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Asymmetric information in automobile insurance: Evidence from driving behavior

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No. 543

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Asymmetric Information in Automobile Insurance: Evidence from Driving Behavior*

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Based on a unique data set of driving behavior we find direct evidence that private information has significant effects on contract choice and risk in automobile insurance. The number of car rides and the relative distance driven on weekends are significant risk factors. While the number of car rides and average speeding are negatively related to the level of liability coverage, the number of car rides and the relative distance driven at night are positively related to the level of first-party coverage. These results indicate multiple and counteracting effects of private information based on risk preferences and driving behavior.

1 Introduction

This paper provides new insights into the relevance of private information in insurance markets based on a telematic data set of insured cars which is inaccessible to the insurance company.¹ The data set contains detailed information about driving behavior, e.g., speed, distance driven, road type, and is recorded approximately every two kilometers (1.24 miles) by a telematic device which is installed in the insured car. While the insurance company uses the aggregate distance driven for the premium calculation, it refrains from accessing any other telematic data.² In addition, we also have access to the corresponding insurance data set which includes all variables used for pricing, policyholders' contract choice (third-party liability and first-party coverage), and information about the submission of liability claims. We link this insurance data set to the telematic data set on the car level. The combination of insurance and telematic data and the fact that most information contained in the telematic data is unobserved by the insurance company allows us to directly test whether private information about driving behavior is relevant for and how it is linked to the policyholder's choice of insurance contract and the conditional loss distribution.

Controlling for the risk classification of the insurance company, we find the following aspects of driving behavior to be significantly linked to contract choice and/or a subsequent downgrade of the Bonus-Malus class:³ average speeding, the number of car rides a policyholder undertakes, and the relative distance driven on weekends and at night. The number of car rides (controlling for the distance driven) and the relative distance driven on weekends are positively related to a subsequent downgrade of the Bonus-Malus class. The effect of the number of car rides is also economically significant. By increasing the number of car rides from an average of two to four per day while adjusting for the average distance driven per car ride the predicted probability of a subsequent downgrade of the Bonus-Malus class increases from 5.58% to 10.44%.⁴ Regarding the link between driving behavior and contract choice, we find that the number of car rides and average speeding are both negatively related to the

¹*Telematics* stands for the fusion of *telecommunication* and *informatics*. It is typically based on a GPS device which allows for the transmission of information about moving objects, e.g., as used in navigation systems.

²The production and installation of the hardware into the cars as well as the collection and management of the telematic data is carried out by an independent telematic company.

³Premiums for third-party liability insurance are based on an experience rating system. A downgrade of the Bonus-Malus class is triggered by the submission of at least one liability claim during one year and results in a higher premium for the following year. We use such a downgrade in the year following the beginning of our telematic data as a proxy for risk.

⁴The mean number of car rides per day in our data sample is 2.73 with a mean probability of a subsequent downgrade of the Bonus-Malus class of 7.09%. If we do not adjust for the average distance driven per car ride by keeping the mean total distance constant, the increase in the predicted probability is still significant from 5.95% with two car rides a day to 9.48% with four car rides a day.

level of third-party liability coverage. In contrast, the number of car rides and the relative distance driven at night are positively related to the level of first-party insurance coverage. Our results suggest multiple and counteracting effects of private information based on risk preferences and driving behavior. The negative relation of the number of car rides and of average speeding to the level of liability coverage indicate a selection and incentive effect based on hidden risk preferences. More risk-averse or less overconfident policyholders both purchase more liability coverage and use their car and drive more considerate by undertaking fewer short car rides and speeding on average less. The positive relation of the number of car rides to the level of first-party coverage and to a subsequent downgrade of the Bonus-Malus class suggest a selection and/or incentive effect based on driving behavior. Policyholders who undertake more short car rides purchase more first-party insurance coverage and are more likely to be subsequently downgraded in their Bonus-Malus class.

Most of the empirical literature on asymmetric information in insurance markets analyzes insurance data alone and tests for the sign of the correlation between the level of insurance coverage and ex post realizations of risk controlling for the risk classification of the insurance company. The classical models both of adverse selection and moral hazard (Arrow, 1963; Pauly, 1974; Rothschild and Stiglitz, 1976; Harris and Raviv, 1978; Holmstrom, 1979; Shavell, 1979) are based on one-dimensional private information and predict a positive correlation. This prediction has been confirmed in the health insurance market (Cutler and Reber, 1998; Cutler and Zeckhauser, 1998) and in the annuity market (Finkelstein and Poterba, 2004, 2014; McCarthy and Mitchell, 2010). However, there is also evidence for a negative correlation between the level of insurance coverage and claims probability in the markets for life insurance (Cawley and Philipson, 1999; McCarthy and Mitchell, 2010) and for Medigap insurance (Fang et al., 2008). Moreover, no statistically significant correlation has been found in automobile insurance (Chiappori and Salanié, 2000; Dionne et al., 2001; Cohen, 2005) and in long-term care insurance (Finkelstein and McGarry, 2006).⁵ We refer to Cohen and Siegelmann (2010) for a review of the empirical literature on asymmetric information in insurance markets.

The existence of counteracting effects of private information poses a challenge for empirical tests based on the residual correlation between the level of insurance coverage and ex post realizations of risk. Failing to reject the null hypothesis of zero residual correlation could either indicate the absence of relevant private information or the presence of multiple, coun-

⁵Puelz and Snow (1994) did find a positive relation between coverage and risk. Their result, however, was subsequently challenged by Chiappori and Salanié, 2000, and Dionne et al., 2001. While Cohen (2005) did not find any correlation for beginning drivers, she did find a statistically significant positive relation for experienced drivers.

teracting effects of private information that cancel each other out with respect to the residual correlation. We also test for the residual correlation based only on our insurance data and fail to reject the null hypothesis of zero residual correlation between the level of first-party insurance coverage and a subsequent downgrade of the Bonus-Malus class. Given our direct empirical evidence that private information does matter, this shows that the absence of residual correlation between the level of insurance coverage and ex post realizations of risk is not sufficient to conclude that private information is absent or irrelevant. In addition, we find a statistically significant positive residual correlation between the level of liability coverage and a subsequent downgrade of the Bonus-Malus class. This points to adverse selection and/or incentive effects which are opposite to the preference-based selection effect in liability coverage discussed above. These joint findings support our interpretation of multiple and counteracting effects of private information about driving behavior and risk preferences.

