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Strategies in Retirement Fund Selection in the Mexican Retirement Market 1997-2018

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Abstract

Objective: This research studies individual investment strategies that can be employed by Mexican workers to choose a retirement savings company, to provide evidence that can guide workers and governments in their pursuit for a higher replacement rate. Methods: To accomplish such task, more than 200,000 individual decisions in rolling-windows are simulated, based on more than twenty-years of market prices on retirement funds in Mexico (1997-2018). Outcome: Results indicate that contrarian-based strategies dominate momentum-based strategies in three out of four categories of funds. Recommendations: Moreover, in two out of four categories of funds the highest return is reached by the system's average, calling for the introduction of an ETF-type of product to the Mexican financial market. Originality: The novelty of this research resides in the perspective of the analysis, positioning the Mexican worker in the role of an investor making a financial choice. Conclusions: The maximum average return is the best way to select a retirement fund manager when there is a guaranteed minimum pension, which acts as a risk-hedge, as it is in the Mexican case.

JEL Classification: D14, G11, G14, H55, J26, J32.

Keywords: AFORE, Contrarian Strategy, Defined-Contribution, Momentum Strategy.

Estrategias de elección de AFORE en el mercado mexicano de ahorro para el retiro 1997-2018

Resumen

Objetivo: Se analizan varias estrategias de inversión para elegir una administradora de ahorro para el retiro (AFORE), proporcionando evidencia que pueda orientar a trabajadores y gobierno a elevar la tasa de reemplazo. Metodología: Para lograr el objetivo se simulan más de doscientas mil decisiones individuales en ventanas móviles, con base en más de veinte años de precios de mercado de fondos de retiro en México (1997-2018). Resultados: Las simulaciones indican que las estrategias contrarias dominan a las estrategias momentum en tres de las cuatro categorías de fondos. Recomendaciones: En dos de las cuatro categorías de fondos, el rendimiento más alto se alcanza con el promedio del sistema, por ello se propone la creación de un producto tipo ETF en el mercado mexicano. Originalidad: La novedad de esta investigación reside en la perspectiva del análisis, en la que se posiciona al trabajador mexicano en el rol de inversionista tomando una decisión financiera. Conclusiones: El retorno promedio máximo es la mejor forma de seleccionar una AFORE cuando existe una pensión mínima garantizada, que actúa como cobertura de riesgo, como es el caso mexicano.

Clasificación JEL: D14, G11, G14, H55, J26, J32.

Palabras clave: AFORE, Contribución Definida, Estrategia Contraria, Estrategia Momentum.

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1. Introduction

Under the defined-contribution pension system in Mexico (new generation), workers can expect a replacement rate of 25.5 percent, the lowest for an OECD country (OECD, 2015). Other estimates are higher; for instance, Alonso et al. (2015) estimate replacement rates between 40 to 50 per cent, however, still at those levels there is an inadequacy risk of retirement income for the new generation, which can drive them into the path of old age poverty. One key element to elevate the replacement rate is by boosting the rate of return on retirement funds, given that, the real rate of return on retirement savings has the highest impact on theoretical replacement rates, surpassing the effect of other factors such as price inflation, real wage growth and real discount rate (OECD, 2015). For instance, the 25.5 percent replacement rate for Mexico is computed by the OECD assuming a 3 per cent real rate of return. If the rate of return increase by 1 per cent, along the working life of the average- earner, male worker, the estimated replacement rate would increase to 32.9 per cent, reaching the same level as Chile or Canada. Such increment in the rate of return can be accomplished not only by compelling fund managers at retirement savings funds to improve their investment practices, but also by fostering workers to choose wisely, that is, to pick the better retirement fund.

This paper analyses the performance of eight momentum and contrarian investment strategies that can be employed by workers to choose a retirement fund manager, searching for the best selection method in the context of the Mexican defined-contribution pension system, using publicly available data from prices of more than twenty years (1997-2018) of the retirement savings funds (AFORE). The working hypothesis in this paper is that worker's strategic behaviour may produce better returns than the market average. To test this hypothesis more than two-hundred thousand worker's decisions are simulated, based on more than twenty years of stock market prices of Mexico's defined contribution retirement funds, in a back-testing, rolling-windows exercise.

It is important to notice that the methodology was developed with the data and framework of the Mexican defined-contribution pension system, however, the methodology can be adapted to other pension systems that involve a worker selecting a pension fund.

In the next section, a brief description of the Mexican defined-contribution retirement system and retirement fund manager selection process from its inception in 1997 to its new reform by the end of 2019 are presented. This is followed by the review of the relevant literature regarding the issue, and a section in which the strategies to be tested are described and procedures are shown. Next, main results are presented, and finally, conclusions are drawn.

