Response of Mexican life and non-life insurers to the low interest rate environment

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Abstract

The purpose of this research is to examine whether insurers have improved their economic performance through efficiency as a reaction to the prolonged period of low interest rates. The results of an analysis of 22 years of data, using a two-stage data envelopment analysis approach (DEA), show that there is an inverse relationship between efficiency and interest rate. The non-life insurance group had a superior level of efficiency compared with that of the life insurance group. It seems that life insurance companies, to some extent, transferred their inefficiency to customers to maintain their solvency. Additionally, this research shows that companies with substantial market power and bancassurance exceeded the performance of the rest of the industry.

Keywords Low interest rates · Insurance · Two-stage DEA · Undesirable outputs

Introduction

In the last 20 to 30 years, interest rates have shown a tendency to drop in multiple markets. Although this has been observed in the long term, it is still a concern for insurance companies around the world. Wuestner (2017) and Rybka (2017) are examples of publications on the currently observed implications in the insurance industry as a result of the long period of reduced interest rates.

The importance of interest rates in the insurance industry is primarily associated with the fact that they constitute one of the two main sources of profit for insurance companies (Brown and Galitz 1982). The first and most evident source of profit is insurance operations, where the income of issued premiums minus acquisition, administration and adjustment costs generate the profit of the operation. The latter

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income source is generated from the investment of technical reserves. The financial product obtained in this way contributes to covering unexpected increases in losses and maintaining the capital required by statutory regulations at its minimum level. Those insurance companies with a negative result in operation, adding up the reduction in financial product yields and the composition of their portfolio, as will be explained later, could be in danger of non-compliance with their obligations concerning their insured clients and risk their ongoing viability in the market.

In Mexico, the interest rate during the 1990s was maintained at an extraordinarily high level. Figure 1 shows the development of the Mexican nominal interest rate with a maturity of 364 days from January 1995 to January 2019. It reveals a rate close to 50% in 1995, with a reduction pattern until the beginning of 1998 and an important recovery at the end of 1998, where it reached 30%, thereafter resuming a downward trend and staying in a prolonged low interest rate period from 2002 to 2018.

The database provided by the Association of Mexican Insurance Companies (AMIS) reveals that investment yields were the main source of income for insurers. Profits, and therefore the compensation of loss in the operations, were obtained thanks to the high interest rates in the market for the instruments in which the technical reserves were invested. Especially in life insurance companies, high interest rates can compensate for higher costs or subscription problems (Eling and Schaper 2017). It would be expected that after a continuous period of interest rate reduction, insurance companies would have to carry out actions to recover their margins.

Low interest rates put special pressure on life insurance products with guaranteed rates or with dividend payments when sharing investment yields after deducting the cost of claims. Insurance companies that sold life contracts in high interest rate periods with guaranteed rates or values have a financial problem resulting from the difference between the investment rates they can execute and the pledged ones, especially if the payment pledge in fixed rates cannot be adjusted afterward depending on the circumstances (Yanh 2007).

Based on the Bank of Mexico (2019).

Fig. 1 Nominal 364-day interbank offering rate in Mexico from January 1995 to January 2019

Insurance supervisors are more concerned about life insurers than the non-life insurance business (Löfvendahl and Yong 2017), and it is said that the impact of a long low interest rate period is lower for non-life insurance companies (Antolin et al. 2011; Dickinson 2000; Holsboer 2000) because these businesses do not include a savings component or dividend payment with guaranteed interest rates in the contract and because the policies are short term, usually with annual maturity. Even though the effect is smaller, the fall in interest rates and thus the reduction in income by reserve investment also motivates non-life insurance companies to take actions to compensate for the diminution in their margins.

Therefore, the effect on each insurance company is different; it depends on the type of commercialised products, the dependency on financial products to generate utilities, the mix of maturities in the investment portfolio, the number of profit and non-profit sharing policies (Holsboer 2000) and the proportion in the policy portfolio of guaranteed rates sold in a high interest rate period.

Our work contributes to the data envelopment analysis (DEA) literature highlighting different aspects of the insurance industry. We cover the role of the financial intermediary service as well as the investment income over the efficiency changes in insurance firms. The academic literature has looked at the effects of low interest rates for prolonged periods (Eling and Holder 2013b), studying the effect on the value of companies, their capital structure, alternative products that mitigate the dependency of the value of guaranteed interest rates and possible solutions to the problem. In the literature on the efficiency of insurance firms, Kaffash et al. (2020) reviewed DEA applications and found that only 10% of the work done from 1993 to 2018 focused on the financial intermediary service of insurers. Furthermore, the role of investment income in efficiency changes was not among the areas of application defined by Kaffash et al. after going through 132 studies, neither in applications with firm-specific factors nor in exogenous factor applications. Therefore, there was a gap in the field. In the financial intermediation literature, Brockett et al (2005), Nourani et al. (2018) and Yang (2006) have investment income as an output of their models. However, in our paper, investment income is a variable that affects the outcome, and it is not an output per se. In these papers, the role of the interest rate as a driver of efficiency efforts is examined. However, Fuentes (1998) suggests that there is a negative effect from financial income for the productivity development of companies and we exploit this hypothesis. The improvement in insurance company efficiency as an immediate response to compensate for margin reduction (Holsboer 2000) is scarcely mentioned in studies that analyse the effects and possible solutions, even though the works of Eling and Schaper (2017) and Huang and Eling (2013) have shown a negative correlation between interest rate level and efficiency.

