EXECUTIVE REPORT
ON FUTURE AUTOMOBILE INSURANCE POLICY OF SAFELIFE

Team Tarheelytics

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INTRODUCTION

Our society is moving towards a new mobility ecosystem, a world that celebrates the availability of autonomous vehicles. Automobile manufacturers have already successfully produced some models with certain levels of automation capabilities. David Carlson, senior vice president at Marsh & McLennan, commented that by 2025, “we will probably be sharing the road with autonomous vehicle technology”[1]. It is of great excitement to welcome the new technology of autonomous vehicles (AVs) that brings benefits in terms of improved transportation mobility, increased driving efficiency and greater passenger safety.

As the leading company in the automobile insurance industry, Safelife stands at the forefront of autonomous vehicle conversation. It is not only beneficial but also pioneering for Safelife to take the initiative to design a new autonomous vehicle insurance policy[2]. Gaining an upper hand in the public adoption of autonomous vehicles over the next decade will offer Safelife momentum to stay at the top of the market in the long run.

[1] *The Impact of Autonomous Vehicles on the Future of Insurance: Hearing before the Subcommittee on Housing and Insurance of the Committee on Financial Services, U.S. House of Representatives, One Hundred Fifteenth Congress, Second Session, May 23, 2018*. Washington: U.S. Government Publishing Office, 2018.

[2] Litman, Todd. *Autonomous Vehicle Implementation Predictions Implications for Transport Planning*. Report. Victoria Transport Policy Institute. 2019.

EXECUTIVE SUMMARY

This report presents a new autonomous vehicle insurance policy for Safelife starting from Jan. 1st, 2019. We provide a pure premium estimate for the new policy and develop a 10-year forecast analysis of pure premium for both the traditional and autonomous vehicle insurance policy. A sensitivity analysis is performed to expect 20 to 25 percent of Safelife's overall business will fall into the new autonomous policy. We also address future insights and scenario concerns into the development of the mobility ecosystem over the next 10 years that might change Safelife's policy design.

We conclude that by 2028, which is the 10-year endpoint we launch the new autonomous vehicle insurance policy:

- Safelife's pure premium of combining autonomous vehicle and the traditional vehicle will be Ĉ 224,503 with 47.4% of personal policy in overall business.
- The total annual auto insurance premium will decrease by 7.3 percent.
- Assuming Safelife would not develop new autonomous vehicle policy, the baseline forecast of the traditional car pure premium is Ĉ 314,297.
- By sensitivity analysis, in order for Safelife to optimize its business profit, Safelife should give discount on autonomous vehicle policy, emphasize on commercial policy marketing, or redistribute the coverage for direct death to other injury category.

AUTONOMOUS VEHICLE INSURANCE POLICY DESIGN

Social Background

We design the autonomous vehicle insurance policy based on Carbia's legislation on automobile vehicle insurance[3]. All automobile owners are obliged to purchase automobile insurance. Besides, Carbia is mirroring the U.S. Federal Automated Vehicle Policy[4], so that the new policy design is highly regulated under the autonomous vehicle framework provided by NHTSA.

Launch Date

The adoption of fully autonomous vehicles seems to be far into the future but the change is happening now.

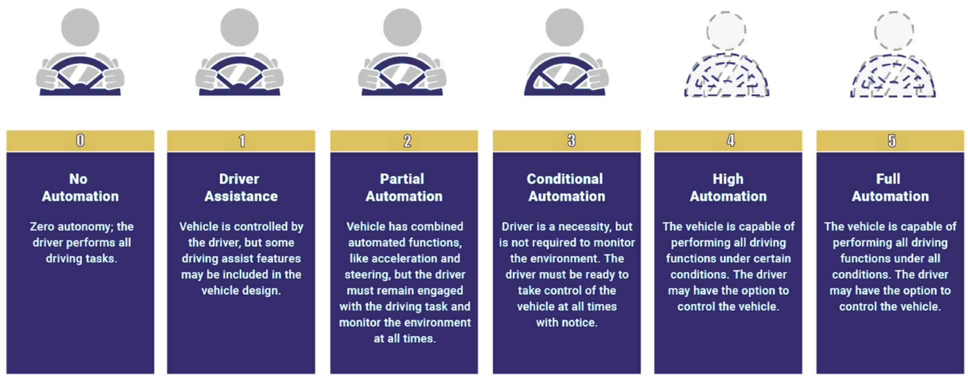

Figure 1. Society of Automotive Engieers(SAE) Automotion Levels

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[3] "2019 Student Research Case Study Challenge," Society of Actuaries, , accessed March 23, 2019, https://www.soa.org/research/opportunities/2019-student-case-study/.

[4] Trasportation.gov U.S. Department of Transportation. https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016.

By adopting SAE International definition for the level of autonomy(Figure 1)[5], we observe Level-1 cars have taken more than 90% share in the autonomous car market, and the governments across regions are constantly working together to enhance its safety and of them by mandating the use of ADAS since 2015. [6]Starting in 2017, Level-2 cars appeared in the market with less than 10% shares, and they will take up a bigger portion of the market at the end of 2024. Since Level-1 and Level-2 autonomous cars currently exist in the market, we recommend launching the policy in **Jan 1st, 2019**.

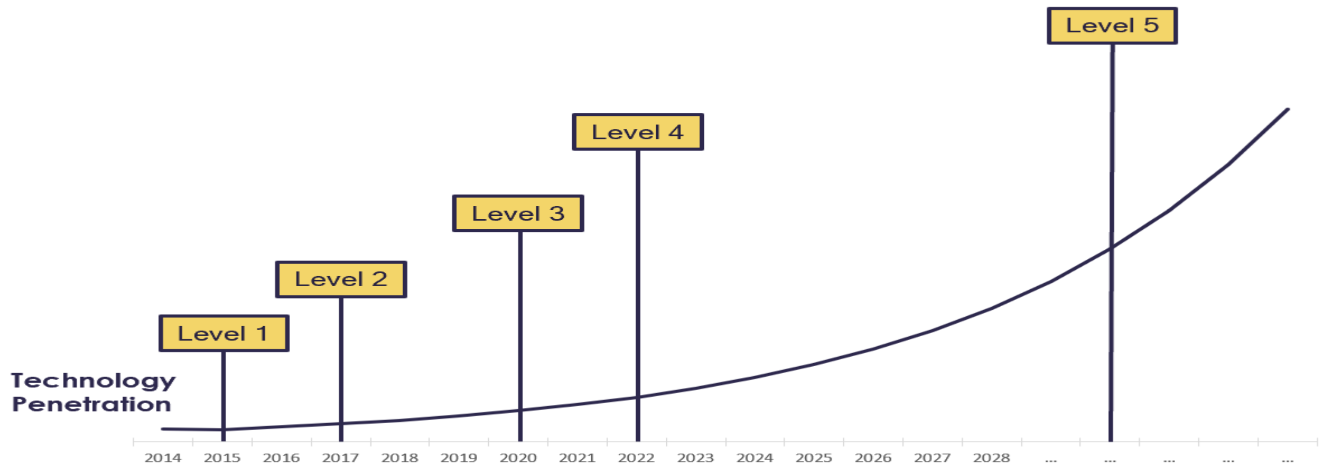

Figure 2. Timeline for Autonomous Vechile Adoption[7]

