

Does Household Finance Matter? Small Financial Errors with Large Social Costs*

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August 27, 2015

Abstract

Households with familiarity bias tilt their portfolios towards a few risky assets that consequently are underdiversified and excessively volatile. To understand the implications of underdiversification for growth and social welfare, we solve in closed form a model of a stochastic, dynamic, general-equilibrium economy with a large number of heterogeneous firms and households, who bias their investment toward a few familiar assets. Consistent with the existing literature, we find that the direct loss from holding an underdiversified portfolio that is excessively risky is modest. However, this loss from an excessively volatile portfolio is amplified because it increases also household consumption-growth volatility. Moreover, these internalities at the household level are magnified further in general equilibrium through the externality on aggregate investment and growth. Our model demonstrates that even if we force the familiarity biases in portfolios to cancel out across households, their implications for consumption and investment choices do not cancel—individual household biases can have significant aggregate effects. Our results illustrate that financial markets are not a mere sideshow to the real economy and that financial literacy, financial regulation, and financial innovation that improve the financial decisions of households can have a significant positive impact on social welfare.

Keywords: Portfolio choice, underdiversification, familiarity bias, behavioral finance, growth, social welfare

JEL classification: G11, E44, E03, G02

*We would like to acknowledge helpful comments from Karim Abadir, Kenneth Ahern, Brad Barber, Giuseppe Bertola, Sebastien Betermier, Andrea Buraschi, Laurent Calvet, Georgy Chabakauri, Bernard Dumas, Rene Garcia, Naveen Khanna, Samuli Knupfer, Kai Li, Abraham Lioui, Florencio Lopez De Silanes, Hanno Lustig, Robert Marquez, Tarun Ramadorai, Paolo Sodini, Marti Subhramanyam, and seminar participants at EDHEC Business School, HEC Montreal, Imperial College Business School, the 2014 HKUST Finance Symposium, the 2015 Adam Smith Conference, and the 2015 FMA Napa Conference on Financial Markets. Harjoat Bhamra is affiliated with CEPR and Imperial College Business School, Tanaka Building, Exhibition Road, London SW7 2AZ; Email: bhamra.harjoat@gmail.com. Raman Uppal is affiliated with CEPR and Edhec Business School, 10 Fleet Place, Ludgate, London, United Kingdom EC4M 7RB; Email: raman.uppal@edhec.edu.

1 Introduction and Motivation

One of the fundamental insights of standard portfolio theory (Markowitz (1952, 1959)) is to hold diversified portfolios. However, evidence from natural experiments (Huberman (2001)) and empirical work (Dimmock, Kouwenberg, Mitchell, and Peijnenburg (2014)) shows households invest in underdiversified portfolios that are biased toward a few familiar assets.¹ Familiarity biases may be a result of geographical proximity, employment relationships or perhaps even language, social networks, and culture (Grinblatt and Keloharju (2001)). Holding portfolios biased toward a few familiar assets forces households to bear more financial risk than is optimal. An important question studied by macroeconomists such as Lucas (1987, 2003) is the determination of the welfare costs to households of variability in aggregate consumption growth. The analogous question at the microeconomic level of how important variability in household wealth is for welfare has been studied empirically by financial economists such as Calvet, Campbell, and Sodini (2007). They find that, within a static mean-variance framework, the welfare costs for individual households arising from underdiversified portfolios are modest. We extend the static framework to a dynamic, general-equilibrium, production-economy setting to examine how underdiversification in household portfolios can impact intertemporal consumption choices of individual households, and upon aggregation, real investment, aggregate growth, and social welfare.

In our paper, we address the following questions. How large are the welfare costs (externalities) of underdiversification for individual households? Are pathologies such as familiarity biases in financial markets merely a sideshow or do they impact the real economy?² How large are the negative externalities for the aggregate economy because households invest in underdiversified portfolios? That is, do household-level portfolio errors cancel out, or does aggregation amplify them, thereby distorting growth and imposing significant social costs? In short, does household finance matter?

Our paper makes three contributions. First, we show that even if the loss to a household from investing in an underdiversified portfolio is modest, once we incorporate the effect of an underdiversified portfolio on the household's intertemporal consumption choice, the welfare loss to the household is much larger. Second, household-level distortions to individual consumption stemming from excessive financial risk taking are amplified by aggregation and have a substantial effect on social welfare. Thus, financial markets are not a sideshow—

¹For surveys of the portfolio behavior of households, see Guiso, Haliassos, and Jappelli (2002), Haliassos (2002), Vissing-Jorgensen (2003), Campbell (2006), and Guiso and Sodini (2013).

²For a review of the literature on the interaction between financial markets and the real economy, see Bond, Edmans, and Goldstein (2012).

portfolio distortions at the micro-level create a macro-level externality in the form of reduced economic growth. Third, there are several policy measures that can be undertaken to improve the welfare of both individual households and society.

To answer the questions listed above, we construct a model of a production economy. Our model builds on the production economy framework developed in Cox, Ingersoll, and Ross (1985). As in Cox, Ingersoll, and Ross, there are a finite number of firms whose physical capital is subject to exogenous shocks. But, in contrast with Cox, Ingersoll, and Ross, we have heterogeneous households with Epstein and Zin (1989) and Weil (1990) preferences and familiarity bias. Each household is more familiar with a small subset of firms. Familiarity creates a desire to concentrate investments in familiar firms at the expense of holding a portfolio that is well-diversified across all firms. Importantly, we specify the model so that households are symmetric in their familiarity biases. The symmetry assumption ensures that the familiarity biases cancel out—that is, the portfolio aggregated over all households is unbiased.

We conceptualize the idea of greater familiarity with certain assets presented in Huberman (2001) via *ambiguity* in the sense of Knight (1921). The lower the level of ambiguity about an asset, the more “familiar” is the asset. To allow for *differences* in familiarity across assets, we extend the modeling approach in Uppal and Wang (2003) along three dimensions: one, we distinguish between risk across states of nature and over time by giving households Epstein-Zin-Weil preferences, as opposed to time-separable preferences; two, we consider a production economy instead of an endowment economy; three, we consider a general-equilibrium rather than a partial equilibrium framework.

Following Kahneman, Wakker, and Sarin (1997), we distinguish between a household’s *experienced* utility—the household’s actual well-being as a function of its choices—and its *decision* utility—the objective it seeks to maximize when making its portfolio and consumption choices.³ In our context, the decision utility exhibits familiarity bias, while the experienced utility does not.

We then determine the optimal portfolio decisions of each household in the presence of familiarity bias using the household’s decision utility. Because of the familiarity-induced tilt, the portfolio return is excessively risky relative to the return of the optimally diversified portfolio without familiarity bias. This extra financial risk also changes the intertemporal consumption-saving decision of a household. The resulting consumption decisions of

³See Chetty (2015) for an excellent exposition of behavioral economics in the context of public policy in general, and of the distinction between experienced and decision utility in particular.

a household are much more volatile than in the absence of a familiarity bias. Upon aggregation, the excessively volatile consumption of individual households distorts aggregate growth.

Welfare of each individual household, and of society as a whole, is measured using experienced utility. The inefficient risk-return tradeoff from the underdiversified portfolio reduces the experienced utility of the individual household; calibrating the model to the empirical findings in Campbell (2006) and Calvet, Campbell, and Sodini (2007) suggests that the resulting welfare loss is modest. However, the underdiversified portfolio causes an increase in consumption volatility, which magnifies the direct loss in household welfare from portfolio underdiversification. Upon aggregation, the excessively volatile consumption of individual households distorts aggregate growth and leads to an even larger loss in social welfare compared to the direct loss from the underdiversified portfolio of each household.

Our results suggest that financial literacy, financial regulation, and financial innovation designed to reduce investment mistakes by households can have a substantial impact on social welfare. Our work thereby provides an example of how improving the decisions made by households in financial markets can generate positive investment externalities; Thaler and Sunstein (2003) provide other examples of how public policy can be used to reduce the investment mistakes of households and Titman (2013) discusses other sources of externalities.

We now describe the related literature. There is a great deal of evidence showing that households hold poorly-diversified portfolios. Guiso, Haliassos, and Jappelli (2002), Haliassos (2002), Campbell (2006), and Guiso and Sodini (2013) highlight underdiversification in their surveys of household portfolios. Polkovnichenko (2005), using data from the Survey of Consumer Finances, finds that for households that invest in individual stocks directly, the median number of stocks held was two from 1983 until 2001, when it increased to three, and that poor diversification is often attributable to investments in employer stock, which is a significant part of equity portfolios. Barber and Odean (2000) and Goetzman and Kumar (2008) report similar findings of underdiversification based on data for individual investors at a U.S. brokerage firm. In a comprehensive and influential paper, Calvet, Campbell, and Sodini (2007) examine detailed government records covering the entire Swedish population. They find that of the investors who participate in equity markets, many are poorly diversified and bear significant idiosyncratic risk. Campbell, Ramadorai, and Ranish (2012) report that for their data on Indian households, “the average number of stocks held across all accounts and time periods is almost 7, but the median account holds only 3.4 stocks on

average over its life.” They also estimate that mutual fund holdings are between 8% and 16% of household direct equity holdings over the sample period.⁴

Typically, the few risky assets that households hold are ones with which they are “familiar.” Huberman (2001) introduces the idea that households invest in familiar assets and provides evidence of this in a multitude of contexts; for example, households in the United States prefer to hold the stock of their local telephone company. Grinblatt and Keloharju (2001), based on data on Finnish investors, find that investors are more likely to hold stocks of Finnish firms that are “familiar;” that is, firms that are located close to the investor, communicate in the investor’s native language, and have a chief executive of the same cultural background. Massa and Simonov (2006) also find that investors tilt their portfolios away from the market portfolio and toward stocks that are geographically and professionally close to the investor, resulting in a portfolio biased toward familiar stocks. French and Poterba (1990) and Cooper and Kaplanis (1994) document that investors bias their portfolios toward “home equity” rather than diversifying internationally. Dimmock, Kouwenberg, Mitchell, and Peijnenburg (2014) test the relation between familiarity bias and several household portfolio-choice puzzles. Based on a survey of U.S. households, they find that familiarity bias is related to stock-market participation, the fraction of financial assets in stocks, foreign-stock ownership, own-company-stock ownership, and underdiversification. They also show that these results cannot be explained by risk aversion.

The most striking example of investing in familiar assets is the investment in “own-company stock,” that is, stock of the company where the person is employed. Haliassos (2002) reports extensive evidence of limited diversification based on the tendency of households to hold stock in the employer’s firm. Mitchell and Utkus (2004) report that five million Americans have over sixty percent of their retirement savings invested in company stock and that about eleven million participants in 401(k) plans invest more than twenty percent of their retirement savings in their employer’s stock. Benartzi, Thaler, Utkus, and Sunstein (2007) find that only thirty-three percent of the investors who own company stock realize that it is riskier than a diversified fund with many different stocks. Remarkably, a survey of 401(k) participants by the Boston Research Group (2002) found that half of the respondents said that their company stock had the same or less risk than a money market fund, even though there was a high level of awareness amongst the respondents about the

⁴Lack of diversification is a phenomenon that is present not just in a few countries, but across the world. Countries for which there is evidence of lack of diversification include: Australia (Worthington (2009)), France (Arrondel and Lefebvre (2001)), Germany (Börsch-Supan and Eymann (2002) and Barasinska, Schäfer, and Stephan (2008)), India (Campbell, Ramadorai, and Ranish (2012)), Italy (Guiso and Jappelli (2002)), Netherlands (Alessie and Van Soest (2002)), and the United Kingdom (Banks and Smith (2002)).

experience of Enron’s employees, who lost a substantial part of their retirement funds that were invested in Enron stock.⁵

The rest of this paper is organized as follows. We describe the main features of our model in Section 2. The choice problem of a household that exhibits a bias toward familiar assets is solved in Section 3, and the equilibrium implications of aggregating these choices across all households are described in Section 4, in which we also evaluate the quantitative implications of the model. We conclude in Section 6. Proofs for all results are collected in the appendix.

2 The Model

In this section, we develop a parsimonious model of a stochastic dynamic general equilibrium economy with a finite number of production sectors and household types. Growth occurs endogenously in this model via capital accumulation. When defining the decision utility of households, we show how to extend Epstein and Zin (1989) and Weil (1990) preferences to allow for familiarity biases, where the level of the bias differs across risky assets.

2.1 Firms

There are N firms indexed by $n \in \{1, \dots, N\}$. The value of the capital stock in each firm at date t is denoted by $K_{n,t}$ and the output flow by

$$Y_{n,t} = \alpha K_{n,t}, \tag{1}$$

for some constant technology level $\alpha > 0$. The level of a firm’s capital stock can be increased by investment at the rate $I_{n,t}$. We thus have the following capital accumulation equation for an individual firm:

$$dK_{n,t} = I_{n,t} dt + \sigma K_{n,t} dZ_{n,t},$$

where σ , the volatility of the exogenous shock to a firm’s capital stock, is constant. The term $dZ_{n,t}$ is the increment in a standard Brownian motion and is firm-specific; the correlation between $dZ_{n,t}$ and $dZ_{m,t}$ for $n \neq m$ is denoted by ρ , which is also assumed to be constant over time and the same for all pairs $n \neq m$. Firm-specific shocks create ex-post heterogeneity across firms. The $N \times N$ correlation matrix of returns on firms’ capital stocks is given by

⁵At the end of 2000, 62 percent of Enron employees’ 401(k) assets were invested in company stock; between January 2001 and January 2002, the value of Enron stock fell from over \$80 per share to less than \$0.70 per share.

$\Omega = [\Omega_{nm}]$, where the elements of the matrix are

$$\Omega_{nm} = \begin{cases} 1, & n = m, \\ \rho, & n \neq m. \end{cases}$$

Firm-level heterogeneity gives rise to benefits from diversifying investments across firms. We assume the expected rate of return is the same across the N firms. Thus, diversification benefits manifest themselves solely through a reduction in risk—expected returns do not change with the level of diversification.

A firm's output flow is divided between its investment flow and dividend flow:

$$Y_{n,t} = I_{n,t} + D_{n,t}.$$

We can therefore rewrite the capital accumulation equation as

$$dK_{n,t} = (\alpha K_{n,t} - D_{n,t})dt + \sigma K_{n,t} dZ_{n,t}. \quad (2)$$

2.2 The Investment Opportunities of Households

There are H households, indexed by $h \in \{1, \dots, H\}$. Households can invest their wealth in two classes of assets. The first is a risk-free asset, which has an interest rate i that we assume for now is constant over time—and we show below, in Section 4.2, that this is indeed the case in equilibrium. Let $B_{h,t}$ denote the stock of wealth invested by household h in the risk-free asset at date t :

$$\frac{dB_{h,t}}{B_{h,t}} = i dt.$$

Additionally, households can invest in N risky firms, or equivalently, the stock of these N firms. We denote by $K_{hn,t}$ the stock of household h 's wealth invested in the n 'th risky firm. Given that the household's wealth, $W_{h,t}$, is held in either the risk-free asset or invested in a risky firm, we have that:

$$W_{h,t} = B_{h,t} + \sum_{n=1}^N K_{hn,t}.$$

The proportion of a household's wealth invested in firm n is denoted by ω_{hn} , and so

$$K_{hn,t} = \omega_{hn} W_{h,t},$$

implying that the wealth invested in the risk-free asset is

$$B_{h,t} = \left(1 - \sum_{h=1}^N \omega_{hn}\right) W_{h,t}.$$

The dividends distributed by firm n are consumed by household h , that is:

$$C_{hn,t} = D_{hn,t} = \frac{K_{hn,t}}{K_{n,t}} D_{n,t},$$

where $C_{hn,t}$ is the consumption rate of household h from the dividend flow of firm n . Hence, the dynamic budget constraint for household h is given by

$$\frac{dW_{h,t}}{W_{h,t}} = \left(1 - \sum_{n=1}^N \omega_{hn,t}\right) idt + \sum_{n=1}^N \omega_{hn,t} (\alpha dt + \sigma dZ_{n,t}) - \frac{C_{h,t}}{W_{h,t}} dt,$$

where $C_{h,t}$ is the consumption rate of household h and $C_{h,t} = \sum_{n=1}^N C_{hn,t}$.

2.3 Preferences and Familiarity Biases of Households

In the absence of any familiarity bias, decision utility and experienced utility coincide. In this case, each household maximizes her date- t utility level, $U_{h,t}$, defined as in Epstein and Zin (1989) by an intertemporal aggregation of date- t consumption flow, $C_{h,t}$, and the date- t certainty-equivalent of date $t + dt$ utility:

$$U_{h,t} = \mathcal{A}(C_{h,t}, \mu_t[U_{h,t+dt}]),$$

where $\mathcal{A}(\cdot, \cdot)$ is the time aggregator, defined by

$$\mathcal{A}(x, y) = \left[(1 - e^{-\delta dt}) x^{1-\frac{1}{\psi}} + e^{-\delta dt} y^{1-\frac{1}{\psi}} \right]^{\frac{1}{1-\frac{1}{\psi}}}, \quad (3)$$

in which $\delta > 0$ is the rate of time preference, $\psi > 0$ is the elasticity of intertemporal substitution, and $\mu_t[U_{h,t+dt}]$ is the date- t certainty equivalent of $U_{h,t+dt}$.⁶

The standard definition of a certainty equivalent amount of a risky quantity is the equivalent risk-free amount in static utility terms, and so the certainty equivalent $\mu_t [U_{h,t+dt}]$ satisfies

$$u_\gamma (\mu_t [U_{h,t+dt}]) = E_t[u_\gamma(U_{h,t+dt})], \quad (4)$$

⁶The only difference with Epstein and Zin (1989) is that we work in continuous time, whereas they work in discrete time. The continuous-time version of recursive preferences is known as stochastic differential utility (SDU), and is derived formally in Duffie and Epstein (1992). Schroder and Skiadas (1999) provide a proof of existence and uniqueness.

where $u_\gamma(\cdot)$ is the static utility index defined by the power utility function⁷

$$u_\gamma(x) = \begin{cases} \frac{x^{1-\gamma}}{1-\gamma}, & \gamma > 0, \gamma \neq 1 \\ \ln x, & \gamma = 1, \end{cases} \quad (5)$$

and the conditional expectation $E_t[\cdot]$ is defined relative to a reference probability measure \mathbb{P} , which we discuss below.

