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Potential improvements to pension funds performance in Mexico

Mejoras potenciales al desempeño de los fondos de pensiones en México

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ABSTRACT:
Nowadays, the average Mexican pension saver makes a noisy and uninformed investment decision of its Public pension fund (AFORE). This is due to AFORE's marketing efforts or back-to-back activities. In the present paper, we propose the use of Markov-Switching models, in order to measure the AFORE performance in normal (crisis) or low (high) volatility time periods. With these measures, we simulated the correspondent fund selection. Our results show improvements in the long-term performance in the individuals' pension savings.
Keywords: Markov-Switching, Sharpe Ratio, Private Pension Funds, Portfolio Selection.

RESUMEN:
Actualmente, el trabajador mexicano promedio hace una selección ruidosa y desinformada de su fondo pensiones (AFORE). Esto debido a esfuerzos mercadológicos o a actividades de tipo "back-to-back". En el presente proponemos el empleo de modelos markovianos de cambio de régimen para medir el desempeño de las AFOREs en periodos normales (de crisis) o de baja (alta) volatilidad. Con estas mediciones, simulamos la correspondiente elección de fondo. Nuestros resultados muestran mejoras de desempeño en el largo plazo para los ahorradores.
Palabras clave: Markov-Switching, Ratio de Sharpe, Fondos de Pensiones Privados, Selección de cartera.

1. Introduction

The Mexican government implemented important reforms to the country's pensions system in 1997. Those reforms paved the way for a gradual migration from a conventional "*defined benefit*" (also called "pay-as-you-go") system, then administered by a government entity, to a "defined contribution" system, in which private firms manage and invest the population's retirement funds. The worker, the employer and the Federal Government make periodical contributions to the worker's retirement account, and these resources are invested through specialized funds known as "*Sociedades de Inversión Especializadas en Fondos para el*

Retiro" - Specialized Mutual Funds for Pensions - (SIEFOREs) in different types of securities, according to a regulatory framework.

Despite the favorable impact of this type reforms on domestic savings rates, on the deepening and diversification of domestic securities' markets, and on healthier public finances, there is still much to be learned. For example, according to Patricia Peinado and Felipe Serrano (2011), there are important differences between the planned pension reforms, the actions implemented, and the effective results, depending on the criteria applied, including the eligibility conditions of future pensioners, defined retirement age, and others. It is clear that a better understanding of defined contribution pension systems is required.

This work studies the Mexican private pensions industry, and compares the historical performance of different SIEFOREs with the hypothetical performance of workers' savings portfolios, had they had access to better SIEFOREs' performance measures, information on prevailing market conditions, and had there not been legal constraints to the transfer of savings among SIEFOREs.

The experiment consists of the use of a two-regime Markov-Switching Sharpe Ratio (MS_SR) as information inputs available to a theoretical saver that makes optimal portfolio allocation decisions, depending on the prevailing market regime. These theoretical portfolios are then benchmarked with SIEFOREs' historical performance during the period of analysis to highlight the cost of the existing limitations in savers' available information, as well as the implicit cost of the rigidity imposed by the impediment to transfer savings from one SIEFORE to another more than once a year.

The following section presents some antecedents and reviews some relevant studies on defined contribution pension reforms in the world, with an emphasis on those of Latin American countries and the Mexican experience. The third section introduces the main methodological aspects of the study, including the construction of the Markov-Switching Sharpe Ratios, as well as an explanation of how that information may be used to make optimal investment decisions under different capital markets conditions. The fourth section reports the simulated performance results, assuming Markov-Switching Sharpe-Ratios are used to decide on the best possible allocation of investments among different SIEFOREs every month, and quantifies the cost of opportunity of more restricted information and regulatory constraints on the transfer of saving from one SIEFORE to another more than once a year. The final section presents some general conclusions, as well as guidelines for future research.

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2. Literature review

Progress in the medical sciences and the effects of technological progress on productivity have created the conditions for an aging population in many countries. The new demographic trends that characterize modern societies in the 21st century (a slowly growing and aging population) raise several relevant concerns for traditional defined benefit pension schemes and their long-term sustainability (Peinado and Serrano, 2014). New approaches are currently under consideration by social scientists and governments at large, and among different schemes, one that has received significant attention due to its consistency and adaptability to the new global demographic trends is the defined contribution pension system (John Williamson et al., 2012).

The first defined contribution pension system was introduced in Chile during the early 1980s as part of broader structural reforms to detonate economic growth and privatize that country's extensive state-owned productive sector (Estelle James, 2005; Santillán-Salgado et al., 2010). The new Chilean pension system was called *Administradoras de Fondos de Pensiones (AFP)* –Pension Funds Managers–, and constituted an important component of Chile's new economic model. During the following two decades, countries in Latin America, Eastern and Central Europe, and the Asian-Pacific region (Japan, Singapore, India) adopted similar systems (James 2005).

