NBER WORKING PAPER SERIES

IS THE VOLATILITY OF THE MARKET PRICE OF RISK DUE TO INTERMITTENT PORTFOLIO RE-BALANCING?

Yi-Li Chien
Harold L. Cole
Hanno Lustig

Working Paper 15382
http://www.nber.org/papers/w15382

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2009

We would like to thank three anonymous referees, our editor Mark Gertler, Fernando Alvarez, Andrew Ang, Michael Brennan, Markus Brunnermeier, Bruce Carlin, Hui Chen, Bhagwan Chowdry, Bernard Dumas, Martin Lettau, Leonid Kogan, Stefan Nagel, Stavros Panageas, Monika Piazzesi and Martin Schneider, as well as the participants of SITE's 2009 Asset Pricing session and the 1st annual workshop at the Zurich Center for Computational Economics, the NBER EFG meetings in San Francisco, the NBER AP meetings in Boston, the ES sessions at the ASSA meetings in Atlanta and seminars at Columbia GSB, UCLA Anderson and MIT Sloan, for helpful comments. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

Is the Volatility of the Market Price of Risk due to Intermittent Portfolio Re-balancing?
Yi-Li Chien, Harold L. Cole, and Hanno Lustig
NBER Working Paper No. 15382
September 2009, Revised September 2011
JEL No. G12

ABSTRACT

Our paper examines whether the well-documented failure of unsophisticated investors to rebalance their portfolios can help to explain the enormous counter-cyclical volatility of aggregate risk compensation in financial markets. To answer this question, we set up a model in which CRRA-utility investors have heterogeneous trading technologies. In our model, a large mass of investors do not re-balance their portfolio shares in response to aggregate shocks, while a smaller mass of active investors adjust their portfolio each period to respond to changes in the investment opportunity set. We find that these intermittent re-balancers more than double the effect of aggregate shocks on the time variation in risk premia by forcing active traders to sell more shares in good times and buy more shares in bad times.

Yi-Li Chien
403 West State Street
Krannert School of Management
Purdue University
West Lafayette
IN 47907
yilichien@gmail.com

Harold L. Cole
Economics Department
University of Pennsylvania
3718 Locust Walk
160 McNeil Building
Philadelphia, PA 19104
and NBER
colehl@sas.upenn.edu

Hanno Lustig
UCLA Anderson School of Management
110 Westwood Plaza, Suite C413
Los Angeles, CA 90095-1481
and NBER
hlustig@anderson.ucla.edu

1 Introduction

One of the largest challenges for standard dynamic asset pricing models is to explain the large counter-cyclical variation in the risk-return trade-off in asset markets. Lettau and Ludvigson (2010) measure the time-variation in the Sharpe ratio on equities in the data. This time variation is driven by variation in the conditional mean of returns (the predictability of returns) as well the variation in the conditional volatility of stock returns. In the data, these two objects are negatively correlated, according to Lettau and Ludvigson (2010), and this gives rise to a considerable amount of variation in the conditional Sharpe ratio: the annual standard deviation of the estimated Sharpe ratio is on the order of 50% per annum.

In fact, in standard asset pricing models, the price of aggregate risk is constant (see, e.g., the Capital Asset Pricing Model of Sharpe (1964) and Lintner (1965)) or approximately constant (see, e.g., Mehra and Prescott (1985)'s calibration of the Consumption-CAPM).[1] The main explanations in the literature for the large variation in the pricing of risk rely on counter-cyclical risk aversion and heteroscedasticity in aggregate consumption growth. In this paper we propose an additional mechanism which has strong empirical support in micro data and can quantitatively account for a substantial portion of the cyclical variation in risk pricing.

In our mechanism, infrequent re-balancing on the part of passive investors contributes to countercylical volatility in risk prices. When the economy is affected by an adverse aggregate shock and the price of equity declines as a result, passive investors who re-balance end up buying equities to keep their portfolio shares constant, while intermittent rebalancers do not and thus end up with a smaller equity share in their portfolio. Hence, in the latter case, more aggregate risk is concentrated among the smaller pool of active investors whenever the economy is affected by a negative aggregate shock. As a result, the quantity of aggregate risk being absorbed by these active traders is counter-cyclical. Since these active traders are actively choosing the composition of their portfolio each period, they need to be induced to absorb this aggregate risk by counter-cyclical

[1] Recently, Campbell and Cochrane (1999) and Barberis, Huang, and Santos (2001), among others, have shown that standard representative agent models with different, non-standard preferences can rationalize counter-cyclical variation in Sharpe ratios.

fluctuations in the equilibrium price of aggregate risk.

There is strong empirical evidence in favor of the underlying micro-behavior posited in our model. There is a large group of households that invest in equities but only change their portfolio shares infrequently, even after large common shocks to asset returns (see, e.g., Ameriks and Zeldes (2004), Calvet, Campbell, and Sodini (2009) and Brunnermeier and Nagel (2008)). Without a specific model in mind, it is hard to know what effect, if any, intermittent re-balancing would have on equilibrium asset prices. In an equilibrium where all households are equally exposed to aggregate shocks, there is no need for any single household to re-balance his or her portfolio in response to an aggregate shock. In the absence of net repurchases and issuance, the average investor simply consumes the dividends in each period. However, in U.S. data, more than 4/5 of the cyclical variation in U.S. equity payouts comes from net repurchases and issuance, not from cash dividends. The failure of intermittent rebalancers to counteract the cyclical effect of equity payouts imputes substantial pro-cyclical variation to their equity portfolio shares that needs to be offset by the equity trades of active investors. This turns out to be sufficient to jump-start our mechanism.

To check the validity of our conjecture, we set up a standard incomplete markets model in which investors are subject to idiosyncratic and aggregate risk. The investors have heterogeneous trading technologies; a large mass of households are non-Mertonian investors who do not change their portfolio in response to changes in the investment opportunity set, but a smaller mass of active or Mertonian investors do. We consider two types of non-Mertonian investors: those that re-balance their portfolio each period to keep their portfolio shares constant, and those that re-balance intermittently. We assume that intermittent rebalancers reinvest the equity payouts in non-rebalancing periods (see e.g. Duffie and Sun (1990)).

The heterogeneity in trading technologies allows us to generate substantial volatility in the risk premiums. In the benchmark economy, we find that the volatility of the price of aggregate risk is 2.3 times higher in the economy with intermittent rebalancers than in the economy with continuously re-balancing non-Mertonian investors. While the individual welfare loss associated with intermittent rebalancing is small relative to continuous rebalancing, and hence small costs would suffice to explain this behavior, the aggregate effects of non-rebalancing are large. That makes this friction a compelling one to study.

The key ingredients are (i) a small supply of Mertonian or fast-moving capital relative to the large supply of non-Mertonian or slow-moving capital in securities markets, (ii) non-state-contingent intermittent rebalancing by passive investors and (iii) constant corporate leverage. Relaxing these assumptions would dampen the amplification of risk price volatility. The small supply of Mertonian capital is plausible given institutional constraints on leverage faced by mutual funds and pension funds, while hedge funds with access to leverage tend to have short investment horizons because of the threat of redemptions. Time-dependent rules can be rationalized by introducing observation and monitoring costs into the analysis (see Duffie and Sun (1990), Gabaix and Laibson (2002), Abel, Eberly, and Panageas (2006) and Alvarez, Guiso, and Lippi (2011)). The micro and macro evidence on investor behavior seems hard to reconcile with the state-contingent rebalancing rules that are implied by fixed costs (see, e.g., Alvarez, Guiso, and Lippi (2011) for recent evidence). Finally, we assume that corporations adjust their balance sheet faster in response to aggregate shocks than most households, and we provide some empirical evidence to support this assumption.

We rely on two additional frictions to match the average risk-free rate and the average risk premium: (i) incomplete markets with respect to the idiosyncratic labor income risk and (ii) limited participation. The first friction produces reasonable risk-free rate implications in a growing economy. The second friction, limited participation, combined with the non-Mertonian trading technology of some market participants, produces a high average equity premium by concentrating aggregate risk, as in Chien, Cole, and Lustig (2011), but they only consider continuously rebalancing non-Mertonian investors. Our paper introduces intermittent rebalancers and shows that these traders increase the volatility of risk premia.

We then use our model as a laboratory for exploring the effects of changes in the composition of the capital supply in financial markets. In our model, increased participation by non-Mertonian investors, i.e., an increase in the supply of slow-moving capital, decreases the average equity premium, but substantially increases its volatility. This seems consistent with the U.S. boom-bust experience during the 20's, characterized by increased stock market participation and a large increase in stock market volatility that lasted well into the 30's. A similar pattern repeated itself in the 90's. Hence, our mechanism can help to understand secular changes in the volatility of stock returns that are largely disconnected from the underlying volatility of macroeconomic shocks.

In the literature, counter-cyclical risk aversion, typically generated by habit persistence, is a standard explanation for the volatility of risk pricing. Habit formation preferences can help match the counter-cyclicality of risk premia in the data (Constantinides (1990), Campbell and Cochrane (1999)), as well as other features of the joint distribution of asset returns and macro-economic outcomes over the business cycle (see Jermann (1998), Boldrin, Christiano, and Fisher (2001)). A key prediction of these preferences is that the household's risk aversion, and hence their allocation to risky assets, varies with wealth. According to Brunnermeier and Nagel (2008), there is little evidence of this in the data.

How close can existing DAPM's get to the 50% number put forward by Lettau and Ludvigson (2010)? An annual calibration of the Campbell and Cochrane (1999) external habit model with large variation in the investor's risk aversion produces a volatility of 21%. The version of our model with the same i.i.d. aggregate consumption growth shocks and constant relative risk aversion investors (CRAA coefficient is five) delivers 14%, and it reproduces the counter-cyclical variation in the Sharpe ratio partly through negative correlation in the conditional mean and volatility of returns. A version of the model with predictability in aggregate consumption growth delivers 25%, an amplification by a factor of three compared to the economy with continuous rebalancers.

In our simple model, our mechanism cannot completely close the gap with the data, in part because it only delivers short-lived cyclical variation in risk prices and hence can only match the cyclical volatility in the dividend yield, not the low-frequency variation. However, in a richer model, our mechanism will augment other sources of cyclical return volatility because these in turn induce greater fluctuations in the portfolio composition of the intermittent rebalancers.[2]

[2]Other channels for time-variation in risk premia that have been explored in the literature include differences

Finally, there is a large literature on infrequent consumption adjustment starting with Grossman and Laroque (1990)'s analysis of durable consumption in a representative agent setting . Reis (2006) adopts a rational inattention approach to rationalize this type of behavior. In work closely related to ours, Lynch (1996) explores the aggregate effects of infrequent consumption adjustment on the equity premium. Lynch (1996)'s model matches the low volatility of aggregate consumption and the low empirical correlation of market returns with aggregate consumption changes. In more recent work, Gabaix and Laibson (2002) extend this analysis to a tractable continuous-time setup that allows for closed-form solutions, and they also characterize the optimal inattention period.[3] Our paper explores the aggregate effect of infrequent portfolio adjustment on the volatility of the equity premium. In our approach, the intermittent rebalancers choose an intertemporal consumption path to satisfy the Euler equation in each period, including non-rebalancing periods, but, in between exogenous rebalancing times, their savings decisions can only affect their holdings of the risk-free assets, not their equity holdings.[4]

The outline of the paper is as follows. Section 2 describes the counter-cyclical variation in the dividend yields, equity payouts and corporate leverage. In section 3, we review the micro and macro evidence in support of the frictions that drive our results. Section 4 describes the environment and the trading technologies. Section 5 discusses the calibration of the model. Section 6 shows the results for a simple version of the economy with only two trading technologies. Section 7 looks at the benchmark economy with three different trading technologies. Finally, section 8 describes an extension of the baseline model with more price volatility that produces more amplification.

in risk aversion (Chan and Kogan (2002), Gomes and Michaelides (2008)), differences in exposure to nontradeable risk (Garleanu and Panageas (2007)), participation constraints (Saito (1996), Basak and Cuoco (1998), Guvenen (2009)), differences in beliefs (Detemple and Murthy (1997)) and differences in information (Schneider, Hatchondo, and Krusell (2005)). Our paper imposes temporary participation constraints on the intermittent rebalancers instead of permanent ones, and it explores heterogeneity in trading technologies instead of heterogeneity in preferences.

[3] Duffie (2010) provides an overview of this literature in his 2010 AFA presidential address on slow-moving capital.

[4] In two related papers, Alvarez, Atkeson and Kehoe (2002, 2009) analyze the equilibrium effects of infrequent bond and money trading on interest rates and exchanges rate in a Baumol-Tobin model; a fixed cost is incurred when transferring money between the brokerage and the checking accounts.

2 Cyclical Variation

Our mechanism operates at business cycle frequencies. As a result, we need to understand the cyclical behavior of dividend yields, equity payouts and leverage. To do so, we run these series through a standard bandpass filter. This allows us to focus on the variation at business cycle frequencies between 1.5 and 8 years. In this section, we document three stylized facts that will guide and motivate our analysis: (i) the price of risk in stock markets is highly counter-cyclical, which renders dividend yields counter-cyclical (ii) leverage in the corporate sector is counter-cyclical but much less so than dividend yields (iii) equity payouts are highly pro-cyclical, driven mostly by net repurchases. These stylized facts will inform the setup of the model. The separate appendix contains a detailed description of the data.

2.1 Counter-Cyclical Variation in Dividend Yields

The dividend yield on U.S. stocks is highly persistent. The log dividend yield only crosses its sample mean three times between 1948.I and 2010.IV. However, the dividend yield also has a large cyclical component. Figure 1 plots the band-pass filtered log dividend yield for the U.S. stock market. The dividend yield is highly counter-cyclical. The dividend yield peaks in most NBER recessions, indicated by the shaded areas. The standard deviation of the cyclical component of the log dividend yield is 7.89% at quarterly frequencies.