We can exploit our continuous-time formulation to write the certainty equivalent of household utility an instant from now in a more intuitive fashion:

$$\mu_t[U_{h,t+dt}] = E_t[U_{h,t+dt}] - \frac{1}{2} \gamma U_{h,t} E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right]. \quad (6)$$

The above expression reveals that the certainty equivalent of utility an instant from now is just the expected value of utility an instant from now adjusted downward for risk. Naturally, the size of the risk adjustment depends on the risk aversion of the household, γ . The risk adjustment depends also on the volatility of the proportional change in household utility, which is given by $E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right]$. Additionally, the risk adjustment is scaled by the current utility of the household, $U_{h,t}$.⁸

Typically, standard models of portfolio choice assume that households know the true expected return α on the value of each capital stock. Such perfect knowledge would make each household fully familiar with every firm and the probability measure \mathbb{P} would then be the true objective probability measure.⁹ However, in practice households do not know the true expected returns, so they do not view \mathbb{P} as the true objective probability measure—they treat it merely as a common reference measure. The name “reference measure” is chosen to capture the idea that even though households do not observe true expected returns, they do observe the same data and use it to obtain identical point estimates for expected returns.

We assume households are averse to their lack of knowledge about the true expected return and respond by reducing their point estimates. For example, household h will change the empirically estimated return on capital for firm n from α to $\alpha + \nu_{hn,t}$, thereby reducing the magnitude of the firm’s expected risk premium ($\nu_{hn,t} \leq 0$ if $\alpha > i$ and $\nu_{hn,t} \geq 0$ if $\alpha < i$).

⁷In continuous time the more usual representation for utility is given by $J_{h,t}$, where $J_{h,t} = u_\gamma(U_{h,t})$, with the function u_γ defined in (5).

⁸The scaling ensures that if the expected proportional change in household utility and its volatility are kept fixed, doubling current household utility also doubles the certainty equivalent. For a further discussion, see Skiadas (2009, p. 213).

⁹In continuous time when the source of uncertainty is a Brownian motion, one can always determine the true volatility of the return on the capital stock by observing its value for a finite amount of time; therefore, a household can be uncertain only about the expected return.

The size of the reduction depends on each household's familiarity with a particular firm—the reduction is smaller for firms with which the household is more familiar. Differences in familiarity across households lead them to use different estimates of expected returns in their decision making, despite having observed the same data. We can see this explicitly by observing that in the presence of familiarity, the contribution of risky portfolio investment to a household's expected return on wealth changes from $\sum_{n=1}^N \omega_{hn,t} \alpha dt$ to $\sum_{n=1}^N \omega_{hn,t} (\alpha + \nu_{hn,t}) dt$. The adjustment to the expected return on a household's wealth stemming from familiarity bias is thus

$$\sum_{n=1}^N \omega_{hn,t} \nu_{hn,t} dt. \quad (7)$$

Without familiarity bias, the decision of a household on how much to invest in a particular firm depends solely on the certainty equivalent. Therefore, to allow for familiarity bias it is natural to generalize the concept of the certainty equivalent. For date $t + dt$ decision utility in the presence of familiarity bias, we extend Uppal and Wang (2003) and define the *familiarity-biased certainty equivalent* by

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = \mu_t[U_{h,t+dt}] + U_{h,t} \times \left(\frac{W_{h,t} U_{W_{h,t}}}{U_{h,t}} \boldsymbol{\nu}_{h,t}^{\top} \boldsymbol{\omega}_{h,t} + \frac{1}{2\gamma} \frac{\boldsymbol{\nu}_{h,t}^{\top} (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}}{\sigma^2} \right) dt, \quad (8)$$

where $U_{W_{h,t}} = \frac{\partial U_{h,t}}{\partial W_{h,t}}$, $\boldsymbol{\omega}_{h,t} = (\omega_{h1,t}, \dots, \omega_{hN,t})^{\top}$ is the column vector of portfolio weights, $\boldsymbol{\nu}_{h,t} = (\nu_{h1,t}, \dots, \nu_{hN,t})^{\top}$, and $\Gamma_h = [\Gamma_{h,nm}]$ is the $N \times N$ diagonal matrix defined by

$$\Gamma_{h,nm} = \begin{cases} \frac{1-f_{hn}}{f_{hn}}, & n = m, \\ 0, & n \neq m, \end{cases} \quad (9)$$

where $f_{hn} \in [0, 1]$ is a measure of how familiar the household is with firm, n . A larger value for f_{hn} indicates more familiarity, with $f_{hn} = 1$ implying perfect familiarity, and $f_{hn} = 0$ indicating no familiarity at all.

The first term in (8), the pure certainty equivalent $\mu_t[U_{h,t+dt}]$, does not depend directly on the familiarity-bias adjustments. As before, we introduce the scaling factor $U_{h,t}$ (see footnote 8 for the role of the scaling factor). The next term, $\frac{W_{h,t} U_{W_{h,t}}}{U_{h,t}} \boldsymbol{\nu}_{h,t}^{\top} \boldsymbol{\omega}_{h,t}$, is the adjustment to the expected change in household utility. It is the product of the elasticity of household utility with respect to wealth, $\frac{W_{h,t} U_{W_{h,t}}}{U_{h,t}}$, and the change in the expected return on household wealth arising from the adjustment made to returns, which is given in (7).

The tendency to make adjustments to expected returns is tempered by a penalty term, $\frac{1}{2} \frac{1}{\gamma} \frac{\boldsymbol{\nu}_{h,t}^{\top} (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}}{\sigma^2}$, which captures two distinct features of household decision making. The

first pertains to the idea that when a household has more accurate estimates of expected returns, she will be less willing to adjust them. The accuracy of household expected return estimates is measured by their standard errors, which are proportional to σ .¹⁰ With smaller standard errors, there is a stiffer penalty for adjusting returns away from their empirical estimates. The second feature pertains to familiarity—when a household is more familiar with a particular firm, she is less willing to adjust its expected return.

3 Portfolio Choice and Welfare of an Individual Household

We solve the model described above in two steps. First, we solve in partial equilibrium the problem of an individual household who suffers from familiarity bias; that is, whose decision utility is given by (11) below. To solve the individual household’s intertemporal decision problem, we show that the portfolio-choice problem can be interpreted as the problem of a mean-variance household, where the familiarity bias is captured by adjusting expected returns. We then show how the mean-variance portfolio choice impacts the intertemporal consumption choice of the household. Comparing the experienced utility to the decision utility allows us to measure the internality (welfare loss) at the individual-household level resulting from familiarity bias. Then, in the next section, we aggregate over all households to get in general equilibrium the externality on social welfare resulting from familiarity bias at the individual-household level.

3.1 The Intertemporal Choice Problem of an Individual Household

In the absence of familiarity-bias, decision utility and experienced utility coincide, and an individual household would choose her consumption rate and portfolio policy according to the standard choice problem:

$$\sup_{C_{h,t}} \mathcal{A} \left(C_{h,t}, \sup_{\omega_{h,t}} \mu_{h,t}[U_{h,t+dt}] \right). \quad (10)$$

In the presence of familiarity bias, the time aggregator in (3) is unchanged—all we do is replace the maximization of the certainty-equivalent $\sup_{\omega_{h,t}} \mu_t[U_{h,t+dt}]$, with the combined maximization and minimization of the familiarity-based certainty equivalent,

¹⁰In our continuous-time framework, an infinite number of observations are possible in finite time, so standard errors equal the volatility of proportional changes in the capital stock, σ , divided by the square root of the length of the observation window.

$\sup_{\omega_{h,t}} \inf_{\nu_t} \mu_{h,t}^{\nu} [U_{h,t+dt}]$ to obtain

$$\sup_{C_{h,t}} \mathcal{A} \left(C_{h,t}, \sup_{\omega_{h,t}} \inf_{\nu_{h,t}} \mu_{h,t}^{\nu} [U_{h,t+dt}] \right). \quad (11)$$

A household, because of its familiarity bias, chooses $\nu_{h,t}$ to *minimize* its familiarity-biased certainty equivalent; that is, the household adjusts expected returns more for firms with which it is less familiar, which acts to reduce the familiarity-biased certainty equivalent.¹¹ By comparing (10) and (11), we can see that once a household has chosen the vector $\nu_{h,t}$ to adjust the expected returns of each firm for familiarity bias, the household makes consumption and portfolio choices in the standard way.

Given any portfolio choice $\omega_{h,t}$ for a household, finding the adjustments to firm-level expected returns is a simple matter of minimizing the familiarity-biased certainty equivalent in (8). For a given portfolio $\omega_{h,t}$, the adjustment $\nu_{hn,t}$ to firm n 's expected return is given by:

$$\nu_{hn,t} = -\frac{W_{h,t} U_{W_{h,t}}}{U_{h,t}} \left(\frac{1}{f_{hn}} - 1 \right) \sigma^2 \gamma \left(\omega_{hn,t} + \rho \sum_{m \neq n} \omega_{hm,t} \right), n \in \{1, \dots, n\}. \quad (12)$$

The above expression shows that if a household is fully familiar with firm n , $f_{hn} = 1$, then she makes no adjustment to the firm's expected return. When she is less than fully familiar, $f_{hn} \in [0, 1)$, one can see that $\nu_{hn,t}$ is negative (positive) when $\omega_{hn,t}$ is positive (negative), reflecting the idea that lack of familiarity leads a household to moderate its portfolio choices, shrinking both long and short positions toward zero.

To solve a household's consumption-portfolio choice problem under familiarity bias we use Ito's Lemma to derive the continuous-time limit of (11), which leads to the following Hamilton-Jacobi-Bellman equation:

$$0 = \sup_{C_{h,t}} \left(\delta u_{\psi} \left(\frac{C_{ht}}{U_{ht}} \right) + \sup_{\omega_t} \inf_{\nu_{h,t}} \frac{1}{U_{h,t}} \mu_{h,t}^{\nu} \left[\frac{dU_{h,t}}{dt} \right] \right), \quad (13)$$

where the function

$$u_{\psi}(x) = \frac{x^{1-\frac{1}{\psi}} - 1}{1 - \frac{1}{\psi}}, \psi > 0,$$

and

$$\mu_{h,t}^{\nu} [dU_{h,t}] = \mu_{h,t}^{\nu} [U_{h,t+dt} - U_{h,t}] = \mu_{h,t}^{\nu} [U_{h,t+dt}] - U_{h,t},$$

with $\mu_{h,t}^{\nu} [U_{h,t+dt}]$ given in (8).

¹¹In the language of decision theory, households are averse to ambiguity and so they minimize their familiarity-biased certainty equivalents.

Assuming a constant risk-free rate, homotheticity of preferences combined with constant returns to scale for production leads to an investment opportunity set that is constant over time, and hence, implies that maximized household utility is a constant multiple of household wealth. In this case, the Hamilton-Jacobi-Bellman equation can be decomposed into two parts: an *intertemporal* consumption-choice problem and a *mean-variance* optimization problem for a household with familiarity bias:

$$0 = \sup_{C_{h,t}} \left(\delta u_\psi \left(\frac{C_{ht}}{U_{ht}} \right) - \frac{C_{ht}}{W_{ht}} + \sup_{\boldsymbol{\omega}_t} \inf_{\boldsymbol{\nu}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t}) \right). \quad (14)$$

In the above expression, $MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t})$ is the objective function of a mean-variance household with familiarity bias:

$$MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t}) = i + (\alpha - i) \mathbf{1}^\top \boldsymbol{\omega}_{h,t} - \frac{1}{2} \gamma \sigma^2 \boldsymbol{\omega}_{h,t}^\top \Omega \boldsymbol{\omega}_{h,t} + \boldsymbol{\nu}_{h,t}^\top \boldsymbol{\omega}_{h,t} + \frac{1}{2\gamma} \frac{\boldsymbol{\nu}_{h,t}^\top (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}}{\sigma^2}, \quad (15)$$

where $\mathbf{1}$ denotes the $N \times 1$ unit vector, $i + (\alpha - i) \mathbf{1}^\top \boldsymbol{\omega}_{h,t}$ is the expected portfolio return, $-\frac{1}{2} \gamma \sigma^2 \boldsymbol{\omega}_{h,t}^\top \Omega \boldsymbol{\omega}_{h,t}$ is the penalty for portfolio variance, $\boldsymbol{\nu}_{h,t}^\top \boldsymbol{\omega}_{h,t}$ is the adjustment to the portfolio's expected return arising from familiarity bias, and $\frac{1}{2\gamma} \frac{\boldsymbol{\nu}_{h,t}^\top (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}}{\sigma^2}$ is the penalty for adjusting expected returns.¹²

In the first part of the mean-variance problem with familiarity bias, the firm-level expected returns are optimally adjusted downward because of lack of familiarity. Because household utility is a constant multiple of wealth, the expression for the optimal adjustment to expected returns in (12) simplifies to:

$$\boldsymbol{\nu}_{h,t} = -\gamma \sigma^2 (\Gamma_h \Omega) \boldsymbol{\omega}_{h,t}. \quad (16)$$

Substituting the above expression into (15), we see that each household faces the following mean-variance portfolio problem:

$$\sup_{\boldsymbol{\omega}_{h,t}} MV(\boldsymbol{\omega}_{h,t}) = \left(i + (\alpha \mathbf{1} + \frac{1}{2} \boldsymbol{\nu}_{h,t} - i \mathbf{1})^\top \boldsymbol{\omega}_{h,t} \right) - \frac{1}{2} \gamma \sigma^2 \boldsymbol{\omega}_{h,t}^\top \Omega \boldsymbol{\omega}_{h,t}, \quad (17)$$

in which $\boldsymbol{\nu}_{h,t}$ is given by (16). When the household is fully familiar with all firms, then Γ_h is the zero matrix, and from (16) we can see the adjustment to expected returns is zero and the portfolio weights are exactly the standard mean-variance portfolio weights. For the case where the household is completely unfamiliar with all firms, then each $\Gamma_{h,nn}$ becomes infinitely large and $\boldsymbol{\omega}_h = \mathbf{0}$: complete unfamiliarity leads the household to avoid any investment in risky firms, in which case we get non-participation in the stock market in this partial-equilibrium setting.

¹²The familiarity-bias adjustment is obtained from a minimization problem, so the associated penalty is positive, in contrast with the penalty for return variance.

3.2 Optimal Portfolio of an Individual Household

In this section, we derive the portfolio of an individual household that maximizes the household's decision utility. We then show the relation between the portfolio chosen and the welfare of a household with a mean-variance objective function, as in Campbell (2006).

Solving from (17) the first-order condition for the vector of optimal portfolio weights, $\omega_{h,t}$, and substituting the resulting optimal weights into (16), we see that the optimal adjustment to expected returns is:

$$\nu_h = -(\alpha - i)(\mathbf{1} - \mathbf{f}_h), \quad (18)$$

where \mathbf{f}_h is the vector of familiarity coefficients

$$\mathbf{f}_h = (f_{h1}, \dots, f_{hN}).$$

The vector of optimal portfolio weights is

$$\omega_h = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \Omega^{-1} \mathbf{f}_h.$$

We can write the n 'th element of the above vector of portfolio weights as

$$\omega_{hn} = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} q_{hn}, \quad (19)$$

where q_{hn} is the correlation-adjusted familiarity of investor h with respect to firm n , defined by

$$q_{hn} = \mathbf{e}_n^\top \Omega^{-1} \mathbf{f}_h,$$

where \mathbf{e}_n is the $N \times 1$ column vector, with a one in the n 'th entry and zeros everywhere else.

Observe from (18) that the optimal adjustment to expected returns in the presence of familiarity bias is

$$\nu_{hn} = -(\alpha - i)(1 - f_{hn}). \quad (20)$$

From (20), we can see that the size of a household's adjustment to a firm's return is smaller when the level of familiarity, f_{hn} , is larger; if $f_{hn} = 1$, then the adjustment vanishes altogether.

For the special case where $\rho = 0$, the quantity $q_{hn} = f_{hn}$, so that the portfolio weight for firm n in (19) simplifies to

$$\omega_{hn} = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} f_{hn}. \quad (21)$$

From (21), we see that the standard mean-variance portfolio weight for firm n in the absence of familiarity, $\frac{1}{\gamma} \frac{\alpha - i}{\sigma^2}$, is scaled by the level of household h 's familiarity with firm n , f_{hn} . As a household's level of familiarity with a particular firm decreases, the proportion of her wealth that she chooses to invest in that firm also decreases.

Next, we characterize the weights in the portfolio of only risky assets: $\mathbf{x}_h = \frac{\boldsymbol{\omega}_h}{\mathbf{1}^\top \boldsymbol{\omega}_h}$. From (19), it follows that

$$x_{hn} = \frac{q_{hn}}{\sum_{n=1}^N q_{hn}}.$$

The familiarity-biased portfolio of only risky assets, \mathbf{x}_h , is the minimum-variance portfolio with a familiarity-biased adjustment.¹³ Given that all risky assets have the same volatility and correlation, the minimum-variance portfolio with no familiarity bias is given by $x_{hn} = \frac{1}{N}$. Familiarity bias tilts the portfolio of only risky assets away from $\frac{1}{N}$, thereby increasing its variance. This also leads the household to reduce the proportion of her overall wealth held in risky assets.

Defining by $SR_{\mathbf{x}_h}$ the Sharpe ratio of the portfolio of only risky assets,

$$SR_{\mathbf{x}_h} = \frac{\alpha - i}{\sigma_{\mathbf{x}_h}}, \quad (22)$$

where

$$\sigma_{\mathbf{x}_h}^2 = \sigma^2 \mathbf{x}_h^\top (I + \Gamma_h) \Omega \mathbf{x}_h$$

can be interpreted as the variance of the household's portfolio of risky assets with an additional penalty term for familiarity bias. This additional term is represented by the diagonal matrix Γ_h defined in equation (9), which is added to the correlation matrix Ω .

On the other hand, the Sharpe ratio of the equal-weighted portfolio of only risky assets, is given by

$$SR_{1/N} = \frac{\alpha - i}{\sigma_{1/N}}, \quad (23)$$

in which the volatility of the equal-weighted portfolio of only risky assets is

$$\sigma_{1/N} = \sigma \sqrt{\frac{1}{N} + \left(1 - \frac{1}{N}\right) \rho}.$$

Comparing (22) to (23), we see that the numerator of $SR_{\mathbf{x}_h}$ is the same as the numerator of $SR_{1/N}$, but in the denominator, $\sigma_{\mathbf{x}_h} > \sigma_{1/N}$ because familiarity bias leads to an underdiversified portfolio that has higher volatility. Consequently, $SR_{1/N} > SR_{\mathbf{x}_h}$.

