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Multigoal-Based Asset Allocation Model in Family Wealth Management

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By introducing the concept of mental accounts in behavioral finance, according to the multigoal-based asset allocation principle, the family should allocate assets to three categories: personal risk category that does not harm basic living standards, market risk category that maintains lifestyle, and aspirational risk category that enhances lifestyle. A rigorous risk-test questionnaire is designed to assess the specific types of risk preferred by family investors (conservative/moderate/aggressive), and the allocation weights of the three categories of assets are entered as constraints into the extended MV model. Then, taking the expected return and standard deviation, as well as the covariance matrix (obtained by the correlation coefficient matrix) of various risky assets as input conditions, and using the optimization toolbox in MATLAB for quadratic programming, the optimal portfolio of financial assets can be obtained according to the specific risk preference of family. After subtracting the entire wealth of family from the necessary non-financial asset allocation, the remaining assets are allocated to the categories suggested by the optimal solution.

Keywords: Family Wealth Management, Mental Accounts, Multigoal-Based Asset Allocation, Modern Portfolio Theory

1. INTRODUCTION

Asset allocation is one of the most important decisions in family wealth management. For a longtime, the most commonly used asset allocation framework has been based on modern portfolio theory (MPT). The theory was founded by Markowitz (1952), also known as the Mean-Variance (MV) model, which is based on the assumptions that the market is effective, the asset correlation remains the same under variable time windows, and the rational man. MPT believes that investors can either achieve the highest return at a given risk level or achieve the lowest risk at a given return. According to MPT, the basic way for families to manage their wealth is to diversify and allocate assets to different asset categories. Despite the popularity of MPT, it has been questioned in recent years, especially during the financial crisis in 2008, where it was shown to be vulnerable. In worst-case circumstances, MPT fails to explain the extreme volatility of security prices. The standard deviation of asset return volatility is several times higher than in the past. Some asset returns even have negative values, and there is an unexpectedly high correlation between different asset classes (asset prices all fall). The diversified investment strategy did not seem to work, and it was thought that the highly liquid investment strategy lost its liquidity. Wealthy families began to re-examine their long-term asset allocation framework and strategy.

Das, Markowitz, Scheid and Statman (2010) proposed in the article "Portfolio Optimization with Mental Accounts" that the mental account process (i.e. multigoal-based process) is as effective as the mean-variance process. By creating separate sub-portfolios for each goal, it does not actually result in sub-optimal returns, provided that the definition of risk is changed from "volatility of return" to "probability of target failure". Risk should not be mathematically defined as the standard deviation of return, but the probability that the goal cannot be achieved. This is the way most people intuitively define risk.

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Nevins (2004) combines MPT with behavioral considered as a finance theory to improve the family wealth management process. The reference They focuses on risk measurement, emphasizing the importance of knowing investor preferences and goals. The and proposes that different estimations of risk tolerance should be introduced for each goal of the family, rather than estimating the overall risk tolerance for the whole family. Better results can be achieved by linking a single strategy to one or more specific goals. Chhabra (2005) attempts to extend the traditional MV framework by introducing personal risk and aspirational goals. The new asset allocation framework enables family investors to allocate all of their assets to establish appropriate portfolios. The resulting portfolio is designed to meet all the needs and preferences of family investors and protect the family from personal, market and aspirational risk factors. Pompian (2011) applies the most prominent investor bias knowledge to the "behavior change" asset allocation decision, showing how to create an investment strategy that uses the latest cutting-edge research to analyze investor behavior bias and how to mitigate or adapt to behavioral biases to improve investment outcomes and determine the "best portfolio allocation in practice" of family wealth.

The global financial crisis, the failure of MPT, and the application of behavioral finance in asset portfolios have produced a new asset-allocation model that introduces a multigoal-based strategic asset allocation framework for family wealth management. In this paper, we first introduce the optimal portfolio model under multigoal-based decision making. By applying the concept of mental accounts in behavioral finance, according to the multigoal-based asset allocation principle, the family should allocate assets to three categories: personal risk category that does not harm basic living standards, market risk category that maintains lifestyle, and aspirational risk category that enhances lifestyle. By designing a rigorous questionnaire of risk test to assess the specific risk preference types of family investors (conservative/moderate/aggressive), the allocation weights of the three categories of assets are entered as constraints into the extended MV model. Then, taking the expected return and standard deviation, as well as the covariance matrix (obtained by the correlation coefficient matrix) of various risky assets as input conditions, and using the optimization toolbox in MATLAB for quadratic programming, the optimal portfolio of financial asset can be obtained according to the specific risk preferences of the family. After subtracting the entire wealth of family from the necessary non-financial asset allocation, the remaining wealth can be used to allocate financial assets according to the optimal solution.

