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**Can the commodity futures be used as effective diversifiers for pension funds  
investment portfolios? A literature review**

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**Abstract**

We examine from theoretical point of view whether commodity futures can produce diversification benefits for the pension funds' investment portfolios. These asset tools have been classified in the alternative investments and as a result they are subjected to worldwide pension regulative restrictions. Reviewing the relative scientific literature of pension funds' investment strategy and risk management, there is evidence that pension funds' trustees might take advantage of commodity futures preference, mainly because of their a) returns' low or negative correlation with these of other traditional options (bonds and stocks) and b) hedging positive properties against the inflation risk, resulting in the optimization of portfolios' risk-return ratio.

**JEL Classifications:** G23, Q02.

**Key words:** Pension funds, Risk Diversification, Alternative Assets, Commodity Futures

**1 Introduction**

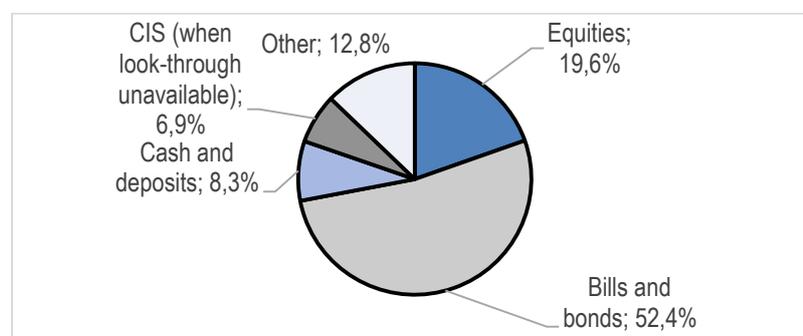
Pension Funds (PF) are considered to be financial vehicles as their size has been increased significantly during the last decade. According to OECD (2020), the total amount of pension assets worldwide has almost doubled since 2009, exceeding the threshold of \$50 trillion at the end of 2019. This trend is of great importance because their investment performance is related not only to the individual but to the social welfare as well. Through this prism, there is extended scientific research focused on the evaluation of investment strategies and risk management strategies adopted by various forms of PF.

The investment strategy of PF has turned into a crucial matter, as their managers have to take decisions in a low interest rate environment, within interrelated global financial markets, during turbulent periods of economy. In such a volatile macro-financial landscape, the trustees can allocate their pension assets in a wide range of traditional investment choices, such as cash, deposits, stocks, treasury bills, bonds and mutual funds. Under these conditions, there is the necessity for the design and implementation of the optimal investment strategy which combines successfully the maximization of portfolio returns with the minimization of risk.

The imposing by the regulators investment limits and performance regulations on pension funds' activities, make the trustees' mission even more and more complicated. Besides, there is a no common legislative framework among the countries through which the investment policy of PF is jointly regulated. The most essential constraints deal with a) the kind of investment means that it is allowed to invest the PF and b) the upper permitted limits of investing per asset class which cannot be exceeded.

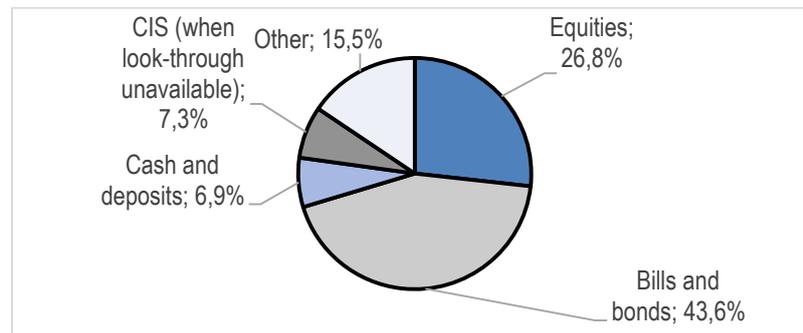
Complementary to the traditional investment tools, there are many other assets which are classified under the general term of alternative investments. In this category are included private equities, private real estate, infrastructure, hedge funds and commodities. Nowadays, it is observed a significant raise of the proportion of asset allocation at this group of investment tools by the PF, of many countries. This is possibly interpreted by the need of PF for gaining increased returns without taking additional risk, in order to fulfill their pension liabilities and guarantee future pension payments. However, the investment in these categories of assets is prohibited in many countries and the relative legislation can be considered as a conservative one.

**Figure 1:** Average allocation of pension assets in selected asset classes and investment vehicles of 28 OECD countries, in 2009 (as a percentage of total investments)



Source: OECD

**Figure 2:** Average allocation of pension assets in selected asset classes and investment vehicles of 37 OECD countries, in 2019 (as a percentage of total investments)



Source: OECD

From Figures 1 and 2, it is observed a substantial raise of PFs' preference for the 'Other' category investment option, as for the OECD countries, the percentage of PFs' asset allocation in such choices has been increased from 12.8% to 15.5%, in 2009 and 2019 respectively. Through them, PF might obtain improved investment returns, so long as not to be undertaken excessive market risk. In the light of this, it is suggested the close pension regulators' monitoring in order to be avoided an undesirable increase of PFs' risk taking, due to their effort of gaining higher returns, by the use of alternative investments.

This paper aims to investigate from theoretical perspective, the potential benefits of the commodity futures integration into PF investment portfolios. In section 2, it is presented the research review relative to the PF investment strategy, while section 3 refers to their investment risk management. In section 4, it is expounded the results of previous studies on the field of PF investment in alternatives assets. Section 5 and 6 contain the scientific review of the commodities' and commodity futures' contribution respectively, to the risk diversification of investment portfolios in general. The paper is concluded in section 7.

## 2 Pension Funds Investment Strategy

Kristjanpoller and Olson (2021) examine the managers' active investment behavior of Chilean DC pension programs, during the period 2007-2013. It is found that when these managers obtain negative returns, they increase their investment activity and their preference for riskier assets. Additionally, there is a rise in the received risk while in high volatility periods.

In their empirical analysis of the Chileans' pension system investment returns, MITTELSTAEDT and OLSEN (2003) emphasize that this country case needs special study, as it

constitutes an example of converting a pension system from the pay-as-you-go form (PAYG) to a pre-funded individual accounts system. Using monthly returns data and conducting tests with the Sharpe's and Jensen's measures, they attempt to explain the relation between the average real annual return (12%) of Chilean pension funds and that of index returns on equity, mutual funds and bonds of the country. Their empirical results conclude that the observed high returns of PF are related to a) the general risk level of the country's investment options and b) the risk degree of the Chilean economy. This conclusion could be useful for countries which consider to reform their pension systems and to convert them to a structure dissimilar to PAYG, as the systematic abnormal returns should not be taken for granted.

Zhang et al., (2020) seeking for the balanced investment policy of a Defined Contribution (DC) pension plan, apply the mean-variance criterion, considering that interest rates and market volatility are stochastic. The results show that a) increase in interest rate volatility causes decrease in bond investment and preference for risky positions, b) risky asset investment policy that is more balanced in comparison with that of bonds, is more sensitive to coefficient (a), given that (a) measures the volatility intensity and c) from the efficient frontier perspective, the higher interest rate volatility, the lower returns are obtained for the same level of investment risk.