¹³If $\rho = 0$, then $x_{hn} = \frac{f_{hn}}{\sum_{n=1}^N f_{hn}}$.

We now compute the welfare loss from familiarity bias of a household that maximizes just the mean-variance objective function in (15); this result will be useful in comparing the welfare gain in the absence of intertemporal consumption to that where the investor desires to smooth intertemporal consumption.

With familiarity bias, the *optimized* mean-variance experienced-utility function can be expressed as

$$\sup_{\boldsymbol{\omega}_{h,t}} \inf_{\boldsymbol{\nu}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t}) = i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2. \quad (24)$$

On the other hand, the optimized experienced-utility function in the absence of a familiarity bias is

$$\sup_{\boldsymbol{\omega}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t} = \mathbf{0}) = i + \frac{1}{2\gamma} SR_{1/N}^2. \quad (25)$$

Clearly, because $SR_{1/N} > SR_{\mathbf{x}_h}$, the utility experienced from a portfolio chosen without a familiarity bias is greater than that from a portfolio chosen with familiarity bias, for a given level of the interest rate. Subtracting (24) from (25), the gain in mean-variance experienced utility is equivalent to an increase in the risk-free interest rate of

$$\begin{aligned} & \sup_{\boldsymbol{\omega}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t} = \mathbf{0}) - \sup_{\boldsymbol{\omega}_{h,t}} \inf_{\boldsymbol{\nu}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t}) \\ &= \frac{1}{2\gamma} \left(SR_{1/N}^2 - SR_{\mathbf{x}_h}^2 \right) \\ &= \frac{1}{2} (\mathbf{1}^\top \boldsymbol{\omega}_h) \sigma_{\mathbf{x}_h} \left(\frac{SR_{1/N}^2 - SR_{\mathbf{x}_h}^2}{SR_{\mathbf{x}_h}} \right), \end{aligned} \quad (26)$$

where in the second line γ has been substituted out using the result $\boldsymbol{\omega}_h = \left(\frac{1}{\gamma} \frac{SR_{\mathbf{x}_h}}{\sigma_{\mathbf{x}_h}} \right) \mathbf{x}_h$. This measure of utility gain is the one used in Campbell (2006, p. 1574). One can also measure the change in utility in percentage terms, in which case the expression is:

$$\frac{\frac{1}{2\gamma} \left(SR_{1/N}^2 - SR_{\mathbf{x}_h}^2 \right)}{i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2}. \quad (27)$$

Having analyzed the portfolio choice of an individual household and the welfare implications of the portfolio choice, we now study the household's consumption decision and the welfare measure in the presence of consumption.

3.3 Optimal Consumption of an Individual Household

We first solve for optimal consumption in terms of household utility. From the Hamilton-Jacobi-Bellman equation in (13), the first-order condition with respect to consumption is

$$\delta \left(\frac{C_{ht}}{U_{ht}} \right)^{-\frac{1}{\psi}} = \frac{U_{ht}}{W_{h,t}}.$$

Substituting the above first-order condition into the Hamilton-Jacobi-Bellman equation allows us to solve for household decision utility, and hence, optimal consumption. We find that

$$U_{h,t} = \left(\frac{C_{ht}/W_{ht}}{\delta^\psi} \right)^{\frac{1}{1-\psi}} W_{h,t}, \quad (28)$$

where a household's optimal consumption-to-wealth ratio is given by

$$\begin{aligned} \frac{C_{h,t}}{W_{h,t}} &= \psi\delta + (1-\psi) \left(\left[i + \left(\alpha \mathbf{1} + \frac{1}{2} \boldsymbol{\nu}_{h,t} - i \mathbf{1} \right)^\top \boldsymbol{\omega}_{h,t} \right] - \frac{1}{2} \gamma \sigma^2 \boldsymbol{\omega}_{h,t}^\top \boldsymbol{\Omega} \boldsymbol{\omega}_{h,t} \right) \\ &= \psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2 \right). \end{aligned} \quad (29)$$

The presence of $SR_{\mathbf{x}_h}$ in the above expression shows that the household's portfolio choice impacts her intertemporal consumption choice. We see from (29) that the optimal consumption-wealth ratio is a weighted average of the impatience parameter δ and the *optimized* single-period, mean-variance objective function, defined in (24). When the substitution effect dominates ($\psi > 1$), choosing a portfolio subject to familiarity bias makes current consumption less attractive relative to saving. In contrast, when the income effect dominates ($\psi < 1$), familiarity bias makes current consumption more attractive than saving. Familiarity bias distorts a household's intertemporal consumption choice as follows

$$\left. \frac{C_{h,t}}{W_{h,t}} \right|_{\text{no bias}} - \left. \frac{C_{h,t}}{W_{h,t}} \right|_{\text{bias}} = (1-\psi) \left(\frac{1}{2\gamma} (SR_{1/N}^2 - SR_{\mathbf{x}_h}^2) \right),$$

assuming a partial equilibrium perspective, where the risk-free interest rate, i , is held fixed (we endogenize the interest rate in the next section).

Finally, we study how the welfare loss arising from underdiversification is amplified because of its effect on intertemporal consumption. If a household is subject to familiarity bias, her lifetime experienced utility level, $U_{h,t}$, is given by

$$U_{h,t}|_{\text{bias}} = \left[\frac{\psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2 \right)}{\delta^\psi} \right]^{\frac{1}{1-\psi}} W_{h,t}, \quad (30)$$

which we obtain by substituting (29) into (28). On the other hand, the lifetime experienced utility level of a household that does not suffer from familiarity bias is given by the following expression, where $SR_{\mathbf{x}_h}$ in (30) is replaced by $SR_{1/N}$:

$$U_{h,t}|_{\text{no bias}} = \left[\frac{\psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} SR_{1/N}^2 \right)}{\delta^\psi} \right]^{\frac{1}{1-\psi}} W_{h,t}.$$

We measure the welfare gain to an individual household (that is, positive externality) from eliminating familiarity bias as the equivalent percentage increase in the level of an individual household's wealth. That is, denoting a household's date- t utility as a function of its wealth by $U_{h,t} = U_h(W_{h,t})$, we find λ_{MP} such that

$$U_h(W_{h,t})|_{\text{no bias}} = U_h((1 + \lambda_{MP})W_{h,t})|_{\text{bias}},$$

i.e.

$$\lambda_{MP} = \left[\frac{\psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} SR_{1/N}^2 \right)}{\psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2 \right)} \right]^{\frac{1}{1-\psi}} - 1. \quad (31)$$

The above equation tells us the percentage increase in the wealth of an individual household that is required to raise the experienced utility of a household with familiarity bias to that of a household without the bias.

3.4 Relation Between the Mean-Variance and Overall Welfare Measures

In this section, we aim to understand how the welfare gain from eliminating the familiarity bias based on the welfare measure in a mean-variance setting without intermediate consumption, which is given in (26), is related to the welfare measure in the presence of intertemporal consumption, given in (31).

To understand the relation between the welfare measures in the absence and presence of intermediate consumption, we consider a household with perfectly inelastic intertemporal consumption. Taking the limit of λ_{MP} in (31) as the parameter driving the elasticity of intertemporal substitution $\psi \rightarrow 0$, we get:

$$\begin{aligned} \lim_{\psi \rightarrow 0} \lambda_{MP} = \lambda_{MV} &= \frac{i + \frac{1}{2\gamma} SR_{1/N}^2}{i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2} - 1 \\ &= \frac{\frac{1}{2\gamma} \left(SR_{1/N}^2 - SR_{\mathbf{x}_h}^2 \right)}{i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2}, \end{aligned}$$

which coincides exactly with the expression that we derived in (27) for the percentage gain in experienced utility in the absence of intermediate consumption. Thus, as long as the household's elasticity of intertemporal substitution is different from zero, the multiperiod measure of welfare gain that allows for intermediate consumption smoothing, λ_{MP} , will exceed the mean-variance measure that ignores intermediate consumption, λ_{MV} .

The ratio of the percentage increase in the overall welfare gain to the percentage increase in the mean-variance welfare gain is denoted by the *amplification factor*, A , where

$$A = \frac{\lambda_{MP}}{\lambda_{MV}} = \left(\left[\frac{\psi\delta + (1-\psi)(MV + \Delta MV)}{\psi\delta + (1-\psi)MV} \right]^{\frac{1}{1-\psi}} - 1 \right) \frac{MV}{\Delta MV}, \quad (32)$$

in which MV is the mean-variance welfare measure before eliminating the familiarity bias and ΔMV is the mean-variance welfare gain stemming from eliminating the familiarity bias. To first order in ΔMV , we obtain

$$A = \frac{1}{\psi \frac{MV}{\delta} + (1-\psi)} \left(1 + \frac{1}{2} \psi \frac{\Delta MV}{\psi \frac{MV}{\delta} + (1-\psi)} + o(\Delta MV) \right).$$

From the above expression, we can see that the overall welfare gain will be larger than the mean-variance welfare gain if $MV > \delta$; that is, if the risk- and familiarity-adjusted expected return is larger than the investor's subjective rate of time preference. We also see that the ratio of the overall welfare gain to the mean-variance welfare gain increases with ψ ; that is, with the willingness of the household to substitute current consumption for future consumption.

Taking the partial derivative of $U_{h,t}/W_{h,t}$ with respect to the single-period mean-variance objective function gives

$$\frac{\partial \left(\frac{U_{h,t}}{W_{h,t}} \right)}{\partial MV} = \left(\frac{1}{\delta} \frac{U_{h,t}}{W_{h,t}} \right)^\psi.$$

The first-order change in welfare induced by a small change, ΔMV , in the single-period, mean-variance objective function is thus given by

$$\left(\frac{1}{\delta} \frac{U_{h,t}}{W_{h,t}} \right)^\psi \Delta MV,$$

in which $\left(\frac{1}{\delta} \frac{U_{h,t}}{W_{h,t}} \right)^\psi$ is an amplification factor which is greater than or equal to 1, when $MV > \delta$. Similarly, one can show that the amplification factor for percentage changes in

lifetime utility is

$$\frac{MV}{\frac{U_{h,t}}{W_{h,t}}} \left(\frac{1}{\delta} \frac{U_{h,t}}{W_{h,t}} \right)^\psi .$$

The amplification factor $\left(\frac{1}{\delta} \frac{U_{h,t}}{W_{h,t}} \right)^\psi$ is equal to 1 if and only if $\psi = 0$. Furthermore, one can show that if $\psi > 1$, then a lower bound for the amplification factor is given by $e^{\frac{MV}{\delta}-1}$ when $MV > \delta$.

In summary, if a household is more patient (smaller δ) or has a greater tolerance for intertemporal consumption fluctuations (larger ψ), the mean-variance loss is amplified.

$$U_{h,t} = \left[\frac{\psi\delta + (1-\psi) \left(i + \frac{1}{2\gamma} \left(\frac{\alpha-i}{\sigma_{hp}} \right)^2 \right)}{\delta^\psi} \right]^{\frac{1}{1-\psi}} W_{h,t} .$$

From the above expression, we can see that in a partial equilibrium framework, where the risk-free interest rate is held fixed along with household wealth, a household's familiarity biases decreases its utility by increasing portfolio risk with no concurrent increase in expected risk premium.

The above expression reflects two aspects of a household's optimization problem. The first is the single-period portfolio choice problem of a static mean-variance optimizing agent, whose maximized utility is given by the expression:

$$i + \frac{1}{2\gamma} \left(\frac{\alpha-i}{\sigma_{hp}} \right)^2 . \quad (33)$$

The second reflects the household's dynamic intertemporal consumption choice, which hinges not only on the portfolio she has chosen but also on how patient she is (given by δ) and how willing she is to substitute consumption over time (given by ψ). Observe that for the special case where $\psi = 0$, the utility of the household reduces to that of a static mean-variance agent. The expression in (33) corresponds to the utility metric used in Campbell (2006, p. 1574) to measure the losses stemming from underdiversification.

4 Social Welfare and Growth

In this section, we study social welfare and growth in general equilibrium. In contrast with Section 3, where we examined how familiarity bias impacts an *individual* household,

we now focus on *aggregate* quantities. That is, we investigate the negative externalities for aggregate growth and social welfare of the distortion in the consumption of individual households when we aggregate over all households and impose market clearing. In the last part of this section, we also provide a quantitative assessment of the effects of familiarity bias on social welfare.

4.1 No Aggregate Familiarity Bias Across Households

In this section, we explain how the familiarity bias is specified for each household so that it is “symmetric” across households and “cancels out in aggregate.”

By “canceling out in aggregate” we mean that the bias in the cross-sectional average risky portfolio across households is zero. We express this condition formally by first writing household h ’s risky portfolio weight for firm n as the unbiased weight plus a bias, i.e.

$$x_{hn} = \frac{1}{N} + \epsilon_{hn},$$

where $\frac{1}{N}$ is the unbiased portfolio weight and ϵ_{hn} is the bias of household h ’s portfolio when investing in firm n . We can now see that “cancelling out in aggregate” is equivalent to the following condition

$$\forall n, \quad \frac{1}{H} \sum_{h=1}^H \epsilon_{hn} = 0, \quad (34)$$

which applies for every firm.¹⁴ The above condition says that while it is possible for an individual household’s portfolio to be biased, that is, to deviate from the unbiased $\frac{1}{N}$ portfolio, this bias must cancel out when forming the average portfolio across all households. We shall refer to (34) as the “no-aggregate-bias condition.”

The following symmetry condition implies that the no-aggregate bias condition holds. For every household $h \in \{1, \dots, H\}$, define the adjusted-familiarity vector (q_{h1}, \dots, q_{hN}) . The symmetry condition states the following: (1) given a household $h \in \{1, \dots, H\}$, for all households $h' \in \{1, \dots, H\}$, there exists a permutation $\tau_{h'}$ such that $\tau_{h'}(q_{h'1}, \dots, q_{h'N}) = (q_{h1}, \dots, q_{hN})$; and, (2) given a firm $n \in \{1, \dots, N\}$, for all firms $n' \in \{1, \dots, N\}$, there exists a permutation $\tau_{n'}$ such that $\tau_{n'}(q_{1n'}, \dots, q_{Hn'}) = (q_{1n}, \dots, q_{Hn})$.

¹⁴An equivalent way of expressing equation (34) is that the mean risky portfolio equals the $\frac{1}{N}$ portfolio:

$$\forall n, \quad \frac{1}{H} \sum_{h=1}^H x_{hn} = \frac{1}{N}.$$

To understand the symmetry condition note that if one were to define a $H \times N$ familiarity matrix,

$$Q = [q_{hn}] \quad (35)$$

then the permutations described in the above symmetry condition imply that one can obtain all the rows of the matrix by rearranging any particular row, and one can obtain all the columns of the matrix by rearranging any particular column.

To interpret the symmetry condition further, observe that it implies that

$$\forall n, \forall h, \quad \frac{1}{H} \sum_{h=1}^H q_{hn} = \frac{1}{N} \sum_{n=1}^N q_{hn}. \quad (36)$$

Intuitively, the condition in (36) says that the mean correlation-adjusted familiarity of a household across all firms, $\frac{1}{N} \sum_{n=1}^N q_{hn}$, is equal to the mean correlation-adjusted familiarity toward a firm from all households, $\frac{1}{H} \sum_{h=1}^H q_{hn}$; furthermore, the total correlation-adjusted familiarity of a household is the same across all households and the total correlation-adjusted familiarity toward a firm is the same across all firms.

Observe also that the condition in equation (36) is equivalent to

$$\forall n, \forall h, \quad \frac{1}{H} \hat{q}_n = \frac{1}{N} \hat{q}_h, \quad (37)$$

where

$$\hat{q}_n = \sum_{h=1}^H q_{hn}, \quad \text{and} \quad \hat{q}_h = \sum_{n=1}^N q_{hn}.$$

From (37) we can also see that \hat{q}_n and \hat{q}_h must be independent of n and h , respectively. The condition in (37) tells us that in addition to the mean risky portfolio being unbiased, and hence equal to $1/N$, the mean proportion of aggregate wealth invested in firm n is $\frac{1}{N}$.

We illustrate the symmetry condition for the case $\rho = 0$ with two examples. For the special case in which the asset returns are uncorrelated, $\rho = 0$, the symmetry condition in (36) simplifies to

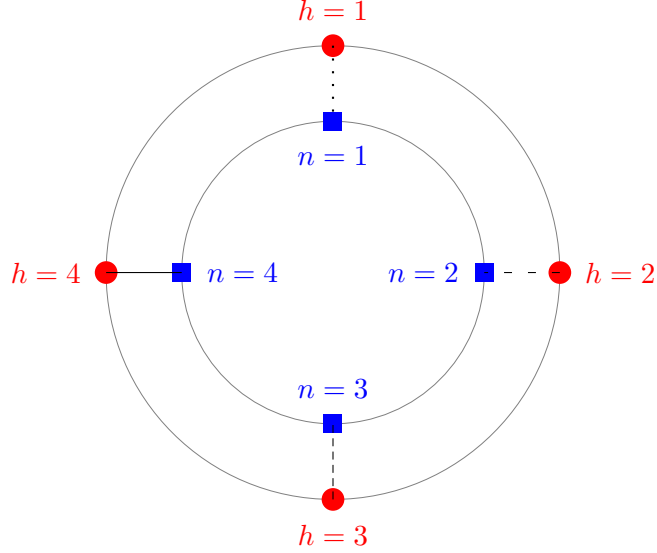
$$\frac{1}{N} \sum_{n=1}^N f_{hn} = \frac{1}{H} \sum_{h=1}^H f_{hn}, \quad \forall h \text{ and } n,$$

and the $H \times N$ familiarity matrix, Q in (35), reduces to

$$F = [f_{hn}].$$

Figure 1: First example of symmetry condition

In this figure, we illustrate the first example of the symmetry condition for familiarity of households with certain firms. We set the number of firms to be equal to the number of households, $N = H$, and assume that household 1 is familiar with firm 1, household 2 is familiar with firm 2, and so on, with each household investing only in the firm with which it is familiar; that is, $f_{1,1} = f_{2,2} = f_{3,3} = \dots = f_{N,N} = f$, where $f \in (0, 1]$, while $f_{hn} = 0$ for $h \neq n$.



In both examples, we set the number of firms to be equal to the number of households, $N = H$, and assume that each household is equally familiar with a different subset of firms, and the household is unfamiliar with the remaining firms. The number of firms in the familiar subset is the same for each household.

