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XARXA DE REFERÈNCIA EN ECONOMIA APLICADA

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Abstract

Our objective is to analyse fraud as an operational risk for the insurance company. We study the effect of a fraud detection policy on the insurer's results account, quantifying the loss risk from the perspective of claims auditing. From the point of view of operational risk, the study aims to analyse the effect of failing to detect fraudulent claims after investigation. We have chosen VAR as the risk measure with a non-parametric estimation of the loss risk involved in the detection or non-detection of fraudulent claims. The most relevant conclusion is that auditing claims reduces loss risk in the insurance company.

Keywords: fraudulent claims, operational risk, claims auditing, risk measure, non-parametric estimation.

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1. Introduction

With the introduction of the Solvency II regulations, it has become clear to insurance companies in Spain that the risk associated with the different operations they carry out needs to be quantified. The primary aim is to quantify the capital needs to enable companies to work in conditions of sufficient solvency. Solvency II has meant a radical change in the accounting and financial structure of insurance companies, which need to start quantifying capital needs according to the risks they take on rather than measure the premiums they underwrite. From now on, risk quantification will take on a fundamental importance in company departments, and the application of methodologies to make it possible to achieve this new objective is becoming especially relevant.

As we will see in the next section, speaking about the Solvency II project means taking into account the different types of risk that can affect the insurance business and differentiating between the life insurance and non-life insurance lines. Essentially we are referring to market risk, credit and liquidity risk (both basically in the area of finance), legal risk and, finally, operational risk. It is this latter risk that will be dealt with in this paper, focusing on one of the aspects that most concerns insurance companies when they analyse the different elements to take into account within the framework of this risk: the appearance of fraudulent actions in policyholder behaviour.

Studying fraud in the context of insurance is not new to Spain. Various studies carried out at sector level (ICEA, 2010 and earlier) have revealed how fraudulent behaviour on the part of policyholders is present in the different business lines and have also shown how its appearance has a direct effect on companies' results accounts. Fraud occurs both when policies are drawn up and when claims are made, although it is in this second area that companies have concentrated their efforts. To give an example, Table 1 allows an analysis of the results of anti-fraud measures in car insurance, showing the results for average spending on investigation and the average saving detected in a group of 21 companies operating in the Spanish market[2].

The aim of this work is to analyse fraud as an operational risk for the insurance company. This means analysing the effect that the introduction of a fraud detection policy can have on the company's results account by quantifying loss risk from the perspective of claims auditing. From the point of view of operational risk, the analysis aims to quantify the effect of failing to detect fraud after investigation.

[2] These 21 companies hold over 34.06% of the total direct insurance premiums and represent over 50.73% of the non-life insurance lines.

TABLE 1.
Distribution of numbers of fraud cases with amounts
Car insurance

Items covered	No. of cases	% of business line	Initial cost	Paid out	Gross fraud avoided	% of initial cost
Liability for property damage	47,976	61.63	66,941,351	25,945,268	40,996,083	61.24
Liability for physical injury	10,956	14.07	193,412,953	68,662,399	124,750,554	64.50
Injuries to self	11,642	14.96	24,100,451	8,226,498	15,873,953	65.87
Theft	4,090	5.25	11,664,071	2,067,476	9,596,595	82.27
Fire	148	0.19	848,008	120,414	727,594	85.80
Personal accident	303	0.39	1,128,157	268,598	859,559	76.19
Window breakage	481	0.62	736,118	328,536	407,582	55.37
Other	1,638	2.10	2,153,801	710,282	1,443,519	67.02
Various items affected	557	0.72	2,321,481	563,468	1,758,013	75.73
Unspecified	51	0.07	254,435	45,715	208,720	82.03
Total business line	77,842	76.60	303,560,826	106,938,654	196,622,172	64.77

Source: Icea (2010).

In this process we will take into account two possible courses of action open to companies vis-à-vis the possible existence of suspicious behaviour on the part of policyholders: 1) assume that fraud exists but without initiating any active policy to control, prevent and detect it; and 2) set up specialized departments to fight fraud (known as SIUs, *Special Investigation Units*), which should be given cases where fraud is suspected so that they can carry out a thorough investigation. As far as the second situation is concerned, many companies in Spain admit that they have no specialist anti-fraud unit, although they have introduced policies to control and detect fraud, normally within appraisal units. In this case, in the same way as in the case of SIUs, we will also take into account the existence of special anti-fraud actions within the company.

The paper is structured as follows. In Section 2 we present the main types of risk considered under the Solvency II project, with special emphasis on the definition of operational risk. In Section 3 we analyse insurance fraud as an operational risk to be borne by insurance companies, making a detailed analysis of the different ways in which it can originate. In Section 4 we present the proposed methodological approximation for making an estimation of loss risk in fraudulent and non-fraudulent claims, from the perspective of claims auditing. In Section 5 we analyse the results derived from applying this methodology to the quantification of loss risk on a sample of car insurance claims from the Spanish market. Finally in Section 6 we present the main conclusions obtained from the work carried out.