The study of González et al., (2020) investigates the impact of PF activity and the patience on their final investment performance. Activity refers to the choice deviation of the PF, in terms of the holding stocks selection, in relation to a typical PF. Patience is linked to the stock holding period of the PF portfolio. Utilizing data from German PF, it is found that a) individual increase in activity and patience do not increase risk-adjusted returns and b) PF portfolio performance may be improved during an instantaneous increase of the activity and the stock holding period.

The research of Broeders et al., (2019) examines the relation between the returns and performance fees of 218 German occupational PF for the period 2012-2017. Total returns, excess returns and performance fees are used as data for 6 different investment options (fixed income, common stock, real estate, private equity, hedge funds and commodities). They do not find any statistical evidence between the portfolio returns and the applied PF investment strategy. Large PF, pay low performance fees for a certain level of excess return, due to their positions in hedge funds and private equities. A possible interpretation of the above it can be considered the PF stronger negotiating ability, due to their size and specialization.

The optimal investment strategy and benefits payment adoption of a Targeted Benefit Plan, within a risk-averse framework, is the subject of the Wang et al., (2019) research. They assume that the financial situation of the plan affects the amount of benefits, the risk is shared between the generations of its members and the investment portfolio consists of both risk-free and risky assets. According to the results, when the risk of pension benefits deterioration increases, the undertaken investment risk is eliminated. In order to be protected the plans' viability, it is opted the risk sharing between the generations via the reduction of pension benefits.

After the Paris Agreement on Climate Change signing in December of 2015, pension funds have to eliminate their carbon footprint, Boermans and Galema (2019). This can be achieved passively, when the included to the portfolio firms reduce their carbon emissions, or actively, by limiting the amount of invested assets in carbon-intensive stocks. Using data from the period 2009-2017 of the German PF, they combine the share holding with the firms' carbon dioxide emissions. They focus on the carbon footprint of PF investment portfolios measurement in relation to their active management. The results show that a) the goal of reducing the carbon footprint succeeded when the composition of the PF portfolios deviates from that of the markets' benchmark and b) this option does not appear to impair the risk-adjusted portfolios performance.

According to Aglietta et al., (2012) the returns of PF portfolios is a combination of market movements, PF asset allocation and active investment management. For the time span 1990-2008, they examine the role of these three factors in configuring the returns of United States defined benefit PF. Empirical results highlight the importance of active management, as it interprets the 26% of returns volatility.

Gökçen and Yalçın (2015), using data from Turkish private pension funds, conclude that the majority of active managers fail to gain significantly higher returns than those applying passive management, since the active management average returns outweigh by only 26 basis points, excluding fees. Managers' herding behavior is cited as a possible interpretation of outperformance failure while it is not ascertained the systematic abnormal returns achievement.

Alda et al., (2017) examine the long-term returns of a UK equity pension fund sample, by applying parametric and non-parametric methodologies, taking into account, both managers' characteristics and market conditions. The results show that managers' personal characteristics, such as their gender and experience, do not significantly affect their investment performance, in contrast to their specialization sufficiency. There are two

categories of managers, the generalists and the specialists. Specialists concentrate their effort, time and resources on a single one specific task, achieving more positive results than the generalists, whose attention is detracted due to their multiple investment goals satisfaction. Also, it is observed the specialists' outperformance in uptrend markets, while the generalists appear to be more efficient during bearish markets' momentum. The above findings might be exploited by management companies with the intention of PF returns' improvement.

Pagnoncelli et al., (2017) propose a two-step hybrid investment strategy, which can be applied by pension funds. They choose asset classes through optimization and they consequently follow passive management in relation to a benchmark index. As risk metrics are used the Variance and the CVaR. The results are compared with the five Chileans' largest pension funds performance and it is found that its implementation produces better absolute returns, higher Sharpe ratio and lower volatility for the tree riskier of them. The existing restrictive regulatory framework is cited as the reason for the two PFs' insufficient performance. Additionally, following their proposed strategy, it is recorded significantly lower management cost in comparison with the PF which apply a pure active management.

In Xie et al., (2018) it is suggested a method of loss aversion estimation, in conjunction with the subjective probability weighting of asset allocation. Utilizing data from 31 pension funds of OECD countries, it is found that a) when there is a wealth increase, investors appear to have greater disappointment aversion, b) there is a direct relationship between individuality loss aversion, as highly optimistic investors show increased disappointment in loss cases, c) investors with a high degree of individualism or men, tend to take high-risk and high-returns positions, d) uncertainty aversion leads an investors' portion to the bonds choice and e) when investors are both loss and risk averse, then compensation for the risky positions works concurrently as a disappointment compensation.

FARRELL and SHOAG (2016) underline the state and local pension plans' shift to non-Defined Benefit (DB) forms. This trend implies the direct members' participation in the plans' investment decisions. They use data from public DB and non-DB plans worldwide and from the members of a Florida's DC plan. They aim to investigate the individual and overall result of such member's involvement in the a) asset allocation distribution, b) management fees, c) investment returns and d) portfolio's rebalancing. The results show slight differences, except from the stronger DB preference for the alternative investments.

Peng (2008) emphasizes the necessity of a timeless prudent management of government pension surpluses, in order to be protected during periods of high stock market volatility.

Examining data from 51 state pension plans over the period 1998-2003, he finds that due to the markets' rise in the late of 1990s, there was a pension contributions decrease with a simultaneous rise of pension benefits. However, these balances were frustrated due to the forthcoming markets' collapse during the period 2000-2002, making the PF more vulnerable. The above highlight the need a) for cautious and long-term oriented management of PF surpluses and b) for stabilizing the pension benefits level, regardless of the pension contributions' percentage.

In the study of Gökçen et al., (2020) it is examined the relation between the Turkish pension funds' returns with their managers' nature. It is found that pension organizations, whose funds are absolutely managed by individual banks, achieve lower returns than those, whose management is conducted by independent companies or by the cooperation of two banks. As interpretation it can be considered the possible complacency of an investment company's managers, who invest out of the competition pressure for the PF's target accomplishment.

### **3 Investment Risk Management of Pension Funds**

Foltin (2018) emphasizes the necessity of a common regulative framework under which public PF investment policy, combined with the risk management, will be properly applied. Public PF's investment objectives should be set, their expectations should be assessed, their positions sizes in the various categories of investment instruments should be determined, their cash flows should be examined and independent consultants and managers should be hired. After all, it is required the risk analysis application, through the appropriate methods.

According to Gutierrez et al., (2019), pension regulators impose a number of investment restrictions on DC pension funds, in their effort to create PF with different risk-return profiles. The results of their research show a weak relation between these constraints and the overall portfolio's risk. In fact, the results are contrary to expectations, as higher-risk pension funds appear to gain lower returns. Using the CVAR methodology, they construct 5 PF under the terms of the Chilean pension system and they then remove the investment restrictions. Their method is based on both active and passive management, where the weights of investment positions change every single year. The results are encouraging, as these portfolios achieve higher returns, while creating distinct and different investment risk profiles.

