Appendix B Supplementary material

Table B.1: Sequential parameter grids and default values for random forest and neural network in discrete (continuous) treatment optimization with 10-fold cross-validation, using the `ranger` and `nnet` package in `R`.

Random forest parameter	**Search grid**	**Default**	**Optimal (G)PS**
Tree-specific parameters			
-max.depth	$\{0, 1, 2, 4, \ldots, 10, 25, 50\}$		25 (1)
-min.node.size	$\{0, 1, \ldots, 5, 10, 25, 50\}$		0 (0)
Stochastic features			
-sample.fraction	$\{0.1, 0.2, \ldots, 1\}$	1	0.1 (0.4)
-mtry	$\{1, 2, \ldots, 8\}$	1	4 (1)
Number of trees			
-num.tree	$\{1, 2, \ldots, 20, 30, 40, 50, 75, 100, 150, \ldots, 5{,}000\}$	500	350 (550)
Neural network parameter			
Network-specific parameters			
-size	$\{1, 2, 4, \ldots, 10, 25, 50\}$		4 (2)
-decay	$\{0, 0.1, 1, 10, 100, 250, 300, \ldots, 1{,}000\}$		100 (550)
Number of iterations			
-maxit	$\{1, 2, \ldots, 20, 30, 40, 50, 75, 100, 150, \ldots, 5{,}000\}$	100	250 (100)

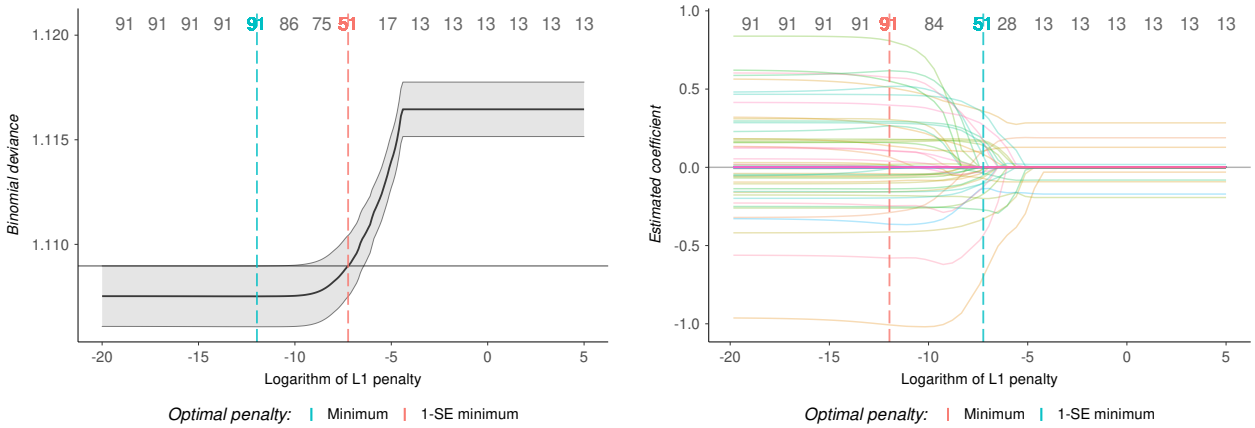


Figure B.1: LASSO cross-validation errors (left) and parameter estimates (right) with the number of non-zero coefficients denoted at the top for the discrete global response model in automobile insurance.

Table B.2: Parameter estimates with standard errors in parenthesis for the discrete global response model after multiple imputation in automobile insurance.