2. METHODOLOGY

2.1 Multigoal-Based Asset Allocation

Every wealthy family faces an investment problem: choosing the kind of asset portfolio that is most likely to achieve the family's goals, including the preservation and appreciation of wealth, providing basic protection for the lifestyles of family members, maintaining a fund for accident prevention, passing on wealth inheritance to family members of different generations, starting new businesses, family philanthropy and impact investment. Over the past decade, many families have fallen prey to the chaos and frustration of investment because of the over simplified assumptions of the MV model. One of the results is are focus on the family's goals and using them as the core determinants of investment strategy and risk control. Based on the experience of recent years and the research results of behavioral finance, this paper introduces a multigoal-based wealth management model, modifies the asset allocation method, and strives to achieve the goals of family investors in a manner consistent with market reality.

We use a categorical approach to introduce a multigoal-based asset allocation model according to the concept of a mental account in behavioral finance. The family actually divides its goals into different categories. In this case, it is obviously not possible to manage all the family wealth by having a single-asset portfolio.

The family should establish specific sub-portfolios of assets for each goal. Multiple strategies should be developed. Each strategy is linked to a specific goal. Instead of trying to determine the overall risk tolerance of family investors, they should measure and manage the risk preference for this goal. Figure 1 shows the difference between the multigoal-based asset allocation process and the traditional asset allocation process. The process is based on multi-goal asset allocation that links the family investor's goals with the corresponding risk management and investment strategies. Investors' goals are based on the reason for having the portfolio, such as maintaining current and future living standards. Risk management is based on risk measures that are consistent with specific goals. Investment strategy is based on the goals and accompanying risk management. Each combination of goals, risks, and strategies can form a separate sub-portfolio of assets, and all sub-portfolios of assets combine to form the total portfolio.

In this paper, we employ Chhabra's (2005) wealth allocation framework to help wealthy families identify risks with different characteristics and priorities. Family should allocate assets to the three general categories described below, based on their own needs and the ability of each asset to achieve family goals at an appropriate level of risk.

Personal Risk: This assets category is intended to reassure families that their standard of living is safeguarded. The value of assets in this category is relatively stable and can be guaranteed. The wealth allocated to this category generally does not suffer significant losses, but the return is below the market level average.

Market Risk: This assets category allows families to maintain their current lifestyles while despite increases in spending and inflation. Assets in this category are designed to balance risk and return, and the return earned is above the inflation level. A very diversified portfolio of assets is often established here (this category corresponds to Markowitz's MPT framework).

Aspirational Risk: This assets category gives families the opportunity to significantly increase their wealth and

Figure 1 The difference between multigoal-based asset allocation process and traditional asset allocation process.

Table 1 Asset classification strategies based on different goals and risks.

Personal Risk **Ensure Basic Living Standards** **Protective Assets**	**Market Risk** **Maintain Existing Lifestyles** **Market Assets**	**Aspirational Risk** **Improve Living Standards** **Aspirational Assets**
Cash	Stock	Private Equity
Bank Deposit	Corporate Bond	Hedge Fund
Bank Financing	Funds	Foreign Exchange
National Debt	Commodities	Precious Metals
Insurance		Derivatives
Primary Residence		Investment Real Estate
Family Trust		Family Charity Fund

achieve their goals and aspirations. Assets in this category are designed to provide a return above the market average to help the family improve their standard of living, but it is also accompanied by greater risks.

