic theoretical issues with this particular construct stem from the dependence of the relative price weights used to construct an index of "capital" on the behaviour of the very rate of interest that we wish it to help us explain. Might this fact not render an exercise, which deploys an aggregate production function in analysing the reasons why the discrepancy between estimates of the productivity of capital in the aggregate and the economy-wide safe real rate of interest has increased over time, as problematic as one which confronts an expert billiard player with a calculus test?

In short the critical stylised facts around which Caballero's analysis is constructed, may not be quite as securely anchored in either careful measurement of the variables concerned or sound microeconomic theory as they at first appear to be.

Errors of optimism and pessimism

Finally, even accepting Caballero's proposition that the world has become increasingly "risk-intolerant" in recent years, questions about just what this signifies remain. Does it mean that agents' tastes for taking well specified objective risks have been and perhaps still are on the move? This interpretation seems to underlie Caballero et al (2017a), at least on my reading. If so, then indeed there is no particular reason to expect such a fundamental change in tastes to be reversed and future policy choices should take account of this consideration. Or does it mean that, though tastes vis-à-vis risk remain the same, the objective risks to which agents are exposed in today's economy are growing? This interpretation seems to fit better with some of the discussion of Caballero et al (2017b), once again on my reading. But perhaps this does not matter much since this phenomenon would be potentially complementary in its effects and policy implications to an increase in risk aversion *per se*.

But a third possibility puts in an appearance, yet again on my own reading, in Cabellero and Simsek (2017) where agents are divided between "optimists" and "pessimists" and the implications of such heterogeneity are analysed: namely, that we are dealing with fundamentally subjective expectations about the likely evolution of events. Expectations of this kind can and do systematically differ from their "objective" equivalents, if indeed the latter concept makes sense – a matter best not pursued further here! – and they can also differ across agents, as Caballero and Simsek stress. But they can change over time too, as individuals revise their views in the light of experience, their own and that of others. It was this possibility that Lavington (1922) and Arthur Pigou (1927) were prominent in stressing in the 1920s, and they accorded an important role in economic fluctuations to the influence of contagious and cumulative "errors of optimism and pessimism" – see Laidler (1999) pp 84–86.

This way of looking things not only opens up the possibility that the increases in "risk intolerance" whose consequences we are now seeing might have arisen in a cumulative manner from recent painful experience, but also, and more importantly, that more favourable future experience could halt and then reverse them. Clearly, to take this possibility seriously would considerably change the view of recent history and of the future policy menu that Caballero embraces.

Hindsight reveals no shortage of "errors of optimism" before 2008: believing that low and stable inflation was sufficient to guarantee asset market stability; believing that the elimination of currency risk inherent in the arrival of the euro also eliminated all those other risks that had long been inherent in the borrowing practices of certain member governments; believing that the risks inherent in American NINJA mortgages could somehow be made to disappear by securitization; forgetting that the mere creation of new dot-com companies did not guarantee a market for their products, and, later, that the construction of new suburban and retirement housing did not guarantee its salability etc.

And hindsight also suggests that, when history revealed these errors, the reaction was to act upon newly formed errors of pessimism: a hasty scramble out of real and now perceived to be risky assets into safe financial assets; a reluctance on the part of the authorities to provide the latter (including but not limited to those that figure in Caballero's story) in sufficient amounts to meet a jump in private demand for them; an accompanying reluctance on the part of too many economists who should have known better to question this hesitant response, on the grounds that what had already been grudgingly done along such lines threatened the imminent onset of hyper-inflation etc.

But, the passage of time has begun to reveal these errors too. So-called ultra-easy monetary policy did not create hyper-inflation. Indeed some of us would complain that over-emphasis on the level of nominal interest rates as indicators of the stance of monetary policy, and an almost wilful propensity to ignore the messages being imparted by the growth rates of those safe assets included in broader measures of domestic money supplies – perhaps another error of pessimism – led to monetary policy remaining too tight for far too long, in the US and the UK, but even more notably in the euro zone – see Congdon (ed) (2017) for a statement of this case.

Now that monetary policy has become easier, however, and economies are on the mend, perhaps expectations will shift towards optimism, and those ever present "dark forces of time and ignorance" will once again begin to seem less threatening than in recent years. If expectations do shift, then today's apparently chronic shortages in the supply of "safe" assets relative to demand will begin to slacken. And perhaps also those many and various, not to say popular, suggestions that the structure of the economy has changed permanently and for the worse, might themselves begin to look like errors of pessimism that helped perpetuate the very malaise that they sought to diagnose. But this is to indulge in foresight – always riskier than hindsight – so in the meanwhile readers are advised to pay careful attention to Professor Caballero's always stimulating research.