			Interactions with `Competitiveness`		**Interactions with `Rate_Change`**			
Risk factor		**Coefficient**	*Competitiveness*	*Competitiveness*^{2}	$[-9.28\%, 1.53\%]$	$(1.53\%, 6.06\%]$	$(8.58\%, 12.58\%]$	$(12.58\%, 27.01\%]$
Constant		-0.9305 (0.0240)***						
Competitiveness		0.0190 (0.0628)			0.0771 (0.0813)		0.1731 (0.0628)**	
Competitiveness^2					0.3070 (0.1897)		-0.0279 (0.2168)	-0.2368 (0.1813)
Rate_Change								
- $[-9.28\%, 1.53\%]$		-0.6224 (0.0403)***	-0.0255 (0.0712)	-0.0701 (0.1896)				
- $(1.53\%, 6.06\%]$		0.0493 (0.0217)*	-0.0151 (0.0802)					
- $(8.58\%, 12.58\%]$		0.0329 (0.0361)	-0.0134 (0.0726)					
- $(12.58\%, 27.01\%]$		0.1811 (0.0291)***	-0.0176 (0.0726)					
Premium_New_Base	$(\times 10^{-2})$	-0.0009 (0.0034)	0.0118 (0.0073)		0.1458 (0.0087)***		-0.0045 (0.0046)	-0.0058 (0.0045)
Premium_New_Base^2	$(\times 10^{-6})$	0.0009 (0.0028)			-0.3857 (0.03777)***			
Undershooting_1		0.0002 (0.0002)				0.0003 (0.0003)		0.0005 (0.0002)*
Undershooting_1^2	$(\times 10^{-6})$	-0.5628 (0.3447)					-0.0161 (0.4469)	
Undershooting_2		0.0005 (0.0002)**	-0.0004 (0.0002)*		0.0010 (0.0002)***	-0.0002 (0.0002)	-0.0001 (0.0002)	
Undershooting_2^2	$(\times 10^{-5})$				-0.1243 (0.0357)***	-0.0075 (0.0107)		-0.0223 (0.0257)
Risk_Level								
- *Low*		-0.0062 (0.0207)	0.1200 (0.0653)		-0.0519 (0.0313)			-0.0566 (0.0363)
- *Medium*		-0.1150 (0.0387)**	-0.1362 (0.0782)		-0.1407 (0.0574)*	0.2235 (0.0533)***	0.1568 (0.0509)**	0.2291 (0.0485)***
- *High*		-0.0638 (0.1518)						0.1677 (0.3131)
Policy_Type								
- *Employee*		-0.0353 (0.0401)	-0.0981 (0.1593)	0.0958 (0.4560)	-0.1032 (0.0826)			
- *Second car*		-0.0867 (0.0469)			-0.2935 (0.0552)***	-0.0431 (0.0747)	0.0875 (0.0549)	-0.0200 (0.0586)