Hence, the purpose of this research is to examine whether insurance companies improved their efficiency as a reaction to the prolonged period of low interest rates, over 22 years of their operation, as well as to determine the characteristics of the most efficient companies. The contributions to the literature can be summarised in five points: (1) we study how the yields of the investment of reserves, the largest liability of an insurer, affect the evolution of efficiency over time, a field largely unexplored in the low-rate environment; (2) we explore whether a decay in financial intermediation can be a driver for efficiency improvement, even though this function

is not considered the core business of an insurer; (3) we expand on the knowledge of insurance industry dynamics in a scarcely researched geographical region; (4) we show regulators whether there is room to encourage more efficiency in the Mexican insurance market or to influence the resulting variables related to the most efficient companies through regulatory measures to develop the industry; and (5) we share with practitioners and stakeholders the behaviour of the sector by company groups in a historical way that will help them to evaluate and control management in the face of interest rate fluctuations.

The analysis of the Mexican insurance market is carried out by following the two-stage DEA methodology. We grouped companies into life, non-life and mixed companies when they offer both life and non-life products. Although the products of the companies differ, for analysis purposes, we build a frontier by line of business, as is commonly done in the DEA literature. Kaffash et al. (2020) explain that 81% of published papers have used this assumption of technological homogeneity. The first stage estimates the technical efficiency of the insurance companies with activity between 1997 and 2018 under a technological model with joint production of desirable and undesirable outputs. Then, the estimates of technical efficiency are treated as a dependent variable in a Tobit regression model with macroeconomic variables specific to the industry in the second stage.

The remainder of this article is organised as follows. A description of the low interest rate period, the effects on insurance companies and ways in which they can react to this environment, as well as the hypothesis examined in this study, are provided in the following section. The discussion of the methodology and the approach to modelling the insurance industry are provided in the subsequent section, and the description of the data used is given in the section after that. The narration and interpretation of results are subsequently presented, and the article concludes with final comments in the last section.

Context

Interest rates have been maintained at low levels in the last 20 to 30 years in most developed countries, reaching historically low levels compared with the 1980s and the beginning of the 1990s, with a gradual decline from the beginning of the 21st century to unprecedented low levels (Obersteadt et al. 2013; Berdin and Gründl 2015; Brunin et al. 2012; Dickinson 2000; Swiss Re 2012). For example, 10-year government bonds in the U.S., U.K. and Germany have stayed under 2%, while in Japan, 10-year financial products were maintained under 2% for more than a decade. While this phenomenon was also seen in emerging economies, including Mexico, interest rates in these geographic regions have been superior to those of developed countries, generating interest for global companies (Swiss Re 2012).

The literature proposes some drivers behind the prolonged fall in interest rates, but there is no consensus (Dickinson 2000; Holsboer 2000; International Monetary Fund 2016; Swiss Re 2010, 2012). The first group of explanations concerns the market adjustment between the supply of and demand for investment funds. From the supply side, there has been an excess of savings in more developed countries due to

an increase in the savings of the older population, who are saving for their retirement directly or through pension funds; insurance companies looking for somewhere to invest their reserves also contributed to the excessive supply of long-term investment funds. In emerging economies as well, there is reported pressure to maintain a low interest rate due to an excess of savings with a lack of investment opportunities. The second reason is due to monetary policies. On the one hand, governments with more cautious tax policies have sought to reduce their debt by diminishing demand for long-term funds. Others with expansionist monetary policies have searched for ways to spur economic growth using low interest rates, for example via direct sales of private market bonds, changing the natural balance of the interest rate. Additionally, the 2008 crisis encouraged both phenomena: while central banks reduced their interest rates to avoid further deterioration in the real economy (Laubach and Williams 2016), investors preferred to invest in government bonds to avoid risky assets, leading to the lowest historical levels for interest rates in governmental bonds.

The prolonged period of low interest rates erodes the solvency of insurance companies and puts their capacity to face their obligations with insureds at risk. Actuaries in life insurance companies need to estimate interest rates in the next 20 or 30 years to determine what premiums to charge each insured client, corresponding with reserves and rates they can guarantee, which is complex and has a certain degree of uncertainty, even when estimating short-term rates (Holsboer 2000). Meanwhile, those in the financial area of the company have the task of matching the terms and rates of their assets and liabilities in order to be protected against changes in interest rates. The ideal match is practically impossible; the maturity or expiration of some products frequently exceeds the duration of available investments in the capital market. Therefore, there can always exist a mismatch between assets and liabilities that needs to be covered with additional reserves. In addition, in high-rate periods, the issuers of bonds and other fixed interest securities preferred new issuances with shorter periods to avoid high-rate payment pledges in the face of a possible reduction in rates.

On the other hand, it is a lengthy process for regulators to establish the maximum technical interest rate, which at the same time is the minimum guaranteed profit for all the durations of savings insurance, for its impact on the determination of reserves: at more technical interest rates, less will involve the policy of reserves (Eling and Holder 2013a, b). In Mexico, article 247 from the Law of Insurance and Surety Institutions establishes the technical interest rate in a model with only one rate for all insurance companies. In other countries, competition impacted the tender of products with attractive guaranteed rates in the period of high interest rates, at times above the minimum established by regulation.

Insurance companies that sold life contracts in high interest rate periods with guaranteed rates of returns have the highest risk regarding interest rates (Brunin et al. 2012; Yanh 2007), especially those with a relevant proportion of sensitive policies to the interest rates in their product mixture. Sensibility to the interest rate is amplified if the savings product contract forces the insurer to pay a minimum rate every year or includes rigid guarantees, withdrawal options without penalties or incremental payments of insured sums attached to the original terms.