The work of Dong and Zheng (2019) explores the contribution of short-selling and portfolio insurance constraints, in order to be ascertained the optimal investment strategy for a DC pension fund whose manager has a loss-averse profile. This is a problem of utility

maximization, as the PF administrators strive for the best result, in relation to an acceptable minimum amount of guarantees. Theoretical and numerical results show that the aforementioned constraints improve portfolio risk management, as their combination ensures that the overall result will not be worse than the minimum guaranteed.

The unhedgeable inflation risk is a significant factor, which affects the purchasing power protection of a pension program participant. Due to the absence of inflation risk market price tools, the value of pension contracts depends on the investors risk profile and the degree of their exposure to this form of risk, Chen et al., (2020). The inflation risk cannot be fully hedged because of a) the lack of such hedging tools and b) the PF participants consuming choices variety in relation to the total economy consuming bundles, as a whole. The above conclusions are of great importance, as the PF members overall welfare can be reduced by 6%, due to the absence of relative hedging inflation financial instruments, given the participants' risk aversion appetite.

In SHEN et al., (2019), PF funding ratio is defined as the proportion of asset values divided by its future benefit obligations. The lower the ratio, the higher the exposure in stock markets risk. Consequently, increasing exposure in risky assets leads to substantial uncertainty exposure.

Cadoni et al., (2017) advocate that the worldwide PF investment performance was significantly deteriorated, due to the financial crisis of 2008. Although, PF investment policy needs to be prudent, in crisis periods it is observed greater risk taking in order to ensure higher returns. Taking into account previous researches on the imposing regulative constraints field, their research reveals the paradox that some investment vehicles, which are considered by the legislative framework to be riskier, may be proved safer than others, which are characterized as of low risk. In particular, portfolios consisting of OECD countries assets (such as bonds), may be riskier than the portfolios which include investment means of non-OECD countries (such as stocks).

Kurach and Papla (2016) examine the foreign exchange risk hedging necessity of Polish' PF portfolios, defining as the optimal hedging ratio the one, in which it is minimized the portfolio variance, in conjunction with the compulsory pension system social objectives. In order to have a more realistic simulation, they incorporate investment constraints and they conclude to the currency risk hedging necessity. Among these restrictions is the ban of the currency derivatives investment. Using forward contracts, results in high portfolio variance when they are limited applied. Taking position in assets of foreign developed markets, especially when

the domestic market is not deep enough, it could be proved obviously beneficial in terms of risk diversification.

The research of Anton et al., (2016) shed light on the impact of derivatives use onto 14 Romanians' second pillar PF portfolios performance, relative to their risk management. The results reveal better returns for the PF which embody derivatives into their investment portfolios, compared to those that they do not include them. In 1% statistical significance level, there is observed a monthly returns increase of 0.4%, for a 1% increase of derivative positions. It is emphasized that these findings can be exploited by a) the pension regulators, for rationally assessing the constraints framework, b) the private investors, during their PF selection and c) the PF trustees, in order to improve their portfolios' risk management.

According to Mohan and Zhang (2014), trustees of underfunded public pension plans tend to overtake investment risk, gaining lower returns. The additional risk taking choice is considered as a compensation for the limited funding. Increased undertaken risk may be interpreted as the result of both fiscal constraints and government accounting standards. There is evidence of pension plans herding investment behavior, as pension plan managers seems to be influenced by the investment strategy of those, who have successfully performed. Finally, pension plan managers may invest in riskier assets in order to assure generous pension provisions.

Randle and Rudolph (2014) emphasize the necessity for alignment of DC pension funds investment risk management with the likelihood of the retirement target achievement, during their members' retirement period. In light of this, it is recommended to strengthen the precautionary nature of supervisory authorities, in order to be minimized the retirement risk. DC pension systems have received strong criticism during the recent financial crisis, because of their inability to provide a sufficient and sustainable retirement income. This pathogenesis was further amplified due to trustees' efforts of managing the short-term volatility against the long-run high retirement provisions.

The DC pension funds investment options are a major risk source for their members, according to BERSTEIN et al., (2013). For this reason, it is necessary to be implemented an appropriate method for monitoring the PF investment risk, so as a) to be set limits in their risk exposure, b) to be defaulted the investment options and c) to be forecasted the retirement and fiscal expenditures regarding the retirees' financial support. Furthermore, the role of managers' investment behavior is considered as additive because it affects the performance of PF investment portfolios.

PENNACCHI and RASTAD (2011) advocate that public PF which increase their investment risk under the Asset Liability Management (ALM), gain relatively low returns at a later time. They also note the tendency for riskier investment choices by PF that discount their liabilities with higher rates. Finally, the larger the number of plan members on PF Trustees Board, the greater the investment risk taking. In this way, trustees strive for increased returns following terms of gambling.

According to Bégin (2020), the volatility and the adjusted-risk balanced structure of pension plans, affects positively the welfare of current and future members, offering them acceptable levels of consumption and satisfaction. Their study reveals that both pension contributions and benefits depend on the plans' surplus and the Volatility Index price (VIX). Through the VIX, it is explained the changing cost of the options which included in the portfolio. An increase of market volatility, raise the embedded guarantees, as they become more expensive. As a result, current generation cope with the pension benefits reduction or with a pension contributions increase.

In the research of Verma and Verma (2018), it is examined the existence of DB pension fund managers' biased behavior, while in their investment decisions. Applying the regression methodology, it is found that in case of foregone losses or low returns, managers tend to take positions in riskier options in the future and vice versa, confirming the managers' risk aversion favor. Furthermore, the investment behavior seems to be influenced by specific pension variables, such as the participants' contribution rate and the amount of future benefits.

Menoncin and Scaillet (2006), support that the optimal DB pension investment portfolio is usually riskier than that of DC plans. DB plans might take on higher investment risk in order to fulfill their promising defined benefits.

Simulating the value of a DC pension plan, Blake et al., (2001), find that such plans can be significantly riskier relative to a DB benchmark. VaR results depend on the following PFs' investment strategy. When it is preferred the static investment in stocks, there are observed higher returns in comparison with the long-term dynamic management. Furthermore, in order to be achieved the same pension result, there is the necessity of a contribution rates increase when contrary to stock holdings, it is preferred the conservative strategy of bonds investing.

#### **4 Pension Funds and Alternative Investments**

Dixon (2008) argues that through alternative investments, it can be achieved diversification benefits for pension fund investment portfolios. In particular, investing in real estate can

contribute to the long run inflation risk hedging. Commodities offer positive returns, due to their negative correlations with those of equities and fixed income investments. Similarly, by investing in infrastructure projects it is ensured unchangeable long horizon cash flows and low correlations in conjunction to other asset classes returns. Finally, investors may gain higher returns by positioning in private equities, relative to benchmark equity indices.

