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THE IMPLICATIONS OF FINANCIAL INNOVATION FOR CAPITAL MARKETS AND HOUSEHOLD WELFARE

Abstract

Our objective is to understand how financial innovation affects investors' optimal asset-allocation decisions and the economic mechanisms through which these decisions influence financial markets, welfare, and wealth inequality. We show that when some investors, such as households, are less confident than other investors about the dynamics of the new asset made available by financial innovation, but learn over time, many "intuitive" results are reversed: financial innovation increases the return volatility and risk premium of the new asset along with volatilities of investors' portfolios. Despite the increase in volatilities, financial innovation improves the welfare of all investors but worsens wealth inequality because experienced investors benefit more from it.

JEL Classification: G11, G12, D53

Keywords: household finance, household portfolio choice, Wealth Inequality, differences in beliefs, parameter uncertainty, Bayesian Learning, recursive utility

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The Implications of Financial Innovation for Capital Markets and Household Welfare*

Adrian Buss[†] Raman Uppal Grigory Vilkov

August 21, 2018

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1 Introduction

Financial markets are being transformed by the rapid pace of *financial innovation*, which makes available new asset classes[1] and financial products with increasingly complex payoff structures[2] to households that previously did not have access to them. For instance, Foxman (2018) writing in Bloomberg reports that "JPMorgan Chase & Co. plans to offer sophisticated investments to a much broader clientele. The bank is slashing requirements to participate in certain alternative investments that its asset management arm once offered mainly to institutions or the ultra rich." At the same time, motivated partly by the low yields on traditional asset classes, a dazzling array of new financial products is being supplied to households; for example, Célérier and Vallée (2017) document that, "Since the end of the 1990s, European financial institutions have designed, marketed and sold more than 2 trillion euros of complex financial products to households." Moreover, the transition from defined-benefit to defined-contribution pension plans, which requires households to make their own financial decisions, makes it increasingly important to understand the effects of financial innovation.

Accordingly, the objective of our research is to study the optimal asset-allocation decisions of investors that get access to a new asset and the economic mechanisms through which these decisions influence financial markets, welfare, and wealth inequality. In particular, the questions we address in our research include the following: Should we expect inexperienced investors, such as households, who are not fully confident about the new asset, to include it in their portfolios at all? How should we expect inexperienced investors to revise their portfolios over time as they learn about the new asset? What will be the impact of investors' trading decisions on the return volatilities and risk premia of new and traditional assets—upon the introduction of the new asset, and in the long run? What will be the welfare consequences of financial innovation and how will it affect wealth inequality between inexperienced and experienced investors?

The traditional literature on financial innovation (see, for example, Kihlstrom, Romer, and Williams (1981), Allen and Gale (1988), Weil (1992), Elul (1997), and Calvet, Gonzalez-Eiras, and Sodini (2004)) assumes that all investors in the economy are fully confident about the return process for the new asset. Under this assumption, it predicts that financial innovation

[1]The new asset classes into which households can invest include hedge funds, private equity, emerging-market equity and debt, mezzanine and distressed debt, real estate, infrastructure, commodities, and cryptocurrencies.

[2]For an example of a structured product designed to increase household participation in the stock market by offering downside protection, see Calvet, Celerier, Sodini, and Vallee (2017). Other new strategies being offered include equity-linked certificates of deposit, smart-beta investments, and alternative-alpha products.

facilitates risk sharing across investors while also improving diversification of each investor's portfolio. Thus, financial innovation should smooth consumption, leading to a *decrease* in the return volatility and risk premium of the new asset. Moreover, financial innovation should improve welfare, with the wealth distribution across investors being constant over time.

However, the assumption that all investors are equally (and fully) confident about the return process is unlikely to hold in the context of new assets.[3] For instance, sophisticated institutional investors are likely to have more confidence about investing in new assets, especially if they have been investing in these assets for a longer period of time. Consequently, the insights from the traditional literature may not apply. The main contribution of our work is to fill this gap in the literature. In particular, we develop a dynamic general-equilibrium model with *two* classes of investors, who differ in their confidence about the asset made available by financial innovation: *experienced* investors, who are fully confident about the new asset (that is, have infinitely precise prior beliefs) and *inexperienced* investors, such as households, who are relatively less confident (that is, have prior beliefs with finite precision) but *learn* over time.[4] Both types of investors have recursive utility functions with a preference for early resolution of uncertainty. There exist *multiple* risky assets—a traditional asset representing publicly traded equities plus the new asset—and a risk-free bond. While experienced investors have access to all three financial assets that are available, inexperienced investors can initially trade only the risk-free bond and traditional risky asset, gaining access to the new asset only after *financial innovation* takes place. Hence, financial markets are incomplete.

We then use this model to demonstrate that if investors differ in confidence, then many of the "intuitive" results in the traditional literature are reversed: financial innovation leads to an *increase* in the return volatility and risk premium of the new asset along with the volatility of investors' portfolios. Despite this increase in volatilities, financial innovation increases the welfare of all investors; however, the wealth share of inexperienced investors decreases over

[3]The difficulties in assessing new asset classes are discussed by: Phalippou (2009), Phalippou and Gottschalg (2009), and Ang and Sorensen (2013) for private equity; Dhar and Goetzmann (2005) for real estate; and Ang, Ayala, and Goetzmann (2014) for hedge funds and private equity. For a discussion of complexity in the design of structured products, see, for instance, Amromin, Huang, Sialm, and Zhong (2018), Carlin, Kogan, and Lowery (2013), and Griffin, Lowery, and Saretto (2014). Hastings, Madrian, and Skimmyhorn (2013) and Lusardi and Mitchell (2014) provide extensive evidence of the lack of financial expertise of households and Campbell (2016) provides a detailed discussion of mistakes made by households when making financial decisions.

[4]One might think that inexperienced investors could simply rely on financial advisers. However, when households lack financial expertise, this makes it difficult also to obtain good financial advice; Bricker, Dettling, Henriques, Hsu, Jacobs, Moore, Pack, Sabelhaus, Thompson, and Windle (2012) and Lusardi and Mitchell (2014) find that fewer than one-third of the respondents in the U.S. Survey of Consumer Finances and U.S. National Financial Capability Study, respectively, consulted financial advisers.

time, thereby *worsening* wealth inequality in contrast to what one would observe if all investors were equally confident.

We now explain the intuition for these novel predictions about the impact of financial innovation on capital markets and welfare. We start by noting that *before* financial innovation gives inexperienced investors access to the new asset, the portfolios of both groups of investors are naturally highly concentrated: experienced investors hold all of the new asset, whereas inexperienced investors overweight the traditional risky asset. *Upon* financial innovation, in the traditional setting with inexperienced investors being fully confident about the new asset, they would instantly switch to holding a well-diversified market portfolio that includes the new asset. In contrast, if inexperienced investors are less than fully confident about the return dynamics of the new asset, but they learn over time, their portfolios would remain highly concentrated in the traditional risky asset even after financial innovation. This bias away from the new asset is *not* because of incorrect beliefs (at the date of financial innovation, inexperienced investors are assumed to have unbiased beliefs about the mean dividend-growth rate) or the lower precision of their beliefs, but because of *learning*, which will lead them to revise their beliefs over time. In particular, inexperienced investors' underweighting of the new asset stems from a *negative* intertemporal hedging portfolio component, whose role is to protect them against downward revisions in beliefs about the dividend-growth rate of the new asset.[5]

The effect of financial innovation on the new asset's return volatility and risk premium would also be strikingly different when investors differ in their confidence: the new asset's return volatility and risk premium would *increase* substantially when it became available to inexperienced investors because learning *amplifies* the fluctuations in the new asset's dividends. For example, positive cash-flow news leads to an upward revision in inexperienced investors' beliefs about the dividend-growth rate of the new asset; consequently, they allocate a larger fraction of their risky portfolio to the new asset, increasing its price-dividend ratio exactly when dividends are high as well.[6]

[5]Technically speaking, inexperienced investors prefer a portfolio that performs well when the new asset's perceived dividend-growth rate is low, or equivalently, marginal utility is high. This is achieved through a *negative* intertemporal hedging position in the new asset because its return is positively correlated with the perceived dividend-growth rate.

[6]The mechanism driving excess volatility in our model is different from that in Collin-Dufresne, Johannes, and Lochstoer (2016a), where it is a consequence of substitution between the risk-free asset and the (single) risky asset, for which ones requires that the elasticity of intertemporal substitution (EIS) be greater to one. In our baseline calibration, excess volatility arises even with EIS = 1 because of the reallocation of wealth from one risky asset to the other risky asset. If EIS were greater than one in our model, the excess volatility would be even greater.

The concentration of investors' portfolios and the resulting increase in the return volatility and risk premium of the new asset would decline only slowly over several decades, as the inexperienced investors' confidence increases (that is, their estimate of the dividend-growth rate becomes more precise).

In spite of the higher volatility, financial innovation would increase the welfare of all investors because it allows both groups of investors to improve portfolio diversification and enhance risk sharing. However, these gains would not be shared equally: because of their more precise beliefs, the wealth share of experienced investors would continue to rise after financial innovation whereas that of inexperienced investors would fall, *worsening* wealth inequality, in contrast to the traditional setting where both classes of investors are assumed to be equally confident. Essentially, the experienced investors offer insurance to the inexperienced investors, which needs to be paid for. This payment leads to the transfer of wealth from inexperienced to experienced investors. This risk-sharing arrangement between experienced and inexperienced investors is captured well by Brian Tracy's quote that: "When a man with money meets up with a man with experience, the man with the experience is going to end up with the money and the man with money is going to end up with the experience."[7]

To ensure the robustness of our results, we show that our results are—qualitatively, and in many cases, even quantitatively—unchanged for several variations and extensions of our baseline model. In our baseline model, financial innovation has a probability of occurring only at a *predetermined* point in time, and the decision about financial innovation is *exogenous*. In the first extension of the model, we endogenize the decision to introduce the asset, with financial innovation more likely if the new asset has performed well and demand for it is high. Next, we endogenize also the timing of financial innovation. We also consider changes in the parameter values used to model the beliefs of inexperienced investors, the preferences of the two groups of investors, and the characteristics of the new asset. Finally, we consider a cost for trading the new asset.

Our paper is related to several strands of the literature. First, our work is related to the literature on learning in general equilibrium. In a comprehensive analysis, Collin-Dufresne, Johannes, and Lochstoer (2016a) show that parameter learning strongly amplifies the impact of macro shocks when a representative investor has a preference for early resolution of uncertainty. In our paper, there are two groups of investors who differ in the precision of their beliefs and

[7]We are grateful to Francis Longstaff for bringing this quote to our attention.

the focus is on the *interaction* between learning and financial innovation. Thus, in contrast to their model that has a single risky asset, we consider an economy with *multiple* risky assets—a traditional asset and a new asset—with parameter uncertainty about only the new asset's expected dividend-growth rate. As a result of having two risky assets, in our model, as explained in footnote 6, excess volatility arises even if EIS is not above one because of the substitution between the two risky assets following changes in the investors' investment-opportunity set, whereas in Collin-Dufresne, Johannes, and Lochstoer (2016a) it arises from the substitution between the risk-free and (single) risky asset, which requires EIS > 1. Also related is the work by Collin-Dufresne, Johannes, and Lochstoer (2016b) and Ehling, Graniero, and Heyerdahl-Larsen (2018), who study overlapping-generations economies in which not all information is passed on to the new generation, so that learning is biased and not fully Bayesian.[8]

Second, we contribute to the literature on household finance, financial literacy, and inequality.[9] Campbell, Ramadorai, and Ranish (2015) and Bach, Calvet, and Sodini (2016, 2017) document how differences in financial decisions contribute to wealth inequality. Piketty (2014) and Lusardi, Michaud, and Mitchell (2017) highlight that the differences in financial decisions are driven to a large extent by differences in financial expertise, which in our paper we label "experience." Consistent with the findings in these papers, our model shows that investors with experience hold portfolios that have higher expected returns and higher volatility. Our work contributes to this literature by illustrating how financial innovation can improve welfare yet worsen wealth inequality.

Our work is related also to the theoretical literature on financial innovation. Simsek (2013a,b) focuses on its impact on portfolio risks and shows that, in the presence of belief disagreement, financial innovation can lead to an increase in portfolio risks for two reasons: one, investors take on new bets, and two, they increase the magnitude of their existing bets. We highlight a *third* channel that causes an amplification of portfolio risks: an endogenous increase in the new asset's return volatility. Iachan, Nenov, and Simsek (2016) show that access to new risky assets, together with heterogeneous beliefs, induces investors to save more,

[8]Earlier papers on parameter learning in single-agent settings with time-separable utility include Detemple (1986), David (1997), Veronesi (2000), David and Veronesi (2002, 2013), and Pástor and Veronesi (2003, 2012). For a comprehensive survey of this literature, see Pástor and Veronesi (2009).

[9]Comprehensive surveys of household finance are presented by Guiso, Haliassos, and Jappelli (2002), Haliassos (2003), Campbell (2006), and Guiso and Sodini (2013). The literature on financial literacy is surveyed by Hastings, Madrian, and Skimmyhorn (2013) and Lusardi and Mitchell (2014). Campbell, Jackson, Madrian, and Tufano (2011) and Campbell (2016) provide an excellent discussion of the importance of regulating financial innovation when households do not have sufficient experience to make financial decisions.

which, in turn, can explain the decline in returns of various asset classes over the last few decades. We demonstrate that in a dynamic setting, the implications of financial innovation are even more subtle and surprising. That is, return volatilities and risk premia first *increase* before slowly converging to their (lower) long-term levels.[10] Note also that none of these studies analyzes learning, which plays an important role here. Basak and Pavlova (2016) show that the entry of new, institutional investors in the commodity markets leads to more volatile returns. In their model, these effects arise because the new investors care about their performance *relative* to a commodity index, whereas in our model they are a consequence of new investors beliefs' being less precise than those of experienced investors. Finally, Gennaioli, Shleifer, and Vishny (2012) focus on the security-issuance aspect of financial innovation; in their model, financial intermediaries cater to investors' preferences for safe cash-flow patterns and their biased beliefs (due to neglected risk), leading to excessive issuance and, in the long-run, fragile markets.