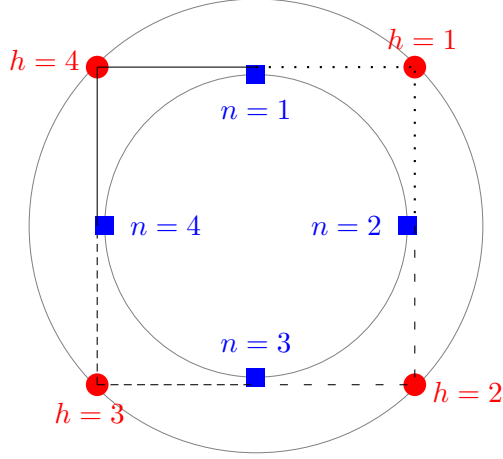
In the first example, illustrated in Figure 1, we assume that household 1 is familiar with firm 1, household 2 is familiar with firm 2, and so on, with each household investing only in the firm with which it is familiar; that is, $f_{1,1} = f_{2,2} = f_{3,3} = \dots = f_{N,N} = f$, where $f \in (0, 1]$, while $f_{hn} = 0$ for $h \neq n$. Thus, the familiarity matrix in this case is:

$$F = \begin{bmatrix} f & 0 & \dots & 0 \\ 0 & f & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 0 & \dots & f \end{bmatrix}.$$

In the second example, illustrated in Figure 2, we assume that each household is familiar with 2 firms. Let the firms be arranged in a circle, and let each household h be equally familiar with the two firms nearest to it on either side. Thus, in this case the familiarity

Figure 2: Second example of symmetry condition

In this figure, we illustrate the second example of the symmetry condition for familiarity of households with certain firms. We set the number of firms to be equal to the number of households, $N = H$, and assume that each household is familiar with two firms. Let the firms be arranged in a circle, and let each household h be equally familiar with the two firms nearest to it on either side.



matrix is:

$$F = \begin{bmatrix} f & f & 0 & \cdots & \cdots \\ 0 & f & f & 0 & \cdots \\ \vdots & \cdots & \cdots & \cdots & \vdots \\ f & 0 & \cdots & 0 & f \end{bmatrix}.$$

4.2 The Equilibrium Risk-free Interest Rate

We now characterize the equilibrium in the economy we are studying by imposing market clearing in the risk-free bond market. The risk-free bond is in zero net-supply, which implies that the demand for bonds aggregated across all households must be zero:

$$\sum_{h=1}^H B_{h,t} = 0.$$

The amount of wealth held in the bond by household h is given by

$$B_{h,t} = (1 - \mathbf{1}^\top \boldsymbol{\omega}_h) W_{h,t},$$

where $\mathbf{1}^\top \boldsymbol{\omega}_h$ is the proportion of household h 's wealth invested in all risky assets. Summing the demand for bonds over households gives

$$0 = \sum_{h=1}^H B_{h,t} = \sum_{h=1}^H (1 - \mathbf{1}^\top \boldsymbol{\omega}_h) W_{h,t} = \sum_{h=1}^H \left(1 - \frac{\alpha - i}{\gamma \sigma^2} \sum_{n=1}^N q_{hn} \right) W_{h,t}.$$

As a consequence of the symmetry assumption, each household will have the same aggregate familiarity across the N assets:

$$\sum_{n=1}^N q_{hn} = \sum_{n=1}^N q_{jn} = \hat{q}.$$

Therefore, the market-clearing condition for the bond simplifies to

$$0 = \left(1 - \frac{\alpha - i}{\gamma \sigma^2} \hat{q} \right) \sum_{h=1}^H W_{h,t}.$$

The equilibrium risk-free interest rate is thus given by the constant

$$i = \alpha - \gamma \sigma_p^2, \tag{38}$$

where

$$\sigma_p^2 = \frac{\sigma^2}{\hat{q}}$$

is the variance of the portfolio held by each household adjusted for familiarity bias.

We can see immediately that reducing familiarity (that is, a reduction in \hat{q}) increases the riskiness of each household's portfolios, σ_p , leading to a greater demand for the risk-free asset, and hence, a decrease in the risk-free interest rate.

4.3 Aggregate Growth and Social Welfare

Substituting the equilibrium interest rate in (38) into the expression for the partial-equilibrium consumption-wealth ratio in (29) gives the consumption-wealth ratio in general equilibrium, which is common across households:

$$\frac{C_{h,t}}{W_{h,t}} = c = \psi \delta + (1 - \psi) \left(\alpha - \frac{1}{2} \gamma \sigma_p^2 \right).$$

The right-hand side of the above expression is constant. Exploiting the fact that the consumption-wealth ratio is constant across households allows us to obtain the ratio of

aggregate consumption, $C_t^{\text{agg}} = \sum_{h=1}^H C_{h,t}$, to aggregate wealth, $W_t^{\text{agg}} = \sum_{h=1}^H W_{h,t}$:

$$\frac{C_t^{\text{agg}}}{W_t^{\text{agg}}} = c.$$

In equilibrium, the aggregate level of the capital stock equals the aggregate wealth of households, because the bond is in zero net supply: $K_t^{\text{agg}} = W_t^{\text{agg}}$, where $K_t^{\text{agg}} = \sum_{n=1}^N K_{n,t}$, is the aggregate level of the capital stock. We therefore obtain the aggregate consumption-capital and consumption-output ratios:

$$\frac{C_t^{\text{agg}}}{K_t^{\text{agg}}} = c,$$

and

$$\frac{C_t^{\text{agg}}}{Y_t^{\text{agg}}} = \frac{c}{\alpha},$$

where aggregate output is given by $Y_t^{\text{agg}} = \sum_{n=1}^N Y_{n,t} = \alpha \sum_{n=1}^N K_{n,t}$.

We now derive the aggregate investment-capital ratio. The aggregate investment flow, I_t^{agg} , is the sum of the investment flows into each firm, $I_t^{\text{agg}} = \sum_{n=1}^N I_{n,t}$. The aggregate investment flow must be equal to aggregate output flow less the aggregate consumption flow, i.e.

$$I_t^{\text{agg}} = \alpha K_t^{\text{agg}} - C_t^{\text{agg}}.$$

It follows that the aggregate investment-capital ratio is given by

$$\frac{I_t^{\text{agg}}}{K_t^{\text{agg}}} = \alpha - c = \psi(\alpha - \delta) - \frac{1}{2}(\psi - 1)\gamma\sigma_p^2.$$

A decrease in an individual household's average familiarity makes its portfolio riskier, that is, σ_p^2 increases. There is then a reduction in the equilibrium expected return on an individual household's portfolio adjusted for risk and familiarity bias, given by $\alpha - \frac{1}{2}\gamma\sigma_p^2$. When the substitution effect dominates ($\psi > 1$), the aggregate investment-capital ratio falls because households will consume more of their wealth.

We now determine trend output growth, g , defined by

$$g = E_t \left[\frac{dY_t^{\text{agg}}}{Y_t^{\text{agg}}} \right].$$

Firms all have constant returns to scale and differ only because of shocks to their capital stocks. Therefore, the aggregate growth rate of the economy is the aggregate investment-capital ratio:

$$g = \frac{I_t^{\text{agg}}}{K_t^{\text{agg}}} = \alpha - c = \psi(\alpha - \delta) - \frac{1}{2}(\psi - 1)\gamma\sigma_p^2. \quad (39)$$

From the above, we see that a fall in the aggregate investment-capital ratio, $I_t^{\text{agg}}/K_t^{\text{agg}}$, reduces output growth, g .

We now study social welfare, that is the aggregate welfare of all households. An individual household's experienced utility level, $U_{h,t}$, is given by

$$U_{h,t} = \kappa_h W_{h,t},$$

where κ_h is given by

$$\kappa_h = \left[\frac{\psi\delta + (1 - \psi) \left(i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2 \right)}{\delta^\psi} \right]^{\frac{1}{1-\psi}}.$$

Our symmetry condition implies that average familiarity is equal across households. Hence, the portfolio held by each household has the same Sharpe, implying that the utility-wealth ratio $\kappa_h = \kappa$. Substituting in the expression for the market-clearing interest rate, we obtain

$$\kappa = \left[\frac{\psi\delta + (1 - \psi) \left(\alpha - \frac{1}{2}\gamma\sigma_p^2 \right)}{\delta^\psi} \right]^{\frac{1}{1-\psi}}. \quad (40)$$

Thus, social welfare is given by U_t^{social} , where

$$U_t^{\text{social}} = \sum_{h=1}^H U_{h,t} = \kappa \sum_{h=1}^H W_{h,t} = \kappa K_t^{\text{agg}}.$$

In the last equality, we have used the fact that aggregate household wealth $\sum_{h=1}^H W_{h,t}$ must equal the level of the aggregate capital stock $K_t^{\text{agg}} = \sum_{n=1}^N K_{n,t}$, because the bond is in zero net supply.

From the expression in (40), we can see that for a given level of the aggregate capital stock, familiarity biases at the household level increase the portfolio risk, σ_p^2 , and decrease social welfare. The intuition is that familiarity biases induce individual households to hold underdiversified portfolios, which leads them to also reduce their overall investment in risky assets. Higher portfolio risk distorts the intertemporal consumption decisions of households. Consequently, aggregate investment is also distorted, which reduces experienced social welfare.

4.4 The Externality from Reducing Familiarity Bias

Education in finance theory is not widespread. For instance, the vast majority of high school students receive no education in portfolio choice. Even at the university level, only

a minority of students study economics or finance and only a small proportion of the population undertake graduate study with a finance element. We know that households benefit from their own individual financial education if it allows them to choose better diversified portfolios as a consequence of overcoming their familiarity biases; that is, financial education has a positive externality. But how significant would be the gains of widespread financial education, financial innovation, and financial regulation that leads households to invest in better-diversified portfolios? In particular, would any macro-externalities make such a policy particularly worthwhile in terms of the economic welfare of society?

To answer this question, we need to understand that the welfare gains take place via two different channels. One is a micro-level externality, whereby a household's welfare is increased purely from choosing a more well-balanced set of investments—the return on a household's financial wealth then becomes less risky, which also reduces her consumption-growth volatility. The second is a macro-level externality, which raises the welfare of all households. From where does this macro externality arise? Its source lies in the decline of risk in every household's portfolio. When the substitution effect dominates the income effect ($\psi > 1$), households prefer to consume less today and invest more for the future in risky firms; therefore, aggregate investment increases, raising the trend growth rate of the economy, and increasing welfare. When the income effect dominates ($\psi < 1$), households prefer to consume more today and invest less in risky production, thereby reducing trend growth, but still increasing welfare.

We now show analytically how to disentangle the micro-level externality channel from the macro-level externality channel. In equilibrium, the level of social welfare can be written as

$$U_t = (\delta^\psi P_t^{\text{agg}})^{\frac{1}{\psi-1}} K_t^{\text{agg}},$$

where P_t^{agg} is the price-dividend ratio of the aggregate capital stock, or equivalently, the aggregate wealth-consumption ratio:

$$P_t^{\text{agg}} = \frac{K_t^{\text{agg}}}{C_t^{\text{agg}}} = \frac{W_t^{\text{agg}}}{C_t^{\text{agg}}}.$$

Importantly, we choose to write the aggregate price-dividend ratio in terms of the endogenous expected growth rate of aggregate output, g , and the volatility of household portfolios, σ_p , i.e.

$$P_t^{\text{agg}} = \frac{1}{\delta + \left(\frac{1}{\psi} - 1\right) \left(g - \frac{1}{2}\gamma\sigma_p^2\right)}.$$

where we see from the expression for g in equation (39) that it is a function of σ_p^2 .

The micro-level positive internality stems from a reduction in household portfolio risk, brought about by financial education, innovation, and regulation. The macro-level externality manifests itself via a change in expected aggregate consumption growth, g . We can separate the micro-level internality and macro-level externality effects on social welfare by observing that

$$\frac{d \ln \left(\frac{U_t^{\text{agg}}}{K_t^{\text{agg}}} \right)}{d \ln(\sigma_p^2)} = \frac{\partial \ln \left(\frac{U_t^{\text{agg}}}{K_t^{\text{agg}}} \right)}{\partial \ln(\sigma_p^2)} + \frac{\partial \ln \left(\frac{U_t^{\text{agg}}}{K_t^{\text{agg}}} \right)}{\partial \ln g} \frac{\partial \ln g}{\partial \ln(\sigma_p^2)},$$

where the first term on the right-hand side captures the micro-level volatility effect and the second term gives the effect of the macro-level externality. Computing the relevant derivatives gives

$$\frac{d \ln \left(\frac{U_t^{\text{agg}}}{K_t^{\text{agg}}} \right)}{d \ln(\sigma_p^2)} = -\frac{1}{2} \gamma P_t^{\text{agg}} \sigma_p^2 \left(\underbrace{\frac{1}{\psi}}_{\text{micro-level internality}} + \underbrace{1 - \frac{1}{\psi}}_{\text{macro-level externality}} \right). \quad (41)$$

We can see that a decline in the risk of household portfolios always increases social welfare. The relative importance of the micro-internality and macro-externality channels is determined by the elasticity of intertemporal substitution, ψ . When ψ is higher, a reduction in risk at the micro-level has a greater impact at the macro-level, because households are more willing to adjust their consumption intertemporally.

4.5 Quantitative Implications of Financial Policy for Social Welfare

We conclude by providing a quantitative assessment of how financial education, regulation, and innovation, which leads households to invest in better-diversified portfolios, could impact experienced social welfare. The main question we ask is how experienced social welfare would change if households did not suffer from a bias toward familiar assets; that is, if the volatility of their portfolio was that of a fully diversified portfolio, $\sigma_{1/N}$, as opposed to σ_p , where $\sigma_{1/N} < \sigma_p$ because of the benefits from diversification. In particular, we quantify the importance of the amplification factor, defined in (32), which tells us how much larger is the overall (percentage) welfare gain when households can smooth intertemporal consumption relative to the mean-variance welfare gain that ignores intermediate consumption. We also analyze the relative importance of the micro-internality and the macro-externality channels for social welfare. We conclude this section by examining the sensitivity of these quantitative results to various assumptions.

To assess the magnitude of the effects of familiarity bias on social welfare, we evaluate the closed-form results derived above using a reasonable set of parameter values. In our model, we have two sets of exogenous parameters. One set of parameters are for the stock-return processes, while the second set governs agents' preferences and familiarity biases. In our analysis, we specify the parameters for the stock-return processes based on empirical estimates reported in Beeler and Campbell (2012, their Table 2).¹⁵ We then report our results for a range of values for the preference parameters.

The first parameter we specify is N , the number of firms in which a household can invest. In the United States, according to the World Federation of Exchanges, the number of companies traded on major U.S. stock exchanges at the end of 2013 was 5,008. To be conservative, we assume that $N = 100$, which one can interpret as 100% of the firms in which a household can invest. Choosing the number of investable stocks to be 100 rather than some larger number is conservative because the effect of the familiarity bias decreases as N decreases. All N firms are assumed to have the same parameters driving their stock returns, and differ only in terms of the shocks to their capital stocks.

Next, we need to specify the parameter α , which is the expected rate of return on stocks. Based on the estimate in Beeler and Campbell (2012, Table 2), we specify that $\alpha = 7.50\%$ per annum, which is the historical average return on the equity market over the period 1930-2008.¹⁶

We now explain the values we choose for the volatility of individual stock returns, denoted by σ , and the correlation between stock returns, denoted by ρ . Herskovic, Kelly, and Van Nieuwerburgh (2014) find that the average of pairwise correlations over the period 1926-2010 for monthly stock returns in the United States to be 30%, so we set the correlation to be $\rho = 30\%$. The volatility of returns for a portfolio with equal amounts invested in N_f familiar assets is given by the following expression:

$$\sigma_p = \left(\frac{1}{N_f} \sigma^2 + \left(1 - \frac{1}{N_f} \right) \rho \sigma^2 \right)^{\frac{1}{2}}. \quad (42)$$

In the expression above, if we set $N_f = N$, we get the volatility of the fully-diversified portfolio, which in our model corresponds to the market portfolio. Beeler and Campbell (2012) report that the volatility of the stock-market return over the period 1930–2008 is

¹⁵We also undertook the analysis using parameters reported in Guvenen (2009), and the results are similar to the ones reported here.

¹⁶We adjust the numbers reported in Beeler and Campbell (2012, Table 2) for continuous compounding by adding half the variance to the estimated mean.

$\sigma_{1/N} = 20.17\%$. Above, we have already specified $N = 100$ and $\rho = 30\%$. Hence, the only free parameter in (42) is the volatility of individual stock returns, σ . Therefore, we choose σ to match the aggregate stock-market volatility of 20.17%. This leads to an estimate of $\sigma = 36.4\%$ for the volatility of individual stock returns.

To impose discipline on our choice of parameter values, we restrict the choice of the familiarity parameters f_{hn} to be either 0 or 1. A value of $f_{hn} = 0$ implies that a household does not invest at all in asset n , while a value of $f_{hn} = 1$ implies that the household is fully familiar with asset n . If household's invests in only 3 familiar assets, as reported in Polkovnichenko (2005), the volatility of the household's portfolio is obtained by setting $N_f = 3$ in equation (42), with $\rho = 0.30$ and $\sigma = 36.4\%$. This leads to a volatility of the familiarity-biased portfolio of $\sigma_p = 26.58\%$. Thus, the volatility of the portfolio of individual households, 26.58%, relative to that of the fully-diversified portfolio, 20.17%, is about 30% higher.¹⁷

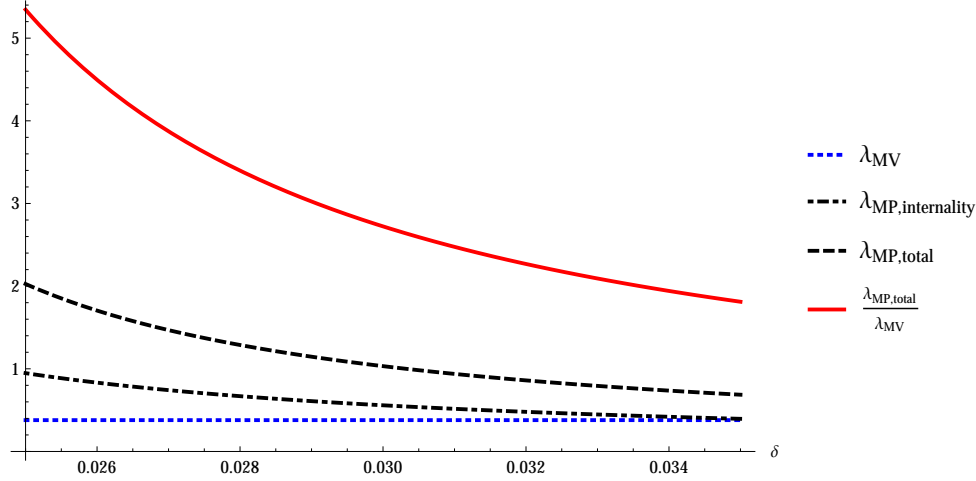
Using the parameter values described above, and setting the base-case values of the three preference parameters to be $\delta = 0.03$, $\gamma = 1.0$, and $\psi = 1.5$, we examine the following four quantities: λ_{MV} , the percentage increase in the mean-variance welfare measure as one moves from the familiarity-biased portfolio based on decision utility to the fully-diversified portfolio based on experienced utility; $\lambda_{MP,internality}$, the percentage increase in the overall welfare measure as one moves from the familiarity-biased portfolio to the fully-diversified portfolio, but keeping fixed the growth rate; $\lambda_{MP,total}$, the percentage increase in the overall welfare measure as one moves from the familiarity-biased portfolio to the fully-diversified portfolio while accounting for also the effect on aggregate growth; and $\lambda_{MP,total}/\lambda_{MV}$, the amplification factor. Note that these measures of the percentage change in welfare correspond to the change in the initial capital stock or, at the level of the household, the change in the household's initial wealth.