2.2 Model Construction

Markowitz's MV has two basic models: one is used to maximize the return of a given risk, and the other is used to minimize the risk of a given return. The former is for investors who have no preferences in terms of risk. They care only about the expected return on investments, as long as it is the maximum regardless of the risk; the second model applies to investors who care only about the investment risk, as long as this risk is minimal regardless of the expected return. It can be seen that the traditional Markowitz portfolio selection model is based on the programming of these two goals, often to fix one and optimize the other. Obviously, these are two ideal states that do not meet the actual family wealth management situation. This paper will employ a multigoal-based decision-making approach, taking into account these two goals simultaneously, and will establish a multigoal-based portfolio model:

$$\max \mathrm{E}(\mathrm{R}_p) = \sum_{i=1}^{n} w_i E(R_i)$$

$$\min \sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_{ij}$$

$$s.t. \begin{cases} \sum_{i=1}^{n} w_i = 1 (i, j = 1, 2, \ldots, n) \\ w_i \geq 0 \end{cases} \quad (1)$$

or

$$\max \mathrm{E}(\mathrm{R}_p) = \sum_{i=1}^{n} w_i E(R_i)$$

$$\max(-\sigma_p^2) = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_{ij}$$

$$s.t. \begin{cases} \sum_{i=1}^{n} w_i = 1 (i, j = 1, 2, \ldots, n) \\ w_i \geq 0 \end{cases} \quad (2)$$

Family investors want both goals to be achieved simultaneously: the expected return of portfolio and the inverse variance of the portfolio are as large as possible, which creates a multigoal problem. In the multi goal programming problem, the weight coefficient of each goal can generally be used to reflect the relative importance of each goal. The more important goal, the greater is the corresponding weight coefficient.

This paper introduces parameter $\alpha (0 \leqslant \alpha \leq 1)$ to construct the objective function of the goal-weighting problem into a comprehensive utility function for the family investor:

$$\mathrm{U}(w) = \alpha \mathrm{E}(\mathrm{R}_\mathrm{p} + (1 + \alpha)(-\sigma_p^2) \quad (3)$$

Table 2 Objective risk tolerance questionnaire for family investor.

No.	Item/Score		1	2	3	4
1	Age		<20 or >60	21∼30	31∼50	51∼60
2	Sex	**Please ask the family customer to tick the specific situation for each row.**		Female	Male	
3	Asset Size		less than 10m	10m∼100m	100m∼1b	more than 1b
4	Family Generations		4g	3g	2g	1g
5	Liabilities		Large	Medium	Small	None
6	Tax Burden		Large	Medium	Small	None
7	Family Business		Exist + financial dilemma	Exist	Willing	None
8	Insurance			Need	No Need	
9	Family Charity			No Need	Need	
10	Children's Education			Need	No Need	

Note: The standardization process of the objective risk measurement: Score(obj.)=(ΣScore-minΣScore)/(maxΣScore-minΣScore).

Therefore, the multigoal programming problem is transformed into a maximization problem of comprehensive utility under weight α:

$$\max \mathrm{U}(w) = \alpha \sum_{i=1}^{n} w_i \mathrm{E}(\mathrm{R_p}) + (1-\alpha)\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \sigma_{ij}\right)$$
$$s.t. \begin{cases} \sum_{i=1}^{n} w_i = 1 (i, j = 1, 2, \ldots, n) \\ w_i \geq 0 \end{cases} \quad (4)$$

Through this transformation, the multigoal linear programming problem can be solved by the single-objective linear programming optimal solution. When α=0, this indicates that family investors are concerned only with risks; while $\alpha = 1$ indicates that family investors care only about the expected return. Of these, the weight can represent the family investor risk tolerance (risk preference), which is a trade-off between the family investor's assessment of risk and return. The bigger the α, the more attention the family investors will pay to the positive effect brought by return, the smaller the α, the more attention the family investors pay to the negative effect brought by risk.

2.3 Process

2.3.1 Risk Preference Assessment of Family Investors

This paper uses the Risk Tolerance Questionnaire to assess the willingness of family investors to take risks. The wealth allocation framework balances the financial ability of investors to take risks (objective risk measures) and the desire of investors to avoid risks (subjective risk measures). The questionnaire does this by including a disclosure of the personal and aspirational goals, risk preference and financial situation of the investor. According to Statman (2004), in order to design a suitable portfolio for a wealthy family, the design of a risk tolerance questionnaire should be fully considered prior to portfolio construction. For more information on identifying investor risk and return preferences, see Sharpe (2001). Based on the previously mentioned wealth allocation framework of Chhabra (2005), according to the multigoal-based asset allocation principle, the family should allocate assets to: the personal risk category that does not jeopardize basic living standards, market risk category that maintains lifestyle, and the aspirational risk category that enhances lifestyle.

