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ARTICLE

Paying for crime: frauds in DPVAT insurance and their impacts on society

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ABSTRACT

The goal of this paper is to assess the weight of fraudulent claim payments of *DPVAT* insurance by the insurer *Líder*, a consortium of private insurers who manage this product. Using the Actuarial Credibility Theory, and a official database, the discrepancy between the *DPVAT* claims ratio and the claims ratios of other private automobile insurance lines of business, proxies for the ideal premium formation for having better system of frauds detection and prevention. The results indicate significant differences among the values. Additionally, in two counterfactual scenarios, it was estimated: (i) what would be the value of the *DPVAT* premium in case the fraud effects were purged, aiming to analyze whether the verified heterogeneity could be explained by the volume of proven frauds; (ii) the financial volume that could potentially be saved by society in case the frauds were subtracted since 2006. It is possible to affirm that not only would the DPVAT's claims ratio be reduced, but also the premiums paid by the insured. Finally, the estimates suggest that society could have saved over BRL 15 billion in 14 years.

KEYWORDS

DPVAT Insurance, Frauds, Claims Ratio, Actuarial Credibility Theory

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1. INTRODUCTION

Misconduct and ethical questions related to human behavior are part of the essence of humanity, and address whether people are more or less prone to breaking rules, violating laws, and commiting crimes. The Behavioral Ethics literature points to both individual and contextual factors as influencing anti-ethical behavior (Treviño et al., 2006). Among the behavioral factors, the main ones involved in decision making are ethical questions of intention, judgement, and awareness, demographic variables, and ethical behavior (Craft, 2013).

There may be different motivations for committing frauds—more specifically light frauds,those ones that do not employ violent methods—like pressure, opportunity, and rationalization (Gouvêa & Avanço, 2006). When related to the activities around insurance, one can connect these matters to the concepts of *information asymmetry* and *moral hazard* – the latest being possibly the least concrete among the diverse types of risk that an entity might be exposed to, precisely because it involves unpredictable, non-observable human decisions and behavior (Okura, 2013; Rowell & Connelly, 2012).

Every fraud is characterized by the breaking of the assumption of good faith of the contract, lie or deliberate facts omission by the economic agents, with the goal to obtain financial gains at the expense of others (Contador, 2011). Insurance fraud, by the policyholder's perspective, can involve property, automobile, life, business, or health insurance products and can be done in many ways, from the "fabrication of loss" to any level of value exaggeration (Boyer, 2007). Frauds were described as the second largest white collar crime in the USA, losing only to tax evasion (Miyazaki, 2009).

Although, in many of these cases, the insurance company is also aware of the illicit act, frauds frequently are not reported or proven, for varying reasons (Macedo et al., 2021; Perez & Wing, 2019; Severino & Peng, 2021). Furthermore, fraud generates losses not only for the company itself, but also for society as a whole, as it increases the insurance premium for all the mutual policyholders, not only for the perpetrators (Tennyson & Salsas-Forn, 2002). Other consequences of insurance fraud include the deteriorating quality of the insurance products and services (Akerlof, 1970).

To draw on the Brazilian experience, according to a report released by *CNSeg*[1], in 2018 alone BRL5.13 billion was registered in claims under suspicion of fraud (15.6% of the total occurred claims), out of which 14% (BRL720 million) have been detected, investigated, and proven. The report shows that the DPVAT insurance – Personal Damage caused by Motorized Land Vehicles – presented the most elevated ratio between proven frauds and occurred claims among the analyzed products: 6,1% of collected premium, representing a total amount of BRL115.8 million in relation to the total of BRL1.9 billion. For this reason, DPVAT is the object of attention of this article.

In 2019 there was a discussion around the possibility of extinction of the DPVAT insurance, which, despite not being realized, generated massive media coverage about the event, leading to an increase in information about the product which reached the population. It is possible to see some reasons for a potential discontinuity of the DPVAT: the high incidence of frauds, reports of corruption, resource mismanagement, and the monopoly of the insurer *Líder,* who are only managers of the product. The temporary measure MP 904/2019[2] was proposed, and even came into effect, but was not voted in time, thus expiring in the beginning of 2020.

Along with this measure, the disruption of *Líder*'s monopoly and the consequent market opening to the product was evaluated[3]. The insurer *Líder* – manager of the DPVAT insurance

– is not a regular insurance company, as it usually defined, but a consortium composed by many insurance companies. Despite the high fraud incidence, *CNSeg*'s report[4] shows that *Líder* presents positive results with the product, suggesting there might be a certain degree of lack of knowledge of the population about their right to the coverage. The measure[5] was approved by the Nacional Council of Private Insurance (*CNSP*) and should have been presented to *SUSEP* (Superintendency of Private Insurance, the Brazilian authority) by August 2020.

There is a lack of academic quantitative studies about the DPVAT. In one of the rare cases, Duarte & Santos Júnior (2015) tried to predict operational results for *Líder*, using traditional indexes of the insurance market, using time series technique. However, the authors did not approach the fraud effects upon the two main pillars of this contractual arrangement: premiums and claims. This is precisely the gap that this article intends to explore.

This work aims to investigate the weight of fraud claims in *Líder*'s expenses, by (i) measuring the impact of the peculiar modeling of this group, in relation to the behavior of other automobile insurance lines, by comparing the credibility premiums through the Actuarial Credibility Theory method – unexplored technique in Brazilian academic articles – and; (ii) estimating how much more policyholders pay for the insurance in regard to what the ideal price would be, i.e., with the lower possible fraud incidence.

In order to achieve this, public data from the private automobile insurance market will be used as a proxy for the ideal premium composition, for having a better system of fraud control, and for prevention in comparison to the DPVAT. Using the historic evolution of the claims ratio (the actuarially fair tax base for insurance) of the private sector, the ideal premiums are estimated using the Actuarial Credibility Theory. Thus, it will be possible to quantify the weight of the frauds upon the social cost of the mandatory insurance.