Defined contribution systems have also become increasingly popular in developed countries such as Canada, Ireland, the United Kingdom and the United States. Defined benefit plans have frequently been used in competitive labor markets as a way to retain highly skilled human capital. By contrast, defined contribution plans cannot fulfill the same task because workers' account balances are fully portable, so workers have no incentive related to pension benefits to stay with their current employer. Notwithstanding, an increasing number of countries have migrated to defined contribution systems. For interested readers, John Turner and Gerard Hughes (2008) discuss the reason for the decline in defined benefit plans and the migration toward defined contribution plans in the more developed countries in much greater detail.

The work of Schmidt-Hebbel (1999) studies the way the substitution of a fully-funded pension system with a defined contribution pension system generates efficiency gains in different markets, contributes to higher savings, and results in increased economic growth. This work identifies the likely factor-market benefits of pension reform and its macroeconomic implications. The findings of this author are that defined benefit systems are consistently beneficial from a macro-economic perspective and suggest that Chile's pension system had positive effects on the labor market, raised the country's savings and improved factor productivity. He also quantifies the pension-fund system's contribution to Chile's economic growth rate and concludes that as much as one fourth of it may be explained by the reform.

In effect, strong evidence confirms the argument that defined contribution pension systems have supported the growth and increasing sophistication of financial markets in the countries that have adopted them. According to Hans Blommestein (1997), pension system reform in emerging markets positively influenced the development of a domestic institutional investors' sector which, in turn, has supported the development of securities markets. This work compares the development of the institutional investors' sector in emerging market economies with the experience of OECD members, identifies possible obstacles to the development of institutional investors and suggests policies to deal with these problems. Santillán-Salgado et al. (2010) study the role of the adoption of the AFP system in Chile during the early 1980s and quantify the relationship between the changes in the breadth and depth of the bond and stock markets and the growth of pension fund investments. They document that, not only did the size of the capital markets grow significantly during the decades that followed the adoption of the defined contributions system, but also the sophistication of the financial products and the number of intermediaries expanded considerably.

Beyond the macroeconomic benefits of defined contribution systems, an important concern of the studies on pension systems policy is to make sure the resources accumulated by future pensioners along their working life provide them with a satisfactory pension. However, the significant demographic differences and economic development conditions from one country to another make it almost impossible to generalize how to measure and project the performance of pension funds.

As the main interest of this work is centered on Mexico's reformed pension system, the following paragraphs review previous research studies that have focused on SIEFORES in some detail. For instance, Adolfo Albo et al. (2007) develop demographic actuarial projections for the size and composition of the Mexican population, and relate them to the documented evolution of the economy through different periods, including economic crises and structural reform episodes, and conclude that the defined- contribution system has various opportunities for improvement, including the establishment of a national pension system that would overcome the fragmentation of different pension regimes in the country. These authors' proposals are extensive and detailed and deserve careful attention by policy makers. However, one recommendation that requires urgent attention is the revision of the contribution that workers and employers should make to the system, currently at 8.1% of the worker's income, below the average for Latin America of 8.7%.

In a similar vein, Javier Alonso et al. (2015) develop macroeconomic and actuarial projections to simulate the expected coverage and replacement rate of the SAR in Mexico for the period 2012-2050, based on demographic and economic forecasts, and report that the pension system limited improvements in coverage rates. In other words, the possibility of obtaining adequate pensions under the current system is restricted to those individuals who enjoy stable long-term employment and thus make significant contributions to their individual accounts every month. These authors also highlight the importance of financial education to improve the population's savings decisions.

Calderón-Colín et al. (2009) extend the analysis and find that in "noisy" markets, such as Mexico's defined benefits pension-fund industry, the number of participant competitors does not significantly reduce mark-ups, contrary to what would be expected in a competitive market. Their modeling exercise concludes, similar to Berstein, Solange and Ruiz (2005) that an increasing number of pension fund managers has not implied a fast mark-up reduction, raising important questions about the adequacy of the regulatory framework for the industry.

Eduardo Fuentes et al. (2010) review the late 1990s reforms to the Mexican pension system and discuss the fiscal benefits attributable to the new system. While they conclude that the various reforms implemented in 1997 clearly represent fiscal and economic benefits for the country, there is a need to increase the rate of replacement to make it converge with international standards. This last suggestion is intended to promote competition among pension-fund managers and to produce indirect benefits for pensioners. Lastly, they focus on the need to help low-income workers have more appropriate retirement pensions.