References

Caballero, R, E Farhi & P-O Gourinchas (2017a) "Rents, technical change, and risk premia. Accounting for secular trends in interest rates, returns on capital, earnings yields and factor shares", *American Economic Review, Papers and Proceedings*, vol 107, pp 614–20.

——— (2017b): "The safe asset shortage conundrum", *Journal of Economic Perspectives*, no 31 (Summer), pp 1–18.

Caballero, R and A Simsek (2017): "A risk-centric model of demand recessions and macroprudential regulation", MIT (mimeo).

Cassel, G (1918): "The theory of social economy" (tr. 1923), London, Jonathan Cape.

Cohen, A and G Harcourt (2003): "Retrospectives: whatever happened to the Cambridge capital theory controversies?" *Journal of Economic Perspectives*, no 17, (Winter) pp 199–214.

Congdon, T (ed) (2017): "Money in the great recession", Cheltenham, E Elgar.

Edgeworth, F Y (1888): "The mathematical theory of banking", *Journal of the Royal Statistical Society*, no 51, pp 113–26.

Fisher, F (1969): "The existence of aggregate production functions", *Econometrica*, no 37, pp 553–77.

Fisher, I (1907): "The rate of interest: its nature, determination, and relation to economic phenomena", New York, Macmillan.

Friedman, M (1953): "The methodology of positive economics, in *Essays in Positive Economics*, Chicago, University of Chicago Press.

Hicks, J (1935): "A suggestion for simplifying the theory of money", *Economica*, no 2, pp 1–19.

Kahn, R (1931): "The relation of home investment to unemployment", *Economic Journal*, no 41, pp 173–98.

Keynes, J (1930): "A treatise on money", London, Macmillan.

——— (1936): "The general theory of employment interest and money", London, Macmillan.

Laidler, D (1999): “Fabricating the Keynesian revolution”, Cambridge University Press.

Lavington, F (1921): “The English capital market”, London, Macmillan.

——— (1922): “The trade cycle”, London, P S King & Son.

Minsky, H (1984): “Induced investment and the trade cycle”, Cambridge Mass, unpublished Ph D dissertation, Harvard University.

Pigou, A (1927): “Industrial fluctuations”, London, Macmillan (second edition 1929).

Robinson, J (1953–54): “The production function and the theory of capital”, *Review of Economic Studies,* no 21, pp 81–106.

Warming, J (1932): “International difficulties arising out of the financing of public works during depression”, *Economic Journal*, no 42, pp 211–24.

Wicksell, K (1893): “Value, capital and rent”, (tr. 1965) London, Allen & Unwin.

——— (1898): “Interest and prices”, (tr. 1936) London, Macmillan, for the Royal Economic Society.

Previous volumes in this series

732 July 2018	The global factor in neutral policy rates: some implications for exchange rates, monetary policy, and policy coordination	Richard Clarida
731 June 2018	The likelihood of effective lower bound events	Michal Franta
730 June 2018	U.S. monetary policy and fluctuations of international bank lending	Stefan Avdjiev and Galina Hale
729 June 2018	Has inflation targeting become less credible?	Nathan Sussman and Osnat Zohar
728 June 2018	Accumulation of foreign currency reserves and risk-taking	Rasmus Fatum and James Yetman
727 June 2018	Recent RMB policy and currency co-movements	Robert N McCauley and Chang Shu
726 June 2018	Residential investment and economic activity: evidence from the past five decades	Emanuel Kohlscheen, Aaron Mehrotra and Dubravko Mihaljek
725 May 2018	Identifying oil price shocks and their consequences: the role of expectations in the crude oil market	Takuji Fueki , Hiroka Higashi , Naoto Higashio , Jouchi Nakajima, Shinsuke Ohyama and Yoichiro Tamanyu
724 May 2018	Do small bank deposits run more than large ones? Three event studies of contagion and financial inclusion	Dante B Canlas, Johnny Noe E Ravalo and Eli M Remolona
723 May 2018	The cross-border credit channel and lending standards surveys	Andrew Filardo and Pierre Siklos
722 May 2018	The enduring link between demography and inflation	Mikael Juselius and Előd Takáts
721 May 2018	Effects of asset purchases and financial stability measures on term premia in the euro area	Richhild Moessner
720 May 2018	Could a higher inflation target enhance macroeconomic stability?	José Dorich, Nicholas Labelle St-Pierre, Vadym Lepetyuk and Rhys R. Mendes
719 May 2018	Channels of US monetary policy spillovers to international bond markets	Elias Albagli, Luis Ceballos, Sebastián Claro and Damian Romero

All volumes are available on our website www.bis.org.