Even though the manufacturers are raising their R&D funding and companies are collaborating in developing more advanced equipment to achieve a higher level of automation, Gill Pratt and the Toyota Research Institute [8]believe that the availability of Level-5 automation (full automation) is not in the near future and "none of us in the

[5] Trasportation.gov U.S. Department of Transportation. https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016.
[6] DigitalTrends, "By 2021, you could be sleeping behind the wheel of an autonomous Volvo XC90" https://www.digitaltrends.com/cars/volvo-xc-90-level-4-autonomy/ 2021 Volvo xc90 level 4.
[7] https://www.gminsights.com/industry-analysis/autonomous-car-market
[8] USA, Toyota. YouTube. January 04, 2017. Accessed March 21, 2019. https://www.youtube.com/watch?v=CFTa2IjMNwM.

automobile or IT industries are close to achieving true Level-5 autonomy.” Therefore fully automated vehicles will not be the target consideration in our policy design and 10-year forecasting.

Liability Coverage

The autonomous vehicle insurance policy will be compatible with the design of traditional automobile vehicle insurance policy. Therefore, policyholders are required to purchase full coverage over Bodily Injury, Personal Injury, Property Damage, Collision, Comprehensive Liability.

In addition to traditional autonomous vehicle insurance requirement, the feature of autonomous car will generate new risks in hardware failure, software failure, and cyber hacking. Hardware failure can be caused by sensors and computers. Autonomous vehicles sensors including radar and audio may have the malfunction which will result in the car accident. Computers processing, output, and satellite may also have a probability of malfunction. Since human control is the primary control of the autonomous vehicle software, certain biased algorithm problems and failure may emerge. Cyber problems include leaking of privacy and hacking which will result in major accidents.

The table below summarizes the new designed autonomous vechicle insurance policy in regards to liability coverages and the influenced parties.

Table 1: Autonomous Vechicle Insurance Policy Requirement

Liability	Definition	Influenced Party
Bodily Injury	Same as traditional automobile insurance policy, Safelife pays for medical and funeral service for the people that are hurt or die from the car accident, regardless of fault.	The party who are injured or die will receive the payment from Safelife.
Personal Injury	Safelife pays in excess of policyholder's medical insurance which resulting from an automobile accident, regardless of fault.	The insured will be the beneficiary in case of injury.
Personal Damage	Safelife pays for physical damage to, or destruction of, tangible property of another, including loss of use, for which an insured is legally liable.	Other damages that physically involved in an automobile accident will be covered by Safelife.
Collision	Safelife pays for repair costs of policyholder's vehicles, regardless of fault.	The repair cost of the insured vehicle will be covered. Therefore property owner will get the payment from Safelife.
Comprehensive	Safelife pays for any loss other than a collision, including all natural disasters, theft and vandalism. New risks generated from autonomous vehicles including hardware malfunction, software error, and cyber liability.	Automated Vehicle Owner will be benefited in this liability. Accidents result from new risks(hardware failure, software failure, and cyber problems) will fall into comprehensive category, and the insured may get certain coverage.

*If an insured is sued in any car accident, Safelife provides legal representation.

Overall Insurance Plan

Similarly, the autonomous vehicle insurance policy will extend the policy type and risk class from Safelife's traditional automobile vehicle. Figure 3 illustrates insurance plan with personal and commercial automobile car type and 27 risks classes.

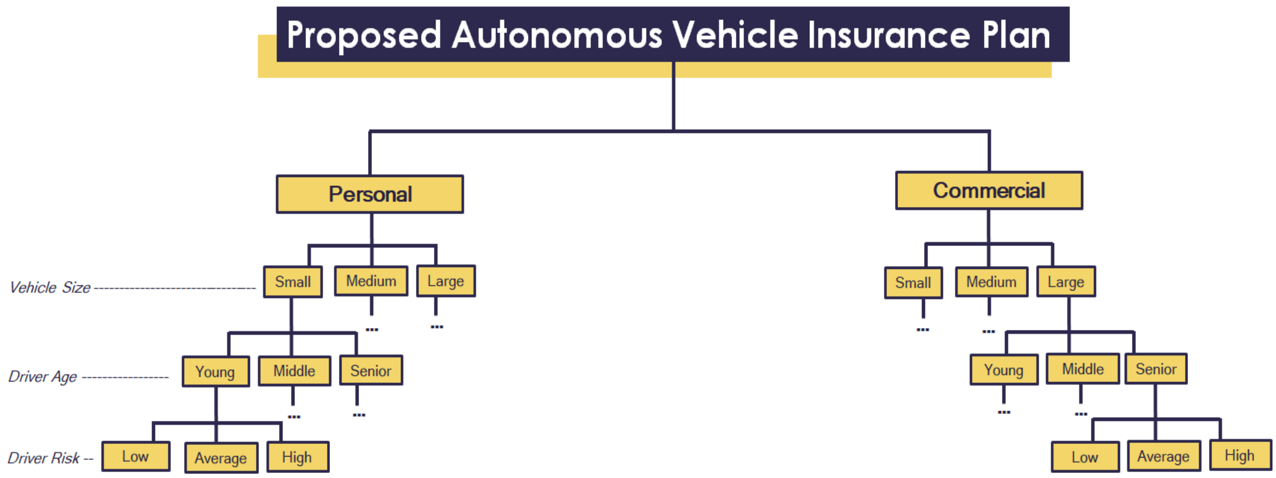

Figure 3. Proposed Autonomous Vehicle Insurance Plan

Policy Type

A policy would be classified as either personal (driving a vehicle you own) or commercial (taxi, ride sharing, car sharing, or rental car) private transportation. Our policy design does not consider commercial trucking or delivery services, where the automobile is owned by companies or institutions.

We expect personal autonomous cars (motorists own or lease their own self-driving vehicles) are preferred by people who travel a lot, reside in sprawling areas, want a particular vehicle or leave personal items in vehicles. Commercial autonomous vehicles which mainly include shared autonomous cars (self-driving taxis transport individuals and groups to destination) are for lower-annual-mileage users, lower-income urban residents.

Risk Class

Without the consideration of Level-5 Automated Level Vehicle, the vehicle size, driver age, and driver risk are still basic features to influence the potential risk in insurance. People pondering on purchasing an autonomous car are more apt to fall into three groups: early adopters (young tech lovers and wealth groups), disabled or handicapped people, and seniors.

While early adopters refer to young people and wealthy people who tend to be open-minded and keep updating to the newest high technologies, the disabled and seniors belong to those individuals that are not able to drive manually.