A representative sample of studies that deal with the financial performance of SIEFORES, and help contextualize the present work, include the those of Marissa Martínez and Francisco Venegas-Martínez (2014), who study the performance of Type 1 and Type 2 SIEFOREs with an equally weighted performance benchmark for each SIEFORE type and an ARIMA-GARCH model. They divide their study period into two sub periods: June 1997 - August 2004 and September 2004 - December 2010. Their results show that, in terms of mean-variance efficiency measured by Sharpe ratios, Type 2 SIEFORES underperform the most, compared with the conservative Type 1. This happens due to the high and asymmetric volatility of the time series. In their conclusions, they recommend, in line with this work's proposal, to develop a better performance measure of SIEFOREs, and the need to inform pension-fund savers when market conditions are in a scenario of higher volatility and greater potential loss.

Óscar V. De la Torre et al. (2015) propose a minimum variance portfolio as a method to build a benchmark portfolio for defined contribution pension funds' performance in Mexico. They perform three discrete event simulations with daily data from January 2002 to May 2013 and compare the results of the minimum variance portfolio with those of a Max Sharpe Ratio portfolio, and, lastly, with a linear combination of the minimum variance and Max Sharpe Ratio portfolios. Using Jeffery Bailey's (1992) risk exposure, market representativeness, and turnover benchmark quality criteria, the authors conclude that the minimum variance portfolio is the preferred benchmark for publicly traded Mexican defined contribution pension funds.

Roberto J. Santillán-Salgado et al. (2016), along the line of work of Martínez-Preece and Venegas-Martínez (2014), study the performance of SIEFOREs in three different sub-periods (1997-2012, 2004-2012 and 2008-2012), and find fractional integration in their returns' time-series, so they propose the use of ARMA-FIGARCH models to measure their long-term performance, as well as to model their volatility and returns.

These references confirm an increasing interest on the defined contribution pension systems structure and functioning. In the case of Mexico, several studies have focused on the performance of SIEFOREs, as the workers' savings accumulation, including reinvested returns, will determine their retirement standard of living. We found no published evidence on the use of Markov-Switching Sharpe ratios in the mutual fund industry, specifically in the case of life-cycle mutual funds, 401K, or Latin American defined contribution pension funds, confirming the originality of the present proposal.

3. Methodology

One of the most frequently used measures to evaluate a portfolio's performance is the Sharpe Ratio, which is simply the risk premium (slope of the Securities Market Line) when the investment set includes a risk-free asset and the tangency portfolio of risky assets:

$$Sharpe\ Ratio = \frac{E_r - rf}{\sigma_r} \tag{1}$$

E_r: the portfolio's expected performance during the evaluation period;

rf : the risk-free rate; and,

σ_r : the standard deviation of the risky assets' portfolio.

However, Sharpe Ratios have been found not to be stable in time. Willi Semler (2011) reports that different studies show that the Sharpe ratio is time varying. First evidences of counter-cyclical Sharpe ratios were detected by Michael Brandt and Qiang Kang (2004), and by Sydney Ludvigson and Serena Ng (2007). Martin Lettau and Sydney Ludvigson (2010) study the conditional Sharpe ratio of U.S. equities, and find that they follow a counter-cyclical behavior and show a high volatility. Yi Tang and Robert Whitelaw (2011) find evidence of time varying Sharpe ratios when they study monthly and daily stock market returns from April 1953 to December 2010. Hanno Lustig and Adrien Vedelhan (2012) find that Sharpe ratios are higher in recessions than in expansion phases.

In order to cope with the structural changes introduced in economic and financial data time series by changing environmental conditions, James Hamilton's (1989) work introduced the Markov Switching model, extending previous work by Stephen Cosslett and Lung-Fei Lee (1985), Stephen Goldfeld and Richard Quandt (1973), and Salih Neftci (1984). Hamilton's model able to identify the possible switches from one state or regime to another, and allows the estimation of specific parameters for each regime.

In portfolio management, the work of Chris Brooks and Gita Persand (2001) uses a bond-equity yield ratio with a two-regime Markov-Switching model to determine how much money to invest in stocks, given the probability of being in a "normal" regime ($\pi_{k=1,t}$) at time t; or in bonds, given the probability of a "crisis" period ($\pi_{k=2,t}$). They use these probabilities to determine optimal investment levels in stocks or bonds: $w = [w_{stocks}, w_{bonds}]' = [\pi_{k=1,t}, \pi_{k=2,t}]$. Their results suggest a superior performance of an active strategy versus a "buy-and-hold" strategy.

Another study that tests a cointegration based investment strategy with Markov-Switching parameters against a buy-and-hold strategy on the Dow Jones Industrial Average is that of Carol Alexander and Anca Dimitru (2005). By taking long positions in "normal" periods and short positions in "crisis" periods, they achieve superior performance of their portfolio (before including transaction costs).