In Figure 3, we plot these four quantities while varying δ , the rate of time preference of households. From the blue dotted line in the figure, we see that λ_{MV} does not change with δ , because λ_{MV} is a mean-variance measure that is unaffected by δ . We also see from the black dashed line that the overall measure of welfare, $\lambda_{MP,total}$, is substantially larger than the mean-variance measure; when δ is low, the solid red line shows that the overall welfare measure is five times larger than the mean-variance measure, but as δ increases and the household is less patient, the ratio $\lambda_{MP,total}/\lambda_{MV}$ declines to about two. Comparing

¹⁷In the expressions of interest, the quantity that appears is the variance of the portfolio of individual households rather than the volatility (standard deviation); and, the variance of the underdiversified portfolios is about 70% higher than the variance of the fully-diversified portfolio.

Figure 3: Multiperiod and single-period welfare as δ changes

In this figure, we plot four welfare measures as the rate of time preference, δ , varies.



$\lambda_{MP,micro}$, given by the black dashed-dotted line to $\lambda_{MP,total}$, given by the black dashed line, we see that the macro-level externality contributes a substantial proportion of the total multiperiod welfare gain.

In Figure 4, we again plot the four quantities, but this time vary ψ , the elasticity of intertemporal substitution, of households. As in the first figure, we see that λ_{MV} does not change with ψ , because λ_{MV} is a single-period measure. We also see from the black dashed line that the multiperiod measure of welfare, $\lambda_{MP,total}$, is larger than the single-period mean-variance measure; when ψ is low, households are less willing to substitute current consumption for future consumption, and so the overall welfare measure is only about 1.5 times the mean-variance measure. However, as ψ increases and households are more willing to substitute current consumption for future consumption, the solid red line shows that the overall welfare gains from diversification are about double the mean-variance welfare gains. Comparing $\lambda_{MP,micro}$, given by the black dashed-dotted line to $\lambda_{MP,total}$, given by the black dashed line, we see that the macro-level externality, given by the gap between these two lines, increases with ψ . Note that for $\psi < 1$, the macro-level externality has a negative impact on the overall welfare gain, as can be seen from (41).

In Figure 5, we plot the four welfare measures as the relative risk aversion of households, γ , varies. We see that λ_{MV} increases with γ , because the effect of diversification on mean-

Figure 4: Multiperiod and single-period welfare as ψ changes

In this figure, we plot four welfare measures as the elasticity of intertemporal substitution, ψ , varies.

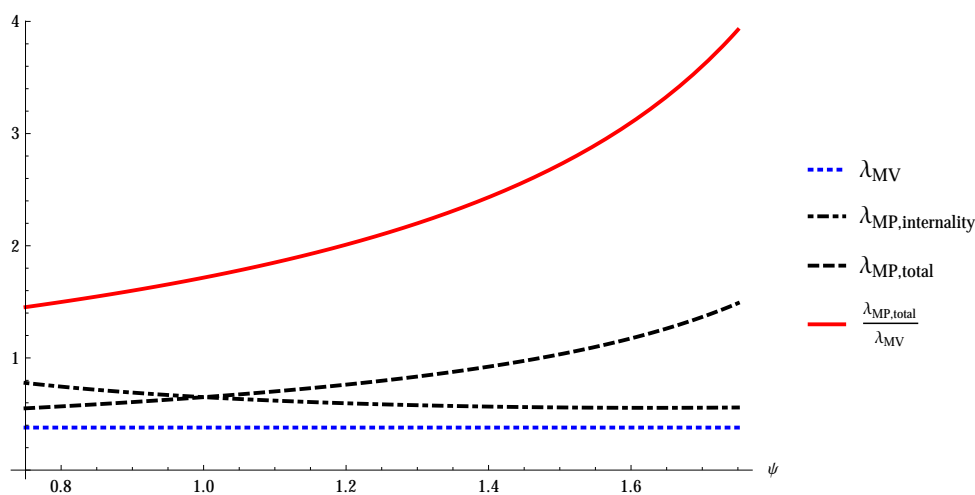
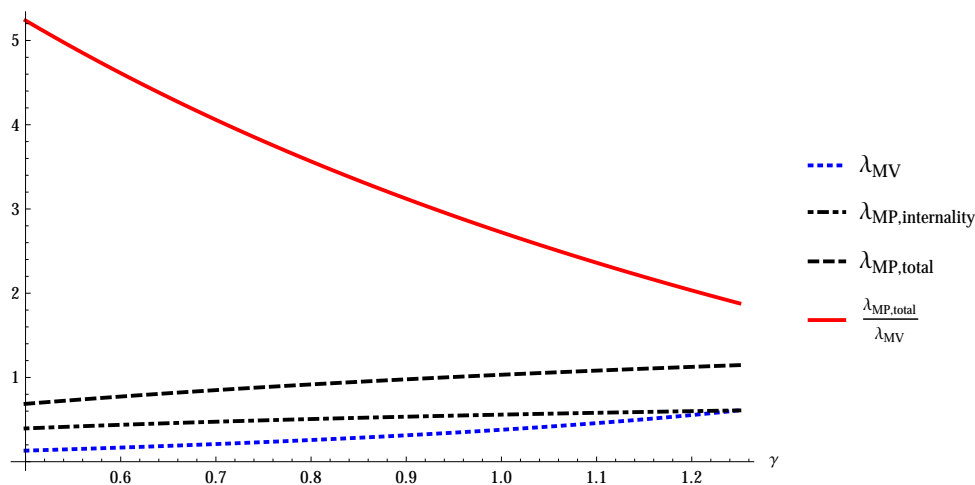


Figure 5: Multiperiod and single-period welfare as γ changes

In this figure, we plot four welfare measures as the relative risk aversion, γ , varies.



variance welfare increases with risk aversion. We also see from the black dashed line that the overall measure of welfare, $\lambda_{MP,total}$, is larger than the mean-variance measure; the red line shows that when γ is low, the overall welfare measure is about 5 times as large as the mean-variance measure, with the ratio $\lambda_{MP,total}/\lambda_{MV}$ declining with γ . The reason for this decline is that the welfare gain depends on the gap between the mean-variance objective function in general equilibrium, given by $\alpha - \frac{1}{2}\gamma\sigma_p^2$, and δ , and this gap is decreasing in γ . Comparing $\lambda_{MP,micro}$, given by the black dashed-dotted line to $\lambda_{MP,total}$, given by the black dashed line, we see that the macro-level externality, given by the gap between these two lines, increases with γ .

The figures above show that if improved financial policies leads households to fully diversify their portfolios, reducing the risk that they bear, then there is also an externality on aggregate growth. This effect increases growth when households are sufficiently willing to substitute consumption over time ($\psi > 1$) – the reason being that greater diversification decreases the price of risk, and so it is optimal for households to consume less today and save more, leading to greater real investment and hence higher aggregate growth. We find that as households become more patient and more willing to substitute consumption intertemporally, there is an increase in the impact of financial policies on social welfare.

These figures also show that for patient households (low δ) with a strong willingness to substitute consumption over time (high ψ), the overall welfare gains can be amplified by a factor of two to five relative to the mean-variance case. A large part of the amplification stems not from the direct internality of a reduction in micro-level volatility from portfolio diversification, but instead from the macro-level growth externality. A reduction in micro-level volatility leads to greater real investment, which drives up growth, and this is a substantial component of the total welfare gains from financial education, financial innovation, and financial regulation that lead households to invest in better diversified portfolios.

4.6 Sensitivity of Results to Modeling Assumptions

One may have at least three concerns about the large effects identified above from households switching to diversified portfolios. First, on the financial side, it is assumed that households are familiar with only $N_f = 3$ assets; if households are familiar with a larger number of assets initially, then the gains from switching to a fully-diversified portfolio will be smaller. Second, besides holding personal portfolios biased toward a few familiar assets, it is possible that some households have wealth invested in professionally-managed mutual funds, which are

well diversified; in this case, the gains from switching their personally-managed portfolio to one that is better diversified may be smaller than in the case where households are assumed to invest in only a few familiar assets. Third, on the real side, it is assumed that firms can adjust instantly and at no cost their investment policies within the firm, and also reallocate capital optimally across firms; if the adjustment of physical capital takes time, then the magnitude of the effects we have identified may be smaller. Below, we examine the sensitivity of our results to these assumptions.

The quantities reported in the experiment undertaken above are driven by the change in the volatility of the household’s portfolio when it is biased toward familiar assets ($\sigma_p = 26.58\%$) relative to when it is fully diversified ($\sigma_{1/N} = 20.17\%$). In this experiment, we assumed that the household is familiar with only $N_f = 3$ risky assets. As the number of familiar assets increases, the volatility of the household’s portfolio, σ_p , declines and approaches the volatility of the fully-diversified portfolio where the household holds all available risky assets: $N_f = N = 100$. The volatility of the portfolio corresponding to different numbers of familiar assets held is displayed below.

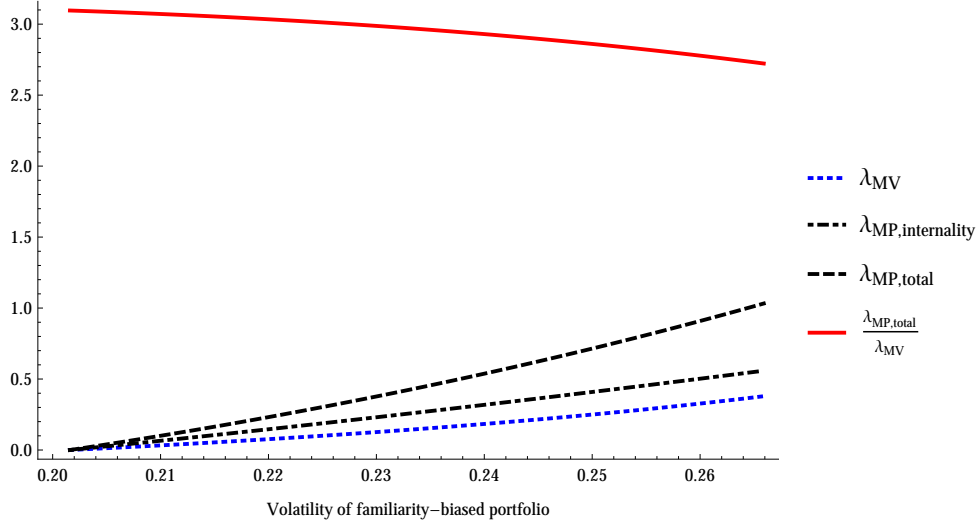
N_f	$\sigma_p(\%)$
3	26.58
6	23.50
9	22.37
12	21.79
100	20.17

In Figure 6 we report the effect of the familiarity bias for different levels of volatility of the familiarity-biased portfolio. Recall that in our base case $\sigma_p = 26.58\%$, which corresponds to the right extreme along the horizontal axis. We see from Figure 6 that as σ_p declines, the gains from moving to a fully diversified portfolio also decline. However, even when the volatility of the familiarity-biased portfolio is 21.79% (corresponding to $N_f = 12$), the multiperiod gains from diversifying are still substantial—equivalent to a 20% increase in the initial capital stock, and as the solid red line shows, the overall welfare gains are about three times as large as the mean-variance welfare gains.

Above, the base case we considered was one where each household held a portfolio with only $N_f = 3$ familiar assets. Then, for robustness, we considered the cases where the number of familiar assets ranges from 3 to 12. But, one may wish to consider a different situation in which, besides holding personal portfolios biased toward a few familiar assets, households also have wealth invested in professionally-managed mutual funds, which are

Figure 6: Multiperiod and single-period welfare for different levels of σ_p

In this figure, we plot four welfare measures for different levels of volatility of the familiarity-biased portfolio σ_p .

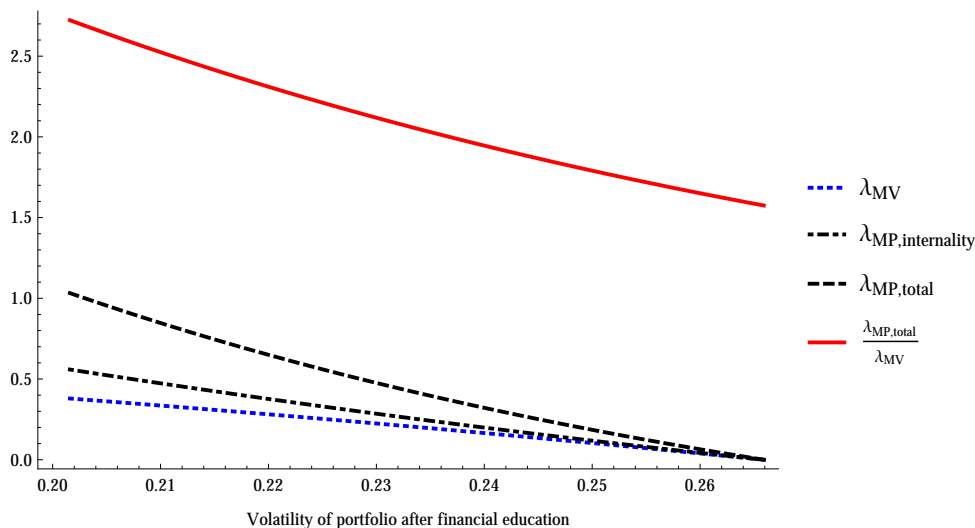


well diversified. In this case, the volatility of the familiarity-biased portfolio will be lower than the 26.58% we have used for the analysis above, where the household was holding only three familiar assets. In order to investigate the effect of the familiarity bias in this kind of a setting, we repeat our analysis assuming now that the household has varying proportions of its wealth invested in a fully-diversified market portfolio, with the remainder of wealth invested in a portfolio biased toward three familiar assets. We consider three cases. In the first case, the household has 30% of its wealth invested in a fully-diversified portfolio, with the rest in a portfolio biased toward three familiar assets; in the second, 45% of wealth is invested in a fully-diversified portfolio; and, in the third, 52.5% of wealth is invested in a fully-diversified portfolio. It turns out that these three cases correspond to the same level of volatility of the biased portfolio, σ_p , as if the household had invested in 6, 9, and 12 familiar assets, respectively, instead of just 3. Thus, based on the previous experiment that we described just above, we conclude that even in this case, the effects of familiarity bias on asset prices and aggregate macroeconomic variables are substantial.

Alternatively, one may wish to consider the case where each household moves from a familiarity-biased portfolio to only a partially-diversified portfolio, rather than a portfolio that is fully diversified. That is, say after financial education, the volatility of the portfolio

Figure 7: Multiperiod and single-period welfare for different levels of volatility of the portfolio after partial diversification

In this figure, we plot four welfare measures for different levels of volatility of the portfolio held by households when the portfolio is only partially diversified, rather than fully diversified.



held by households decreases from σ_p but not all the way to $\sigma_{1/N}$. In Figure 7 we report the effect of the familiarity bias for different levels of volatility of the portfolio in which households invest after financial education. Recall that in our base case $\sigma_{1/N} = 20.17\%$, which corresponds to the left extreme along the horizontal axis. We see from Figure 7 that as the volatility of the partially-diversified portfolio in which households invest increases, the gains from diversification are obviously smaller. However, even with a partial improvement in diversification, say moving from an investment in $N_f = 3$ to $N_f = 9$ assets instead of all 100 assets, the overall welfare gains from diversifying are equivalent to a 58% increase in the initial capital stock, and these gains are about two times as large as the mean-variance welfare gains.

Finally, to study the impact of assuming that investment levels can be adjusted instantaneously, one can use the approach in Obstfeld (1994, p. 1325) where it is assumed that the annual welfare gain converges toward the long-run annual gain at an instantaneous rate of x percent, which is about 2.2% per annum based on the work of Barro, Mankiw, and Sala-i-Martin (1992). Therefore, the actual capitalized welfare gain, λ^{actual} is related to the

reported welfare gain λ as follows:

$$\lambda^{\text{actual}} = \int_0^{\infty} i \lambda (1 - e^{-xt}) e^{-it} dt = \lambda \frac{x}{i+x}.$$

If the interest rate is 0.56% per annum, then $\frac{x}{i+x} = 79\%$. This implies that the actual welfare gains are about 79% of the welfare gains reported in the tables above, indicating that they are still quite large.

5 Policy Measures

In this section, we discuss various policy measures that could be used to reduce the negative internality and externality arising from the familiarity biases of households. In the neoclassical framework, the policy tool used to offset familiarity bias would be motivated only by the negative externality. Within the behavioral framework, the policy tool is used also to offset the internality arising from familiarity bias. In the neoclassical framework, the kind of policy tool used would be one that provides a subsidy to invest in unfamiliar stocks. Clearly, this would have to be household-specific because the familiarity bias is household specific, and hence, is not impractical. In contrast, the behavioral model acknowledges the behavioral biases underlying underdiversification, and therefore, suggests policy measures that are not household specific, such as financial literacy, financial innovation, sensible default portfolios.