PURE PREMIUM ESTIMATE AND TEN-YEAR FORECASTING

Modeling Pure Premium

Our goal is to develop a pure premium estimation for the new policy. To estimate the expected pure premiums in the next 10 years, we follow the procedures as below:

1. A 10-year forecast of traditional vehicles' expected pure premium (the average loss per exposure unit) will be performed as a baseline.
2. When the new autonomous vehicle policy is taken into consideration starting from our designated launch date, we apply multiple modifiers to identify and quantify what factors will likely affect future pure premiums.
3. We will then combine the expected pure premium of new autonomous vehicles and traditional automobile to develop a combined insurance pure premium 10-year forecast.

Baseline Pure Premium Estimation

We develop a baseline pure premium estimation based on Safelife's traditional automobile insurance historical data from 2009 to 2018. The baseline forecast is the average pure premium of traditional cars, before the entrance of autonomous vehicles. It can also be understood as a steady state under the assumption that the current mobility environment persists, which means no higher level of automation will be developed.

The baseline average pure premium is calculated by the following formula:

$$\text{Pure Premium} = \text{Frequency} \times \text{Severity}, \text{ where}$$

$$\text{Expected Severity} = \text{Incurred Losses} \div \text{Incurred Claims}$$

$$\text{Frequency} = \text{Incurred Cliams} \div \text{Earned Exposures}$$

Frequency

As the observations of frequency for each risk class is in timely order, we adopt Times Series Analysis to predict the frequency over the next decade[9]. Figure 4 below is an illustration of 10 year forecasting for risk class SYA in traditional commercial vehicle from 2019 to 2028 based on.the original claim history of the frequency.

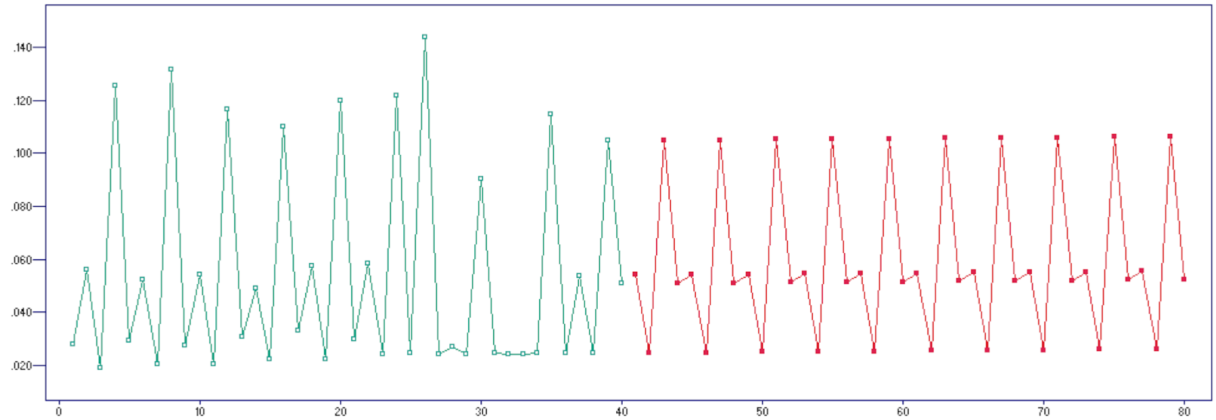

Figure 4： Traditonal Commercial Vechicle 10-year Forecast for SYA Class (Vehicle Size: Small, Driver Age: Young, and Driver Risk: Average)

Severity

With respect to the forecast of expected severity, we assume that the severity will only be affected by the inflation rate from year to year. We then reference the projected annual

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[9] The results are added to the original data history and can be found in the Excel of supporting calculations.

inflation rate from 2010 to 2023 by International Monetary Fund (IMF) and suppose that the inflation rate would not change in the following years until our last prediction period of 2028[10]. Therefore, the expected quarterly severity of 5 coverages for 27 risk classes can be obtained by applying the yearly inflation. Following the above formula of calculating pure premium, we presented the numerical results are shown in the Excel file attached.

Pure Premium Modifier

After we achieve the baseline forecast of pure premium based on the traditional automobile insurance history data, we identify and quantify the factors that will influence the insurance pure premium with the adoption of autonomous vehicle into the market.

Table 2:Frequency Modifiers

Modifier	Discussion
Auto Insurance Fraud	Insurance Research Council has estimated that 13-17 percent of auto insurance claims are fraudulent.[11] With techonologicall automation improvement, more data are available to insurance groups. We expect that this will aid insurers to identify fraud better and ealier in the claims process. A gradual reduction in claim frequency will take place over time as we expect that more fraudulent claims will be recognized and a general reduction will be reported.
Human Error	The NHTSA determined that 94% of car crashes are caused by human error.[12] Autonomous cars will effectively reduce the probability of human error by 13

[10] US Inflation Forecast 2018, 2019 and up to 2060, Data and Charts - Knoema.com." Knoema. Accessed March 23, 2019. https://cn.knoema.com/kyaewad/us-inflation-forecast-2018-2019-and-up-to-2060-data-and-charts.
11 *Insurance Research Council Finds That Fraud and Buildup Add Up to $7.7 Billion in Excess Payments for Auto Injury Claims*. Report. Insurance Research Council. 2015.
12 NHTSA, Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety, September 2016.

	percent.[13] As a result, we assumes significantly reduction will be noticed in claim frequency.

Table 3: Severity Modifiers

Modifier	Discussion
Inflation	Inflation is a general increase in money value. Hence, it will have the same impact on the severity.
Repair Costs	Advanced technology will increase vehicle complexity, leading to higher repairation costs. CCC Information Services elaborates that average auto repariation cost will be increase by 3 percent every year since 2013[14], and it was driven by the higher average number of parts replaced per claim and higher labor hours per claim.

Combined Pure Premium 10-Year Forecast

In the discussion of the forecast of the combined automobile market, we assume:

- No advanced technologies beyond Level-5 automation will be developed in the near future;
- Autonomous cars will not be army-based;
- Rental vehicles market will not expand.
- The market share of personal and commercial auto claim remains at 47.4% and 52.6% respectively.[15]

13 "Insurance in the new mobility ecosystem Quantifying an uncertain future", Deloitte Development LLC., 2016.
[14] http://www.cccis.com/wp-content/uploads/2016/03/CC2016_FINAL_6.pdf
[15] "Commercial Vehicles in Use in the U.S. 2005-2015 | Statistic." Statista. Accessed March 23, 2019. https://www.statista.com/statistics/274375/commercial-vehicles-in-use-in-the-us/.
"Number of Cars in U.S." Statista. Accessed March 23, 2019.