2. DPVAT

The Personal Damage caused by Motorized Land Vehicles (DPVAT) insurance was originally previewed by the Law n. 73/1966, and then disciplined by the Law n. 6,194/1974. It is a product of mandatory coverage to all automobile owners in Brazil, paid annually along with the annual license, and has the objective to pay for the indemnities to the victims of traffic accidents. Because it is mandatory, DPVAT has a few peculiar and unique characteristics in relation to what is usually seen in insurance policies.

DPVAT is entirely managed by the insurer *Líder*, that holds a monopoly of this market. The Nacional Council of Private Insurance (*CNSP*), through resolution number 154/2006, has determined the constitution of two specific consortiums to be administrated by a specialist insurer under the quality of leader. In order to attend this demand, *Seguradora Líder do Consórcio do Seguro DPVAT S.A.* (Leader Insurer for the Consortium of the DPVAT Insurance), or simply *Líder*, was created by the decree number 2,797/2007. This consortium is formed by the main automobile insurance companies, in a proportional ratio to each of their participation in private automobile insurance market.

Firstly, the mandatory nature of the product limits the consumer's autonomy of will, asit does not allow the policyholder to choose the amount to be insured (Borges & Oliveira, 2018). Therefore, it disregards psychological aspects of the insurance demands such as the individuals' level of risk aversion, or their risk propensity (Laas et al., 2016). Furthermore, there is no possibility to choose another insurance company, due to the fact of the monopoly.

The DPVAT regulatory framework suppresses determined control tools that are common for private insurers to use, such as the selection of better risks, a possible extra/lower charges for bigger/smaller risks, and deductibles, implying zero cost to the indemnity access. Even the fraud combat and prevention mechanisms were very recently implemented. According to *Líder*'s official website, only since 2017 have the fraud detection and investigation strategies been implemented in DPVAT's management and, as can be seen, they have not yet been enough to restrain fraud occurrences.

There are three types of indemnity: Death, Permanent Disability and Supplementary Medical Assistance Expenses (DAMS). The value of the death indemnity is fixed in BRL 13,500.00. For permanent disability, up to BRL 13,500.00 is paid, depending on the intensity of and repercussions from the victim's injury, based on a table provided by law. The medical expenses, in turn, will be reimbursed in function of the victim's expenses in their treatment, limited to BRL 2,700.00. All of these values are relatively low when compared to the coverages offered in the private insurance market, considering similar insurance plans. However, the policy does not consider the conditions, circumstances, or severity of the occurrence, only the victim's status. Moreover, the amount is paid independently of establishment of guilt, and even if an excluding of the casualty principle is observed, such as fortuitous or force majeure (Borges & Oliveira, 2018).

According to *Líder*'s own reports[6], in 2019 353,252 claims were paid in total, out of which 11% were due to the Death cover, 67% Permanent Disability and 22% DAMS. A total of 6,435 frauds were identified in that year, out of which, unsurprisingly, 75% were from Permanent Disability, 16% from Medical Expenses and 9% from Death. The Brazilian state with the most fraud incidences was Ceará, with 25% of the occurrences.

It should be noted that this design is not exclusive to Brazil. The European Union (EU) also has a regulation that makes the insurance for damage caused by motor vehicles compulsory. There is uniformity between the laws and traffic restrictions in member countries, being an object of law since 1972 (Borges & Oliveira, 2018). The directive covers the minimum amounts to be compensated (€1,000,000 per victim or €5,000,000 regardless the victims number in case of personal accident, and €1,000,000 per occurrence in case of damage to property) and is mainly focused on repairing the damage caused, guaranteeing compensation even to victims of accidents caused by unidentified drivers, and those from different countries. The norm also considers as insured all passengers in the vehicle, instead of just the driver.

Despite the similarities to the Brazilian design, the European regulation does not create an exclusive product to be operated by a monopolistic consortium. The EU objective is to standardize the products offered by the different insurers in the different member countries, and guarantee protection and payment to victims regardless of region and institution, reducing the bureaucracy involved. The directive also does not limit the product to be sold by a specific institution, allowing the insured to choose a company and negotiate the best price according to their preferences and claims history.

3. THEORETICAL BACKGROUND

When dealing with aspects of moral hazard, one should always begin the theoretical basis with the seminal article by Akerlof (1970), a pioneer in determining the economic costs of dishonesty in an environment of uncertainty. In this study, the author uses the automobile market, in which sellers know, but buyers do not, the quality of a new automobile, to discuss the concept of informational asymmetry. He concludes that trust-based economic models need informal,

unwritten guarantees as preconditions for production and trade. However, the distinction between good and bad quality is inherent to business, and this explains the price formation mechanism of many economic transactions, uncertainty being one of the most important aspects.

With a similar approach, but specifically examining the insurance market, Rothschild and Stiglitz (1976) analyzed competitive markets in which the traded products characteristics were not fully known by at least one of the transaction parties. The authors demonstrated not only that a competitive equilibrium may not exist, but also that, when it does, it may have strange properties, and that a small portion of imperfect information can have a significant impact on competitive markets. Moreover, they noted that in a situation of informational asymmetry, the price equilibrium of conventional competitive analysis alone was no longer feasible. Finally, the structure of market equilibrium, as well as its existence, depended on a number of assumptions that required perfect information, and that, even under plausible conditions, equilibrium sometimes did not exist.

Stellwagen (1927, p. 161) defines moral hazard as "that which contemplates intangible fragilities and propensities that cannot be measured by any pricing method, and cannot be taken into account previously by requesting a premium rate". In Varian (2015) it is possible to better understand the effect of moral hazard on the microeconomic aspects of insurance: in a market with moral hazard, the market equilibrium will be affected by supply rationing, because firms will not be willing to expose themselves to the hidden risk. Moreover, offering more means necessarily changing the willingness of clients in relation to their risk-taking behavior.