Finally, Johannes Hauptmann et al. (2014) develop a warning system with a Markov-Switching model and probit regressions to reallocate assets depending on which of three different regimes prevails: "normal bullish", "normal bearish" and "crisis" time periods. All these works use the basic form of Hamilton's (1989) filter:

$$r_t : \Phi(\mu_{k=i}, \sigma^2_{k=i}) \tag{2}$$

where $\mu_{k=i}$ is the mean of the $k-th$ regime and $\sigma^2_{k=i}$ is its corresponding variance. Other results that can be obtained from Hamilton's filter include the probability of being in the k[th] regime at time t ($\pi_{k=2,t}$), and a transition probability matrix given by:

$$P = \begin{bmatrix} \pi_{k=1,k=1} & \pi_{k=2,k=1} \\ \pi_{k=1,k=2} & \pi_{k=2,k=2} \end{bmatrix} \tag{3}$$

In line with Brooks and Persand (2001), Alexander and Dimitru (2005), and Hauptmann et al. (2014), this work is interested in the mean ($\mu_{k=i}$) and standard $\sigma_{k=i} = \sqrt{\sigma^2_{k=i}}$ deviation of each regime, along with the probability of being in each regime at $t+1$ (the next period):

$$[\pi_{k=1,t+1}, \pi_{k=2,t+1}]' = [[\pi_{k=1,t}, \pi_{k=2,t}]]P \tag{4}$$

With the regime probability vector (4), it is possible to determine if SIEFORES are in a "fair performance" regime (normal regime in terms of the aforementioned references) or a "poor performance" regime, in a given period. Also, the mean and standard deviation of each regime are used to determine each SIEFORE's Markov-Switching Sharpe ratio in each regime, in each period *t*, as follows:

$$Markov\ Switching\ Sharpe\ Ratio_{k=i,t} = \frac{\mu_{k=i} - rf}{\sigma_{k=i}} \tag{5}$$

The final objective is to test what could have happened in a future pensioner's portfolio performance had it had access to a Markov-Switching performance measure, such as (5) choosing the best SIEFORE, given the probability of being in any of the two regimes at time t.

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4. Results: Empirical analysis

The approach followed in the empirical analysis is based on the generation of simulation results to support the argument that access to better quality information on the performance of SIEFOREs may give future pensioners the opportunity to improve their allocation decisions. Moreover, if, at the same time, institutional restrictions that limit the transference of savings among SIEFOREs to only once a year were eliminated, simulation results suggest the system could further improve its performance.

SIEFOREs are responsible for investing the pension savings of Mexican workers. There are five types of SIEFOREs: SB4 (or type 4 SIEFOREs), designed for savers aged under 36 years; SB3 (or type 3 SIEFOREs), that follow an investment policy appropriate for savers between 37 and 45 years; SB2 (or type 2 SIEFOREs), designed for a population with ages between 46 and 59 years; SB1 (or type 1 SIEFOREs), for individuals over 60; and SB0 (or type 0 SIEFOREs), for already retired individuals. The authorized investment policy for each SIEFORE type is presented in *Table 1*. This work's analysis is centered on SB1 to SB4 type SIEFOREs, as SB0 type respond to a different portfolio management rationale since retired individuals are no longer interested in transferring their savings from one SIEFORE to another.

Table 1
Holding Limits by SIEFORE Type
(Current Regulation)

Asset type restrictions (min/max)	***SB0***	***SB1***	***SB2***	***SB3***	***SB4***
Mexican Gov. bonds 1/	51%/100%	51%/100%	0%/100%	0%/100%	0%/100%
Mexican corp. bonds 1/	0%/100%	0%/100%	0%/100%	0%/100%	0%/100%
Mexican stocks	0%/5%	0%/5%	0%/25%	0%/30%	0%/40%
Gov. and corp. global bonds 2/	0%/100%	0%/100%	0%/100%	0%/100%	0%/100%
Global equity markets 3/	0%/5%	0%/5%	0%/25%	0%/30%	0%/40%
Commod. 4/	0%	0%	0%/5%	0%/10%	0%/10%
FX risk limits					
Foreign Currency denominated securities	0%	0%/20%	0%/20%	0%/20%	0%/20%

Note: Percentages represent the minimum and maximum allowed in each category of investment vehicles.
Source: CONSAR (2016), https://www.gob.mx/consar.

Our sample of ten SIEFOREs includes those with historical data for the period from November 30, 2008, through December 30, 2014, a sampling decision intended to avoid the risk of a survivor bias in the analysis.