Our result of offsetting effects of asymmetric information based on risk preferences and driving behavior is consistent with the literature that examines the effect of hidden risk preferences. Chiappori et al. (2006) examine the extent to which models of adverse selection and moral hazard can be generalized while still predicting a positive correlation between chosen level of insurance coverage and the expected value of indemnity.⁶ They emphasize that hidden degree of risk aversion can be pivotal for violating the prediction of positive correlation. de Meza and Webb (2001) show that a separating equilibrium with a negative relation between coverage and accident probability can exist if hidden information about the degree of risk aversion is combined with hidden investment in risk reduction, and if insurance contracts entail administrative costs. Finkelstein and Poterba (2014) also argue that if asymmetric information is present on multiple characteristics, including the degree of risk aversion, then the result of rejecting (not rejecting) the hypothesis of non-dependence between the level of insurance coverage and risk may not be indicative of the existence (absence) of asymmetric information. Cohen and Einav (2007) develop a structural model which accounts for unobserved heterogeneity in both risk and risk aversion. By using a large data set of an Israeli insurance company, they find that unobserved heterogeneity in risk aversion is much larger than unobserved heterogeneity in risk. Sandroni and Squintani (2013) study an equilibrium model with overconfident policyholders and find that unobservable overconfidence can explain the negative relationship between the level of insurance coverage and ex-post realizations in a competitive market.

Our paper is most closely related to the recent literature that tests for the effects of mul-

⁶If there are multiple loss levels, Koufopoulos (2007) shows that the positive correlation property between the level of insurance coverage and *accident probability* (as opposed to the expected value of indemnity) may not hold.

tidimensional private information in insurance markets. Finkelstein and McGarry (2006) use individual-level survey data on long-term care insurance and show that individuals' self-reported beliefs of entering a nursing home is positively related to both subsequent nursing home use and insurance coverage. Despite the existence of this risk-based selection, actual nursing home use and insurance coverage is not positively correlated. The authors explain this fact by providing evidence that the risk-based selection is offset by a selection based on heterogeneous degrees of risk aversion as proxied by seat belt usage and investment in preventive health care measures. Fang et al. (2008) also use individual-level survey data on Medigap insurance to examine the reasons for the significant negative correlation between insurance coverage and medical expenditure. They show that cognitive ability rather than risk preferences is the essential factor explaining this negative relation.

We contribute to this literature by analyzing a unique data set that is provided by an independent and unbiased third party, the telematic company. The data contains detailed information about real decisions and behavior of individuals that is of direct interest to but unobserved by the insurance company.⁷ In addition, the level of detail of the telematic data allows us to analyze multiple aspects of driving behavior and test for their relations to contract choice and risk.

Finkelstein and Poterba (2014) propose an empirical test based on “unused observables,” i.e. on characteristics which are observed by the insurance company but are not used for pricing, either voluntarily or for legal reasons. They argue that if those characteristics are significantly related to contract choice and risk, then this is direct evidence of relevant private information which is not confounded by hidden information on risk preferences. In their study of the UK annuity market, they use postcode information which is collected by the insurance company but not used for pricing. They find that the inhabitants' socio-economic characteristics of different postcode areas are correlated with both survival probability and choice of insurance coverage. Similarly, Saito (2006) uses postcode information which is collected but not used by insurance companies for pricing in automobile insurance. The author rejects the hypothesis that policyholders who live in high accident probability regions are more likely to purchase insurance. Unused but observed data, although not used in pricing, might be used in other types of underwriting activities by the insurance company. For example, policyholders who observably differ in their underlying risk might be offered different contracts, might be scrutinized differently in the claims settlement process, or might face different renewal or cancellation policies. In that case, a significant relation between the

⁷Responses to survey questions can be biased, in particular if they relate to self-reported probabilities of future events. Examples include the anchoring bias of unfolding bracket questions (Hurd et al., 1998; Hurd, 1999) and problems of focal responses (Gan et al., 2005).

“unused observable” and contract choice might reflect those different underwriting policies. The telematic data set provides us with information which is *unobserved* by the insurance company. Thus, the insurance company is not able to condition any type of underwriting or cancellation activity on that information.

Last, our setting further benefits from the fact that liability insurance is mandatory and policyholders who are rejected by insurers are distributed evenly among all insurance companies in the market. This is particularly important as Hendren (2013) finds more private information held by individuals who are rejected by insurance companies compared to non-rejectees. This can explain the lack of significant results of previous literature on the existence of private information in insurance markets.

The paper is structured as follows. Section 2 provides detailed information about the insurance contract based on distance driven and about the telematic and insurance data sets. In Section 3, we introduce the indices for driving behavior and specify the econometric model. We present and discuss our results in Section 4, perform robustness checks in Section 5, and conclude in Section 6.

2 Background and Data

The insurance company offers a pay-as-you-drive insurance contract in addition to its existing car insurance contract. Cars insured under this contract are equipped with a telematic device which uses GPS. The pricing of this pay-as-you-drive contract is based on the aggregate distance driven - fewer kilometers driven imply a lower premium - and on the road type used.⁸ The company distinguishes between three road types: urban, country road, and motorway. Kilometers driven on country roads and motorways are scaled down by a factor of 0.8. Furthermore, policyholders get a 5% discount on the premium of full comprehensive insurance coverage. In addition to the pay-as-you-drive feature, the telematic device is equipped with an emergency device and a crash sensor. If activated, either by the car driver or in case of an accident, an emergency signal is sent to the helpdesk of the insurance company. The helpdesk will then try to contact the policyholder and call emergency services if needed or if the policyholder cannot be reached. An additional benefit of the telematic device is that stolen cars can be tracked via GPS. Policyholders have to pay a one-time fee for the installation of the telematic device and a monthly fee for the safety services.

⁸For a total distance of up to 4,000 km (2,485 miles) per year the premium for liability and comprehensive insurance is reduced by 25%, between 4,000 km (2,485 miles) and 6,000 km (3,728 miles) by 20%, between 6,000 km (3,728 miles) and 8,000 km (4,971 miles) by 15% and between 8,000 km (4,971 miles) and 10,000 km (6,214 miles) by 10%.

Since policyholders can choose this pay-as-you-drive contract, the characteristics of policyholders under this contract might differ from those that decided not to choose this contract. Based on a random sample of policyholders who did not to opt for this contract, we show in Section 4 that the pay-as-you-drive contract is more likely to be chosen by younger, female policyholders living in urban areas who drive more valuable cars with higher engine power. Our results thus apply to the population that selected this contract.

The economic rationale for pay-as-you-drive insurance contracts is the internalization of accident and congestion externalities. Edlin and Karaca-Mandic (2006) estimate that the externality cost due to an additional driver in California is around \$1,725 – \$3,239 per year. Vickrey (1968) proposed the idea of *distance-based pricing* as a solution to the externality problem. However, insurance companies have only recently started to offer such contracts. In the U.S., the insurance companies Progressive, Allstate, and State Farm recently started to offer pay-as-you-drive insurance contracts for privately owned cars. Liberty Mutual offers pay-how-you-drive insurance contracts for fleets. Edlin (2003) argues that monitoring costs for mileage-based pricing might be too high and suggests that regulatory enforcement could be necessary since private gains might be much smaller than social gains. Bordoff and Noel (2008) estimate that a US nationwide implementation of pay-as-you-drive insurance would result in a 8% reduction of mileage driven which would yield a social benefit of \$50 billion per year, a reduction of carbon dioxide emission by 2%, and a reduction of oil consumption by 4%. They also estimate that two thirds of all households would pay a lower premium under pay-as-you-drive insurance with an average saving of \$270 per car per year. Parry (2005) shows that the welfare gains of implementing pay-as-you-drive insurance in reducing driving-related externalities are much larger compared to the welfare gains obtained by increasing gasoline tax.