Jackwerth and Slavutskaya (2016) investigate the effects of alternative investments inclusion into PF portfolios, as the decreasing observed returns of equities and bonds, amid the financial crisis. It is examined their impact from the perspective of risk diversification, returns' left-tails elimination and positive asymmetry existence. For the period 1994-2012, hedge funds selection seems to be more gainful compared to other investment choices, such as real estate, commodities, foreign equities, funds of funds and mutual funds. By alternatives, PF strive for their volatility reduction and their asset value stability. Giving a 10% margin for such investment vehicles, it is provided evidence of a random hedge fund portfolio over-performance, compared to those which contain other alternative investment means. However, the transparency lack and the high fees level are considered as the most significant drawbacks of this strategy.

According to Andonov et al., (2015), it is noticed an institutional investors' shift, among them the pension funds, to the alternative investments such as real estate, private equities, hedge funds, commodities and infrastructure, during the last decade. Investing in real estate is considered to be one of the most important choices, as it offers excellent opportunities for internal or intermediated investment management. In terms of cost and performance, investing in such assets shows significant heterogeneity and depends not only on the size of the organization but on its investment approach as well. They conclude that larger PF, which invest internally in real estate, reduce their costs and lead them to higher net returns. On the contrary, smaller PF choose to invest in this specific market through external managers or fund-of-funds. As a general conclusion, it is stated the increased cost and the disproportionate returns decrease, due to the external management preference.

Stalebrink (2016) states that investing in alternatives aligns with to the modern portfolio theory principles, as it is observed risk diversification for a given returns level, due to their low correlation compared to traditional investment options. As reasons for the PF investment raise in such assets are underlined a) the aim of portfolios volatility elimination, b) the losses decrease over high volatility periods and c) the fact of financial markets high correlation, due to the contemporary globalization reality. However, a significant portion of public PF show limited or even zero preference in alternative investments. As possible interpretations for the

above, it can be assumed the imposed pension regulative investment restrictions, the information asymmetry, the high investment risk, the lack of these markets access and general political reasons.

Peng and Wang (2020) support that the sharp stock market decline of 2000 and the collapse of financial markets in 2008, were the reasons due to which, the two important public and state pension programs variables in the US came under scrutiny: the funded ratio and the percentage of unfunded pension liability. At the same time, in terms of investment asset allocation, there was a significant increase in alternative investment forms. This option, despite the disadvantages of increased transaction costs and low liquidity, has significant advantages, such as low returns volatility (given the weak correlation of the observed returns between traditional and alternative investments) and high portfolio performance over the long horizon. Their research uses data from 92 pension plans for the period 2001-2014 and concludes that a) through alternative investments and especially private equities, it was achieved a substantially positive portfolio performance effect b) the higher funded ratio, in parallel with high investment returns expectation, the more alternatives assets integration in PF portfolios.

According to Broeders et al., (2021) pension funds tend to invest in low-liquidity investment options such as real estate, hedge funds, infrastructure, mortgages and private equity. Through this strategy it is enhanced the portfolio risk diversification, the liabilities hedging and the liquidity premium, given their long-term investment horizon. Both liquidity and capital requirements are set as pivot factors for the PF investing tendency for low-liquidity assets. Hedging with derivatives increases not only the liquidity but the capital requirements as well. Empirical results reveal a hump-shaped of the liabilities duration graph for the risky asset portfolio part, which is constructed by illiquid assets. Also, low liquidity investment options seem to be affected by the funding ratio and the pension funds' type and size.

Cumming et al., (2014) recommend the alternative assets inclusion into the PF investment portfolios, given the long investment horizon of such organizations and the adequacy of their funds availability. However, the improvement of their risk- return ratio is not always satisfied by all types of alternatives and their integration must be decided in combination with traditional investment options. Specifically, investments in a) real estate, reduce obviously the risk aversion, b) commodities, appear as an intermediate situation, c) hedge funds, are presented as similar to bonds and d) private equities, affect substantially in the most aggressive portfolios cases. Their method is characterized as flexible and it is applied a combination of normal methods, in order to take advantage of the better alternative asset

returns. They set a performance target, which is placed between two selected benchmarks: the minimum accepted performance and the wishing one. In progress, they proceed in the optimal solution, taking into account a number of risk factors. Their empirical results are encouraging as they seem to be more superior over the Markowitz's classic mean-variance approach, even in economic crisis environment.

Leal and Mendes (2010) investigate the results of hedge funds integration into Brazilian PF. They compare a typical PF with another one which it invests in hedge funds. The results are positive as it is highlighted a) the risk-return ratio improvement, b) the yearly accumulated return increase and c) portfolios' rebalancing elimination. The PF gains an annual return up to 6%, reducing in parallel its investment risk.

Gregoriou and Rouah (2002) refer to the advantages of PF investment in alternatives, such as hedge funds and funds of hedge funds. In bear markets, these assets are suitable for the risk diversification, due to a) their low correlation with the stock markets, b) their returns enhancement, c) the risk reduction and d) the risk-adjusted returns increase. Their illiquid nature makes them appropriate long-term investment options. An acceptable percentage range of investing in such tools is considered the 10-20%. However, hedge funds charge management fees of 1-2% and performance fees of about 20%. Special attention is required in order to assess other factors while in the hedge funds selection, such as their size, the number of managers and their philosophy of investment strategy. After all, their positions' evaluation is considered a difficult procedure, due to the low transparency.

Umeh and Okonu (2018) testify the real estate contribution into the performance of a Nigerian PF mixed-asset portfolio. For the time span 2007-2016, they find that a) there are risk diversification benefits and b) the portfolio achieves enhanced returns. These results are considered positive, as this framework can be used not only by pension organizations' managers but also by other institutional investors' trustees.

According to Lekander (2017) there are conflicting factors that affect the pension organizations' investment portfolios management. These may depend on the structure and the duration of liabilities, the existing regulatory framework and the types of investment risks that the portfolios are affected. Based on the interview methodology, he gathers information from seven pension fund managers of Sweden and Finland about their organizations' real estate investment. The findings show that this investment option achieves a) reduced volatility risk due to low correlations, b) better returns due to illiquidity premium and c) long-term liabilities matching because of income and inflation linkage.

Aubry et al., (2017) present commodities as one of the main categories of alternative investments. Their basic feature is their intrinsic economic value for consumption (agricultural products) or for manufacturing process (metals and energy), while their value is determined by the market mechanisms, according to supply and demand. In addition, it is usually observed a low correlation with traditional investments and a high one with inflation, resulting in their use as a hedging instrument against the price level increase. They also appear a high liquidity degree, when they are traded through futures markets. The analysis shows the systematically low relation between the pension plans' characteristics and the alternatives. Small pension plans prefer the hedge funds and the commodities investment (which they have not recently recorded substantial returns), in contrast to the larger ones, where they have achieved encouraging results through the selection of private equities. The empirical results suggest a) the systematically negative and statistically significant relation between alternative investments and portfolios' returns, which it is resulted by the hedge funds' low returns and b) that the hedge funds integration contributes to the portfolios' volatility elimination while other alternative assets increase it.