2. Solvency II: different types of risk for the insurance company

The various technical specifications of the Solvency II project (CEIOPS, 2010) included in different quantitative impact studies identify the risks that affect the insurance business.

Basically distinctions are made between the following: 1) the risk associated with non-life insurance; 2) market risk; 3) credit risk; 4) life insurance risk; 5) health insurance risk; and finally 6) operational risk.

The risk associated with non-life insurance basically comprises premium risk, reserve risk and disaster risk. Premium risk is associated with the risk that the costs deriving from claims submitted to the company in any period of time may be greater than the premiums received. Reserve risk involves the inaccurate estimation of technical provisions or an excessive deviation from the average. Finally, disaster risk is associated with the submission of a number of claims so extreme that they have not even been considered in the calculation of premium risk and/or reserve risk.

Market risk is associated with possible changes in the variables defined by the financial instruments used by the insurance company. This means, for example, changes in interest rates, changes in the value of shares or in property prices when the property market has been used as an investment line. Variations in exchange rates also tend to be included in this section.

Credit risk takes into account the company's exposure to third parties, considering the likelihood of non-payment and ratings changes (credit standing of securities issuers).

Life insurance risk considers changes in the biometric factors taken into account in policy design (basically patterns of mortality, longevity and sickness) and possible decreases in portfolio values (e.g. increases in buybacks) and rising costs.

Health insurance risk takes into account the possible appearance of higher-than-expected costs (e.g. the real costs of the cover being higher than those taken into account when setting rates) and insufficient income (e.g. a large number of cancellations) as well as the appearance of extreme contingencies such as epidemics.

Finally, operational risk – the basic objective of this work – takes into account the losses that may come about through errors in the company's internal processes, in its day-to-day business, due to the actions of its own employees or the influence of external factors. Following Panjer's definition (2006:12), when we speak of operational risks we refer to those that include flaws in company organization, policy underwriting and claim processing, along with other items such as insurance marketing and the launching of new products. They are usually referred to as “risks that are difficult to quantify or to measure a priori”, often due to lack of information.

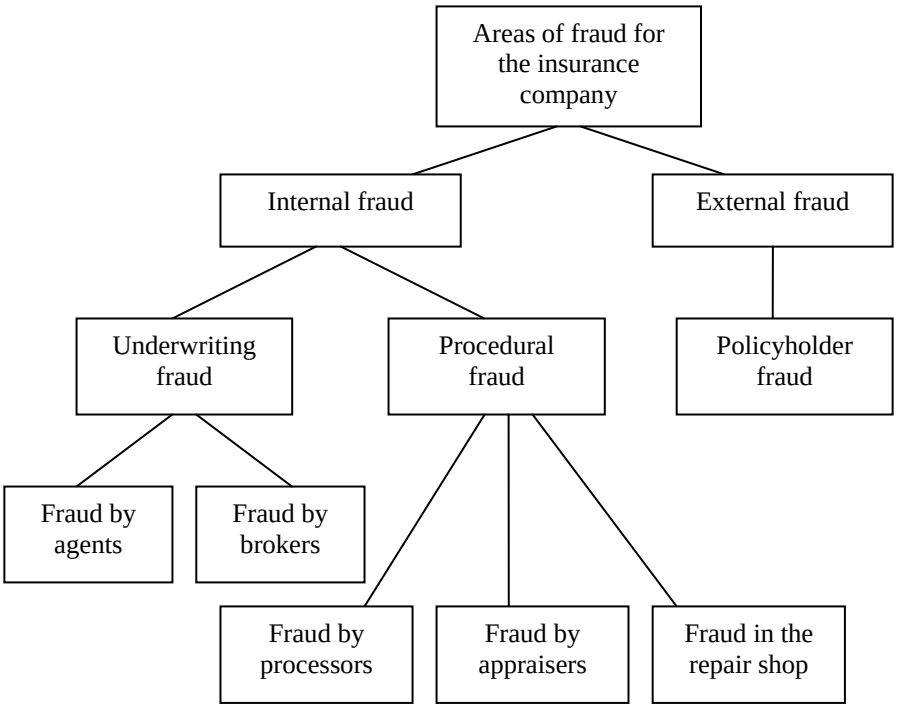
Following the above definition, the non-detection of fraudulent behaviour can be considered a source of operational risk within the insurance company just as it would in any other type of company. However, the areas where fraud can occur within the insurance business are very diverse, as we will see in detail in the next section.

3. Fraud as an operational risk in the insurance business

We need to analyse the different areas associated with fraud as an operational risk for the company. In Figure 1 we start from the difference between what we can term internal fraud and external fraud for the company. In general terms, when we talk of internal fraud we refer

to that committed by the insurance company's employees or by others who, although not actually staff members, work for the company. External fraud includes the much more frequent situation where the fraudulent action is carried out by the actual policyholders, trying to obtain wrongful benefit from their insurance policy.