Profit and loss (P&L) has an important impact on life insurance companies, typically coming from the spread between earnings from their portfolio investment and the pledged interest in their insurance policies (Albrecht 2003; Brown and Galitz 1982). On average, in the U.S., the return on investment (ROE) from 2003 to 2007 was 12%, while in 2012, the rank decreased to 6–8%. In addition, having to cover risk with capital and reserves, life insurance companies with longer-term exposure can require more capital from shareholders to maintain their solvency margin and larger reserves to guard against adverse fluctuations in interest rates. Other implications of interest rate reduction are an increase in the present value of future payments, which require a larger prime rate to maintain the benefits at the same level, reducing the incentive to pay annuities, with the risk of reducing the demand for savings products and an anticipated cancellation of policies (Swiss Re 2012). Changes in interest rates can also affect the value of insurance company shares and disturb capital structure (Doherty and Garven 1995; International Monetary Fund 2016).

Not all lines of business are affected to the same degree. Compared to life insurance companies, non-life insurers are affected less in their net results by a fall in interest rates because their products are short term, usually renewable annually and with a short time lapse between the payment of premiums and claims (Antolin et al. 2011; Siglienti 2000). In these cases, insurance companies update their prices annually and invest their money in short-term investments; therefore, their sensibility to interest rate fluctuation is marginal, and the importance of income from investments is relatively smaller. The structure of non-life insurance company liabilities determines their sensibility to interest rates. Those with short-tail liabilities will have less sensitivity compared with those that have longer-tail risks with claims paid in a more distant future. The rate risk management in these lines of business can be managed with a prudent administration of assets and liabilities.

Insurance companies have several tools to help them cope with the risk of persistently low interest rates, such as a change in investment strategy, an increase in pricing, changes to their products and improvements in their internal processes.

In terms of investments, life insurance companies could increase the duration of their assets to ensure a better match between assets and liabilities (Antolin et al. 2011), or, in the case of temporary increments in interest rates, investment in shorter duration assets with slightly higher earnings for the long-term securities to take advantage of the situation. It has also been observed that risk appetite has grown in insurance companies seeking to invest in riskier instruments (Löfvendahl and Yong 2017) and higher and more aggressive expected return rates, as far as regulation allows. Coverage strategies have been found to mitigate their interest rate risk exposure based on derivatives that allow them to manage and mitigate risk by ensuring higher interest rates (Bank for International Settlements 2016; Siglienti 2000; Swiss Re 2012).

The effect of market rates on utility margins can also be compensated for by increasing premiums, restoring profitability, even though competitors that have suffered less impact and have other instruments available for long-term investments could lead the insured to cancel their policy and opt for another financial instrument or insurance company. A more disciplined underwriting effort could also implicitly increase prices, as has been explained, to guarantee future benefits. Baldwin (2016) reports an increase in the cost of insurance in the U.S. due to low interest rates and increases in

the cost of reinsurance, leaving the insured with the options of having a higher premium to maintain their benefits, sacrificing benefits when they do not increase their premium or surrendering the policy and losing part of its current value.

In terms of actions for recovering margins through products, it is preferable to balance between products that are more sensitive to interest rates and those that are not sensitive to interest rates when increasing market share in the lines with positive technical results and withdrawing from high-risk non-core businesses, in addition to modifying the terms of new policies with lower guaranteed rates to progressively reduce liabilities (Obersteadt et al. 2013; Siglienti 2000). They can also offer the exchange of current policies for new products with similar benefits and more coverage possibilities, for example, with guarantees based on inflation instead of the nominal rate.

Last, in addition to the financial and product adjustments that insurance companies can implement to enhance the effects of low interest rates, it is always possible to promote better efficiency. Efforts to reduce costs because of declining revenues might include workforce reductions, adoption of new technologies to save costs, attempts to reduce waste or even a reduction in the quality of services (Grifell-Tatjé and Lovell 2015). Eling and Schaper (2017), in their research on insurance companies in 14 European countries from 2002 to 2013, find that for life companies, high interest rates can compensate for higher costs or underwriting problems, since during periods of low interest rates insurance companies became stricter with underwriting and cost management, operating more efficiently to compensate for lower interest income. On the other hand, Huang and Eling (2013), in an empirical study, also found a negative relationship between interest rate and efficiency in non-life insurance companies in rapidly growing countries identified as BRIC (Brazil, Russia, India and China).

The objective of this research is to contribute to the knowledge on the insurance industry in Mexico, analysing the change in efficiency of insurance companies as a response to the prolonged period of low interest rates and the variables that could characterise the most efficient insurance companies under the conditions faced by the Mexican market between 1997 and 2018: interest rate reduction and deregulation, which opened the doors to foreign companies in the form of subsidiaries and financial groups.

The analysis of the empirical data from the Mexican insurance industry reviews whether bancassurance companies tend to be more efficient than traditional insurers. In an analysis from 2005–2006 of the insurance market in Italy, bancassurance outperformed traditional life insurance companies in terms of cost efficiency, according to Fiordelisi and Ricci (2011). Rathanath and Rao (2016) found that the sale cost of traditional distribution channels is approximately double the cost of selling through bancassurance in India. The analysis also looks at whether the most efficient companies capture a larger section of the market and more elevated rents. As the efficient structure hypothesis states: with the possibility of offering lower prices than their competitors, efficient companies can capture higher rents and market share (Choi and Weiss 2005; Cummins and Rubio-Misas 2006; Biener and Eling 2017).

Methodology

The study of insurance company reactions to the prolonged period of low interest rates is performed by applying the two-stage DEA procedure, a multidimensional method broadly used for the evaluation of contextual variables and their relationship with efficiency (Banker and Natarajan 2008; Simar and Wilson 2011), initially proposed by Ray (1988, 1991).