Examining the investment policies of the eight largest Canadian public pension funds (the Big Eight), Bédard-Pagé et al., (2016) underline their shift to low-liquidity alternative investment options, such as real estate, infrastructure and private equity. As possible explanation it is considered the prolonged maintenance of the low interest rates environment and the consequent necessity for achieving higher returns. Investing in real estate and infrastructure offers relatively predictable cash flows and inflation protection, operating as bonds substitute. In addition, the selection of private equity can offer potentially significant returns on the larger investors' portfolios.

Based on the percentage of 33 US states pension funds' investment in alternatives during 2017 (private equity, hedge funds, real estate, commodities, infrastructure and natural resources), Park and Hooke (2018) conclude that the average annual return (4.50%), over a 10-year horizon for the five states with the largest proportion, is lower (5.59%), compared to that of the five states with the smaller percentage. Although the sample size is considered small by the authors themselves, it is emphasized that the above conclusion may be due to the completely different PF investment strategy. They also remark that the alternatives integration in such portfolios, creates two different forms of costs, relative to external managers: the fixed fees, that are independent of any investment gains or losses and the performance fees, which they are paid in case of the investments' value increase.

The IMF (2019) states that due to the low interest rates environment, institutional investors are pressured to seek for more risky and illiquid investment vehicles, in order to achieve their targets, from the returns perspective. This situation has also affected the DB pension funds, whose trustees have taken higher risk, as their liabilities duration is typically higher than this of their assets. In an effort to secure their returns, they have increased their positions in long-term duration investment options, copying inevitably with higher liquidity risk. These investment instruments include various forms of alternative classes, such as private equity, real estate and infrastructure, which are mainly characterized by long periods of limited trading and extremely low leverage.

## **5 Risk Diversification with Commodities**

Boal and Wiederhold (2020) confirm the low correlation degree between commodities and traditional investment instruments, resulting in investment portfolios' risk diversification. After all, the introduction of negative or low correlation investment tools in a portfolio can reduce its volatility, without sacrificing its returns.

Belousova and Dorfleitner (2012) refer to commodities as a distinct category of investment instruments. Their main properties are a) the effectiveness in hedging the expected and unexpected inflation risk, b) their prices determination depends on the economic situation and the phase of the economic cycle, c) their pricing is mostly assessed in US dollars and d) their valuation does not follow traditional methods, as it depends on economic conditions and it is influenced by the supply and demand dynamics. Their main characteristic is the low correlation with stocks and bonds. The research examines the potential diversification benefits of commodities into a Europeans' investor portfolio. The results seem to be positive, as the inclusion in the portfolio of a) industrial metals, agricultural and livestock products reduces the risk and b) energy products and precious metals, not only reduces the risk but improves its returns as well.

Öztek and Öcal (2017) argue that investors wish to reduce their risk portfolio through diversification strategies, taking advantage of the low correlations of various investment instruments. Such tools are commodities, which for periods before 2004 have shown a low degree of correlation with stocks. Their research extends to the period after the financial crisis and up to 2012, which is characterized as financialization era of the commodities markets, due to the growing involvement of financial investors in these markets. Examining the hypothesis of the correlations upward trend, they conclude that in calm periods, there is no strong indication of high correlations between agricultural commodities and stocks, resulting in

diversification opportunities. However, the correlations are increased during the crisis periods. For precious metals in relation to stocks, even the higher observed trend especially in turbulent times, it remains lower comparing to other markets. Therefore, it is appropriate to incorporate commodities into a stock portfolio, especially in calm phases of the market.

In the research of Gagnon et al., (2020) it is examined the contribution to risk diversification of commodity indices inclusion into a Canadian investment portfolio. Using monthly returns for the period 1993-2019 for a portfolio which consists of a) the S & P / TSX Composite Index (representing the stock market), b) the S&P Canada Aggregate Bond Total Return Index (related to the bond market) ) and c) the Bank of Canada 1-month commercial paper rate (relating to risk-free investment), they then incorporate as commodity indices the a) Bank of Canada Commodity Price Index (BCPI) and Bank of Canada Commodity Price Index excluding energy (BCPIEX ), b) Bloomberg Commodity Total Return Index (BCOM) and Bloomberg Commodity Total Index return excluding energy (BCOMEX) and c) Morningstar Commodity Currency Index (MSCCI). Empirical results show limited diversification benefits prior and during the financialization period. However, this is reversed while in the post-financialization phase. The index choice plays an important role, as it is not observed the same degree of risk diversification for all of them. Also, the combination of an international index with a domestic one, it can work positively in diversification terms, improving significantly the portfolios' performance.

Mensi et al., (2014) present as basic characteristics of oil and cereal markets the increased volatility and their high interrelation. The returns and the excessive volatility of these markets are significantly affected by the OPEC's announcements. In particular, statements related to the reduction of oil production are considered to be bad news and vice versa. This suggests an asymmetric influence on markets, affecting directly their volatility. Volatility forecasting could help investors to take decisions about optimizing the weights and the hedging ratios of oil and cereals portfolios and to explore diversification effects.

## **6 Risk Diversification with Commodity Futures**

Demiralay et al., (2019), investigate the contribution of commodity futures to portfolio risk diversification. Using monthly data from the period 1992-2014, they compose 6 hypothetical portfolios and analyze the correlation degree in accordance with the potential diversification

benefits. According to the empirical results, the inclusion of commodity futures into investment portfolios of emerging and developed markets reduces the correlations intensity, making them attractive diversifiers for stock portfolios. From the cross-sectional correlations point of view, it is observed a higher degree of correlation for energy and metal futures with emerging and developed markets. This leads to further financialization of these commodity markets. However, the greater similarity between futures and developed markets movement, highlighting them as efficient diversification tools for emerging market portfolios. The diversification benefits of commodity futures remain visible for emerging and developed stock market portfolios even in economic uncertainty periods.

Kanamura (2018) states that an asset contributes to a portfolio risk diversification, when in terms of asymmetry (skewness), its distribution returns approaches the normal, more than another portfolio which does not contain the same asset. Using a Dynamic Conditional Correlation model with exogenous financial variables, he finds evidence of diversification effects due to small but strong conditional correlations between the S&P 500, U.S. 10-year treasury notes and the DJ-AIG commodity index. Comparing the portfolio efficient frontiers with or without inclusion of commodity futures, it is investigated the portfolio optimization by applying the mean-conditional value at risk (mean-CVAR) method. It is revealed the improvement of the portfolio efficient frontiers, which contains this type of assets.

According to Shelly (2017), the evolution of commodity derivatives markets has transformed the role of commodities from consuming to investing one. Through their trading, it can be enhanced the market risk management and risk hedging, as the commodities producers can now pass on the risk of price changes to other groups of investors, such as speculators and arbitrageurs, who are not directly related to these markets. Taking into account that the prices of products are influenced by different factors in relation to those of stocks, there is an increase of their use as diversification means. In her study, it is examined the extent to which commodity derivatives can be used as alternative investments in emerging markets portfolios and whether their potential diversification benefits are similar with those of developed markets portfolios. The results show that a) the integration of commodity futures into stocks and bonds portfolios, offers diversification benefits, due to their low positive or negative correlations, b) the commodity derivatives can operate efficiently as hedging tools against the inflation risk and c) optimal portfolios can be obtained due to the combination of stocks and commodity futures.