2. Mexico's Defined-Contribution Retirement System

By mid-1997, private-sector workers' retirement system in Mexico experienced a major overhaul that changed the way in which pensions were financed and paid. The retirement scheme changed from a defined-benefit arrangement to a defined-contribution one. In the retirement phase, in the new system, pensions would be paid by either annuities or a programmed withdrawal and mainly financed by the balance in the worker's individual savings account, accumulated during his working

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years, called the accumulation phase (OECD, 2016).

During the accumulation phase an equivalent to 6.5% of a formal sector worker's wage is saved and deposited in the worker's individual retirement savings account. The contribution to this amount is divided as follows: 1.125% saved by the worker, 5.15% contributed by the employer, and 0.225% paid by the federal government. An additional federal government contribution, called "*cuota social*", for up to 6.29% is added to the individual account of low-wage earners to help them to increase their balance (CONSAR, 2018a). This individual account will finance the acquisition of a financial product in the retirement phase and it is managed during the accumulation phase by a specialized financial institution, called AFORE, created to such purpose. As of 1997, there were seventeen companies providing retirement funds management services, although, via mergers and acquisitions, as of November 2019 there were ten companies in Mexico that provided such service for workers. Each provider (AFORE) manages a set of five mandatory retirement funds (SIEFORES from SB_0 to SB_4), that is, there were fifty available mandatory retirement funds. As can be seen in Table 1, regulations regarding AFORES in Mexico take Modigliani's (1966) life cycle perspective to categorize active workers propensity for taking risks (Nuñez and León, 2018). Recall that Modigliani's (1966) assumption is that, on average, the earning power diminishes well before the termination of life; therefore, as people get older, they consume more and save less.

Table 1. Retirement funds available in Mexico as of November 2019

Retirement Fund (SIEFORE)	Age Bracket	Equity (maximum)	Structured Assets (maximum)	Year of inception
SB_4	36 & younger	45%	20%	2008
SB_3	37-45	35%	20%	2008
SB_2	46-59	30%	15%	1997
SB_1	60 & older	10%	10%	2005
SB_0	60 & older	0%	0%	2015

Source: Authors with information from (CONSAR, 2018a).

Under Mexican regulation, as of November 2019, people were not allowed to take a higher risk than the one associated with their age-group. For instance, a forty-eight years old person was allocated to the fund SIEFORE SB_2. Therefore, she could choose any on the ten fund managers (AFORES) that offer such services. If for some reason she desires to reallocate to another category of funds, she can move but only if the new category is less risky in terms of investment profile, that is, he can move to SIEFORE SB_1 but not to SB_4. Once allocated to an age-determined category of funds (SIEFORE), the worker can freely choose a provider for the retirement fund management (AFORE) with the available information. Notice that the worker can change company freely once a year, or twice if the switch is to a provider with a higher historical return that the incumbent.

Mexico's regulator for retirement savings, the Comisión Nacional del Sistema de Ahorro para el Retiro (CONSAR), publishes information that is meant to help workers to select an AFORE. In its regular information releases, CONSAR issues the historical moving average returns of the retirement fund managers (CONSAR, 2019) and this information is also in the individual account statements that every worker with an individual retirement savings account receives three times a year (OECD, 2016). One problem with this setting is that this is the only relevant information workers have at their disposal to take such decision, then, at least implicitly, CONSAR is suggesting that a momentum strategy may be employed by workers to select a retirement fund. The problem of this advice is not only that, in general, past returns are not good predictors of future performance, unless some form of informational inefficiency is present, but also that, if such inefficiency exists, the regulator's suggested strategy for workers may be mistaken with dire results in their retirement income adequacy.

One important issue to be noticed is that the decisions simulated in this paper comply with CONSAR's regulatory framework, that is, the choice among different companies within a category of funds was the norm, ruling out category jumps. Also, in constructing the strategies, only the historical return was considered as this is the only information available for the workers and that is also the reason volatility measures were not used in this regard. Finally, only one company was selected instead of a portfolio of two or more of them, as in other studies regarding asset allocation. Simulations ran with the data from the inception of the retirement fund category (See Table 1) to September 4th, 2018, with the available companies at each category from SB_1 to SB_4. Since the SB_0 fund late inception does not allow for strategic behaviour to be tested, the information regarding this category is left out of the analysis henceforward.

In the next section, the relevant literature regarding retirement fund management, and retirement fund selection is reviewed.