In the first stage, with a non-parametric approximation of frontier analysis, efficiency is determined for an insurance company with the estimation of the existing distance between the quantity of inputs used and the outputs it generates, regarding the quantity of inputs and outputs of the best practices that form the frontier of production for the group of companies to which it belongs (Daraio and Simar 2007). The comparison, in the case of efficiency oriented to inputs, takes the form of a number between (0, 1], with the result of the ratio between optimal inputs and observed inputs required to generate the outputs of the company in evaluation. Consequently, efficient companies obtain the value of 1.

The second stage of the procedure estimates, with Tobit regression, the relationship of macroeconomic variables and characteristics of the companies with the estimated efficiency from the previous stage. The literature (e.g. Banker and Natarajan 2008; Banker et al. 2019; Johnson and Kuosmanen 2012; Simar and Wilson 2011) discusses the statistical properties and conditions under which the obtained estimators are consistent in the second stage with truncated regression, ordinary least squares (OLS) and Tobit. Even though Simar and Wilson (2011) argue that only truncated regression provides consistent estimations, Banker et al. (2019) concluded that regression of the second DEA stage identifies with precision the impact of contextual factors in a statistically consistent form, except when sufficient conditions are violated, meaning that inputs with contextual variables are highly correlated (see also Thanassoulis et al. 2008).

The work of Banker et al. (2019) fills a gap in the literature by offering a statistical fundament for the application of the two-stage DEA in the measurement of efficiency and its relationship to contextual variables. The adaptation of the procedure to this research is described in its two stages in the following sections.

DEA first stage

For the measurement of efficiency, it is assumed that the function of production technology of the insurance industry generates two outputs: coverage of risk commercialised in the market as insurance policy (desired output) and the service of payment of financial loss or accident rate (undesired output), following Fuentes and Reyna (2018).

The reader should assume, to represent production technology in terms of the compound of inputs, a non-negative vector of desired outputs $y = (y_1, \dots, y_N) \in R_+^M$ and a non-negative vector of undesired outputs $b = (by_1, \dots, by_N) \in R_+^M$. Following Grifell-Tatjè and Lovell (2000), the representation of the technology is expressed in

the form (1), including all the desired and undesired outputs with the possibility of generating a given vector of inputs.

$$L^t(y^t, b^t) = \{x^t : x^t \text{ can produce } y^t, b^t\} \quad (1)$$

This technology is a closed, convex compound of inputs and has strong disposability of inputs $[x^t \in L^t(y^t, b^t) \Rightarrow x^{t'} \in L^t(y^t, b^t), x^{t'} \geq x^t]$. All the x^t vectors will belong to their contemporary $L(y^t, b^t)$, even though not all will be in the isoquant of inputs defined by:

$$I^t(y^t, b^t) = \{x^t : x^t \in L(y^t, b^t), \lambda x^t \notin L^t(y^t, b^t), \lambda < 1\}. \quad (2)$$

For all the vectors of x^t inputs, it is possible to estimate their distance to the input isoquant with the function of radial distance expressed (3).

$$D^t(x^t, y^t, b^t) = \{\theta : x^t / \theta \in L^t(y^t, b^t)\} \quad (3)$$

If the x^t vector belongs to the isoquant, the function of radial distance $D^t(x^t, y^t, b^t)$ will be equal to 1 and will have a value higher than 1 for the rest of the vectors of inputs that belong to $L^t(y^t, b^t)$.

In the literature, there are additional assumptions found for joint production technology:

1. *Null-joint* from the desired outputs vector y with the non-desired outputs vector b (Färe and Grosskopf 2003).
2. *Weak disposability* of undesired outputs and *free disposability* of desired outputs and inputs (Färe et al. 1989, 2005).

Production technology of the insurance industry should be estimated from a linear programme that not only increases desired outputs. It should also shorten undesired outputs in the face of efficiency improvements and technological change. According to Thanassoulis et al. (2008), the methods to estimate undesired outputs can be classified into direct and indirect. In this research, we estimate the efficiency with a method of each type, with the intention to give conclusions more robust support if the results are confirmed in both methods.

In the indirect approach expressed in model (4), Sieford and Zhu's (2002) proposal is used based on a linear monotonic transformation of undesired outputs taking advantage of DEA's translation invariance property (Cooper et al. 2007) because the envelope form is the same even though the data of inputs or outputs are transferred in the plane where the model is implemented. In the first step, Sieford and Zhu (2002) multiply the undesired product quantities by less than 1 and find a v_r value of sufficient magnitude to turn negative values into positive values in such a way that $\underline{b} = -b + v > 0$ with equation $\{b\} + 1$. Even though model (4), henceforth called model SZ, does not comply with the weak disposability assumption of $\{b\} + 1$ products, the results of these linear programmes, as will be seen later, are not distant from those of the model that complies with this assumption.

$$\begin{aligned}
& \bar{b}_j = -b_j + w > 0 \\
& [D(x^0, y^0, b^0)]^{-1} = \min_{\theta} \theta \\
& \text{subject to } \sum_{k=1}^K z^k x_n^k \leq \theta x_n^0, \quad n = 1, \dots, N \\
& \sum_{k=1}^K z^k y_m^k \geq y_m^0, \quad m = 1, \dots, M \\
& \sum_{k=1}^K z^k \bar{b}_j^k \geq \bar{b}_j^0, \quad j = 1, \dots, J \\
& \sum_{k=1}^K z^k = 1, \quad k = 1, \dots, K \\
& z^k \geq 0, \quad k = 1, \dots, K
\end{aligned} \tag{4}$$

The direct model in (5) corresponds to Kuosmanen (2005) with the extension of Färe and Grosskopf (2003) taken from Fuentes and Reyna's (2018) proposal; henceforth, we will call this model KFG. The programme in (5) maintains the assumptions previously defined for the joint production of desired and undesired products and adds the v and μ variables, reinforcing the assumption of free disposability of inputs and restricting the reduction of products.