As time proceeds, due to the general inflation and population growth, traditional vehicles will continue its trending of exponential increase. Furthermore, there still exist other factors that will influence the steady increment of pure premium when autonomous cars are considerably available in the market after the year of 2020. Figure 5 shows the trend of the expected pure premium from 2009 to 2028 under the impact of all possible factors indicated below[16].

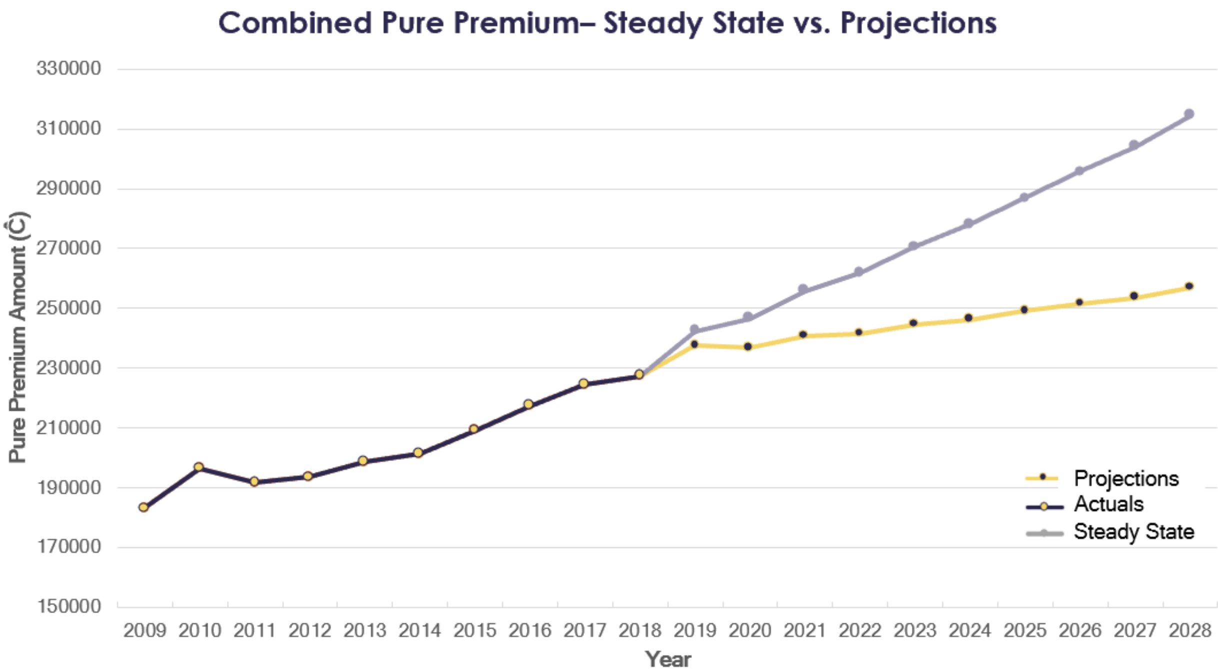


Figure 5: Combined Pure Premium- Steady State- Projections

Looking at the 10 years projection and knowing that traditional vehicles premiums are Ĉ242420.9 in 2019:

16 Archived Tables." III. Accessed March 23, 2019. https://www.iii.org/table-archive/20967.

- By the entrance of autonomous vehicles to the market, the premiums will be reduced by approximately 13 percent until 2028 because of reduction on human error in car crashed.
- Reduction on fraudulent claims will reduce the premiums by 10 percent.
- The general inflation, population growth, and increased repair costs of autonomous cars will in all increase the total premiums by 4.9 percent to the Year 2028.
- Take all the factors into consideration, we estimates the premiums of combined traditional cars and autonomous vehicles will be Ĉ224,503.9 in 2028. This gives a 7.3 percent decrease in premiums relatively to the steady state.

SENSITIVITY ANALYSIS

Given the management's goal that the new policy accounts for 20 to 25 percent of Safelife's overall business in the next 10 years since our launch date, we perform a sensitivity analysis on pure premium to boost up Safelife's financial growth. Taking the 2028 expected overall pure premium as an example, there are 4 factors that we need to consider:

1. New Policy Percentage of all policies sold by Safelife
2. Human Error Reduction Modifier
3. Auto Insurance Fraud Reduction Modifier
4. Severity Modifier

We expect both Human Error Reduction Modifier and Auto Insurance Fraud Reduction Modifier to increase due to the higher level of automation. In addition, since Severity Modifier involves inflation rate and population growth, we anticipate it to increase as well.

We vary each of the factors by a change rate of 25% and assume that the expected pure premium for the traditional policies is unchanged. To better demonstrate the qualitative effect of each important factors on the pure premium, we conduct another set of sensitivity analysis using a change rate of 50%.

Expected Pure Premium Prediction Sensitivity Analysis									
		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Variable Values	Base Case	New Policy Percentage Increases **25%** and **50%**		Human Error Reduction Modifier Increases **25%** and **50%**		Auto Insurance Fraud Reduction Modifier Increases **25%** and **50%**		Severity Modifier Increases **25%** and **5%**	
New Policy Percentage	20%	25.00%	30.00%	20%	20%	20%	20%	20%	20%
Human Error Reduction Modifier	0.1	0.1	0.1	0.125	0.15	0.1	0.1	0.1	0.1
Auto Insurance Fraud Reduction Modifier	0.13	0.13	0.13	0.13	0.13	0.1625	0.195	0.13	0.13
Severity Modifier	1.049	1.049	1.049	1.049	1.049	1.049	1.049	1.31125	1.10145
Expected Pure Premium for New Policies (in ₵) in year 2028	224503	258153.184	258153.184	250982.2622	243811.3404	248509.5306	238865.8771	322691.48	271060.8432
Expected Pure Premium for Traditional Policies (in ₵) in year 2028	314297	314297	314297	314297	314297	314297	314297	314297	314297
Expected Overall Pure Premium of Safelife (in ₵) in year 2028	296338.2000	300261.0460	297453.8552	301634.0524	300199.8681	301139.5061	299210.7754	315975.8960	305649.7686
Percentage Change in Expected Pure Premium	–	**0.01324**	0.00376	**0.01787**	0.01303	**0.01620**	0.00969	**0.06627**	0.03142

- ***Formulae of Calculation:***

1. *E[2028 Expected Overall Pure Premium of Safelife] = Percentage of New Policy*E[2028 Expected Pure Premium for New Policies] + (1-Percentage of New Policy)*E[2028 Expected Pure Premium for Traditional Policies] (E[Traditional Policies] is assumed to static and unchanged for sensitivity analysis);*
2. *E[New Policies]=E[Traditional Policies]*(1-Human Error Reduction Modifier)*(1-Auto Insurance Fraud Reduction Modifier)*Severity Modifier.*

Figure 6: Expected Pure Premium Prediction Sensitvity Analysis

Recomendation

According to our sensitivity analysis on the predicted expected pure premium of year 2028, we distinguish that the percentage of the new insurance policy of the overall business of Safelife is the dominant factor of the expected pure premium. In order to sufficiently optimize the pure premium, we propose to Safelife the following recommendations:

Recommendation 1

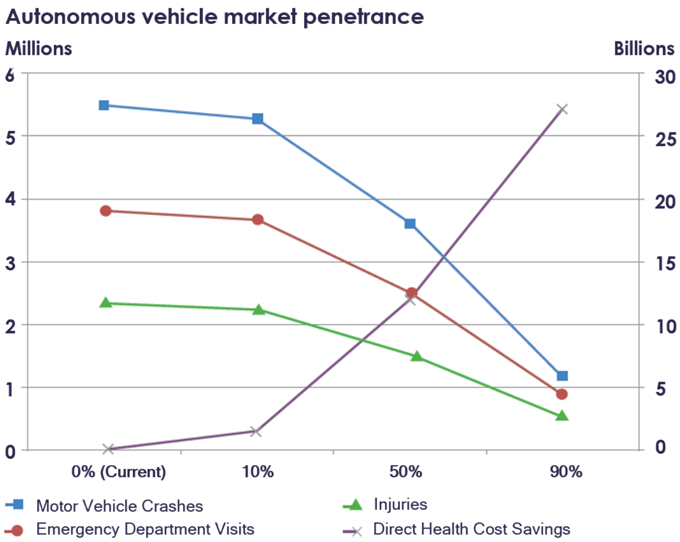
Both the sensitivity report and the exploratory data analysis demonstrate that the expected loss has the least sensitivity corresponding to the changes in percentage of autonomous vehicle insurance sale, and the new insurance policy is more profitable compared with the traditional automobile insurance policy. Therefore, Safelife should provide discount for the new autonomous vehicle insurance in order to increase the sales of new insurance policy and to reduce the expected loss.

Recommendation 2

Based on the fact that the commercial vehicles are going to have a bigger share in the market, Safelife should emphasize more on commercial policy market. In order to have more commercial policies sold, Safelife should use marketing and advertising strategies. With more commercial policies, pure premium will decrease, and thus increasing Safelife's profit.

Recommendation 3

Based on our research shown in Figure 6[17], there will be a dramatic reduction in the number and cost of traumatic injuries, which will save a substantial amount for individual in his or her health care expense. As the the volume of injury-causing crashes decreases, we recommend Safelife to reallocate the death coverage to cover other injury categories[18].



Source: *The Journal of Trauma and Acute Care Surgery*, U.S. October 2015

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[17] Luttrell, Kevin, Michael Weaver, and Mitchel Harris. "The Effect of Autonomous Vehicles on Trauma and Health Care." Journal of Trauma and Acute Care Surgery79, no. 4 (2015): 678-82. doi:10.1097/ta.0000000000000816.

[18] The Impact of Autonomous Vehicles on the Future of Insurance: Hearing before the Subcommittee on Housing and Insurance of the Committee on Financial Services, U.S. House of Representatives, One Hundred Fifteenth Congress, Second Session, May 23, 2018. Washington: U.S. Government Publishing Office, 2018.

FUTURE INSIGHTS

Data Limitation

The ten-year forecast we have conducted above is built on the past data of personal and commercial auto insurance claims from 2009 to 2018 provided. Although past observations clearly demonstrate seasonality and trends to a certain extent, the dataset is not large enough, and thus bringing limitation on our prediction model. Meanwhile, as we try to smooth the dataset as much as possible, there is also arbitrary factor such as natural disaster or etc., which cannot be captured by time series modeling. Moreover, due to the lack of data for autonomous vehicle insurance, we derive multipliers for influential factors, inflation, human driving errors reduction, and etc., to forecasting the new insurance policy pure premium. All of the above factors may deviate our forecasting results, but the overall prediction is substantial. To further resolve the risks arouse from lack of observations, we include a few more recommendations to provide a more comprehensive report for Safelife upon the launch of the new auto insurance policy.

Future Consideration

Following up on the discussion of the limitation on the prediction model, our research indicates a technology boom in the next decade, which will radically reform the automobile industry and the auto insurance industry. In the era of self-driving cars, the auto insurance industry is expected to face challenges in ethical dilemma and unprecedented risks.

Our primary concerns for personal auto claim are the ethical critiques for self-driving car and who should be liable for car incidents. According to Products Liability doctrines, when the suspected components of the automobile are proven to be defective as specified, the manufacturer should be the responsible party of the accident[19].

Additionally, since the autonomous vehicle is a heavy computer-based product, it faces the risk of cyber security. The autonomous vehicles cellular carriers are vulnerable under cyber attacks such as hacking or cyber virus, which will lead to severe criminal activities carried by hackers including hijacking, wounding with intent, and even terrorist attacks.

With respect to commercial auto claim, although the commercial vehicles usually experience high accident rates because of driver is not the responsible party, as the autonomous cars are putting into service, the human caused accidents will dramatically decrease, in which the overall accidents rate will drop.

[19] Jeffrey K. Gurney, Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles, 2013 U. Ill. J.L. Tech. & Pol'y 247, 2013

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We would like to express our deepest appreciation to people who offered their time and help to the completion of this project. A special gratitude is sent to Prof. Charles Dunn, who introduced information about the SOA case competition and elaborated on essential actuarial concepts; Prof. Robin Cunningham, who provided consulting advice on our actuarial modeling and related analysis issues; Mr. Dev Patel, who offers us insights on real-world auto-insurance policy-making and Ms. Qianyue Ma, who designed the team logo for our team and provided assistance on our diagram plotting and report layout.

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4 USA, Toyota. YouTube. January 04, 2017. Accessed March 21, 2019. https://www.youtube.com/watch?v=CFTa2IjMNwM.

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Mexico, UAE, South Africa), Growth Potential, Competitive Market Share & Forecast, 2018 – 2024. Report no. GMI1224. Global Market Insights. 2018.

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16 The Impact of Autonomous Vehicles on the Future of Insurance: Hearing before the Subcommittee on Housing and Insurance of the Committee on Financial Services, U.S. House of Representatives, One Hundred Fifteenth Congress, Second Session, May 23, 2018. Washington: U.S. Government Publishing Office, 2018.

17 Ibid.

18 Jeffrey K. Gurney, Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles, 2013 U. Ill. J.L. Tech. & Pol'y 247, 2013.