The cyclical behavior of the dividend yield is consistent with large increases in expected (excess) returns during recessions. Lettau and Ludvigson (2010) measure the conditional Sharpe ratio on U.S. equities by forecasting stock market returns and realized volatility (of stock returns) using different predictors, and they obtain highly countercyclical and volatile Sharpe ratios, with an annual standard deviation of 50%.

2.2 Cyclical Variation in Corporate Leverage

We define leverage in the corporate sector (including the financial sector) as debt (including deposits) divided by debt plus the market value of equity. Leverage in the corporate sector has varied substantially in our post-war sample (1952.I -2010.IV). The mean leverage ratio in the sample is 65%, and the standard deviation of leverage is 7.73%. However, the cyclical component of leverage only has a standard deviation of 1.86% and hence only accounts for less than a quarter of total volatility. A one standard deviation change in the business cycle component would take leverage from its mean of 65% to 66.8%.

2.3 Pro-Cyclical Variation in Equity Payouts

Finally, we take a look at aggregate U.S. equity payouts. Equity payouts come in two forms. The first is standard cash dividends, and the second is net repurchases. Equity payouts are sometimes negative in the data due to the impact of net issuance. The distinction between dividends and net repurchases matters, because investors must actively buy or sell their equity claims to offset the impact of the firm's repurchases on their portfolio. In the case of cash dividends, they do not; consuming dividends is sufficient. As we will document, the cyclical fluctuations in U.S. equity payouts are driven largely by net repurchases. The top panel in figure 2 plots the cyclical variation in the payouts to U.S. shareholders of publicly traded companies (full line) divided by national income in the post-war sample (1952.I -2010.IV). Clearly, net payouts tend to drop significantly during most recessions, especially in the second half of the sample. As the figure shows, this is entirely driven by net issuance and repurchases rather than dividends (dashed line). The standard deviation of cyclical payouts is 0.86% over the entire post-war sample, while the standard deviation of net issuance is 0.85%. We also computed the equity payouts for all U.S. corporations, including private companies, using Flow of Funds data, plotted in the bottom panel of figure 2. We found similar steep declines in payouts to shareholders during recessions. The standard deviation is 0.81% over the entire sample for net issuance, compared to 0.28% for dividends and 0.86% for total net payouts. Our findings are in line with the equity payout facts documented by Larrain and Yogo (2007) and by Jermann and Quadrini (2011).

In sections 6 and 7, we will develop and test a calibrated model that seeks to match the cyclical behavior of the dividend yield. In this model, we choose to keep corporate leverage constant, to keep the model tractable, and we let debt and equity payouts bear the burden of adjustment to aggregate consumption growth shocks. While corporate leverage does vary over the business cycle in the data, this cyclical variation is much smaller than the variation in dividend yields. Introducing counter-cyclical corporate leverage in the model would mitigate our mechanism.

3 Micro and Macro Evidence on Investor Inertia

While directly held stocks still accounted for 46% of all U.S. equities between 2005-2010 (Source: Table B100.e, Flow of Funds), the median U.S. investor holds equities mostly in retirement accounts and pooled investment funds such as mutual funds. The 2007 Survey of Consumer Finances (SCF) reports that only 17.9% of families, mostly wealthy households, have any directly held stocks in their portfolio while 52.6% of households had retirement accounts. The median holding of directly held stocks was $17,000, compared to $56,000 for pooled investment funds and $45,000 for retirement accounts.[5] The passive investors in our model will represent the median equity investor, who mostly holds stocks indirectly.

3.1 Investor Response to Dividends

The response to dividend payments on the part of investors in directly held stocks is markedly different from that of mutual fund investors. The median equity investor, who hold equities mostly in mutual funds and retirement accounts, tends to simply reinvest dividends in his equity portfolio. Baker, Nagel, and Wurgler (2007) look at the cross-sectional evidence from U.S. brokerage account data. For mutual funds, they find that a large fraction of households reinvest a large fraction of dividends. In fact, the median household in their data automatically reinvests all mutual fund dividends (see p. 263, Baker, Nagel, and Wurgler (2007)). However, they also conclude from the cross-sectional evidence that ordinary cash dividends from directly held stocks, held mostly by wealthier households, are withdrawn from the household portfolio at a higher rate than capital

[5] In the SCF definition, pooled investment funds exclude money market mutual funds and indirectly held mutual funds and include all other types of directly held pooled investment funds, such as traditional open-end and closed-end mutual funds, real estate investment trusts, and hedge funds.

gains.

3.2 Investor Response to Capital Gains

There is a wealth of evidence indicating that many of these equity investors also behave very passively in response to capital gains or losses, and rarely adjust the composition of their portfolio.

Brokerage Account Evidence The earliest evidence come from U.S. retirement accounts. Ameriks and Zeldes (2004) find that over a period of 10 years 44% of households in a TIAA-CREF panel made no changes to either flow or asset allocations, while 17% of households made only a single change. Recently, Calvet, Campbell, and Sodini (2009), in a comprehensive dataset of Swedish households, found a weak response of portfolio shares to common variation in returns: between 1999 and 2002, the equal-weighted share of household financial wealth invested in risky assets drops from 57% to 45% in 2002, which is indicative of very weak re-balancing by the average Swedish household during the bear market.

Survey Evidence There is also a wealth of survey evidence which is consistent with the notion that most investors behave very passively. Using data from the Panel Study of Income Dynamics, Brunnermeier and Nagel (2008) conclude that inertia is the main driver of asset allocation in U.S. household portfolios, while time-varying risk aversion in response to changes in wealth only plays a minor role because the portfolio composition does not respond to shocks to liquid wealth (other than valuation-driven shocks). Furthermore, the Investment Company Institute (ICI) and Securities Industry and Financial Markets Association (SIFMA) conducted a survey of over 5000 U.S. household in 2008. They found that among households owning equities 57% of households had conducted no trades in the past 12 months.[6] In addition, Alvarez, Guiso, and Lippi (2011) summarize the evidence from a 2003 survey of 1,800 Italian households which found that 45% of these Italian households conducted either one trade or less per year. They conclude that 'a

[6] This figure is consistent with their findings from earlier surveys conducted in 1998 (58%), 2001 (60%) and 2004 (60%). (See Investment Company Institute: Equity Ownership in America, 2005.)

component of the adjustment costs faced by investors is information gathering' which lead to optimal time-dependent rules, like the ones adhered by the intermittent rebalancers in our model.

Mutual Fund Flow Evidence The aggregate evidence from U.S. mutual fund data is certainly consistent with this view of the median investor. During the stock market rally from 1990 to 1998, the share of U.S. equity mutual funds in total assets of the mutual fund industry increased from 23% to 62%. Between 1998 and 2002, after the end of this rally, the equity share dropped to 43%, only to recover and reach 60% in 2006. Between 2007 and 2008, the share dropped again to 40%. (Source: ICI Factbook, Table 4, year-end total net assets by investment classification). Broadly speaking, there was a huge increase in the equity share during the stock market rally of the 90's, followed by big declines after the end of the tech boom. Subsequently, there was a recovery between 2002 and 2007 in the stock market which lifted the share of equity mutual funds, and then it decreased again during the last two years.

The slow response of the median equity investor to capital gains and losses obviously applies to equity payouts that accrue in the form of net repurchases and issuance, which account for most of the cyclical variation in equity payouts. As a result, active investors have to absorb net repurchases.[7] We assume these equity payouts in the model are automatically reinvested by the passive investors who fail to rebalance, in light of the empirical evidence cited above, but not by active investors.

4 Model

We consider an endowment economy in which households sequentially trade assets and consume. All households are ex ante identical, except for the restrictions they face on the menu of assets that they can trade. These restrictions are imposed exogenously. We refer to the set of restrictions that a household faces as a household trading technology. The goal of these restrictions is to capture

[7]Since the model features a constant supply of shares and the adjustment occurs through the supply of bonds, strictly speaking, equity payouts in the model come only in the form of dividends. However, we could extend the analysis to allow for shocks to the supply of equity shares.

the observed portfolio behavior of most households.

We will refer to households as being *non-Mertonian traders* if they take their portfolio composition as given and simply choose how much to save or dissave in each period. Other households optimally change their portfolio in response to changes in the investment opportunity set. We refer to these traders as *Mertonian traders* since they actively manage the composition of their portfolio each period. To solve for the equilibrium allocations and prices, we extend the method developed by Chien, Cole, and Lustig (2011) to allow for non-Mertonian traders who only intermittently adjust their portfolio. In this section, we describe the environment and we describe the household problem for each of the different asset trading technologies. We also define an equilibrium for this economy.

4.1 Environment

There is a unit measure of households who are subject to both aggregate and idiosyncratic income shocks. Households are ex ante identical, except for the trading technology they are endowed with. Ex post, these households differ in terms of their idiosyncratic income shock realizations. All of the households face the same stochastic process for idiosyncratic income shocks, and all households start with the same present value of tradeable wealth.

In the model time is discrete, infinite, and indexed by $t = 0, 1, 2, ...$ The first period, $t = 0$, is a planning period in which financial contracting takes place. We use $z_t \in Z$ to denote the aggregate shock in period t and $\eta_t \in N$ to denote the idiosyncratic shock in period t. z^t denotes the history of aggregate shocks, and similarly, η^t denotes the history of idiosyncratic shocks for a household. The idiosyncratic events η are i.i.d. across households with mean one. We use $\pi(z^t, \eta^t)$ to denote the unconditional probability of state (z^t, η^t) being realized. The events are first-order Markov, and we assume that

$$\pi(z^{t+1}, \eta^{t+1}|z^t, \eta^t) = \pi(z_{t+1}|z_t)\pi(\eta_{t+1}|\eta_t).$$

Since we can appeal to a law of large number, $\pi(\eta^t)$ also denotes the fraction of agents in state z^t that have drawn a history η^t. We introduce some additional notation: $z^{t+1} \succ z^t$ or $\eta^{t+1} \succ \eta^t$

means that the left hand side node is a successor node to the right hand side node. We denote by $\{z^\tau \succ z^t\}$ the set of successor aggregate histories for z^t including those many periods in the future; ditto for $\{\eta^\tau \succ \eta^t\}$. When we use $\succeq$, we include the current nodes z^t or η^t in the set.

There is a single non-durable goods available for consumption in each period, and its aggregate supply is given by $Y_t(z^t)$, which evolves according to

$$Y_t(z^t) = \exp\{z_t\} Y_{t-1}(z^{t-1}), \tag{1}$$

with $Y_0(z^0) = 1$. This endowment goods comes in two forms. The first part is non-diversifiable income that is subject to idiosyncratic risk and it is given by $\gamma Y_t(z^t)\eta_t$; hence γ is the share of income that is non-diversifiable. The second part is diversifiable income, which is not subject to the idiosyncratic shock, and is given by $(1-\gamma)Y_t(z^t)$.

All households are infinitely lived and rank stochastic consumption streams according to the following criterion

$$U(\{c\}) = \sum_{t \geq 1, (z^t, \eta^t)}^{\infty} \beta^t \pi(z^t, \eta^t) \frac{c_t(z^t, \eta^t)^{1-\alpha}}{1-\alpha}, \tag{2}$$

where $\alpha > 0$ denotes the coefficient of relative risk aversion, and $c_t(z^t, \eta^t)$ denotes the household's consumption in state (z^t, η^t). Henceforth, we suppress the histories z^t, η^t in the notation whenever the history dependence is obvious.

4.2 Assets Traded

Households trade assets in securities markets that re-open every period. These assets are claims on diversifiable income, and the set of traded assets, depending on the trading technology, can include one-period Arrow securities as well as debt and equity claims. Households cannot directly trade claims to aggregate non-diversifiable income (labor income).

We define equity as a leveraged claim to aggregate diversifiable income ($(1-\gamma)Y_t(z^t)$). Corporate leverage is constant in our economy. Instead, the equity payouts will adjust to aggregate shocks. We use $V_t[\{X\}](z^t)$ to denote the no-arbitrage price of a claim to a payoff stream $\{X\}$ in period t with history z^t, and we use $R_{t+k,t}[\{X\}](z^{t+k})$ to denote the gross return between t and $t+k$. $R_{t+1,t}[\{1\}](z^t)$ denotes the one-period risk-free rate. We denote the price of a unit claim to the final good in aggregate state z^{t+1} acquired in aggregate state z^t by $Q_t(z_{t+1}, z^t)$.

To construct the debt and the equity claim, we assume that aggregate diversifiable income in each period is split into a debt component (aggregate interest payments net of new issuance) and an equity component (aggregate dividend payments net of new equity issuance denoted $D_t(z^t)$). For simplicity, the bonds are taken to be one-period risk-free bonds. Since we assume a constant leverage ratio ψ, the supply of one-period non-contingent bonds $B_t^s(z^t)$ in each period needs to adjust such that:

$$B_t^s = \psi\left[(1-\gamma)V_t[\{Y\}] - B_t^s\right],$$

where $V_t[\{Y\}](z^t)$ denotes the value of a claim to aggregate income in node z^t. The payout to bond holders is given by $R_{t,t-1}[1](z^{t-1})B_{t-1}^s(z^{t-1}) - B_t^s(z^t)$, and the payments to shareholders, $D_t(z^t)$, are then determined residually as:

$$D_t = (1-\gamma)Y_t - R_{t,t-1}(z^{t-1})[1]B_{t-1}^s + B_t^s.$$

In our model, the supply of shares is constant and all equity payouts come exclusively in the form of dividends. We denote the value of the equity claim as $V_t[\{D\}](z^t)$. $R_{t,t-1}[\{D\}](z^t)$ denotes the gross return on the dividend claim between $t-1$ and t. A trader who invests a fraction $\psi/(1+\psi)$ in bonds and the rest in debt is holding the market portfolio. The equity payout/output ratio is given by the following expression:

$$\frac{D_t}{Y_t} = (1-\gamma)\left(1 + \frac{\psi}{1+\psi}\left[\frac{V_t[\{Y\}]}{Y_t} - (1+R_{t,t-1}[1])\frac{V_{t-1}[\{Y\}]}{Y_{t-1}}\exp\{-z_t\}\right]\right). \tag{3}$$

As can easily be verified, the payout/output ratio is pro-cyclical provided that the price-dividend ratio of a claim to aggregate (or diversifiable) output is. Since our calibrated benchmark model produces procyclical price/dividend ratios, the equity payout/output ratio inherits this property, as in the data. Note that these equity payouts can be negative, as is true in the data.