Finally, our work is related to the literature on heterogeneous investors and portfolio constraints. For instance, Chabakauri (2015) studies the effect of a limited-participation constraint and demonstrates that it leads to a higher market price of risk, excess volatility, and a lower price-dividend ratio.[11] In contrast to this literature, our key objective is to study the effects *at and after* financial innovation, which can be interpreted as the relaxation of a constraint on the portfolio of inexperienced investors, and we document that many effects of financial innovation are reversed if one group of investors is less than fully confident about the returns on an asset.[12]

The rest of the paper is organized as follows. In Section 2, we describe features of the baseline model of the economy we study, equilibrium in this economy, and our solution approach. In Section 3, we analyze the effect of financial innovation on portfolio positions, capital markets, and welfare. Section 4 concludes. Technical details and a robustness analysis containing various variations and extensions of the baseline model are relegated to the appendices.

[10] This dynamic process of financial innovation, in combination with Bayesian learning, shares similarities with Pástor and Veronesi (2012), who study the impact of new government policies on stock prices when a representative investor faces uncertainty about government policies.

[11] Other work includes Basak and Cuoco (1998), Basak and Croitoru (2000), Panageas (2005), Gallmeyer and Hollifield (2008), Prieto (2013), and Chabakauri (2013).

[12] There are also several papers that study the effect of heterogeneous beliefs in the absence of portfolio constraints; for instance, Harrison and Kreps (1978), Detemple and Murthy (1994), Zapatero (1998), Scheinkman and Xiong (2003), Dumas, Kurshev, and Uppal (2009), and Xiong and Yan (2010). In contrast to these papers, in which investors have risk-neutral or time-additive preferences, we incorporate recursive preferences, in the presence of which parameter learning leads to an additional risk premium and excess volatility. Moreover, our focus is on the interaction between heterogeneous beliefs and financial innovation.

2 A Model of Financial Innovation

In this section, we describe the general-equilibrium model that we develop to study the impact of financial innovation. The key feature of the economy is that it is populated by *two* groups of investors who *differ* in their access to financial assets and in their confidence (that is, the precision of their beliefs) about the dynamics of the new asset; otherwise the framework is kept as simple as possible to illustrate the key economic mechanisms in the clearest possible way.

The first group, experienced investors, have access to all three available financial assets and are fully confident regarding the new asset. The second group, inexperienced investors, such as households, gain access to the new asset only after *financial innovation* and are not fully confident about the dynamics of the new asset, but learn about it over time. Intuitively, one can think of our framework as a setting in which a subset of investors, such as (sophisticated) institutional investors, has access to a new asset before it becomes available to other (less-sophisticated) investors, such as households.[13] We describe the details of our model next.

2.1 Economic Framework

The model is set in discrete time, with time interval Δ_t and a finite horizon T; that is, $t \in \{1, 2, \ldots, T\}$.

Investors: The two groups of investors, indexed by $k \in \{1, 2\}$, are assumed to have identical Epstein and Zin (1989) and Weil (1990) preferences over consumption $C_{k,t}$ of the single consumption good.[14] Specifically, lifetime utility $V_{k,t}$ is defined recursively as

$$V_{k,t} = \left[(1 - \beta) \, C_{k,t}^{1-\frac{1}{\psi}} + \beta E_t^k \left[V_{k,t+1}^{1-\gamma} \right]^{\frac{1}{\phi}} \right]^{\frac{\phi}{1-\gamma}}, \tag{1}$$

where E_t^k denotes the time-t conditional expectation under an investor's subjective probability measure, β is the rate of time preference, $\gamma > 0$ is the coefficient of relative risk aversion, $\psi > 0$ is the elasticity of intertemporal substitution (EIS), and $\phi = \frac{1-\gamma}{1-1/\psi}$. Accordingly, the stochastic

[13] One could also describe our model as one where the market for the new asset is initially "segmented" so that access to this asset is limited to sophisticated investors, with financial innovation being the phenomenon that removes this segmentation and makes the asset available to a broader class of investors.

[14] It would be straightforward to allow for heterogeneity in investors' preferences; we assume identical preferences so that we can focus on the effects of financial innovation.

discount factor (SDF) of investors in group k is given by:

$$M_{k,t+1} = \beta\, \xi_t \, \exp\Big((-1/\psi)\, \Delta c_{k,t+1} - (\gamma - 1/\psi)\, v_{k,t+1} \Big), \tag{2}$$

where $\Delta c_{k,t+1}$ denotes log consumption growth, $v_{k,t+1} \equiv \log(V_{k,t})$ denotes log lifetime continuation utility, and $\xi_t \equiv E_t^k \left[\exp\big((1-\gamma)\, v_{k,t+1} \big) \right]^{(\gamma - 1/\psi)/(1-\gamma)}$.

Financial Assets: There exist three financial assets. The first asset is a risk-free single-period discount bond in zero net supply, indexed by $n = 0$. In addition, there are two risky assets, indexed by $n \in \{1, 2\}$—each in unit supply and modeled as a claim to the dividend stream, $D_{n,t}$, of a Lucas (1978) tree. Specifically, we assume that, for each tree, log dividend growth $\Delta d_{n,t+1} \equiv \ln\big[D_{n,t+1}/D_{n,t} \big]$ can be described by an IID Normal model with expected dividend-growth rate μ_n and dividend-growth volatility σ_n:

$$\Delta d_{n,t+1} = \mu_n + \sigma_n \, \varepsilon_{n,t+1}, \tag{3}$$

where $\varepsilon_{n,t+1} \sim \mathcal{N}(0,1)$, and $\varepsilon_{1,t+1}$ and $\varepsilon_{2,t+1}$ are assumed to be uncorrelated.[15] We interpret the first risky asset as a traditional asset that has been available to all investors for some time already, for example, public equity, whereas the second risky asset represents a new asset. All financial assets are assumed to be perfectly liquid.[16]

We assume that experienced investors ($k = 1$) have access to all three financial assets. In contrast, inexperienced investors ($k = 2$) can trade only the risk-free bond and the traditional risky asset until date $t = \tau - 1$; the new asset becomes available to them at date τ only if *financial innovation* occurs.[17] Technically, at time $t = \tau$, the new asset is made available with probability p, so that financial innovation cannot be fully anticipated.[18]

[15]Even though dividends are uncorrelated, asset returns, which depend on equilibrium prices, will be correlated.

[16]In practice, trading in a new asset might entail transaction costs. Therefore, in Appendix C we introduce a transaction cost for the new asset and demonstrate that our results are robust to this.

[17]If one wished to consider a model where the new asset was available from the very outset, one could set $\tau = 1$. However, to understand the effects of financial innovation, one would then need to compare the economy where the new asset was available to inexperienced investors with an economy where it was not. In contrast, our model, where the new asset is not available for dates $t < \tau$ but is available for $t \geq \tau$ (with probability p), allows us to undertake this comparison within the same economy.

[18]Note that this implies that financial innovation can occur only at a predetermined point in time. In practice, introduction of a new asset is undertaken by financial intermediaries whose decision will depend on the demand for the new asset. Therefore, in Appendix C we consider extensions of the model in which the timing and decision to introduce the new asset are endogenous and demonstrate that our results are robust to these changes.

2.2 Learning

The second key difference between the two groups of investors is that when inexperienced investors gain access to the new asset they are less confident about the asset than experienced investors, but they learn about the asset's dynamics over time.[19] Specifically, we assume that while experienced investors are fully confident about the new asset's dividend dynamics, inexperienced investors are uncertain about its expected dividend-growth rate, μ_2. For ease of exposition, we also assume that both groups of investors know the dividend dynamics of the traditional asset and know that the two assets' dividends are uncorrelated.[20]

More formally, inexperienced investors start with a conjugate prior $\mu_2 \sim \mathcal{N}(\mu_{2,\tau}, A_\tau\, \sigma_2^2)$ at date τ and update their beliefs based on realized dividend growth using Bayes' rule. This prior, combined with the dividend dynamics in (3), implies a time-t posterior density function $p(\mu_2|\Delta d_{2,\tau}, \ldots, \Delta d_{2,t}) = \mathcal{N}(\mu_{2,t}, A_t\, \sigma_2^2)$, with the dynamics of $\mu_{2,t}$ and A_t being described by

$$\mu_{2,t+1} = \mu_{2,t} + \left(\Delta d_{2,t+1} - \mu_{2,t}\right) \frac{A_t}{1 + A_t}, \tag{4}$$

$$A_{t+1} = \frac{1}{1/A_t + 1}. \tag{5}$$

Consequently, even though the dividend dynamics of the new asset are driven by an IID model with constant parameters, from the perspective of inexperienced investors the expected dividend-growth rate, $\mu_{2,t+1}$, is time-varying. In particular, it is a martingale, so revisions in beliefs constitute permanent shocks to the inexperienced investors' investment-opportunity set. Finally, note that inexperienced investors do not learn from the behavior of experienced investors; rather, they "agree to disagree."[21]

For illustration, Panel A of Figure 1 plots the expected dividend-growth rate of the new asset as perceived by the inexperienced investors, $\mu_{2,t+1}$, for a simulated path of the economy. Intuitively, when realized dividend growth is higher than expected, highlighted in shaded gray, the investors revise their beliefs about μ_2 upward and vice versa for lower than expected growth.

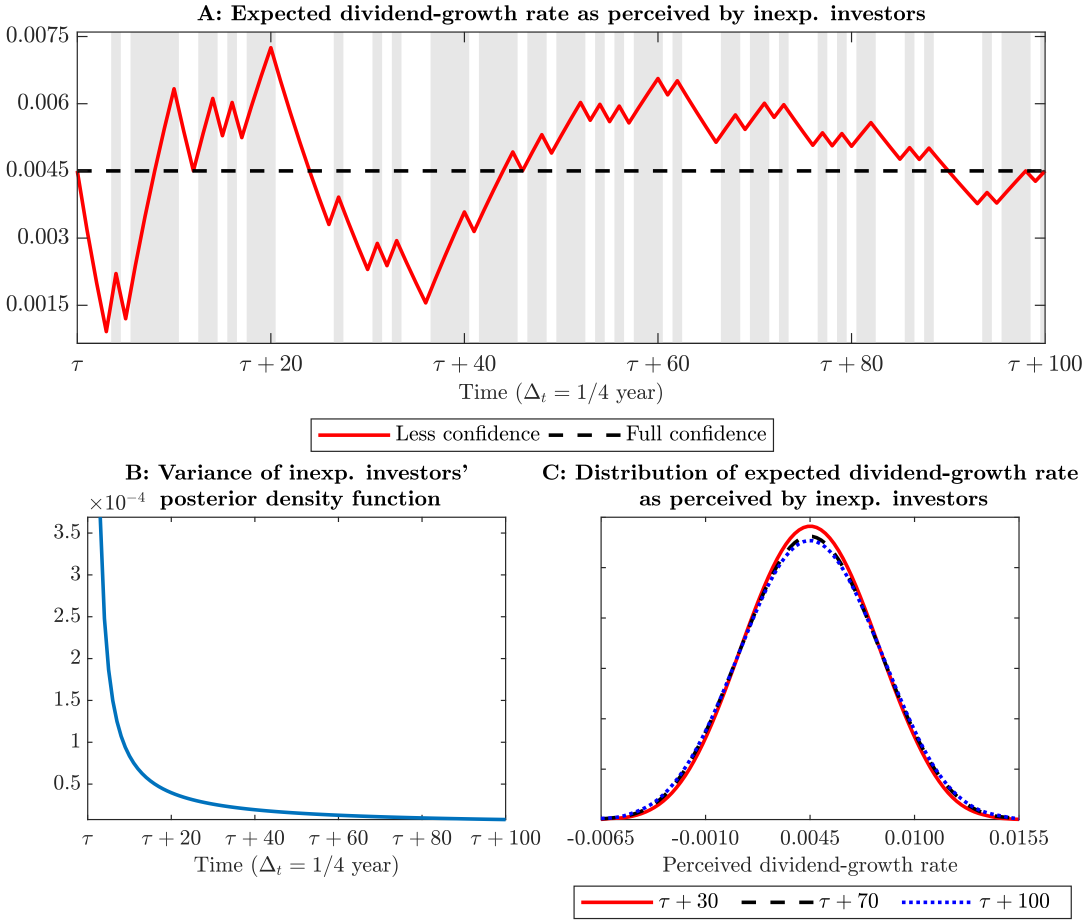
[19]There is substantial empirical evidence about the difficulties in assessing a new asset because of limited data and investor inexperience; see footnote 3.

[20]The model could be extended to incorporate generalizations, such as parameter uncertainty for both investors, parameter uncertainty about both risky assets, and uncertainty about the new asset's dividend-growth volatility. Also, one could allow inexperienced investors to learn about the new asset starting from date $t = 1$ instead of $t = \tau$, even though the new asset becomes available for trading only at date τ. The results in these cases are similar to the ones for the baseline model.

[21]Morris (1995) explains why it is reasonable to assume that investors have different priors and that this is fully consistent with rationality. There is a large literature that uses this formulation; see, for example, Basak (2005), Dumas, Kurshev, and Uppal (2009), and the papers cited therein.