Due to the safety features of telematic devices, the European Commission has passed a recommendation supporting the EU-wide implementation of a telematic based emergency call (eCall) service for the transmission of in-vehicle emergency calls (European Commission, 2011). This service is required to be fully implemented in new cars by 2018. In response, several automobile manufacturers such as BMW, Ford, GM, Peugeot, and Volvo have already begun to equip their cars with telematic units and to offer various services to their customers, e.g., automatic crash response and stolen vehicle tracking.

2.1 Telematic Data

An independent telematic company develops the hardware and collects and manages the telematic data. Each data point includes date, time, GPS-coordinates, direction of driving,

current speed, distance driven since the last data point, ignition status of the engine, and road type (urban, country road, or motorway). A data point is recorded when the engine is started, after approximately every two kilometers (1.24 miles) driven, and when the engine is switched off. Our data set covers 2,340 cars for a period of 3 months, from February 1st, 2009, to April 30th, 2009, comprising 3.7 million individual data points.⁹

We restrict the data set to car rides where a definitive start and end was recorded. Moreover, we exclude car rides with unrealistically high values of speed (above 200 km/h = 124.27 mph which is above the 99.9% quantile of the empirical distribution) and of distances between data points (above the 99.9% quantile). The excluded car rides are likely to be caused by a connection failure with the GPS satellite.¹⁰ These exclusions leave us with 3.15 million data points. Table 1 displays the summary statistics of the telematic data. The average speed driven on urban roads is 47.72 km/h (29.65 mph) which is close to the countrywide legal speed limit of 50 km/h (31.07 mph). The average speed driven on country roads (73.87 km/h = 45.9 mph) and motorways (113.22 km/h = 70.35 mph) is well below the countrywide legal speed limits of 100 km/h (62.14 mph) and 130 km/h (80.78 mph), respectively. The average total distance driven by each policyholder within the three months period is 2,061 km (1,281 miles), which relates to a yearly average of 8,212 km (5103 miles). Based on data of the local automobile club, the nationwide average yearly distance driven per driver is 13,140 km (8,165 miles). Policyholders of the telematic insurance contract drive less than the nationwide average, which suggests selection due to the pricing of the contract.¹¹

⁹Those are all the pay-as-you-drive contracts the insurer had in his portfolio on February 1st, 2009.

¹⁰Most of those excluded car rides reveal further unrealistic characteristics such as speed above 200 km/h (124 mph) at the time the engine is switched on or off, or at the only data point in between, or in urban areas.

¹¹We discuss a potential selection bias in Section 5.2.

Table: 1: SUMMARY STATISTICS TELEMATIC DATA

	road type			total
	urban	country	motorway	
number of cars				2,340
number of car rides				537,181
number of data points	1,717,049	686,042	744,542	3,147,633
avg. speed in km/h	47.72	73.87	113.22	78.03
(mph)	(29.65)	(45.90)	(70.35)	(48.49)
Q10 speed in km/h	24	46	80	34
(mph)	(15)	(29)	(50)	(21)
Q25 speed in km/h	36	60	96	50
(mph)	(22)	(37)	(60)	(31)
Q50 speed in km/h	48	74	116	74
(mph)	(30)	(46)	(72)	(46)
Q75 speed in km/h	58	88	132	106
(mph)	(36)	(55)	(82)	(66)
Q90 speed in km/h	72	102	142	130
(mph)	(45)	(63)	(88)	(81)
std. dev. speed in km/h	18.99	22.56	24.00	35.67
(mph)	(11.79)	(14.01)	(14.91)	(22.16)
distance driven in km	2,041,466	1,195,018	1,567,140	4,803,624
(miles)	(1,268,508)	(742,550)	(973,776)	(2,984,834)
avg. distance/ride in km				8.94
(miles)				(5.56)
avg. distance/car in km	876	523	798	2,061
(miles)	(544)	(325)	(496)	(1,281)
Q10 distance/car in km	115	32	34	2,061
(miles)	(71)	(20)	(21)	(1,281)
Q25 distance/car in km	311	107	130	2,061
(miles)	(193)	(66)	(81)	(1,281)
Q50 distance/car in km	702	294	392	1,475
(miles)	(436)	(183)	(244)	(917)
Q75 distance/car in km	1,273	672	1,019	2,842
(miles)	(791)	(418)	(633)	(1,766)
Q90 distance/car in km	1,856	1,363	2,046	4,493
(miles)	(1,153)	(847)	(1,271)	(2,792)

Table 1 shows the summary statistics of the telematic data for the whole data set and for each of the three road types. The 10%, 25%, 50%, 75% and 90% quantiles are labeled Q10, Q25, Q50, Q75 and Q90, respectively.

The insurance company has access only to the telematic data that is necessary for the pricing of the pay-as-you-drive contract, i.e., to the aggregate distance driven per road type. The

insurer contractually refrains from accessing any other telematic data because of privacy concerns. The telematic data set thus provides us with detailed private information about driving behavior which is inaccessible to the insurance company. This setting allows us to directly test whether private information as reflected in driving behavior is relevant for the level of insurance coverage and risk.

2.2 Insurance Data

For all privately owned cars in the telematic data set the corresponding insurance contract data is linked on the car level via an anonymous identification number. We thus exclude all corporate cars from the data set. The insurance data comprises all the information used for pricing of the policies in February 2009. An update of the insurance data set for February 2010 is used to extract information about the submission of a liability claim during that year. We therefore restrict the telematic data set to those cars which are still insured under the pay-as-you-drive contract after one year. Last, only cars with more than 4 kW (5.4 HP) were included.¹² This leaves us with 1,849 insurance contracts for our analysis.

For each contract, the insurance data contains the following information:

- *Car-related information:* age, brand, engine power, and catalog price of the car at initial registration
- *Policyholder-related information:* age, gender, and postcode¹³
- *Bonus-Malus class:* Premiums for third-party liability insurance are based on an experience-rating scheme. There are 19 Bonus-Malus classes which reflect the car owner's history of claims. Each Bonus-Malus class is related to a scaling factor of a base premium ranging from 44% (lowest class) to 170% (highest class). A car owner with no driving experience starts with 110% of the base premium. If a policyholder does not file a liability claim during a year, then he is upgraded one class (*Bonus*) and pays the next lowest percentage of the base premium in the following year. If a policyholder files a liability claim during the year, then he is downgraded three classes (*Malus*) and pays the corresponding higher percentage in the following year.¹⁴

¹²All cars with 4 kW (5.4 HP) or less are micro-cars which are license-exempt vehicles with a maximum speed of 45 km/h (28 mph). The driving behavior of a micro-car is closer to the driving behavior of a moped than to that of a car.