FIGURE 1.
Sources of fraud for the insurance company



Source: own compilation

3.1. Internal fraud: within the company itself

Internal fraud, or that committed within the framework of the day-to-day functioning of the insurance business itself, can be broken down into two basic concepts: 1) underwriting fraud and 2) procedural fraud.

Although we can also take into account various different situations within each main type, generally speaking when we refer to underwriting fraud we mean fraud committed by agents and brokers in the course of actually supplying insurance policies. We refer to situations in which, for example, people who do not fulfil the necessary requirements (because of exclusions in the policy conditions or similar situations, for instance) are allowed to take out a particular policy, and the person who supplies that policy is aware that the conditions have not been met[3]. Measuring operational risk in this context means taking into account observed behaviour regarding the total amount of cover underwritten (with maximum and minimum levels), the total number of premiums underwritten in connection with that insurance, and the likelihood that a claim will be made and the fraud will not be detected. Extrapolation

[3] We are not therefore referring to situations of adverse selection, when the company does not know of any pre-existing aggravating risk factors.

exercises will normally need to be carried out to enable the results obtained at sample level to be generalized to apply to the entire insurance portfolio. What really happens is that situations are included where cover is offered for risks that are not included in the contract, where the company should not have accepted payment of premiums but where it should not have had to make any payments either.

In the second possibility considered – procedural fraud – there are three basic situations involved: fraud by processors, fraud by appraisers and fraud in the repair shop. These three actions all seek to guarantee that the policyholder will receive payment of a claim for an item not covered by the policy or to unduly increase the amount of payment. In general terms, measuring operational risk in this context calls for information on the following concepts: 1) the total number of frauds detected by the company in relation to each of the three types; 2) an analysis of the risk profile for each type of fraud in order to try to quantify the percentage of undetected fraud in the portfolio; 3) measurement of the compensation that should have been paid if the accident had happened under expected conditions[4], 4) quantification of compensation finally paid, and 5) comparison with the premiums paid by policyholders. The result obtained should enable us to reach an approximation of the operational risk associated with bad practices involving insurance company staff. The investigation costs could be very low, since the people involved (i.e. appraisers, mechanics, etc) are very familiar with how the company works and will act in such a way as to raise the least possible suspicion.

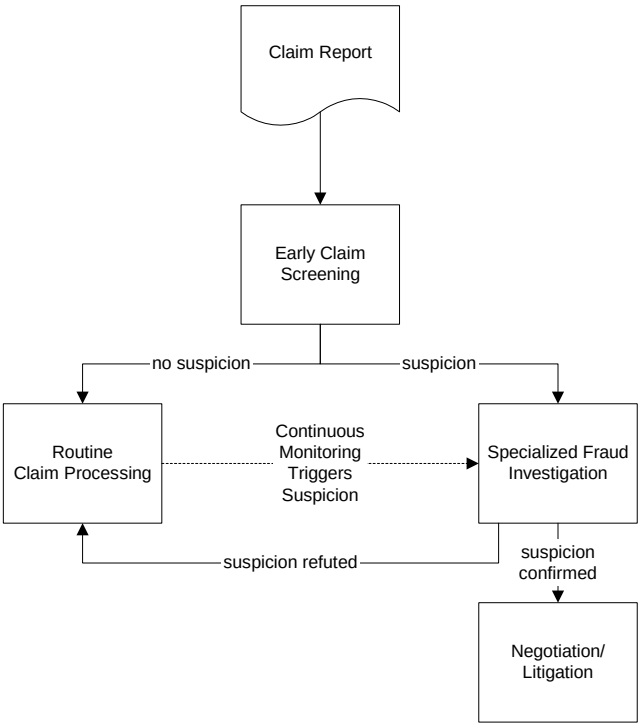
3.2 External fraud: policyholder fraud

External fraud, which is probably the most studied in the existing literature and on which companies can find much more information, is committed by policyholders, i.e. the people who take out insurance cover. In fact this type of fraud may actually be committed in collusion with company staff, and therefore it needs to be remembered that in some cases internal fraud and external fraud may coexist. However, it often involves actions carried out independently by policyholders who seek to obtain wrongful compensation under the insurance they have contracted (either by planning the accident, i.e. planned fraud, or by inflating costs, i.e. build-up).

Quantifying the operational risk linked to external fraud means taking into account the anti-fraud policy followed by the company, i.e. whether or not the company has a claims auditing system or a special investigation unit. The dynamics of anti-fraud procedures within an insurance company are shown in Figure 2. As we can see, once a claim is submitted to the company and has undergone the initial audit, if it is not suspicious the process involves following normal procedures (the left-hand part of the chart), but if there are any indications of fraud it will be channelled through a more thorough auditing process (the right-hand part of the chart). However, the procedures shown in Figure 2 do not always form part of companies' auditing systems. Hence it is not always possible to find special fraud investigation units in companies, many of which often include anti-fraud measures as part of the procedures to be carried out by appraisers, without there being specific acknowledgment of the task.