Table 2
List of SIEFORES
in the Sample

Azteca	Inbursa	Principal	XXI Banorte
Banamex	Invercap	Profuturo GNP	
Coppel	Metlife	SURA	

Source: CONSAR (2014).

The MS-SRs are calculated according to changes in volatility regimes, identified following Hamilton's (1989) methodology. Sharpe ratios are used because they represent comprehensive performance measures, and because they express the expected returns premiums per unit of risk. Additionally, Maximum Sharpe Ratios (Max Sharpe Ratios) are estimated for each SIEFORE type and used as the benchmark against which individual

SIEFOREs are compared. In other words, a Max Sharpe Ratio portfolio represents the optimal combination of assets that complies with the legal limits established for each category of financial assets, for each SIEFORE type. In that sense, the Max Sharpe Ratio portfolio is equivalent to the Tangency Portfolio, that is, the particular combination of risky financial assets that corresponds to the tangency point between the risky-assets' efficient frontier, and the straight line that represents all possible combinations between the Risk-Free Asset and that particular portfolio. In other words, the Max Sharpe Ratio portfolio is an optimal portfolio for each SIEFORE type. The MS-SRs are used to identify which SIEFORE is more attractive within each given type, under different market regimes. To estimate the Max Sharpe Ratio benchmark portfolios, the investment-level restrictions established by CONSAR, according to *Table 1,* are operationalized using commercial public domain indices, as detailed in *Table 3*:

Table 3
Asset Type, Market Available
Securities, and Vendor

Asset type benchmark used herein	***Index***	***Vendor***
Mexican Government bonds	Valmer Government	VALMER- Mexican Stock Exchange
Mexican corporate bonds	Valmer Corporate	VALMER- Mexican Stock Exchange
Mexican equity market	IPC	Mexican Stock Exchange
Government and corporate global bonds	World Bond Investment Grade ex MBS	Citigroup Inc.
Global equity markets	MSCI World	MSCI Inc.
Commodities	DJ-UBS commodity index	Dow Jones – Citigroup Inc.

Source: Authors' own elaboration with publicly available data.

The model that determines the investment weights of the Max Sharpe Ratio portfolio solves the following mathematical problem:

$$\underset{\mathrm{w_p}}{\operatorname{argmax}}\left(\mathrm{w}_{\mathrm{P}}'\left(\mathrm{r}-(rf\cdot 1)\right)\right)\left(\mathrm{w}_{\mathrm{P}}'\mathrm{C}\mathrm{w}_{\mathrm{p}}\right)^{-1/2} \tag{6}$$

Subject to:

$$\mathrm{w}_{\mathrm{P}}'1 = 1$$
$$\mathrm{w_p} \leq h$$
$$\mathrm{w_p} \geq l$$

In the previous expression, $\mathbf{w_p} \leq h$ is a column vector that contains the proportion invested in each asset category, $\mathbf{r} = [\mu_i]$ is a $N \times 1$ vector of expected returns μ_i for each asset category *i*, **C** is a $N \times N$ covariance matrix, and **1** is a $N \times 1$ vector of ones. The expected return vector and the covariance matrix are continuously compounded returns with data from the previous 250 days. Also, l and h are the low and high investment legal limits for each asset category, according to *Table 1*.

Table 4
Performance of Type 1 SIEFOREs During "Fair Performance" and "Poor Performance" Periods

Panel A Gaussian MS Analysis for Type 1 SIEFOREs					

SIEFORE	Net return (%)	Expected return"fair perf."	Expected return"poor perf."	Expected risk "fair perf."	Expected risk "poor perf."
MaxS-SB1	72.8608	6.987***	20.641	2.1692	10.721
Azteca	41.6939	6.2808***	1.8377	2.5344	8.1996
Banamex	56.0163	7.9772***	2.1275	2.6799	8.885
Coppel	37.9507	6.6128***	-0.3589	2.1561	7.1758
Inbursa	42.5623	4.5389***	10.152***	0.4772	1.9336
Invercap	49.9814	8.5699***	-9.2593	4.0682	17.688
Metlife	46.2641	7.607***	-0.422	2.8267	9.2518
Principal	49.2131	7.907***	0.3849	2.7015	8.2567
Profuturo GNP	48.9634	8.6142***	-0.6648	2.8248	8.7931
SURA	60.2435	7.786***	4.4733	2.9248	8.8978
XXI Banorte	54.1112	7.7262***	1.8701	2.5587	8.4907

Panel B an Example of the Ranking of Type 1 SIEFOREs on December 2014.