3. Literature Review

Early scientific literature on asset management and portfolio performance was focused on the fund manager as a decision maker and was not specialized in retirement funds. For instance, (Markowitz, 1952) created the concept of the efficient frontier of the set of attainable expected return and variance combinations to build a portfolio. This development was followed by several works regarding portfolio building, the measurement of the risk-reward relationship, and manager's performance. Treynor (1965) proposed to gauge portfolio performance with the excess of portfolio return above the risk-free rate, adjusted by a proxy of systematic risk, the portfolio's *Beta*. Sharpe (1966) used the standard deviation of the portfolio returns to quantify risk, a broader risk measure than Treynor's since it considers both, systematic and unsystematic risks. Jensen (1968) employed the CAPM theory to build a model to determine the sources of the excess portfolio returns compared with the risk-free rate. He proposed the econometric calculation of the manager's ability with the parameter *Alpha* while using the other parameter in the regression analysis, the *Beta*, as a measure of risk.

These early papers were followed by countless articles in the following years and in some of them, the object of analysis shifted towards retirement funds, albeit the manager was still the main subject of analysis. For instance, Brinson et al. (1986) focused on the investment management process of 91 large U.S. pension plans, finding that investment policy (portfolio of long-term asset classes weighted by long-term allocations) dominated investment strategy (market timing and security selection). Coggin et al., (1993) studied the selection and market timing skills in a random sample of 71 equity pension fund managers. They found that selection and timing measures were, respectively, on average positive and negative, and negatively correlated. These research papers were followed by others focused on Latin America and other emerging economies. For instance, Walker (1993a and 1993b) studied the performance of privately-managed fixed income and equity portfolios in the Chilean retirement funds; Antolin (2008) analysed the risk-adjusted aggregate investment performance in privately-managed pension funds for nine countries; and Tapia (2008) performed a comparative analysis of 23 countries privately-managed pension funds, including allocation among asset classes.

A new wave of studies focused on Latin America was published more recently. For example, Santillán et al. (2016) analysed the return and volatility of the retirement saving funds in Mexico. They found evidence that volatility and return may be correlated with lags of themselves several periods back, implying that returns do not behave consistently with an efficient market. Sandoval et al. (2018) studied the selectivity, market timing and investment leadership in the Chilean retirement funds, concluding that the investment management abilities displayed by retirement fund managers are not enough to cover fees. Nuñez and León. (2018) developed a proposal for a reference portfolio in the Mexican retirement-savings system based on the optimization of the replacement rate. They found that their resulting portfolios are more conservative that the ones in place and favour a higher fixed income proportion and lower maturity than the former. García et al. (2021) developed a methodology to solve the dynamic optimization problem created by the new Generational AFOREs, created by the end of 2019 in the fashion of target date funds. They modelled the asset allocation of funds as a multi-period optimization problem, in which the objective is minimizing risk subject to a lower bound constrain for the total return. The outcome is a set of optimal solutions associated with a specific glide-path or investment trajectory. Overall, most of their solutions show the preference for risky assets at early stages and bonds closer to retirement. Duque et al. (2021) propose a time-dynamic asset allocation model for defined-contribution systems, which considers wealth as the state variable. They use stochastic dynamic programming focussing on risk and on performance relative to a benchmark, in which investment decisions depend on the time of retirement and the wealth at each point of time. Using the Chilean pension system data, they find that the system´s default strategy, offered to those workers that do not make a choice of retirement savings fund, shows a god overall performance, however, a system that monitors each worker's wealth and adjust the strategy accordingly, can reduce the expected shortfall at retirement.

The suggestion of a personalization in the market of retirement funds is also present in the research of Turner and Klein (2021). They study retirement target date funds and argue that they do not account for differences in individual risk aversion within the target date group and that to attain the level of financial education needed to manage a well-diversified portfolio for millions of people is an unrealistic task. So, they propose three innovations to target date funds that can help individual pension participants to better manage their financial market risks. The proposals are offer three levels of risk within the target date funds, offer access to a robot advisor, and targeted informational interventions.

There is also scientific literature regarding retirement funds and their selection and management by the client or the worker. One distinctive feature of these papers is that the decision of selecting a retirement fund manager or an asset allocation by the worker is considered a financial decision and analysed as one. One key reference in this matter is provided by Benartzi and Thaler

(2007). They analysed and summarized several issues related to workers' decisions regarding their financial choices in retirement savings and the heuristic rules applied by workers. They cited several behavioural experiments that lead them to conclude that when the number of choices is low, people tend to use the "1/n rule" to pick a retirement fund, that is, they just equally allocate resources among options. Although, when there are many choices, the "1/n rule" is not practical and people tend to favour fixed income retirement funds. Moreover, when people are offered a set of already diversified retirement funds, they do not stick just to one fund; when given the opportunity, they tend to pick more than one instead. Finally, and more important for the current paper, Benartzi and Thaler also found that when people are given the autonomy regarding investment decisions for their retirement savings, they seem to take suboptimal choices, when compared to professionally built portfolios or the pension systems default option.