2.3.2 Evaluating Risk Preference of Family Investors

After administering a rigorous risk test to the family investor, we can obtain two standardized scores Score(obj.) and Score(sub.) based on the objective risk measure and the subjective risk measure through the standardization process. After a simple arithmetic average of these two standardized scores, we can obtain the comprehensive risk preference score of the family investor. When the score of the family investor's comprehensive risk preference test is below 0.33 (1/3), we believe that the risk preference of the family investor is conservative; when the score of family investor's comprehensive risk preference is above 0.67 (2/3), the risk preference of family investor is aggressive; when the score of family investor's comprehensive risk preference is between 0.33 and 0.67 (1/3∼2/3), the risk preference of family investor is moderate. For different types of family investors, we define the allocation boundaries for the three general categories of assets in accordance with Chhabra's (2005) wealth allocation framework shown below in Table 4.

2.3.3 Linear Programming Based on Portfolios of General Assets

After determining the specific risk preference types of family investors (i.e., conservative/moderate/aggressive), we input the allocation weight boundaries of the three categories of assets as constraints to the extended MV model, and then the yields of various risk assets. With the standard deviation and the covariance between the various risky assets (obtained by the correlation coefficient matrix) as input conditions, the optimization toolbox in MATLAB can solve this quadratic programming problem. That is to say, under certain risk preference parameters, the optimal portfolio can be obtained.

Table 3 Subjective risk tolerance questionnaire for family investor.

No.	Item/Score	Range		
1	Different types of asset allocation preference (A + B + C = 100)	Low Risk/Low Return A*1	Mid Risk/Mid Return B*2	High Risk/High Return C*3
2	The maximum loss ratio of the portfolio value	D∈[0, 50]	D> 50 treated as 50	
3	Average annual return on investment expected in the next decade	E∈[1, 3]	E> 3 treated as 3	

Note: The standardization process of the subjective risk measurement: Score 1 = $((A * 1 + B * 2 + C * 3) - 100)/(300 - 100)$; Score 2 = D/50; Score 3 = $(E - 1)/(3 - 1)$; Score(sub.) = (Score1 + Score2 + Score3)/3.

Table 4 General asset allocation framework for family investors with different risk preference types.

	General Assets		
Family Investor's Risk Preference	**Personal Risk Ensure Basic Living Standards Protective Assets**	**Market Risk Maintain Existing Lifestyles Market Assets**	**Aspirational Risk Improve Living Standards Aspirational Assets**
Conservative	40%–70%	30%–50%	0%–10%
Moderate	30%–60%	40%–60%	0%–10%
Aggressive	20%–40%	50%–70%	10%–20%

3. RESULTS

3.1 Asset Return and Risk Computation

At present, the goals of the wealthy family mainly relate to asset preservation and inheritance, asset appreciation and allocation, tax planning, insurance and pension, children's education, and family charity arrangements. According to the specific risk preference types and planning goals of family investors, we can prioritize the asset allocation of some personal and aspirational risk categories. For the remaining assets, we use the extended Markowitz for portfolio optimization. The common tools of financial management include bank savings, fixed income, stocks, funds, real estate, and gold. Based on the pool of financial assets commonly used in family offices, and data availability, this paper selects 10 commonly-used financial instruments as risky asset portfolios, such as bonds, China A-shares, US stocks, Hong Kong stocks, emerging market stocks, funds, real estate, commodities, foreign exchange and gold. We choose bank savings as the main risk-free asset allocation. This paper uses annual data ranging from 2002 to 2018. A one-year interest rate of bank deposit benchmark is used to measure the bank deposit market. If there is any adjustment in the middle of the year, the time-weighted method is used to obtain the annual average value; the annual yield of the CSI Universal Bond Index is used to measure the bond market; the annual return of the Shanghai Composite Index is used to measure the China A-shares market; the annual return of the Standard & Poor's 500 Index is used to measure the US stock market; the annual return of the market value of Chinese companies (H shares) listed on the main board of the Hong Kong Stock Exchange is used to measure the Hong Kong stock market; the annual return of the MSCI Emerging Markets Index is used to measure the emerging stock market; the weighted average of the annual return of the SSE Fund Index and the SZSE Fund Index is used to measure the fund market; the annual return calculated from the average annual sales price of commercial housing is used to measure the real estate market; the annual return of the South China Commodity Futures Composite Index is used to measure the bulk commodity market; the annual return on the real effective exchange rate index of the RMB is used to measure the foreign exchange market; the gold price offered by the World Bank (US dollar/ounce) is used to measure the gold market. All the return data and related descriptive statistics for 10 assets are normalized as shown in the following table:

3.2 Efficient Frontier of Risky Assets

According to the annual return data of each risky asset, the expected return and standard deviation of ten kinds of risky financial assets can be calculated, and then the correlation coefficient matrix and covariance matrix of ten kinds of risky financial assets can be calculated by MATLAB.