All households are initially endowed with a claim to their per capita share of both diversifiable and non-diversifiable income. In period 1, each agent's financial wealth is constrained by the value of their claim to tradeable wealth in the period 0 planning period, which is given by:

$$(1-\gamma)V_0[\{Y\}](z^0) \geq \sum_{z_1} Q_1(z_1, z^0)\hat{a}_0(z^1, \eta^0), \tag{4}$$

where both z^0 and η^0 simply indicate the degenerate starting values for the stochastic income process.[8]

4.3 Trading Technology

A trading technology is a restriction on the menu of assets that the agent can trade in any given period. This includes restrictions on the frequency of trading as well. The set of asset trading technologies that we consider can be divided into two main classes: Mertonian trading technologies and non-Mertonian trading technologies. Agents with a Mertonian or active trading technology optimally choose their portfolio composition given the menu of assets that they are allowed to trade in each period and given the state of the investment opportunity set. We initially focus on Mertonian traders who can trade a complete menu of state-contingent securities with payoffs contingent on aggregate but not idiosyncratic shocks, in addition to non-contingent debt and equity. These trading technologies are superior to non-Mertonian trading technologies that keep the target composition of their portfolios fixed. Non-Mertonian traders only choose how much to save each period. We will consider three types of non-Mertonian traders: (i) traders who hold only debt claims, (ii) traders who hold debt and equity claims in fixed proportion, and (iii) traders who allow the recent history of equity returns to determine their holdings of debt and equity because they only periodically rebalance their portfolios, but have a fixed equity share target.

[8] In the quantitative analysis we only look at the ergodic equilibrium of the economy; hence, the assumptions about initial wealth are largely irrelevant. We assume that, during the initial trading period, households with portfolio restriction sell their claim to diversifiable income in exchange for their type appropriate fixed weighted portfolio of bonds and equities.

Mertonian Trader This Mertonian trader has access to a complete menu of contingent claims on z and she faces no restrictions on his holdings of bonds and equity. We consider a household entering the period with net financial wealth $\hat{a}_t(z^t, \eta^t)$. This household buys securities in financial markets (state contingent bonds $a_t(z_{t+1}; z^t, \eta^t)$, non-contingent bonds $b_t(z^t, \eta^t)$, and equity shares $s_t^D(z^t, \eta^t)$) and consumption $c_t(z^t, \eta^t)$ in the good markets subject to this one-period budget constraint:

$$\sum_{z_{t+1}} Q_t(z_{t+1}) a_t(z_{t+1}) + s_t^D V_t[\{D\}] + b_t + c_t \leq \hat{a}_t + \gamma Y_t \eta_t \text{ for all } z^t, \eta^t,$$

where $\hat{a}_t(z^t, \eta^t)$, the agent's net financial wealth in state (z^t, η^t), is given by his state-contingent bond payoffs, the payoffs from his equity position and the non-contingent bond payoffs:

$$\hat{a}_t = a_{t-1}(z_t) + s_t^D \left[D_t + V_t[\{D\}] \right] + R_{t,t-1}[1] b_{t-1}. \tag{5}$$

Finally, the households face exogenous limits on their net asset positions, or solvency constraints,

$$\hat{a}_t(z^t, \eta^t) \geq 0. \tag{6}$$

Traders cannot borrow against their future labor income.

Non-Mertonians For all non-Mertonian trading technologies, the menu of traded assets only consists of non-contingent debt and equity claims. We consider a Non-Mertonian household entering the period with net financial wealth $\hat{a}_t(z^t, \eta^t)$. This household buys non-contingent bonds $b_t(z^t, \eta^t)$, and equity shares $s_t^D(z^t, \eta^t)$) and consumption $c_t(z^t, \eta^t)$ in the good markets subject to this one-period budget constraint:

$$s_t^D V_t[\{D\}] + b_t + c_t \leq \hat{a}_t + \gamma Y_t \eta_t, \text{ for all } z^t, \eta^t,$$

where $\hat{a}_t(z^t, \eta^t)$, the agent's net financial wealth in state (z^t, η^t), is given by the payoffs from his equity position and the non-contingent bond payoffs:

$$\hat{a}_t = s_t^D \left[D_t + V_t[\{D\}]\right] + R_{t,t-1}[1]b_{t-1}. \tag{7}$$

Non-Mertonian traders face the same solvency constraints.

A non-Mertonian trading technology also specifies an exogenously assigned and fixed target $\varpi^\star$ for the equity share. We refer to these traders as non-Mertonian precisely because the target does not respond to changes in the investment opportunity set.

There are two types of these non-Mertonian traders. A *continuous-rebalancer* adjusts his equity position to the target $\varpi^\star$ in each period. An *intermittent-rebalancer* adjusts his equity position to the target only every n periods; in non-rebalancing periods, all (dis-)savings occur through adjusting the holdings of the investor's risk-free asset.[9]

Continuous-Rebalancing (*crb*) Trader Non-Mertonian traders re-balance their portfolio in each period to a fixed fraction $\varpi^\star$ in levered equity and $1 - \varpi^\star$ in non-contingent bonds, and hence they earn a return:

$$R_t^{crb}(\varpi^\star) = \varpi^\star R_{t,t-1}[\{D\}] + (1 - \varpi^\star)R_{t,t-1}[1]$$

If $\varpi^\star = 1/(1 + \psi)$, then this trader holds the market in each period and earns the return on a claim to all tradeable income: $R_{t,t-1}[\{(1 - \gamma)Y\}]$. Without loss of generality, we can think of non-participants as *crb* traders with $\varpi^\star = 0$.

[9]As in Lynch (1996) and Duffie (2010), we assume that investors fix their periods of inattention rather than solving for the optimal inattention period. Building on earlier work by Duffie and Sun (1990) and Gabaix and Laibson (2002), Abel, Eberly, and Panageas (2006) consider a portfolio problem in which the investor pays a cost to observe her portfolio, and they show that even small costs can rationalize fairly large intervals in which the household does not check its portfolio, and finances its consumption out of the riskless account. We do not endogenize the decision to observe the value of the portfolio, but, instead, we focus on the aggregate equilibrium implications of what Abel, Eberly, and Panageas (2006) call 'stock market inattention'.

Intermittent-Rebalancing (*irb*) Trader An *irb* trader's technology is defined by his portfolio target (denoted $\varpi^\star$) and the periods in which he rebalances (denoted $\mathcal{T}$). We assume that rebalancing takes place at fixed intervals. For example, if he rebalances every other period, then $\mathcal{T} = \{1, 3, 5, ...\}$ or $\mathcal{T} = \{2, 4, 6, ...\}$.

We define the trader's equity holdings as $e_t(z^t, \eta^t) = s_t^D(z^t, \eta^t)V_t[\{D\}](z^t)$. In re-balancing periods, this trader's equity holdings satisfy:

$$\frac{e_t}{e_t + b_t} = \varpi^\star.$$

However, in non-rebalancing periods, the implied equity share is given by $\varpi_t = e_t/(e_t + b_t)$ where e_t evolves according to the following law of motion:

$$e_t = e_{t-1}R_{t,t-1}[\{D\}]$$

for each $t \notin \mathcal{T}$. This assumes that the *irb* trader automatically re-invests the payouts in equity in non-rebalancing periods.[10] After non-rebalancing periods, the *irb* trader with an equity share $\varpi_{t-1}(z^{t-1})$ earns a rate of return:

$$R_t^{irb}(\varpi_{t-1}) = \varpi_{t-1}R_{t,t-1}[\{D\}] + (1 - \varpi_{t-1})R_{t,t-1}[1].$$

Since setting $\mathcal{T} = \{1, 2, 3, ...\}$ generates the continuous-rebalancer's measurability constraint, the continuous-rebalancer can simply be thought of as a degenerate case of the intermittent-rebalancer. Hence, we can state without loss of generality that a non-Mertonian trading technology is completely characterized by $(\varpi^\star, \mathcal{T})$. In our quantitative analysis we assume that the set of *irb* traders is such that an equal number of them rebalance in every period.

[10]When the average investor simply consumes the equity payouts, then there is no need for trade in shares between the average non-Mertonian and the average Mertonian trader. Once the *irb* trader reinvests the procyclical equity payouts, then the Mertonian traders have to sell shares after good aggregate shocks and buy shares after bad aggregate shocks.

4.4 Equilibrium

We assume there is always a non-zero measure of Mertonian traders to guarantee the uniqueness of the stochastic discount factor. For Mertonian traders, we let μ_m denote their measure. For non-Mertonian traders, we denote the measure of *irb* (*crb*) traders with μ_{irb} (μ_{crb}) and their portfolio target with $\varpi^\star$; for nonparticipants, we use μ_{np} to denote their measure. (The portfolio target of non-participants is equal to zero.)

The non-state-contingent bond market clearing condition is given by

$$\sum_{\eta^t} \left[\mu_m b_t^m + \mu_{crb} b_t^{crb} + \mu_{irb} b_t^{irb} + \mu_{np} b_t^{np}\right] \pi(\eta^t|z^t) = V_t[\{(1-\gamma)Y - D\}], \tag{8}$$

and the equity market clearing condition is given by

$$\sum_{\eta^t} \left[\mu_m e_t^m + \mu_{irb} e_t^{irb} + \mu_{crb} e_t^{crb}\right] \pi(\eta^t|z^t) = V_t[\{D\}], \tag{9}$$

where we index the holdings of the Mertonian traders, continuous rebalancers, intermittent rebalancers and non-participants respectively by $\{m, crb, irb, np\}$.

The market clearing condition in the state-contingent bond market is given by:

$$\sum_{\eta^t} \left[\mu_m a_t^m(z_{t+1})\right] \pi(\eta^t|z^t) = 0. \tag{10}$$

An equilibrium for this economy is defined in the standard way. It consists of a list of bond and dividend claim holdings, a consumption allocation and a list of bond and tradeable output claim prices such that: (i) given these prices, a trader's asset and consumption choices maximize her expected utility subject to the budget constraints, the solvency constraints and the measurability constraints, and (ii) the asset markets clear (eqs. (8), (9),(10)).

To solve for the equilibrium of our model we develop an extension of the multiplier method developed by Chien, Cole, and Lustig (2011). They use measurability restrictions to capture the portfolio restrictions implied by the different trading technologies. This leads them to use a cumulative Lagrangian multiplier as the relevant household state variable. They develop an analytic characterization of the household's share of aggregate consumption and the stochastic discount factors in terms a single moment of the distribution of these cumulative Lagrangian multipliers. They then use these results to construct a computational algorithm to solve for an equilibrium of their model. The key advantage of their methodology is it allows us to solve for equilibrium allocations and prices without having to search for the equilibrium prices that clear each security market. Section A in the appendix provides a detailed discussion of how we extend their methodology to handle intermittent rebalancers.[11]

4.5 Analytical Experiment

To explain the importance of rebalancing for aggregate risk sharing, we look at a version of our economy in which aggregate consumption growth is not predictable: $\pi(z'|z) = \pi(z')$. There are no non-participants in this economy.

Without Idiosyncratic risk In addition, we consider a version of the model without idiosyncratic η shocks ($\eta = 1$). The active traders effectively face complete markets, albeit subject to binding solvency constraints. Finally, we assume that the non-Mertonian traders want to hold the market portfolio: their target share is $\varpi^{\star} = 1/(1+\psi)$. The complete markets allocation is characterized by constant consumption shares for all households:

$$c_t(z^t) = \widehat{c}Y(z^t). \tag{11}$$

[11] In continuous-time finance, Cuoco and He (2001) and Basak and Cuoco (1998) used stochastic weighting schemes to characterize allocations and prices. Our approach differs because it provides a tractable and computationally efficient algorithm for computing equilibria in environments with a large number of agents subject to idiosyncratic risk as well as aggregate risk, and heterogeneity in trading technologies. The use of cumulative multipliers in solving macro-economic equilibrium models was pioneered by Kehoe and Perri (2002), building on earlier work by Marcet and Marimon (1999). Our use of measurability constraints to capture portfolio restrictions is similar to that in Aiyagari, Marcet, Sargent, and Seppala (2002) and Lustig, Sleet, and Yeltekin (2007), who consider an optimal taxation problem, while the aggregation result extends that in Chien and Lustig (2010) to an incomplete markets environment.

Since all households are ex ante identical, the consumption share is one ($\widehat{c}$ =1) for all households. Even with *crb* passive traders, this allocation can be implemented since the passive traders can simply hold the market portfolio. In equilibrium, they then consume the dividends from holding the market portfolio of equity and debt. All asset prices are identical to those that obtain in the Breeden-Lucas-Rubinstein representative agent economy, since we are implementing the complete markets allocation. The market price of risk is constant, and so is the risk-free rate.

Next, we consider a version with *irb* passive traders. The *irb* trader buys more shares than usual after high aggregate consumption shocks and buys fewer shares than usual after low aggregate consumption growth shocks. Why? Consider the case in which 1/3 of *irb* traders rebalances each period. Let us start with *irb* traders who do not rebalance in that period. They account for 2/3 of all *irb* traders in the calibrated model. The 2/3 of *irb* traders who do not rebalance that period re-invest the dividends automatically. Hence, they buy more shares after good aggregate consumption growth shocks than after bad aggregate consumption growth shocks. This becomes apparent from the expression for the payout ratio in equation (3). Moreover, the 1/3 of *irb* traders who do rebalance do not offset this cyclical buying of shares, because they have a fixed equity target.