Thaler and Sunstein (2003) define a policy to be “paternalistic” if it is selected with the goal of influencing the choices of affected parties in a way which will make those parties better off in terms of their experienced utility; that is, they recognize the possibility that in some cases individuals make inferior choices, which they would change if they had complete information, unlimited cognitive abilities and no lack of willpower. Thaler and Sunstein (2003) recommend “nudges” that gently guide people in a direction that increases experienced utility. Below, we consider a variety of paternalistic policies that could ameliorate the familiarity biases of households.

One policy measure is to introduce default portfolios that are well diversified. There is substantial evidence that the choice of a default option can be extremely important (see Samuelson and Zeckhauser (1988)), because when a particular choice is designated as the default, it attracts a disproportionate market share. Similar to the policy advocated by Benartzi and Thaler (2004), where people commit in advance to allocating a proportion of their future salary increases toward retirement savings, one could design sensible default

options that encourage households to invest in portfolios that are diversified across equities and asset classes. For example, households could be offered a small number of portfolios to choose from, with the portfolios having different levels of risk, but all of them being well diversified. Madrian and Shea (2001) study the impact of automatic enrollment on 401(k) savings behavior. They find that participation is significantly higher under automatic enrollment and that a substantial fraction of the participants retain the default contribution rate and fund allocation. Cronqvist and Thaler (2004) describe the experience of Sweden, where the government introduced a private plan for social security savings. Participants in this plan were allowed to form their own portfolios by selecting up to five funds from an approved list, where one fund was chosen (with some care) to be a “default” fund for anyone who, for whatever reason, did not make an active choice. This default fund was diversified internationally—with 65% invested in non-Swedish stock, 17% in Swedish stocks, 10% in inflation indexed-bonds, 4% in hedge funds, and 4% in private equity—and had a very low expense ratio (17 basis points). In the context of our model, the default fund would be one that was diversified across the N risky assets. Therefore, households who chose to invest in this default fund would have equality between their decision utility and experienced utility.

A second policy measure is financial education. For example, households could be educated about the benefits of diversification. Empirical evidence suggests that financial literacy can play an important role in improving decisions made by households. For instance, Bayer, Bernheim, and Scholz (2008) find that both participation in and contributions to voluntary savings plans are significantly higher when employers offer frequent seminars about the benefits of planning for retirement. Dimmock, Kouwenberg, Mitchell, and Peijnenburg (2014) also find that, while general education has only a small effect in reducing familiarity bias, an increase in financial competence does reduce this bias. In our setting, the objective of financial education would be to demonstrate to households that investing in a few familiar stocks leads to portfolios that underperform on average. Financial education could also inform households about the benefits of investing in broadly-diversified funds, such as mutual funds and ETFs, that do not require familiarity with particular assets.

A third alternative is to introduce financial regulation to limit the tendency of households to bias portfolios toward a few familiar assets. For example, financial regulation could be introduced to prohibit companies from providing employees own-company stock when matching the pension contributions of employees. Similarly, financial regulation could prohibit the use of own-company stock in 401(k) plans. Requiring mutual funds to simplify investment procedures would lower the barrier to entry and increase investments in these di-

versified assets. The findings in Iyengar, Huberman, and Jiang (2004) that there is *negative* correlation between the number of investment options offered in a plan and the participation rate in that plan, supports financial regulation that limits the number of investment options that are offered. In the context of our model, financial regulation would require households to invest a minimum proportion of wealth in funds rather than individual assets.

Finally, one could encourage financial innovation in order to design products that make it easier for households to invest in diversified portfolios. Simplifying the design of investment plans and introducing schemes to rebalance the portfolio automatically are relatively low-cost ways to ensure that households invest in portfolios that are well diversified.

6 Conclusion

Our results indicate that the impact on household welfare of financial policy, through education, innovation, and regulation, can be substantial, once we account also for the effects that improved portfolio diversification has on intertemporal consumption smoothing and aggregate growth. The analysis in our paper suggests that the answer to the question posed in the title is a resounding “yes.” Household finance matters a great deal because small improvements in the financial decisions of individual households have the potential to generate large economic gains for society: a small step for households can be a giant leap for society.

A Appendix

In this appendix, we provide all derivations for the results in the main text.

A.1 The Certainty Equivalent

For clarity, we rewrite (6) as the following Lemma.

Lemma 1 *The date- t certainty equivalent of investor h 's date- $t + dt$ utility is given by*

$$\mu_t[U_{h,t+dt}] = E_t[U_{h,t+dt}] - \frac{1}{2} \gamma U_{h,t} E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right].$$

Proof of Lemma 1

The definition of the certainty equivalent in (4) implies that

$$\mu_t[U_{h,t+dt}] = E_t \left[U_{h,t+dt}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}.$$

Therefore

$$\mu_t[U_{h,t+dt}] = E_t \left[U_{h,t+dt}^{1-\gamma} \right]^{\frac{1}{1-\gamma}} = E_t \left[U_{h,t}^{1-\gamma} + d(U_{h,t}^{1-\gamma}) \right]^{\frac{1}{1-\gamma}}.$$

Applying Ito's Lemma, we obtain

$$\begin{aligned} d(U_{h,t}^{1-\gamma}) &= (1-\gamma)U_{h,t}^{-\gamma}dU_{h,t} - \frac{1}{2}(1-\gamma)\gamma U_{h,t}^{-\gamma-1}(dU_{h,t})^2 \\ &= (1-\gamma)U_{h,t}^{1-\gamma} \left[\frac{dU_{h,t}}{U_{h,t}} - \frac{1}{2}\gamma \left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right]. \end{aligned}$$

Therefore

$$\begin{aligned} \mu_t[U_{h,t+dt}] &= E_t \left[U_{h,t+dt}^{1-\gamma} \right]^{\frac{1}{1-\gamma}} = U_{h,t} \left(E_t \left[1 + (1-\gamma) \left[\frac{dU_{h,t}}{U_{h,t}} - \frac{1}{2}\gamma \left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right] \right)^{\frac{1}{1-\gamma}} \\ &= U_{h,t} \left(1 + (1-\gamma) \left[E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2}\gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right] \right)^{\frac{1}{1-\gamma}} \\ &= U_{h,t} \left(1 + (1-\gamma) \left[E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2}\gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right] \right)^{\frac{1}{1-\gamma}}. \end{aligned}$$

Hence,

$$\mu_t[U_{h,t+dt}] = U_{h,t} \left(1 + E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2} \gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right) + o(dt).$$

Therefore, in the continuous time limit, we obtain

$$\frac{\mu_t[dU_{h,t+dt}]}{dt} = \frac{\mu_t[U_{h,t+dt}] - U_{h,t}}{dt} = U_{h,t} \left(E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2} \gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right).$$

A.2 The Familiarity-Biased Certainty Equivalent

Auxiliary Lemmas for Proof of (8)

In order to derive (8), giving the familiarity-biased certainty equivalent, we shall need some additional definitions and lemmas.

Existing work (Uppal and Wang (2003)) considers familiarity biases with respect to orthogonal factors. In contrast, we assume investors have varying degrees of familiarity with respect to firms, rather than the orthogonal factor structure underlying firm-level returns. In general, firms have returns which are not mutually orthogonal, so we cannot directly use the results in Uppal and Wang (2003). We must transform the matrix Γ_h , which encodes familiarity biases with respect to firms into a matrix $\bar{\Gamma}_h$, which encodes familiarity biases with respect to orthogonal factors. Having changed to the orthogonal factor basis, we use the derivation of the penalty function for deviations from the reference probability measure given in Theorem 1 of Uppal and Wang (2003). We can then obtain the correct form of the penalty function with respect to the original non-orthogonal basis of shocks to firm-level returns.

We begin by defining the orthogonal *factor basis*.

Definition 1 *The factor basis is a vector Brownian motion, $\bar{\mathbf{Z}}$ (under the common reference measure \mathbb{P}):*

$$\bar{\mathbf{Z}} = (\bar{Z}_1, \dots, \bar{Z}_N)^\top,$$

where \bar{Z}_n , $n \in \{1, \dots, N\}$ is a set of mutually orthogonal standard Brownian motions under \mathbb{P} such that

$$\bar{\mathbf{Z}} = M^{-1}(Z_1, \dots, Z_N)^\top,$$

and

$$M = \Omega^{\frac{1}{2}}. \tag{A1}$$

To see how the above definition is constructed, observe that the matrix M^\top maps the factor basis to the original non-orthogonal basis:

$$M^\top \bar{\mathbf{Z}} = (Z_1, \dots, Z_N)^\top.$$

We now uncover the properties of M . We know that

$$(dZ_1, \dots, dZ_N)^\top (dZ_1, \dots, dZ_N) = \Omega$$

and so

$$M^\top d\bar{\mathbf{Z}} d\bar{\mathbf{Z}}^\top M = \Omega.$$

We know that $d\bar{Z}_i d\bar{Z}_j = \delta_{ij} dt$, where δ_{ij} is the Kronecker delta, and so

$$d\bar{\mathbf{Z}} d\bar{\mathbf{Z}}^\top = I,$$

where I is the $N \times N$ identity matrix. Therefore

$$M^\top M = \Omega.$$

We have some degree of freedom with how we define M , so for parsimony we assume that M is symmetric, i.e. $M^\top = M$. Hence

$$M^2 = \Omega.$$

The matrix Ω is real and symmetric. Therefore, Ω has N real eigenvalues, $d_n \in \mathbb{R}$, $n \in \{1, \dots, N\}$ and the corresponding (column) eigenvectors \underline{e}_n , $n \in \{1, \dots, N\}$ are mutually orthogonal with real elements. We can therefore define the $N \times N$ real matrix

$$S = [\underline{e}_1, \dots, \underline{e}_N]$$

and use S to diagonalize Ω :

$$\Omega = SDS^{-1},$$

where $D = \text{diag}(d_1, \dots, d_N)$. It follows that the square root of the matrix Ω is given by

$$\Omega^{\frac{1}{2}} = SD^{\frac{1}{2}}S^{-1},$$

so we obtain

$$M = \Omega^{\frac{1}{2}}.$$

Intuitively, the factor basis $\bar{\mathbf{Z}}$ represents a set of mutually orthogonal factors underlying the returns on firms' capital and we can use it to rewrite the stochastic differential equations for the evolution of firms' capital stocks as

$$\left(\frac{dK_1 + D_1 dt}{K_1}, \dots, \frac{dK_N + D_N dt}{K_N} \right)^\top = \alpha \mathbf{1} dt + \sigma M d\bar{\mathbf{Z}}.$$

We now exploit the factor basis representation to define the measure \mathbb{Q}^{ν^h} .

Definition 2 The probability measure \mathbb{Q}^{ν_h} is defined by

$$\mathbb{Q}^{\nu_h}(A) = \mathbb{E}[1_A \xi_{h,T}],$$

where \mathbb{E} is the expectation under \mathbb{P} , A is an event and $\xi_{h,t}$ is the exponential martingale (under the reference probability measure \mathbb{P})

$$\frac{d\xi_{h,t}}{\xi_{h,t}} = \frac{1}{\sigma} \bar{\nu}_{h,t}^\top d\bar{\mathbf{Z}}_t,$$

where the $N \times 1$ vector $\bar{\nu}_{h,t}$ is the factor basis representation of the $N \times 1$ vector $\nu_{h,t}$:

$$\bar{\nu}_{h,t} = M^{-1} \nu_{h,t}. \quad (\text{A2})$$

Recall that when an investor is less familiar with a particular firm, she adjusts its expected return, which is equivalent to changing the reference measure to a new measure, denoted by \mathbb{Q}^{ν_h} . Applying Girsanov's Theorem, we see that under the new measure \mathbb{Q}^{ν_h} , the evolution of firm n 's capital stock is given by

$$dK_{n,t} = [(\alpha + \nu_{hn,t})K_{n,t} - D_{n,t}]dt + \sigma K_{n,t} dZ_{n,t}^{\nu_h},$$

where $Z_{n,t}^{\nu_h}$ is a standard Brownian motion under \mathbb{Q}^{ν_h} , such that

$$dZ_{n,t}^{\nu_h} dZ_{m,t}^{\nu_h} = \begin{cases} dt, & n = m. \\ \rho dt, & n \neq m. \end{cases}$$

Lemma 2 The matrix, $\bar{\Gamma}_h$, which encodes familiarity biases with respect to the factor basis is given by

$$\bar{\Gamma}_h = \Omega^{-\frac{1}{2}} \Gamma_h \Omega^{\frac{1}{2}}. \quad (\text{A3})$$

Proof of Lemma 2

Consider a linear map which acts on \mathbf{Z} and is represented with respect to the original basis via the matrix A . Suppose the same linear map is represented with respect to the factor basis via the matrix \bar{A} . It is well known that

$$\bar{A} = M^{-1} A M.$$

Therefore, under the factor basis, the matrix $\bar{\Gamma}_h$, which encodes familiarity biases with respect to the factor basis is given by

$$\bar{\Gamma}_h = M^{-1} \Gamma_h M = \Omega^{-\frac{1}{2}} \Gamma_h \Omega^{\frac{1}{2}}.$$

We now define a penalty function for using the measure \mathbb{Q}^{ν_h} instead of \mathbb{P} . Since the factor basis is orthogonal, we can use Theorem 1 in Uppal and Wang (2003) to define the penalty function with respect to the factor basis as shown below.

Definition 3 *The penalty function for investor h associated with her familiarity biases is given by*

$$\hat{L}_{h,t} = \frac{1}{\sigma^2} \bar{\boldsymbol{\nu}}_{h,t}^\top \bar{\Gamma}_h^{-1} \bar{\boldsymbol{\nu}}_{h,t}.$$

The following additional definition will aid in understanding the role of the penalty function.

Definition 4 *The probability measure $\mathbb{Q}^{\nu_{h,n}}$ is defined by*

$$\mathbb{Q}^{\nu_{h,n}}(A) = \mathbb{E}[1_A \xi_{h,n,T}],$$

where \mathbb{E} is the expectation under \mathbb{P} , A is an event and $\xi_{h,n,t}$ is the exponential martingale (under the reference probability measure \mathbb{P})

$$\frac{d\xi_{h,n,t}}{\xi_{h,n,t}} = \frac{1}{\sigma} \bar{\nu}_{h,n,t} d\bar{Z}_{n,t}.$$

The probability measure $\mathbb{Q}^{\nu_{h,n}}$ is just the measure associated with familiarity bias along the n 'th orthogonal factor. Familiarity bias along this factor is equivalent to using $\mathbb{Q}^{\nu_{h,n}}$ instead of \mathbb{P} , which leads to a loss in information. The information loss stemming from familiarity bias along the n 'th orthogonal factor can be quantified via the date- t conditional Kullback-Leibler divergence between \mathbb{P} and $\mathbb{Q}^{\nu_{h,n}}$, given by

$$D_{t,u}^{KL}[\mathbb{P}|\mathbb{Q}^{\nu_{h,n}}] = E_t^{\mathbb{Q}^{\nu_{h,n}}} \left[\ln \left(\frac{\xi_{h,n,u}}{\xi_{h,n,t}} \right) \right].$$

Now observe that the penalty function can be written in terms of the information losses along each of the orthogonal factors, i.e.

$$\hat{L}_{h,t} = D_{t,u}^{KL}[\mathbb{P}|\mathbb{Q}^{\nu_{h,n}}][\bar{\Gamma}_h^{-1}]_{nm} D_{t,u}^{KL}[\mathbb{P}|\mathbb{Q}^{\nu_{h,m}}], \quad n, m \in \{1, \dots, N\}, \quad (\text{A4})$$

where we employ the Einstein summation convention.

We now unravel the intuition embedded within (A4). We can think of $\bar{\Gamma}_h^{-1}$ as a weighting matrix for information losses, analogous to the weighting matrix in the generalized method of moments. Suppose, for simplicity that $\rho = 0$, so the shocks to firm-level returns are mutually orthogonal, rendering the original basis equal to the orthogonal factor basis. Suppose further that investor h is completely unfamiliar with all the orthogonal factors save factor 1. In this case,

$$\bar{\Gamma}_h^{-1} = \text{diag} \left(\frac{f_1}{1 - f_1}, \mathbf{0}_{N-1}^\top \right),$$

where $\mathbf{0}_{N-1}$ is the $(N - 1) \times 1$ vector of zeros. The penalty function reduces to

$$\hat{L}_{h,t} = \frac{f_1}{1 - f_1} (D_{t,u}^{KL}[\mathbb{P}|\mathbb{Q}^{\nu_{h,1}}])^2,$$

so the information losses along the factors with which the investor is totally unfamiliar are not penalized in the penalty function. The investor is penalized only for deviating from \mathbb{P} along a particular factor if she has some level of familiarity with that factor. If she has full familiarity with a factor, the associated penalty becomes infinitely large, so when making decisions involving this factor, she will not deviate at all from the reference probability measure \mathbb{P} .

We end with the main lemma of this section, which shows how to write the penalty function when using the original non-orthogonal basis of shocks to firm-level returns.

Lemma 3 *The penalty function for investor h associated with her familiarity biases can be written in terms of the original non-orthogonal basis*

$$\hat{L}_{h,t} = \frac{1}{\sigma^2} \boldsymbol{\nu}_{h,t}^\top (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}.$$

Proof of Lemma 3

From Definition 3, we know

$$\hat{L}_{h,t} = \frac{1}{\sigma^2} \bar{\boldsymbol{\nu}}_{h,t}^\top \bar{\Gamma}_h^{-1} \bar{\boldsymbol{\nu}}_{h,t}.$$

From Equations (A1), (A2), and (A3), we obtain

$$\begin{aligned} \hat{L}_{h,t} &= \frac{1}{\sigma^2} (\Omega^{-\frac{1}{2}} \boldsymbol{\nu}_{h,t})^\top (\Omega^{-\frac{1}{2}} \Gamma_h \Omega^{\frac{1}{2}})^{-1} (\Omega^{-\frac{1}{2}} \boldsymbol{\nu}_{h,t}) \\ &= \frac{1}{\sigma^2} \boldsymbol{\nu}_{h,t}^\top \Omega^{-\frac{1}{2}} \Omega^{-\frac{1}{2}} \Gamma_h^{-1} \Omega^{\frac{1}{2}} \Omega^{-\frac{1}{2}} \boldsymbol{\nu}_{h,t} \\ &= \frac{1}{\sigma^2} \boldsymbol{\nu}_{h,t}^\top \Omega^{-1} \Gamma_h^{-1} \boldsymbol{\nu}_{h,t} \\ &= \frac{1}{\sigma^2} \boldsymbol{\nu}_{h,t}^\top (\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}. \end{aligned}$$

The above lemma tells us that we do not obtain the correct penalty function merely through replacing $\bar{\boldsymbol{\nu}}_{h,t}$ and $\bar{\Gamma}_h$ by $\boldsymbol{\nu}_{h,t}$ and Γ_h , respectively. The matrix Γ_h must be post-multiplied by the correlation matrix, Ω , to reflect the fact that a given level of familiarity with respect to a particular firm translates into a familiarity with respect to firms with correlated returns. We can see this explicitly by noting that

$$[\Gamma_h \Omega]_{nm} = \begin{cases} \frac{1-f_n}{f_n}, & n = m \\ \rho \frac{1-f_n}{f_n}, & n \neq m \end{cases}. \quad (\text{A5})$$

While the matrix Γ_h is diagonal, the matrix $\Gamma_h \Omega$, which appears in the penalty function is not diagonal – familiarity bias with respect to a particular firm translates into familiarity bias with respect to correlated firms – the level of translated familiarity bias depends directly on the correlation coefficient.