Another kind of individual suboptimal behaviour is workers' unresponsiveness to pricing or return considerations, that been reported in Mexico. Swartz et al. (2008) hypothesized that workers in Mexico cannot see complexity or noise variables. This allows retirement fund managers to charge prices above their marginal costs and makes workers unreactive to price competition in their investment decision. This problem was still present in Mexico a decade after initially reported in the literature. CONSAR (2017) published that four out of ten transfers between Mexican retirement funds went to AFORES offering a lower historical performance than the incumbent. One possible explanation for this suboptimal individual behaviour is found in Rodríguez (2018), who hypothesizes that this could be happening by the existence of a halo effect, as most of the providers in the Mexican retirement fund market are part of financial and commercial conglomerates or governmental health and insurance institutions with strong brands that agglomerate several financial products. In his model, the halo effect may produce a bias in the worker's financial choice regarding retirement fund manager.

In the current paper, several strategies that can be used to pick a retirement fund manager in México are back tested and compared, to find the best among them, using three criteria: the maximum average return, the Sharpe ratio and the probability of winning. One important feature shared by these strategies is that they are easy to compute using the little information available to workers, such as historical performance. The strategies are simulated in a rolling-windows exercise, using more than twenty years of data of prices of the retirement funds in Mexico. Such analysis has not been published before and provides new evidence that can guide workers and government regulators in search of a higher replacement rate. It is important to notice that even if this study uses data from Mexico, the methodology can be replicated to any other pension system in which workers may decide their retirement fund.

4. Momentum vs. Contrarian Strategies: Fundamentals and Procedures

In this section, the fundamentals of the investment strategies to be tested and the procedures used to simulate them are described and discussed.

4.1 The fundamentals of contrarian and momentum strategies.

Contrarian investing is a value investing philosophy based on the belief that investors overreact to news, pushing up or down securities prices. The strand of this philosophy that is analysed in this paper is the *buying the losers strategy*, which assumes the existence of a long-term negative serial correlation in securities prices, called price reversal (Damodaran, 2012). Empirical evidence of this behaviour, consistent with an overreaction to dramatic unexpected events, was early described by De Bondt and Thaler (1985). They showed that portfolios considering the worst 35 underperforming securities (*losers*) yielded a 19.6% higher return than the market average in the 36 months after portfolio formation, while the portfolios composed by the 35 top performing securities lag the market by 5%. Furthermore, De Bondt and Thaler (1987) confirmed the existence of the long-term reversal, showing that reversal patterns are consistent with overreaction, and that the winner-loser effect cannot be attributed to changes in risk or primarily to size, and Jegadeesh and Titman (1995) showed that the main component of contrarian profits emerges from overreaction to firm-specific factors.

Momentum investing is an investment strategy based on the existence of mid-term upward patterns in security prices, that is, when a positive serial correlation in prices exists (Damodaran, 2012). Such behaviour, contrary to the concept of market efficiency and random walks, may be related to behavioural biases, such as overconfidence, self-attribution, or others. For an extensive survey on behavioural biases and momentum see Subrahmanyam (2018). Empirical evidence of momentum was presented by Jegadeesh and Titman (1993), who arranged stocks in deciles defined in terms of performance for the 1965 to 1989 period, showing that the top decile securities overperformed the bottom decile securities in a horizon from three to twelve months, and Chan et al. (1999), who showed that using past returns and earnings momentum to build stock picking strategies in two periods: 1973-1993 and 1994-1998 would have earned significant profits over a six to twelve months period. That is, from the empirical evidence in the literature, momentum investing excess profits seem to be present over a relatively short period of time, in instances of at most twelve months long.

4.2 Procedures for simulations.

All simulations were developed in MATLAB and Microsoft Excel and the code and calculations are available on request to academic users as a complement to this article. The data used on the analysis is the daily prices of the four SIEFORES (retirement funds SB_1 to SB_4) for each of the retirement fund management providers available (AFORES), registered at the Mexican Stock Exchange from the 1st July 1997 to 4th September 2018 (CONSAR, 2018b). Risk-free rate data were collected from Infosel Financiero database (INFOSEL, 2018). The Mexican government one-year, zero-coupon bond rate (CETES364) is used as risk free rate for simulations. Once the data is adjusted for matching beginnings and ends, there were more than one hundred and fifty thousand observations of daily prices for the SIEFORES used to simulate and analyse rolling-windows worker's investment strategies. Since the data on prices was presented ordered by trading days, each year is assumed to be composed by 252 trading days in all calculations.