Obviously, the complete markets allocations in equation (11) cannot be implemented. The non-rebalancing *irb* trader consumption shares drift down below 1 after good aggregate shocks, because they buy more shares, and the shares increase above 1 after bad shocks, because they buy fewer shares, or they even sell shares. As a result, to clear the market, the active traders as a group sell more shares than usual after high aggregate consumption growth realizations to the *irb* traders and they buy more shares than usual after low aggregate consumption growth realizations. Thus, after a series of negative aggregate consumption growth shocks, the *irb*'s equity share ϖ_{t-1} would be much lower than what is required to hold the market, and $R_t^{irb}(\varpi_{t-1}, \tilde{z}_t)$ is increasingly less exposed to aggregate consumption risk. In this new equilibrium, the relative wealth of the non-Mertonian *irb*, traders $\widehat{A}_t^{irb}(z^t)/\sum_{j\in\{z,irb\}}\widehat{A}_t^{j}(z^t)$ cannot be invariant w.r.t aggregate shocks.

With Idiosyncratic risk Next, we consider the same economy, now with idiosyncratic risk. Diversifiable income accounts for a fraction $1-\gamma$ of total wealth. Furthermore, recall that the distribution of idiosyncratic shocks is independent of aggregate shocks. We assume that the non-Mertonian traders belong to the class of continuous-rebalancers (*crb*), and suppose that they hold the market portfolio: their target share is $\varpi^{\star} = 1/(1+\psi)$. Also, suppose that there are no non-participants in this economy. The *crb* trader can choose a consumption path that is proportional to aggregate output:

$$c_t(z^t, \eta^t) = \widehat{c}_t(\eta^t) Y(z^t), \tag{12}$$

where the share $\widehat{c}_t$ does not depend on the history of aggregate shocks z^t, but only on the history of idiosyncratic shocks. This particular consumption path in eq. (12) is feasible for the non-Mertonian trader simply by trading a claim to aggregate consumption (the market), i.e., maintaining a portfolio with $\varpi^{\star} = 1/(1+\psi)$ invested in equity. There is in fact an equilibrium in which all agents only trade claims to aggregate consumption, as shown by Krueger and Lustig (2009). In this equilibrium, the equity premium is still the Breeden-Lucas-Rubenstein representative agent equity premium, because all households bear the same amount of aggregate risk, and the market price of risk is constant.

The logic is the same as before in the economy without idiosyncratic risk, but now it applies to the average agent. The average agent should simply consume the dividends to hold the market portfolio. The equity share in his portfolio remains constant at $1/(1+\psi)$ if he does so. Instead, the **average** *irb* trader buys more shares than usual after high aggregate consumption shocks and buys fewer shares than usual after low aggregate consumption growth shocks. As a result, the active traders as a group sell more shares than usual after high aggregate consumption growth realizations to the *irb* traders and they buy more shares than usual after low aggregate consumption growth realizations. The dynamics of *irb* equity shares are as described above for the case without idiosyncratic risk.

Because of the nature of the trading technology, adverse aggregate shocks endogenously concentrate aggregate risk among the Mertonian traders. This destroys the constant representative agent risk price result in the case of i.i.d. aggregate shocks without non-participants. The p/d ratio cannot be constant in equilibrium. The risk premium has to increase after bad shocks and decrease after good shocks.

5 Calibration of Economy

This section discusses the calibration of the parameters. In section 6 and 7, we then evaluate the calibrated version of the model to examine the extent to which our model can account for the empirical moments of asset prices, and in particular the counter-cyclical volatility of the market price of risk.

5.1 Preferences and Endowments

The model is calibrated to annual data. We set the coefficient of relative risk aversion α to five and the time discount factor β to .95. These preference parameters allow us to match the collaterizable wealth to income ratio in the data when the tradeable or collateralizable income share $1-\gamma$ is 10%, as discussed below. The average ratio of household wealth to aggregate income in the US is 4.30 between 1950 and 2005. The wealth measure is total net wealth of households and non-profit organizations (Flow of Funds Tables). With a 10% collateralizable income share, the implied ratio of wealth to consumption is 5.28 in the model's benchmark calibration.[12]

Our benchmark model is calibrated to match the aggregate consumption growth moments from Alvarez and Jermann (2001). The average consumption growth rate is 1.8% and the standard deviation is 3.16%. These are the moments of U.S. per capita aggregate consumption between 1889-1978 used in Mehra and Prescott (1985)'s seminal paper. Recessions are less frequent than expansions: 27% of realizations are low aggregate consumption growth states. The first-order autocorrelation coefficient of aggregate consumption growth (ρ_z) is zero. Aggregate consumption

[12]As is standard in this literature, we compare the ratio of total outside wealth to aggregate non-durable consumption in our endowment economy to the ratio of total tradeable wealth to aggregate income in the data. Aggregate income exceeds aggregate non-durable consumption because of durable consumption and investment.

growth is identically and independently distributed over time: $\pi(z'|z) = \pi(z')$. The elements of the discretized process for z are $\{0.9602, 1.0402\}$.

We calibrate the labor income process as in Storesletten, Telmer, and Yaron (2007), except that we eliminate the counter-cyclical variation (CCV) of labor income risk. Hence, the variance of labor income risk is constant in our model. This allows us to focus on the effects of changes in composition of non-Mertonian traders pool and their target equity share. The Markov process for the log of the labor income share $\log \eta$ has a standard deviation of 0.71, and its autocorrelation is 0.89. We use a 4-state discretization for both aggregate and idiosyncratic risk. The elements of the discretized process for η are $\{0.3894, 1.6106\}$.

Equity in our model is simply a leveraged claim to diversifiable income. In the Flow of Funds, the ratio of corporate debt-to-net worth is around 0.65, suggesting a leverage parameter ψ of 2. However, Cecchetti, Lam, and Mark (1990) report that standard deviation of the growth rate of dividends is at least 3.6 times that of aggregate consumption, suggesting that the appropriate leverage level is over 3. Following Abel (1999) and Bansal and Yaron (2004), we choose to set the leverage parameter ψ to 3.

5.2 Computation

To compute the equilibrium of this economy, we follow the algorithm described by Chien, Cole, and Lustig (2011), who use truncated aggregate histories as state variables. We keep track of lagged aggregate histories up to 7 periods. The details are in section D of the appendix. Our objective is to examine the response of the moments of equilibrium asset prices, consumption growth, portfolio returns and the welfare to changes in the frequency of rebalancing by non-Mertonian equity holders and the level of their equity target.

6 Quantitative Experiments in Calibrated Economy

To illustrate the effect of trading technology on equilibrium prices, we start by using a simpler version of our economy with only two types of traders. The pool of traders consists of 5% Mertonian traders and 95% non-Mertonian traders. These shares represent fractions of human wealth in each trader pool. The actual distribution of financial wealth is endogenous.

We consider two types of non-Mertonian equity holders: (1) those who rebalance every period (*crb*) and (2) those who rebalance every 3 years (*irb*). This level of inertia is modest compared to what researchers have documented in the data (see, e.g., the evidence reported by Ameriks and Zeldes (2004), Calvet, Campbell, and Sodini (2009) and Brunnermeier and Nagel (2008)). We assume that an equal fraction of *irb* traders rebalances every period.

We consider three simple quantitative experiments. In experiment (1), the non-Mertonian traders are *crb* traders who have an equity target of 25% $\varpi^{\star} = 1/(1+\psi)$, and therefore hold the market, i.e., a claim to aggregate output. In experiment (2), the non-Mertonian traders are nonparticipants (*np*). These are effectively *crb* traders who have equity target $\varpi^{\star} = 0$. In experiment (3), the non-Mertonian traders are *irb* traders who hold the market and have an equity target $\varpi^{\star} = 1/(1+\psi)$. 1/3 of these traders rebalance in each period. The first experiments is similar in spirit to our prior work, Chien, Cole, and Lustig (2011); the second experiment is a version of Guvenen (2009)'s limited participation economy, while the third experiment highlights the novel mechanism in this paper.

Table I reports the asset pricing results, where equity is a claim to the payout process D defined in equation (3). We report the maximum unconditional Sharpe ratio or market price of risk ($\frac{\sigma(m)}{E(m)}$) the standard deviation of the maximum SR ($Std(\frac{\sigma_t(m)}{E_t(m)})$), the equity risk premium $E\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$, the standard deviation of excess returns $\sigma\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$, the Sharpe ratio on equity, the mean risk-free rate $E\left(R_{t+1,t}[1]\right)$ and the standard deviation of the risk-free rate $\sigma\left(R_{t+1,t}[1]\right)$. To help us understand the mechanism that is generating these results, figure 3 shows a sample path of the equity share of the average Mertonian trader for each of the three experiments in the top panel and a sample path of non-Mertonian traders in the bottom panel.

6.1 Continuous Rebalancing Experiment

In the first experiment, the combination of a Mertonian traders and non-Mertonian *crb* traders, both of which face idiosyncratic and aggregate risk, leads to a low risk free rate of 2.8%, compared to 12% in the representative agent economy. The risk-free rate is essentially constant, and there is a modest equity premium of 2.8%, while the Sharpe ratio on equity is also low at 0.19. More importantly, from our perspective, the market price of risk is constant. This outcome arises in the *crb* equilibrium because the equity share in the Mertonian trader's portfolio is constant, as is clear from the top panel in figure 3. Recall that our economy satisfies the assumptions we imposed in the IID example (see subsection 4.5). In this version of the model without non-participants, the representative agent Breeden-Lucas-Rubinstein risk premium is obtained provided that all non-Mertonian traders are of the *crb* type. Furthermore, this BLR risk premium is constant.

In experiment (2) and (3), as we replace the *crb* traders by non-participants and *irb* traders respectively, we see increasingly counter-cyclical equity shares in the next two experiments, which in turn will impute volatility to risk prices.

6.2 Limited Participation Experiment

In the second experiment, we replace the *crb* traders with non-participants (*np*). As is to be expected, the concentration of aggregate risk delivers an even lower risk-free rate of 1.2%, while the equity premium increases to 8.4% and the Sharpe ratio on equity is 0.52. Furthermore, we now see some volatility in the pricing of risk. The standard deviation of the market price increases from 0 to 5.4%. The amount of aggregate risk being absorbed by the Mertonian trader is relatively larger in bad times, i.e., after a history of low aggregate consumption growth shocks, rather than good times due to the savings behavior of the nonparticipant. After each low realization of the aggregate growth shock z_t, the wealth of non-participants increases relative to average wealth. As a result, after each bad shock, the Mertonian trader has to take a more levered position in equities to offset the larger bond position of the nonparticipants. This is shows in the top panel of figure 3.

6.3 Intermittent Rebalancing Experiment

Finally, in the third experiment, we replace the *crb* traders with the *irb* traders. The average risk-free rate is very similar to the *crb* case, while the equity premium and the market price of risk are slightly lower than in the *crb* case. However, the key change that results from the insertion of the *irb* traders is the much higher volatility of risk pricing. The standard deviation of the market price of risk increases to 13.6, up from 5.4%. The bottom panel of figure 3 shows that the equity share of the *irb* traders drops after low aggregate consumption growth shocks, forcing the Mertonian traders to lever up even more, as is clear from the top panel. The equity share of the average *irb* trader is highly pro-cyclical. This leads him to absorb more aggregate risk after a history of high aggregate consumption growth shocks, and less after a series of low aggregate consumption growth shocks, relative to the *crb* trader whose equity share does not vary. This in turn renders the amount of aggregate risk being absorbed by the Mertonian trader, who is on the other side of these trades, to be counter-cyclical. As a result, the price of risk has to be counter-cyclical as well to clear all securities markets. The bottom panel clearly shows how relatively small movements in the *irb* traders' average share can lead to fairly large fluctuations in the volatility of risk pricing if there many non-Mertonian traders and not very many Mertonian traders.

6.4 Relative Scarcity of Mertonian Capital

One of the key factors in generating volatility in the equity shares of Mertonian traders, and hence in the volatility of risk prices, is the small fraction of Mertonian traders in our example: only 5% of human wealth is held by Mertonian traders. To illustrate this, we increased the share of Mertonian traders in our third example from 5% to 50%, and we correspondingly reduced the share of *irb* traders to 50%. The moments of asset prices obtained in this case are reported in the last column of Table I. The volatility in the equity shares of the Mertonian traders largely disappears (not shown in Table), and as a result the volatility of the market price of risk drops to 0.72%.

7 Quantitative Results in Benchmark Economy

In our benchmark economy, we have three different types of traders. As was illustrated using these experiments, each of these serves a distinct purpose in our mechanism. The concentration of aggregate risk by non-participants allows us to match the level of risk premia while the *irb* traders impute countercyclical volatility to risk premia. We start by calibrating the size of the trader pools in section 7.1. The calibration of all other parameters is unchanged, as is the frequency of rebalancing for *irb* traders; they rebalance every three years. Importantly, aggregate consumption growth is i.i.d. and the cross-sectional variance of idiosyncratic risk is constant. Section 7.2 describes the moments of asset prices in the benchmark economy. In section 7.3 and 7.4, we document the countercyclicality of Sharpe ratios and dividend yields. Finally, section 7.5 describes the model's implications for the distribution of wealth and consumption, while 7.6.1 and 7.6.2 focus on changes in the relative supply of Mertonian and non-Mertonian capital.