[4] The investigations we have carried out so far have focused basically on the coverage of property damage to cars, for which there is a great deal of information available. However, the possible size of operational risk in the context of physical injury, with fewer claims but significantly larger amounts of money involved, makes it necessary to highlight this concept and the need for it to be quantified.

FIGURE 2.
Claims processing and auditing



Source: Viaene *et al.* (2007)

Quantifying operational risk from the point of view of external fraud has to take into account whether or not the company carries out claim auditing for fraud detection purposes. If the company does not carry out a thorough fraud investigation, operational risk can be quantified by taking into account the expected proportion of fraudulent claims and the total compensation paid by the company for this concept. However, if the company does not have enough practical knowledge of its own regarding fraudulent claims borne, another solution would be to use the proportion of fraud found in the sector as a whole, using figures like those shown in Table 1. With insurance against damage to property, therefore, where it is normal to use data for average costs borne by insurance companies in the sector as a whole, one solution would be to quantify operational risk by taking into account the expected proportion of fraudulent cases and the average compensation paid (calculating both the average accident rate associated with fraud and the product between the expected number of fraudulent cases and the average amount paid). Certainly the difference that exists between the proportion of fraudulent claims borne by the company and the compensation actually paid can be large, and therefore the quantification of operational risk may not be accurate.

In cases where the company follows an active anti-fraud policy, the quantification of operational risk should take into account a series of additional parameters, basically the cost of the investigation and the savings deriving from it. One way of doing this, as we do in this study, is to analyse the company's loss risk vis-à-vis the detection or non-detection of fraudulent behaviour once an active anti-fraud policy has been introduced. The aim of this is to compare the economic costs that the company would have to assume if it did not detect frauds with the costs associated with reducing compensation payments as a result of the frauds detected. The overall economic cost would therefore be calculated based on two

concepts: on the one hand, the cost deriving from the payment of the compensation, and on the other, the cost associated with claims auditing. Note that under the approximation presented in this paper we consider that claims auditing includes all those costs associated with the claim that are not part of the actual compensation to the claimant.

Quantifying loss risk can be carried out by applying alternative methodologies (see Klugman *et al.*, 2008, for an extensive review of loss models). We chose Value at Risk as the measurement in this study, then carried out a non-parametric estimation of the loss risk vis-à-vis the detection or non-detection of fraudulent claims, as detailed in the following sections.

4. Non-parametric estimation of loss risk in fraudulent and non-fraudulent claims

A widely used method of measuring risk is the Var_α, where α is a probability close to 1, with the most common values being 0.95, 0.99 and 0.995. Its value is equivalent to:

$$Var_\alpha = Inf\{x, F_X(x) \geq \alpha\} = F_X^{-1}(x), \qquad (1)$$

where $F_X(\cdot)$ is the distribution function of a random variable *X*, which in our case coincides with the cost of the claims. The Var_α is the value of the variable based on which the probability of there being a greater cost is close to zero (1-α). The greater the value of the cost associated with the Var_α, the greater the risk taken on by the company.

To calculate the Var_α in (1) we need to estimate the distribution function $F_X(\cdot)$ of the claims cost random variable. Parametric assumptions as to the shape of this function – such as the Normal, the t-Student and the Lognormal – can be used to do this. However, if the distribution shape does not coincide with the one drawn by these distributions we may incur high biases in the risk estimation, and this may cause the risk to be greatly over or under-estimated.

When the size of the available sample is large, as in this case, non-parametric estimation is a valid alternative for estimating $F_X(\cdot)$ and, therefore, the Var_α. Among non-parametric methods, empirical distribution is a simple way of approximating $F_X(\cdot)$. However, this estimation is only defined in the values of the sample observations, and so it often tends not to supply the exact value for the Var_α. Interpolation is the most common solution in these cases (Bolancé *et al.*, 2008, suggest a non-parametric estimation method for loss risk).

Kernel estimation provides a simple way of obtaining an estimation of the Var_α based on sample information. Papers such as those by Bolancé *et al.* (2003, 2008) and Burch-Larsen et al. (2005) suggest a number of valid methods for analysing the distribution of the variables that measure claims cost.

The kernel estimation of the distribution function can be interpreted as a smoothing of the empirical distribution and therefore has the advantage of being defined in all the values of the variable. We describe below the estimation of the Var_α based on the kernel estimation of the distribution function $F_X(\cdot)$.