$$\begin{aligned}
& [D(x^0, y^0, b^0)]^{-1} = \min_{\theta, v^k, \mu^k} \theta \\
& \text{subject to } \sum_{k=1}^K (v^k + \mu^k) x_n^k \leq \theta x_n^0, \quad n = 1, \dots, N \\
& \sum_{k=1}^K v^k y_m^k \geq y_m^0, \quad m = 1, \dots, M \\
& \sum_{k=1}^K v^k b_j^k = b_j^0, \quad j = 1, \dots, J \\
& \sum_{k=1}^K (v^k + \mu^k) = 1 \\
& v^k, \mu^k \geq 0, \quad k = 1, \dots, K \\
& \sum_{k=1}^K b_j^k > 0, \quad j = 1, \dots, J \\
& \sum_{j=1}^J b_j^k > 0, \quad k = 1, \dots, K
\end{aligned} \tag{5}$$

With the exposed models, efficiency was estimated for each company group in one run of DEA, putting together a pool with observations from 1997 to 2018, forming an only great frontier equivalent to the last step of a sequential DEA (Tulkens and Eeckaut 1993). This procedure assumes that technology is remembered, and each company is compared with the best practices from all the companies with activity in the period. The decision to create an only frontier for each group is also discussed in the Data section.

DEA second stage

In the second stage of DEA, efficiency results are introduced in a linear regression model, in this case in a panel-type Tobit, to research whether efficiency is related to changes in the interest rate and variables that support the hypothesis. The Tobit regression model has been considered an adequate method for the second stage of DEA for being doubly bound between 0 and 1, as well as the efficiency rank score, assuming that errors are homoscedastic and are distributed normally $e_{i,t} \sim N(0, \sigma^2)$.

The efficiency ($Efficiency_{i,t}$) in the second stage model is considered a latent variable with the following relation of the observed efficiency score (0):

$$\begin{aligned} \theta &= 0 & \text{if } Efficiency_{i,t} \leq 0, \\ \theta &= 1 & \text{if } Efficiency_{i,t} \geq 1, \\ \theta &= Efficiency_{i,t} & \text{if } 0 < Efficiency_{i,t} < 1. \end{aligned} \quad (6)$$

The model seeks to assess whether insurance companies responded with efficiency actions to reduce their costs and mitigate drops in interest rates, hence the first contextual variable corresponds to the effective annual Interbank Offering Rate to 364 days ($interest_rate_t$); then, to determine the characteristics of the most efficient companies, three dummy variables appear to indicate characteristics of insurance companies: i) whether or not they belong to financial groups, with which bancassurance will be distinguished ($financial_group_{i,t}$) given that all insurance companies owned by a financial group operate in the bancassurance fashion and ii) the second and third dummy variables represent two of the three groups of insurance companies, life ($life_{i,t}$) and non-life ($no_life_{i,t}$). The dummy variable of mixed ones is omitted to avoid perfect multicollinearity. The intercept (β_0) will capture the medium value of the mixed group. Finally, the percentage of market share is included to assess the efficient company hypothesis ($market_share_{i,t}$).

$$\begin{aligned} Efficiency_{i,t} &= \beta_0 + \beta_1 interest_rate_t + \beta_2 financial_group_{i,t} + \beta_3 life_{i,t} \\ &+ \beta_4 no_life_{i,t} + \beta_5 market_share_{i,t} + e_{i,t} \end{aligned} \quad (7)$$

Data

The empirical research on insurance company responses to the prolonged period of low interest rates during the period 1997–2018 uses data published by three institutions. Annual results of insurance companies from 1997 to 2001 come from the AMIS, and those from 2002 to 2018 were obtained from publications of the industry regulator, the Insurance and Surety National Commission. The 364-, 182-, 91- and 28-day interest rates in Mexico come from the Bank of Mexico's databases.¹ All insurance companies with activity and published financial statements from 1997 to 2018 were included in the analysis. However, the sample was reduced to 92% of the total observations after eliminating records with incomplete data in the publications or with negative values due to the effect of extraordinary accounting records such as reserve releases.

DEA constructs the frontier with production possibilities from a group of observations; therefore, the companies included in each group are subject to the same technological conditioning (González 2001). Looking for the company groups to be technologically homogeneous, in the first stage of the two-stage DEA, companies are grouped by their specialty as life insurance companies when offering products for people in the market, non-life if their products are directed to protecting properties and mixed if they commercialise products for people as well as for properties. Table 1 shows the number of companies under analysis by year and group. The non-life group presents the highest growth in number of companies, starting from nine in 1997 to 24 in 2018. In contrast, mixed companies decreased from 28 in 1997 to 21 in 2018 as an effect of a law introduced in 2002 that does not allow new insurance companies to deal in products for both people and properties.

Once insurance companies are classified by group, a low number of observations in each year (minimum 8 and maximum 29) can be observed in Table 1. With the size of this sample and the number of inputs and outputs, a contemporary DEA would present low discrimination by dimensionality problems. Clearly, the sequential version of DEA by group is a more appropriate option in the face of this problem, since it allows for the construction of production frontiers with observations from different years, with better discrimination of efficient and inefficient companies.

The selection of inputs in this research has the restriction of the aggregation grade of information published by the AMIS, unlike the financial states distributed by the CNSF that include a larger breakdown of countable concepts. The granularity of information allows us to distinguish two inputs: x_1 to represent administrative costs and x_2 to represent acquisition costs. The first, which on average represents 47% of the cost of inputs, groups the expense in insurance company employees, staff hired by honorarium, materials, systems and other operational inputs for insurance companies. The second input includes the cost of commissions and bonds given to intermediaries, as well as marketing expenses. In the insurance industry, there are

¹ Even if the 364-day interest rate is considered the most suitable for the insurance sector analysis for the study, the other terms are included, i.e. 182, 91 and 28 days.