Let $R_t^{1,\psi(\varepsilon_t),i}$ be the one-year return of SIEFORE $SB_i^{\psi(\varepsilon_t)}$ indexed by time $t\epsilon[\underline{t},\overline{t}]$, where $i =$

{1,2,3,4} and $\psi(\varepsilon_t)$ is the set of existing AFORES during the interval $\varepsilon_t = \{t, t-1, \dots, t-252\}$. Since simulations are developed in a rolling-windows basis $R_{t+1}^{1,\psi,i}$ is the one-year return for the period started in time $t-251$, that is, the 252-day period started a day later that $R_t^{1,\psi,i}$. In a similar way, let $R_t^{3,\psi(\theta_t),i}$ be the three-year return of SIEFORE $SB_i^{\psi(\theta_t)}$ indexed by time t, where $i = \{1,2,3,4\}$ and $\psi(\theta_t)$ is the set of existing AFORES during the interval $\theta_t = \{t, t-1, \dots, t-756\}$.

Define a contrarian strategy as one in which the worker chooses the worst performer in the feasible set of options with the available information, showing a strong belief in price reversals. As opposite, define a momentum strategy, as the one in which the worker picks the best performer in the same conditions as describe in the former strategy. Also assume that there are two types of strategies, one short-term, in which there is a one-year commitment with the decision and the second, a long-term strategy, in which there is a lifetime commitment with the choice (with a minimum of five years commitment).

Under these conditions there are four contrarian strategies and four momentum strategies to be tested in each fund category $SB_1 - SB_4$. They are summarized in Table 2. Each strategy is labelled $[w-j-k]_i$, that is, type w= {contrarian (C), momentum (M)}, commitment j = {ST (1 Year), LT (5 years +)} and period of reference k = {12 months, 36 months}, indexed for each SIEFORE $i = \{1,2,3,4\}$.

Table 2. Summary of simulated strategies for each SIEFORE

Strategy	**Description**	**Period of reference**	**Length of commitment**
Contrarian Investing	Buy and hold the worst performing fund available in the period of reference		
C-ST-12		12 months	12 months
C-ST-36		36 months	12 months
C-LT-12		12 months	5 years +
C-LT-36		36 months	5 years +
Momentum Investing	Buy and hold the best performing fund available in the period of reference		
M-ST-12		12 months	12 months
M-ST-36		36 months	12 months
M-LT-12		12 months	5 years +
M-LT-36		36 months	5 years +

Source: Authors.

The procedure used to calculate the value of the eight strategies was the following: $R_t^{1,\psi(\varepsilon_t),i}$ and $R_t^{3,\psi(\theta_t),i}$ were computed for every feasible t, $SB_i^{\psi(\varepsilon_t)}$ and $SB_i^{\psi(\theta_t)}$ and were ordered from top performer to worst performer for each t, $SB_i^{\psi(\varepsilon_t)}$ and $SB_i^{\psi(\theta_t)}$. That constitutes the information set available for the workers in order to make a choice of the AFORE that will manage their retirement savings at each $t+1$, represented by $I_{t+1}\left(R_t^{1,\psi(\varepsilon_t),i}, R_t^{3,\psi(\theta_t),i}\right)$.