Bansal et al., (2014) examine the effect of integrating commodity futures into stocks and bonds portfolios and how suitable can be proved as alternative investing vehicles for the risk-

averse investors. They use data from the period 2005-2011 and they conclude for these assets that a) commodity futures present higher returns and lower risk in relation to the stocks, b) they can be used as autonomous investment instruments from the risk-neutral investors, c) the risk-averse investors utility is maximized, as it is observed an increase in the average portfolio return, due to the negative correlation of commodity futures returns with that of bonds and the low correlation with the stocks returns and d) there are diversification benefits after their inclusion into stocks and bonds portfolios.

Batavia et al., (2012) underline the defensive role of commodities investments, as high returns are observed when stock and bond returns decline. However, this does not have a constant effect over time, because of the increasing correlation between stock and commodities returns. In extreme market conditions, especially in downturns, the integration of commodity futures does not seem to significantly improve the portfolios diversification, as there is no significant change in the Sharpe's ratio.

The research of Lagesh et al., (2014) reveals low degree of conditional correlations among futures commodity indices, stock indices, high-maturity bonds and Treasury Bills, giving them properties that favor the investment risk diversification. In crisis periods, the conditional correlation of agricultural commodity futures appears to be lower than that of both long-run and short-run bonds. Similarly, in times of stock markets high volatility, it is observed low conditional correlation in the returns of commodity futures indices (on metals, energy and agriculture) with these of the stock indices.

According to Cheung and Miu (2010), the diversification benefits of commodity futures are substantial and statistically significant over the long run. Their behavior presents the particularity of low returns (high), in periods of low (high) volatility. Infrequent and extreme events related to these markets might explain the overall long-term diversification benefits, especially in upward markets phases. These benefits may not be universal, especially for resource-based economies. However, their use seems to be preferable to more conservative investors, with low risk appetite.

Daskalaki et al., (2014) support that commodities are considered as separate category of alternative investment tools, whose price determinants differ from those of traditional instruments. Their heterogeneous structure is an additional feature of these assets. Therefore, investors should carefully choose the appropriate pricing model for commodity futures while calculating gaining returns, in accordance with their risk taking.

Gorton and Rouwenhorst (2004) claim that commodity futures positions offer to the investors not only high returns but also a lower downside risk, especially in the cases of

including them into stocks and bonds portfolios. In terms of standard deviation and given the observed positive skewness of their returns, these assets are presented as less-risky compared to the corresponding stock derivatives. The negative correlation of commodity futures returns with those of stocks and bonds, contributes to the portfolios risk diversification, especially during long holding periods. Possible interpretations of the above are a) the higher gained returns in relation to those of stocks and bonds, during unexpected inflation periods and b) their ability to diversify the cyclical variance of stocks and bonds returns.

From the perspective of a stand-alone investment tool and in comparison to stocks, JENSEN et al., (2000) characterize commodity futures as instruments of low returns and high standard deviation. However, their use as portfolio components, it can optimize the portfolios' risk–return ratio. In addition, they put emphasis on the relation of commodity futures performance with the applied monetary policy. In restrictive monetary policy periods, commodity futures enhance the risk–return ratio, not only as autonomous investment choice but also as a portfolio's component. The opposite results occur in the case of expansive monetary policy. Consequently, the stringency of monetary policy can be used as a means of the portfolios structure determination, given their property to operate as hedging tools against the inflation risk.

Picker (2005) describes the commodity futures as investment instruments whose returns a) are similar but less volatile in comparison with those of stocks, b) are negatively correlated with the stocks and bonds returns and c) are positively correlated with inflation. Additionally, they can be considered as less riskier assets than stocks. That is because their distribution returns, opposite to stocks, show positive skewness. Furthermore, commodity futures offer diversification benefits due to their hedging properties against the inflation risk.

## **7 Conclusion**

The last two decades period has been defined as the financialization era of commodities markets, due to the observed wide participation of financial investors in these. Integrating commodity futures into investment portfolios may be proved beneficial in diversification terms because of their a) return low or negative correlation with these of other traditional options and b) positive hedging impact against the inflation risk. As alternatives assets, commodity futures are inevitably subjected to pension regulative constraints. Reviewing the relative scientific literature, there is strong evidence that commodity futures can be handled as effective diversifiers for PF investment portfolios, according to the market momentum or

even the applied economic policy. However, further future research is required, in order to be empirically confirmed the above benefits for PF investment portfolios. This particular investigation field is of great importance, not only for the PF portfolio managers, during the construction of well diversified portfolios but for the pension regulators as well, in order to be reexamined the existing investment restrictions.

## References

- Aglietta, M., Brière, M., Rigot, S., & Signori, O. (2012). Rehabilitating the role of active management for pension funds. *Journal of Banking & Finance*, 36(9), 2565-2574. <https://doi.org/10.1016/j.jbankfin.2012.05.017>.
- Alda, M., Andreu, L., & Sarto, J. L. (2017). Learning about individual managers' performance in UK pension funds: The importance of specialization. *The North American Journal of Economics and Finance*, 42, 654-667. <https://doi.org/10.1016/j.najef.2017.09.006>.
- Andonov, A., Eichholtz, P., & Kok, N. (2015). Intermediated investment management in private markets: Evidence from pension fund investments in real estate. *Journal of Financial Markets*, 22, 73-103. <https://doi.org/10.1016/j.finmar.2014.11.002>.
- Anton, S. G., Toader, E., & Firtescu, B. (2016). DOES RISK MANAGEMENT USING DERIVATIVES IMPROVE THE FINANCIAL PERFORMANCE OF PENSION FUNDS? EMPIRICAL EVIDENCE FROM ROMANIA. *Transformations in Business & Economics*, 15(3C), 565-579.
- Aubry, J.P, Chen, A., & Munnell, A.H. (2017). A FIRST LOOK AT ALTERNATIVE INVESTMENTS AND PUBLIC PENSIONS. Retrieved from [https://crr.bc.edu/wp-content/uploads/2017/06/slp\\_55.pdf](https://crr.bc.edu/wp-content/uploads/2017/06/slp_55.pdf). Accessed February 25, 2020
- Bansal, Y., Kumar, S., & Verma, P. (2014). Commodity futures in portfolio diversification: Impact on investor's utility. *Global Business and Management Research*, 6(2), 112-121.
- Batavia, B., Parameswar, N., & Wagué, C. (2012). Portfolio diversification in extreme environments: are there benefits from adding commodity futures indices?. *European Research Studies Journal*, 15(3), 33-48. <https://www.um.edu.mt/library/oar//handle/123456789/31221>.
- Bédard-Pagé, G., Demers, A., Tuer, E., & Tremblay, M. (2016). Large Canadian Public Pension Funds: A Financial System Perspective. Retrieved from <https://www.bankofcanada.ca/wp-content/uploads/2016/06/fsr-june2016-bedard-page.pdf>. Accessed March 18, 2021
- Bégin, J. F. (2020). Levelling the playing field: A VIX-linked structure for funded pension schemes. *Insurance: Mathematics and Economics*, 94, 58-78. <https://doi.org/10.1016/j.insmatheco.2020.06.009>.