SIEFORE ranking	Sharpe ratio "fair perf."	Sharpe ratio "poor perf. "	Sharpe ranking "fair perf."	Sharpe ranking "poor perf."	Net return ranking
MaxS-SB1	1.2216	1.4643			
Azteca	0.7669	-0.3786	9	5	9
Banamex	1.3583	-0.3168	2	3	2
Coppel	1.0554	-0.7388	7	9	10
Inbursa	0.4225	2.6942	10	1	8
Invercap	1.0404	-0.8029	8	10	4
Metlife	1.1568	-0.5798	6	7	7
Principal	1.3214	-0.552	4	6	5
Profuturo GNP	1.5141	-0.6377	1	8	6
SURA	1.1792	-0.0527	5	2	1

XXI Banorte	1.3245	-0.3618	3	4	3

* = Significant at 10%; ** = Significant at 5%; *** = Significant at 1%.
Note: Significance levels are reported for the Expected Return variables because the Quasi-Maximum Likelihood algorithm suggested in Hamilton (1994) was used in the estimations.

Source: Own elaboration with data retrieved from CONSAR (2014), https://www.gob.mx/ consar.

According to the net return ranking in *Table 4*, Coppel is the worst performer, and SURA the best. However, according to the MS-SR (*Table 4*), Profuturo-GNP (GNP hereafter), and Banamex are the best performers during "fair performance" periods (GNP is a "middle-rank performer" according to the net return method), but Inbursa and SURA are the best SIEFOREs during "poor performance" times. If savers were informed of which SIEFOREs are the best performers during "fair performance" and "poor performance" periods and had information about which regime prevails at every moment, they would be able to reallocate their pension savings and optimize the performance of their portfolio.

The MS-SRs and the Max Sharpe benchmark portfolio for each SIEFORE are obtained from the net returns calculated from the SIEFORE's market prices (), as published by the Mexican Stock Exchange on a daily basis.

While historical SIEFORE prices may be obtained since 1997, the currently prevailing investment policy was not authorized until March 2008. The new rules created six different types of SIEFOREs (SB0 to SB5). However, in February 2013, SIEFORES 4 and 5 were merged leaving only five types (as previously mentioned). Historical stock prices for each SIEFORE, adjusted for mergers and splits, have been published by CONSAR since 2008. The daily data retrieved for the present analysis runs from November 30, 2008 through December 31, 2014, as the first nine months of 2008 are used for estimation purposes. Net returns are estimated in continuous form as:

$$\Delta\%(SB_{i,t}) = \ln(\mathrm{SB}_{i,t}) - \ln(\mathrm{SB}_{i,t-1}) \quad (7)$$

Hamilton's (1989) filter is used on the returns of each SIEFORE and their corresponding benchmark, because "fair performance" and "poor performance" periods form part of a latent process that may be modeled as a two-state Markovian process, with the probability of being in a "fair performance" regime ($k = 1$) or a "poor performance" regime ($k = 2$) denoted by π_1 and π_2, respectively. Daily mean returns and standard deviations are estimated for the two regimes with Hamilton's (1989) filter:

$$\Delta\%(SB_{i,t}) = \begin{cases} \mu_{i,k=1} + \varepsilon_t, \varepsilon_t \sim \Phi(0, \sigma_{k=1}) \text{ if } \pi_1 > 0.5 \\ \mu_{i,k=2} + \varepsilon_t, \varepsilon_t \sim \Phi(0, \sigma_{k=2}) \text{ if } \pi_2 > 0.5 \end{cases} \quad (8)$$

The realization of state k in period t is modeled and determined with a fixed transition matrix that contains the probability of being in regime $k = m$ in time t and transiting to regime $k = n$ at $t + 1$. This transition probability is denoted by $p_{m,n}$, as represented in the following probability transition matrix:

$$\mathbf{P} = \begin{bmatrix} p_{1,1} & p_{2,1} \\ p_{1,2} & p_{2,2} \end{bmatrix} \quad (9)$$

Combining the mean and standard deviation observed for each SIEFORE in each regime along with their corresponding performance benchmark, a Markov-Switching Sharpe ratio is estimated as in (5). The daily-expected return ($\mu_{i,k}$), standard deviation ($\sigma_{i,k}$) and Sharpe ratio are then used to rank SIEFOREs within their investment type.

To test this work's proposal, three portfolios that represent the performance that savers' portfolios could have had from January 2010 to December 2014, had they invested their resources under the following three sets of conditions (scenarios), are simulated:

1. An "uninformed" scenario, where investment levels respond to the net asset value of each SIEFORE observed at the end of the previous month, following Calderón-Colín et al. (2009).