a. In a short-term, contrarian, one-year reference strategy, called C-ST-12, the workers choice would be represented by $V_{t+1}^{C-ST-12} = \min_{\psi(\varepsilon_t)} \left\{ R_t^{1,\psi(\varepsilon_t),i} \right\}$. That is, the simulated worker would chose the worst performer in the period of reference. In accordance to the rules of the Mexican regulator, this worker keeps its commitment one year. In addition to that, the worker is assumed to choose again following the original rule once the year had pass, and the rule keeps holding up to the end of the data. This rule applies to all the short-term commitment strategies.
b. In a short-term, contrarian, three-year reference strategy, called C-ST-36, the workers choice would be $V_{t+1}^{C-ST-36} = \min_{\psi(\theta_t)} \left\{ R_t^{3,\psi(\theta_t),i} \right\}$.
c. As discussed earlier in this section, the performance of some of these strategies changed when the length of time in which they were applied varied. Therefore, another set of simulations was performed assuming a long-term commitment. That is, once the AFORE is chosen, the worker keeps its commitment to life and does not leave the company. The minimum size of the commitment is assumed to be five years. For instance, in a long-term, contrarian, one-year reference strategy, called C-LT-12, the workers choice would be $V_{t+1}^{C-LT-12} = \min_{\psi(\varepsilon_t)} \left\{ R_t^{1,\psi(\varepsilon_t),i} \right\}$ and in a long-term, contrarian, three-year reference strategy, called C-LT-36, the workers choice would be $V_{t+1}^{C-LT-36} = \min_{\psi(\theta_t)} \left\{ R_t^{3,\psi(\theta_t),i} \right\}$. It can be noticed that strategies C-ST-12 and C-LT-12 share the same decision rule, which is also true for strategies C-ST-36 and C-LT-36. The difference between such pairs is the way in which the information sets are built. For instance, the short-term commitment, the feasible set of AFORE choices is larger, because of in their construction all the available AFORES that existed in such period were considered (from 10 to 17). In the case of the long-term commitment, AFORES that were not operational in the last five years were not considered in the computations, therefore, the feasible set of choices was composed by the 10 AFORES working as of December 2019.
d. The same procedure was followed to build the simulations of the momentum strategies, albeit in steps b)-d) it is assumed that the worker would choose the best provider of retirement fund management. For instance, in a short-term, momentum, one-year reference strategy, called M-ST-12, the workers choice would be $V_{t+1}^{M-ST-12} = \max_{\psi(\varepsilon_t)} \left\{ R_t^{1,\psi(\varepsilon_t),i} \right\}$, and so on. These second strand of strategies are somewhat like the strategy implicitly suggested by CONSAR, the Mexican regulator, that is, chose the better historical performer.
e. In order to measure performance, the average of the return of each strategy is calculated. For instance, the average of the strategy C-ST-12 is computed in the following way

$$\underset{i,t\epsilon[\underline{t},\overline{t}]}{average} \left[\underset{R_t^{1,\psi(\varepsilon_t),i}}{arg\ min} \left\{ V_{t+1}^{C-ST-12} \right\} \right] \ for\ every\ i\ and\ all\ t. \tag{1}$$

f. That is, all the rolling-window, one-year return of the C-ST-12 strategies are averaged across all the time the series runs, categorized by all $SB_i^{\psi(\varepsilon_t)}$. The use of a simple average is justified by the fact that each segment of time is homogeneous (252 days). As a measure of volatility, the standard deviation over the set used to calculate the average for each fund and strategy is used.

g. To compute the system's average return and the volatility, the rolling-window, one-year return is calculated for all the attainable set of companies providing retired fund management services (AFORES) to workers for each SIEFORE (SB1 to SB4) and then averaged, and the standard deviation is also computed over the same set as a measure of volatility. That is,

$$\underset{i,t\epsilon[\underline{t},\overline{t}]}{average}[I_t] \ for\ every\ i\ and\ all\ t \qquad (2)$$

h. represents the average one-year, system return for each SB_i.

i. Three criteria were used to compare strategies. First, the maximum absolute return among tested strategies and the market average, results that were confirmed as statistically significant using standard hypothesis testing, assuming normality, second, the Sharpe Ratio (Sharpe, 1966), calculated with the average returns, volatility and the risk free rate for each fund, strategy and the market averages, and third, the probability of winning between strategies arranged in pairs, also confirmed as statistically significant using hypothesis testing.

Results of the eight strategies and the market average for each SIEFORE are presented, compared, and analyzed in the next section.

5. Simulation Results

Results of the simulations are depicted in Table 3. There are 36 simulation outcomes, eight strategies, and four SIEFORES plus the four market averages. Therefore, to describe and analyze it in an orderly manner, this section was divided into three subsections based on the criteria used to evaluate each strategy.

Table 3. Simulation Results

SIEFORE	Strategy	Observa-tions	Share of winners	Average Return	Volatility	Sharpe Ratio
SB_1 number of observations 42,813 average return 6.28% volatility 4.25% Sharpe ratio 0.1463	C-ST-12	2,701	56%*	6.90%**	5.07%	0.2441
	M-ST-12	2,701	44%	5.79%	4.59%	0.0276
	C-ST-36	1,974	62%*	6.59%**	5.02%	0.2365
	M-ST-36	1,974	38%	5.10%	4.83%	-0.0645
	C-LT-12	1,920	54%*	5.49%	0.73%	0.6075
	M-LT-12	1,920	46%	5.19%	0.80%	0.1766
	C-LT-36	1,416	60%*	5.49%	0.78%	0.7424
	M-LT-36	1,416	40%	5.14%	0.89%	0.2611
SB_2 number of observations 61,887 average return 9.19%	C-ST-12	4,435	35%	9.05%	6.64%	-0.0510
	M-ST-12	4,435	65%*	9.74%**	7.40%	0.0472
	C-ST-36	3,820	48%	7.86%	4.77%	-0.0752
	M-ST-36	3,820	52%*	7.46%	6.32%	-0.1194
	C-LT-12	3,821	36%	6.35%	1.08%	0.5127