Based on this concept, Boyer and Peter (2020) jointly analyzed adverse selection and insurance fraud in a competitive insurance market, in a scenario in which agents have prior knowledge of their probability of suffering an accident. They use the Rothschild and Stiglitz (1976) methodology to demonstrate that high risks will be fully covered, while low risks may be excluded from the market. They also demonstrated that, for a moderate cost of auditing, low risks will be rationalized, which increases the total value of fraud in the economy.

One-sided changes in behavior are quite treated in relation to health insurance, mainly tied to the concept of moral hazard. For Maia et al. (2012) the moral hazard is arising from changes in consumer behavior, especially when they have insurance protection coverage. More specifically, the probability of insurance overusing in face of the knowledge of the imminent occurrence of the plan's loss. Through empirical tests, there is a significant increase in the use of benefits, especially in consultations and diagnostic tests in the months prior to the insured's lapse. There is vast literature in health economics addressing moral hazard problems, which, despite being very relevant, is not the core of this work.

Once the factors of informational asymmetry, moral risk and adverse selection have been presented, we can then relate them to the central point of discussion – insurance fraud, its motivations, impacts, and prevention and combat measures. To enter this subject, the Behavioral Ethics literature is adequate, since it seeks, with a business bias, to explain ethical behaviors and decision-making that involve moral dilemmas, their costs and benefits.

Craft (2013), for instance, observes that among the behavioral factors, the main ones in decision-making involving ethical issues are intention, judgment and awareness, demographic variables and ethical behavior, the latter being less and less observed. Treviño et al. (2006), in turn, point out that individuals can be divided into two groups:*utilitarians*, who focus on the ends of decision-making, and *formalists*, who focus on the means, and who, therefore, have different approaches to issues identified as ethical, i.e., conflicts with high moral intensity.

According to Gouvêa and Avanço (2006), there may be several motivations for committing fraud, more specifically light fraud, that which does not use violent methods,including pressure, opportunity and rationalization. The first, pressure, refers to a need for obtaining monetary resources: e.g., settling debts, or for financial or emotional instability. The second refers to loopholes in contracts, situations that may go unnoticed or that are difficult to prove. And the third allows the fraudster to justify their illicit act.

Miyazaki (2009) seeks to understand why many people find it acceptable to commit light insurance fraud, such as submitting higher than actual loss amounts, and what could change this perception. The results show that while a high volume of resources is applied in the fight against fraud, most of these initiatives are focused on identifying the fraudsters rather than the reason for such behavior and therefore do not work on a change of attitude towards fraud. Public initiatives have been identified as one of the biggest obstacles to reducing fraudulent activities, and changing public perception is seen as a potential but partial solution.

When dealing with prevention and combat measures, Derrig (2002) discusses the precautions adopted by companies - which, for the most part, tend to invest the least amount possible in accident investigations and the acquisition of additional information. Some of the practices include independent medical examinations, accident reconstructions, depositions, negotiations, and, ultimately, resorting to legal proceedings.

A plausible way, already practiced by the market to reduce and curb fraud, especially in car insurance, is the implementation of so-called *deductibles* (Kaas et al., 2008). This is the imposition of an amount (fixed or as a proportion of the loss) which the policyholder is responsible for bearing in the occurrence of a loss. In other words, it is the risk portion that will not be transferred to the insurer. Thus, "by making consumers pay part of the claim, insurance companies can ensure that they always have an incentive to exercise a little caution" (Varian, 2015, p. 765). Schmidt (1961) evaluates how valid the idea that deductible copayments curb moral hazard is in the face of a few different factors, reaching the conclusion that copayments have an effect in curbing only one of these factors: the overzealous pursuit of small legitimate claims.

Smith and Head (1978), in turn, analyze the pricing process of such deductibles, and this procedure should follow some guidelines based on their business objectives and technical aspects. Under the first aspect, deductibles should play the role of minimizing adverse selection, passing on some portion of the insurance costs to the insured, deterring harmful claims, maintaining risk collections, minimizing insured dissatisfaction, and considering the insured's tax positions. Under the second, one considers the data-lacking nature with which to price the premium, the effect of inflation and the consequences of deductibles on operating costs.

More recently, Wang et al. (2008) used deductibles in the Taiwanese automobile market to analyze the effects of both informational asymmetry and moral hazard on insurance pricing in this industry. Their results confirm the existence of informational asymmetry in the insurance market, and also show that deductibles have a positive effect in controlling moral hazard, and that the effects of adverse selection are minimal.

In order to make the detection and definition of monitoring costs possible, the use of correct methodologies is essential. Among many possible methods, Cowell et al. (2007) use the Bayesian method to model the operational risks of insurers. Specifically, the authors use Bayesian networks to model the cost of a fraudulent payment, combining several variables to determine the probability of the wrongful claim final cost. Among them, previous underwriter experience, control of claims triggers and the probability of fraud detection, are fundamental elements for pricing insurance contracts.

Still on fraud detection systems, Brockett et al. (1998) created a mechanism for classifying frauds for the personal injury in automobile accidents insurance, more specifically with the application of neural networks, based on *Kohonen's Self-Organizing Maps*, for the construction of a system that used collections of fraud indicators as classification. They concluded that it is possible to use this method for the identification and classification of frauds and it also proved to be more efficient than the methods already used, identifying frauds that had not been previously identified. Okura (2013) examined the relation between moral hazard and insurance fraud, showing how the insurance company's effort to reduce the probability of accidents change when the insurer increases their investment in the prevention of insurance frauds.

Even in the international literature, articles that adopt the Actuarial Credibility Theory in policy pricing are rare. Pai et al. (2015) use this approach in the insurance evaluation for swine mortality. Since this is a relatively new product that depends on numerous variables, such as geographic region, contagious diseases, and even moral hazards of livestock farmers, the study used this methodology as a way to identify explanatory factors with a view to obtaining greater accuracy in the pricing process.