Figure 1: Learning

This figure illustrates Bayesian learning in our model. Panel A depicts the dividend-growth rate for the new asset, as perceived by inexperienced investors, for a simulated path of the economy. The shaded gray areas indicate periods of higher than expected dividend growth for the new asset. Panel B shows the (deterministic) decline in the variance of the inexperienced investors' posterior, $A_t\sigma_2^2$, over time. Panel C shows the distribution, across simulation paths, of the expected dividend growth rate of the new asset as perceived by the inexperienced investors, $\mu_{2,t}$ after the elapse of 30, 70, and 100 periods. This figure is based on the following parameter values: $\Delta_t = 1/4$ year, $\mu_{2,\tau} = \mu_2 = 0.0045$, $A_\tau = 20$, and $\sigma_2 = 0.0275$.



As a result, inexperienced investors are sometimes more optimistic and at other times more pessimistic than experienced investors. With every new observation, inexperienced investors gain in confidence and their estimate of the new asset's expected dividend-growth rate becomes more precise, that is, the posterior uncertainty declines (Panel B), which explains the increasingly *smaller updates* to the perceived growth rate over time (technically, the impact of the realized dividend growth $\Delta d_{2,t+1}$ on $\mu_{2,t+1}$ declines as A_t declines). In the long-run, the posterior variance $A_t\,\sigma_2^2$ actually converges deterministically to zero, such that the perceived growth rate converges as well—though not necessarily to the true value μ_2. Panel C shows the probability density function—across simulation paths—of the new asset's expected dividend-growth rate as perceived by the inexperienced investors, $\mu_{2,t+1}$, for different dates. Note that there is substantial variation in beliefs even after a lengthy period of learning.

2.3 Investors' Optimization Problem and Equilibrium

The objective of investors in group k is to maximize their expected lifetime utility (1), by choosing their consumption, $C_{k,t}$, and their holdings in the available financial assets, $\theta_{k,n,t}, n \in \{0, \ldots, N_{k,t}\}$, subject to the budget equation

$$C_{k,t} + \theta_{k,0,t} \, S_{0,t} + \sum_{n=1}^{N_{k,t}} \Delta\theta_{k,n,t} \, S_{n,t} \;\leq\; \theta_{k,0,t-1} + \sum_{n=1}^{N_{k,t}} \theta_{k,n,t-1} \, D_{n,t}, \tag{6}$$

where $\Delta\theta_{k,n,t}$ denotes the change in the shares held of asset n, $S_{n,t}$ denotes the price of asset n, and $N_{k,t}$ denotes the number of assets available to investor k.[22] Intuitively, the left-hand side of budget equation (6) describes the amount allocated to consumption, the purchase or sale of the (newly issued) short-term bond, and changes in the portfolio positions in the risky assets; and the right-hand side reflects the available funds, stemming from the unit payoff of the (maturing) short-term bond as well as the dividends from the holdings of the available risky assets. We derive the first-order conditions for consumption and asset-allocation choices in Appendix A.1.

Equilibrium in the economy is defined as a set of consumption and asset-allocation policies, along with the resulting price processes for the financial assets, such that the consumption policies of all investors maximize their lifetime utility, that these consumption policies are financed by the asset allocations that investors choose, and that markets for financial assets and the consumption good clear. The equations characterizing equilibrium are given in Appendix A.2.

2.4 Solving for the Equilibrium

If financial markets are *complete*, one can separate the task of identifying the equilibrium into two distinct steps by exploiting the condition that investors can achieve perfect risk sharing. First, one would identify the optimal allocation of aggregate consumption across investors, and

[22] In particular, while experienced investors always have access to all financial assets ($N_{1,t} = 2, \forall t$), inexperienced investors initially have access to only the risk-free discount bond and the traditional risky asset ($N_{2,t} = 1, t < \tau$) and gain access to the second risky asset only if financial innovation occurs ($N_{2,t} = 2$ for $t \geq \tau$ if $\mathcal{I}_\tau = 1$), where $\mathcal{I}_\tau \in \{0, 1\}$ indicates whether financial innovation has occurred.

then, in the second step, determine the portfolio policy of each investor that supports this consumption allocation and the resulting asset prices.

However, in economies such as the one considered here in which financial markets are *incomplete* because investors cannot trade all available securities, one must solve *simultaneously* for the consumption and investment policies of the two groups of investors along with asset prices, leading to an equation system that requires backward and forward iteration in time, instead of a purely recursive system. Dumas and Lyasoff (2012) show how this backward-forward system of equations can be reformulated to obtain a purely recursive system, using a "time shift" for a subset of the equations that characterize the equilibrium. We solve for the equilibrium numerically, extending the algorithm proposed by Dumas and Lyasoff (2012) to the case of parameter uncertainty with Bayesian learning, multiple risky assets, and Epstein-Zin-Weil preferences. Details of this numerical algorithm are provided in Appendix B.

Technically, when identifying the equilibrium in the model, we need to keep track of four state variables: the consumption share of the experienced investors, $\omega_{1,t} \in (0,1)$; the dividend share of the first risky asset $\delta_{1,t} \in (0,1)$, the dynamics of which follow from the joint dividend dynamics in equation (3); the expected dividend-growth rate of the new asset as perceived by the inexperienced investors, $\mu_{2,t}$, with its dynamics specified in equation (4); and, the (deterministic) posterior variance of the inexperienced investors' beliefs, $A_t\,\sigma_2^2$, with its dynamics specified in equation (5).

3 The Effects of Financial Innovation

In this section, we illustrate the economic mechanisms through which financial innovation influences the dynamics of the investors' asset-allocation decisions, capital markets, and welfare.

3.1 Parameter Values

The parameter values used in our numerical illustrations are summarized in Table 1. We solve the model at a quarterly frequency ($\Delta_t = 1/4$ year) for $T = 800$ periods; that is, for a total of 200 years.[23] We follow Collin-Dufresne, Johannes, and Lochstoer (2016a) and set for all investors the (quarterly) rate of time-preference to $\beta = 0.994$, the coefficient of relative risk aversion to $\gamma = 10$, the elasticity of intertemporal substitution parameter to $\psi = 1$, and,

[23]The distant terminal date is chosen to minimize any effects resulting from the finite horizon.

Table 1: Model Parameters

This table reports the parameter values used for our numerical illustrations. The choice of these parameter values is explained in Section 3.1.

Variable	Description	Base Case
Δ_t	Trading (and observation) interval	1/4 year
T	Total number of trading dates (quarters)	800
τ	Date of introduction of the new asset (quarters)	40
p	Probability of introduction of the new asset	0.50
β	Rate of time preference (per quarter)	0.994
γ	Relative risk aversion	10
ψ	Elasticity of intertemporal substitution	1.0
$w_{2,1}$	Initial wealth share of the inexperienced investors	2/3
μ_n	Expected dividend growth (per quarter)	0.45%
σ_n	Dividend growth volatility (per quarter)	2.75%
ρ	Correlation between dividend growth rates	0
$\delta_{1,1}$	First asset's share of total initial dividends	0.80
λ	Leverage factor	2.5
$\mu_{2,\tau}$	Initial mean of inexperienced investor's prior distribution	0.45%
A_τ	Initial precision of inexperienced investor's prior distribution	20
$\underline{\mu}_2, \bar{\mu}_2$	Truncation boundaries for beliefs of inexperienced investors	$[-0.65\%, 1.55\%]$

to accommodate the fact that most assets are implicitly levered, apply a leverage factor of $\lambda = 2.5$ when computing the returns of the claims to the dividend trees. For the two dividend trees, $n \in \{1, 2\}$, we set the quarterly expected dividend-growth rate μ_n to 0.45% and the corresponding volatility σ_n to 2.75%.[24] Together with an initial dividend share of the first tree, $\delta_{1,1}$, of 0.80, this implies a mean and volatility of the annual aggregate consumption growth of 1.80% and of 3.73%, respectively, close to the U.S. per capita consumption-growth moments of 1.72% and 3.28% from 1889 to 1994.

We assume that the inexperienced investors get access to the new asset at time $\tau = 40$ (that is, after ten years) with probability $p = 0.50$. At the date of financial innovation, the mean of the inexperienced investors' prior distribution, $\mu_{2,\tau}$, is set equal to the true expected

[24]The symmetric choices guarantee a quite stable *mean* dividend share over time, thereby eliminating any effects arising from a drift in the mean. Note, however, that in the long-run a bimodal distribution with dividend shares of zero and one arises—as is standard for such models; see, for example, Cochrane, Longstaff, and Santa-Clara (2008). While this might pose some problems for a long-term analysis, it is less important for our analysis of the dynamics for the initial years following financial innovation. Furthermore, we confirmed that the results remain unchanged for a stationary distribution of the dividend share.

dividend-growth rate μ_2, and the parameter governing the initial precision, A_τ, is set to 20.[25] The inexperienced investors' beliefs are truncated at $\underline{\mu}_2 = -0.65\%$ and $\bar{\mu}_2 = 1.55\%$.[26] Initially, inexperienced investors are endowed with 2/3 of the total wealth, as it seems reasonable that at the start a majority of investors do not participate in the new asset. Their initial wealth is concentrated in the traditional risky asset; that is, they do not have any debt and are not endowed with any shares of the new asset. Consequently, experienced investors hold all the shares of the new asset with the rest of their wealth in the traditional risky asset; they, too, start out with zero debt.

It is important to highlight that our key results are a consequence of differences in the confidence (precision) of the two groups of investors rather than specific parameter choices. We rely only on the fact that investors have a preference for early resolution of uncertainty, that is, $\gamma > 1/\psi$, so that changes in investors' continuation utility, and hence, stochastic investment-opportunity set, are priced. Other than that, the specific choices for the parameter values have, qualitatively, no effect on the results. In particular, in Appendix C, we demonstrate that the results are qualitatively unchanged for variations in: investors' preferences, inexperienced investors' prior beliefs, the process of financial innovation, and the characteristics of the new asset. The quantitative effects of changes in parameter values are also typically quite small and are discussed briefly after the presentation of each set of results below.

We illustrate our main results using figures. In these figures, we report the dynamics of the quantities of interest for the 40 periods (that is, 10 years) prior to financial innovation and the 100 periods (that is, 25 years) following financial innovation, averaged across 100,000 simulated paths of the economy. In addition to our base-case setting, in which inexperienced investors are less than fully confident but learn about the new asset over time (labeled in the figures as the case of *less confidence*), we also report the results for the traditional setting in which inexperienced investors have *full confidence* about the true dividend-growth rate of the new asset. Moreover, to illustrate the effects arising from changes in confidence (that is,

[25] $A_\tau \sigma_2^2$ represents the reciprocal of the prior precision, so that the prior density converges to a uniform distribution as A_τ approaches infinity and converges to a single value as A_τ approaches zero. Intuitively, A_τ denotes the number of quarters of data used to update an initially flat prior.

[26] Accordingly, we use a truncated Normal prior for μ_2, which results in a truncated Normal posterior with the same truncation bounds (see the online appendix of Collin-Dufresne, Johannes, and Lochstoer (2016a)). Conveniently, the updating equations for the hyperparameters, $\mu_{2,t+1}$ and A_{t+1}, remain the same—though $\mu_{2,t+1}$, in general, no longer corresponds to the subjective conditional mean of the new asset's dividend growth.

learning), we also report the case of *fixed confidence* in which inexperienced investors' precision is (artificially) fixed at its initial level: $A_t = A_\tau = 20$ for $t \geq \tau = 40$.

3.2 Asset Allocation

We start by studying the asset-allocation decisions of the two groups of investors. Figure 2 shows the dynamics of the investors' portfolio shares, that is, the proportion of their wealth allocated to each of the three financial assets.

Before the introduction of the new asset at time τ, *neither group of investors holds the market portfolio* and there are large differences in the portfolios of experienced and inexperienced investors.[27] In particular, because inexperienced investors do not have access to the new asset, they have zero invested in it (Panel A) and are overinvested in the traditional asset (Panel C); in contrast, experienced investors are overinvested in the new asset (Panel B). As a consequence of this under-diversification, the risky parts of the portfolios of both groups of investors are *more volatile* than if all investors had access to the new asset, resulting in a precautionary-savings motive from both investors. However, because inexperienced investors have no access to the new asset, and therefore bear more risk than experienced investors, they have a stronger precautionary-savings motive; thus, in equilibrium, they are long the bond (Panel E).