4.1. Kernel estimation of the distribution function

Let $X_1,...,X_n$ be a sample of independent and equally distributed observations of the random variable *X*. In our case this coincides with the claims cost variable in car insurance. The kernel estimation of the distribution function $F_X(\cdot)$ is

$$\hat{F}_X(x) = \frac{1}{n}\sum_{i=1}^{n} K\left(\frac{x - X_i}{b}\right), \qquad (2)$$

where *b* is the window or smoothing parameter of the estimation which, as its name indicates, controls the degree of smoothing carried out. The larger this parameter, the smoother the estimation and vice versa. The value of the smoothing parameter we use in this paper is (Azzalini, 1981, and Silverman, 1986, Chapter 3),

$$b = 3{,}572 \cdot \sigma_X \cdot n^{-1/3}.$$

Function $K(t) = \int_{-\infty}^{t} k(s)ds$ is a distribution function, where $k(\cdot)$ is the kernel function, which coincides with a symmetrical density function, centred on zero and limited or asymptotically limited. In this paper we use the Epanechnikov kernel (Silverman, 1986),

$$k(\cdot) = \begin{cases} \frac{3}{4}(1-t^2) & si\ |t| \le 1 \\ 0 & si\ |t| > 1 \end{cases}.$$

Azzalini (1981) shows that the estimator defined in (2) has an average quadratic error which is asymptotically lower than that of the empirical distribution.

The value of the estimated Var_α is:

$$\hat{Var}_\alpha = \hat{F}_X^{-1}(x). \qquad (3)$$

The inverse function above cannot be obtained exactly and therefore it needs to be obtained numerically. Azzalini (1981) suggests using the Newton-Raphson algorithm to calculate the inverse in (3).

5. Loss risk through fraud on a sample of car accidents: claims auditing

In this section we assess the extent to which the auditing of accident claims reduces the insurer's loss risk. To this end we use a sample taken from a company's car insurance portfolio which contains information on 17,081 claims, of which 698 are fraudulent and the rest are not. For each claim we have information on the compensation and the cost of the audit, including appraisal work and anti-fraud procedures in those cases where there were indications of fraud. Table 2 shows the main descriptive statistics.

TABLE 2.
Descriptive statistics of claims costs
Data in euros

	Without auditing[a]					
	No.	Average	Typical deviation	Minimum	Median	Maximum
Fraud	698	885	1,434	0	554	17,251
Non fraud	16,383	620	1,230	0	335	63,960
Total	17,081	631	1,240	0	339	63,960
	With auditing[b]					
	No.	Average	Typical deviation	Minimum	Median	Maximum
Fraud	698	233	158	0	190	2,271
Non fraud	16,383	659	1,249	9	370	64,011
Total	17,081	642	1,226	9	361	64,011

Source: own compilation. No.= number of cases. [a] Note that the concept "without auditing" is equivalent to taking into account only the amount of compensation associated with the claim. [b] In this case the amount of compensation plus the cost of the auditing is taken into account.

Table 2 shows that the number of fraudulent claims is very low, just 4.1% of total claims[5]. However, the average cost of fraudulent claims is reduced by 74% if these claims are audited. As far as claims without fraud are concerned (the majority), the average cost increases by 6% after auditing. If all the claims are taken together, after auditing the average cost increases by 1.8%. However, we have to take into account that the distribution of claims costs has a marked asymmetry towards the right, a fact that can be deduced by comparing the average and the median of the variable. In all the cases analysed (fraud, non fraud and total) the median is lower than the average. This implies the existence of extreme values, i.e. very high costs that could severely affect the company's solvency. It is therefore essential to analyse the extent to which auditing reduces the company's loss risk.

5.1. Quantifying loss risk

In this section we analyse the risk taken on by the company in two situations: that in which all claims submitted are audited and that in which no claims are audited. Calculations are made for fraudulent claims, non-fraudulent claims, and for all claims taken together. Table 3 shows the results obtained for the Var_α .

TABLE 3
Values of the Var_α

	Without auditing		
	$\alpha = 0.95$	$\alpha = 0.99$	$\alpha = 0.995$
Fraud	2,841	6,957	9,088
Non fraud	1,929	5,351	8,026
Total	1,989	5,429	8,255
	With auditing		
	$\alpha = 0.95$	$\alpha = 0.99$	$\alpha = 0.995$
Fraud	560	843	880
Non fraud	1,993	5,516	8,260
Total	1,939	5,375	8,126

Source: own compilation.

[5] According to Artís *et al.* (2002) the percentage of undetected fraudulent claims in the insurance portfolio is estimated to be around 5%.

In Table 3 we can see that auditing considerably reduces risk when fraud is involved and increases it noticeably when there is no fraud. However, when we analyse the portfolio as a whole we can see that risk is reduced by between 1% and 2% when auditing is carried out on all automobile claims.

Figure 3 shows the values of the Var_α in relation to α that are associated with the costs of fraudulent claims when auditing confirms the existence of fraud and when it does not. Figure 4 shows the quotient between risk with auditing detecting fraud and without auditing detecting fraud in the whole interval of values of α, which are positioned between 0.95 and 0.995. This quotient is positioned between 0.1 and 0.2, and therefore auditing means a risk reduction of between 80% and 90% in the fraudulent claims group.