2. A "partially informed" scenario, where savers have access to a set of information similar to that presented in *Table 4*, the assumption being that, while savers have access to performance data, and are aware of the prevailing market conditions, they face an imperfect information flow and suffer from other externalities, such as: a) the fact that their SIEFORE is managed by a financial institution that takes advantage of back-to-back activities, including other financial products such as loans or insurance (i.e., the saver is tied to that SIEFORE due to associated contracts); b) savers can only change their SIEFORE investments once a year, due to legal restrictions; c) they are influenced by intensive marketing efforts (as suggested by Roberto Calderón-Colín et al. (2009). Nowadays, Mexican law allows Mexican pension savers to transfer their savings from one SIEFORE to another only once a year. While this measure aims to protect savers, avoiding the risk of a potential market impact on their savings, and to minimize potential irregular marketing actions, the legal

limitation represents an externality that impedes the flow of resources to the best performing SIEFOREs. This scenario is simulated with the algorithm described in Appendix A.

3. A "completely informed scenario" where the legal restriction of transferring savings from one SIEFORE to another only once a year is replaced with the possibility to change them once a month, so all savers act rationally and change their savings to the best performing SIEFORE during "fair performance" and "poor performance" periods, based on information similar to that in *Table 4*. This scenario is modeled with the decision-making algorithm presented in Appendix B.

The simulated "all savers" portfolio accumulated returns, for each of the three scenarios, and for the whole period, is presented in *Table 5*:

Table 5
Performance of Simulated Portfolios for Each SIEFORE Type Under Different Scenarios
(Accumulated Returns from Nov. 30 2008 through Dec. 31 2014)

	SB1	***SB2***	***SB3***	***SB4***
1. Simulated Uninformed Decisions	35.9223	49.1748	48.7185	54.8667
2. Simulated Informed Decisions	49.3851	51.7513	51.7333	51.0524
3. Simulated Fully Informed Decisions	40.3401	106.7983	106.7983	149.4667
Difference between 1. and 2.	13.4628	2.5765	3.0148	-3.8143
Difference between 1. and 3.	4.4178	57.6235	58.0798	94.6000
Difference between 2. and 3.	-9.0450	55.0470	55.0650	98.4143

Source: Authors' own simulations, according to the definition of the theoretical scenarios.

The difference in returns observed among the three scenarios is very significant, especially between the uninformed and the fully informed scenarios (*1*. and *3*.) and the informed and fully informed scenarios (*2*. and *3*.). These results are in line with the findings of Calderón-Colín et al. (2009) and show the huge opportunity costs of the uninformed decision-making process.

5. Conclusions

Competition among pension fund managers should improve the pension-savings portfolios' performance in Mexico. However, as Calderón-Colín et al. (2009) and Jorge Guillén (2011) point out, there is little competition among Mexican pension funds (SIEFOREs) due to informational asymmetry and to the absence of legal incentives that enhance it.

This study uses Markov-Switching models to calculate the changing Sharpe Ratios ($S_{i,k}$) of SIEFOREs during a sample period of historical data (November 1st, 2008, through December 31st, 2014), under two possible market regimes ("fair performance" and "poor performance"), and uses them to simulate hypothetical savers' allocation decisions, depending on which SIEFORE represents an optimal choice (highest Sharpe ratio). A monthly back-test is run with three theoretical portfolios. The first portfolio corresponds to the "optimal allocation" under an uninformed scenario, where its composition is determined using the normalized Net Asset Value of each SIEFORE as the weighting method:

$$w_i = NAV_i / \sum NAV_i \tag{10}$$

The second portfolio corresponds to the optimal allocation of savings under a partially informed scenario, in which the Markov-Switching information is available to all savers (they know which regime prevails at any moment in time), but they still face the legal restriction of changing their investment proceedings among SIEFOREs only once a year. In this scenario, the weighting method is the normalized Markov-Switching Sharpe ratio:

$$w_i = \begin{cases} S_{i,k} / \sum S_{i,k} & \text{if } S_{i,k} > 0 \\ 0\% & \text{if } S_{i,k} \leq 0 \end{cases} \tag{11}$$

The third portfolio corresponds to a "fully informed" scenario that also assumes that the legal restriction of transferring savings among SIEFOREs once a year is replaced by a less restrictive rule that allows transfers once a month. Therefore, all savers can freely invest in the SIEFORE that shows the highest Markov-Switching Sharpe ratio. That is, the investment weights in this simulated portfolio are:

$$w_i = \begin{cases} 100\% & \text{if } S_{i,k} = \max\left(S_{i,k}\right) \\ 0\% & \text{if } S_{i,k} < \max\left(S_{i,k}\right) \end{cases} \tag{12}$$

The results from the simulation suggest that the return performance of pension savings under partially informed and fully informed scenarios could have improved the full period's performance by between 0.5 and 3 times with respect to what really happened (the uninformed scenario).