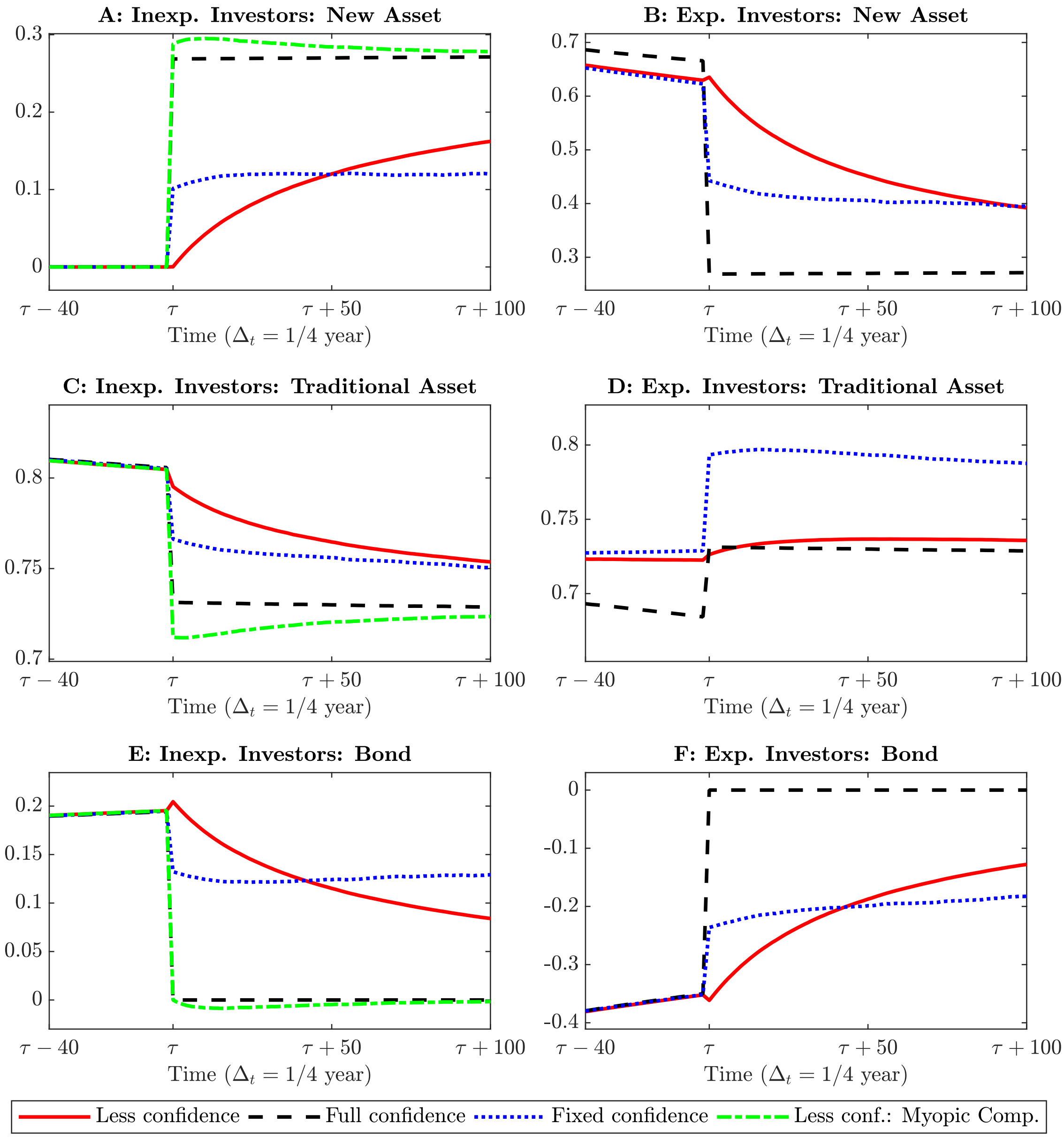
After the introduction of the new asset at time τ, the portfolios of the two groups of investors depend crucially on the confidence of inexperienced investors. If inexperienced investors had full confidence about the dividend dynamics of the new asset (that is, the traditional setting), both groups of investors would have *identical* portfolios; in particular, they would hold the market portfolio and have zero position in the risk-free bond. In contrast, if inexperienced investors are less confident, the portfolios of the two groups of investors continue to deviate substantially from the market portfolio: while inexperienced investors buy the new asset for diversification reasons as soon as they get access, their investment is rather small initially, and increases only slowly over time (Panel A). Even twenty-five years after financial innovation (that is, at $t = \tau + 100$), inexperienced investors still assign a substantially smaller weight to the new asset relative to experienced investors.

This under-diversification is entirely due to a *negative* intertemporal-hedging-portfolio component. That is, inexperienced investors wish to hold a portfolio that performs well when

[27]The weights in the market portfolio are equal to the relative size, measured by market capitalization, of the two risky assets; in our setting equal to about 78% and 22% for the traditional and the new asset, respectively.

Figure 2: Asset Allocation

This figure shows the dynamics of the portfolio shares of inexperienced investors (left column) and experienced investors (right column) over time, based on the parameter values described in Section 3.1. The results are conditional on financial innovation taking place and averaged across simulation paths. Panels A and B show the average proportion of wealth invested in the new asset, Panels C and D the average proportion of wealth invested in the traditional risky asset, and Panels E and F the average fraction of wealth invested in the risk-free bond.



marginal utility is high or, equivalently, the new asset's perceived dividend-growth rate is low, which is achieved through a negative hedging position in the new asset because its return is positively correlated with the perceived growth rate. This can be seen by studying the *myopic component* of the new asset's optimal portfolio share, as illustrated by the green dotted-dashed line in Figure 2, which is the portfolio of an investor who ignores next period's changes in his investment-opportunity set.[28]

Over time, because of learning, the perceived dividend-growth rate settles down (that is, the posterior precision increases). Hence, the magnitude of the negative hedging demand declines, and thus, inexperienced investors gradually increase their holdings in the new asset. These implications of learning can be nicely seen by examining the case with fixed confidence. In that case, changes in the perceived dividend-growth rate do not decline over time and, hence, the negative hedging demand and the portfolio holdings are virtually constant.[29]

The portfolio shares of the inexperienced investors in the other assets follow naturally from their positions in the new asset. That is, because in the presence of learning the inexperienced investors are underinvested in the new asset, they continue to be overinvested in the traditional asset (Panel C)—though to a lesser extent than in the pre-innovation period. Moreover, inexperienced investors have a long position in the risk-free bond; this is because, with risk aversion $\gamma > 1$, parameter uncertainty leads to precautionary savings. Over time, as the confidence of inexperienced investors increases, their precautionary-savings motive declines, and so does the portfolio share allocated to the bond.

Finally, to clear the markets for the two risky assets, experienced investors, even after the new asset becomes available to all investors, are overinvested in the new asset (Panel B) and underinvested in the traditional risky asset (Panel D), relative to the traditional setting where inexperienced investors are fully confident, in which all investors would be holding the market portfolio. Similarly, to clear the bond market, experienced investors take a short position in the bond, which is (in absolute terms) declining over time (Panel F). The result that experienced investors allocate a larger share of their wealth to risky assets and load more aggressively on

[28] Note that the myopic portfolio component for the new asset initially slightly "over-shoots," in that it exceeds the holdings for the case of full confidence. The reason for this is that the myopic component is computed under the assumption that there are no changes in the investment-opportunity set in the next period, yet investors still acknowledge changes in the periods thereafter. In a truly myopic setting, i.e., with log utility, the inexperienced investors' portfolio share in the new asset is constant over time.

[29] For the case of *fixed confidence*, the negative intertemporal hedging component is smaller, and hence, compared to the case of *less confidence*, the allocation to the new asset is greater at the time of financial innovation (Panel A). The reason for the smaller intertemporal hedging component is that, as we shall see below in Panel C of Figure 4, with fixed confidence the discount rate is higher in the long run, and hence marginal utility has a *smaller* sensitivity to changes in the perceived dividend-growth rate.

certain risk factors (in our setting, the new asset) is consistent with the empirical evidence reported in Bach, Calvet, and Sodini (2016).[30]

We now discuss briefly how the asset-allocation results described in this subsection depend quantitatively on the parameters values, with additional details provided in Appendix C. While varying the EIS has virtually no impact on the asset allocation, variations in risk aversion matter—in a natural way—for the importance of the intertemporal hedging demand. That is, if investors are less risk averse, this reduces the hedging demand. Similarly, if inexperienced investors' prior distribution is more precise, the fluctuations in their beliefs are smaller, and hence, there is a smaller negative hedging demand. Moreover, as intuition would suggest, if inexperienced investors are initially pessimistic (optimistic) about the prospects of the new asset, they, in general, invest less (more) into the new asset, but this has no impact on the hedging component.

3.3 Stochastic Discount Factor

Panels A and B of Figure 3 illustrate the volatility of the stochastic discount factor (SDF) of the inexperienced and experienced investors, respectively. If inexperienced investors had full confidence, as in the traditional setting, the volatility of their SDF would increases (slightly) at the introduction of the new asset, while the volatility of the SDF of experienced investors would fall substantially. On the other hand, if inexperienced investors' have less than full confidence, but they learn over time, the volatility of the SDF of both groups of investors is *higher*. In particular, the volatility of the SDF of the inexperienced investors increases considerably at the introduction of the new asset. Over time, as the confidence of inexperienced investors increases, the volatility of the SDF declines for both groups of investors, whereas in the case with fixed confidence (i.e., no learning), the volatility of the SDF stays constant over time.

The substantial increase in the volatility of the inexperienced investors' SDF can be fully attributed to their limited confidence, combined with Bayesian learning. To see this, note that shocks to the log SDF, which is given in (2), can be written as

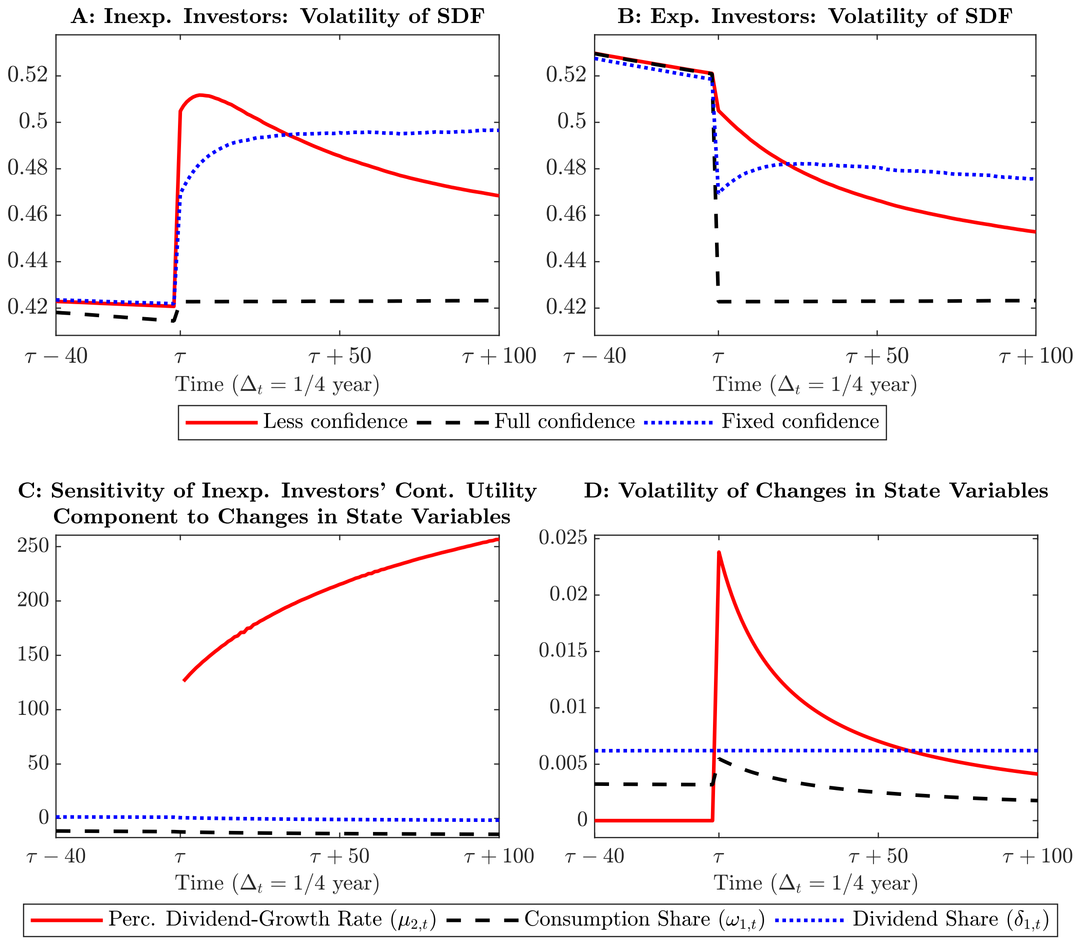
$$m_{k,t+1} - E_t^k[m_{k,t+1}] = -\,(1/\psi)\left(\Delta c_{k,t+1} - E_t^k[\Delta c_{k,t+1}]\right) - (\gamma - 1/\psi)\left(v_{k,t+1} - E_t^k[v_{k,t+1}]\right). \quad (7)$$

Expressing the SDF in terms of these two components makes it clear that, if relative risk aversion is not equal to the reciprocal of EIS ($\gamma \neq 1/\psi$), then shocks to future log continuation utility,

[30]Note, however, that because we have a general-equilibrium model with bonds in zero net supply (that is, inside bonds), experienced investors' holdings in risky assets are levered in order that the bond market clears.

Figure 3: Stochastic Discount Factors

This figure shows the dynamics of the volatility of the stochastic discount factor, based on the parameter values described in Section 3.1. Panels A and B show the average conditional volatility of the stochastic discount factor for the inexperienced and experienced investors, respectively. Panel C depicts the average sensitivity of the inexperienced investors' continuation utility component of their stochastic discount factor with respect to the state variables and Panel D shows the volatility of changes in the state variables—in both cases for the setting with differences in confidence. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the subjective beliefs.



$v_{k,t+1}$, are a source of priced risk—in addition to shocks to log consumption growth, $\Delta c_{k,t+1}$. The second term on the right-hand side of (7), reflecting variations in the log continuation-utility component, can be further decomposed into the following three terms:

$$v_{k,t+1} - E_t^k[v_{k,t+1}] = \tag{8}$$

$$\left[\frac{\partial v_{k,t}}{\partial \mu_{2,t}}\left(\mu_{2,t+1} - E_t^k[\mu_{2,t+1}]\right) + \frac{\partial v_{k,t}}{\partial \omega_{1,t}}\left(\omega_{2,t+1} - E_t^k[\omega_{2,t+1}]\right) + \frac{\partial v_{k,t}}{\partial \delta_{1,t}}\left(\delta_{1,t+1} - E_t^k[\delta_{1,t+1}]\right)\right],$$

which correspond to the three stochastic state variables in the economy: (i) the new asset's dividend-growth rate as perceived by the inexperienced investors, $\mu_{2,t}$ (only relevant for $t \geq \tau$); (ii) the experienced investors' share of aggregate consumption, $\omega_{1,t}$; and (iii) the traditional asset's share of total dividends, $\delta_{1,t}$. Thus, shocks to investor's log continuation utility depend on its sensitivity to the state variables and shocks to these state variables.