Significance levels: *5%-level, **1%-level, ***0.1%-level or less

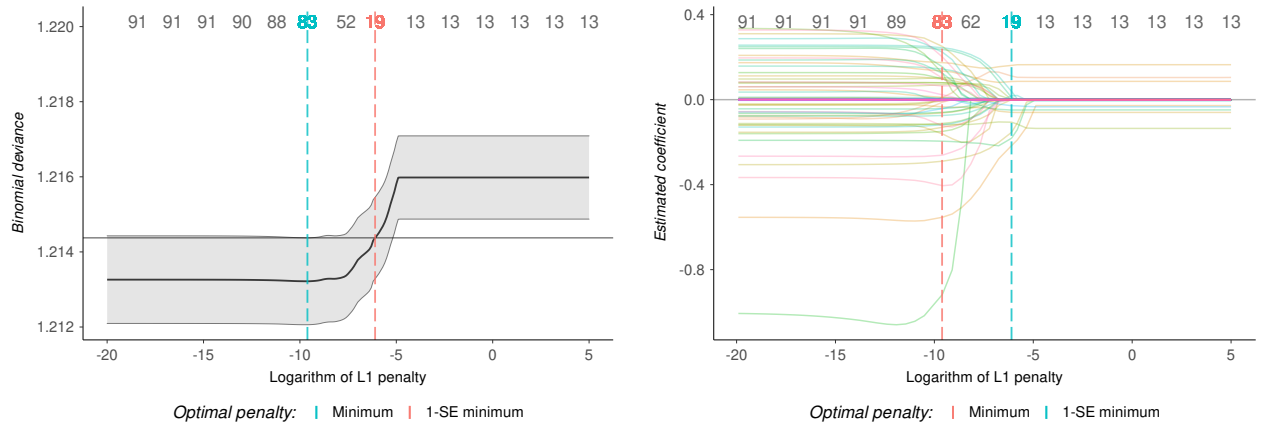
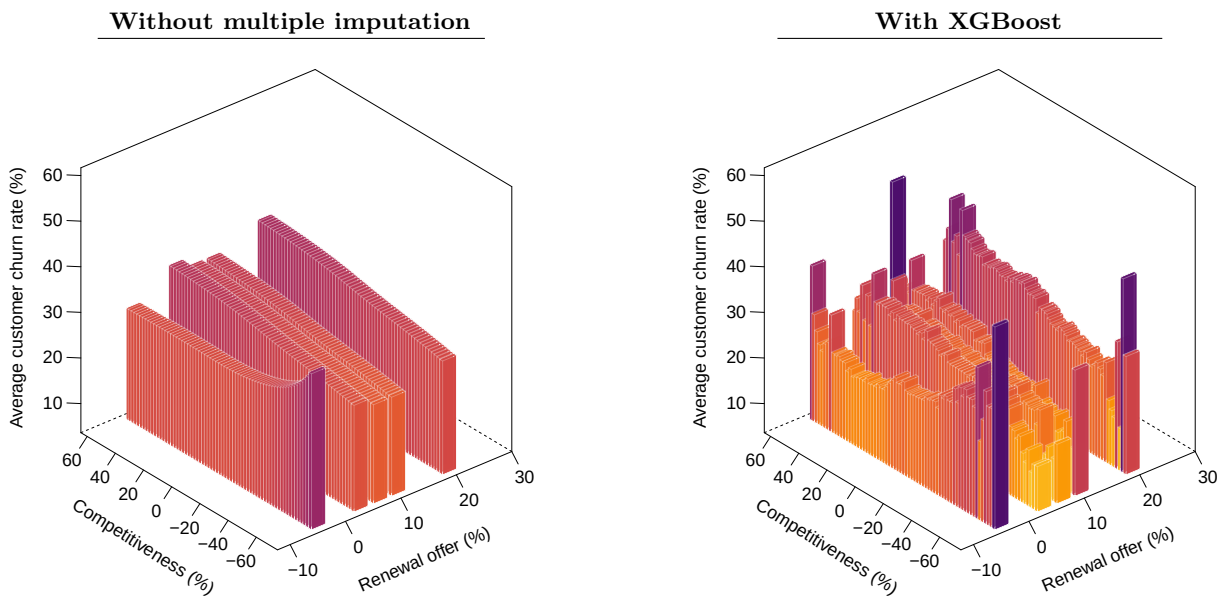


Figure B.2: LASSO cross-validation errors (left) and parameter estimates (right) with the number of non-zero coefficients denoted at the top for the discrete global response model without multiple imputation in automobile insurance.