¹³The policyholder is not necessarily the primary driver of the car since the insurance contract covers every person that drives the car with the approval of the policyholder.

¹⁴The national insurance association monitors the Bonus-Malus record for each nationwide registered car owner which is accessible to all insurance companies.

- *Downgrade of Bonus-Malus class:* We use downgrades of the Bonus-Malus record between February 2009 and February 2010 to proxy for risk.
- *Coverage of third-party liability insurance:* The insurance company offers two levels of third-party liability coverage which are both in excess of the level mandated by the insurance law: € 10 million and € 15 million.
- *Coverage of first-party insurance:* The insurance company offers three levels of first-party coverage: none, comprehensive insurance (covers losses from vandalism, theft, weather etc.), and full comprehensive insurance (in addition including at-fault collision losses).¹⁵

Table 2 provides the summary statistics of the insurance data set. Full comprehensive and high liability coverage is on average bought by older policyholders and for more recently built and more valuable cars with a stronger engine. Moreover, customers of full comprehensive and high liability coverage experience on average fewer downgrades of the Bonus-Malus class.

3 Empirical Approach

3.1 Driving Behavior

We examine four characteristics of individual driving behavior utilizing the information contained in our telematic data set: average speeding above legal speed limits, the number of car rides, the relative distance driven on weekends, and the relative distance driven at night.

The speeding index is given by

$$AvgSpeeding = \frac{\sum_j \sum_{i \in \Delta_n} (v_{ij} - u_j)}{n} \quad (1)$$

where j is the road type (urban, country, motorway), u_j is the countrywide legal speed limit for road type j in km/h (urban: 50 km/h = 31.07 mph, country: 100 km/h = 62.14 mph, motorways: 130 km/h = 80.78 mph), $i = 1, \dots, n$ is a data point, v_{ij} is the speed of the car at data point i on road type j , and $\Delta_n = \{i = 1, \dots, n | v_{ij} > u_j\}$ is the set of data points at which the speed of the car is above the legal speed limit.¹⁶

¹⁵We do not use information on deductible choice since the standard deductible of € 300 is chosen by more than 99% of all policyholders.

¹⁶The countrywide legal speed limits are the maximum speed limits. The actual legal speed limit can be lower either permanently, e.g., in residential areas or road sections prone to accidents, or temporarily, e.g., due to road works or construction sites. We thus might underestimate the extent to which drivers speed by using the countrywide legal speed limits for each road type.

Table 2: SUMMARY STATISTICS INSURANCE DATA

	Mean				
	total	none / compr.	full compr.	liab. 10m	liab. 15m
car's characteristics:					
age in years	3.47	6.74	1.92	3.68	2.99
engine power in kW (HP)	87.09 (116.74)	83.52 (111.96)	88.78 (119.01)	86.57 (116.05)	88.3 (118.36)
value in €	26,709	26,204	27,023	26,656	26,835
policyholder's characteristics:					
age in years	48.67	48.16	48.91	48.13	49.91
male	0.61	0.61	0.61	0.61	0.62
urban	0.44	0.42	0.45	0.45	0.42
Bonus-Malus class	0.52	0.55	0.51	0.52	0.51
downgrade BM class in %	7.6	9.7	6.6	7.9	7.0
N	1,849	595	1,254	1,293	556

Table 2 presents the average of all the variables in the insurance data set. Column 2 “total” includes all contracts, column 3 “none/compr.” includes contracts with comprehensive coverage or no first-party insurance coverage. Column 4 “full compr.” includes contracts with full comprehensive coverage. Column 5 “liab. 10m” includes all third-party liability insurance contracts covering up to €10 million, column 6 “liab. 15m” includes contracts covering up to €15 million. The variable “urban” is set to 1 if the policyholder lives in a municipality with more than 40,000 inhabitants and 0 otherwise. Bonus-Malus class gives the scaling factor for the base premium of liability coverage.

The second index $\#Rides$ is the number of car rides driven between February 1st, 2009 and April 30th, 2009. We define a car drive if the engine is switched on, a distance is driven, and the engine is switched off.

For the other two indices, we derive the distance driven on weekends and at night relative to the total distance driven per policyholder, $DistWE/Dist$ and $DistNight/Dist$. For the distance driven on weekends, we use all data points recorded between Saturday 0:00 am and Sunday midnight. For the distance driven at night, we use all data points recorded between sunset and sunrise, using the monthly average as a proxy for both.

We derive all four indices for each car in our data set. The summary statistics for the indices are given in Table 3. Average speeding and the number of car rides are on average higher for full comprehensive and low liability coverage. The number of car rides is on average higher and the distance driven at night is on average lower for policyholders who were downgraded in their Bonus-Malus class. Table 4 shows the quantiles of each of the four indices.

Table 3: SUMMARY STATISTICS INDICES

	first-party cov.		liability cov.		ΔBM class		
	total	0	1	0	1	0	1
mean AvgSpeeding	3.15	3.05	3.19	3.2	3.02	3.15	3.16
mean #Rides	243	217	255	246	236	238	293
mean DistWE/Dist	0.268	0.286	0.26	0.268	0.269	0.266	0.288
mean DistNight/Dist	0.083	0.083	0.083	0.084	0.081	0.085	0.062
N	1,849	595	1,254	1,293	556	1,708	141

Table 3 shows the mean of the four indices for all contracts, a split to the coverage choices and for contracts with and without a downgrade in Bonus-Malus class. First-party coverage (first-party cov.) is 1 for full comprehensive insurance and 0 otherwise. Third-party liability insurance (liability cov.) is set to 0, if €10m are covered and is 1, if coverage is €15m. ΔBM class is set to 1, if the policyholder's Bonus-Malus class was downgraded during the subsequent year and 0 otherwise.

Table 4: QUANTILES OF INDICES

	Q10	Q25	Q50	Q75	Q90
AvgSpeeding	1.06	1.73	2.73	4.02	5.84
#Rides	54	109	212	336	462
DistWE/Dist	0.093	0.165	0.249	0.343	0.458
DistNight/Dist	0	0.014	0.052	0.123	0.214

Table 4 shows the 10% (Q10), 25% (Q25), 50% (Q50), 75% (Q75) and 90% (Q90) quantiles of the four indices for all contracts.