Panel C of Figure 3 show the sensitivities of the inexperienced investors' continuation-utility component of the SDF when they have less than full confidence[31] and Panel D shows the volatility of changes in the state variables over time. Notably, the sensitivity with respect to the perceived dividend-growth rate is (at least) an order of magnitude bigger than the sensitivities with respect to the consumption share and the dividend share. This is a consequence of learning about the new asset by the inexperienced investors, who have recursive utility with a preference for early resolution of uncertainty, and therefore, are highly averse to the permanent shocks to the perceived dividend-growth rate of the new asset.[32] Note that the sensitivity with respect to the perceived dividend-growth rate is actually increasing over time.[33] However, this increase is offset by an even stronger decrease in the volatility of changes in beliefs (Panel D),[34] which explains the decline in the volatility of the inexperienced investors' SDF over time (Panel A).

We now discuss briefly how these results depend on the choice of parameters values. Increases in both risk aversion and EIS strengthen the importance of the continuation-utility component of the SDF (see equation (7)), and hence, further increase the volatility of the SDF. Also, as one would expect, if inexperienced investors are more confident about the new asset, their beliefs fluctuate less, which decreases SDF volatility. Similarly, a decrease in the size of the new asset, decreases SDF volatility.

[31]In the case of full confidence, that is, in the absence of further learning, the sensitivity with respect to the perceived dividend-growth rate is irrelevant because there are no fluctuations in beliefs. The sensitivities with respect to the other two state variables are similar to the case of less than full confidence.

[32]Intuitively, the sensitivity of the *in*experienced investors' continuation utility with respect to the consumption share of the experienced investors is negative because lower consumption implies lower utility. Moreover, because the inexperienced investors over-weight the traditional asset in their portfolio, the sensitivity with respect to the dividend share of the traditional asset is positive.

[33]This is because the discount rate declines over time as confidence increases. As a result, the importance of cashflows in the (distant) future, which are more sensitive to changes in the expected growth rate because of compounding, increases.

[34]This figure is reminiscent of Panel C of Figure 1 that shows the decline in the inexperienced investors' posterior variance.

3.4 Capital Markets

We now study the implications of financial innovation for asset returns.[35]

Before we explain the effects of financial innovation on asset returns, note that in the absence of parameter uncertainty and when all investors have access to all assets, the risk premium of the asset with the larger dividend share—all else equal—would be higher than that of the other asset (see, e.g., Cochrane, Longstaff, and Santa-Clara (2008)). This is because of its larger dividend share, this asset's dividends constitute a larger fraction of aggregate consumption, and thus, co-vary more with it.

In contrast, in our model, *prior* to financial innovation ($t < \tau$) the risk premium of the new asset, despite having a smaller dividend share, is of the same magnitude as the risk premium of the traditional risky asset (Panels A and B of Figure 4)—for all settings. This is because, prior to financial innovation, experienced investors need to be compensated for bearing the risk of holding all of the new asset. The pattern for the return volatilities (Panels C and D) is similar to the results in the standard setting where all investors are fully confident; that is, the volatility is slightly lower for the new asset. Thus, before the new asset becomes available to all investors, the Sharpe ratio of the new asset is *endogenously* higher than that of the traditional risky asset (Panels E and F).

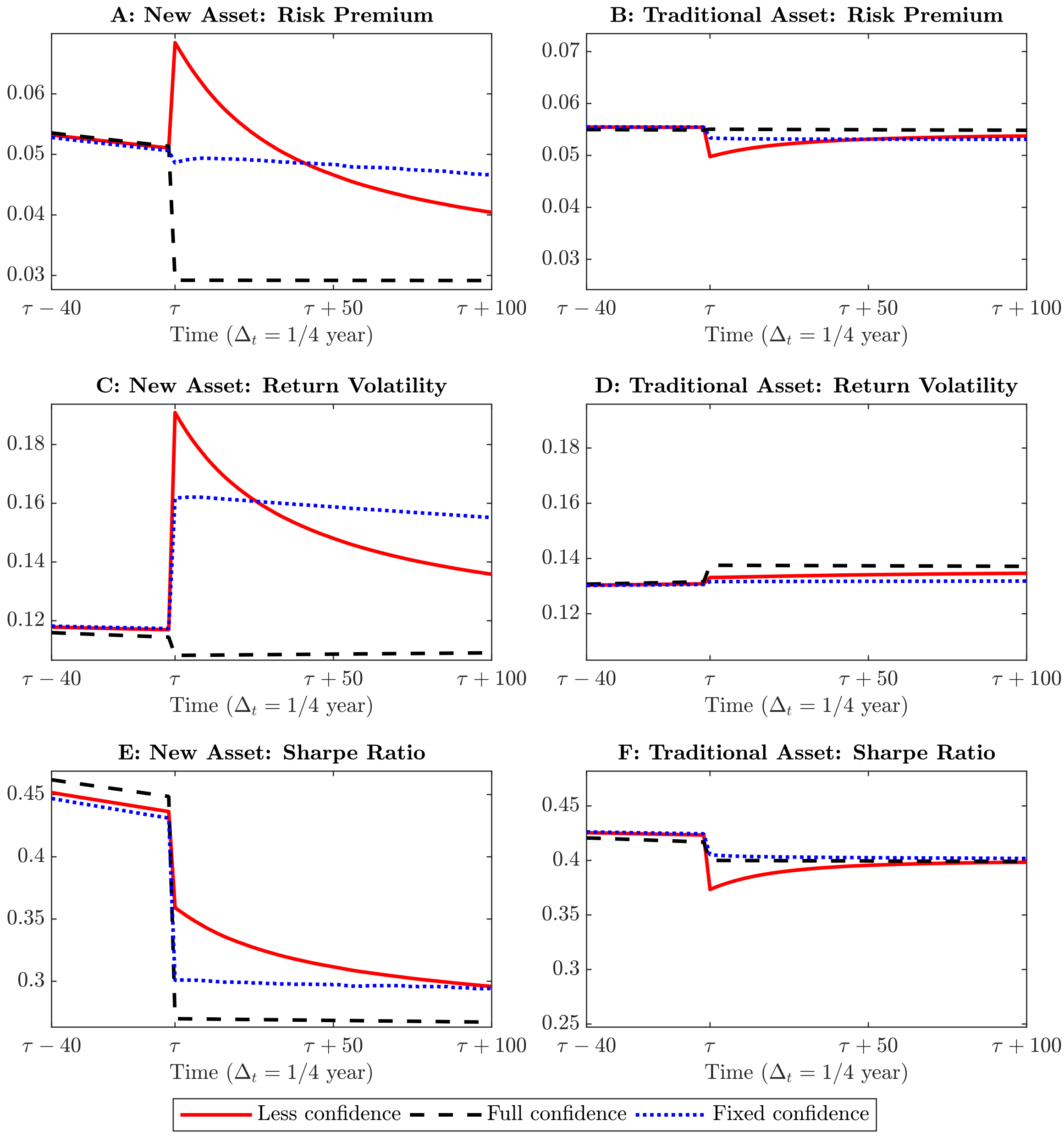
After financial innovation occurs, there is a dramatic change in the return moments of the new asset, which differ substantially depending on the confidence of inexperienced investors. If inexperienced investors were fully confident, then the new asset's risk premium would *drop* substantially (Panel A of Figure 4) when it became available to them because the risk of holding the new asset would now be shared between the two groups of investors. Because the return volatility is largely unchanged (Panel C), the Sharpe ratio of the new asset would also *drop* substantially at the time of financial innovation (Panel E). On the other hand, the return moments of the traditional asset would be only marginally affected by financial innovation (Panels B, D, and F).

In contrast, if inexperienced investors are less confident and they learn over time, the implications of financial innovation are considerably different and in stark contrast to "conventional wisdom." In particular, upon financial innovation, the return volatility of the new

[35] We do not include a discussion of asset *prices* in addition to our discussion of asset *returns*, because dividend-growth rates in the model are exogenous and IID, and therefore, price-dividend ratios are essentially the inverse of (long-term) expected returns.

Figure 4: Moments of Asset Returns

This figure shows the dynamics of the return moments of the new and traditional risky assets over time, based on the parameter values described in Section 3.1. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs. Panels A and B show the average conditional return volatilities, Panels C and D the average conditional risk premia, and Panels E and F the average conditional Sharpe ratios of the new asset and the traditional asset, respectively.



asset *increases* (Panel C) and is much higher than the volatility of the traditional risky asset, which does not change much at the date of financial innovation (Panel D). To understand the reason for the higher return volatility of the new asset, recall that positive (negative) cash-flow news for the new asset leads to an upward (downward) revision in the dividend-growth rate as perceived by the inexperienced investors (cf. equation (4)). Consequently, inexperienced investors allocate a larger (smaller) fraction of their risky portfolio to the new asset. As a result, positive (negative) cash-flow news lead to a higher (lower) price-dividend ratio for the new asset exactly when dividends are high (low) as well, thereby *amplifying* the variations in its dividend and creating "excess volatility." Over time, the changes in the inexperienced investors' beliefs decrease and so does the new asset's return volatility. But, even 25 years after introduction (that is, at $\tau + 100$), the return volatility of the new asset (Panel C) is still higher than that of the traditional asset (Panel D).

Importantly, in our model, excess volatility arises even for the case of EIS $= 1$ because of the substitution effect between the two *risky* assets. In fact, it is present even if EIS < 1. In contrast, in the single-risky-asset setting in Collin-Dufresne, Johannes, and Lochstoer (2016a), excess volatility arises only if EIS > 1, which leads to a substitution between the risk-free and the single risky asset. Setting EIS > 1 in our model would also give rise to this effect, further increasing excess volatility.

Similar to the increase in volatility, if inexperienced investors are less confident, the new asset's risk premium is also *increased* by financial innovation (Panel A of Figure 4)—even though financial innovation allows the investors to share the risk of holding the new asset. To understand the economic mechanism driving this result, note that an asset's risk premium is given by

$$E_t[r_{n,t}] - r_{0,t} = -\mathrm{Corr}_t\big(M_{k,t+1}, r_{n,t+1}\big)\,\mathrm{Vol}_t\big(M_{k,t+1}\big)\,\mathrm{Vol}_t\big(r_{n,t+1}\big), \tag{9}$$

where $r_{n,t}$ denotes the return on asset n. While both—the volatility of the new asset's return and the volatility of the investors' SDFs—increase upon financial innovation, the correlation of the SDF with the new asset's return increases only marginally (that is, it is smaller in absolute terms), so that the risk premium on the new asset increases. Over time, the new asset's risk premium declines because of the decline in the volatility of the SDF and the volatility of the new asset's return.

At the time of financial innovation, the Sharpe ratio of the new asset declines substantially (Panel E of Figure 4). Intuitively, the availability of the new asset to all investors increases aggregate demand for the asset. Thus, because the asset is in fixed supply, its attractiveness for investors must decrease, which is achieved by a drop in its Sharpe ratio. As confidence about the new asset increases over time, and consequently, the demand strengthens further, this "equilibrium incentive" must also strengthen, implying a further decline in the Sharpe ratio over time.[36]

Studying the case of fixed confidence (that is, fixed precision) highlights the importance of learning. In particular, if confidence does not increase over time, return volatility is essentially constant after financial innovation, and thus, considerably higher in the long-run because the magnitude of the changes in investors' beliefs is not declining. As a result, the changes in the price-dividend ratio that cause the excess volatility do not decline either. This, in turn, also leads to a higher risk premium.[37]

We now discuss briefly how the quantitative results for the new asset's return moments depend on the choice of parameters values, with additional details provided in Appendix C. If inexperienced investors are less risk averse, they trade more aggressively, which leads to more excess volatility explaining the stronger increase in the risk premium (in relative terms). If the proportion of the wealth of inexperienced investors increases, the effects on returns moments are, in general, more pronounced. Similarly, if the new asset is smaller (i.e., its share of initial dividends is smaller), the increase in return volatility is more pronounced because the changes in the inexperienced investors' demand for the new asset have to be absorbed by a smaller supply; however, the impact of financial innovation on the risk premium is smaller because there is less aggregate risk in the economy resulting from parameter uncertainty. If inexperienced investors are initially pessimistic (optimistic) about the prospects of the new asset, this increases (reduces) the risk premium. Finally, if inexperienced investors are less confident at the time of financial innovation, their beliefs fluctuate more, which increases the excess volatility and risk premium.