7.1 Trader Pool Composition

In the most recent Survey of Consumer Finances, 51.1% of households reported owning stocks directly or indirectly. Therefore, the fraction of non-Mertonian traders with zero equity holding (non-participants) is calibrated to 50%. In order to deliver a large equity premium, a small fraction of Mertonian traders need to bear the residual aggregate risk created by non-participant. Hence, we set the share of Mertonian traders equal to 5%, and non-Mertonian traders who hold equities to 45%. These shares represent fractions of total human wealth, not financial wealth, owned by each trader type.[13] In the case with *irb* traders, the optimal target equity share of *irb* traders turns out to 41%. This will be our benchmark.

[13] Because of the homogeneity of the investor's optimization problem, we can reallocate human wealth within each trader pool without affecting equilibrium asset prices.

7.2 Moments of Asset Prices

Table II reports moments of asset prices generated by simulating data from a model with 3,000 agents for 10,000 periods, where, as before, equity is a claim to the payout process D defined in equation (3). The table considers two cases: one with 45% *crb* trader and the other with 45% *irb* trader. In the upper part of Table II, we report the maximum unconditional Sharpe ratio or market price of risk $(\frac{\sigma(m)}{E(m)})$, the standard deviation of the maximum SR $(Std(\frac{\sigma_t(m)}{E_t(m)}))$, the equity risk premium $E\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$, the standard deviation of excess returns $\sigma\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$, the Sharpe ratio on equity, the mean risk-free rate $E\left(R_{t+1,t}[1]\right)$ and the standard deviation of the risk-free rate $\sigma\left(R_{t+1,t}[1]\right)$. In the lower part of Table II, we report the standard deviation of the conditional risk premium on equity $Std\left[E_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$, the standard deviation of the conditional volatility of risk premium on equity $Std\left[\sigma_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$ and the standard deviation of the conditional SR on equity $Std\left[SR_t\right]$.

CRB In the case with *crb* traders, the maximum SR is 0.304 and the standard deviation of the maximum SR is 6.11%. The equity premium is 4.35% and the Sharpe ratio on equity is 0.29. The average risk-free rate is 2.35% and its volatility is 0.20%. Finally, we also decompose the variation in the SR on equity; the standard deviation of the conditional risk premium on equity is 0.86%, the standard deviation of the conditional volatility is 0.134% and this produces a standard deviation of the conditional SR is 6.11%.

IRB In the case with *irb* traders, the maximum SR is 0.29 and the standard deviation of the maximum SR is 14.06%. This represents a 230% increase in the volatility. The equity premium drops to 4.16% while the standard deviation of stock returns increases to 16.45%. The Sharpe ratio on equity drops to 0.25. The moments of the risk-free rate are virtually unchanged. So, while the unconditional risk premia are lower in the economy with intermittent rebalancing, the volatility of conditional risk premia triples, and the behavior of interest rates is largely unaffected.

The intermittent rebalancing behavior also increases the volatility of conditional moments on equity returns significantly. The standard deviation of the conditional risk premium increases from

0.86% to 2.19%, the standard deviation of the conditional volatility increases from 0.134 to 0.35%, and the standard deviation of the conditional SR on equity increases from 6.11% to 14.06%.

Since corporate leverage is fixed, the equilibrium equity payout process changes when we substitute *irb* for *crb* traders. However, our results are not driven by the change in the payout process. When we instead adopt the payout/output D/Y process for the *crb* case and compute the resulting *irb* equilibrium , the volatility of the market price of risk still increases to 13.36%, which is only marginally lower than the 14.06% outcome in the benchmark economy with constant corporate leverage. So, it is the nature of traders that drives our results.

To help assess the strength of our mechanism, we can use the implied standard deviation of the market price of risk in an annual calibration of the Campbell and Cochrane (1999) external habit model as a benchmark, with the same i.i.d aggregate consumption growth process as in our economy. All of the other parameters are taken directly from Campbell and Cochrane (1999). In this annual calibration of their model, the standard deviation of the market price of risk is 21%. In our benchmark economy with CRRA (constant relative risk aversion) agents, our model generates 14.06%, 1/3 less than the external habits model. However, as we will show in section 8, the volatility generated by our model increases to 25.11% if we introduce predictability in aggregate consumption growth.

Figure 5 plots a 100-year simulation of the equity share (full line) of the Mertonian trader in the case with *irb* traders in the top panel; the bottom panel shows the case with *crb* traders. The shaded areas are low aggregate consumption growth states, and the dashed line is a 4-period moving average of aggregate consumption growth. Clearly, there is much more counter-cyclical variation in the equity share of the Mertonian traders in the *irb* case, especially on the downside. This variation in the equity share of the Mertonian traders is the driving force behind our amplification mechanism.

7.3 Countercyclical Variation in Risk Prices

The variation in market price of risk created by the *irb* traders is counter-cyclical; it mirrors the variation in the active trader's equity share. Figure 6 plots the conditional Sharpe ratio on equity against the history of aggregate consumption growth shocks for the benchmark case. The shaded areas denote the low aggregate consumption growth realizations. The dotted line shows 4-period moving average of aggregate consumption growth; the full line shows the conditional Sharpe ratio.

In the *irb* case, the conditional risk premium on equity increases with each low aggregate consumption growth realization, and decreases with each high aggregate consumption growth realization. The conditional Sharpe ratio on equity is even more counter-cyclical, because the conditional volatility decreases with each negative aggregate consumption growth realization, as shown in the bottom panel of figure 7. In the data, the conditional mean and standard deviation of stock returns are negatively correlated, according to Lettau and Ludvigson (2010). Our model can replicate these dynamics.

Figure 8 shows this in a scatter plot representation of the same 100 simulations, with the weighted average of aggregate consumption growth shocks on the x-axis and the conditional Sharpe ratio. On the other hand, in the *crb* case, shown in figure 9, the conditional Sharpe ratio is only weakly counter-cyclical.

7.4 Dividend Yields

Our mechanism generates counter-cyclical variation in risk premia and dividend yields (dividend/price (Div/P) ratios). However, this variation is not persistent enough to match the behavior of the dividend yield and the predictability of stock returns over longer horizons. The failure of our model to match the persistence of the dividend yield is not surprising. In our model, most of the variation in risk premia occurs at business cycle frequencies. In the data, there is a substantial amount of variation in the price dividend ratio at lower frequencies.

The investment strategy considered here is to buy-and-hold a fixed number of shares, and receive dividends Div. Since equity payouts in our model can be negative, as in the data, we need to define a non-negative dividend process to study log dividend yields. Here, we follow Abel (1999) and we model the dividends as a levered version of aggregate consumption, with dividend growth determined by the following equation: $\Delta \log Div - E(\Delta \log Div) = \lambda [\Delta \log C - E(\Delta \log C)]$. Pricing this redundant security is straightforward. The leverage parameter λ is 3.

Table III lists the results for the benchmark economy. In the case of *irb* traders, the standard deviation of the log dividend yield is 3.27%, compared to 1.74% in the economy with *crb* traders. Still, in the data, the standard deviation of the cyclical component of the log dividend yield is 7.73% in the quarterly data (CRSP NYSE-AMEX-NASDQ 1945-2010). Figure 10 plots a time series of the dividend yield against aggregate consumption growth shocks. Importantly, the variation in dividend yields produced by our model is strongly counter-cyclical. The top panel shows the results in the case of leverage is 3. When we increase leverage to 4, the volatility of the log dividend yield increases to 4.60%, which brings us closer to the 7.73% target.

Even though our mechanism contributes a lot of volatility to risk premia, most of this variation is temporary in nature. As a result, the first-order autocorrelation coefficient of the log dividend yield actually is only 0.55 in the *irb* benchmark, down from 0.75 in the *crb* case. In the data, the autocorrelation of the log dividend yield is 0.93. However, if we allow for a structural break in the dividend yield in 1991, following Lettau and Van Nieuwerburgh (2007), the autocorrelation in the data is 0.77. As a result of this lack in persistence in risk premia and the dividend yield, our model cannot match the predictability of equity returns at longer horizons in U.S. data (see section F.1 in the separate appendix for separate results).

7.5 Portfolio, Wealth, Consumption and Welfare Costs

The first panel in Table IV reports the moments of household portfolio returns in the benchmark case. In the *irb* case, the Mertonian traders realize an excess return of 2.80% and a SR of 0.29, compared to only 2.81% and 0.26 respectively for the *irb* trader. The optimal average portfolio share for a non-Mertonian *irb* trader is only 41% (compared to 51% in the *crb* case), because the equity premium is lower.

We also evaluate the welfare cost of being a non-Mertonian *crb* or *irb* trader. This cost is measured by the percentage of consumption compensation to Mertonian traders so that they are indifference to become non-Mertonian traders. Given the optimal equity share target in each case, the welfare cost of being a non-Mertonian *irb* trader in the *irb* case is three times higher than that in the *crb* case (3.50% vs. 1.13%) because the risk premium is much more volatile and hence the cost of not responding to variation in the investment opportunity set is much larger. We also report the welfare cost of being an *irb* trader compared to a *crb* trader holding fixed the equity share target at 41%. The cost is small (0.33%) and positive: an *irb* trader would give up a 0.33% of her consumption in order to become a *crb* trader.

On the other hand, an *irb* trader –setting his target share optimally– would be willing to pay 0.55% of consumption to become a *crb* trader who can optimally choose his target. This number is the difference between 3.50% (reported as the welfare cost(%) of *irb* to z at the optimal equity share for *irb*) and 2.95% in Table IV (reported as the welfare cost(%) of *crb* to z at the optimal equity share for *crb*). This 0.55% number is the true cost of not rebalancing. It is small relative to the cost of not responding to changes in the investment opportunity set. The costs of not rebalancing are small; the costs of having a fixed equity target are large.

The second panel in Table IV reports the moments of household consumption growth, and the moments of aggregate consumption growth for each group of traders. In the *crb* case, the volatility of household consumption growth is inversely related to the degree of sophistication of the trader: 3.24% for Mertonian traders, 3.34% for the *crb* traders and 3.60% for non-participants. However, the relation between consumption volatility and trader sophistication reverses itself at the group level. The volatility for the Mertonian trader segment is 1.48%, compared to 1.22% for the non-Mertonian equity holders, and 0.72% for the non-participants. These results highlight the fact that these traders are exposed to different types of risk. Mertonian traders are more exposed to aggregate risk, and non-Mertonian traders are more subject to idiosyncratic risk.

Now, in the case of the *irb* traders, the volatility of the Mertonian trader's consumption growth (at the group level) decreases to 1.43%, while, at the household level, the volatility of household consumption growth for non-Mertonian equity holders decreases from 3.34% to 3.28%. Other than that, the second moment of consumption is very similar to *crb* case at both individual and group level. Overall, what is striking is how similar the unconditional moments are in the case of *crb* and *irb* traders, both in terms of portfolio returns and household consumption. The main quantitative difference is the increase in the volatility of household consumption growth for the non-Mertonian equity holders.

Finally, the third panel in Table IV reports the household wealth statistics. The Mertonian trader accumulates 1.35 times as much wealth as the average household in the baseline *crb* case, while the non-Mertonian trader accumulates 1.14 times as much, and the non-participant only 0.83 times the average. These fractions are virtually unchanged in the *irb* case. However, the wealth of the non-Mertonian trader (expressed as a fraction of average wealth) becomes more volatile – it increases from 18% to 28%.

Our model has reasonable cross-sectional consumption implications. In our model, Mertonian investors load up on aggregate consumption risk, earn higher portfolio return and end up richer. This is consistent with the data. The consumption of the 10% wealthiest households is 5 times more exposed to aggregate consumption growth than that of the average US household (Parker and Vissing-Jorgensen (2009)). Malloy, Moskowitz, and Vissing-Jorgensen (2009) find that the average consumption growth rate for stock-holders is between 1.4 and 2 times as volatile as that of non-stock holders. They also find that aggregate stockholder consumption growth for the wealthiest segment (upper third) is up to 3 times as sensitive to aggregate consumption growth shocks as that of non-stock holders.

7.6 Supply of Capital

Our model produces novel implications for changes in capital supplied by investors with different trading technologies. We start by considering changes in the supply of non-Mertonian capital in the form of variation in these investors' target equity shares. Next, we consider changes in the supply of Mertonian capital. Finally, we take a look at the empirical evidence in U.S. data.

7.6.1 Supply of non-Mertonian Capital

The participation of non-Mertonian traders tends to increase the volatility in risk premia. In our model, this mechanism operates in two ways: (i) as we shift non-Mertonian traders from the *crb* type to the *irb* type and (ii) as we increase the target share of equity in the non-Mertonian trader's portfolio. We discuss both of these effects below.

Table V varies the target equity share from 35% to 45%. The first panel reports result for the case when the target equity share of the non-Mertonian trader $\varpi^{\star}$ is 35%, the second panel considers the case of a 40% target share, and finally, the last panel looks at the case of 45%.

As we increase the equity holdings of the non-Mertonian equity traders from 35% to 45%, the average market price of risk, the equity premium and the Sharpe ratio all decrease. This is the standard effect of an increase in stock market participation: aggregate risk being spread out over a larger pool of investors.

But, there is non-standard volatility effect as well. Increasing the target share of equity for Non-Mertonian equity traders increases the volatility substantially, from 5.16% in the *crb* case (10.79% in the *irb* case), with 35% target equity share (see left panel of Table V), to 6.78% (15.46%) with 45% target share (see right panel of Table V). This volatility effect is new.

In sum, the more equity non-Mertonian traders hold, the higher is the volatility of risk prices. A 10 percentage point increase in the target share for equities delivers a 50% increase in the volatility of risk prices. As we increase the target equity share to 45%, the equity risk premium actually turns negative after a series of high aggregate consumption growth shocks. This explains why the volatility of the Sharpe ratio surpasses that of the market price of risk.

7.6.2 Supply of Mertonian capital

The volatility of risk premia depends critically on the size of the Mertonian trader pool. We fix the target equity share at 41%. As we grow the size of the Mertonian trader pool, the volatility of the market price of risk decreases at a fast rate. Table VI reports the conditional moments in the case of a 10% Mertonian trader pool (up from 5% in the benchmark case).