APPENDIX A – R CODE

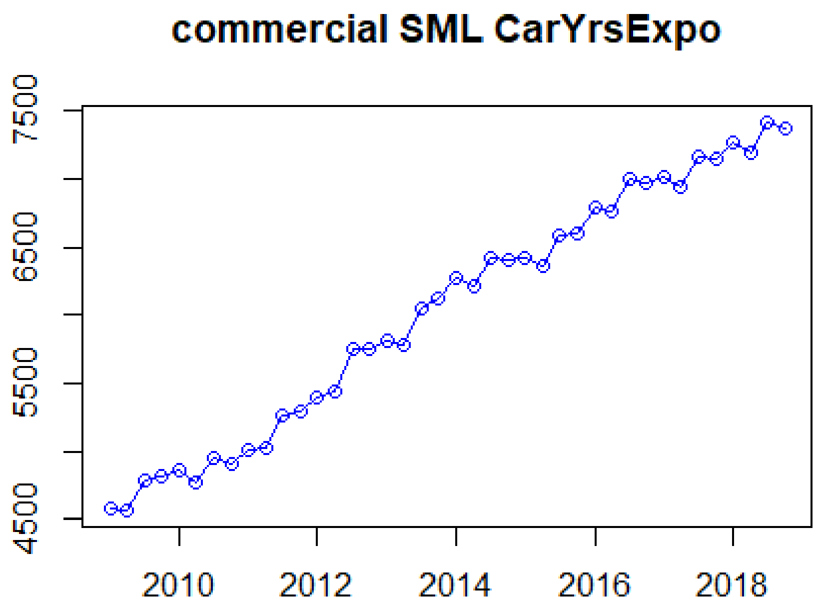
```
setwd("C:/Users/Melody/Desktop")
auto_claims <- read_xlsx('data_without_title.xlsx')
## New names:
## * `Bodily Injury` -> `Bodily Injury..6`
## * `Property Damage` -> `Property Damage..7`
## * Comprehensive -> Comprehensive..8
## * Collision -> Collision..9
## * `Personal Injury` -> `Personal Injury..10`
## * ... and 5 more
names(auto_claims) <- make.names(names(auto_claims),unique = TRUE)
head(auto_claims, 10)
## # A tibble: 10 x 15
##     Year   Qtr Risk.Class Type  Car.years.of.Ex~ Bodily.Injury..6
##    <dbl> <dbl> <chr>      <chr>            <dbl>            <dbl>
##  1  2009     1 SML        Pers~            15036               95
##  2  2009     1 LSL        Pers~             4563               21
##  3  2009     1 MYA        Pers~             4322               82
##  4  2009     1 SMA        Pers~            16801               96
##  5  2009     1 MSL        Pers~            13979              151
##  6  2009     1 LYL        Pers~             3136               63
##  7  2009     1 LSA        Pers~            20636              285
##  8  2009     1 LMA        Pers~            25318              729
##  9  2009     1 SYL        Pers~             2602               92
## 10  2009     1 MYL        Pers~             2575               84
## # ... with 9 more variables: Property.Damage..7 <dbl>,
## #   Comprehensive..8 <dbl>, Collision..9 <dbl>, Personal.Injury..10 <dbl>,
## #   Bodily.Injury..11 <dbl>, Property.Damage..12 <dbl>,
## #   Comprehensive..13 <dbl>, Collision..14 <dbl>,
## #   Personal.Injury..15 <dbl>
unique(auto_claims$Risk.Class)
```

```
##  [1] "SML" "LSL" "MYA" "SMA" "MSL" "LYL" "LSA" "LMA" "SYL" "MYL" "MYH"
## [12] "LML" "MSA" "LYA" "MMA" "LYH" "SSA" "MML" "LMH" "SSL" "SSH" "MMH"
## [23] "SYA" "LSH" "SYH" "MSH" "SMH"
```

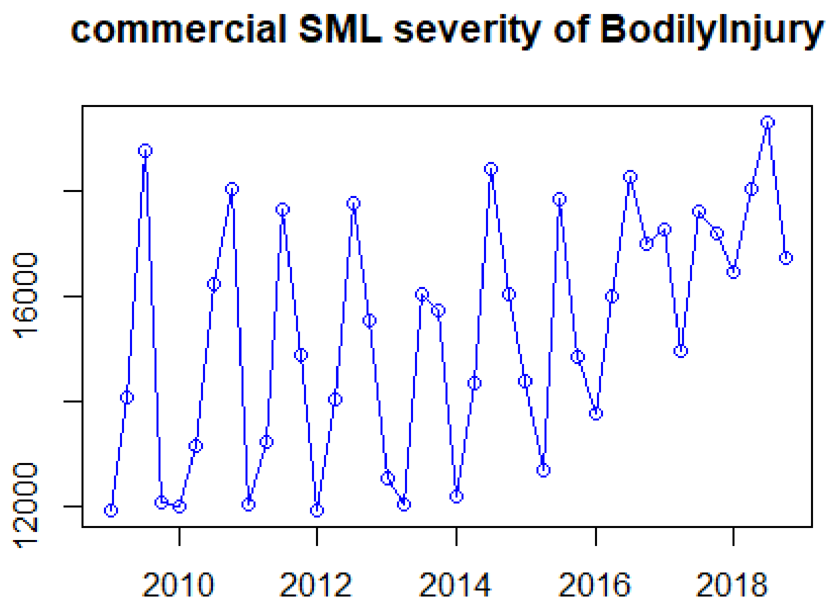
```
auto_claims <- auto_claims %>%
  select(Year = Year,
         Qtr = Qtr,
         RiskClass = Risk.Class,
         Type = Type,
         CarYrsExposure = Car.years.of.Exposure,
         num_BodilyInjury = Bodily.Injury..6,
         num_PropertyDamage = Property.Damage..7,
         num_Comprehensive = Comprehensive..8,
         num_Collision = Collision..9,
         num_PersonalInjury = Personal.Injury..10,

         amt_BodilyInjury = Bodily.Injury..11,
         amt_PropertyDamage = Property.Damage..12,
         amt_Comprehensive = Comprehensive..13,
         amt_Collision = Collision..14,
         amt_PersonalInjury = Personal.Injury..15
         ) %>%
  mutate(s_BodilyInjury = amt_BodilyInjury / num_BodilyInjury,
         s_PropertyDamage = amt_PropertyDamage / num_PropertyDamage,
         s_Comprehensive = amt_Comprehensive / num_Comprehensive,
         s_Collision = amt_Collision / num_Collision,
         s_PersonalInjury = amt_PersonalInjury / num_PersonalInjury,

         f_BodilyInjury = num_BodilyInjury / CarYrsExposure,
         f_PropertyDamage = num_PropertyDamage / CarYrsExposure,
         f_Comprehensive = num_Comprehensive / CarYrsExposure,
         f_Collision = num_Collision / CarYrsExposure,
         f_PersonalInjury = num_PersonalInjury / CarYrsExposure)
```

```
head(auto_claims, 10)
## # A tibble: 10 x 25
##      Year   Qtr RiskClass Type  CarYrsExposure num_BodilyInjury
##     <dbl> <dbl> <chr>     <chr>          <dbl>            <dbl>
##  1  2009      1 SML       Pers~          15036               95
##  2  2009      1 LSL       Pers~           4563               21
##  3  2009      1 MYA       Pers~           4322               82
##  4  2009      1 SMA       Pers~          16801               96
##  5  2009      1 MSL       Pers~          13979              151
##  6  2009      1 LYL       Pers~           3136               63
##  7  2009      1 LSA       Pers~          20636              285
##  8  2009      1 LMA       Pers~          25318              729
##  9  2009      1 SYL       Pers~           2602               92
## 10  2009      1 MYL       Pers~           2575               84
## # ... with 19 more variables: num_PropertyDamage <dbl>,
## #   num_Comprehensive <dbl>, num_Collision <dbl>,
## #   num_PersonalInjury <dbl>, amt_BodilyInjury <dbl>,
## #   amt_PropertyDamage <dbl>, amt_Comprehensive <dbl>,
## #   amt_Collision <dbl>, amt_PersonalInjury <dbl>, s_BodilyInjury <dbl>,
## #   s_PropertyDamage <dbl>, s_Comprehensive <dbl>, s_Collision <dbl>,
## #   s_PersonalInjury <dbl>, f_BodilyInjury <dbl>, f_PropertyDamage <dbl>,
## #   f_Comprehensive <dbl>, f_Collision <dbl>, f_PersonalInjury <dbl>
personal <- auto_claims[auto_claims$Type == 'Personal', ]
commercial <- auto_claims[auto_claims$Type == 'Commercial', ]
coverages <- c('BodilyInjury', 'PropertyDamage', 'Comprehensive',
'Collision',
               'PersonalInjury')

for (i in unique(auto_claims$RiskClass)){
  assign(paste('commercial', i, 'CarYrsExpo', sep = "_"),
         commercial[commercial$RiskClass == i, 5])
```