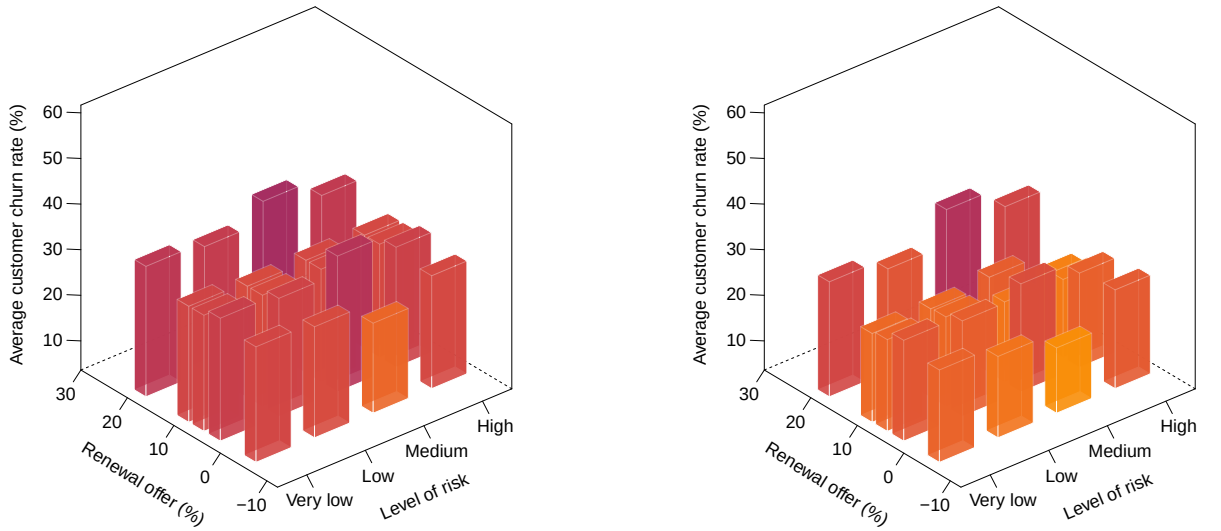
Table B.3: Parameter estimates with standard errors in parenthesis for the discrete global response model without multiple imputation in automobile insurance.

			Interactions with `Competitiveness`		Interactions with `Rate_Change`			
Risk factor		**Coefficient**	*Competitiveness*	*Competitiveness*^{2}	$[-9.28\%, 1.53\%]$	$(1.53\%, 6.06\%]$	$(8.58\%, 12.58\%]$	$(12.58\%, 27.01\%]$
Constant		-0.8776 (0.0116)***						
Competitiveness		0.1528 (0.0239)***						
Competitiveness^2								
Rate_Change								
- $[-9.28\%, 1.53\%]$		-0.3062 (0.0193)***	-0.0255 (0.0712)	-0.0701 (0.1896)				
- $(1.53\%, 6.06\%]$		0.0713 (0.0120)***	-0.0151 (0.0802)					
- $(8.58\%, 12.58\%]$		-0.0008 (0.0117)	-0.0134 (0.0726)					
- $(12.58\%, 27.01\%]$		0.1475 (0.0119)***	-0.0176 (0.0726)					
Premium_New_Base	$(\times 10^{-2})$	-0.0009 (0.0034)			0.1458 (0.0087)***			
Premium_New_Base^2	$(\times 10^{-6})$	-0.0539 (0.0142)***			0.6661 (0.0306)***			
Undershooting_1		0.0002 (0.0001)*						
Undershooting_1^2	$(\times 10^{-6})$							
Undershooting_2		0.5075 (0.0495)***	-0.6292 (0.1221)***					
Undershooting_2^2	$(\times 10^{-5})$							
Risk_Level								
- *Low*		-0.0489 (0.0096)***						
- *Medium*		-0.0338 (0.0209)			-0.2588 (0.0373)***	0.1644 (0.0349)***		0.1894 (0.0345)***
- *High*		-0.0285 (0.0907)						0.1677 (0.3131)
Policy_Type								
- *Employee*		-0.0577 (0.0181)**	-0.0981 (0.1593)	0.0958 (0.4560)	-0.1032 (0.0826)			
- *Second car*		-0.0770 (0.0157)***			-0.2935 (0.0552)***	-0.0431 (0.0747)	0.0875 (0.0549)	-0.0200 (0.0586)