Table 1 Number of companies included in the research

Group	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Life	9	10	11	10	8	12	9	14	16	15	16	16
Non-life	9	12	11	12	12	13	12	18	18	19	19	20
Mixed	28	27	28	29	28	29	26	25	24	24	23	25
Total	46	49	50	51	48	54	47	57	58	58	58	61
Group	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Life	16	14	17	18	22	22	18	22	21	21	22	343
Non-life	20	21	20	22	24	25	20	21	21	23	24	396
Mixed	25	22	26	24	25	25	24	25	21	21	21	550
Total	61	57	63	64	71	72	62	68	63	65	67	1289

other kinds of inputs, claim or loss adjustment expenses, necessary to grant service to the insured during the claim and adjustment process. However, the cost of the third input is added to the rest of the loss expenses (cost of the undesired product) in the income statements of insurance companies, preventing its isolation; because its amount is a small fraction of the total cost of losses and its behaviour is similar to that of undesired products, a bias is not expected in the estimation of efficiency by problems of model specification.

The definition of the products in this research follows the proposal of Fuentes and Reyna (2018). This research considered that the main product of an insurer is the insurance policy that it sells to customers, and claims are generated in the insurance production function as an undesired product. This joint production of desired and undesired products is assumed in the insurance industry considering that insurance companies are motivated to expand their market share with the protection products they offer and, at the same time, they seek to control the frequency and severity of the losses suffered by their insured clients (Schlesinger and Venezian 1986; Ben-Shahar and Logue 2012). The definition of desired and undesired products is also sustained by observing the other side of the transaction: consumers acquire insurance policies (desired products) to obtain financial protection in the event of a potential loss and, at the same time, by making rational decisions they avoid harm such as accidents and damage to their properties (undesired products). Under this reasoning, compensation of losses or claims is an inherent product of the insurance operation that both sides of the transaction try to minimise. The approximation to the desired product y is formed by the number of issued and paid policies of the life, medical expenses automobile and property and casualty products, and the undesired product b is approximated with the number of paid claims to the insured. The quantities of inputs and outputs were obtained by dividing the annual amount of administration expenses, acquisition expenses, issued premiums and the net cost of the accident rate between the National Consumer Price Index (INPC), obtaining some favourable effects for the treatment of data. First, there is no public information on the number of employees, insurance agents, insurance policies

Table 2 Inputs and outputs

Inputs		
Administrative expenses	x_1	Annual administrative expenses divided by w
Acquisition expenses	x_2	Annual acquisition expenses divided by w
Outputs		
Issued and paid policies (desired product)	y	Annual issued and paid policies divided by w
Reported claims (undesired products)	b	Annual net accident rates divided by w

w : national index of prices for the consumer of that year

and claims for all periods, and the existing information does not follow the same criteria; meanwhile, using the INPC as the price to obtain quantities generates homogeneous units. Second, it converts all the numbers into pesos from the same year, eliminating the effect of inflation. Both effects allow comparison of the companies in the first stage of the two-stage DEA.

The variables that represent inputs and outputs are shown in Table 2, and the annual amount of each concept before conversion into quantities appear in Appendix 1, where the expansion of the sector with the growth of written premiums can be observed, especially in the non-life group. A second point to highlight is a slower rhythm in the growth of administration expenses compared to acquisition expenses; could this signify an effort to make the operation more efficient in insurance companies? The results of the first stage of the two-stage analysis will reveal the answer to this question.

Results

First-stage results

The estimations obtained with both indicated methodologies are shown in Fig. 2a and b. As previously noted, both methodologies are directed at the evaluation of the joint production of desired and undesired products, and even if criticism and different approaches exist in the theoretical field for the treatment of undesired products, both methodologies showed their capacity to discriminate between companies according to their efficiency score with very similar results. Figures 2a and b show that the patterns of behaviour of both models are almost identical in the three insurance company groups. The estimated efficiency scores show that the life group mean is 0.38 in Model KFG and 0.37 in Model SZ, the non-life group mean is 0.50 in Model KFG and 0.48 in Model SZ, and the mixed group mean is 0.41 in both models. It is noteworthy that the efficiency scores are low on average; going deeper into individual estimations, 60% of the observations obtained a score lower than 0.4, and close to 10% of the observations created the frontiers of production with scores equal to 1.

The mixed group shows a slow trend of improvement in efficiency. Unlike the other groups, life companies show, on average, a faster improvement in

Fig. 2 a Efficiency model KFG. b Efficiency model SZ

efficiency from 1997 to 2006 and a deterioration period from that point until 2014. The faster improvement in efficiency could be related to greater sensitivity to low interest rates, which drives those responsible for the business to carry out actions such as expense reduction and adjustments in their investments, products and active policy portfolio. The behaviour of the life group after 2006 can be explained by the recuperation of the required margin by shareholders through increasing prices and changes in the rates pledged to the insured.

Second-stage results

Tables 4, 5, 6, 7, 8, 9, 10 and 11 in Appendix 2 report the marginal effects of the Tobit regressions obtained with STATA for the Mexican rates with terms of 364, 182, 91 and 28 days. Estimations with efficiency scores of the KFG and SZ models are remarkably similar, as could be anticipated when observing the first-stage results of the DEA. Also, all likelihood tests are reported for each regression. The p values of the LR Chi square statistics are 0.0000 in all cases, so at 99% the model is valid at this level of confidence. At the same time, the pseudo R^2 values for all models are around 41% and the number of uncensored observations (92% of the total observations) are additional elements for not rejecting the Tobit regression results.