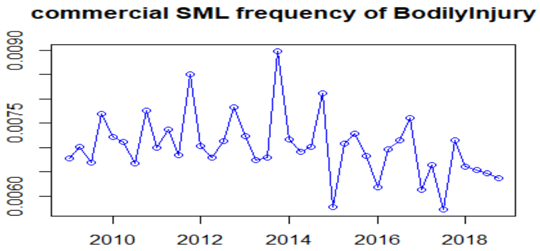
```
  assign(paste('commercial', i, 's', 'BodilyInjury', sep = "_"),
         commercial[commercial$RiskClass == i, 16])
  assign(paste('commercial', i, 's', 'PropertyDamage', sep = "_"),
         commercial[commercial$RiskClass == i, 17])
  assign(paste('commercial', i, 's', 'Comprehensive', sep = "_"),
         commercial[commercial$RiskClass == i, 18])
  assign(paste('commercial', i, 's', 'Collision', sep = "_"),
         commercial[commercial$RiskClass == i, 19])
  assign(paste('commercial', i, 's', 'PersonalInjury', sep = "_"),
         commercial[commercial$RiskClass == i, 20])

  assign(paste('commercial', i, 'f', 'BodilyInjury', sep = "_"),
         commercial[commercial$RiskClass == i, 21])
  assign(paste('commercial', i, 'f', 'PropertyDamage', sep = "_"),
         commercial[commercial$RiskClass == i, 22])
  assign(paste('commercial', i, 'f', 'Comprehensive', sep = "_"),
         commercial[commercial$RiskClass == i, 23])
  assign(paste('commercial', i, 'f', 'Collision', sep = "_"),
         commercial[commercial$RiskClass == i, 24])
  assign(paste('commercial', i, 'f', 'PersonalInjury', sep = "_"),
         commercial[commercial$RiskClass == i, 25])
}
commercial_SML_CarYrsExpo_ts <- ts(commercial_SML_CarYrsExpo, frequency = 4,
                                   start = c(2009, 1))
plotc(commercial_SML_CarYrsExpo_ts)
title('commercial SML CarYrsExpo')
```




```
commercial_SML_s_BodilyInjury_ts <- ts(commercial_SML_s_BodilyInjury,
frequency = 4,
                                       start = c(2009, 1))
plotc(commercial_SML_s_BodilyInjury_ts)
title('commercial SML severity of BodilyInjury')
```




```
commercial_SML_f_BodilyInjury_ts <- ts(commercial_SML_f_BodilyInjury,
frequency = 4,
                                        start = c(2009, 1))
plotc(commercial_SML_f_BodilyInjury_ts)
title('commercial SML frequency of BodilyInjury')
```




```
# ONLY TABLE/FILE NAMES NEED TO BE CHANGED
write.table(commercial_SMH_CarYrsExpo, "commercial_SMH_CarYrsExpo.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_f_BodilyInjury,
"commercial_SMH_f_BodilyInjury.tsm",
            row.names = FALSE, col.names = FALSE)
```

```
write.table(commercial_SMH_s_BodilyInjury,
"commercial_SMH_s_BodilyInjury.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_f_Collision, "commercial_SMH_f_Collision.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_s_Collision, "commercial_SMH_s_Collision.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_f_Comprehensive,
"commercial_SMH_f_Comprehensive.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_s_Comprehensive,
"commercial_SMH_s_Comprehensive.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_f_PropertyDamage,
"commercial_SMH_f_PropertyDamage.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_s_PropertyDamage,
"commercial_SMH_s_PropertyDamage.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_f_PersonalInjury,
"commercial_SMH_f_PersonalInjury.tsm",
            row.names = FALSE, col.names = FALSE)
write.table(commercial_SMH_s_PersonalInjury,
"commercial_SMH_s_PersonalInjury.tsm",
            row.names = FALSE, col.names = FALSE)
```