The aim of the family investor is to maximize the utility objective function (equation 4), which is a trade-off between the family investor's assessment of risk and return. We calculate the asset allocation in the portfolio according to the risk-return optimal principle, and divide the entire financial portfolio into two parts: risk-free and risky assets. The risky

Table 5 The return data and related descriptive statistics for all assets.

Year	Bonds	A-shares	US Stocks	HK Stocks	Emerging Market	Fund	Real Estate	Commodities	FX	Gold
2002	3.74%	−15.75%	−23.80%	18.65%	−9.09%	−19.22%	3.69%	5.17%	−8.09%	17.91%
2003	0.92%	13.36%	22.32%	186.05%	42.29%	11.68%	4.84%	45.21%	−5.81%	14.04%
2004	−2.64%	−16.52%	9.33%	21.96%	13.12%	−16.07%	15.04%	9.43%	−4.63%	6.84%
2005	10.75%	−6.58%	3.84%	181.91%	31.51%	0.30%	16.72%	21.47%	5.76%	20.30%
2006	2.65%	126.55%	11.78%	127.36%	22.13%	151.13%	6.29%	4.71%	−0.37%	14.54%
2007	−1.84%	93.74%	3.65%	60.29%	30.38%	142.83%	14.77%	13.07%	2.08%	27.26%
2008	14.83%	−65.47%	−37.58%	−31.59%	−47.25%	−49.93%	−1.65%	−34.85%	11.79%	−8.26%
2009	−1.41%	74.25%	19.67%	89.88%	58.32%	81.18%	23.18%	56.52%	−7.22%	32.15%
2010	1.92%	−13.43%	11.00%	23.24%	11.69%	8.82%	7.50%	11.39%	3.55%	24.38%
2011	5.57%	−22.90%	−1.12%	−20.23%	−15.55%	−23.57%	6.46%	−17.52%	6.16%	20.55%
2012	2.51%	4.60%	11.68%	5.13%	13.86%	9.15%	8.10%	4.03%	0.42%	1.86%
2013	−2.05%	−7.07%	26.39%	−6.18%	−0.78%	3.53%	7.70%	−12.52%	6.22%	−26.94%
2014	11.28%	53.35%	12.39%	26.59%	3.36%	34.12%	1.39%	−16.76%	3.73%	−3.51%
2015	7.98%	5.63%	−0.69%	−8.20%	−8.09%	17.78%	7.41%	−13.52%	2.22%	−13.99%
2016	1.48%	−5.84%	11.24%	19.91%	7.11%	1.51%	10.06%	53.13%	−5.07%	5.41%
2017	−1.07%	5.46%	18.42%	23.55%	27.82%	2.14%	5.56%	8.85%	−1.22%	6.07%
2018	9.59%	−25.52%	−7.01%	−24.61%	−12.18%	−22.89%	10.71%	−6.88%	−1.79%	−6.08%
Exp(Ret)	**3.78%**	**11.64%**	**5.38%**	**40.81%**	**9.92%**	**19.56%**	**8.69%**	**7.70%**	**0.46%**	**7.79%**
Std.Dev.	**5.35%**	**48.35%**	**16.30%**	**67.32%**	**25.04%**	**55.52%**	**6.03%**	**25.29%**	**5.50%**	**15.92%**

Table 6 Correlation coefficient matrix of risky financial assets.