We now define the new measure \mathbb{Q}^{ν_h} . We start from the exponential martingale (under the reference measure \mathbb{P})

$$\frac{d\xi_{h,t}}{\xi_{h,t}} = \frac{1}{\sigma} \bar{\nu}_{h,t}^\top d\bar{\mathbf{Z}}_t,$$

where the $N \times 1$ vector $\bar{\nu}_{h,t}$ is the factor basis representation of the $N \times 1$ vector $\nu_{h,t}$:

$$\bar{\nu}_{h,t} = (M^\top)^{-1} \nu_{h,t}.$$

The new measure \mathbb{Q}^{ν_h} is defined by

$$\mathbb{Q}^{\nu_h}(A) = \mathbb{E}[1_A \xi_{h,T}],$$

where \mathbb{E} is the expectation under \mathbb{P} .

We now define a penalty function for using the measure \mathbb{Q}^{ν_h} instead of \mathbb{P} . Since the factor basis is orthogonal, we can follow Uppal and Wang (2003) and define the penalty function (with respect to the factor basis) as

$$L_{h,t} = \frac{1}{2\gamma} \frac{1}{\sigma} \bar{\nu}_{h,t}^\top \bar{\Gamma}_h^{-1} \frac{1}{\sigma} \bar{\nu}_{h,t},$$

where $\bar{\Gamma}$ is the familiarity matrix with respect to the factor basis:

$$\bar{\Gamma} = (M^\top)^{-1} \Gamma M^{-1}.$$

The intuition behind the definition of the penalty function is that it measures the familiarity-weighted distance between the reference measure and the measure \mathbb{Q}^{ν_h} , where the distance between them is the conditional Kullback-Leibler divergence between \mathbb{P} and \mathbb{Q}^{ν_h} . The penalty function is also a familiarity-weighted measure of the information lost by using \mathbb{Q}^{ν_h} instead of \mathbb{P} .

Using the original non-orthogonal basis for shocks to firms' capital stocks, we obtain

$$L_{h,t} = \frac{1}{2\gamma} \frac{\nu_{h,t}^\top \Gamma_h^{-1} \nu_{h,t}}{\sigma^2}.$$

$$\frac{1}{\sigma} \nu_{h,t}^\top M^{-1} \bar{\Gamma}^{-1} \frac{1}{\sigma} (M^\top)^{-1} \nu_{h,t}$$

$$M^{-1} \bar{\Gamma}^{-1} (M^\top)^{-1} = (\bar{\Gamma} M)^{-1} (M^\top)^{-1} = (M^\top \bar{\Gamma} M)^{-1} = \Gamma^{-1}$$

We now define a way of quantifying the information lost for each orthogonal factor when \mathbb{Q}^{ν_h} is used to approximate \mathbb{P} . Conditional on date- t , the information lost at date- u along the n 'th orthogonal factor when \mathbb{Q}^{ν_h} is used to approximate \mathbb{P} is given by:

$$L_{n,t,u}[\mathbb{P}|\mathbb{Q}^{\nu_h}] = E_t^{\mathbb{Q}^{\nu_h}} \left[\ln \left(\frac{\xi_{h,n,u}}{\xi_{h,n,t}} \right) \right].$$

Conditional on date- t , the information lost at date- u when \mathbb{Q}^{ν_h} is used to approximate \mathbb{P} is given by the conditional Kullback-Leibler divergence between \mathbb{P} and \mathbb{Q}^{ν_h} :

$$L_{t,u}[\mathbb{P}|\mathbb{Q}^{\nu_h}] = E_t^{\mathbb{Q}^{\nu_h}} \left[\ln \left(\frac{\xi_{h,u}}{\xi_{h,t}} \right) \right].$$

Theorem 1 *The date- t familiarity-biased certainty equivalent of date- $t + dt$ investor utility is given by*

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = \widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}] + U_{h,t}L_{h,t}dt, \quad (\text{A6})$$

where $\widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}]$ is defined by

$$u_{\gamma}(\widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}]) = E_t^{\mathbb{Q}^{\nu_h}}[u_{\gamma}(U_{h,t+dt})], \quad (\text{A7})$$

and

$$L_{h,t} = \frac{1}{2\gamma} \frac{\boldsymbol{\nu}_{h,t}^{\top}(\Gamma_h \Omega)^{-1} \boldsymbol{\nu}_{h,t}}{\sigma^2}, \quad (\text{A8})$$

where $\boldsymbol{\nu}_{h,t} = (\nu_{h1,t}, \dots, \nu_{hN,t})^{\top}$ is the column vector of adjustments to expected returns, and $\Gamma_h = [\Gamma_{h,nm}]$ is the $N \times N$ diagonal matrix defined by

$$\Gamma_{h,nm} = \begin{cases} \frac{1-f_{hn}}{f_{hn}}, & n = m, \\ 0, & n \neq m, \end{cases}$$

and $f_{hn} \in [0, 1]$ is a measure of how familiar the investor is with firm, n , with $f_{hn} = 1$ implying perfect familiarity, and $f_{hn} = 0$ indicating no familiarity at all.

Proof of Theorem 1

Using the penalty function given in Lemma 3, the construction of the familiarity-biased certainty equivalent of date- $t + dt$ utility is straightforward – it is merely the certainty-equivalent of date- $t + dt$ utility computed using the probability measure \mathbb{Q}^{ν_h} plus a penalty. The investor will choose her adjustment to expected returns by minimizing the familiarity-biased certainty equivalent of her date- $t + dt$ utility — the penalty stops her from making the adjustment arbitrarily large by penalizing her for larger adjustments. The size of the penalty is a measure of the information she loses by deviating from the common reference measure, adjusted by her familiarity preferences, and so

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = \widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}] + U_{h,t}L_{h,t}dt,$$

where $\widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}]$ is defined by

$$u_{\gamma}(\widehat{\mu}_{h,t}^{\nu}[U_{h,t+dt}]) = E_t^{\mathbb{Q}^{\nu_h}}[u_{\gamma}(U_{h,t+dt})],$$

and

$$L_{h,t} = \frac{1}{2\gamma} \widehat{L}_{h,t}.$$

(8) follows from Theorem , so we restate it formally as the following Corollary before giving a proof.

Corollary 1 *The date- t familiarity-biased certainty equivalent of date- $t+dt$ investor utility is given by*

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = \mu_t[U_{h,t+dt}] + U_{h,t} \times \left(\frac{W_{h,t} U_{W_{h,t}}}{U_{h,t}} \boldsymbol{\nu}_{h,t}^{\top} \boldsymbol{\omega}_{h,t} + L_{h,t} \right) dt, \quad (\text{A9})$$

where $U_{W_{h,t}} = \frac{\partial U_{h,t}}{\partial W_{h,t}}$ is the partial derivative of the utility of investor h with respect to her wealth.

Proof of Corollary 1

The date- t familiarity-biased certainty equivalent of date- $t + dt$ investor utility is given by (A6), (A7), and (A8). We can see that $\hat{\mu}_{h,t}^{\nu}[U_{h,t+dt}]$ is like a certainty equivalent, but with the expectation taken under \mathbb{Q}^{ν_h} in order to adjust for familiarity bias. From Lemma 1, we know that

$$\hat{\mu}_{h,t}^{\nu}[U_{h,t+dt}] = U_{h,t} \left(1 + E_t^{\mathbb{Q}^{\nu_h}} \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2} \gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] \right) + o(dt).$$

We therefore obtain from (1)

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = U_{h,t} \left(1 + E_t^{\mathbb{Q}^{\nu_h}} \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2} \gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] + L_{h,t} dt \right) + o(dt). \quad (\text{A10})$$

Applying Ito's Lemma, we see that under \mathbb{Q}^{ν_h}

$$dU_{h,t} = W_{h,t} \frac{\partial U_{h,t}}{\partial W_{h,t}} \frac{dW_{h,t}}{W_{h,t}} + \frac{1}{2} W_{h,t}^2 \frac{\partial^2 U_{h,t}}{\partial W_{h,t}^2} \left(\frac{dW_{h,t}}{W_{h,t}} \right)^2,$$

where

$$\frac{dW_{h,t}}{W_{h,t}} = \left(1 - \sum_{n=1}^N \omega_{hn,t} \right) idt + \sum_{n=1}^N \omega_{hn,t} \left((\alpha + \nu_{h,t}) dt + \sigma dZ_{n,t}^{\mathbb{Q}^{\nu_h}} \right) - \frac{C_{h,t}}{W_{h,t}} dt.$$

Hence, from Girsanov's Theorem, we have

$$E_t^{\mathbb{Q}^{\nu_h}} \left[\frac{dU_{h,t}}{U_{h,t}} \right] = E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] + \frac{W_{h,t}}{U_{h,t}} \frac{\partial U_{h,t}}{\partial W_{h,t}} \boldsymbol{\omega}_{h,t}^{\top} \boldsymbol{\nu}_{h,t} dt.$$

We can therefore rewrite (A10) as

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = U_{h,t} \left(1 + E_t \left[\frac{dU_{h,t}}{U_{h,t}} \right] - \frac{1}{2} \gamma E_t \left[\left(\frac{dU_{h,t}}{U_{h,t}} \right)^2 \right] + L_{h,t} dt + \frac{W_{h,t}}{U_{h,t}} \frac{\partial U_{h,t}}{\partial W_{h,t}} \boldsymbol{\omega}_{h,t}^{\top} \boldsymbol{\nu}_{h,t} dt \right) + o(dt).$$

Using (6) we obtain

$$\mu_{h,t}^{\nu}[U_{h,t+dt}] = \mu_t[U_{h,t+dt}] + U_{h,t} \left(L_{h,t} dt + \frac{W_{h,t}}{U_{h,t}} \frac{\partial U_{h,t}}{\partial W_{h,t}} \boldsymbol{\omega}_{h,t}^{\top} \boldsymbol{\nu}_{h,t} dt \right) + o(dt).$$

and hence (8).

A.3 Derivation of (12)

We restate (12) as the following Proposition.

Proposition 1 *For a given portfolio, $\omega_{h,t}$, adjustments to firm n 's expected return are given by*

$$\nu_{hn,t} = -\frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \left(\frac{1}{f_{hn}} - 1 \right) \sigma^2 \gamma \left(\omega_{hn,t} + \rho \sum_{m \neq n} \omega_{hm,t} \right), \quad n \in \{1, \dots, N\}.$$

Proof of Proposition 1

From (8), we can see that

$$\inf_{\nu_{h,t}} \mu_{h,t}^{\nu}[U_{h,t+dt}]$$

is equivalent to

$$\inf_{\nu_{h,t}} \frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \nu_{h,t}^{\top} \omega_{h,t} + \frac{1}{2\gamma\sigma^2} \nu_{h,t}^{\top} (\Gamma_h \Omega)^{-1} \nu_{h,t}.$$

The minimum exists and is given by the FOC

$$\frac{\partial}{\partial \nu_{h,t}} \left[\frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \nu_{h,t}^{\top} \omega_{h,t} + \frac{1}{2\gamma\sigma^2} \nu_{h,t}^{\top} (\Gamma_h \Omega)^{-1} \nu_{h,t} \right] = 0$$

Carrying out the differentiation and exploiting the fact that $(\Gamma_h \Omega)^{-1}$ is symmetric, we obtain

$$0 = \frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \omega_{h,t} + \frac{1}{\gamma\sigma^2} (\Gamma_h \Omega)^{-1} \nu_{h,t}.$$

Hence

$$\nu_{h,t} = -\gamma\sigma^2 \frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \Gamma_h \Omega \omega_{h,t}.$$

Using (A5), we obtain

$$\nu_{h,n,t} = -\gamma\sigma^2 \frac{W_{h,t}U_{W_{h,t}}}{U_{h,t}} \frac{1-f_n}{f_n} \left(\omega_{h,n,t} + \rho \sum_{m \neq n} \omega_{h,m,t} \right).$$

A.4 Derivation of the Hamilton-Jacobi-Bellman Equation

We restate the Hamilton-Jacobi-Bellman Equation as the following Proposition.

Proposition 2 *The utility function of an investor with familiarity biases is given by the following Hamilton-Jacobi-Bellman equation:*

$$0 = \sup_{C_{h,t}} \left(\delta u_{\psi} \left(\frac{C_{ht}}{U_{ht}} \right) + \sup_{\omega_t} \inf_{\nu_{h,t}} \frac{1}{U_{h,t}} \mu_{h,t}^{\nu} \left[\frac{dU_{h,t}}{dt} \right] \right), \quad (\text{A11})$$

where the function

$$u_\psi(x) = \frac{x^{1-\frac{1}{\psi}} - 1}{1 - \frac{1}{\psi}}, \psi > 0,$$

and

$$\mu_{h,t}^\nu [dU_{h,t}] = \mu_{h,t}^\nu [U_{h,t+dt} - U_{h,t}] = \mu_{h,t}^\nu [U_{h,t+dt}] - U_{h,t},$$

with $\mu_{h,t}^\nu [U_{h,t+dt}]$ given in (8).

A.4.1 Proof of Proposition 2

Writing out (11) explicitly gives

$$U_{h,t}^{1-\frac{1}{\psi}} = (1 - e^{-\delta dt}) C_{h,t}^{1-\frac{1}{\psi}} + e^{-\delta dt} (\mu_{h,t}^\nu [U_{h,t+dt}])^{1-\frac{1}{\psi}},$$

where for ease of notation sup and inf have been suppressed. Now

$$\begin{aligned} (\mu_{h,t}^\nu [U_{h,t+dt}])^{1-\frac{1}{\psi}} &= (U_{h,t} + \mu_{h,t}^\nu [dU_{h,t}])^{1-\frac{1}{\psi}} \\ &= U_{h,t}^{1-\frac{1}{\psi}} \left(1 + \mu_{h,t}^\nu \left[\frac{dU_{h,t}}{U_{h,t}} \right] \right)^{1-\frac{1}{\psi}} \\ &= U_{h,t}^{1-\frac{1}{\psi}} \left(1 + \left(1 - \frac{1}{\psi} \right) \mu_{h,t}^\nu \left[\frac{dU_{h,t}}{U_{h,t}} \right] \right) + o(dt). \end{aligned}$$

Hence

$$U_{h,t}^{1-\frac{1}{\psi}} = \delta C_{h,t}^{1-\frac{1}{\psi}} dt + U_{h,t}^{1-\frac{1}{\psi}} \left(1 + \left(1 - \frac{1}{\psi} \right) \mu_{h,t}^\nu \left[\frac{dU_{h,t}}{U_{h,t}} \right] \right) - \delta U_{h,t}^{1-\frac{1}{\psi}} dt + o(dt),$$

from which we obtain (A11).

A.5 Mean-Variance Portfolio Choice with Familiarity Bias

We collect Equations (14) and (15) in the following Proposition.

Proposition 3 *The investor's optimization problem consists of two parts, a mean-variance optimization*

$$\sup_{\omega_{h,t}} \inf_{\nu_{h,t}} MV(\omega_{h,t}, \nu_{h,t}),$$

and an intertemporal consumption choice problem

$$0 = \sup_{C_{h,t}} \left(\delta u_\psi \left(\frac{C_{ht}}{U_{ht}} \right) - \frac{C_{ht}}{W_{ht}} + \sup_{\omega_t} \inf_{\nu_{h,t}} MV(\omega_{h,t}, \nu_{h,t}) \right), \quad (\text{A12})$$

where

$$MV(\omega_{h,t}, \nu_{h,t}) = i + (\alpha - i) \mathbf{1}^\top \omega_{h,t} - \frac{1}{2} \gamma \sigma^2 \omega_{h,t}^\top \Omega \omega_{h,t} + \nu_{h,t}^\top \omega_{h,t} + \frac{1}{2\gamma} \frac{\nu_{h,t}^\top (\Gamma_h \Omega)^{-1} \nu_{h,t}}{\sigma^2}, \quad (\text{A13})$$

and $\mathbf{1}$ denotes the $N \times 1$ unit vector.

Proof of Proposition 3

Assuming a constant risk-free rate, homotheticity of preferences combined with constant returns to scale for production implies that we have $U_{h,t} = \kappa_h W_{h,t}$, for some constant κ_h . Equations (A12) and (A13) are then direct consequences of (A9) and (13).

We summarize the results on optimal portfolio choice in the following Proposition.

Proposition 4 *The optimal adjustment to expected returns is:*

$$\boldsymbol{\nu}_h = -(\alpha - i)(\mathbf{1} - \mathbf{f}_h),$$

where \mathbf{f}_h is the vector of familiarity coefficients

$$\mathbf{f}_h = (f_{h1}, \dots, f_{hN})^\top.$$

The vector of optimal portfolio weights is

$$\boldsymbol{\omega}_h = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \Omega^{-1} \mathbf{f}_h. \quad (\text{A14})$$

We can write the n 'th element of the above vector of portfolio weights as

$$\omega_{hn} = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} q_{hn},$$

where q_{hn} is the correlation-adjusted familiarity of investor h with respect to firm n , defined by

$$q_{hn} = \mathbf{e}_n^\top \Omega^{-1} \mathbf{f}_h, \quad (\text{A15})$$

where \mathbf{e}_n is the $N \times 1$ column vector, with a one in the n 'th entry and zeros everywhere else.