3.2 Econometric Model

We test for the direct effect of private information on contract choice and risk by extending the econometric model suggested by Finkelstein and Poterba (2014). Their model is based on Chiappori and Salanié (2000) who propose the following bivariate probit model for insurance coverage and risk

$$Coverage = 1(X\beta + \varepsilon_1 > 0) \quad (2)$$

$$Risk = 1(X\gamma + \varepsilon_2 > 0) \quad (3)$$

where X is the vector of all risk classifying variables used by the insurance company. They test the null hypothesis that the correlation ρ of the error terms ε_1 and ε_2 is zero and interpret rejecting the null hypothesis as an indication for the existence of private information. A statistically significant, positive correlation coefficient is consistent with the classical models of adverse selection and moral hazard with asymmetric information about one parameter

of the loss distribution (Arrow, 1963; Pauly, 1974; Rothschild and Stiglitz, 1976; Harris and Raviv, 1978; Holmstrom, 1979; Shavell, 1979). Chiappori et al. (2006) show that this prediction can be extended to general settings, including, for example, heterogeneous preferences and multidimensional hidden information linked with hidden action. However, they point out that the prediction about the positive relation between the level of insurance coverage and risk might no longer hold if the degree of risk aversion is private information.

Finkelstein and Poterba (2014) propose the following extension of Chiappori and Salanié (2000)

$$Coverage = 1(X\beta_1 + Y\beta_2 + \varepsilon_1 > 0) \quad (4)$$

$$Risk = 1(X\gamma_1 + Y\gamma_2 + \varepsilon_2 > 0) \quad (5)$$

where Y includes information which is observed but not used by the insurance company. Under the null hypothesis that there is no private information contained in Y that is relevant for contract choice and risk, we have $\beta_2 = 0$ and $\gamma_2 = 0$. The benefit of this model extension is that the rejection of the null hypothesis directly provides evidence of relevant private information independent of the type of asymmetric information. This model is appropriate in our context as the information Y is not observed by the insurance company but accessible to the econometrician.

Unlike in Chiappori and Salanié (2000) and Finkelstein and Poterba (2014), policyholders in our data set simultaneously choose the level of coverage along two dimensions, first-party and third-party liability coverage. To take into account potential interaction between these two choices, we apply a trivariate probit model. This model consists of three probit regressions based on the Geweke-Hajivassiliou-Keane (GHK) smooth recursive simulator. Interpretation of the results of this trivariate probit model is analogous to the interpretation of the bivariate probit model. We define the dependent variables of the three probit equations as follows. For liability coverage, we set $CovLiab = 1$ if the upper limit is € 15m and $CovLiab = 0$ if the upper limit is € 10m. For first-party coverage, we set $CovFP = 1$ if the contract covers at-fault losses (full comprehensive insurance) and $CovFP = 0$ otherwise. The dependent variable ΔBM is set to 1 if the policyholder was downgraded in his Bonus-Malus class within the subsequent year and is set to 0 otherwise.

X comprises the set of variables which the insurance company uses for the pricing of the contract (see Section 2.2). We also include the aggregate distance driven by the policyholder since this is the part of the telematic data which the insurance company observes and uses for setting the premium. In addition, we control for the interaction between engine power

(kW) and the value of the car and for the interaction between the number of car rides and the total distance driven. The latter term controls for the effects of different driving patterns on coverage choice and change in Bonus-Malus class. For example, an urban driver typically drives more frequently but shorter distances. The interaction term also controls for driving experience as a policyholder who drives a lot of long distance car rides has more driving experience.

Y is the set of the four indices $AvgSpeeding$, $\#Rides$, $DistWE/Dist$, and $DistNight/Dist$ that characterize driving behavior and are constructed from the telematic data set (see Section 3.1). This information is not observed by the insurance company.

We thus apply the following trivariate probit model

$$CovLiab = 1(X\beta_1 + Y\beta_2 + \varepsilon_1 > 0) \quad (6)$$

$$CovFP = 1(X\gamma_1 + Y\gamma_2 + \varepsilon_2 > 0) \quad (7)$$

$$\Delta BM = 1(X\delta_1 + Y\delta_2 + \varepsilon_3 > 0) \quad (8)$$

with

$$Y = (AvgSpeeding, \#Rides, DistWE/Dist, DistNight/Dist)$$

and test the null hypothesis that there is no private information contained in Y that is relevant for contract choice and risk, i.e. we test for $\beta_2 = 0$, $\gamma_2 = 0$ and/or $\delta_2 = 0$.

We then compare the direct evidence about the relevance of private information with the results obtained from the residual correlation test. In particular, we apply the model of Chiappori and Salanié (2000) by testing for the sign of the correlation coefficients $\rho_{Liab,FP}$, $\rho_{Liab,\Delta BM}$ and $\rho_{FP,\Delta BM}$ of each pair of residual error terms ε_1 , ε_2 and ε_3 both excluding and including the set of variables $Y = (AvgSpeeding, \#Rides, DistWE/Dist, DistNight/Dist)$. Comparing the results allows us to assess whether the conclusions that would have been drawn from the results of the residual correlation test are consistent with the direct evidence. Moreover, any differences in the results indicate additional hidden information.

4 Results and Discussion

Table 5 reports the results of the trivariate probit model, Equations (6), (7), and (8).

Table 5: COEFFICIENTS OF TRIVARIATE PROBIT MODEL

	<i>CovLiab</i>	<i>CovFP</i>	ΔBM
<i>AvgSpeeding</i>	-0.0111* (0.0059)	0.003 (0.0069)	0.0026 (0.0031)
<i>#Rides</i>	-0.0002* (0.0001)	0.0003** (0.0001)	0.0002*** (0.0001)
<i>DistWE/Dist</i>	0.0307 (0.0951)	-0.1335 (0.1119)	0.0934* (0.0495)
<i>DistNight/Dist</i>	0.1295 (0.1365)	0.3345** (0.1673)	-0.0463 (0.0802)
<i>#Rides*distance driven</i>	4.62e-11 (2.72e-11)	-8.02e-11*** (3.39e-11)	-2.78e-11** (1.50e-11)
kW	0.0015** (0.0008)	-0.0005 (0.0009)	0.0003 (0.0005)
age of car	-0.0116*** (0.0031)	-0.1003*** (0.0049)	0.0073*** (0.0014)
value of car	1.41e-06 (2.23e-06)	-1.04e-06 (2.69e-06)	-2.75e-07 (1.34e-06)
urban	-0.0509** (0.0224)	0.0733** (0.0266)	0.0231** (0.0126)
male	-0.0053 (0.0236)	0.178 (0.0281)	-0.0016 (0.0123)
Bonus-Malus class	-0.0342 (0.0766)	-0.3012*** (0.0884)	0.043* (0.0384)
age of policyholder	0.0014* (0.0008)	-0.0003 (0.001)	0.0005 (0.0004)
total distance driven	-2.23e-08 (2.08e-08)	7.49e-08*** (2.67e-08)	1.82e-08 (1.08e-08)
kW*value of car	-1.91e-08* (1.02e-08)	1.77e-08 (1.26e-08)	-3.89e-09 (6.87e-09)
Pseudo- R^2	0.0160	0.3532	0.0508
N	1,849	1,849	1,849

Table 5 reports the results for each of the three equations of the trivariate model. Coefficients are marginal effects. Heteroscedastic robust standard errors are stated in parentheses. Significance levels are labeled ***, ** and * at 1%, 5% and 10%, respectively.