	Bonds	A-shares	US Stocks	HK Stocks	Emerging Market	Fund	Real Estate	Commodities	FX	Gold
Bonds	1									
A-shares	−0.3556	1								
US Stocks	−0.6475	0.4599	1							
HK Stocks	−0.1543	0.4858	0.3928	1						
Emerging Market	−0.6054	0.6307	0.7357	0.7467	1					
Fund	−0.3741	0.9686	0.3803	0.4480	0.5782	1				
Real Estate	−0.4375	0.3183	0.3823	0.3416	0.6542	0.3467	1			
Commodities	−0.5398	0.3219	0.5077	0.6117	0.7937	0.2928	0.6086	1		
FX	0.5419	−0.2611	−0.2807	−0.2745	−0.5254	−0.1660	−0.3663	−0.7102	1	
Gold	−0.2835	0.3841	0.0643	0.5117	0.5731	0.4016	0.4650	0.5634	−0.3577	1

Table 7 Covariance matrix of risky financial assets.

	Bonds	A-shares	US Stocks	HK Stocks	Emerging Market	Fund	Real Estate	Commodities	FX	Gold
Bonds	0.0029	−0.0092	−0.0057	−0.0056	−0.0081	−0.0111	−0.0014	−0.0073	0.0016	−0.0024
A-shares	−0.0092	0.2338	0.0362	0.1581	0.0764	0.2601	0.0093	0.0394	−0.0069	0.0296
US Stocks	−0.0057	0.0362	0.0266	0.0431	0.0300	0.0344	0.0038	0.0209	−0.0025	0.0017
HK Stocks	−0.0056	0.1581	0.0431	0.4532	0.1258	0.1674	0.0139	0.1042	−0.0102	0.0548
Emerging Market	−0.0081	0.0764	0.0300	0.1258	0.0627	0.0804	0.0099	0.0503	−0.0072	0.0228
Fund	−0.0111	0.2601	0.0344	0.1674	0.0804	0.3083	0.0116	0.0411	−0.0051	0.0355
Real Estate	−0.0014	0.0093	0.0038	0.0139	0.0099	0.0116	0.0036	0.0093	−0.0012	0.0045
Commodities	−0.0073	0.0394	0.0209	0.1042	0.0503	0.0411	0.0093	0.0640	−0.0099	0.0227
FX	0.0016	−0.0069	−0.0025	−0.0102	−0.0072	−0.0051	−0.0012	−0.0099	0.0030	−0.0031
Gold	−0.0024	0.0296	0.0017	0.0548	0.0228	0.0355	0.0045	0.0227	−0.0031	0.0254

Table 8 Case study: the results of risk questionnaire for family investor

No.	Item/Score	1	2	3	4	Score	Norm. Value
1	**Age**				51∼60	**4**	
2	**Sex**			Male		**3**	
3	**Asset Size**			100m∼1b		**3**	
4	**Family Generations**		3g			**2**	
5	**Liabilities**		Medium			**2**	
6	**Tax Burden**		Medium			**2**	
7	**Family Business**	Exist + financial dilemma				**1**	
8	**Insurance**		Need			**2**	
9	**Family Charity**			Need		**3**	
10	**Children's Education**		Need			**2**	
Total						**24**	**0.5714**

No.	Item/Score	Range			Score	Norm. Value
1	**User Preferences**	40*1	50*2	10*3	**170**	0.35
2	**Maximum Loss Ratio**	15			**15**	0.3
3	**Annual Expected Return**	2			**2**	0.5
Total						**0.3833**
Risk Preference						**0.4774**
Risk aversion coefficient						**12.2619**

Note: objective risk preference score $= 4+3+3+2+2+2+2+3+2 = 24$, after standardization $= (24-8)/(36-8) = 0.5714$; subjective risk preference score consists of three parts: score1 $= ((40*1+50*2+10*3)-100)/(300-100) = 0.35$, score2 $= 30/50 = 0.3$, score3 $= (2-1)/(3-1) = 0.5$. The arithmetic average of these three parts is obtained: subjective score$= (0.35+0.3+0.5)/3 = 0.3833$; the overall risk preference score of the family customer is $(0.57+0.72)/2 = 0.4774$, and the corresponding risk aversion coefficient A$= 60 - 100 * 0.4774 = 12.2619$.

Table 9 Family financial asset portfolio allocation (moderate risk preference).