The amplification channel is still operative, but the effect is smaller. In the case with 10% Mertonian traders, the volatility of the market price of risk is 3.34%, and this number increases to 6.70% when we replace the *crb* traders with *irb* traders. In the benchmark case with only 5% Mertonian traders, these numbers were 6.11% and 14.06% respectively, as reported in Table II. So, the amplification channel has weakened considerably. The standard deviation of the conditional Sharpe ratio on equity is exactly equal to the standard deviation of the market price of risk in all cases considered.

7.6.3 Changes in the Supply of Capital to U.S. Equity Markets

Variation in the relative supply of non-Mertonian capital driven by changes in the stock market participation rate may help us to understand long-term swings in U.S. stock market volatility that seem disconnected from the underlying macro volatility. In 1927, stockholders represented 3.4-5 percent of the population. By 1930, this fraction had doubled to 7.3-8.9 percent (Source: Perlo (1958)), thus dramatically expanding the supply of slow-moving capital to U.S. equity markets. At the same time, the supply of fast-moving capital was presumably much smaller than it is today. The U.S. economy subsequently witnessed a sizeable, long-lasting increase in stock market volatility, starting in the 30's, which lasted well into the next decade. Long-term volatility, measured by an 8-year moving average of (annualized) daily stock return standard deviations shown in figure 11, peaked in 1931 at 28% per annum. Subsequently, the participation rate decreased back to 4.1 percent by 1952, while long-term volatility in the stock market fell back to 10 percent per annum. There was a second wave of increased participation starting in the 70's. In 1970, the percentage of families holding stocks was 25%. By 1989, this fraction had increased to 31.7%. After that, during the 90's, there was large uninterrupted increase to 48.9% in 1998 and 51.9% in 2000. This second, steep increase in stock market participation was followed by another increase in long-term volatility from a low of 11% in the late 80's to 18% in 2006 (Source: Direct and Indirect Holdings of Stocks in Survey of Consumer Finances), while overall macro volatility was trending down during the 90's and the first half of the 00's.

8 Quantitative Results in Mehra-Prescott Economy

In our benchmark economy, aggregate consumption growth is not predictable. This section relaxes this restriction. By allowing for additional sources of stock price volatility in the economy with *crb* traders, the amplification delivered by the switch to *irb* traders grows larger. This extension of the baseline model get us closer to our targets in the data.

Mehra and Prescott (1985) choose to match the first-order serial correlation (ρ_z) of the growth rate of U.S. per capita aggregate consumption between 1889-1978. The sample values for the U.S. economy is -0.14. When we adopt Mehra and Prescott (1985)'s calibration of the aggregate consumption growth process, the model delivers an equity premium of 7.8 % and a maximum Sharpe ratio of 0.41. More importantly, the standard deviation of the market price of risk increases to 25.11% (8.4%) in the *irb* (*crb*) case. Hence, the amplification, as we replace the *crb* traders with *irb* traders, increases from 2.3 to 3 times. Furthermore, the volatility of the log dividend yield, with leverage 3, is 6.4%, just short of our empirical target of 7.7%. When leverage is 4, the volatility of the dividend yield is 8.03%. Hence, allowing for other sources of price volatility strengthens our amplification mechanism considerably. Other sources (e.g., habit preferences, long run risks etc.) would have similar effects.

This version of the model with *irb* traders produces an equilibrium wealth distribution with fat tails (kurtosis is 4.24), while its *crb* counterpart does not (kurtosis is 3.26). Hence, intermittent re-balancing may be an additional factor contributing to wealth inequality. This deserves to be explored further.

9 Conclusion

Our paper shows that slow-moving capital supplied by intermittent portfolio re-balancers should be considered as an important contributing factor to the puzzling volatility of Sharpe ratios in equity markets. Our welfare cost calculations suggest that small costs might suffice to deter households from continuously re-balancing. However, the aggregate impact on equilibrium asset prices is large.

This makes it an appealing friction.

Secular changes in the volatility of U.S. stock returns that seem disconnected from the underlying macro volatility lend some support to the mechanism that we have uncovered. In the 30's and 90's, periods of sustained volatility in the U.S. stock market were preceded by an increase in the supply of slow-moving capital. During the 40's, 50's and 60's, which were periods of relative calm in the stock markets, the supply of slow-moving capital was much smaller. These dynamics are consistent with the predictions of our model generated by changes in the supply of non-Mertonian (subsection (7.6.1)) and Mertonian capital (subsection (7.6.2)). Gains in stock market participation, without commensurate increases in the supply of fast-moving capital, may inevitably contribute to increased stock market volatility as well as decreases in the risk premium.

References

Abel, A. B. (1999): "Risk Premia and Term Premia in General Equilibrium," *Journal of Monetary Economics*, 43, 3–33.

Abel, A. B., J. C. Eberly, and S. Panageas (2006): "Optimal Inattention to the Stock Market," *American Economic Review Papers and Proceedings*, 97(2), 244–248.

Aiyagari, S. R., A. Marcet, T. J. Sargent, and J. Seppala (2002): "Optimal Taxation Without State-Contingent Debt," *Journal of Political Economy*, 110(6), 1220–1254.

Alvarez, F., A. Atkeson, and P. J. Kehoe (2002): "Money, Interest Rates, and Exchange Rates with Endogenously Segmented Markets," *Journal of Political Economy*, 110(1), 73–112.

——— (2009): "Time-Varying Risk, Interest Rates, and Exchange Rates in General Equilibrium," *Review of Economic Studies*, 76(3), 851–878.

Alvarez, F., L. Guiso, and F. Lippi (2011): "Durable consumption and asset management with transaction and observation costs.," *American Economic Review*, forthcoming.

Alvarez, F., and U. Jermann (2001): "Quantitative Asset Pricing Implications of Endogenous Solvency Constraints," *Review of Financial Studies*, 14, 1117–1152.

Ameriks, J., and S. P. Zeldes (2004): "How do Household Portfolio Shares Vary with Age?," Working Paper Columbia University.

Baker, M., S. Nagel, and J. Wurgler (2007): "The Effects of Dividends on Consumption," *Brookings Papers on Economic Activity*, 1, 231–291.

Bansal, R., and A. Yaron (2004): "Risks for the Long Run: A Potential Resolution of Asset Prizing Puzzles," *The Journal of Finance*, 59, 1481–1509.

Barberis, N., M. Huang, and T. Santos (2001): "Prospect Theory and Asset Prices," *Quarterly Journal of Economics*, 116(1), 1–53.

Basak, S., and D. Cuoco (1998): "An Equilibrium Model with Restricted Stock Market Participation," *Review of Financial Studies*, 11(2), 309–341.

Boldrin, M., L. Christiano, and J. Fisher (2001): "Habit Persistence, Asset Returns, and the Business Cycle," *American Economic Review*, 91(1), 149–66.

Brunnermeier, M. K., and S. Nagel (2008): "Do Wealth Fluctuations Generate Time-Varying Risk Aversion? Micro-Evidence on Individuals' Asset Allocation," *American Economic Review*, 98:3, 713–736.

Calvet, L. E., J. Y. Campbell, and P. Sodini (2009): "Fight Or Flight? Portfolio Rebalancing By Individual Investors," *The Quarterly Journal of Economics*, February, 301–346.

Campbell, J. Y., and J. H. Cochrane (1999): "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior," *Journal of Political Economy*, 107(2), 205–251.

Cecchetti, S. G., P.-S. Lam, and N. C. Mark (1990): "Mean Reversion in Equilibrium Asset Prices," *American Economic Review*, Vol. 80, No. 3, 398–418.

Chan, Y. L., and L. Kogan (2002): "Catching Up With the Joneses: Heterogeneous Preferences and the Dynamics of Asset Prices," *Journal of Political Economy*, 110, 1255–1285.

Chien, Y., H. Cole, and H. Lustig (2011): "A Multiplier Approach to Understanding the Macro Implications of Household Finance," *Review of Economic Studies*, 78(1), 199–234.

Chien, Y., and H. Lustig (2010): "The Market Price of Aggregate Risk and the Wealth Distribution," *Review of Financial Studies*, 23(4), 1596–1650.

Constantinides, G. M. (1990): "Habit-formation: A Resolution of the Equity Premium Puzzle," *Journal of Political Economy*, 98, 519–543.

Cuoco, D., and H. He (2001): "Dynamic Equilibrium in Infinite Dimensional Economies with Incomplete Financial Markets," *Annals of Economics and Finance*, 2, 265–296.

Detemple, J., and S. Murthy (1997): "Equilibrium asset prices and no-arbitrage with portfolio constraints," *Review of Financial Studies*, 10, 1133–1174.

Duffie, D. (2010): "Presidential Address: Asset Price Dynamics with Slow-Moving Capital," *Journal of Finance*, 65(4), 1237–1267.

Duffie, D., and T.-S. Sun (1990): "Transactions Costs And Portfolio Choice In A Discrete-Continuous-Time Setting," *Journal of Economic Dynamics and Control*, 14, 35–51.

Gabaix, X., and D. Laibson (2002): "The 6D Bias and the Equity Premium Puzzle," *NBER Macroeconomics Annual*, pp. 257–312.

Garleanu, N., and S. Panageas (2007): "Young, Old, Conservative and Bold: The Implications of Heterogeneity and Finite Lives for Asset Pricing," *Working Paper Wharton*.

Gomes, F., and A. Michaelides (2008): "Asset Pricing with Limited Risk Sharing and Heterogeneous Agents," *Review of Financial Studies*, 21(1), 415–448.

Goyal, A., and I. Welch (2004): "A Comprehensive Look at the Empirical Performance of the Equity Premium Prediction," *Review of Financial Studies*, 21, 1455–1508.

Grossman, G., and G. Laroque (1990): "Asset Pricing and Optimal Portfolio Choice in the Presence of Illiquid Durable Consumption Goods.," *Econometrica*, 58(1), 25–51.

Guvenen, F. (2009): "A Parsimonious Macroeconomic Model for Asset Pricing," *Econometrica*, 77(6), 1711 – 1750.

Jermann, U. (1998): "Asset Pricing in Production Economies," *Journal of Monetary Economics*, pp. 257–275.

Jermann, U., and V. Quadrini (2011): "Macroeconomic effects of financial shocks," *American Economic Review*, forthcoming.

Kehoe, P. J., and F. Perri (2002): "International Business Cycles with Endogenous Incomplete Markets," *Econometrica*, 70(3), 907–928.

Krueger, D., and H. Lustig (2009): "When is Market Incompleteness Irrelevant for the Price of Aggregate Risk (and When is it Not)?," *Journal of Economic Theory*, 145(1), 1–41.

Larrain, B., and M. Yogo (2007): "Does Firm Value Move Too Much to be Justified by Subsequent Changes in Cash Flow?," *Journal of Financial Economics*.

Lettau, M., and S. C. Ludvigson (2010): "Measuring and Modeling Variation in the Risk-Return Tradeoff," in *Handbook of financial econometrics*, ed. by Y. Ait-Sahalia, and L. P. Hansen, vol. 1, pp. 618–682. North Holland.

Lettau, M., and S. Van Nieuwerburgh (2007): "Reconciling the Return Predictability Evidence," *Review of Financial Studies*, 21(4), 1607–1652, Review of Financial Studies.

Lintner, J. (1965): "Security Prices, Risk and Maximal Gains from Diversification," *Journal of Finance*, 20, 587–615.

Lustig, H., C. Sleet, and S. Yeltekin (2007): "Fiscal hedging with nominal assets," *Journal of Monetary Economics*, 55(4), 710–727.

Lynch, A. W. (1996): "Decision Frequency and Synchronization Across Agents: Implications for Aggregate Consumption and Equity Return," *The Journal of Finance*, 51(4), 1479–1497.

Malloy, C., T. Moskowitz, and A. Vissing-Jorgensen (2009): "Long-Run Stockholder Consumption Risk and Asset Returns," *Journal of Finance*, forthcoming.

Marcet, A., and R. Marimon (1999): "Recursive Contracts," Working Paper Universitat Pompeu Fabra.

Mehra, and E. Prescott (1985): "The Equity Premium: A Puzzle.," *Journal of Monetary Economics*, 15(2), 145–161.

Parker, J. A., and A. Vissing-Jorgensen (2009): "Who Bears Aggregate Fluctuations and How?," *American Economic Review: Papers and Proceedings*, 99(2), 399–405.

PERLO, V. (1958): "People's Capitalism and Stock," *American Economic Review*, 48, 333–347.

REIS, R. (2006): "Inattentive consumers," *Journal of Monetary Economics*, 53, 1761–1800.

SAITO, M. (1996): "Limited Participation and Asset Prices," *Working Paper University of British Columbia*.

SCHNEIDER, M., J. C. HATCHONDO, AND P. KRUSELL (2005): "A Quantitative Model of Competitive Asset Pricing Under Private Information," Working Paper Stanford University.

SHARPE, W. (1964): "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," *Journal of Finance*, 19, 425–444.

STORESLETTEN, K., C. TELMER, AND A. YARON (2007): "Asset Pricing with Idiosyncratic Risk and Overlapping Generations," *Review of Economic Dynamics*, 10(4), 519–548.