The coefficients of the four driving indices *AvgSpeeding*, *#Rides*, *DistWE/Dist* and *DistNight/Dist* are reported in the first four rows for each of the three probit regressions. In the remaining rows, we report the coefficients of the insurance company's risk classifying variables, the Pseudo- R^2 , and the number of observations. The first column reports the coefficients of

the liability coverage equation (6), the second column of the first-party coverage equation (7), and the third column of the downgrade of the Bonus-Malus class equation (8). For interpreting the coefficients we only report marginal effects, which we derive from separately estimating the trivariate probit model. Both signs and statistical significances of coefficients are identical when estimating the trivariate probit model simultaneously. In our following discussion we focus on the effects of private information contained in the four driving indices.

The results in the third column show that the number of car rides is a highly statistically significant risk factor, controlling for the distance driven and the interacting effect with distance driven. An additional car ride in the 3 month observation period is related to a 0.02% increase in the probability of a subsequent downgrade of the Bonus-Malus class. To illustrate the economic significance of this effect, we derive predicted probabilities of a subsequent downgrade of the Bonus-Malus class for different numbers of car rides. We take the estimated coefficients of our trivariate probit model and set all variables to the mean of their empirical distribution. We then vary the number of car rides and derive the associated probabilities of a subsequent downgrade of the Bonus-Malus class from Equation (8).

Table 6 reports the predicted probabilities for the lower quartile, the mean, and the upper quartile of the empirical distribution of the number of car rides per day. We also report the predicted probabilities for two car rides per day, e.g.. driving to work, and four car rides a day, e.g.. driving to work and separately to a supermarket. The third column shows the predicted probabilities when adjusting the total distance driven for the average distance driven per car ride. The differences in the predicted probabilities can be interpreted as arising from additional car rides. The fourth column shows the predicted probabilities when keeping the total distance driven at the mean. These differences can be related to stopovers of car rides, e.g., stopping at the supermarket on the way home from work. The differences in the predicted probabilities are economically significant. When adjusting for the average distance driven per car ride, undertaking four as opposed to two car rides per day almost doubles the predicted probability from 5.58% to 10.44%. Even when keeping the total distance driven at the mean, the increase of the predicted probability from 5.95% to 9.48% is economically significant.

We note that any differences between urban and rural driving are controlled for by urban living and by the interaction term between the number of car rides and distance driven. A possible explanation for this risk factor is that the start and the end of a car ride are particularly exposed to accident risk since the driver has to fulfill multiple tasks such as pulling out the car into the passing traffic, switching on the radio or the navigation system, adjusting the driving mirrors and seat, or parking the car which involves slowing down,

Table 6: IMPACT OF #RIDES ON ΔBM

#Rides/day	quantile	predicted probability of ΔBM	
		mean total distance driven	adj. for distance driven/ride
1.22	25%	4.90%	4.27%
2	42.5%	5.95%	5.58%
2.73	50%	7.09%	7.09%
3.78	75%	9.02%	9.78%
4	78.3%	9.48%	10.44%

Column 3 shows the predicted probabilities of a change in Bonus-Malus class using the estimated coefficients of the trivariate model and setting all variables to the mean of their empirical distribution. Column 4 reports the predicted probability when adjusting the total distance driven for the average distance per car ride.

potentially looking for a parking spot, and reversing into it. Towards the end of the drive, the driver’s mind might also be already distracted by the actual purpose of the drive, e.g., a meeting, shopping, or outdoor activity. Furthermore, the statistically significant result for the interaction term $\#Rides * total\ distance\ driven$ shows that driving experience reduces the probability of a downgrade in the Bonus-Malus class.

The third column of Table 5 also shows that the relative distance driven on weekends is a statistically significant risk factor. This result might give empirical support to the phenomenon of *Sunday drivers* who use their cars relatively more during leisure time. Last, we note that speeding is not significantly related to a downgrade of the Bonus-Malus class. This could arise from the fact that we underestimate speeding by applying countrywide legal speed limits per road type. In particular, we might underestimate the effect of speeding at street areas which are prone to accident since speed limits in these areas are likely to be below the countrywide speed limits.

We now discuss the relation between the four driving indices and contract choice, as reported in the first and second column of Table 5. The results in the first column show that both average speeding and the number of car rides are negatively related to the level of liability coverage. More precisely, driving on average one km/h (0.62 mph) more above legal limits is related to a 1.11% decrease in the probability of choosing the high liability coverage option. Furthermore, undertaking one additional car ride in the 3 month observation period is related to a 0.02% decrease in the probability of choosing the high liability coverage option.

These results in combination with the fact that the number of car rides is a significant risk factor are opposite to the predictions of adverse selection and moral hazard. They could be explained by selection based on heterogeneous, hidden degrees of risk aversion linked with hidden action (de Meza and Webb, 2001) or overconfidence (Sandroni and Squintani, 2013;

Koufopoulos, 2008). Policyholders who are more risk-averse or less overconfident purchase a higher level of liability coverage, speed on average less, undertake fewer car rides, and are less likely to be downgraded in the Bonus-Malus class.¹⁷

In contrast, the results for first-party insurance coverage as shown in the second column of Table 5 are consistent with the predictions of adverse selection and moral hazard. The number of car rides is positively related to the level of first-party coverage. Policyholders who undertake more car rides are more likely to purchase full comprehensive insurance coverage and more likely to experience a Bonus-Malus downgrade. Specifically, undertaking an additional car ride in the 3 month observation period is associated to a 0.03% increase in the probability of choosing full comprehensive insurance coverage. Last, the relative distance driven at night is positively related to the level of first-party coverage and more experienced drivers as proxied by the interaction term $\#Rides * total\ distance\ driven$ by less first-party coverage.

To sum up, the results of the trivariate probit model show that the four driving indices contain relevant private information for contract choice and risk as measured by a subsequent downgrade of the Bonus-Malus class. Furthermore, the effects related to third-party liability coverage are opposite to the effects related to first-party coverage. The results suggest a negative association between the level of liability coverage and risk, while they suggest a positive association between the level of first-party coverage and risk. These opposite correlation signs could result from an overlay of risk-based and preference-based selection effects. The risk-based selection originates from private information on risk characteristics which overlays the selection based on preferences such as risk aversion. Since the potential severity of liability claims is much higher than the one of first-party claims, the preference-based selection might have a relatively stronger effect on liability coverage than it has on first-party coverage. Differences in the degrees of risk aversion might be a much more important factor when facing claims in millions of € than when facing a loss that is restricted by the value of the car. Another explanation for the negative relation of liability coverage and risk is that a relevant fraction of policyholders are overconfident. As the optimal amount of insurance is lower for overconfident policyholders and given that liability insurance is mandatory, overconfidence could also explain the opposite effects on liability and on first-

¹⁷Our results show that the level of liability coverage is positively related to the age of the policyholder. There is empirical evidence that individuals become more risk averse and less overconfident when they get older (e.g., Morin and Suarez, 1983; Bucciol and Miniaci, 2011; Insurance Research Council, 2000-2003). Sandroni and Squintani (2013) show that decreasing overconfidence leads to an increase in insurance coverage. This supports our conjecture that risk aversion and overconfidence affect the choice of liability coverage.

party coverage.¹⁸

In Table 7, we report the correlation coefficients $\rho_{Liab,FP}$, $\rho_{Liab,\Delta BM}$, and $\rho_{FP,\Delta BM}$ of each pair of residual error terms in the trivariate probit model, Equations (6), (7), and (8).