Portfolio return	Portfolio Std. Dev.	Bank Savings	Bonds	US Stocks	HK Stocks	Fund	Real Estate
5.46%	**6.05%**	45.22%	27.39%	14.54%	5.82%	1.56%	5.48%

investment depends on the investor's risk aversion coefficient. When performing linear programming, this paper first adopts the boundary constraints, the expected return of assets and the covariance matrix among assets to solve the effective frontier of the risky portfolio; then introduces risk-free assets and borrowing assets (negative constraints), as well as the risk aversion coefficient A$(= 60 - 100 * \alpha)$ based on the previously questionnaire for family investor. By taking the effective frontier of risky asset as the input parameters, we can determine the proportion of the family investor's risk-free assets and risky assets, as well as the proportion within each risky asset.

Use MATLAB to solve the effective frontier of the risky assets portfolio as shown below:

3.3 Case Study

Family asset allocation is a complex process. The above analysis can provide guidance on the allocation of financial assets to the family. The application of specific family asset allocation strategies can be generally carried out according to the following steps:

(1) Analysis of basic information of family: much data needs to be collected, including financial and non-financial information.

(2) Analysis of the status quo of family asset allocation: mainly ascertains the family's assets and liabilities, and determines whether the current household asset allocation is reasonable.

(3) Determination of the optimal portfolio of family asset allocation: according to the previous basic information, the risk aversion coefficient of the family can be calculated by means of the process proposed in this paper, and the optimal financial portfolio of the family asset allocation can be obtained by the said procedure. This is not to say that the family assets must be allocated strictly in accordance with the above-mentioned optimal portfolio. This optimal portfolio only provides a benchmark reference for wealthy families, so that the allocation of family assets is not too far from the

Table 10 Allocations of family assets.

Risk Category	Asset Category	Non-Financial Assets	Financial Assets	Proportion of Financial Assets	Multigoal-based Asset Allocation (Rounding)	Proportion of Multigoal-based Asset Allocation	Proportion of General Assets Allocation
		(1)	(2)	(3)	(4)	(5)	(6)
Personal Risk (Protective Assets) Ensure Basic Living Standards	**Cash**	2,000			2,000	2.50%	**55.00%**
	Bank Savings		28,940	45.22%	29,000	36.25%	
	Pension	200			200	0.25%	
	Insurance	2,000			2,000	2.50%	
	Children's Education	600			600	0.75%	
	Tax planning	200			200	0.25%	
	Family Trust	10,000			10,000	12.50%	
Market Risk (Market Assets) Maintain Existing Lifestyles	**Bonds**		17,530	27.39%	17,500	21.88%	**39.38%**
	US Stocks		9,307	14.54%	9,300	11.63%	
	HK Stocks		3,722	5.82%	3,700	4.63%	
	Fund		995	1.56%	1,000	1.25%	
Aspirational Risk (Aspirational Assets) Improve Living Standards	**Real Estate**		3,506	5.48%	3,500	4.38%	**5.63%**
	Family Charity Fund	1,000			1,000	1.25%	
Total		**16,000**	**64,000**		**80,000**	**100.00%**	**100.00%**

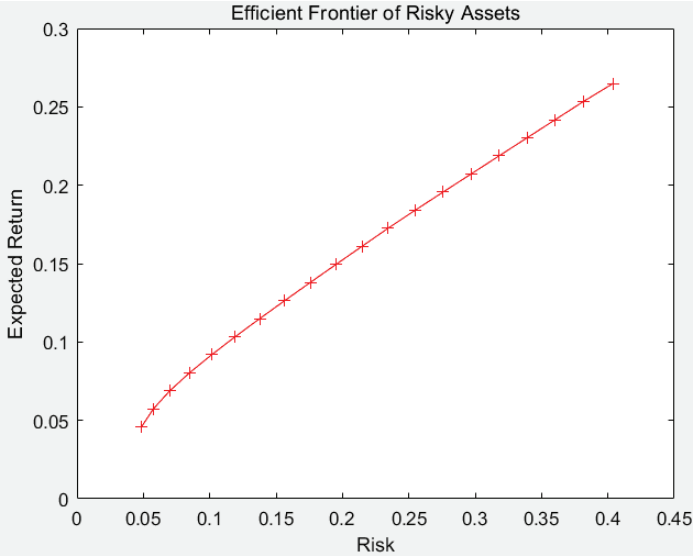

Figure 2 Effective frontier of risky assets portfolio.

optimal portfolio, because only the optimal portfolio of family asset allocation can bring the greatest benefit to family members.