FIGURE 3
Var_α for the cost of fraudulent claims

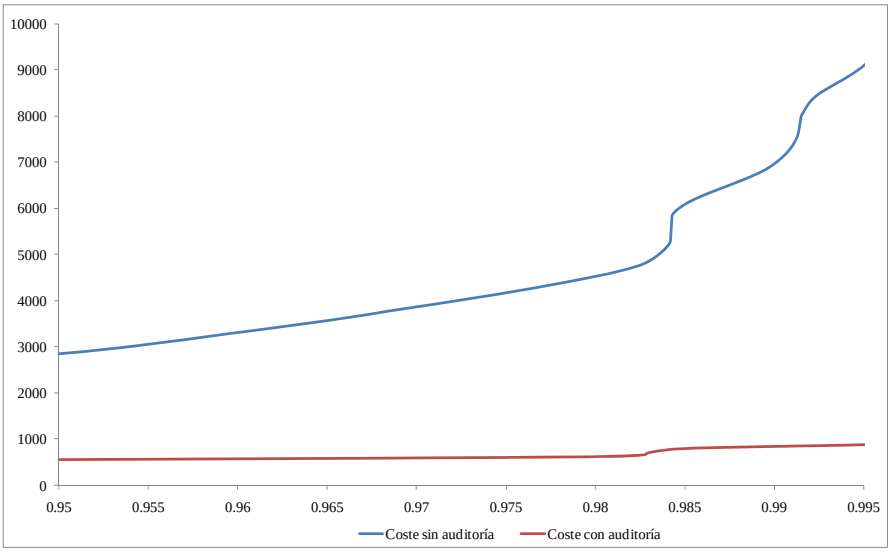
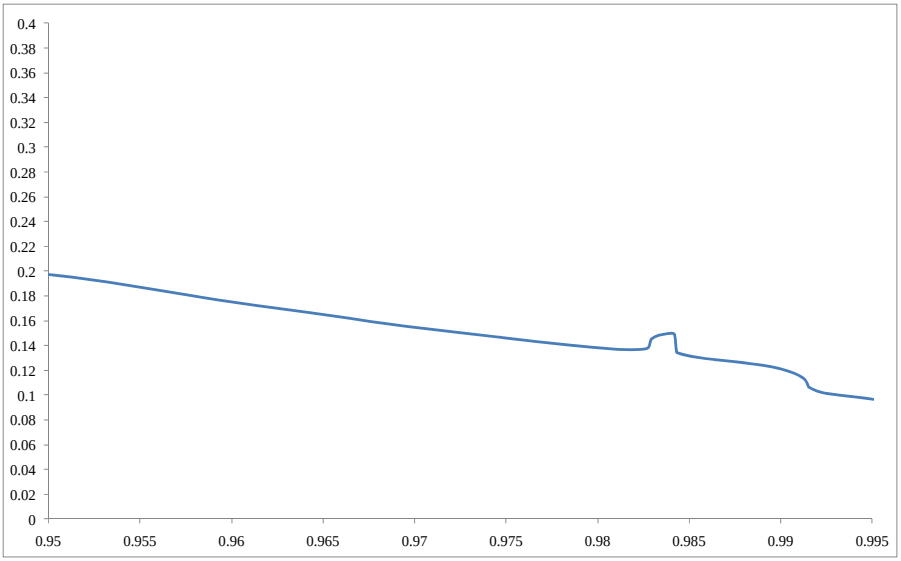


FIGURE 4
Quotient between the risk with auditing and without auditing of fraudulent claims



Figures 5 and 6 show the same results as Figures 3 and 4, but for the costs of claims without fraud. As we can see, in this case the risks with and without auditing are very similar. The quotient between both risks is positioned between 1.02 and 1.04, and so if the claims are not fraudulent the auditing means an increase in loss risk of between 2% and 4%.