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volatility 6.99%	M-LT-12	3,821	64%*	6.76%	1.49%	0.6546
Sharpe ratio	C-LT-36	3,317	24%	5.93%	0.66%	0.6454
-0.0287	M-LT-36	3,317	76%*	6.65%	1.15%	0.9957
SB_3	C-ST-12	1,964	48%	7.15%	5.66%	0.4246
number of observations	M-ST-12	1,964	52%*	6.76%	4.74%	0.4257
25,844	C-ST-36	1,338	50%*	5.19%	3.00%	0.3390
average return	M-ST-36	1,338	50%	5.39%	5.17%	0.2363
7.50%	C-LT-12	1,115	56%*	6.02%	0.95%	1.2130
volatility	M-LT-12	1,115	44%	5.77%	0.99%	0.9095
5.41%	C-LT-36	611	80%*	5.60%	0.47%	1.5129
Sharpe ratio 0.5089	M-LT-36	611	20%	4.97%	1.10%	0.0708
SB_4	C-ST-12	1,838	50%*	6.94%	5.81%	0.3783
number of observations	M-ST-12	1,838	50%	6.79%	5.29%	0.3869
25,844	C-ST-36	1,397	44%	5.97%	4.35%	0.4167
average return	M-ST-36	1,397	56%*	6.23%	6.74%	0.3072
8.08%	C-LT-12	1,115	52%*	6.36%	1.02%	1.4627
volatility	M-LT-12	1,115	48%	6.44%	1.39%	1.1310
6.03%	C-LT-36	611	68%*	6.01%	0.62%	1.7891
Sharpe ratio 0.5520	M-LT-36	611	32%	5.48%	1.79%	0.3297

Source: Own Calculations with the cited data.

* The strategy yields a higher return than the opposite strategy in more than 50% of pairings at 95% confidence.

** The average return of the strategy is larger than the market average at 95% confidence.

5.1 Maximum average return analysis.

In this context, the best strategy is the one with the highest average return in the time frame. Following this criterium, on average the best strategy that a worker could have used to pick a retirement fund manager (AFORE) for SIEFORE SB_1 is C-ST-12. That is, a theoretical 60 plus old worker who picked the worst performing fund manager (AFORE) based on the return during the last year and kept changing each year choosing again the worst performer, would have reached the highest return, beating the market average in the fund SB_1.

Things were different for SIEFORE SB_2. In this case, a worker that picked an AFORE based on the M-ST-12 would have reached the highest average return. That is, the best performance is reached when the worker chooses the best performer during the previous year and changes every year, following the same rule.

For SB_3 and SB_4 retirement funds, the best strategy would be to go with the market average. The problem they would have is that such financial product does not exist in the Mexican financial market. This would provide a rationale for financial authorities and financial intermediaries for the construction and release of an ETF type of financial product that can be incorporated in the mix when the worker chose retirement fund manager. Such a proposal is another outcome of this research.

Finally, all outcomes were compared with their corresponding market average using hypothesis testing, looking for statistical significance.

5.2 Sharpe ratio analysis.

In this subsection, simulation outcomes are compared using a return measure known as the Sharpe ratio (Sharpe, 1966), which yields the return over the risk-free rate of a certain strategy given the units of the risk taken, proxied by a broad measure of volatility such as the standard deviation.

Sharpe ratios for the long-term commitment strategies are higher than other instances in the back-testing exercise. This happens because the volatility goes down as time committed lengthens, and the long-term strategies involved a commitment of at least five years. Therefore, C-LT-36 is the best relative return strategy for retirement funds (SIEFORES) SB_1, SB_3, and SB_4, that is, the workers that relied on long-time price reversals reached the highest return regarding risk-free rate and volatility. Thus, the best strategy in any of the three SIEFORES was buying the worst performer in terms of return for the previous three years and to hold it indefinitely, with at least five years of commitment.

The exception is retirement fund SB_2. In the case of this SIEFORE, the best strategy in terms of Sharpe ratio is M-LT-36, that is, if the worker chooses the best performer of the last three years and hold it for at least five years, he would achieve the highest return over the risk-free rate, considering the level of risk taken, proxied by volatility.

5.3 Probability of winning.

The proposed strategies and their outcomes can be arranged as 16 pairs of strategies differentiated only by the investment philosophy that determined them, as presented in Table 2. That is, each pair of strategies share the period of commitment (12 months or at least five years), the period of formation (12 months or 36 months) and the number of observations. In each pair, one strategy is contrarian-based (the worker selected the worst performer) and the other is momentum-based (the worker selected the best performer). Each observation is built on a rolling-windows basis, that is, a decision a day is simulated during all the attainable period for each strategy, AFORE, and SIEFORE.