Being more efficient, as a response from insurance companies to the low interest rate environment, is indicated by the negative coefficient of the interest rate and the statistical validity of the variable, p value (0.000), in all the specified models (364, 182, 91 and 28 days for both efficiency scores). The confidence interval of the interest rate variable coefficient includes a negative number rank, discarding the zero value (at 99%), and confirming the effect of changes in the interest rate in the conditional mean of the efficiency scores. Therefore, the insurance industry, as a group, responded with efficiency actions to counteract the loss in their margins during the prolonged low interest rate period.

The variable $market_share_{i,t}$ was statistically significant for all estimated models, with a p value of 0.000. Furthermore, these coefficients had both the highest dimension in the marginal effects and a positive sign for all the models. This suggests that companies with higher efficiency scores are at the same time the ones who have been gaining more market share, as has been shown previously in the analysis of the first-stage DEA results.

In all the specifications of the model, the marginal effect of $financial_group_{i,t}$ turns out to have a positive sign and statistical significance (p value of 0.000). Hence, there is evidence indicating that bancassurance maintains a positive relationship with efficiency scores. In Mexico, as in other geographies, there are advantages for insurance sales in bank branches, first because of scale and scope economies using available resources for banking services and second because of the compulsory purchase of insurance associated with certain types of credit.

The variables non-life and life were statistically significant for all regressions. The estimations indicate that the efficiency of non-life and life insurance companies has evolved in a similar pattern. A larger answer in the life group would have been expected, and the result might reflect the recovery of lost profits due to low interest rates through a price increase and changes in contractual conditions, among others the defensive reactions already described previously. Regarding the mixed group, their permanence in the market of the inefficient companies of this group is possibly associated with their capacity to resolve the needs of their insureds integrally, that they are ready to pay higher prices for the service instead of maintaining policies with different insurance companies. The non-life group, even though it is most related to efficiency scores, is also the group with the largest percentage of new companies, and is also characterised by the presence of insurance companies with more growth in the market, with shares that were previously held by larger mixed insurance companies.

Conclusions

Operating earnings and investment yields of technical reserves are the two main sources of insurers' income. Investment return contributes to maintaining the minimum amount of capital demanded by statutory regulations and also functions as a cushion against unexpected increases in claims. In the past, when the yields of reserve investment were higher than expected, profits or operating costs could be higher. Hence, after a continuous decline in interest rates, insurers had to take action to recover their margins.

The empirical findings in this research demonstrate that the Mexican insurance industry responded with efficiency actions to recover lost margins in the face of income reductions due to the investment of reserves. Life insurance companies were expected to have the highest efficiency levels as the market was facing a low interest rate trend, with a more acute impact on structural profitability. However, the non-life

group showed a higher level of efficiency than the life insurance group. It seems that, to some extent, life companies transferred their inefficiency to customers with increments in rates in order to maintain their solvency.

Bancassurance companies were among the most efficient insurers, in line with the evidence found in other geographies. Companies with higher market share in the three groups also turn out to be more efficient than their peers. Hence, our results are consistent with those of diverse studies that support the hypothesis of efficient structure.

Dickinson (2000) and the International Monetary Fund (2016) observe that the prolonged low interest rate period should not be seen only as a problem because it has positive effects on the world economy and in insurance companies. A lower rate environment leads to investment and, in consequence, larger economic growth with more income that would translate in time to an environment with more demand for insurance. This research provides empirical evidence of the positive effect of the prolonged low interest rate period, as it stimulates insurance companies to be more efficient, which in moments of high competition could translate into lower prices for consumers.

In the coming years, after the end of the expansion that followed the Great Recession and the long-term implications of the COVID-19 pandemic, nominal interest rates could be cut to support recovery, among other policy tools of national governments (Lubik and Matthes 2019; International Monetary Fund 2020). Most likely, life insurance companies are more prepared than before to deal with this economic environment. However, considering the findings of this research, Mexican insurance supervisors may need to introduce measures to protect the interests of policyholders.

This research also suggests that if interest rates went back to high levels, managers would probably report higher utilities and have the opportunity to undertake larger expenses, being less efficient than they had been in past decades. Thus, in a low interest rate environment, active managers could transfer their inefficiency, to some extent, to the customer through higher prices. In a high interest rate environment, they might run the company with higher costs, creating the problem of vertical moral hazard. Managerial behaviour is out of the scope of this paper; however, it should receive special attention in future studies.

Appendix 1: Inputs and outputs

See Table 3.

Appendix 2: Regression results

Table 4 Marginal effects after Tobit regression results with efficiency from the Model KFG with a rate of 364 days

LR $\chi^2(5)=293.15$				Prob $> \chi^2=0.0000$		
Log likelihood = - 207.12541				Pseudo $R^2=0.4144$		
Variable	dy/dx	Std err	z	$P> z $	[95% confidence interval]	
Financial_group ^a	0.1555457	0.01431	10.87	0.000	0.127504	0.183588
Market_share	1.992178	0.16773	11.88	0.000	1.66343	2.32093
Interest_rate	- 0.0047076	0.00084	- 5.63	0.000	- 0.006346	- 0.003069
Life ^a	0.0360165	0.01404	2.56	0.010	0.008493	0.06354
Non_life ^a	0.1413012	0.01415	9.99	0.000	0.113566	0.169037

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.28% of the total observations

Table 5 Marginal effects after Tobit regression results with efficiency from the Model SZ with a rate of 364 days