Notedly, in the Brazilian context there is a lack of academic works that approach this subject in depth and with factual assertiveness. An example is Contador (2011), the most complete paper on insurance fraud, that yet treats it with a microeconomic bias. It points out relevant points, such as the fact that "the DPVAT insurance is certainly the most vulnerable to professional fraud, since the bureaucratic procedures are simple, the judiciary is pro-accident and the indemnities are paid without difficulties", but it does not deepen in the verification of such affirmation. Perhaps due to the lack of reliable sources, or due to the nonexistence of specific data on these themes, there are gaps to be filled. This work proposes to fill some of them, including by the usage of necessary actuarial framework.

4. METHODOLOGY

According to the actuarial insurance policy pricing theory, the prospective definition of the insurance premium value is expected to express the future evolution of claims (Bowers et al., 1997; Klugman et al., 2012). However, the prior claims experience of an insurer is usually used to form such an expectation (Kaas et al., 2008). Therefore, a portfolio with large fraudulent claims expenses is expected to have significantly higher premiums than a theoretical optimal value, when compared to a portfolio with little or no fraud experience (Boyer & Peter, 2020; Contador, 2011). This evaluation will be made through the Credibility Theory, broadly disseminated in the actuarial literature (Pai et al., 2015).

Kaas et al. (2008) describe the Credibility Theory as a mixed-experience pricing system for determining the pure insurance premium value considering not only individual experience, but also the collective experience of portfolios of similar coverage. This method is used when one wants to estimate the premium value based on a real and known sample, but one not large enough to be generalized to apply to all cases. A weighting is then made between the expected value considering the previous claims experience ($\overline{X}_j$) and a so-called *manual rate* ($\overline{X}$) which refers to a statistically more consolidated prize, calculated with a broader experimental base, endowed with characteristics similar to the sample studied, but more robust. Its formula is given by:

$$P_C = z_j \overline{X}_j + \left(1 - z_j\right) \overline{X}, \tag{1}$$

where P_C is called *Credibility Premium*, and z_j is called *credibility factor* and expresses how credible the individual experience of portfolio *j* is, assuming values between 0 and 1, and the closer to 1, the greater the credibility is. This value, according to the Law of Large Numbers, is obtained through approximation to the Normal distribution.

In this paper, the manual premium ($\bar{X}$) will express a *hypothetical ideal premium*. That is, an estimate of the ideal premium with better monitoring and detection of fraud, represented by the premium of the private market's automobile insurance policies for covering Personal Accident for Passengers (APP), Automobile Hull, and Facultative Civil Liability for Vehicles (RCFV). The value of the sample ($\bar{X}_j$), on the other hand, is *real data from the sector* between 2006-2020, so that could be verified the impact of fraud on insurance premiums. The closer the value found z_j for is to 0, the closer the *ideal premium* would be to the insurance market experience. In the exact opposite, z_j close to 1, the more credible is the experience itself, signaling high historical consistency.

4.1. The *Bühlmann-Straub* Model

With the *Bühlmann-Straub* model it is possible to develop the equation for the credibility premium, considering each variable X_j as a portfolio with stochastic dynamics over several periods. Thereby, X_{jt} represents the claims ratio measure for *j-th* portfolio, j = 1, 2, ..., J, on year *t*, t = 1, 2, ..., T, considering that all portfolios are exposed every period. It is assumed that the claims pattern can be summarized by the statistic mean of the cell (m_j) and a random white noise value. Like so, the random variables (r.v.) X_{jt} are independent among portfolios and follow distribution $N(m_j,s^2)$. The variable X_{jt} is defined as:

$$X_{jt} = m + \Xi_j + \Xi_{jt}, j = 1,...,J, t = 1,...,T \quad (2)$$

where the portfolios' Ξ_j fixed effects are independent and identically distributed (iid), with mean $E[\Xi_j]= 0$ and $Var[\Xi_j]= a$, as well as the random variables Ξ_j, which are also iid with mean $E[\Xi_j]= 0$ and $Var[\Xi_j]= s^2/w_{jt}$, for every j and t. In this model, w_{jt} represents the weight of each variable X_{jt} that, in turn, corresponds to the relative precision of each observation. Furthermore, it is assumed that the r.v. Ξ_j are independent of Ξ_j.

As the objective is to assess whether all experiments are homogeneous or not, Analysis of Variance (ANOVA) is performed. If the null hypothesis is rejected (equal means), there is evidence to conclude that there will be greater variation between the individual means $\bar{X}_{jt}$ and the general mean of the observations $\bar{X}$. Thus, the following quantities are assumed:

a) SSB – Sum of the Squares Between groups:

$$SSB = \sum_{j=1}^{J} T(\overline{X_j} - \bar{X})^2 \quad (3)$$

Under the null hypothesis, the mean of the variable SSB is proven to be $(J-1)s^2$. Since the value s^2 is unknown, the second parameter is used to estimate the value, as follows:

b) SSW – Sum of the Squares Within groups:

$$SSW = \sum_{j=1}^{J}\sum_{t=1}^{T} T(X_{jt} - \bar{X}_j)^2, \quad (4)$$

which, in turn, has as mean $J(T-1)s^2$. Dividing SSB by J–1, and SSW by $J(T-1)$, two new quantities are obtained: MSB (Mean of the Squares Between groups) and MSW (Mean of the Squared Within groups), that are non-biased estimators for the average distance between portfolios (MSB) and for the average time dispersion within the same portfolio (MSW).

With these new quantities, the F-test is performed, which indicates the null hypothesis rejection if the value for MSB is significantly higher than the value for MSW.

$$F = \frac{MSB}{MSW} = \frac{\frac{1}{J-1}\sum_{j=1}^{J} T(\overline{X_j} - \overline{X})^2}{\frac{1}{J(T-1)}\sum_{j=1}^{J}\sum_{t=1}^{T} T(X_{jt} - \overline{X}_j)^2} \tag{5}$$

Under the null hypothesis, the variable SSB divided by s^2 has as distribution $\chi^2_{(J-1)}$, while SSW divided by the same denominator has as distribution $\chi^2_{(J(T-1))}$, and these two variables are independent. Hence, the statistic F has a Fisher-Snedecor distribution, with (J–1, J(T –1)) degrees of freedom. This way, the statistical significance can be reached.