Table I: Moments of Asset Prices: Simple Economy

	Experiment 1	Experiment 2	Experiment 3	
target equity share ($\varpi^\star$)		25%		25%
Non-Mertonian equity holder	**crb**	**np**	**irb**	**irb**
Mertonian	5%	5%	5%	50%
Non-Mertonian ***crb***	95%	0%	0%	0%
Non-Mertonian ***irb***	0%	0%	95%	50%
Non-Mertonian ***np***	0%	95%	0%	0%
$\frac{\sigma(M)}{E(M)}$	0.1934	0.5226	0.203	0.191
$Std\left[\frac{\sigma_t(M)}{E_t(M)}\right]$	0.0157	5.399	13.630	0.716
$E\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	2.795	8.435	2.379	2.792
$\sigma\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	14.50	16.29	16.432	14.674
Sharpe Ratio	0.192	0.517	0.144	0.190
$E\left(R_{t+1,t}[1]\right)$	2.745	1.219	2.845	2.734
$\sigma\left(R_{t+1,t}[1]\right)$	0.010	0.155	0.204	0.025
$Std\left[SR_t\right]$	0.0157	5.399	13.630	0.716

Moments of annual returns. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). The target equity share is 25%. Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with $3,000$ agents and $10,000$ periods.

Table II: Moments of Asset Prices: Benchmark Economy

target equity share ($\varpi^\star$)	41%	
Non-Mertonian equity holder	**crb**	**irb**
Mertonian	5%	5%
Non-Mertonian ***crb***	45%	0%
Non-Mertonian ***irb***	0%	45%
Non-Mertonian ***np***	50%	50%
$\frac{\sigma(M)}{E(M)}$	0.304	0.296
$Std\left[\frac{\sigma_t(M)}{E_t(M)}\right]$	6.116	14.068
$E\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	4.353	4.166
$\sigma\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	14.708	16.451
Sharpe Ratio	0.296	0.253
$E\left(R_{t+1,t}[1]\right)$	2.356	2.412
$\sigma\left(R_{t+1,t}[1]\right)$	0.200	0.286
$Std\left[E_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.860	2.193
$Std\left[\sigma_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.134	0.355
$Std\left[SR_t\right]$	6.116	14.068

Moments of annual returns. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with $3,000$ agents.

Table III: Moments of Equity returns and the Dividend Yield: Benchmark Economy

Non-Mertonian equity holder	**crb**	**irb**
Mertonian	5%	5%
Non-Mertonian ***crb***	45%	0%
Non-Mertonian ***irb***	0%	45%
Non-Mertonian ***np***	50%	50%
	Leverage 3	
$E\left(R_{t+1,t}[CD] - R_{t+1,t}[1]\right)$	3.614	3.504
$\sigma\left(R_{t+1,t}[CD] - R_{t+1,t}[1]\right)$	12.169	13.653
Sharpe ratio	0.297	0.257
$\sigma\left(pd[CD]\right)$	1.737	3.268
$\rho\left(pd[CD]\right)$	0.749	0.550
	Leverage 4	
$E\left(R_{t+1,t}[CD] - R_{t+1,t}[1]\right)$	4.889	4.734
$\sigma\left(R_{t+1,t}[CD] - R_{t+1,t}[1]\right)$	16.451	18.377
Sharpe ratio	0.297	0.258
$\sigma\left(pd[CD]\right)$	2.536	4.595
$\rho\left(pd[CD]\right)$	0.750	0.551

Notes: The investment strategy is to buy-and-hold a fixed number of shares and to receive dividends with growth rate $\Delta \log Div - E(\Delta \log Div) = \lambda \left[\Delta \log C - E(\Delta \log C)\right]$. In the top panel, the leverage parameter λ is 3. In the bottom panel, the leverage parameter λ is 4. This table reports moments of annual returns conditional on history of aggregate shocks z^t. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. Results for 41% equity share non-Mertonian target ($\varpi^\star$). The results are generated by simulating an economy with $3,000$ agents and $10,000$ periods.

Table IV: Moments of Household Portfolio Returns and Consumption: Benchmark Economy

Non-Mertonian equity holder	**crb**	**irb**
Mertonian	5%	5%
Non-Mertonian ***crb***	45%	0%
Non-Mertonian ***irb***	0%	45%
Non-Mertonian ***np***	50%	50%
	Panel I: Household Portfolio	
	Excess Return	
Mertonian Trader	2.801	2.818
Non-Mertonian Equity Holder	1.788	1.684
	Sharpe Ratio	
Mertonian Trader	0.291	0.259
Non-Mertonian Equity Holder	0.297	0.245
	Additional Stats	
Optimal Equity Share for irb	0.510	0.410
Welfare cost(%) of irb to z at optimal equity share for irb	1.138	3.500
Optimal Equity Share for crb	0.680	0.560
Welfare cost(%) of crb to z at optimal equity share for crb	0.777	2.957
Welfare cost(%) of irb to crb at 41% equity share	−0.107	0.338
	Panel II Household Consumption	
	Std. Dev. at Household level	
Mertonian Trader	3.248	3.283
Non-Mertonian Equity Holder	3.345	3.285
Non-Mertonian non-participant	3.608	3.602
	Std. Dev. of Group Average	
Mertonian Trader	1.485	1.436
Non-Mertonian Equity Holder	1.228	1.252
Non-Mertonian non-participant	0.720	0.718
	Panel III: Household Wealth	
	Average Household Wealth Ratio	
Mertonian Trader	1.355	1.315
Non-Mertonian Equity Holder	1.147	1.157
Non-Mertonian non-participant	0.832	0.827
	Stdev. of Household Wealth Ratio	
Mertonian Trader	0.180	0.282
Non-Mertonian Equity Holder	0.086	0.111
Non-Mertonian non-participant	0.089	0.093
	Stdev. of Aggregate Equity Share	
Non-Mertonian Equity Holder	0.025	0.071
	Correlation of Aggregate Equity Share	
Non-Mertonian Equity Holder	0.059	0.498

Panel I reports moments of household portfolio returns, Panel II reports moments of household consumption, and Panel III reports moments of household wealth: we report the average excess returns on household portfolios and the Sharpe ratios, we report the standard deviation of household consumption growth (as a multiple of the standard deviation of aggregate consumption growth), and we report the standard deviation of group consumption growth (as a multiple of the standard deviation of aggregate consumption growth); the last panel reports the average household wealth ratio, as a share of total wealth, and the standard deviation of the household wealth ratio. Results for 41% equity share non-Mertonian target ($\varpi^\star$).The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with $3,000$ agents and $10,000$ periods.

Table V: Target Equity Shares and Moments of Asset Prices: Benchmark Economy

equity share target ($\varpi^\star$)	35%		40%		45%	
Non-Mertonian equity holder	**crb**	**irb**	**crb**	**irb**	**crb**	**irb**
Mertonian	5%	5%	5%	5%	5%	5%
Non-Mertonian ***crb***	45%	0%	45%	0%	45%	0%
Non-Mertonian ***irb***	0%	45%	0%	45%	0%	45%
Non-Mertonian ***np***	50%	50%	50%	50%	50%	50%
$\frac{\sigma(M)}{E(M)}$	0.398	0.377	0.331	0.312	0.250	0.254
$Std\left[\frac{\sigma_t(M)}{E_t(M)}\right]$	5.164	10.795	5.943	13.906	6.783	15.466
$E\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	5.844	5.670	4.797	4.512	3.531	3.156
$\sigma\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)$	14.888	15.909	14.813	16.578	14.817	17.122
Sharpe Ratio	0.393	0.356	0.324	0.272	0.238	0.184
$E\left(R_{t+1,t}[1]\right)$	1.993	2.059	2.249	2.332	2.556	2.654
$\sigma\left(R_{t+1,t}[1]\right)$	0.147	0.227	0.183	0.257	0.215	0.304
$Std\left[E_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.722	1.677	0.839	2.201	0.964	2.622
$Std\left[\sigma_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.133	0.130	0.131	0.301	0.169	0.638
$Std\left[SR_t\right]$	5.164	10.795	5.944	13.906	6.783	16.275
$Std[\log(e)](\%)$	0.069	0.069	0.059	0.071	0.066	0.086

This table reports moments of annual returns. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents and 10,000 periods.

Table VI: Conditional Moments and size of Mertonian Trader Pool: Benchmark Economy

Non-Mertonian equity holder	**crb**	**irb**
Mertonian	10%	10%
Non-Mertonian ***crb***	40%	0%
Non-Mertonian ***irb***	0%	40%
Non-Mertonian ***np***	50%	50%
$\frac{\sigma(m)}{E(m)}$	0.284	0.271
$Std\left[\frac{\sigma_t(M)}{E_t(M)}\right]$	3.337	6.696
$Std\left[E_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.458	0.972
$Std\left[\sigma_t\left(R_{t+1,t}[D] - R_{t+1,t}[1]\right)\right]$	0.130	0.212
$Std\left[SR_t\right]$	3.337	6.696

This table reports moments of annual returns conditional on history of aggregate shocks z^t. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. Results for 41% equity share non-Mertonian target ($\varpi^\star$). The results are generated by simulating an economy with 3,000 agents of each types and 10,000 periods.

Figure 1: Business Cycle Variation in log Dividend Yield.

Filtered log dividend yield in deviation from the mean plotted against NBER recessions (shaded areas). Quarterly data from CRSP VW index for AMEX-NASDAQ-NYSE. We applied a Baxter-King bandpass filter that returns component with periods between 1.5 and 8 yrs assuming no drift and no unit root. We used $K = 8$ lags.

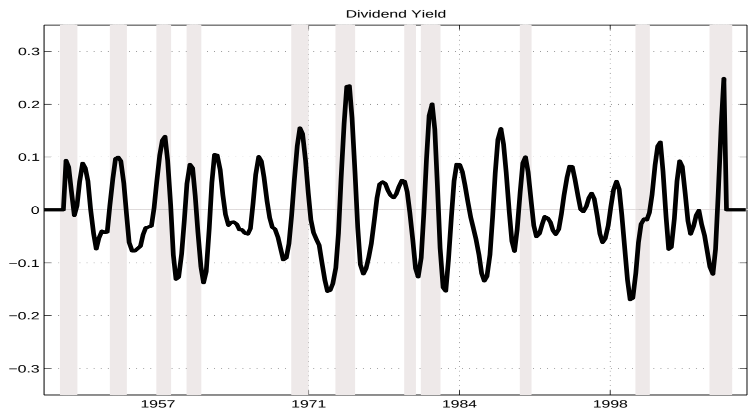

Figure 2: Business Cycle Variation in Payouts of Publicly Traded Firms to U.S. Shareholders.

The full line plots the filtered annualized net payouts to shareholders scaled by aggregate national income (current dollars). The dashed line plots dividends dividend by national income. The top panel uses quarterly data from CRSP VW index for AMEX-NASDAQ-NYSE. The bottom panel uses quarterly data from the Flow of Funds. National income data from BEA Table 1.12. Net payouts is defined as cash dividends minus net issuance. We applied a Baxter-King bandpass filter that returns the component with periods between 1.5 and 8 yrs assuming no drift and no unit root. We used $K = 8$ lags.

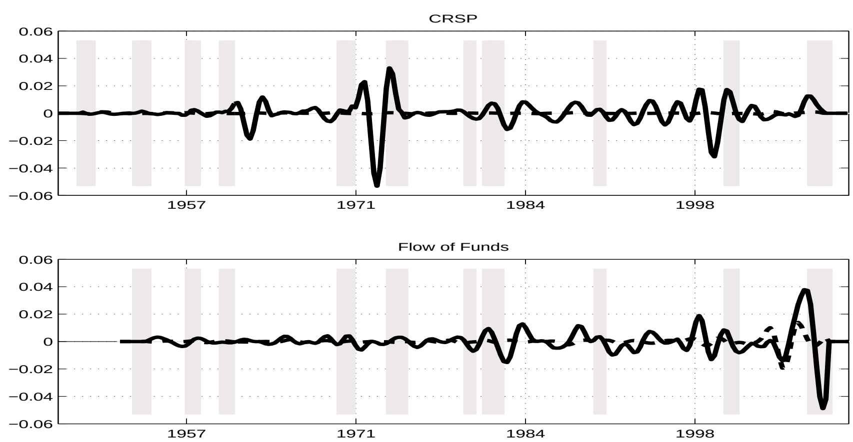

Figure 3: Equity Shares of Mertonian and Non-Mertonian Traders: Simple Economy

Results for three experiments in simple economy. The top panel shows the equity shares of the Mertonian traders for experiment (1)-(3). The bottom panel shows the equity shares of the non-Mertonian traders. This calibration has 5% Mertonian traders and 95% non-Mertonian traders. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents.

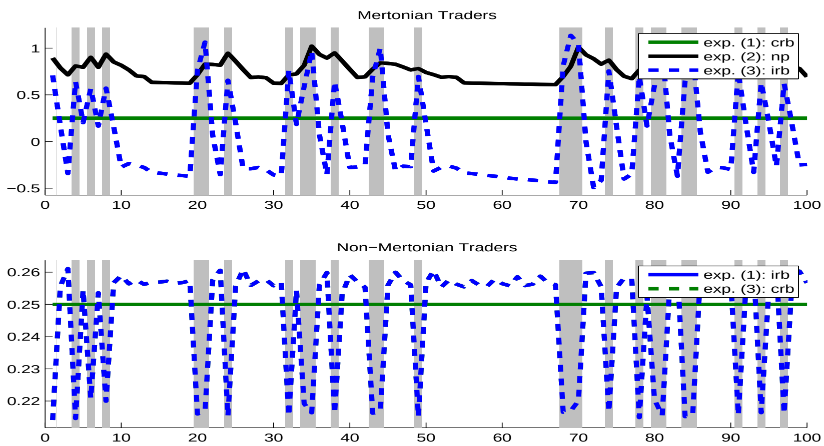

Figure 4: The Supply of Mertonian Capital and Equity Shares of Mertonian Traders: Simple Economy

Results for three experiments in simple economy. The panel shows the equity shares of the Mertonian traders for the case of 5% Mertonian traders and 95% non-Mertonian traders (experiment (iii)), and the case of 50% z-complete traders and 50% non-Mertonian traders. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Storesletten, Telmer, and Yaron (2007) calibration of idiosyncratic shocks without CCV; Alvarez and Jermann (2001) calibration of aggregate consumption growth shocks. The target equity share is 25%. Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents.