If we denote by $\mathbf{x}_h = \frac{\boldsymbol{\omega}_h}{\mathbf{1}^\top \boldsymbol{\omega}_h}$ the weights in the risky assets normalized by the total investment in all N risky assets, then the optimal portfolio of risky assets is

$$x_{hn} = \frac{q_{hn}}{\sum_{n=1}^N q_{hn}}.$$

With familiarity bias, the optimized portfolio-choice objective function can be expressed as:

$$\sup_{\boldsymbol{\omega}_{h,t}} \inf_{\boldsymbol{\nu}_{h,t}} MV(\boldsymbol{\omega}_{h,t}, \boldsymbol{\nu}_{h,t}) = i + \frac{1}{2} \frac{1}{\gamma} \left(\frac{\alpha - i}{\sigma_{\mathbf{x}_h}} \right)^2,$$

where

$$\sigma_{\mathbf{x}_h}^2 = \sigma^2 \mathbf{x}_h^\top (I + \Gamma_h) \Omega \mathbf{x}_h.$$

Proof of Proposition 4

Minimizing (15) with respect to $\nu_{h,t}$ gives (16). Substituting (16) into (15) and simplifying gives

$$MV_h = i + (\alpha - i)\pi_h - \frac{1}{2}\gamma\pi_h^2\sigma^2\mathbf{x}_h^\top(I + \Gamma_h)\Omega\mathbf{x}_h,$$

where π_h is the proportion of household h 's wealth held in risky assets,

$$\pi_h = \mathbf{1}^\top \boldsymbol{\omega}_h,$$

and \mathbf{x}_h is the vector of risky asset weights,

$$\mathbf{x}_h = \frac{\boldsymbol{\omega}_h}{\pi_h}.$$

We find \mathbf{x}_h by minimizing $\sigma^2\mathbf{x}_h^\top(\Omega + \Gamma_h)\mathbf{x}_h$, so we can see that \mathbf{x}_h is household h 's minimum-variance portfolio adjusted for familiarity bias. The minimization we wish to perform is

$$\min \frac{1}{2}\mathbf{x}_h^\top(I + \Gamma_h)\Omega\mathbf{x}_h$$

subject to the constraint

$$\mathbf{1}^\top \mathbf{x}_h = 1.$$

The Lagrangian for this problem is

$$L_h = \frac{1}{2}\mathbf{x}_h^\top(I + \Gamma_h)\Omega\mathbf{x}_h + \lambda_h(1 - \mathbf{1}^\top \mathbf{x}_h),$$

where λ_h is the Lagrange multiplier. The first order condition with respect to \mathbf{x}_h is

$$(I + \Gamma_h)\Omega\mathbf{x}_h = \lambda_h\mathbf{1}.$$

Hence

$$\mathbf{x}_h = \lambda_h\Omega^{-1}(I + \Gamma_h)^{-1}\mathbf{1} = \lambda_h\Omega^{-1}\mathbf{f}_h,$$

where

$$\mathbf{f}_h = (f_{h1}, \dots, f_{hN})^\top.$$

The first order condition with respect to λ_h gives us the constraint

$$\mathbf{1}^\top \mathbf{x}_h = 1,$$

which implies that

$$\lambda_h = \left[\mathbf{1}^\top \Omega^{-1} \mathbf{f}_h \right]^{-1}.$$

Therefore, we have

$$\mathbf{x}_h = \frac{\Omega^{-1}\mathbf{f}_h}{\mathbf{1}^\top \Omega^{-1}\mathbf{f}_h}.$$

Substituting the optimal choice of \mathbf{x}_h back into $\mathbf{x}_h^\top (I + \Gamma_h)\Omega\mathbf{x}_h$ gives

$$\mathbf{x}_h^\top (I + \Gamma_h)\Omega\mathbf{x}_h = \frac{\mathbf{f}_h\Omega^{-1}(I + \Gamma_h)\Omega\Omega^{-1}\mathbf{f}}{[\mathbf{1}^\top\Omega^{-1}\mathbf{f}]^2} = \frac{\mathbf{f}_h\Omega^{-1}(I + \Gamma_h)\mathbf{f}}{[\mathbf{1}^\top\Omega^{-1}\mathbf{f}]^2} = \frac{\mathbf{f}_h^\top\Omega^{-1}\mathbf{1}}{[\mathbf{1}^\top\Omega^{-1}\mathbf{f}_h]^2} = \lambda_h. \quad (\text{A16})$$

Therefore, to find the optimal π , we need to minimize

$$MV_h = i + (\alpha - i)\pi_h - \frac{1}{2}\gamma_h\pi_h^2\sigma^2\lambda_h.$$

Hence

$$\pi_h = \frac{1}{\lambda_h} \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2},$$

which implies that

$$\boldsymbol{\omega}_h = \pi_h\mathbf{x}_h = \frac{1}{\lambda_h} \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \lambda_h\Omega^{-1}\mathbf{f}_h = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \Omega^{-1}\mathbf{f}_h.$$

We can rewrite the expression for $\boldsymbol{\omega}_h$ in (A14) in terms of the familiarity-biased adjustment made to expected returns:

$$\boldsymbol{\omega}_h = \frac{1}{\gamma} \Omega^{-1} \frac{\alpha\mathbf{1} + \boldsymbol{\nu}_h - i\mathbf{1}}{\sigma^2},$$

where

$$\begin{aligned} \boldsymbol{\nu}_h &= -(\alpha - i)\mathbf{a}_h, \\ \mathbf{a}_h &= \mathbf{1} - \mathbf{f}_h. \end{aligned}$$

We now use (A14) to derive an expression for ω_{hn} , that is, the n 'th element of $\boldsymbol{\omega}_n$. For all $n \in \{1, \dots, N\}$, define \mathbf{e}_n , the $N \times 1$ column vector, with a one in the n 'th entry and zeros everywhere else. Clearly $\{\mathbf{e}_1, \dots, \mathbf{e}_N\}$ is the standard basis for \mathbb{R}^N and the proportion of investor h 's wealth invested in firm n is given by

$$\omega_{hn} = \mathbf{e}_n^\top \boldsymbol{\omega}_h.$$

We define

$$q_{hn} = \mathbf{e}_n^\top \Omega^{-1}\mathbf{f}_h,$$

and so

$$\omega_{hn} = q_{hn} \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2}, \quad (\text{A17})$$

and

$$\pi_h = \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \sum_{n=1}^N q_{hn}. \quad (\text{A18})$$

It follows from (A17) that the n 'th element of investor h 's portfolio of risky assets is given by

$$x_{hn} = \frac{\omega_{hn}}{\sum_{n=1}^N \omega_{hn}} = \frac{q_{hn}}{\sum_{n=1}^N q_{hn}}.$$

Substituting the expression for the optimal portfolio weight into the mean-variance objective function gives the optimized mean-variance objective function:

$$MV = i + \frac{1}{2} \frac{1}{\lambda_h \gamma} \left(\frac{\alpha - i}{\sigma} \right)^2.$$

Using (A16) we thus obtain the result in the proposition.

The following proposition summarizes results on optimal consumption choice.

Proposition 5 *An investor's optimal consumption-to-wealth ratio is given by*

$$\frac{C_{h,t}}{W_{h,t}} = \psi \delta + (1 - \psi) \left(\left[i + (\alpha \mathbf{1} + \frac{1}{2} \boldsymbol{\nu}_{h,t} - i \mathbf{1})^\top \boldsymbol{\omega}_{h,t} \right] - \frac{1}{2} \gamma \sigma^2 \boldsymbol{\omega}_{h,t}^\top \boldsymbol{\Omega} \boldsymbol{\omega}_{h,t} \right) \quad (\text{A19})$$

$$= \psi \delta + (1 - \psi) \left(i + \frac{1}{2\gamma} SR_{\mathbf{x}_h}^2 \right). \quad (\text{A20})$$

Proof of Proposition 5

From the Hamilton-Jacobi-Bellman equation in (13), the first-order condition with respect to consumption is

$$\delta \left(\frac{C_{ht}}{U_{ht}} \right)^{-\frac{1}{\psi}} = \frac{U_{ht}}{W_{h,t}}.$$

Substituting the above first-order condition into the Hamilton-Jacobi-Bellman equation allows us to solve for investor utility, and hence, optimal consumption. We obtain (A19).

A.6 Gordon Growth Formula

Investor h 's optimal consumption-wealth ratio given in (A20) can be rewritten as

$$\frac{C_{h,t}}{W_{h,t}} = i + \gamma \sigma_{p,h}^2 - g_h,$$

where $\sigma_{p,h}^2$ is the variance of the optimal portfolio held by household h in equilibrium and g_h is household h 's expected consumption growth, given by

$$g_h dt = E_t \left[\frac{dC_{h,t}}{C_{h,t}} \right] = E_t \left[\frac{dW_{h,t}}{W_{h,t}} \right].$$

We therefore obtain household h 's wealth-consumption ratio

$$\frac{W_{h,t}}{C_{h,t}} = \frac{1}{i + \gamma \sigma_{p,h}^2 - g_h}.$$

Note that the risk-neutral growth rate of household h 's consumption is given by

$$\widehat{g}_h = g_h - \gamma \sigma_{p,h}^2,$$

and so

$$\frac{W_{h,t}}{C_{h,t}} = \frac{1}{i - \widehat{g}_h}.$$

A.7 No Aggregate Familiarity Bias Across Investors

We start by formally stating the “no aggregate bias condition.”

Definition 5 *Suppose investor h 's risky portfolio weight for firm n is given by*

$$x_{hn} = \frac{1}{N} + \epsilon_{hn},$$

where $\frac{1}{N}$ is the unbiased portfolio weight and ϵ_{hn} is the bias of investor h 's portfolio when investing in firm n . The biases ϵ_{hn} “cancel out in aggregate” if

$$\forall n, \frac{1}{H} \sum_{h=1}^H \epsilon_{hn} = 0.$$

The following proposition gives the symmetry condition, which implies that the no-aggregate bias condition holds.

Proposition 6 *For every investor $h \in \{1, \dots, H\}$, define the adjusted-familiarity vector (q_{h1}, \dots, q_{hN}) , where q_{hn} is defined in (A15). If the following symmetry condition holds:*

1. *given an investor $h \in \{1, \dots, H\}$, for all investors $h' \in \{1, \dots, H\}$, there exists a permutation $\tau_{h'}$ such that $\tau_{h'}(q_{h'1}, \dots, q_{h'N}) = (q_{h1}, \dots, q_{hN})$; and,*
2. *given a firm $n \in \{1, \dots, N\}$, for all firms $n' \in \{1, \dots, N\}$, there exists a permutation $\tau_{n'}$ such that $\tau_{n'}(q_{1n'}, \dots, q_{Hn'}) = (q_{1n}, \dots, q_{Hn})$,*

then there is no aggregate bias.

Proof of Proposition 6

Observe that the no aggregate bias condition is equivalent to

$$\frac{1}{H} \sum_{h=1}^H q_{hn} = \frac{1}{N} \sum_{n=1}^N q_{hn}. \quad (\text{A21})$$

Now define a $H \times N$ familiarity matrix,

$$Q = [q_{hn}].$$

The permutations described in the symmetry condition imply that one can obtain all the rows of the matrix by rearranging any particular row, and one can obtain all the columns of the matrix by rearranging any particular column, which implies that (A21) is satisfied.

A.8 Equilibrium

The following proposition summarizes equilibrium prices and quantities.

Proposition 7 *The equilibrium risk-free interest rate is given by the constant*

$$i = \alpha - \gamma \sigma_p^2, \quad (\text{A22})$$

where

$$\sigma_p^2 = \frac{\sigma^2}{\hat{q}}$$

is the variance of the portfolio held by each investor and \hat{q} is defined by

$$\forall h, \hat{q} = \hat{q}_h,$$

where $\hat{q}_h = \sum_{n=1}^N q_{hn}$.

The aggregate price-dividend ratio is given in terms of the endogenous expected growth rate of aggregate output, g , and the perceived volatility of investor portfolios, σ_p by

$$\begin{aligned} p_t^{agg} &= \frac{1}{i + \gamma \sigma_p^2 - g} \\ &= \frac{1}{\alpha - g}, \end{aligned}$$

where i is the risk-free interest rate given in (A22), γ is the risk aversion of investors in this economy, σ_p^2 is the variance of the portfolio held by each investor, α is the risk-adjusted discount rate, and g is the expected growth rate of the dividend flow paid out by an individual firm, which is also common across all firms, and hence equal to the endogenous expected growth rate of aggregate output, given by

$$g = \psi(\alpha - c) + (1 - \psi) \frac{1}{2} \gamma \sigma_p^2.$$

The general equilibrium economy-wide consumption-wealth ratio is given by

$$\frac{C_t^{agg}}{W_t^{agg}} = c = \alpha - g,$$

where

$$c = \psi \delta + (1 - \psi) \left(\alpha - \frac{1}{2} \gamma \sigma_p^2 \right).$$

The aggregate growth rate of the economy is the aggregate investment-capital ratio,

$$g = \frac{I_t^{agg}}{K_t^{agg}},$$

which is given by

$$\frac{I_t^{agg}}{K_t^{agg}} = \alpha - c = \psi(\alpha - \delta) - \frac{1}{2}(\psi - 1)\gamma\sigma_p^2. \quad (\text{A23})$$

Proof of Proposition 7

We start by observing the symmetry condition in Theorem 6 implies that

$$\forall n, \forall h, \frac{1}{H} \sum_{h=1}^H q_{hn} = \frac{1}{N} \sum_{n=1}^N q_{hn},$$

which is equivalent to

$$\forall n, \forall h, \frac{1}{H} \hat{q}_n = \frac{1}{N} \hat{q}_h, \quad (\text{A24})$$

where

$$\hat{q}_n = \sum_{h=1}^H q_{hn}, \quad \hat{q}_h = \sum_{n=1}^N q_{hn}.$$

From (A24) we can also see that \hat{q}_n and \hat{q}_h must be independent of n and h , respectively.

We now prove that the condition that \hat{q}_h is independent of h implies that the risk-free interest rate is the constant given by (A22). Market clearing in the bond market implies that

$$\sum_{h=1}^H B_{h,t} = 0., \quad (\text{A25})$$

where the amount of wealth held in the bond by investor h is given by

$$B_{h,t} = (1 - \pi_{h,t})W_{h,t}.$$

Using the expression for $\pi_{h,t}$ given in (A18), we can rewrite the market clearing condition (A25) as

$$\sum_{h=1}^H \left(1 - \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \left(\sum_{n=1}^N q_{hn} \right) \right) W_{h,t} = 0.$$

Hence,

$$\begin{aligned} 0 &= \sum_{h=1}^H \left(W_{h,t} - \hat{q}_h \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} W_{h,t} \right) \\ \sum_{h=1}^H W_{h,t} &= \frac{1}{\gamma} \frac{\alpha - i}{\sigma^2} \sum_{h=1}^H \hat{q}_h W_{h,t} \\ i &= \alpha - \frac{\sum_{h=1}^H W_{h,t}}{\sum_{h=1}^H \hat{q}_h W_{h,t}} \gamma \sigma^2 \\ &= \alpha - \frac{1}{\hat{q}} \gamma \sigma^2. \end{aligned}$$

Therefore, in equilibrium

$$B_{h,t} = 0.$$

We thus conclude that in equilibrium, each investor invests solely in risky firms.

Substituting the equilibrium interest rate in (A22) into the expression in (A20) for the consumption-wealth ratio for each individual gives the general equilibrium consumption-wealth ratio:

$$\frac{C_{h,t}}{W_{h,t}} = c,$$

where

$$c = \psi\delta + (1 - \psi)\left(\alpha - \frac{1}{2}\gamma\sigma_p^2\right).$$

Observe that in the expression above, all the terms on the right-hand side are constants, implying that the consumption-wealth ratio is the same across investors. Exploiting the fact that the consumption-wealth ratio is constant across investors allows us to obtain the ratio of aggregate consumption-to-wealth ratio, where aggregate consumption is $C_t^{\text{agg}} = \sum_{h=1}^H C_{h,t}$ and aggregate wealth is $W_t^{\text{agg}} = \sum_{h=1}^H W_{h,t}$:

$$\frac{C_t^{\text{agg}}}{W_t^{\text{agg}}} = c.$$

Equation (1) implies

$$\sum_{n=1}^N Y_{n,t} = \alpha \sum_{n=1}^N K_{n,t},$$

and Equation (2) implies

$$d\left(E_t\left[\sum_{n=1}^N K_{n,t}\right]\right) = E_t\left[d\sum_{n=1}^N K_{n,t}\right] = \alpha \sum_{n=1}^N K_{n,t} - \sum_{n=1}^N D_{n,t}dt.$$

In equilibrium $\sum_{n=1}^N K_{n,t} = W_t^{\text{agg}}$ and $\sum_{n=1}^N D_{n,t} = C_t^{\text{agg}}$. Therefore,

$$\frac{dW_t^{\text{agg}}}{W_t^{\text{agg}}} = \left(\alpha - \frac{C_t^{\text{agg}}}{W_t^{\text{agg}}}\right) dt.$$

We also know that

$$\frac{dW_t^{\text{agg}}}{W_t^{\text{agg}}} = \frac{dY_t^{\text{agg}}}{Y_t^{\text{agg}}}$$

and so

$$g dt = E_t\left[\frac{dY_t^{\text{agg}}}{Y_t^{\text{agg}}}\right] = \left(\alpha - \frac{C_t^{\text{agg}}}{W_t^{\text{agg}}}\right) dt.$$

Therefore

$$c = \alpha - g.$$

From (A22) it follows that

$$c = i + \gamma\sigma_p^2 - g.$$

We now derive the aggregate investment-capital ratio. The aggregate investment flow must be equal to aggregate output flow less the aggregate consumption flow:

$$I_t^{\text{agg}} = \alpha K_t^{\text{agg}} - C_t^{\text{agg}}.$$

It follows that the aggregate investment-capital ratio is given by (A23).

Trend output growth is given by $E_t \left[\frac{dY_t^{\text{agg}}}{Y_t^{\text{agg}}} \right]$. Observe that $Y_t^{\text{agg}} = \alpha K_t^{\text{agg}} = \alpha W_t^{\text{agg}} = \frac{\alpha}{c} C_t^{\text{agg}}$. It follows that trend output growth equals the growth rate of aggregate consumption:

$$g = E_t \left[\frac{dY_t^{\text{agg}}}{Y_t^{\text{agg}}} \right].$$

We now relate trend output growth to aggregate investment. Firms all have constant returns to scale and differ only because of shocks to their capital stocks. Therefore, the aggregate growth rate of the economy is the aggregate investment-capital ratio:

$$g = \frac{I_t^{\text{agg}}}{K_t^{\text{agg}}}.$$

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