Table 7: CORRELATIONS OF RESIDUAL ERROR TERMS

	without private information	with private information
$\rho_{Liab,FP}$	0.113** (0.0106)	0.128*** (0.0041)
$\rho_{Liab,\Delta BM}$	0.061* (0.0822)	0.06* (0.0944)
$\rho_{FP,\Delta BM}$	-0.015 (0.7311)	0.000 (0.9967)
N	1,849	1,849

Table 7 presents the residual correlation of the trivariate model for all combinations of the three probits. Significance levels are labeled ***, ** and * at 1%, 5% and 10%, respectively. P-values are stated in parentheses.

We first test for the positive correlation property between insurance coverage and risk as if we did not have access to the additional private information contained in Y . The first column reports the correlation coefficients when excluding the four driving indices from the trivariate probit model. This model is thus a trivariate version of Chiappori and Salanié (2000), Equations (2) and (3). We fail to reject the null hypothesis of zero correlation between first-party coverage and a downgrade of the Bonus-Malus class, $\rho_{FP,\Delta BM} = 0$, which is consistent with the results of most empirical studies in automobile insurance, see e.g. Chiappori and Salanié (2000) and Dionne et al. (2001). As discussed in Chiappori et al. (2006) and Finkelstein and Poterba (2014), we cannot draw unambiguous conclusions from failing to reject the null hypothesis about the existence and relevance of asymmetric information. And this is exactly confirmed by our direct evidence. Although we fail to reject the null hypothesis of zero residual correlation between first-party coverage and a downgrade

¹⁸While it is true that individuals who are more risk-averse value insurance coverage more, the effect of risk aversion on the value of risk control is ambiguous (see Ehrlich and Becker, 1972; Dionne and Eeckhoudt, 1985; Jullien et al., 1999). Moreover, if insurance coverage and risk control are substitutes, then a higher level of insurance coverage might reduce the willingness to invest in risk control. Depending on the setting, more risk-averse individuals might as well purchase more insurance coverage but invest less in risk control and thereby be of higher risk. Jullien et al. (2007) develop a principal-agent model with hidden degree of risk aversion and show that, depending on the parameters, the correlation between insurance coverage and risk can be positive, negative, or zero. Cohen and Einav (2007) present a structural model which accounts for unobserved heterogeneity in both risk and risk aversion. By using a large data set of an Israeli insurance company they find a strong positive correlation between unobserved risk aversion and unobserved risk which strengthens the positive correlation property.

of the Bonus-Malus class, we do find that private information, in particular the number of car rides, is relevant for the level of first-party insurance coverage and for a downgrade of the Bonus-Malus class (see Table 5).

A similar conclusion can be drawn about interpreting the statistically significant positive correlation of the residual error terms between liability coverage and a downgrade of the Bonus-Malus class, $\rho_{Liab,\Delta BM}$. The positive sign of the correlation coefficient is new to the literature which has focused on first-party coverage. This can be interpreted as arising from adverse selection and/or incentive effects. The negative relation of both average speeding and number of car rides to the level of liability insurance coverage (see Table 5) suggest at least an additional preference-based selection effect which is opposite to the one of adverse selection. The positive correlation coefficient in conjunction with the results on average speeding and the number of car rides is thus another indication of overlaying risk-based and preference-based selection effects.

Last, the correlation between the residual error terms of the liability and first-party coverage equations $\rho_{Liab,FP}$ is highly statistically significant and positive. This is consistent with some private information, such as risk aversion, which explains why policyholders who choose full comprehensive coverage also choose the high liability coverage option.

The second column in Table 7 reports the correlation coefficients between the residual error terms when including the four driving indices in the trivariate probit model. The results do not change. The correlation coefficient $\rho_{FP,\Delta BM}$ between the error terms of first-party coverage and risk remains to be not statistically different from zero. Similarly, the correlation coefficients $\rho_{Liab,FP}$ and $\rho_{Liab,\Delta BM}$ between the error terms of liability and first-party coverage and between liability coverage and risk remain statistically significant and positive.

5 Robustness

5.1 Disposable Income

Income might influence the level of insurance coverage and driving behavior. The insurance company does not collect income information in the underwriting process. To control for income in our model, we use data on purchasing power for 2009.¹⁹ Purchasing power in this data set is defined as yearly gross income minus direct taxes and social security contributions plus interest earnings and transfer payments. We merge the average purchasing power per

¹⁹The purchasing power data was provided by the Austrian Institute for SME Research.

resident on the postcode level with the insurance data set through the postcode information. Table 8 shows the average purchasing power for the different levels of insurance coverage.

Table 8: SUMMARY STATISTICS PURCHASING POWER

	first-party cov.		liability cov.		ΔBM class		
	total	0	1	0	1	0	1
purch. power in €	17,572	17,369	17,668	17,597	17,513	17,579	17,476

Table 8 shows the average purchasing power for all contracts, for splits to the contracts choices and for contracts with and without a downgrade in BM class. First-party coverage (first-party cov.) is 1 for full comprehensive insurance and 0 otherwise. Third-Party liability insurance (liability cov.) is set to 0, if €10m are covered and is 1, if coverage is €15m. ΔBM class is set to 1, if the policyholder's Bonus-Malus class was downgraded during the subsequent year and 0 otherwise.

Table 9 states the results of the trivariate probit model with purchasing power as an additional control variable. We conclude that purchasing power is not significantly related to any of the three dependent variables. More importantly, our previous results are robust to including purchasing power as an additional variable.