In order to find the best linear homogeneous unbiased predictor of the risk $\sum h_{it} X_{it}$ premium $m+\Xi_j$, the MSE (Mean of the Square Error) is minimized, using the following estimators:

$$w_{j\Sigma} = \sum_{t=1}^{T} w_{jt} \; ; \tag{6}$$

$$w_{\Sigma\Sigma} = \sum_{j=1}^{J} w_{j\Sigma} \; ; \tag{7}$$

$$z_j = \frac{a w_{j\Sigma}}{s^2 + a w_{j\Sigma}} \; ; \tag{8}$$

$$z_\Sigma = \sum_{j=1}^{J} z_j \; ; \tag{9}$$

$$X_{jw} = \sum_{t=1}^{T} \frac{w_{jt}}{w_{j\Sigma}} X_{jT} \; ; \tag{10}$$

$$X_{ww} = \sum_{j=1}^{J} \frac{w_{j\Sigma}}{w_{\Sigma\Sigma}} X_{jw} \; ; \tag{11}$$

$$X_{zw} = \sum_{j=1}^{J} \frac{z_j}{z_\Sigma} X_{jw} \; . \tag{12}$$

Using these statistics, the relative importance of each insurance sector in the joint portfolio is estimated ($w_{j\Sigma}$), in order to estimate the credibility factor of each line of business (LOB).

4.2. Parameters estimation through the *Bühlmann-Straub* model

The credibility estimators are based on the parameters m, a e s^2. The latter two are calculated based on the weighted sum of squares within (SSW) and the weighted sum of squares between (SSB):

$$SSW = \sum_{j,t} w_{jt} \left(X_{jt} - X_{jw} \right)^2 \tag{13}$$

$$SSB = \sum_j w_{j\Sigma} \left(X_{jw} - X_{ww} \right)^2 \tag{14}$$

Consequently, the parameters for the model are estimated as follows:

$$\widetilde{s^2} = \frac{1}{J(T-1)} \sum_{j,t} w_{jt} \left(X_{jt} - X_{jw} \right)^2 ; \tag{16}$$

$$\tilde{a} = \frac{\sum_j w_{j\Sigma} \left(X_{jw} - X_{ww} \right)^2 - (J-1)\widetilde{s^2}}{w_{\Sigma\Sigma} - \sum_j w^2{}_{j\Sigma} / w_{\Sigma\Sigma}} ; \tag{17}$$

$$\tilde{z} = 1 - \frac{MSW}{MSB} , \tag{18}$$

where is $\tilde{a}$ the estimate of the variance within each insurance LOB, $\widetilde{s^2}$ is the estimate of the total variance of all portfolios, $\tilde{m}$ estimates the global mean between all portfolios and z, at last, the vector of each LOBs credibility factor. The full implementation of this model was made using the statistical software R.

5. ANALYSIS OF RESULTS

5.1. Data and descriptive analysis

In this work, public databases of the Brazilian insurance industry were used, extracted from the System of Statistics of the Superintendency of Private Insurance (SES-SUSEP), in July/2020. From the database, it was extracted the values of premiums earned, and claims incurred of the lines of business 0520 (Personal Accident for Passengers –APP), 0531 (Automobile Hull), 0553 (Facultative Civil Liability for Vehicles –RCFV) and 0588 (DPVAT).

Aiming to mitigate eventual temporal disparities from generating events on a cash basis, the monthly data available in the SES-SUSEP database were grouped on a half-yearly basis, from January/2006 to June/2020. This methodological option is a simplifying hypothesis that seeks to reduce great variations in the claims ratios by virtue of the premium *pro rata temporis* allocation and/or effective indemnity disbursement by the insurance company, softening the *seasonal effect* (Areias & Carvalho, 2021; Euphasio Junior & Carvalho, 2022). Generally, car insurance is sold and renewed in the middle or at the end of the year, and DPVAT has its collecting peak in January, which is the month of compulsory licensing of vehicles in Brazil. All results were also generated using monthly data, producing very similar results to those presented here, which can be sent upon request.

From these values the claims ratios were calculated (claims incurred divided by earned premiums, a traditional measure of performance of insurance portfolios, which makes up the tariff base for actuarially fair premiums) for each period. Figure 1 presents the claims ratios historical evolution for each LOB.

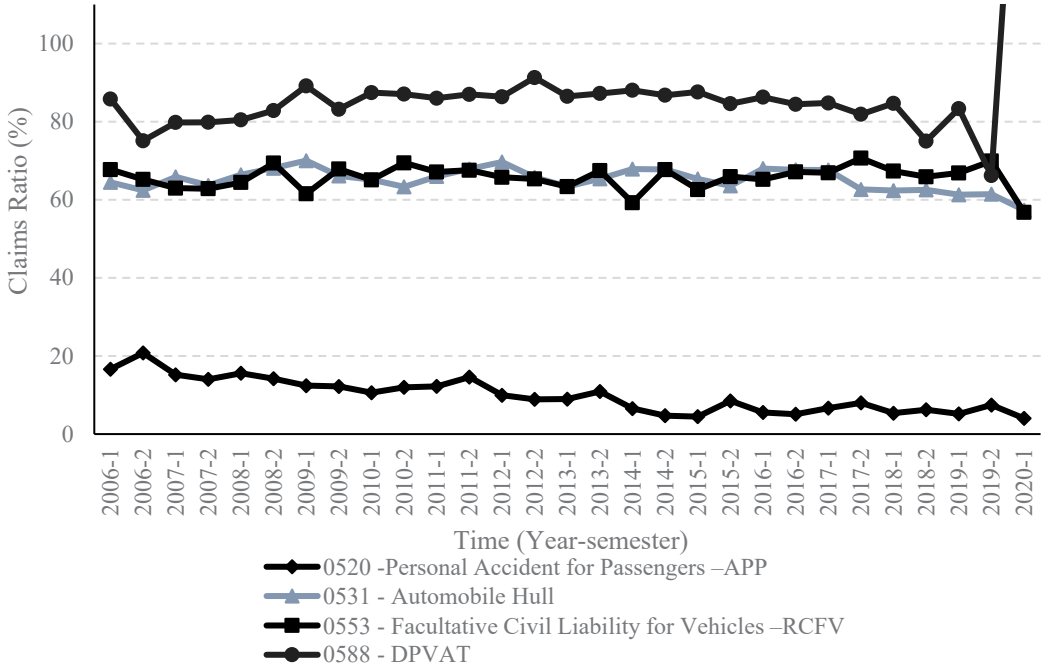

Figure 1. Evolution over time of the claims ratios by LOB (2006-2020)
Source: own elaboration.