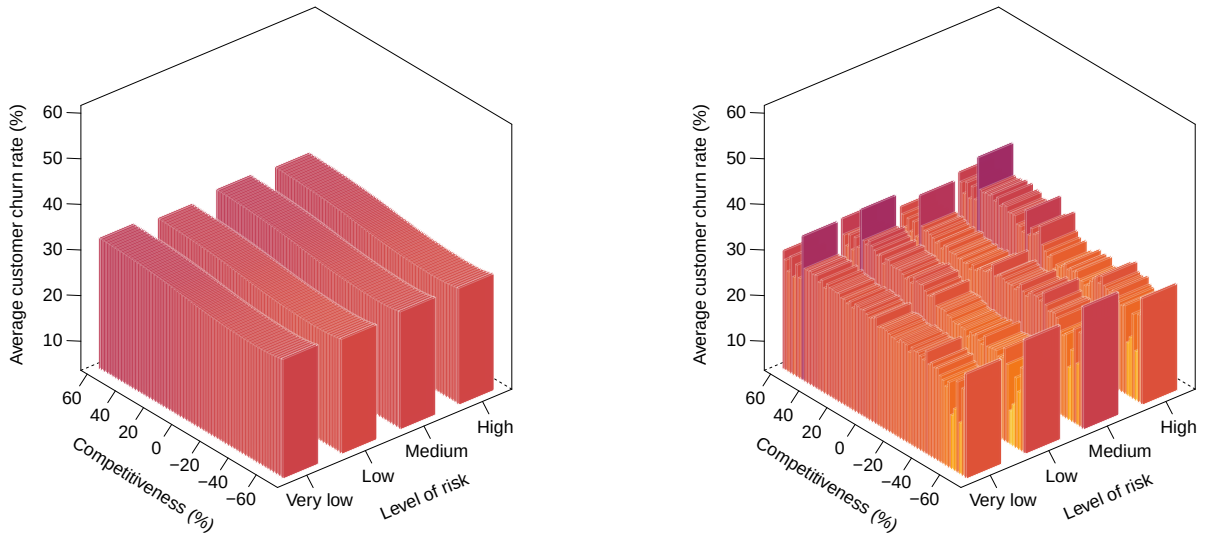
Significance levels: *5%-level, **1%-level, ***0.1%-level or less