Our results provide guidelines for future public policy and regulatory initiatives, including the recommendation that a mean-variance (risk-return) performance measurement for each SIEFORE should be published to promote informed decisions by savers, and to encourage competition among pension fund managers. We also recognize some limitations in the study, such as the short period of observations, and the choice of the Markov-Switching performance of the Max Sharpe benchmark portfolio instead of other MS multifactor models (e.g., Marcelle Chauvet, 2000). These areas of potential extension on the subject open new opportunities to explore methods to improve the performance of defined contribution pension fund portfolios in countries that have adopted this system.

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Annexes

Appendix A. Using Markov-Switching Sharpe Ratios in Partially Informed Scenarios

This appendix presents the decision-making algorithm that a theoretical group of pension savers would have followed if they had had access to Markov-Switching Sharpe ratios, such as those presented in *Table 4* (page 15), along with the probability of being in "fair performance" or "poor performance" periods. We assume that even if savers have access to this information, they suffer the impact of some externalities such as the fact that their SIEFORE is managed by a division of a big financial institution, or that the marketing efforts of their SIEFORE lead them to not entirely informed decisions. We also assume that the impact of the legal restriction of transferring retirement holdings from one SIEFORE to another only once a year has an impact on the investment levels. Therefore, to simulate the partially informed scenario portfolio the following algorithm is used:

Definitions:

$S_{i,k}$= Sharpe ratio of the i-th SIEFORE at time time, given the k-regime.

$I_{MaxSharpe}$= The Max Sharpe portfolio that measures the performance of all the SIEFOREs in a given type or investment regime such as SB1, SB2, SB3 or SB4.

$\mu_{MaxSharpe,k}$=The expected return, observed at t, of the Max Sharpe portfolio, given the k volatility regime.

$\sigma_{MaxSharpe,k}$The expected risk or standard deviation, observed at t, of the Max Sharpe portfolio, given the k volatility regime.

$\mu_{i,k}$= The expected return, observed at t, of the i-th SIEFORE, given the k volatility regime.

$\sigma_{i,k}$= The expected risk or standard deviation, observed at t, of the i-th SIEFORE, given the k volatility regime.

$P_t(k = 2|\Delta\% I_{MaxSharpe,t})$= The probability that the performance or investment policy of the SIEFOREs in a given investment style or type is in regime 2 or "poor performance", given the past-observed data of the benchmark.

Algorithm:

For February 2010 to December 2014

1. Calculate the Markov Switching values of $\mu_{i,k}$ and $\sigma_{i,k}$ using all the historic data of $\Delta\%(SB_{i,t})$ at t in each SIEFORE.
2. Calculate, the expected return $\mu_{MaxSharpe,k}$ and risk $\sigma_{MaxSharpe,k}$ of the performance benchmark, along with the probability of being in regime $k = 1,2$ or π_1.
3. Define regime $k = 1,2$ as:

$$k = \begin{matrix} 1 & \text{if } \pi_1 > 0.5 \\ 2 & \text{if } \pi_1 > 0.5 \end{matrix} \tag{A.1}$$

4. For all the SIEFOREs in the simulated type or investment regime, determine the smoothed or actual Markov-Switching Sharpe ratio, using the monthly rate of the 28-day CETES as the risk-free rate:

$$S_{i,k} = \mu_{i,k} - \frac{E(rf)}{\sigma_{i,k}} \tag{A.2}$$

5. Calculate the investment level in each SIEFORE using the following expression:

$$w_i = \begin{cases} S_{i,k}/\sum S_{i,k} & \text{if } S_{i,k} > 0 \\ 0\% & \text{if } S_{i,k} \leq 0 \end{cases} \tag{A.3}$$

6. Use the investment level in each SIEFORE to calculate the weighted mean return of the simulated portfolio P:

$$\Delta\%(P_t) = \sum_{i=1}^{N} w_i \cdot \Delta\%(SB_{i,t}) \tag{A.4}$$

A base-100 value is assumed in January 2010 for each SIEFORE type, using the SIEFORES described in *Table 2*.

Appendix B: Using Markov-Switching Sharpe Ratios in Fully Informed Scenarios.

The same definitions and steps of Appendix A are followed to simulate the portfolios for this scenario. The only difference is that the legal restriction that prevents savers from changing their savings from one SIEFORE to another more than once a year is relaxed. If that were the case, fully informed savers could have shifted their holdings to the highest Markov-Switching Sharpe ratio SIEFORE. Only step 5 in the Appendix A algorithm changes, and is replaced by:

Calculate the investment level in each SIEFORE, using the following expression:

$$w_i = \begin{cases} 100\% & \text{if } S_{i,k} = \max(S_{i,k}) \\ 0\% & \text{if } S_{i,k} < \max(S_{i,k}) \end{cases} \tag{B.1}$$

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