(4) Revision of the family asset allocation strategy according to financial goals: after ascertaining the various needs of the family and their financial status, the financial goals of the family are determined. The financial goal is the key to the allocation of family assets, because these assets are allocated to achieve the corresponding financial goals. Financial goals include short-term goals and medium- and long-term goals. Short-term goals are generally achieved in the near future recent years, and may include things such as the purchase of new cars, new houses, and so on. The long-term goals are generally more than 10 years. The most typical family long-term financial goals include the endowment insurance and children's education. The asset allocation is revised and optimized from the family's financial goals to maximize the overall benefits to the family.

Now, we implement our multigoal-based family asset allocation process from a specific case.

Casestudy: Mr. Ge, 58 years old, is the owner of a manufacturing company that has a turnover of 100 million yuan per year, debt leverage, and its net profit is negative. Tax planning of the company is required (2 million yuan). The total assets of the family are around 800 million. His wife, Ms. Liao is 51 years old, and a housewife. The couple have a son, 24-years-old, graduating from a US university, and want to establish a trust fund of 100 million with their son as beneficiary. Both parents are currently in good health. Every year, Mr. Ge needs to raise 0.4 million per year (5 years) for both parents, and his son's education expenses amount to 0.6 million per year (10 years). The family's cash expenses are 1 million per year (20 years), and he needs to buy insurance at1 million yuan per year (20years). In order to make an impact investment, Mr. Ge is also preparing to set up a family charity fund of 10 million.

Risk profile: The questionnaire survey conducted with Mr. Ge yielded the results shown in Table 8 below.

According to Chhabra's (2005) wealth allocation framework, Mr. Ge's family comprehensive risk preference is 0.4774, ranging from 0.33 to 0.67. Therefore, this paper classifies the family as having a moderate risk preference. Assuming the risk-free asset rate is 0.02389 (1-year deposit rate), the loan interest rate is 0.05492 (1-year short-term loan rate), we put the family risk aversion coefficient of 12.2619, the effective frontier of the risk assets previously solved, and moderate boundary constraints of general assets into MATLAB for quadratic programming, resulting in the values shown in Table 9 below.

After subtracting the entire wealth of family from the necessary non-financial asset allocation, the remaining wealth can be used to allocate financial assets according to the optimal solution. Finally, we can calculate all the asset allocation solution for the family.

4. CONCLUSIONS

Fifty years after Markowitz outlined the foundations of MPT, most family investors' portfolios are still not diversified. MPT describes these disparate differences as deviations from rational investment. In this paper, we try to understand the reasons for the lack of diversity and emphasize the difference between the risk-return preferences of family investors and traditional preferences. To solve this problem, we have provided a multigoal-based asset allocation framework suitable for family investors based on an extension of Markowitz's work. This extended model begins with the consolidation of all assets and liabilities of family investors, including housing, mortgages and human capital, not just financial assets. We introduce different risk concepts for family investors to complement Markowitz's market risk framework. This allows us to increase the ability to provide downside protection and upside potentiality for the usual diversified core portfolio

based on family investors' risk-return preferences. The goal of this wealth allocation framework is to allow for optimal risk allocation, that is, resource budgeting between personal, market, and aspirational risk dimensions to meet the security and expectations of family investors while still benefiting from positive market trends. In order for family investors to receive appropriate wealth allocation, risk assessment must be made prior to asset allocation.

REFERENCES

1. Markowitz H. Portfolio selection[J]. The Journal of Finance, 1952, 7(1): 77–91.
2. Das S, Markowitz H, Scheid J, et al. Portfolio optimization with mental accounts[J]. Journal of Financial and Quantitative Analysis, 2010, 45(2): 311–334.
3. Nevins D. Goals-based investing: Integrating traditional and behavioral finance[J]. The Journal of Wealth Management, 2004, 6(4): 8–23.
4. Chhabra A B. Beyond Markowitz: a comprehensive wealth allocation framework for individual investors[J]. The Journal of Wealth Management, 2005, 7(4): 8–34.
5. Pompian M. Behavioral finance and wealth management: how to build investment strategies that account for investor biases[M]. John Wiley & Sons, 2011.
6. Statman M. What do investors want?[J]. The Journal of Portfolio Management, 2004, 30(5): 153–161.
7. Sharpe W. Individual risk and return preferences: A preliminary survey[R]. Working paper available at www. stanford. edu/∼ wfsharpe/art/rrsurvey/vienna2001.htm, 2001.