(a) Average customer churn for renewal offers and competitiveness

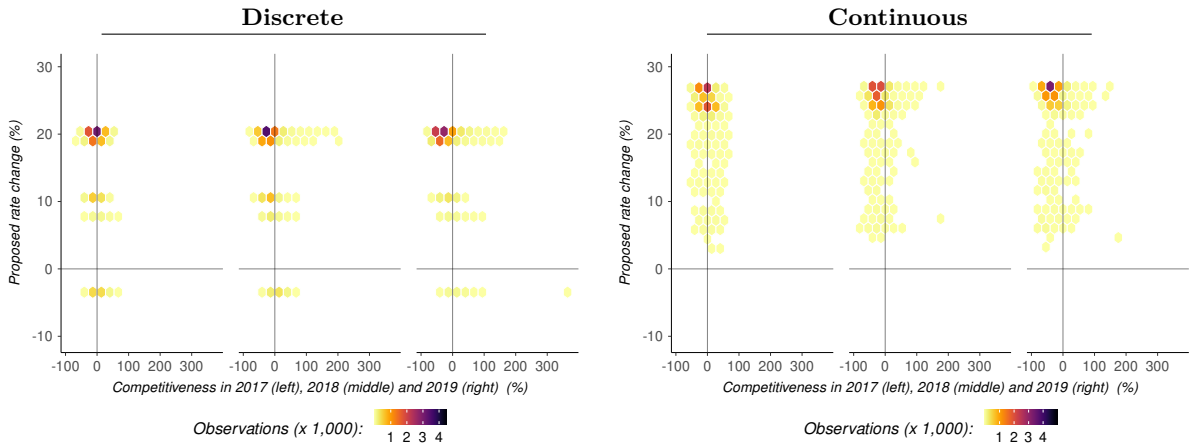


(b) Average customer churn for renewal offers and level of risk

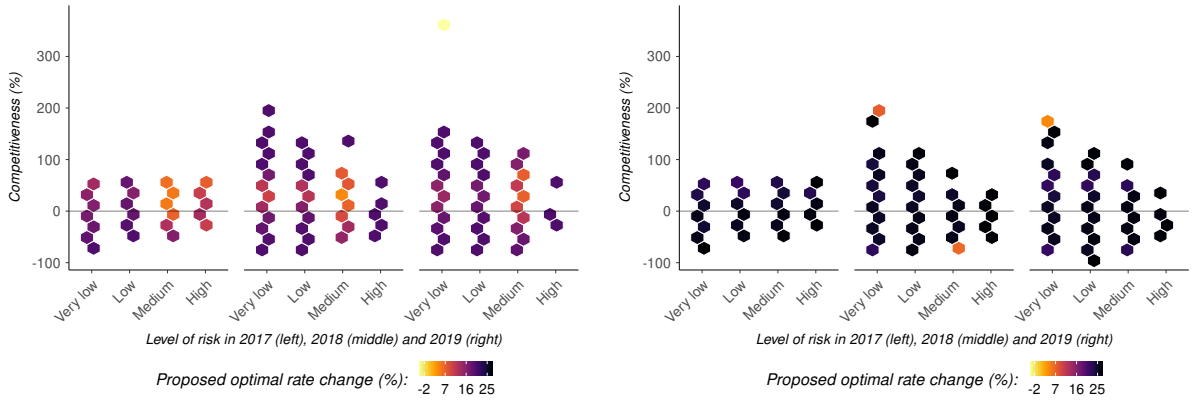


(c) Average customer churn for level of risk and competitiveness

Figure B.3: Average customer churn estimate for each renewal offer and every competitiveness (panel (a)) and level of risk (panel (b)) as well as aggregated over all renewal offers (panel (c)) with discrete rate changes without multiple imputation (left) and with XGBoost (right) in automobile insurance.