3.5 Welfare and Wealth Shares

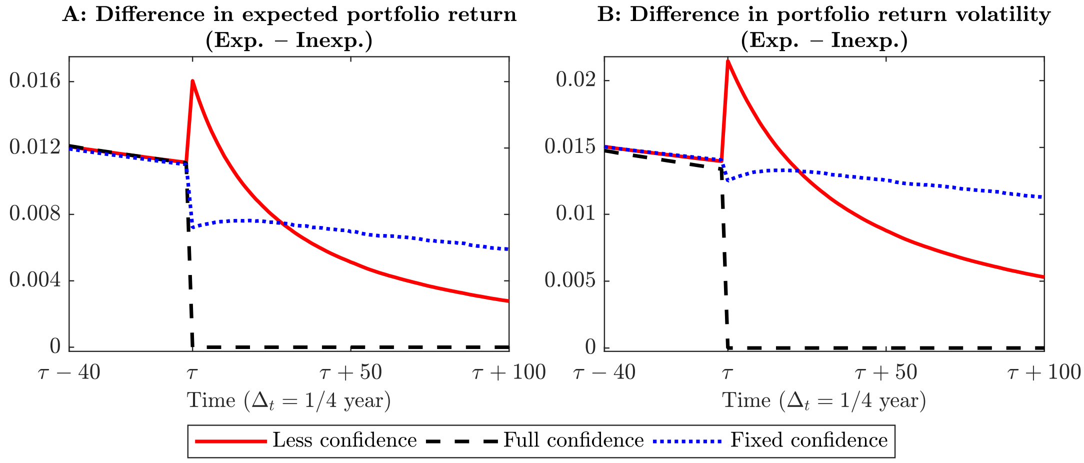
Finally, we discuss the implications of financial innovation for investors' welfare and wealth shares. To understand the impact of financial innovation on these quantities, it will be useful

[36] Learning also has direct implications for the cyclicality of the new asset's return. In particular, while with fully-confident inexperienced investors, the new asset's risk premium, return volatility and Sharpe ratio are procyclical (inconsistent with what is observed empirically), inexperienced investors who are less than fully-confident, combined with Bayesian learning, induce strong *countercyclical* variation in these quantities. For further details, see the accompanying Internet Appendix.

[37] Note that the level of both quantities is initially lower than in the case where inexperienced investors have less confidence. This is because of the lower sensitivity of the price-dividend ratio to changes in the investors' perceived dividend growth rate (as discussed in Footnote 29).

Figure 5: Difference in Portfolio Returns

This figure shows the dynamics of the differences between the inexperienced and experienced investors' portfolio returns. Panels A and B show the differences in the expected portfolio returns and in the portfolio volatilities, respectively. The figure is based on the parameter values described in Section 3.1. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



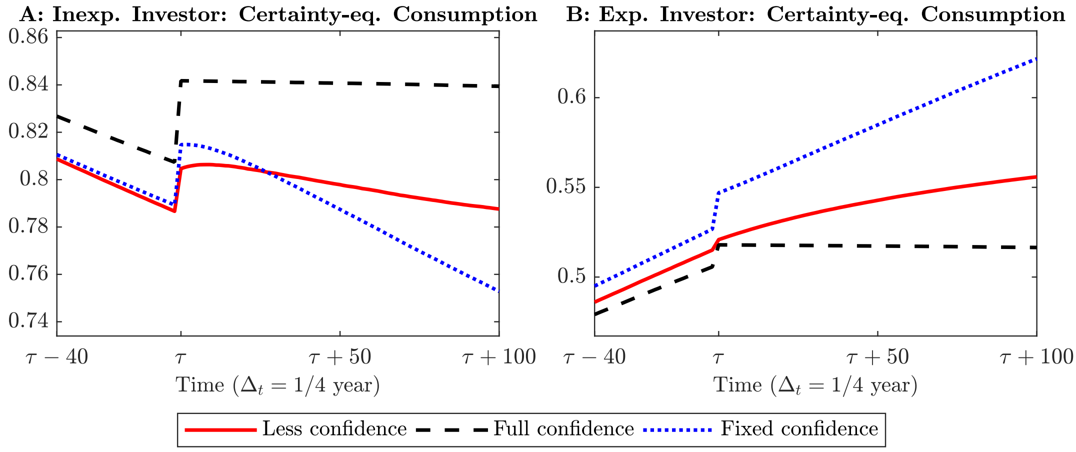
to first study the *differences* in the expected portfolio returns and portfolio volatilities of experienced and inexperienced investors.

Figure 5 shows that in the pre-innovation period, experienced investors earn higher portfolio returns because of their investment in the new asset (Panel A). However, their portfolio volatility is also higher (Panel B). After financial innovation, the differences in the expected portfolio returns and volatilities of the two investors would drop to zero if inexperienced investors were fully confident; that is, both groups of investors would be identical, and thus, would hold the same portfolio. In contrast, if inexperienced investors are less confident about the new asset, financial innovation actually first *increases* the differences in the expected returns and volatilities of the two investors portfolios because of the increases in the new asset's expected return and its return volatility. Only in the long run do the differences in these two quantities decline to values below those prior to financial innovation and below those in the absence of financial innovation. This pattern—where the portfolios of experienced investors have higher mean returns but are also more volatile—is consistent with the empirical evidence in Bach, Calvet, and Sodini (2016).

We now turn to investors' welfare, measured by their certainty-equivalent consumption (normalized by total output). Note that in our model, the beliefs of experienced investors

Figure 6: Welfare Levels

This figure shows the dynamics of the investors' certainty-equivalent consumption (normalized by total output) for the inexperienced and the experienced investor, respectively. The figure is based on the parameter values described in Section 3.1. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



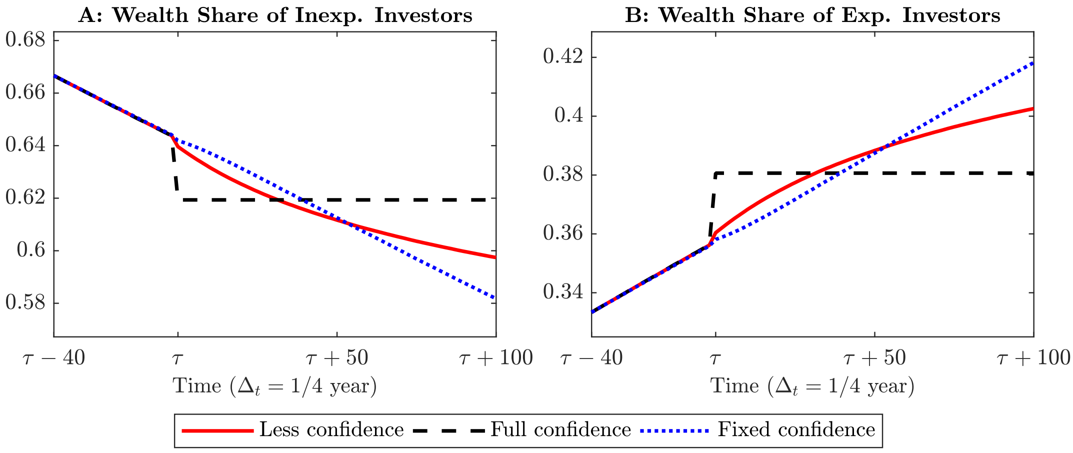
coincide with the objective beliefs. Also, while inexperienced investors are less than fully confident, their beliefs are, on average, unbiased and their learning is fully Bayesian. Hence, we compute welfare using the subjective beliefs of each group of investors; that is, according to the expression in (1).[38]

First, recall that inexperienced investors are endowed with a majority of the wealth. Thus, their level of certainty-equivalent consumption (Panel A of Figure 6) is, in general, higher than that of experienced investors (Panel B). In the pre-innovation period ($t < \tau$), the certainty-equivalent consumption of the inexperienced investors is declining over time (Panel A), whereas it is increasing for the experienced investors (Panel B). This is because of the higher portfolio returns, and in turn, higher consumption growth enjoyed by experienced investors because of their access to the new asset.

[38]We computed welfare also under the objective beliefs for both investors. For experienced investors this leads to no change because their beliefs coincide with the objective measure, so Panel B of Figure 6 is unchanged. But, also for inexperienced investors (Panel A), the pattern is very much the same, with the introduction of the new asset at time τ leading to an improvement in welfare. Intuitively, at introduction, inexperienced investors actually have the correct beliefs (that is, their prior is unbiased); later on, their beliefs will differ from true ones, but on average their beliefs remain unbiased. For a more detailed discussion of computing welfare under distorted beliefs, see Brunnermeier, Simsek, and Xiong (2014) and for a discussion of welfare in multi-asset economies see Fedyk, Heyerdahl-Larsen, and Walden (2012).

Figure 7: Wealth Shares

This figure shows the dynamics of the wealth share for the inexperienced and the experienced investor, respectively. The figure is based on the parameter values described in Section 3.1. The results are conditional on financial innovation taking place and averaged across simulation paths.



The introduction of the new asset at time τ is beneficial for both groups of investors, and leads to a jump in welfare levels. In particular, inexperienced investors see their welfare increase with financial innovation because having access to a new asset improves their investment-opportunity set, which allows them to achieve higher expected long-term portfolio returns, and consequently, higher expected consumption growth. This effect is stronger if inexperienced investors are fully confident about the dividend dynamics of the new asset, and hence, are willing to allocate substantial wealth to the new asset more quickly. Experienced investors also benefit from financial innovation because it allows them to achieve better risk sharing; that is, they can share the risk of holding the new asset. In the long run, experienced investors are better off if inexperienced investors are less confident, because then experienced investors have an informational advantage. Thus, in the case of differences in confidence, the welfare of experienced investors increases over time, while that of inexperienced investors declines.[39]

We can also measure the effect of financial innovation on the wealth shares of the two investors. As illustrated in Figure 7, the wealth share mirrors the behavior of welfare levels. In particular, if inexperienced investors were fully confident about the new asset, the wealth share of inexperienced and experienced investors would be constant after financial innovation,

[39]In the absence of financial innovation, the pattern of welfare and wealth shares would be similar to what it is during the pre-innovation period.

implying that financial innovation would *not* worsen wealth inequality.[40] However, when inexperienced investors are less than fully confident, their wealth share, even after financial innovation, declines over time, while that of the experienced investor increases over time, leading to a *worsening* in wealth inequality. In the absence of learning by inexperienced investors, financial innovation worsens wealth inequality at an even faster rate.

We now discuss briefly how the quantitative results described in this subsection depend on the parameters values, with additional details provided in Appendix C. If inexperienced investors are less risk averse, or if they are more confident about the new asset, this strengthens the improvement in welfare and limits the decline in their wealth share. Intuitively, both changes imply that they allocate more capital to the new asset which, in turn, increases diversification benefits and expected portfolio returns. For the same reason, if inexperienced investors are initially pessimistic (optimistic) about the prospects of the new asset, their welfare gains from financial innovation are smaller (bigger) because they invest less (more) into the new asset. Finally, a reduction in the size of the new asset limits its diversification benefit which, in turn, limits the increase in the inexperienced investors' welfare.

4 Conclusion

In this paper, we have studied the optimal asset-allocation decisions of investors that, as a result of financial innovation, get access to a new asset, and how their decisions influence financial markets, welfare, and wealth inequality. We do this by developing a model of a dynamic general-equilibrium economy with two types of investors: (i) *experienced* investors, who are fully confident regarding the new asset, and (ii) *inexperienced* investors, such as households, who are less confident about the return dynamics of the new asset but *learn* about it, so that their confidence increases over time.

Our main contribution is to show that the effects of financial innovation are strikingly different if experienced and inexperienced investors differ in confidence. For example, even after financial innovation occurs, inexperienced investors would allocate only a small fraction of their capital to the new asset, because of a large negative intertemporal hedging demand

[40]The sudden decrease (increase) in the wealth share of inexperienced (experienced) investors at the time of financial innovation for the case where inexperienced investors have full confidence is explained by the increase in the price of the new asset: because only experienced investors are holding the new asset prior to financial innovation, they are the sole beneficiaries of this increase, and so their wealth share increases.

(designed to protect them against downward revisions in their beliefs about the dividend-growth rate of the new asset). Moreover, the new asset's return volatility and risk premium would *increase* substantially when it became available to inexperienced investors because the portfolio rebalancing stemming from learning about the new asset would *amplify* the fluctuations in the new asset's dividends. Both the return volatility and risk premium of the new asset would decline only slowly over several decades, as the inexperienced investors gain confidence about its dividend-growth rate.

Finally, in spite of the increase in volatility, financial innovation would immediately increase the welfare of both types of investors because of the improved diversification benefits and risk-sharing opportunities. However, the gains would not be shared equally when investors differ in confidence: because of the greater confidence of experienced investors, their wealth share would rise, while that of inexperienced investors would fall, *worsening* wealth inequality.

Our results have important implications for the regulation of financial innovation. In particular, they not only demonstrate the impact of financial innovation on welfare, but also show that the benefits of financial innovation may not be shared equally across different groups of investors. Moreover, we demonstrate how the introduction of the new asset affects capital markets in general, including the effect on the returns of existing assets.

More generally, our analysis highlights the importance of accounting for differences in confidence and learning when making predictions about the effects of financial innovation. In particular, the consequences of financial innovation can be counter-intuitive and very different from those in a setting in which all investors are equally confident, even if beliefs are unbiased on average and learning is fully Bayesian.