Pairs of strategies are compared to each other using the probability of winning, that is, the number of times a strategy yields a better return than its opposite as a share of the number of attainable experiments is used to define the better strategy.

As can be seen in Table 3, in ten out of sixteen pairings between contrarian and momentum strategies there is a larger probability of winning by choosing a contrarian-based strategy, showing a general dominance of contrarian strategies over momentum ones. However, when the analysis is controlled by a retirement fund, there is a different story. A contrarian-based strategy is dominant in SIEFORE SB_1 (4 out of 4 instances), in SB_3 (3 out of 4 instances) and SB_4 (3 out of 4 instances), while momentum is a dominant strategy in SB_2 (4 out of 4 instances).

Results are discussed in the next section and conclusions are drawn.

6. Conclusion

This study analyses the performance of several momentum and contrarian investment strategies that can be employed in a simple way by workers with easily available information to choose a retirement fund manager. Its main objective is to determine the best of such strategies and the best selection method. To accomplish that, more than two hundred and twenty thousand workers' decisions on retirement fund manager selection were simulated in a back-testing, rolling-windows exercise using daily prices for retirement funds available in Mexico's defined-contribution retirement system over a period of more than twenty years. Three different criteria were used to define the best strategy, among thirty-two contrarian and momentum-based strategies, placing the worker in the role of a long-term investor: absolute average return, Sharpe ratio and the probability of winning. Best strategies according to each tested criterion are summarized in Table 4.

Table 4. The best strategy to select retirement fund

Retirement Fund (SIEFORE)	Absolute average return	Sharpe ratio	Probability of winning
SB1	C-ST-12	C-LT-36	Contrarian
SB2	M-ST-12	M-LT-36	Momentum
SB3	Market Average	C-LT-36	Contrarian
SB4	Market Average	C-LT-36	Contrarian

Source: Own Calculations with the cited data.

The first conclusion drawn from this exercise is that contrarian-based strategies are dominant in fund SB_1 and momentum-based strategies are the dominant in fund SB_2. In SIEFORES SB_3 and SB_4 contrarian strategies are best when using the Sharpe ratio and probability of winning as criteria, albeit market average is the best way to approach decision making in these two retirement funds. This first set of results hints the presence of serial correlations on retirement funds prices, negative serial correlation in the case of contrarian dominance, and positive serial correlation in the case of momentum dominance.

The second conclusion would involve the determination of the best overall strategy for each retirement fund. The answer to this question is not as simple as it seems. For instance, in retirement fund SB_1, using the Sharpe ratio, the best strategy of the eight tested is C-LT-36, that is, this strategy produces the highest return over the risk-free rate for a unit of risk taken. Other strategies yield a higher return than C-LT-36, for instance, C-ST-12. However, such difference in return is not compensated at the same rate for a unit of risk taken by the worker, that is, strategy C-ST-12 is not as efficient as strategy C-LT-36. Still, the fact is that under the framework used for simulations there is not a higher return than C-ST-12, and that would mean a significantly higher pension for the worker. Recall that OECD (2015) estimates that a one-hundred basis points difference in the real rate of return, in their theoretical model for Mexico represents almost a ten percent increment in workers' replacement rate. Notice from Table 3 that the difference between strategies in average return is more than one-hundred and forty basis points, which is a statistically significant, but also in terms of replacement rate. Therefore, as a second conclusion of this exercise, the recommendation to workers would be to choose the highest average return strategy.

There are two additional remarks to the second conclusion that would be further developed as research projects. First, one argument not to choose a riskier asset that does not produce a proportionally higher return for retirement is that the worker would face the risk of retiring in a downside risk period, suffering losses in his retirement fund and replacement rate. However, as it was mentioned before, for the Mexican case, there is some coverage for cases in which losses are catastrophic enough, that the worker does not reach a minimum pension: the government would complement the retirement money to reach such minimum pension (Alonso et al., 2015) and (OECD, 2016). That may act as a hedge for workers, taking at least some of the heavy losses away, which may induce a riskier bias in their behaviour. Second, in retirement funds SB_3 and SB_4, the highest return would be reached if workers would have access to earn the market average. The problem is that such a financial product does not exist in Mexico's retirement fund market as of 2019. Then there is a space in the market for the creation of an ETF- based product that can be offered to workers in the moment of their retirement fund manager decision or as a default option. The basis to construct such a product would be a matter of further research.

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