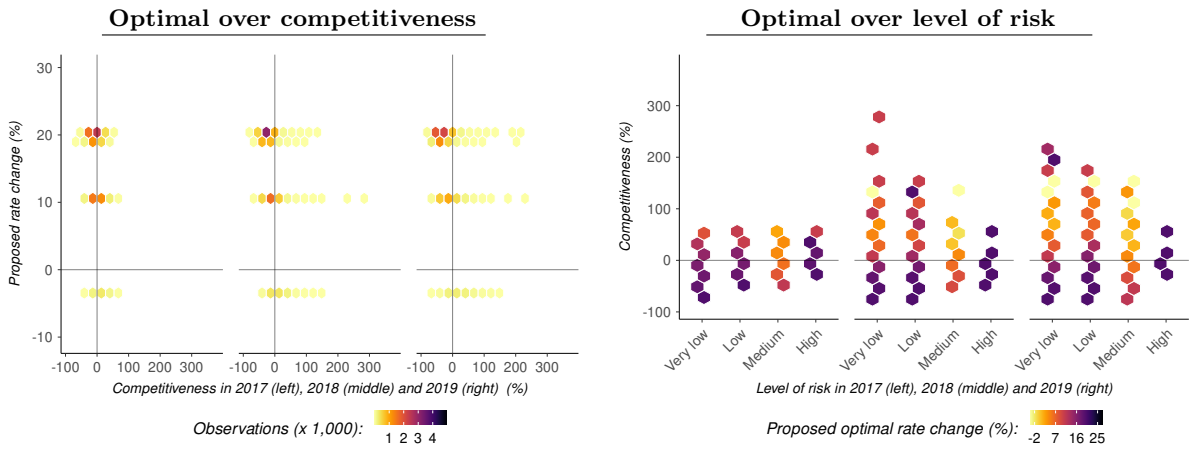


(a) Optimal rate changes over competitiveness

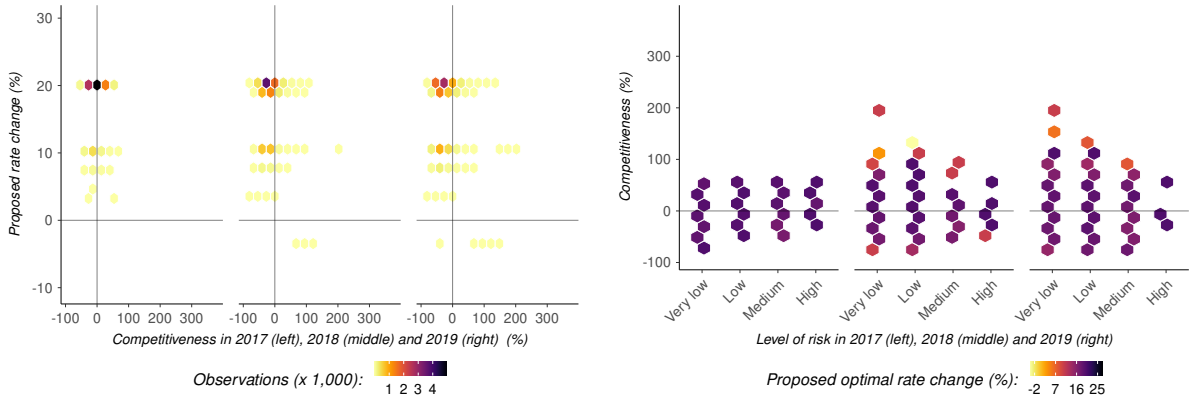


(b) Optimal rate changes over level of risk and competitiveness

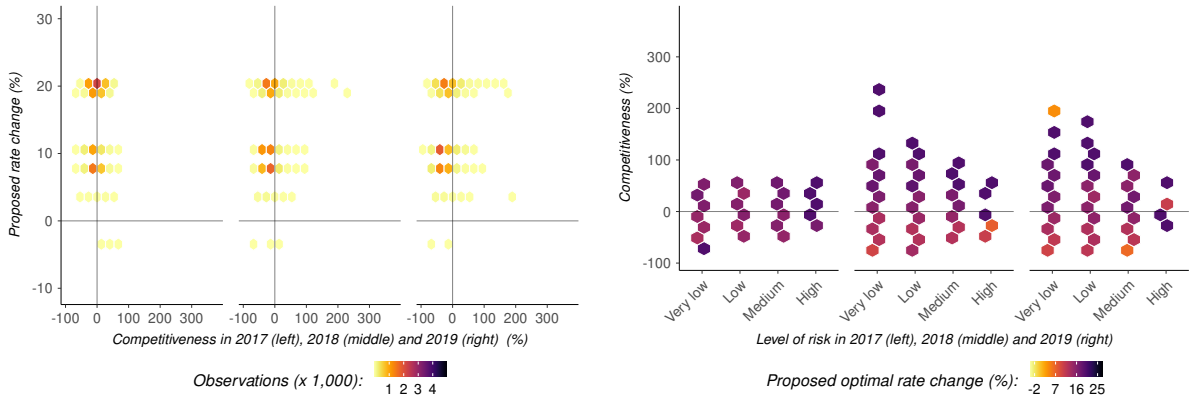
Figure B.4: Optimal rate changes over the competitiveness (panel (a)) jointly with the level of risk (panel (b)) for $\tau = 3$ consecutive renewals with discrete (left) and continuous (right) rate changes in automobile insurance.



(a) Optimal rate changes for discrete global response model without multiple imputation



(b) Optimal rate changes for discrete global response model with XGBoost



(c) Optimal rate changes for restricted continuous dose-response function

Figure B.5: Optimal rate changes over the competitiveness (left) jointly with the level of risk (right) for $\tau = 3$ consecutive renewals with discrete rate changes without multiple imputation (panel (a)) and with XGBoost (panel (b)), and continuous rate changes restricted to the five categorical rate change medians (panel (c)) in automobile insurance.