A Optimality Conditions and Equilibrium

A.1 Investors' Optimality Conditions

The objective of each investor k is to maximize her expected lifetime utility given in equation (1), by choosing consumption, $C_{k,t}$, and the holdings in the available financial assets, $\theta_{n,k,t}, n \in \{0, \dots, N_{k,t}\}$:

$$V_{k,t}\big(\{\theta_{k,n,t-1}\}\big) = \max_{C_{k,t},\{\theta_{k,n,t}\}} \left[(1-\beta)\, C_{k,t}^{1-\frac{1}{\psi}} + \beta E_t^k \left[V_{k,t+1}\big(\{\theta_{k,n,t}\}\big)^{1-\gamma}\right]^{\frac{1}{\phi}}\right]^{\frac{\phi}{1-\gamma}},$$

subject to the budget equation (6).[41]

Denoting the Lagrange multiplier associated with the budget equation by $\eta_{k,t}$, the Lagrangian can be written as

$$\begin{aligned}\mathcal{L}_{k,t} = \sup_{C_{k,t},\{\theta_{k,n,t}\}} \; \inf_{\eta_{k,t}} & \left[(1-\beta)\, C_{k,t}^{1-\frac{1}{\psi}} + \beta E_t^k \left[V_{k,t+1}^{1-\gamma}\right]^{\frac{1}{\phi}}\right]^{\frac{\phi}{1-\gamma}} \\ & + \eta_{k,t} \big(\theta_{k,0,t-1} + \sum_{n=1}^{N_{k,t}} \theta_{k,n,t-1}\, D_{n,t} - C_{k,t} - \theta_{k,0,t}\, S_{0,t} - \sum_{n=1}^{N_{k,t}} \Delta\theta_{k,n,t}\, S_{n,t}\big),\end{aligned}$$

and the corresponding first-order conditions are given by

$$\begin{aligned}\frac{\partial \mathcal{L}_{k,t}}{\partial C_{k,t}} &= \frac{1}{1-\frac{1}{\psi}} \left\{(1-\beta)\, C_{k,t}^{1-\frac{1}{\psi}} + \beta E_t^k \left[V_{k,t+1}^{1-\gamma}\right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}}\right\}^{\frac{1}{1-\frac{1}{\psi}}-1} (1-\beta) \left(1-\frac{1}{\psi}\right) C_{k,t}^{-\frac{1}{\psi}} - \eta_{k,t} \\ &= (1-\beta)\; C_{k,t}^{-\frac{1}{\psi}}\, V_{k,t}^{\frac{1}{\psi}} - \eta_{k,t} \equiv 0, \qquad \text{(A1)}\end{aligned}$$

$$\frac{\partial \mathcal{L}_{k,t}}{\partial \eta_{k,t}} = \theta_{k,0,t-1} + \sum_{n=1}^{N_{k,t}} \theta_{k,n,t-1}\, D_{n,t} - C_{k,t} - \theta_{k,0,t}\, S_{0,t} - \sum_{n=1}^{N_{k,t}} \Delta\theta_{k,n,t}\, S_{n,t} \equiv 0, \quad \text{and} \qquad \text{(A2)}$$

$$\begin{aligned}\frac{\partial \mathcal{L}_{k,t}}{\partial \theta_{k,n,t}} &= \frac{1}{1-\frac{1}{\psi}}\, V_{k,t}^{\frac{1}{\psi}}\, \beta\, \frac{1-\frac{1}{\psi}}{1-\gamma}\, E_t^k \left[V_{k,t+1}^{1-\gamma}\right]^{\frac{\gamma-\frac{1}{\psi}}{1-\gamma}} (1-\gamma)\; E_t^k \left[V_{k,t+1}^{-\gamma} \frac{\partial V_{k,t+1}}{\partial \theta_{k,n,t}}\right] - \eta_{k,t} S_{n,t} \\ &= \beta\, V_{k,t}^{\frac{1}{\psi}}\, E_t^k \left[V_{k,t+1}^{1-\gamma}\right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}-1} E_t^k \left[V_{k,t+1}^{-\gamma} \frac{\partial V_{k,t+1}}{\partial \theta_{k,n,t}}\right] - \eta_{k,t}\, S_{n,t} \equiv 0. \qquad \text{(A3)}\end{aligned}$$

[41] For ease of exposition, in the following derivations we do not explicitly write the dependence of $V_{k,t}$ on the incoming (i.e., date $t-1$) asset holdings, $\{\theta_{k,n,t-1}\}$.

Using the Envelope Theorem we can compute the derivatives of the value function $V_{k,t}$ with respect to $\theta_{k,n,t-1}$:

$$\frac{\partial V_{k,t}}{\partial \theta_{k,0,t-1}} = \frac{\partial \mathcal{L}_{k,t}}{\partial \theta_{k,0,t-1}} = \eta_{k,t}, \tag{A4}$$

$$\frac{\partial V_{k,t}}{\partial \theta_{k,n,t-1}} = \frac{\partial \mathcal{L}_{k,t}}{\partial \theta_{k,n,t-1}} = \eta_{k,t}\left(D_{n,t} + S_{n,t}\right), \quad n \in \{1,2\}. \tag{A5}$$

In summary, the optimality conditions for each investor k are given by the following set of equations. First, the budget equation from (A2):

$$C_{k,t} + \theta_{k,0,t}\, S_{0,t} + \sum_{n=1}^{N_{k,t}} \Delta\theta_{k,n,t}\, S_{n,t} \;=\; \theta_{k,0,t-1} + \sum_{n=1}^{N_{k,t}} \theta_{k,n,t-1}\, D_{n,t}, \tag{A6}$$

which equates the uses and sources of funds. Second, the pricing equations, from equations (A3) to (A5), which equate the price of an asset to the expected payoff from holding it:

$$S_{0,t} = E_t^k\left[M_{k,t+1}\right],$$
$$S_{n,t} = E_t^k\left[M_{k,t+1}\left(S_{n,t+1} + D_{n,t+1}\right)\right], \quad n \in \{1,2\},$$

where the stochastic discount factor $M_{k,t+1}$, given in equation (2) on page 9, subsumes the Lagrange multiplier $\eta_{k,t}$ from equation (A1).

A.2 Characterization of Equilibrium

Equilibrium in the economy can then be characterized by the following set of equations: the budget equation (A6), the "kernel conditions" that equate the prices of the assets across investors:

$$E_t^1\left[M_{1,t+1}\right] = E_t^2\left[M_{2,t+1}\right], \tag{A7}$$

$$E_t^1\left[M_{1,t+1}\left(S_{n,t+1} + D_{n,t+1}\right)\right] = E_t^2\left[M_{2,t+1}\left(S_{n,t+1} + D_{n,t+1}\right)\right]; \quad n \in \{1,2\}, \tag{A8}$$

and the market-clearing conditions:[42]

$$\sum_{k=1}^{2} \theta_{k,0,t} = 0, \quad \text{and} \quad \sum_{k=1}^{2} \theta_{k,n,t} = 1, \quad n \in \{1,2\}. \tag{A9}$$

[42]By Walras' law, market clearing in the asset markets guarantees market clearing for the consumption good.

B Numerical Algorithm

We use the time-shift proposed by Dumas and Lyasoff (2012) to obtain a recursive system of equations characterizing equilibrium. That is, at date t, the "shifted" system of equations consists of the date-t kernel conditions (A7) and (A8), the date-t market-clearing conditions (A9), and the date-$t+1$ budget equations (A6):

$$C_{k,t+1,j} + \theta_{k,0,t+1,j} S_{0,t+1,j} + \sum_{n=1}^{N_{k,t}} \left(\theta_{k,1,t+1,j} - \theta_{k,1,t}\right) S_{1,t+1,j} \leq \theta_{k,0,t} + \sum_{n=1}^{N_{k,t}} \theta_{k,n,t}\, D_{n,t+1,j}, \forall k, j,$$

where the J future states (nodes) are denoted by $j = 1, \ldots, J$.[43] In total, we have a system of $2K + 2\,N_{k,t}$ equations with $2K + 2\,N_{k,t}$ unknowns: next period's consumption, $C_{k,t+1,j}$, for both investors and J states, and both investors' holdings in the assets, $\theta_{k,n,t}$.

The system of equations is solved recursively, starting from $T-1$. At each date t, we solve the equation system over the *grid of the state variables.* Next, when solving the system for date $t-1$, we interpolate (over the grid) the optimal date-t portfolio positions, $\theta_{k,n,t}$ and corresponding security prices, $S_{n,t}$, using the terminal conditions $\theta_{k,n,T} = 0$ and $S_{n,T} = 0$, $\forall n, k$. After solving the shifted system for all dates $t \in \{0, ..., T-1\}$, one has solved all equations from the global system—except the date-0 budget equations, which have not been used because of the time shift. Thus, one only needs to solve the time-0 budget equations based on interpolating functions for the date-0 prices, $S_{n,0}$, and holdings, $\theta_{k,n,0}$. The endowed holdings $\theta_{k,n,-1}$ are exogenous to the system and reflect the incoming (endowed) wealth of the investors.

There are four state variables: (a) the consumption share of the experienced investors, $\omega_{1,t} \in (0,1)$; (b) the dividend share of the first risky security $\delta_{1,t} \in (0,1)$, the dynamics of which follow from the joint dividend dynamics in (3); (c) the expected dividend-growth rate of the new asset as perceived by the inexperienced investors, $\mu_{2,t}$, with its dynamics specified in (4); and, (d) the (deterministic) posterior variance of the inexperienced investors' beliefs, $A_t\, \sigma_2^2$, with its dynamics specified in (5).

[43] We approximate the joint dynamics of the dividends in (3) using a four-node, equal probabilities tree with growth realizations $\{(u_1, u_2), (d_1, u_2), (u_1, d_2), (d_1, d_2)\}$, where $u_n \equiv \mu_n + \sigma_n$ and $d_n \equiv \mu_n - \sigma_n$ are chosen to match the expected dividend-growth rate and volatility of asset n. Under the inexperienced investors' probability measure, the probabilities are set to $p_{2,t}/2$ and $\left(1 - p_{2,t}\right)/2$ for the first and last two nodes, respectively. $p_{2,t}$ is chosen to match the inexperienced investors' perceived dividend-growth rate, $\mu_{2,t}$.

C Alternative Specifications and Extensions

To study the robustness of our results, we now evaluate the impact of financial innovation for several variations and extensions of the economy in which inexperienced investors are less confident about the expected dividend-growth rate of the new asset compared to experienced investors. For each of these variations, we reproduce all the quantities studied for the *baseline* economy, but to save space, report only a subset.

C.1 Alternative Specifications for Investors' Preferences

In a first step, we study the impact of variations in the investors' preferences. In particular, we consider the case of a lower risk aversion ($\gamma = 7.5$) and the case of a higher EIS ($\psi = 1.5$). We also consider an economy in which inexperienced investors are initially endowed with a higher fraction of aggregate wealth ($\omega_{2,1} = 0.8$). The results for these variations are shown in Figure C1.

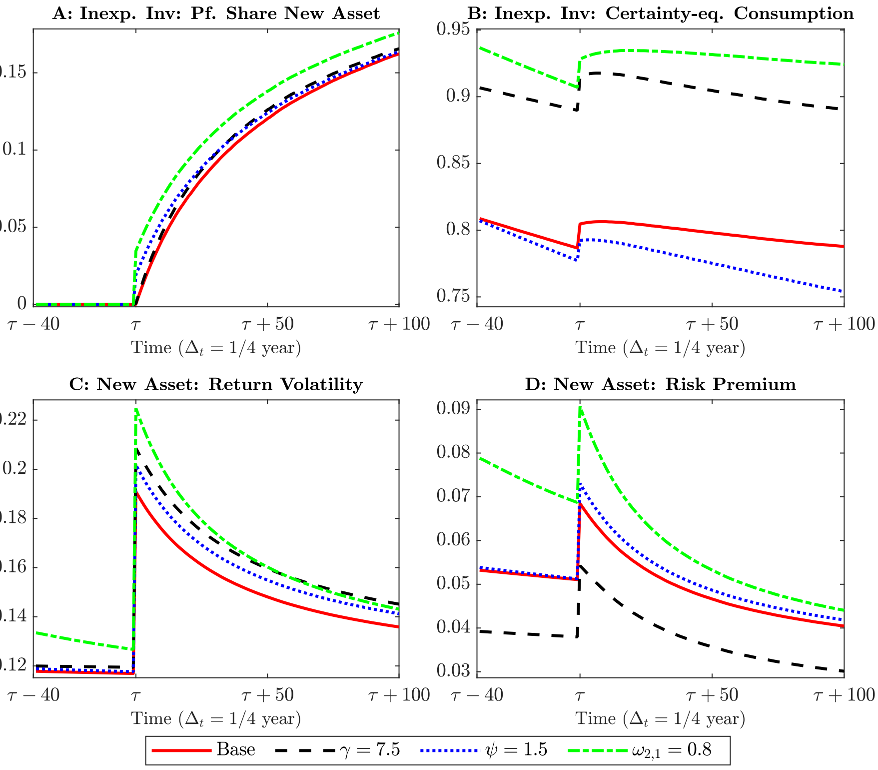
None of these variations affects the qualitative results but there are some quantitative changes. For example, a reduction in risk aversion (which reduces the negative hedging demand) as well as an increase in the initial wealth share of the inexperienced investors imply a higher portfolio share of the new asset in the inexperienced investors' portfolio (Panel A). This, in turn, increase diversification benefits and portfolio returns, such that the increase in their certainty-equivalent consumption at financial innovation is a bit stronger (Panel B). Finally, all three variations imply (relatively) stronger increases in the new asset's return volatility (Panel C) because they strengthen the fluctuations in the new asset's price-dividend ratio in response to a change in beliefs; either because inexperienced investors trade more aggressively ($\gamma = 7.5$), or because they have a stronger impact on the price ($\omega_{2,1} = 0.8$), or due to the substitution effect between the risky portfolio and the risk-free asset ($\psi = 1.5$). This leads to a higher excess volatility which, in turn, increases the new asset's risk premium (Panel D). In the case of a lower risk aversion this effect dominates an opposing effect resulting from the lower aversion to the risk of changes in the perceived dividend-growth rate.