Analyzing Figure 1, the comparison between the lines of business shows that the DPVAT LOB presents historical claims ratios consistently higher than the other exclusive lines of the private insurance market. This can be explained by the fact that DPVAT is a mandatory insurance policy for all vehicle owners, administered by a monopolistic consortium of private companies formed by the CNSP. The large size of their portfolio, the mandatory nature and the particular characteristics of the product make risk selection, oversight and monitoring for fraud more difficult. Moreover, they do not have sufficient incentive to do this monitoring, as is the case with private insurers.

After all, as shown in Figure 2, in every semester, Líder presented a surplus. The only notable exception was the sharp and progressive reduction in premiums collected in 2019, resulting in the sudden increase in the claims ratio in 2020. These facts are related to the product extinction discussion proposed by the government in the second half of 2019. MP 904/2019 was even published, extinguishing the product temporarily, but it was not voted on in time and was then annulled. The result was a huge drop in revenue, as many people stopped paying the tax, and, of the insured who paid, some requested a refund.

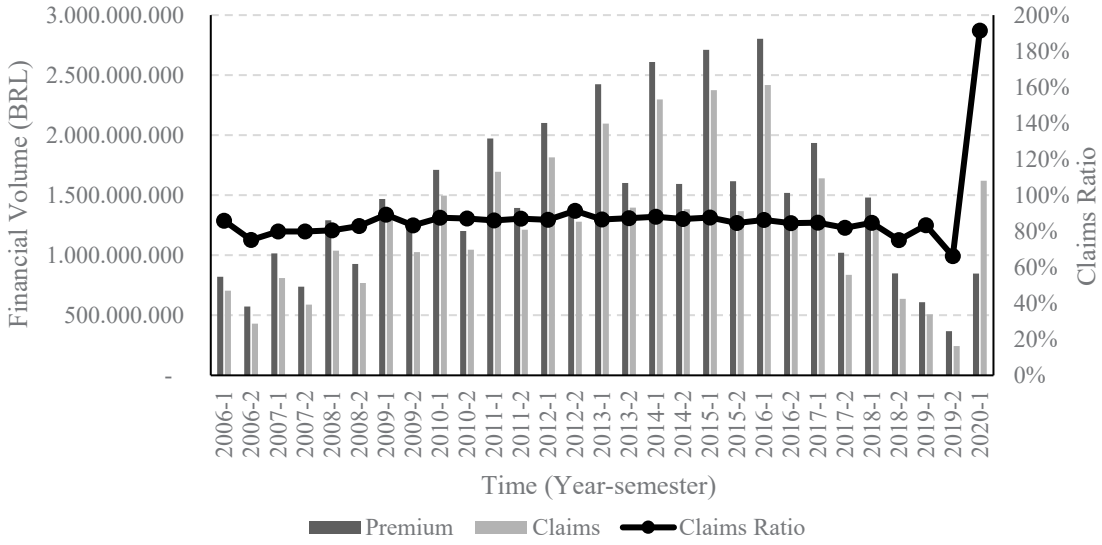

Figure 2. Evolution over time of the premium and claims volumes and the claims ratio of the DPVAT (2006-2020)
Source: own elaboration.

Furthermore, due to its nature, the DPVAT premium is not subject to adjustments in relation to several factors typical of insurance products, such as risk aversion of potential consumers, additional charges for greater risks, among others, since it is mandatory for all insured in a uniform manner (varying only by vehicle category). Thus, it is not possible to underwrite each risk individually, making it difficult to identify profiles that are more or less prone to risk, as well as possible fraudsters more evident.

5.2. Results of the Bühlmann-Straub Model Estimates

From Table 1, as the p-value is lower than any significance level, we conclude that there is statistically significant evidence to state that the LOBs patterns are distinct from one another. Therefore, there is a basis for estimating the credibility premiums through the Bühlmann-Straub model, assuming strict heterogeneity among portfolios, using Equations 6 to 18.

Table 1
Test for homogeneity of mean standards (ANOVA)

Source of Variation	d.f.	SS	MS	F	p-value
LOB	3	95,632	31,877	276.82	< 0.001***
Residuals	112	12,897	115.00		

Note: '***' significant at 1%; '**' significant at 5%; '*'significant at 10%.
Source: own elaboration.

According to Table 2, it is noted that the values of z for all cases are close to 1, but not identical. This result shows the high historical consistency of each LOB. As expected, the credibility premium (*pr*), here understood as the claims ratio, calculated for the DPVAT was higher than the others, because a higher incidence of fraud is expected in it than in the standard private insurance LOBs. In particular, one should pay attention to the fact that the credibility premium (claims ratio) for the 0531 LOB was 25,54% lower than the DPVAT credibility premium. The 0553 LOB, in turn, presented a claims ratio 25.012% lower than the DPVAT credibility premium.

Table 2
Results of the obtained Bühlmann-Straub Model estimates

J	LOB	z	pr
1	0520 - Personal Accident for Passengers (APP)	0.99602	9.937262
2	0531 - Automobile Hull	0.99615	65.190315
3	0553 - Facultative Civil Liability for Vehicles (RCF-V)	0.99634	65.651596
4	0588 - DPVAT	0.99629	87.548961

Source: own elaboration.