APPENDIX B – SAS CODE

```
/*This sas program aims to conduct 10-year forecast on severity and
calculation of pure premium.*/
proc import datafile="C:\Users\Yirun Li\Documents\Spring
2019\SOA\personal.csv"
     out=mydata
     dbms=csv
     replace;
       datarow=2;
     getnames=yes;
run;

Data mydata1;
set mydata;
if x_2="Personal";
rename var2=year x=quarter x_1=risk x_3=exposure x_4=nbi x_5=npro x_6=ncom
x_7=ncol x_8=npi x_9=abi x_10=apro x_11=acom x_12=acol x_13=api;
drop var1 x_2;
run;

data mydata2;
set mydata1;
asum=abi+apro+acom+acol+api;
nsum=nbi+npro+ncom+ncol+npi;
odds=asum/exposure;
run;

Proc sort data=mydata2;
by descending exposure;
run;

Data mydata3;
set mydata2;
sbi=abi/nbi;
spro=apro/npro;
scom=acom/ncom;
scol=acol/ncol;
spi=api/npi;

fbi=nbi/exposure;
fpro=npro/exposure;
fcom=ncom/exposure;
fcol=ncol/exposure;
fpi=npi/exposure;

keep year quarter risk sbi spro scom scol spi fbi fpro fcom fcol fpi;
run;

Data mydata4;
set mydata3;
ppbi=sbi*fbi;
pppro=spro*fpro;
```

```
ppcom=scom*fcom;
ppcol=scol*fcol;
pppi=spi*fpi;
pp=ppbi+pppro+ppcom+ppcol+pppi;
run;

Proc sort data=mydata3;
by risk quarter year;
run;

Proc transpose data=mydata3;
run;

data mydata4;
set mydata3;
if year=2018;
run;

Data mydata5;
set mydata4;
sbi=sbi*(1+0.02436);
spro=spro*(1+0.02436);
scom=scom*(1+0.02436);
scol=scol*(1+0.02436);
spi=spi*(1+0.02436);
year=2019;
run;

Data mydata6;
set mydata5;
sbi=sbi*(1+0.02126);
spro=spro*(1+0.02126);
scom=scom*(1+0.02126);
scol=scol*(1+0.02126);
spi=spi*(1+0.02126);
year=2020;
run;

Data mydata7;
set mydata6;
sbi=sbi*(1+0.02038);
spro=spro*(1+0.02038);
scom=scom*(1+0.02038);
scol=scol*(1+0.02038);
spi=spi*(1+0.02038);
year=2021;
run;

Data mydata8;
set mydata7;
sbi=sbi*(1+0.02074);
spro=spro*(1+0.02074);
scom=scom*(1+0.02074);
scol=scol*(1+0.02074);
spi=spi*(1+0.02074);
year=2022;
run;
```

```
Data mydata9;
set mydata8;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2023;
run;

Data mydata10;
set mydata9;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2024;
run;

Data mydata11;
set mydata10;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2025;
run;

Data mydata12;
set mydata11;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2026;
run;

Data mydata13;
set mydata12;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2027;
run;

Data mydata14;
set mydata13;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
```

```
spi=spi*(1+0.0212);
year=2028;
run;

Data mergespersonal;
set mydata5 mydata6 mydata7 mydata8 mydata9 mydata10 mydata11 mydata12
mydata13 mydata14;
run;

data mergespersonal;
set mergespersonalal;
ppbi=sbi*fbi;
pppro=spro*fpro;
ppcom=scom*fcom;
ppcol=scol*fcol;
pppi=spi*fpi;
pp=ppbi+pppro+ppcom+ppcol+pppi;
run;
***********;
proc means data=mydata4 sum;
var pp;
class year;
output out=personalpppast sum=sum/autoname;
run;

proc means data=mergepersonal sum;
var pp;
class year;
output out=personalpppred sum=sum/autoname;
run;

Data personalpppast;
set personalpppast;
if year^=.;
keep year sum;
run;

Data personalpppred;
set personalpppred;
if year^=.;
keep year sum;
run;

Data personalpptwenty;
set personalpppast personalpppred;
run;

Proc print data=personalpptwenty;
run;
*********************************************************;
proc import datafile="C:\Users\Yirun Li\Documents\Spring
2019\SOA\commercial.csv"
     out=mydata15
     dbms=csv
     replace;
       datarow=2;
     getnames=yes;
```

```
run;

Data mydata16;
set mydata15;
if x_2="Commerci";
rename var2=year x=quarter x_1=risk x_3=exposure x_4=nbi x_5=npro x_6=ncom
x_7=ncol x_8=npi x_9=abi x_10=apro x_11=acom x_12=acol x_13=api;
drop var1 x_2;
run;

data mydata17;
set mydata16;
asum=abi+apro+acom+acol+api;
nsum=nbi+npro+ncom+ncol+npi;
odds=asum/exposure;
run;

Proc sort data=mydata17;
by descending exposure;
run;

Data mydata18;
set mydata17;
sbi=abi/nbi;
spro=apro/npro;
scom=acom/ncom;
scol=acol/ncol;
spi=api/npi;

fbi=nbi/exposure;
fpro=npro/exposure;
fcom=ncom/exposure;
fcol=ncol/exposure;
fpi=npi/exposure;

keep year quarter risk sbi spro scom scol spi fbi fpro fcom fcol fpi;
run;

Data mydata19;
set mydata18;
ppbi=sbi*fbi;
pppro=spro*fpro;
ppcom=scom*fcom;
ppcol=scol*fcol;
pppi=spi*fpi;
pp=ppbi+pppro+ppcom+ppcol+pppi;
run;

Proc sort data=mydata19;
by risk quarter year;
run;

Proc transpose data=mydata19;
run;

data mydata20;
set mydata19;
```

```
if year=2018;
run;

Data mydata21;
set mydata20;
sbi=sbi*(1+0.02436);
spro=spro*(1+0.02436);
scom=scom*(1+0.02436);
scol=scol*(1+0.02436);
spi=spi*(1+0.02436);
year=2019;
run;

Data mydata22;
set mydata21;
sbi=sbi*(1+0.02126);
spro=spro*(1+0.02126);
scom=scom*(1+0.02126);
scol=scol*(1+0.02126);
spi=spi*(1+0.02126);
year=2020;
run;

Data mydata23;
set mydata22;
sbi=sbi*(1+0.02038);
spro=spro*(1+0.02038);
scom=scom*(1+0.02038);
scol=scol*(1+0.02038);
spi=spi*(1+0.02038);
year=2021;
run;

Data mydata24;
set mydata23;
sbi=sbi*(1+0.02074);
spro=spro*(1+0.02074);
scom=scom*(1+0.02074);
scol=scol*(1+0.02074);
spi=spi*(1+0.02074);
year=2022;
run;

Data mydata25;
set mydata24;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2023;
run;

Data mydata26;
set mydata25;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
```

```
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2024;
run;

Data mydata27;
set mydata26;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2025;
run;

Data mydata28;
set mydata27;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2026;
run;

Data mydata29;
set mydata28;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2027;
run;

Data mydata30;
set mydata29;
sbi=sbi*(1+0.0212);
spro=spro*(1+0.0212);
scom=scom*(1+0.0212);
scol=scol*(1+0.0212);
spi=spi*(1+0.0212);
year=2028;
run;

Data mergescommercial;
set mydata21 mydata22 mydata23 mydata24 mydata25 mydata26 mydata27 mydata28
mydata29 mydata30;
run;

data mergescommercial;
set mergescommercial;
ppbi=sbi*fbi;
pppro=spro*fpro;
ppcom=scom*fcom;
ppcol=scol*fcol;
```

```
pppi=spi*fpi;
pp=ppbi+pppro+ppcom+ppcol+pppi;
run;

proc means data=mydata19 sum;
var pp;
class year;
output out=commercialpppast sum=sum/autoname;
run;

proc means data=mergescommercial sum;
var pp;
class year;
output out=commercialpppred sum=sum/autoname;
run;

Data commercialpppast;
set commercialpppast;
if year^=.;
keep year sum;
run;

Data commercialpppred;
set commercialpppred;
if year^=.;
keep year sum;
run;

Data commercialpptwenty;
set commercialpppast commercialpppred;
run;

Proc print data=commercialpptwenty;
run;

Proc print data=personalpptwenty;
run;
```