Table 9: COEFFICIENTS OF TRIVARIATE PROBIT MODEL

	<i>CovLiab</i>	<i>CovFP</i>	ΔBM
<i>AvgSpeeding</i>	-0.0116* (0.0059)	0.0037 (0.0072)	0.0024 (0.0031)
<i>#Rides</i>	-0.0002* (0.0001)	0.0003** (0.0001)	0.0002*** (0.0001)
<i>%DistWE</i>	0.0300 (0.0954)	-0.1335 (0.1119)	0.0935* (0.0582)
<i>%DistNight</i>	0.1295 (0.1365)	0.3345** (0.1673)	-0.0459 (0.0770)
<i>#Rides*distance driven</i>	4.64e-11* (2.79e-11)	-7.92e-11*** (2.97e-11)	-2.79e-11** (1.22e-11)
kW	0.0015* (0.0008)	-0.0005 (0.0011)	0.0003 (0.0004)
age of car	-0.0117*** (0.0030)	-0.1002*** (0.0070)	0.0073*** (0.0013)
value of car	1.50e-06 (2.12e-06)	-1.24e-06 (3.14e-06)	-2.42e-07 (1.12e-06)
urban	-0.04778* (0.0228)	0.0681** (0.0269)	0.0244** (0.0127)
male	-0.0067 (0.0232)	0.199 (0.0271)	-0.002 (0.0126)
Bonus-Malus class	-0.0322 (0.0833)	-0.3050*** (0.0884)	0.044* (0.0377)
age of policyholder	0.0014* (0.0008)	-0.0004 (0.0009)	0.0005 (0.0004)
total distance driven	-2.22e-08 (2.24e-08)	7.33e-08*** (2.45e-08)	1.83e-08 (1.12e-08)
purchasing power	-3.17e-06 (4.03e-06)	5.30e-06 (5.23e-06)	-1.32e-06 (2.00e-06)
kW*value of car	-1.89e-08* (9.86e-09)	1.80e-08 (1.97e-08)	-3.85e-09 (5.00e-09)
Pseudo- R^2	0.0162	0.3537	0.0512
N	1,849	1,849	1,849

Table 9 shows the results for each of the three equations of the trivariate model when controlling for purchasing power. Reported coefficients are marginal effects. Heteroscedastic robust standard errors are stated in parentheses. Significance levels are labeled ***, ** and * at 1%, 5% and 10%, respectively.

Table 10 shows the results for the residual correlation when including purchasing power in the trivariate probit model. Again, our results and conclusion from Section 4 do not change.

Table 10: CORRELATIONS OF RESIDUAL ERROR TERMS

	without private information	with private information
$\rho_{Liab,FP}$	0.125*** (0.0044)	0.133*** (0.003)
$\rho_{Liab,\Delta BM}$	0.06* (0.0728)	0.06* (0.0913)
$\rho_{FP,\Delta BM}$	0.006 (0.8822)	0.007 (0.8691)
N	1,849	1,849

Table 10 presents the residual correlation of the trivariate model for all combinations of the three probits when controlling for purchasing power. Significance levels are labeled ***, ** and * at 1%, 5% and 10%, respectively. P-values are stated in parentheses.

5.2 Selection of pay-as-you-drive contracts

The pay-as-you-drive insurance contract is offered for choice. Thus, the results previously obtained might not apply to policyholders who are insured under the traditional car insurance contract. We test for differences in the characteristics of pay-as-you-drive policyholders and an additional data set of 2,000 randomly selected cars which are insured under the original insurance contract in February 2009. The policyholders in this data set thus decided not to switch to the pay-as-you-drive contract. Data cleaning (excluding cars with less than 4 kW = 5.4 HP) leaves us with 1,987 insurance contracts. Table 11 provides the summary insurance statistics under the original insurance contract.

Table 11: SUMMARY STATISTICS ORIGINAL INSURANCE DATA

	Mean				
	total	none / compr.	full compr.	liab. 10m	liab. 15m
car's characteristics:					
age in years	5.32	7.18	0.94	5.53	4.83
engine power in kW (HP)	75.83 (101.69)	74.41 (99.79)	79.17 (106.17)	75.49 (101.23)	76.62 (102.75)
value of car in €	22,768	22,615	23,127	22,588	23,188
policyholder's characteristics:					
age in years	54.65	54.82	54.25	54.57	54.83
male	0.67	0.70	0.63	0.68	0.67
urban	0.21	0.19	0.25	0.20	0.21
Bonus-Malus class	0.46	0.46	0.45	0.46	0.45
number of obs.	1,987	1,394	593	1,392	595

Table 11 presents the average of all the variables in the insurance data set under the original contract. Column 2 “total” includes all contracts, column 3 “none/compr.” includes contracts with comprehensive coverage or no first-party insurance coverage. Column 4 “full compr.” includes contracts with full comprehensive coverage. Column 5 “liab. 10m” includes all third-party liability insurance contracts covering up to €10 million, column 6 “liab. 15m” includes contracts covering up to €15 million. The variable “urban” is set to 1 if the policyholder lives in a municipality with more than 40,000 inhabitants and 0 otherwise. Bonus-Malus class gives the scaling factor for the base premium of liability coverage.

We run the following selection equation

$$Selection = 1(X_{orig}\gamma_1 + \varepsilon_1 > 0)$$

which is based on both samples of policyholders. *Selection* is a binary variable, equal to 1 if the policyholder chose and equal to 0 if the policyholder did not choose the pay-as-you-drive insurance contract. X_{orig} consists of all variables used by the insurance company for pricing the original insurance contract (see Section 2.2). This does not include the aggregate distance driven by policyholders.

Table 12 reports the results of the selection equation. It shows that all the variables are highly significant for the selection of the pay-as-you-drive insurance contract. It is more likely to be chosen by younger and female individuals who live in urban areas and are in a higher Bonus-Malus class. Moreover, they own more recently built and valuable cars with higher engine power. These results indicate that the characteristics of the population who chose the pay-as-you-drive contract are different from the population who decided not to be

insured under this contract.

Table 12: COEFFICIENTS OF SELECTION EQUATION

	Coefficients
kW	0.0014** (0.0007)
age of car	0.0016 (0.0021)
value of car	4.04e-06** (1.68e-06)
urban	0.2522*** (0.0195)
male	-0.0622*** (0.0194)
Bonus-Malus class	1.7238*** (0.1178)
age of policyholder	-0.0055*** (0.0006)
CovLiab	-0.0234 (0.0195)
CovFP	0.4082*** (0.0213)
Pseudo- R^2	0.2429074
N	3,985

Table 12 presents the results of the probit regression on the selection into the telematic insurance contract. Reported coefficients are marginal effects. Heteroscedastic robust standard errors are stated in parentheses. Significance levels are labeled ***, ** and * at 1%, 5% and 10%, respectively.

6 Conclusions

We capitalize on having access to detailed data on driving behavior of policyholders in automobile insurance which is inaccessible to the insurance company. By connecting this data to the corresponding insurance data we provide direct evidence that driving behavior is relevant for contract choice in first-party and third-party liability insurance as well as for risk. Whereas the number of car rides and average speeding are negatively related to the level of liability coverage, the number of car rides and the relative distance driven at night are positively related to the level of first-party insurance coverage. Moreover, the number of car rides and the relative distance driven on weekends are significant risk factors. These

results combined suggest the coexistence and interaction of risk-based and preference-based selection effects.

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