In the following section, we will analyze whether this observed difference (reduction of the order of 25%) in the credibility premiums (claims ratios) among the lines of business can be explained by the high incidence of fraud in DPVAT. That is, the following counterfactual scenario will be evaluated: if it were possible to exclude fraudulent amounts in full, would the claims ratio of DPVAT insurance be similar to that of the other lines of business?

5.3. Counterfactual scenario 1: calculating the ideal DPVAT premium by excluding fraud

As previously justified, the private insurance LOBs were taken as the ideal standard of operation. Specifically, the Automobile Hull (0531) and Facultative Civil Liability for Vehicles (0553) LOBs, which present indemnity characteristics analogous to DPVAT, having traffic accidents as the events generating indemnity. In case the central hypothesis of this work is valid, when subtracting the values of frauds from the costs of DPVAT claims, its premium value should become equivalent to the others. In this way, the difference observed between the claims ratios – the actuarially fair rate, the base for premiums - would be fully justified by frauds, excluding the possibility of differences among the portfolios' performance due to other reasons.

Equation 19, below, expresses the statistical premium, calculated by the product between the average probability and the average severity, in order to obtain the actuarially fair value:

$$PE = \frac{Claim\ Amount}{Total\ units\ exposed\ to\ risk} \times \frac{Total\ Loss}{Claim\ Amount} \tag{19}$$

$$PE = \frac{Total\ Loss}{Total\ units\ exposed\ to\ risk}$$

From official reports, the Table 3 information were extracted.

Table 3
Frequency and Severities of Occurred Claims and Proven Frauds

Year	Occurred Claims Severities (BRL)	Occurred Claims (Frequency)	Total Fraud Amount (BRL)	Total Fraud Frequency
2019	750,960,145.00	353,232	194,185,043.38	10,215

Source: own elaboration.

For this counterfactual exercise, it is assumed that the amounts of fraud identified and duly proven by Líder have already been subtracted from the amount provided to SUSEP. Thus, the fraud values observed in Table 3 refer to the sum of values proven by Líder and the values of proven fraud provided by the CNSeg report. With this, the Statistical Premium of DPVAT insurance was calculated in two different scenarios, with and without fraud. The results are shown in Table 4.

Table 4
Values and Quantities of Occurred Claims and Proven Frauds

Scenario with frauds			Scenario without frauds	
Number of Claims	353,232	→	Number of Claims*	343,017
Number of units exposed to risk	87,558,364			
Total Loss	750,960,145.00	→	Total Loss*	556,775,101.62
PE =	8.577		**PE*=**	6.359

Source: own elaboration.

Therefore, the results indicate that the fraud-free Statistical Premium would have a reduction of 25.9%. This order of magnitude is very close to the differential observed in the previous section between the credibility premiums (claims ratios) estimated for DPVAT and the other private insurance LOBs. One should always bear in mind that private insurance traded by individual companies has several mechanisms to detect and combat fraud. As practices adopted, one can mention the possibility of selecting and underwriting better risks, additional charge systems (discounts) for larger (smaller) risks, through the *bonus-malus* system and deductibles. None of this is available to Líder.

At last, one should highlight the evident efforts of Líder in the use of the best fraud identification and detection techniques. On its own official website, it informs that "(...) heavy investments were made in the modernization of systems, with the use of advanced database analysis technologies, integrated with artificial intelligence systems. Today, all requests for compensation of DPVAT Insurance receive continuous monitoring, being evaluated by artificial intelligence software, which contains tools for systemic filtering of suspicious occurrences, and risk control". However, even though the strategies were implemented in 2017, it is difficult to verify the real effectiveness of such measures, even in 2019. Especially given the portfolio size and the compensation requested, and the eligibility conditions maintenance and concession criteria.

5.4. Counterfactual Scenario 2: retrospective adjustments to premiums and claims

The main goal of this section is to estimate the total volume of resources that could be saved by society if the frauds could have been purged in the period between 2006 and 2020. To make the exercise viable, the new portfolio's claims ratio was calculated, proportionally to the estimated

reductions (25.9%). Thus, all time series values – half-yearly premiums and claims – were also adjusted, obtaining the new series (Figure 3).

Figure 3 highlights that a 25% reduction in the DPVAT claims ratio, due to the fraud elimination, would lead this LOB to present a performance absolutely similar to LOBs of the private insurance market: 64.9%. Figure 4 shows how the temporal path of both financial time series would have been (i.e., premiums and claims), according to the same reduction, always producing the claims ratio of 64.9%.

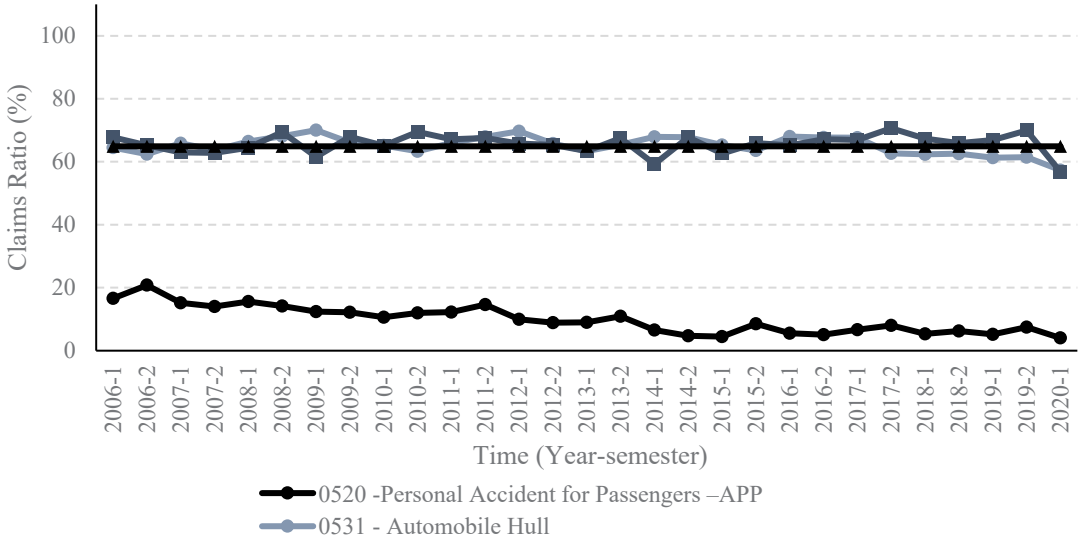

Figure 3. Evolution over time of the claims ratio of each LOB, by semester, with adjusted DPVAT claims (2006-2020)
Source: own elaboration.