Belousova, J., & Dorfleitner, G. (2012). On the diversification benefits of commodities from the perspective of euro investors. *Journal of Banking & Finance*, 36(9), 2455-2472.

<https://doi.org/10.1016/j.jbankfin.2012.05.003>.

Berstein, S., Fuentes, O., & Villatoro, F. (2013). Default investment strategies in a defined contribution pension system: a pension risk model application for the Chilean case. *Journal of Pension Economics & Finance*, 12(4), 379. DOI:10.1017/S1474747213000073.

Blake, D., Cairns, A. J., & Dowd, K. (2001). Pensionmetrics: stochastic pension plan design and value-at-risk during the accumulation phase. *Insurance: Mathematics and Economics*, 29(2), 187-215. [https://doi.org/10.1016/S0167-6687\(01\)00082-8](https://doi.org/10.1016/S0167-6687(01)00082-8).

Boal, F., & Wiederhold, J. (2020). Rethinking Commodities. Retrieved from <https://www.google.com/search?client=firefox-b-d&q=sp500+rethinking+commodities>.

Accessed April 4, 2021

Boermans, M. A., & Galema, R. (2019). Are pension funds actively decarbonizing their portfolios?. *Ecological Economics*, 161, 50-60.

<https://doi.org/10.1016/j.ecolecon.2019.03.008>.

Broeders, D. W., Jansen, K. A., & Werker, B. J. (2021). Pension fund's illiquid assets allocation under liquidity and capital requirements. *Journal of Pension Economics & Finance*, 20(1), 102-124. <https://doi.org/10.1017/S1474747219000398>.

Broeders, D. W., van Oord, A., & Rijsbergen, D. R. (2019). Does it pay to pay performance fees? Empirical evidence from Dutch pension funds. *Journal of International Money and Finance*, 93, 299-312. <https://doi.org/10.1016/j.jimonfin.2019.02.010>.

Cadoni, M., Melis, R., & Trudda, A. (2017). Pension funds rules: Paradoxes in risk control. *Finance Research Letters*, 22, 20-29. <https://doi.org/10.1016/j.frl.2017.05.003>.

Chen, D. H., Beetsma, R. M., & van Wijnbergen, S. J. G. (2020). Unhedgeable inflation risk within pension schemes. *Insurance: Mathematics and Economics*, 90, 7-24.

<https://doi.org/10.1016/j.insmatheco.2019.10.009>.

Cheung, C. S., & Miu, P. (2010). Diversification benefits of commodity futures. *Journal of International Financial Markets, Institutions and Money*, 20(5), 451-474.

<https://doi.org/10.1016/j.intfin.2010.06.003>.

Cumming, D., Helge Haß, L., & Schweizer, D. (2014). Strategic asset allocation and the role of alternative investments. *European Financial Management*, 20(3), 521-547.

<https://doi.org/10.1111/j.1468-036X.2012.00642.x>.

Daskalaki, C., Kostakis, A., & Skiadopoulos, G. (2014). Are there common factors in individual commodity futures returns?. *Journal of Banking & Finance*, 40, 346-363.

<https://doi.org/10.1016/j.jbankfin.2013.11.034>.

Demiralay, S., Bayraci, S., & Gencer, H. G. (2019). Time-varying diversification benefits of commodity futures. *Empirical Economics*, 56(6), 1823-1853.

<https://doi.org/10.1007/s00181-018-1450-7>.

Dixon, A. D. (2008). The rise of pension fund capitalism in Europe: an unseen revolution?. *New Political Economy*, 13(3), 249-270. <https://doi.org/10.1080/13563460802302560>.

Dong, Y., & Zheng, H. (2019). Optimal investment of DC pension plan under short-selling constraints and portfolio insurance. *Insurance: Mathematics and Economics*, 85, 47-59.

<https://doi.org/10.1016/j.insmatheco.2018.12.005>.

Farrell, J., & Shoag, D. (2016). Asset management in public DB and non-DB Pension Plans. *Journal of Pension Economics & Finance*, 15(4), 379-406.

<https://doi.org/10.1017/S1474747214000407>.

Foltin, C. (2018). An examination of state and local government pension underfunding—Implications and guidance for governance and regulation. *Research in Accounting Regulation*, 30(2), 112-120. <https://doi.org/10.1016/j.racreg.2018.09.003>.

Gagnon, M. H., Manseau, G., & Power, G. J. (2020). They're back! Post-financialization diversification benefits of commodities. *International Review of Financial Analysis*, 71, 101515.

<https://doi.org/10.1016/j.irfa.2020.101515>.

Gökçen, U., Özsoy, S. M., & Yalçın, A. (2020). Firm boundaries, incentives, and fund performance: Evidence from a private pension fund system. *Emerging Markets Review*, 43, 100682.

<https://doi.org/10.1016/j.ememar.2020.100682>.

Gökçen, U., & Yalçın, A. (2015). The case against active pension funds: Evidence from the Turkish Private Pension System. *Emerging Markets Review*, 23, 46-67.

<https://doi.org/10.1016/j.ememar.2015.04.007>.

Gonzalez, T. A., van Lelyveld, I., & Lučivjanská, K. (2020). Pension fund equity performance: Patience, activity or both?. *Journal of Banking & Finance*, 115, 105812.

<https://doi.org/10.1016/j.jbankfin.2020.105812>.

Gorton, G., & Rouwenhorst, K.G. (2004). FACTS AND FANTASIES ABOUT COMMODITY FUTURES. Retrieved from

[https://www.nber.org/system/files/working\\_papers/w10595/w10595.pdf](https://www.nber.org/system/files/working_papers/w10595/w10595.pdf). Accessed March 17, 2021

Gregoriou, G. N., & Rouah, F. (2002). The role of hedge funds in pension fund portfolios: Buying protection in bear markets. *Pensions: An International Journal*, 7(3), 237-245.

<https://doi.org/10.1057/palgrave.pm.5940199>.

Gutierrez, T., Pagnoncelli, B., Valladão, D., & Cifuentes, A. (2019). Can asset allocation limits determine portfolio risk–return profiles in DC pension schemes?. *Insurance: Mathematics and Economics*, 86, 134-144. <https://doi.org/10.1016/j.insmatheco.2019.02.009>.

IMF. (2019). INSTITUTIONAL INVESTORS: FALLING RATES, RISING RISK. Retrieved from

<https://www.imf.org/en/Publications/GFSR/Issues/2019/10/01/global-financial-stability-report-october-2019#Chapter3>. Accessed March 18, 2021

Jackwerth, J. C., & Slavutskaya, A. (2016). The total benefit of alternative assets to pension fund portfolios. *Journal of Financial Markets*, 31, 25-42.

<https://doi.org/10.1016/j.finmar.2016.06.002>.