LR $\chi^2(5)=282.27$				Prob $> \chi^2=0.0000$		
Log likelihood = - 201.09711				Pseudo $R^2=0.4124$		
Variable	dy/dx	Std err	z	$P> z $	[95% confidence interval]	
Financial_group ^a	0.152903	0.01434	10.66	0.000	0.124793	0.181013
Market_share	1.974209	0.16703	11.82	0.000	1.64684	2.30158
Interest_rate	- 0.0046663	0.00083	- 5.6	0.000	- 0.0063	- 0.00303
Life ^a	0.0292484	0.01399	2.09	0.037	0.001823	0.056674
Non_life ^a	0.1287836	0.01417	9.09	0.000	0.101002	0.156565

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.61% of the total observations

Table 6 Marginal effects after Tobit regression results with efficiency from the Model KFG with a rate of 182 days

LR $\chi^2(5) = 292.76$				Prob > $\chi^2 = 0.0000$		
Log likelihood = - 207.32054				Pseudo $R^2 = 0.4138$		
Variable	dy/dx	Std err	z	$P > z $	[95% confidence interval]	
Financial_group ^a	0.1555899	0.01431	10.88	0.000	0.127549	0.183631
Market_share	1.991388	0.16776	11.87	0.000	1.66259	2.32019
Interest_rate	- 0.0046969	0.00084	- 5.6	0.000	- 0.006342	- 0.003052
Life ^a	0.0364158	0.01404	2.59	0.009	0.008903	0.063928
Non_life ^a	0.141531	0.01415	10	0.000	0.113803	0.169259

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.28% of the total observations

Table 7 Marginal effects after Tobit regression results with efficiency from the Model SZ with a rate of 182 days

LR $\chi^2(5) = 281.95$				Prob > $\chi^2 = 0.0000$		
Log likelihood = - 201.2561				Pseudo $R^2 = 0.4119$		
Variable	dy/dx	Std err	z	$P > z $	[95% confidence interval]	
Financial_group ^a	0.1529483	0.01434	10.66	0.000	0.124839	0.181057
Market_share	1.973506	0.16705	11.81	0.000	1.64609	2.30092
Interest_rate	- 0.004661	0.00084	- 5.57	0.000	- 0.006301	- 0.003021
Life ^a	0.0296358	0.01399	2.12	0.034	0.002221	0.05705
Non_life ^a	0.1290104	0.01417	9.1	0.000	0.101236	0.156785

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.61% of the total observations

Table 8 Marginal effects after Tobit regression results with efficiency from the Model KFG with a rate of 91 days

LR $\chi^2(5) = 292.46$				Prob $> \chi^2 = 0.0000$		
Log likelihood = - 207.46996				Pseudo $R^2 = 0.4134$		
Variable	dy/dx	Std err	z	$P > z $	[95% confidence interval]	
Financial_group ^a	0.1556736	0.01431	10.88	0.000	0.127634	0.183713
Market_share	1.99078	0.16778	11.87	0.000	1.66194	2.31962
Interest_rate	- 0.0044105	0.00079	- 5.57	0.000	- 0.005962	- 0.002859
Life ^a	0.0368016	0.01403	2.62	0.009	0.009301	0.064302
Non_life ^a	0.1418783	0.01414	10.03	0.000	0.114162	0.169595

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.28% of the total observations

Table 9 Marginal effects after Tobit regression results with efficiency from the Model SZ with a rate of 91 days

LR $\chi^2(5) = 281.86$				Prob $> \chi^2 = 0.0000$		
Log likelihood = - 201.29837				Pseudo $R^2 = 0.4118$		
Variable	dy/dx	Std err	z	$P > z $	[95% confidence interval]	
Financial_group ^a	0.1530363	0.01434	10.67	0.000	0.124929	0.181144
Market_share	1.973165	0.16707	11.81	0.000	1.64571	2.30062
Interest_rate	- 0.004392	0.00079	- 5.56	0.000	- 0.005939	- 0.002845
Life ^a	0.0299918	0.01398	2.15	0.032	0.002588	0.057395
Non_life ^a	0.1293466	0.01417	9.13	0.000	0.101583	0.15711

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.61% of the total observations

Table 10 Marginal effects after Tobit regression results with efficiency from the Model KFG with a rate of 28 days

LR $\chi^2(5) = 291.94$				Prob $> \chi^2 = 0.0000$		
Log likelihood = - 207.73025				Pseudo $R^2 = 0.4127$		
Variable	dy/dx	Std err	z	$P > z $	[95% confidence interval]	
Financial_group ^a	0.1556864	0.01431	10.88	0.000	0.127648	0.183725
Market_share	1.990078	0.16778	11.86	0.000	1.66123	2.31892
Interest_rate	- 0.0046899	0.00085	- 5.52	0.000	- 0.006354	- 0.003026
Life ^a	0.0369513	0.01403	2.63	0.008	0.009453	0.06445
Non_life ^a	0.1419808	0.01414	10.04	0.000	0.114267	0.169695

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.28% of the total observations

Table 11 Marginal effects after Tobit regression results with efficiency from the Model SZ with a rate of 28 days

LR $\chi^2(5) = 281.32$				Prob > $\chi^2 = 0.0000$		
Log likelihood = - 201.57042				Pseudo $R^2 = 0.4110$		
Variable	dy/dx	Std err	z	P > z	[95% confidence interval]	
Financial_group ^a	0.1530499	0.01434	10.67	0.000	0.124943	0.181157
Market_share	1.972443	0.16707	11.81	0.000	1.64498	2.2999
Interest_rate	- 0.0046683	0.00085	- 5.51	0.000	- 0.006328	- 0.003009
Life ^a	0.0301455	0.01398	2.16	0.031	0.002744	0.057547
Non_life ^a	0.1294541	0.01416	9.14	0.000	0.101693	0.157215

^ady/dx is for a discrete change of dummy variable from 0 to 1

Uncensored observations: 92.61% of the total observations

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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