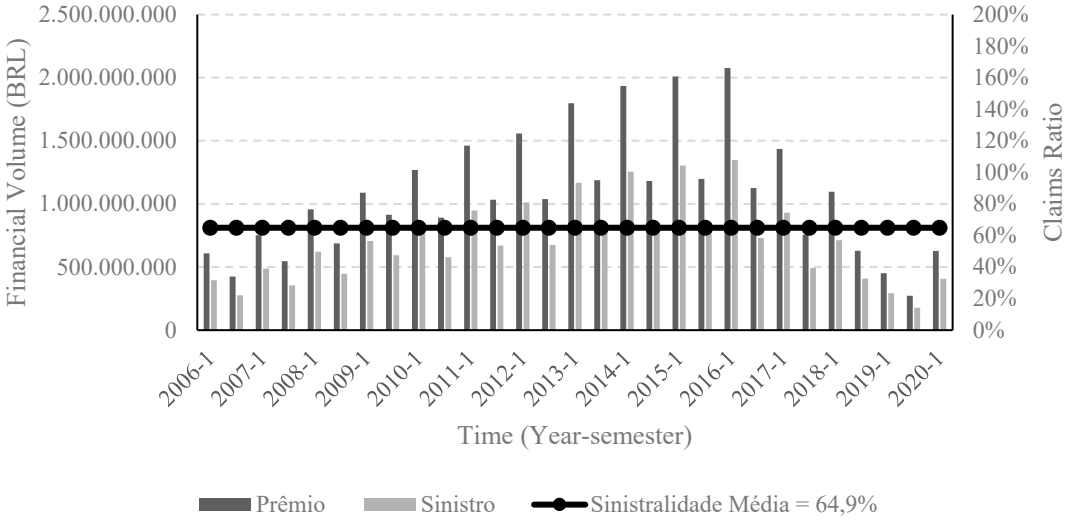

Figure 4. Evolution of the adjusted premium and claims volume over time, and the claims ratio for the DPVAT LOB (2006-2020)
Source: own elaboration.

Next, the new aggregate premium volume for each period from the first half of 2006 to the first half of 2020 was calculated. All values were brought to the present value of June/2020, using the *IPCA* (Consumer Price Index) as deflator. As an estimate, the total value of BRL 15,488,676,127.08 was obtained.

This value, over BRL 15 billion, could have been saved by society, from the reduction in premiums of the compulsory insurance under the hypothesis that the frauds had been purged. This would be the amount saved if the mechanisms to combat fraud had been effectively adopted by the Líder insurer, or, in other words, if the average claims ratio of the DPVAT had an similar pattern to that of analogous automobile LOBs in the private insurance market.

This amount is in no way insignificant, especially at a time when the country is facing a serious economic crisis after years of recession and mediocre growth. After having required the Pension Reform, approved in 2019, to mitigate successive public sector deficits, Brazil was faced with the need to grant emergency aid to the population as an economic stimulus in the context of the Covid-19 pandemic. To size the relevance of this order of magnitude, it is equal to half the federal government's total yearly expenditure[7] with the country's main social program, *Bolsa Família*, which was equal to BRL 30.36 billion and BRL 32.94 billion in 2018 and 2019, respectively.

6. FINAL REMARKS

This paper sought to analyze the social weight of undue payments of DPVAT caused by fraud, its impact on the claims ratio of the product and, consequently, on the premium value paid by the insured. The results showed statistical evidence to conclude that the portfolios are heterogeneous, in view of the discrepancy of the DPVAT claims rate in relation to analogous automobile LOBs of the private insurance market, using the Actuarial Credibility Theory through the Bühlmann-Straub model. The credibility premiums for Automobile Hull and Facultative Civil Liability for Vehicles were, respectively, 25.54% e 25.012% lower than DPVAT's credibility premium.

In the first counterfactual scenario, we proceeded with the estimation of what the DPVAT premium would be in a hypothetical scenario in which there would be no fraud, emulating the situation in which fraud could be controlled and monitored with the same effectiveness of the coverage offered by private insurers. The results indicate that the fraud-free actuarially fair premium would have a reduction of 25.9%. This order of magnitude is very close to the differential observed between the estimated credibility premiums for DPVAT and the other private insurance LOBs.

In the second counterfactual scenario, an estimate of the aggregate saving for society was obtained, in case fraud could be deducted from premiums, if the average DPVAT's claims ratio had a pattern similar to the analogous automobile LOB of the private insurance market. As a result, it was calculated a significant BRL 15 billion that would be available to society to allocate freely according to individual preferences. This shows the relevance and urgency of adopting mechanisms to combat and prevent fraud by the Líder insurance company.

Despite having achieved important results, this work has limitations. Among them, one can mention the lack of access to microdata from the insurers (including Líder), that forced the use of only the regulator's public database, which is aggregated and with claims recognized on a cash basis, not by accrual. The microdata would allow a greater analytical depth of the frauds that occur in automobile insurance, especially regarding the periodicity and recurrence, besides allowing the study of the motivations behind these frauds. It is suggested these aspects to be analyzed in future studies.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

AUTHOR'S CONTRIBUTION

1st author: data curation (equal); formal analysis (equal); investigation (equal); software (same); validation (equal); visualization (same); writing - original draft (same); writing - proofreading and editing (same). **2nd author:** conceptualization (leadership); data curation (equal); formal analysis (equal); investigation (equal); methodology (same); project management (leadership); software (same); supervision (leadership); validation (equal); visualization (same); writing - original draft (same); writing - proofreading and editing (same).