Jensen, G. R., Johnson, R. R., & Mercer, J. M. (2000). Efficient use of commodity futures in diversified portfolios. *Journal of Futures Markets: Futures, Options, and Other Derivative Products*, 20(5), 489-506. [https://doi.org/10.1002/\(SICI\)1096-9934\(200005\)20:5%3C489::AID-FUT5%3E3.0.CO;2-A](https://doi.org/10.1002/(SICI)1096-9934(200005)20:5%3C489::AID-FUT5%3E3.0.CO;2-A).

Kanamura, T. (2018). Diversification effect of commodity futures on financial markets. *RIETI Quantitative Finance and Economics*, 2(4), 821-836.

<http://dx.doi.org/10.3934/QFE.2018.4.821>.

Kristjanpoller, W. D., & Olson, J. E. (2021). The effect of market returns and volatility on investment choices in Chile's defined contribution retirement plan. *Journal of International Money and Finance*, 112, 102321. <https://doi.org/10.1016/j.jimonfin.2020.102321>.

- Kurach, R., & Papla, D. (2016). Should pension funds hedge currency risk? The case of Poland. *Baltic Journal of Economics*, 16(2), 81-94.  
<https://doi.org/10.1080/1406099X.2016.1187429>.
- Lagesh, M. A., Kasim C, M., & Paul, S. (2014). Commodity futures indices and traditional asset markets in India: DCC evidence for portfolio diversification benefits. *Global Business Review*, 15(4), 777-793. <https://doi.org/10.1177%2F0972150914543418>.
- Leal, R. P. C., & Mendes, B. V. D. M. (2010). The risk-return relationship of pension funds with investments in hedge funds. *Latin American Business Review*, 11(2), 141-169.  
<https://doi.org/10.1080/10978526.2010.496307>.
- Lekander, J. R. (2017). How do institutional pension managers consider real estate: A perspective from Sweden and Finland. *Journal of Property Investment & Finance*, 35(1), 26-43. <https://doi.org/10.1108/JPIF-05-2016-0033>.
- Menoncin, F., & Scaillet, O. (2006). Optimal asset management for pension funds. *Managerial Finance*, 32(4), 347-374. <https://doi.org/10.1108/03074350610652260>.
- Mensi, W., Hammoudeh, S., Nguyen, D. K., & Yoon, S. M. (2014). Dynamic spillovers among major energy and cereal commodity prices. *Energy Economics*, 43, 225-243.  
<https://doi.org/10.1016/j.eneco.2014.03.004>.
- Mittelstaedt, H. F., & Olsen, J. C. (2003). An empirical analysis of the investment performance of the Chilean pension system. *Journal of Pension Economics & Finance*, 2(1), 7-24. DOI: 10.1017/S147474720200120.
- Mohan, N., & Zhang, T. (2014). An analysis of risk-taking behavior for public defined benefit pension plans. *Journal of Banking & Finance*, 40, 403-419.  
<https://doi.org/10.1016/j.jbankfin.2013.12.011>.
- OECD. (2020). Pension Markets in Focus 2020. Retrieved from <http://www.oecd.org/daf/fin/private-pensions/globalpensionstatistics.htm>. Accessed January 20, 2021
- Öztek, M. F., & Öcal, N. (2017). Financial crises and the nature of correlation between commodity and stock markets. *International Review of Economics & Finance*, 48, 56-68.  
<https://doi.org/10.1016/j.iref.2016.11.008>.

- Pagnoncelli, B. K., Cifuentes, A., & Denis, G. (2017). A two-step hybrid investment strategy for pension funds. *The North American Journal of Economics and Finance*, 42, 574-583. <https://doi.org/10.1016/j.najef.2017.09.001>.
- Park, C., & Hooke, J. (2018). 2018 STATE PENSION FUND INVESTMENT PERFORMANCE REPORT. Retrieved from <https://www.mdpolicy.org/library/doclib/2018/04/Policy-Report-2018-02.pdf>. Accessed March 18, 2021
- Peng, J. (2008). State public pension management over the business cycle. *Journal of Public Budgeting, Accounting & Financial Management*, 20(1), 1-21. <https://doi.org/10.1108/JPBAFM-20-01-2008-B001>.
- Peng, J., & Wang, Q. (2020). Alternative investments: is it a solution to the funding shortage of US public pension plans?. *Journal of Pension Economics & Finance*, 19(4), 491-510. <https://doi.org/10.1017/S147474721900012X>.
- Pennacchi, G., & Rastad, M. (2011). Portfolio allocation for public pension funds. *Journal of Pension Economics & Finance*, 10(2), 221-245. <https://doi.org/10.1017/S1474747211000102>.
- Picker, L. (2005). Investing in Commodity Futures?. Retrieved from <https://www.nber.org/digest/jan05/investing-commodity-futures>. Accessed March 17, 2021
- Randle, T., & Rudolph, H.P. (2014). Pension Risk and Risk-Based Supervision in Defined Contribution Pension Funds. Retrieved from <https://openknowledge.worldbank.org/bitstream/handle/10986/18355/WPS6813.pdf?sequence=1&isAllowed=y>. Accessed March 11, 2021
- Shen, S., Pelsser, A., & Schotman, P. (2019). Robust hedging in incomplete markets. *Journal of Pension Economics & Finance*, 18(3), 473-493. DOI:10.1017/S1474747218000069.
- Shelly, S. (2017). EMERGENCE OF COMMODITY DERIVATIVES AS DEFENSIVE INSTRUMENT IN PORTFOLIO RISK HEDGING: A CASE OF INDIAN COMMODITY MARKETS. *Studies in Business & Economics*, 12(1), 202-234. DOI 10.1515/sbe-2017-0015.
- Stalebrink, O. J. (2016). Public pension funds and alternative investments: A tale of four Swedish national pension funds. *International Journal of Public Administration*, 39(2), 107-121. <https://doi.org/10.1080/01900692.2014.988869>.

Umeh, O. L., & Okonu, A. A. A. (2018). Real estate performance in Nigeria pension fund. *Journal of Property Investment & Finance*, 36(5), 454-465. <https://doi.org/10.1108/JPIF-02-2018-0009>.

Verma, R., & Verma, P. (2018). Behavioral biases and retirement assets allocation of corporate pension plans. *Review of Behavioral Finance*, 10(4), 353-369. <https://doi.org/10.1108/RBF-01-2017-0009>.

Wang, S., Rong, X., & Zhao, H. (2019). Optimal investment and benefit payment strategy under loss aversion for target benefit pension plans. *Applied Mathematics and Computation*, 346, 205-218. <https://doi.org/10.1016/j.amc.2018.10.030>.

Xie, Y., Hwang, S., & Pantelous, A. A. (2018). Loss aversion around the world: Empirical evidence from pension funds. *Journal of Banking & Finance*, 88, 52-62. <https://doi.org/10.1016/j.jbankfin.2017.11.007>.

Zhang, L., Li, D., & Lai, Y. (2020). Equilibrium investment strategy for a defined contribution pension plan under stochastic interest rate and stochastic volatility. *Journal of Computational and Applied Mathematics*, 368, 112536. <https://doi.org/10.1016/j.cam.2019.112536>.