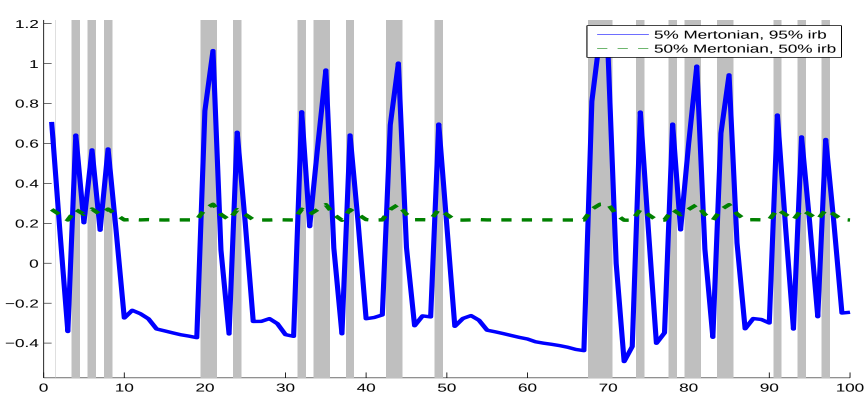

Figure 5: Equity Share of Mertonian Trader: Benchmark Economy

The full line shows the equity share for the Mertonian trader (axis on the left hand side). The dashed line is a 4-period moving average of aggregate consumption growth with linearly decreasing weights. This calibration has 50% non-participants, 5% Mertonian and 45% either *crb* or *irb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with $3,000$ agents.

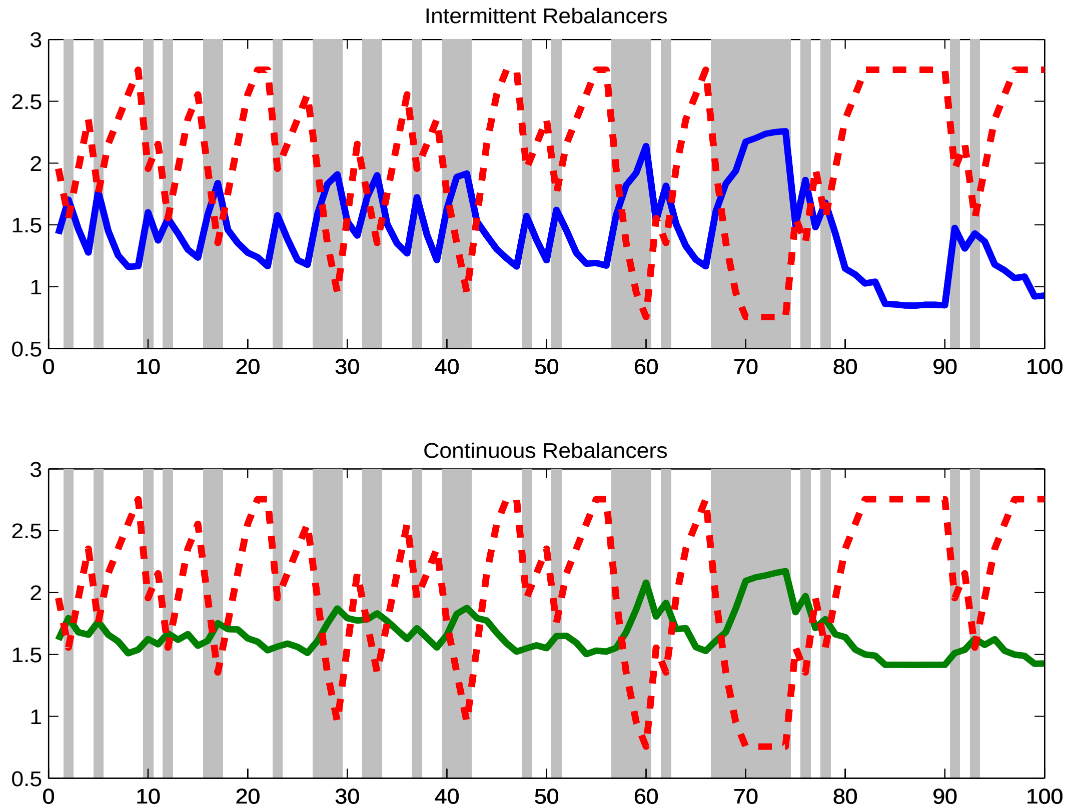

Figure 6: Conditional Sharpe Ratio: Benchmark Economy

The full line is the conditional Sharpe ratio (on the left hand side axis). The dashed line is a 4-period moving average of aggregate consumption growth with linearly decreasing weights. This calibration has 50% non-participants, 5% Mertonian and 45% either in *crb* or *irb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents and 10,000 periods.

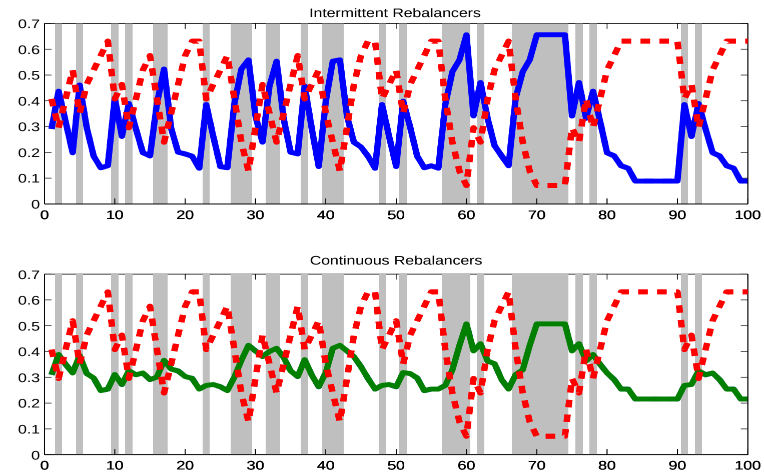

Figure 7: Conditional Expected Excess return and Volatility with IRB Traders: Benchmark Economy.

The full line in the top panel is the conditional expected excess return (on the left hand side axis). The full line in the bottom panel is the conditional standard deviation (on the left hand axis). The dashed line is a 4-period moving average of aggregate consumption growth with linearly decreasing weights. This calibration has 50% non-participants, 5% Mertonian and 45% *irb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents and 10,000 periods.

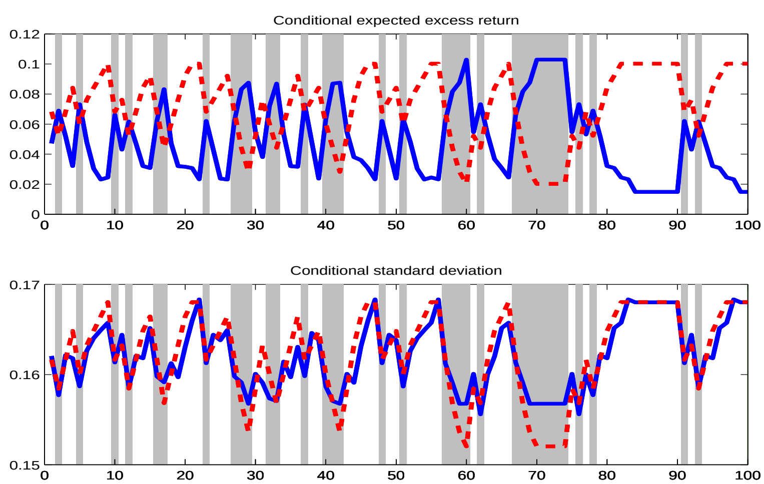

Figure 8: Conditional Sharpe Ratio: Benchmark Economy with *irb* Non-Mertonian Traders.

Scatter plot of the 100 data points in figure 6. On the x-axis is a 4-period moving average of aggregate consumption growth with linearly decreasing weights. On the y-axis is the conditional expected excess return on equity. This calibration has 50% non-participants, 5% complete and 45% *irb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents.

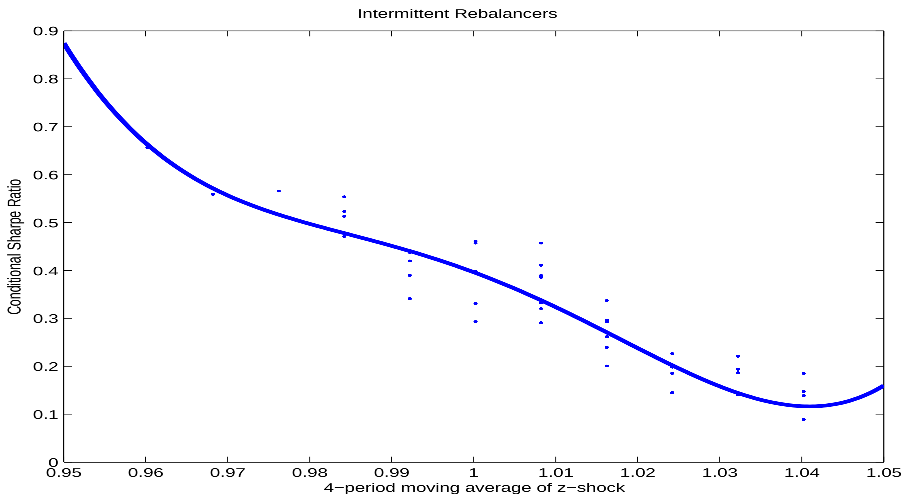

Figure 9: Conditional Sharpe Ratio: Benchmark Economy with *crb* Non-Mertonian Traders.

Scatter plot of the 100 data points in figure 6. On the x-axis is a 4-period moving average of aggregate consumption growth with linearly decreasing weights. On the y-axis is the conditional expected excess return on equity. This calibration has 50% non-participants, 5% complete and 45 % *crb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with 3,000 agents.

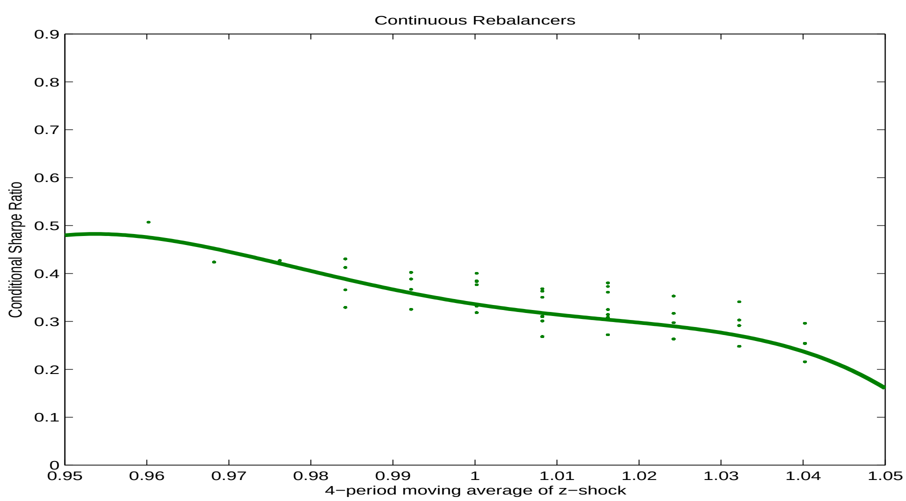

Figure 10: Log Dividend Yield: Benchmark Economy

The investment strategy is to buy-and-hold a fixed number of shares and to receive dividends with growth rate $\Delta \log Div - E(\Delta \log Div) = \lambda [\Delta \log C - E(\Delta \log C)]$. In the top (bottom) panel, the leverage parameter λ is 3 (4). On the y-axis is the demeaned log of the dividend yield. This calibration has 50% non-participants, 5% complete and 45% *crb* traders. The target equity share is 41%. The *irb* traders re-balance every three periods in a staggered fashion (1/3 each year). Parameters: $\alpha = 5$, $\beta = 0.95$, collateralized share of income is 10%. The results are generated by simulating an economy with $3,000$ agents.

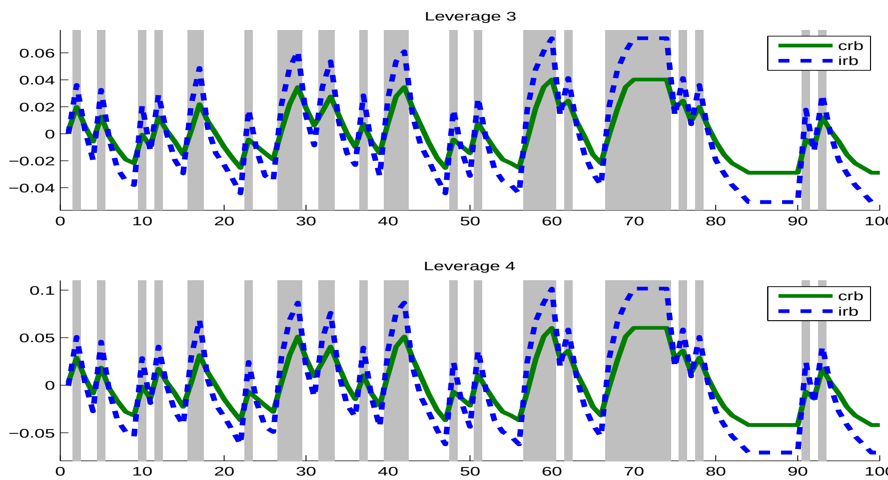

Figure 11: Low-Frequency Variation in U.S. Stock Market Volatility.

8-year Moving Average of Annualized Standard Deviation of Daily Stock Return Volatility. We compute the following measure of annual stock market volatility: $Vol_t = \sum_{i=t-249}^{t} (r_i - \overline{r})^2 \div 250$. The figure plots an 8-year moving average of Vol_t. Daily Stock Return data from CRSP value-weighted index for AMEX-NASDAQ-NYSE (1925-2010).