C.2 Alternative Specifications for the Inexperienced Investors' Prior Beliefs

Second, we consider the implications of varying the inexperienced investors' prior beliefs. In particular, we study the case of more precise prior beliefs ($A_\tau = 40$) and the case in which inexperienced investors are initially pessimistic about the new asset ($\mu_{2,\tau} = 0.23\%$), that is, have biased prior beliefs. We also consider an extension in which inexperienced investors can learn, even though they do not have access to the new asset yet, from time $t = 1$ onward

Figure C1: Alternative Specifications: Investors' Preferences

This figure shows the dynamics of the inexperienced investors' portfolio share of the new asset, their certainty-equivalent consumption, the new asset's return volatility, and its risk premium over time. The figure is based on the model variations described in Appendix C.1. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



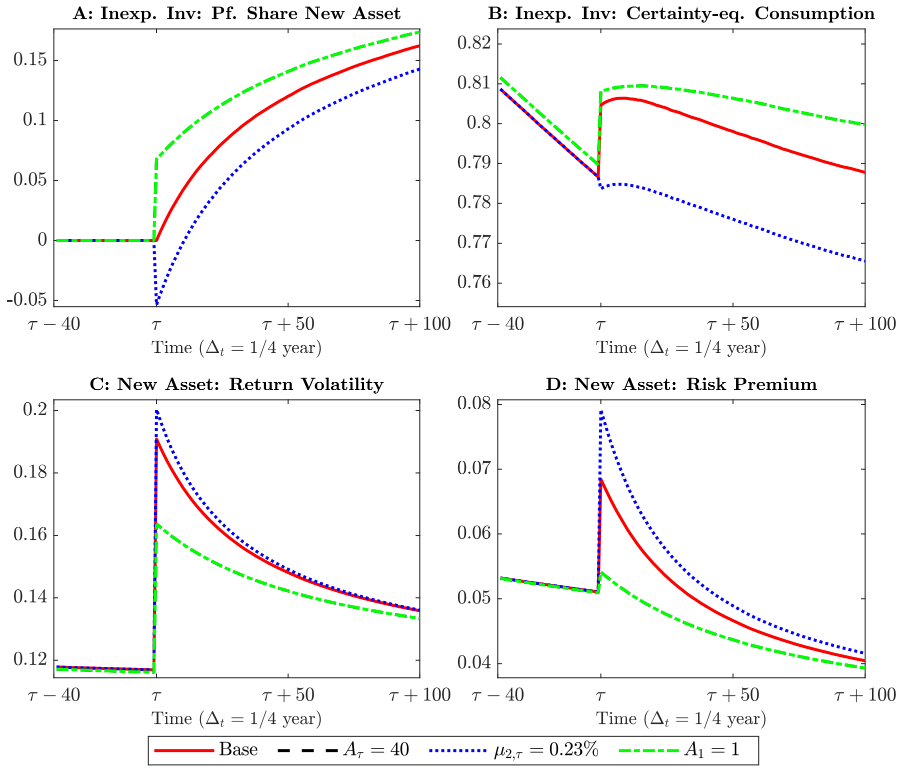
($A_1 = 1$), which (implicitly) increases the precision at time τ. The results are reported in Figure C2. Again, the results are qualitatively unchanged by these variations.

Quantitatively, inexperienced investors invest more into the new asset for the two cases with a higher precision at time τ (Panel A),[44] because of a smaller (negative) hedging demand. This implies slightly higher welfare gains (Panel B). In contrast, if inexperienced investors are initially pessimistic, they invest less, which leads to smaller welfare gains. As expected, a higher precision at time τ limits the excess volatility for the new asset (Panel C) because the inexperienced investors' demand for the new asset is less sensitive to cash-flow news due to smaller revisions in the perceived dividend-growth rate. This, in turn, reduces the new asset's

[44]Note that the *average* results for the two cases of $A_\tau = 40$ and $A_1 = 1$ are virtually identical; before and after financial innovation. Intuitively, the precision at time τ coincides in both setups (i.e., $A_\tau = 40$) and the average (across paths) of the posterior mean in the case of $A_1 = 1$ equals the constant prior mean for $A_\tau = 40$. Obviously, there will be differences across paths due to the differences in the posterior mean introduced by learning from time $t = 1$.

Figure C2: Alternative Specifications: Inexperienced Investors' Prior Beliefs

This figure shows the dynamics of the inexperienced investors' portfolio share of the new asset, their certainty-equivalent consumption, the new asset's return volatility and its risk premium over time. The figure is based on the model variations described in Appendix C.2. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



risk premium (Panel D). In contrast, in the presence of pessimistic inexperienced investors, the risk premium increases because of the lower demand for the new asset.

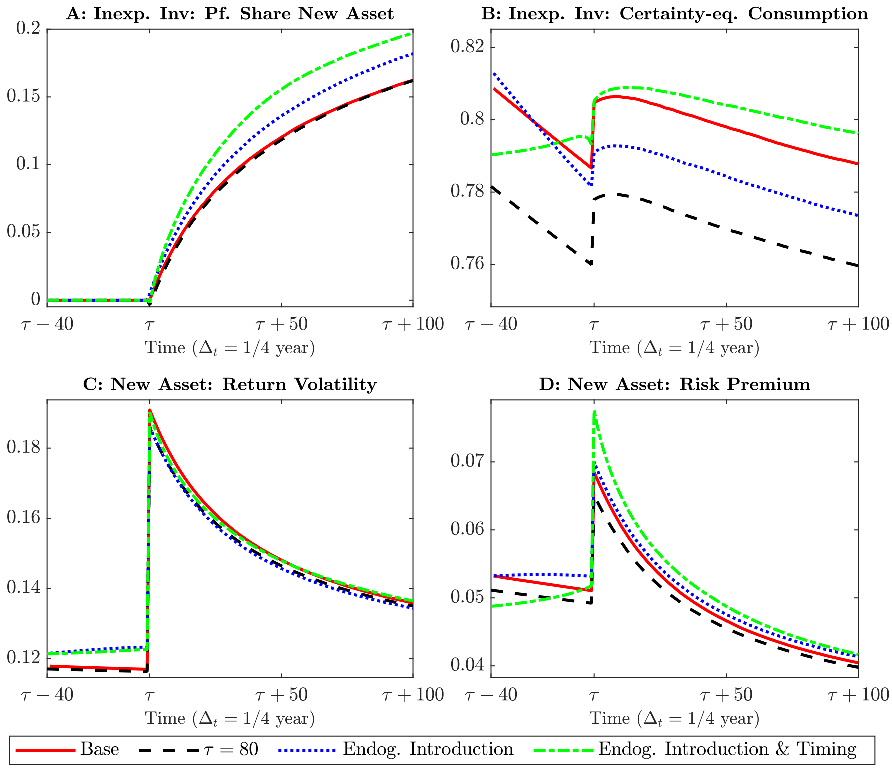
C.3 Alternative Specifications for Financial Innovation

In this subsection, we study variations in the process of financial innovation. First, we consider the case of financial innovation occurring at a later point in time ($\tau = 80$). As is shown in Figure C3, this has virtually no impact on the results—neither qualitatively nor quantitatively.

Next, we consider two, more elaborate, extensions. So far, the decision to introduce the new asset was exogenous. In practice, however, new assets are introduced endogenously by financial intermediaries with profit incentives. Thus, a new asset may become available only if there is sufficient demand for it, and thus, financial intermediaries can extract some profits by charging fees. Instead of modeling these institutional details explicitly, we adopt a reduced-form

Figure C3: Alternative Specifications: Process of Financial Innovation

This figure shows the dynamics of the inexperienced investors' portfolio share of the new asset, their certainty-equivalent consumption, the new asset's return volatility and its risk premium over time. The figure is based on the model variations described in Appendix C.3. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



approach to extend the base-case economy so that the decision to introduce the new asset is endogenous.

In the first extension ("Endog. Introduction"), we consider the case in which financial innovation is more likely if an asset has performed well and demand for it is high or, in the parlance of the investment industry, when the new asset is "hot." Specifically, we assume that at time $\tau = 40$, the new asset is introduced only if its share of aggregate dividends is higher than some threshold value, which we set to 20%.[45] Figure C3 confirms that qualitatively, our predictions for the impact of financial innovation remain unchanged. Even quantitatively, most of the predictions are unaffected.

In the second extension ("Endog. Introduction & Timing"), we study the case in which both the introduction *and* the timing of financial innovation are endogenous. Recall that so far we

[45]The threshold is set such that the unconditional probability (at date $t = 1$) of the new asset being introduced at $\tau = 40$ is still about 50%.

had assumed that if the new asset was not introduced at a predetermined date τ, it would never be introduced. Now, we endogenize the timing of financial innovation; that is, we assume that the new asset can be introduced at any date, if its share of total dividends is above a threshold of 22.5%.[46] As a result, the timing of financial innovation is now stochastic. Once again, we see from Figure C3 that, qualitatively and quantitatively, the predictions remain unchanged.

C.4 Alternative Specifications for the Characteristics of the New Asset

Finally, we study variations in the characteristics of the new asset. The corresponding results are shown in Figure C4. We consider the case in which the new asset's initial share of aggregate dividends is very small ($\delta_{2,1} = 0.025$), thus providing only marginal diversification benefits and instead being a purely "speculative asset." Naturally, decreasing the size of the new asset implies that its portfolio share decreases (Panel A). Moreover, because the new asset now provides smaller diversification benefits, the relative welfare gains are weaker; though still positive (Panel B). The increase in the new asset's return volatility is substantially bigger (Panel C) because the fluctuations in the inexperienced investors' demand, resulting from changes in beliefs, have to be absorbed by a smaller supply. Finally, the increase in the risk premium is—in relative and absolute terms—smaller because there is less aggregate risk in the economy (Panel D).

In practice, trading in new assets often entails sizeable trading costs. Consequently, we also consider an extension of our baseline economy in which the new asset is illiquid after being introduced, which we model as a proportional transaction cost; that is, each investor has to pay a constant fraction $\kappa = 2.5\%$ of the (dollar) value of the trade.[47]

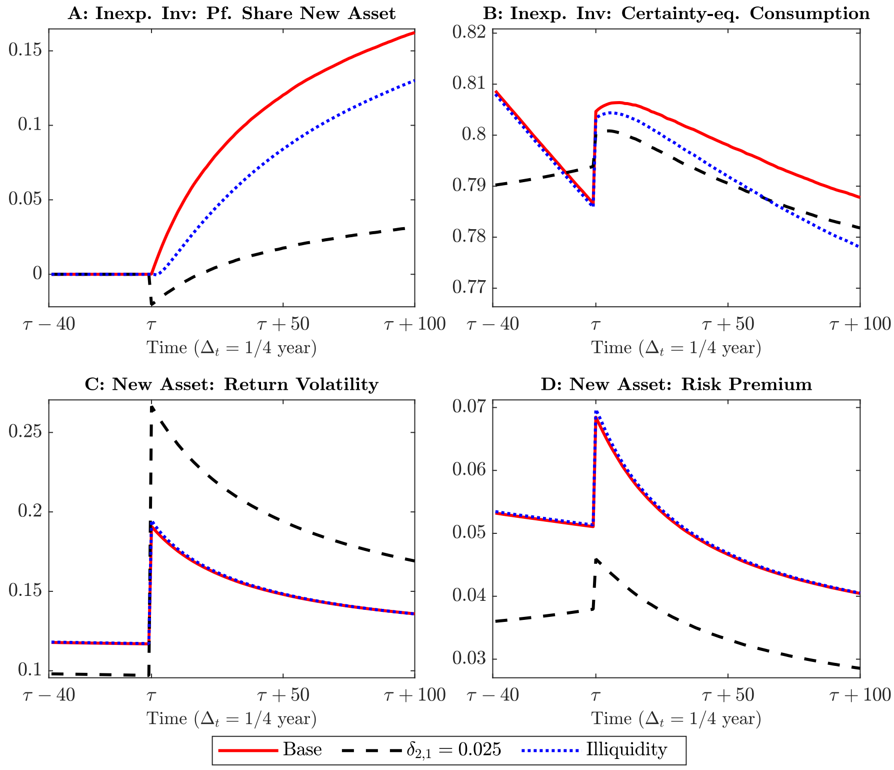
Qualitatively, our main insights are not affected by illiquidity, and, even quantitatively the effect of transaction costs is small. The only substantial effect of transaction costs is on the trading decisions of investors. In the presence of transaction costs, inexperienced investors invest in the new asset more slowly (Panel A) because frequent changes in the stock holdings are costly. Consequently, they benefit less from the diversification benefits, and hence, the increase in welfare is smaller (Panel B). The changes in the new asset's return moments are very small (Panels C and D), though transaction costs give rise to a small *liquidity premium.*

[46] This threshold level is chosen so that the unconditional probability (at $t = 1$) of the new asset being available for trading for the inexperienced investors at time $\tau = 40$ (that is, the asset has been introduced at some point $t \leq \tau$) is about 50%. If one were to use a threshold of 20% (as in the previous case), the unconditional probability of the new asset being introduced would go up, but the implications would remain unchanged.

[47] Details of how the model with transaction costs is solved (by extending the dual formulation of Buss and Dumas (2018)) are given in the Internet Appendix.

Figure C4: Alternative Specifications: Characteristics of the New Asset

This figure shows the dynamics of the inexperienced investors' portfolio share of the new asset, their certainty-equivalent consumption, the new asset's return volatility and its risk premium over time. The figure is based on the model variations described in Appendix C.4. The results are conditional on financial innovation taking place, averaged across simulation paths and computed under the objective beliefs.



Instead of trading the new asset at a cost, inexperienced investors often use the correlated, more liquid, traditional asset as a substitute (we assume that the traditional risky asset can be traded at no cost). Consequently, shocks to the cash flows of the new asset spill over to the traditional asset, thereby substantially *increasing* the return correlation between the new and traditional risky assets in the post-innovation period relative to the baseline model with zero transaction costs. This, in turn, reduces the diversification benefits from the new asset.

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