FIGURE 5
Var_α for the cost of non-fraudulent claims

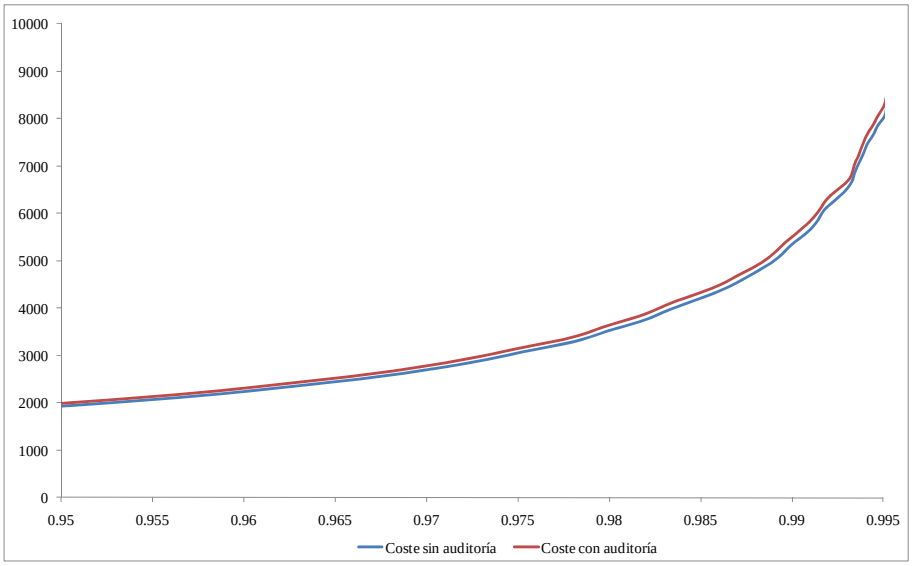
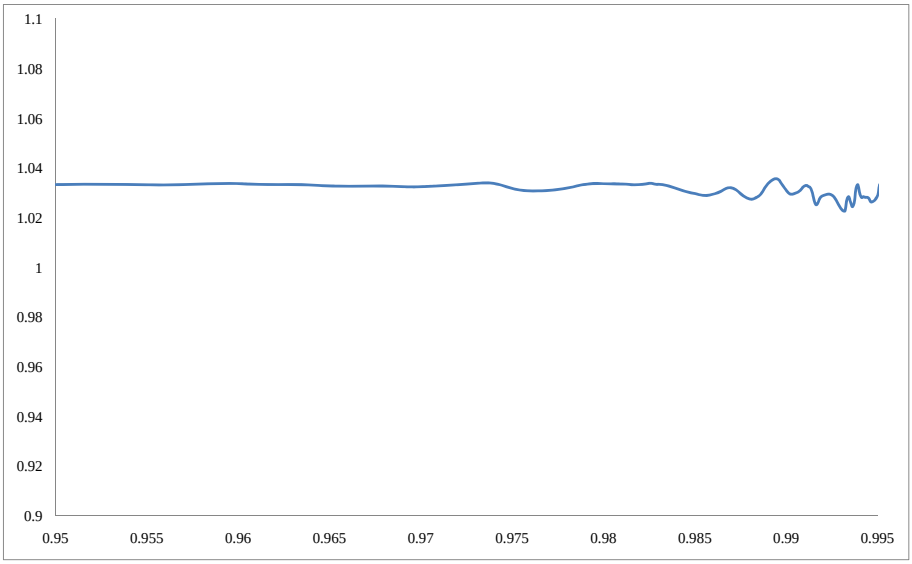


FIGURE 6
Quotient between the risk with auditing and without auditing
of non-fraudulent claims



It has to be taken into account that the number of non-fraudulent claims amounts to 95.9% of claims, and it is therefore important to assess the extent to which the reduction in risk after auditing fraudulent claims compensates the increase in risk the auditing brings about if the claim is not fraudulent. This is analysed in Figures 7 and 8. The Var_α is shown again here but

now for all claims taken together whether fraudulent or not, this being interpreted as the total portfolio risk. In Figure 8 we see how the risk with auditing tends to be positioned below the risk without auditing, given that the result of the quotient between the two is lower than the unit in practically all the values of α that are represented. If we calculate the average of the represented values of the quotient between the risk with and without auditing, we find that this is equal to 0.984, which means a reduction in loss risk of 1.6% for the portfolio as a whole.

FIGURE 7
Var_α for the cost of total claims

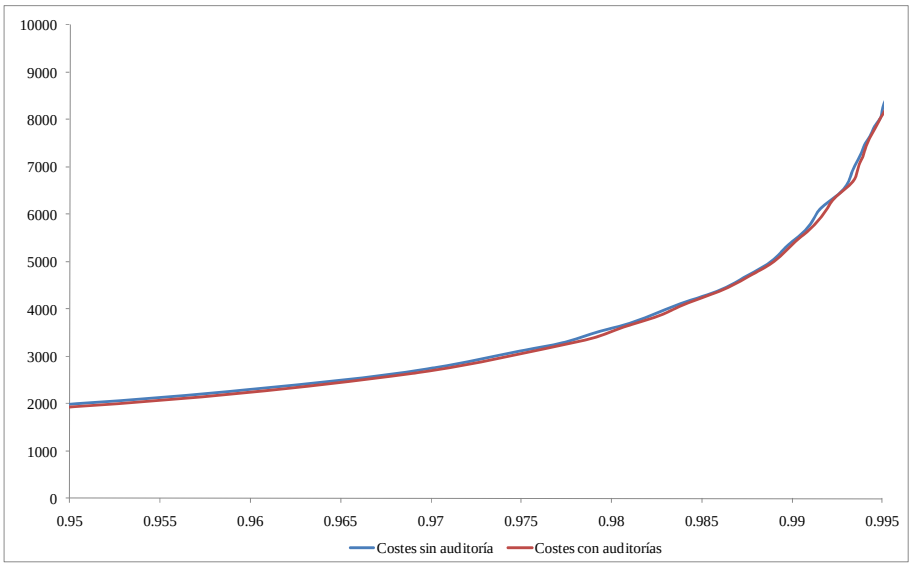
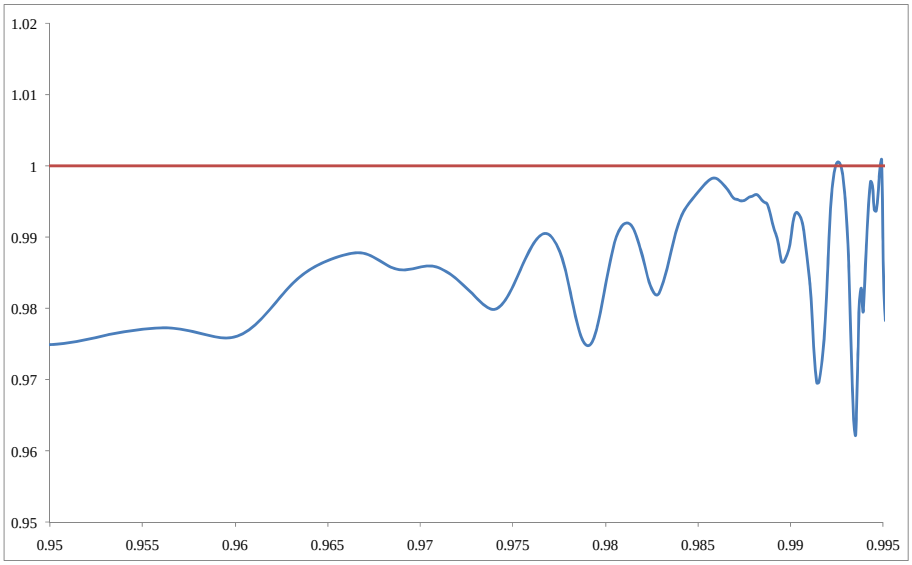


FIGURE 8
Quotient between the risk with and without auditing
for total claims



6. Conclusions

The non-detection of fraudulent behaviour can be considered a source of operational risk within the insurance company. Although different areas can be associated with fraud in the company, external fraud includes the much more frequent situation where the fraudulent action is carried out by the actual policyholders, trying to obtain wrongful benefit from their insurance policy, in our case in the context of car damages.

Quantifying operational risk from the point of view of external fraud has to take into account whether or not the company carries out claim auditing for fraud detection purposes. We chose Value at Risk as the risk measure, then carried out a non-parametric estimation of the loss risk vis-à-vis the detection or non-detection of fraudulent claims without and with auditing.

According our results, the auditing of claims considerably reduces loss risk when there has been fraud, while it increases the risk slightly when the opposite is the case. In fraudulent claims auditing reduces loss risk by between 80% and 90%, while in non-fraudulent claims it increases the risk by between 2% and 4%. In overall terms, i.e. for the total claims analysed whether fraudulent or not, auditing reduces the loss risk by between 1% and 2%. The results obtained justify the introduction of active fraud detection policies in insurance companies.

7. References

Artís, M., Ayuso, M., Guillén, M., 2002. "Detection of automobile insurance fraud with discrete choice models and misclassified claims", *Journal of Risk and Insurance*, 69, 3, 325-340.

Azzalini, A., 1981. "A note on the estimation of a distribution function and quantiles by kernel method", *Biometrica*, 68, 1, 326-328.

Bolancé, C., Guillén, M., Nielsen, J.P., 2003. "Kernel density estimation of actuarial loss functions", *Insurance: Mathematics and Economics*, 32, 1, 19-36.

Bolancé, C., Guillén, M., Pelican, E., Vernic, R., 2008. "Skewed bivariate models and nonparametric estimation for the CTE risk measure", *Insurance: Mathematics and Economics*, 43, 3, 386-393.

Buch-Larsen, T., Guillén, M., Nielsen, J.P., Bolancé, C., 2005. "Kernel density estimation for heavy-tailed distributions using the Champernowne transformation", *Statistics*, 39, 6, 503-518.

CEIOPS, 2010. *QIS5, Quantitative Impact Study-5*, Committee of European Insurance and Occupational Pensions Supervisors, http://www.ceiops.eu.

ICEA, 2010. *El fraude al seguro español, Estadística año 2009.* Investigación Cooperativa entre Entidades Aseguradoras y Fondos de Pensiones, Informe nº 1.157, Madrid.

Klugman, S.A., Panjer, H.H., Willmot, G.E., 2008. *Loss models. From data to decisions, Third Edition.* New Jersey: John Wiley and Sons.

Panjer, H.H., 2006. *Operational Risk. Modeling analytics,* New Jersey: Wiley-Interscience.

Silverman, B.W., 1986. *Density estimation for statistics and data analysis*, Chapman and Hall, London.

Viaene, S., Ayuso, M., Guillén, M., VanGheel, D., Dedene, D., 2007. "Strategies for detecting fraudulent claims in the automobile insurance industry", *European Journal of Operational Research*, 176, 1, 565-583.

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