Annex 11A. Helmet Regulation in Vietnam: Impact on Health and Medical Impoverishment. Tables and Figures

Supplemental material for: Olson, Z., J.A. Staples, C.N. Mock, N.P. Nguyen, A.M. Bachani and others. 2017. "Helmet Regulation in Vietnam: Impact on Health, Equity, and Medical Impoverishment." In *Disease Control Priorities* (third edition): Volume 7, *Injury Prevention and Environmental Health*, edited by C.N Mock, R. Nugent, O. Kobusingye, and K.R. Smith. Washington, DC: World Bank.

Table 11A.1. Parameters Used for the Extended Cost-Effectiveness Analysis (ECEA) of Helmet Policy in Vietnam, with Justification

Parameter	Estimate (Range)	Justification and References
Population of Vietnam	84,221,100	Verguet and others 2013 (Data from 2007)
Pre-policy RTI deaths	12,800	Verguet and others 2015 (Data from 2007)
Pre-policy non-fatal RTIs	445,048	Verguet and others 2015 (Data from 2007)
Proportion of RTI deaths attributable to motorcycles	57.9% (51.3% - 72.7%)	Estimate from a post-policy verbal autopsy study of 1,061 RTI deaths performed in 2008-2009 (Ngo and others 2012). Lower bound from a 2001 community-based survey describing proportion of non-fatal RTI attributable to motorcycles (cited in WHO 2010). Upper bound from a 2004 analysis of that determined 72.7% of 7,915 vehicle collisions involved a motorcycle (cited in Tien and others 2011).
Proportion of non-fatal RTIs attributable to motorcycles	59% (51.3% - 74.8%)	Estimate from a survey circa 2002 (cited in Hung, Stevenson, and Ivers 2006); similar to estimate of proportion of RTI deaths attributable to motorcycles obtained from a post-policy verbal autopsy study of 1,061 RTI deaths performed in 2008-2009 (Ngo and others 2012). Lower bound from a 2001 community-based survey describing proportion of non-fatal RTI attributable to motorcycles (cited in WHO 2010). Upper bound from a 2010 prospective study that found 74.8% of 477 RTI hospital admissions were motorcycle riders (GSO 2010); similar to a 2004 analysis of that determined 72.7% of 7915 vehicle collisions involved a motorcycle (cited in Tien and others 2011).
Proportion of non-fatal motorcycle RTIs with head injury	20.6% (9.5% - 31.7%)	Estimate derived from lower bound: If 9.5% of injured motorcyclists have a head injury during an epoch in which 93% of riders are wearing helmets and the relative risk of head injury comparing helmet users to non-helmet users is 0.31, an epoch in which 30% of riders are wearing helmets is likely to result in 20.6% of injured motorcyclists having head injuries (see Equations S1 and S2). Lower bound from a 2010 post-policy prospective study of 477 RTI

		admissions that found 34 of 357 motorcycle riders reported their head as the principally injured region (Government of Viet Nam 2007). Upper bound derived by adding to the estimate the difference between the estimate and lower bound.
Pre-policy helmet use	29.9% (20% - 40.1%)	Estimate from the weighted average of a 2005 population-based observational survey of 16,560 motorcyclists on 5 road categories (Hung, Stevenson, and Ivers 2006). Lower bound derived by subtracting from the estimate the difference between the upper bound and the estimate. Upper bound from non-weighted observational cross sectional data taken in November 2007 (just prior to full enforcement of the policy) from 110,677 motorcycle riders in 3 provinces (Government of Viet Nam 2007).
Post-policy helmet use	92.5% (82.5% - 97.5%)	Estimate from non-weighted observational cross sectional data taken from 554,781 motorcycle riders in 3 provinces in 2008 - 2011 (Nguyen and others 2013a). Lower bound derived by the arbitrary subtraction of 10% from the estimate. Upper bound derived by the arbitrary addition of 5% to the estimate.
Proportion of incorrectly fastened helmets	22%	Estimate taken from a survey of 377 motorcyclists at Taiwanese petrol-stations who reported a crash while wearing a helmet in the past year (Viet Nam News 2014). Note that only 1.5% of 554,781 motorcycle riders were observed with a completely unfastened helmet in a non-weighted observational cross sectional study of in 3 Vietnamese provinces in 2008 – 2011 (Nguyen and others 2013a), but that anecdotal evidence suggests unfastened or loosely fastened helmets are far more prevalent than that.
Proportion of less safe helmet designs	25%	Estimate derived from the prevalence of half-face, open-face, and cap style helmets acquired in a 2011 cross sectional roadside study in which 582 motorcyclists agreed to provide their helmet for standard quality testing in exchange for a new helmet (Le and Blum 2013) Estimate of 56% of motorcyclists with half-coverage helmets taken from a survey of 377 motorcyclists at Taiwanese petrol-station with a crash while wearing a helmet in the past year (Viet Nam News 2014). Estimate of 88% of

		helmets worn improperly from a newspaper report that describes a survey of over 11,000 people (Viet Nam News, 2014)
Proportion of helmets of substandard quality	81%	Estimate derived from the proportion of helmets failing at least one standard quality test among those acquired in a 2011 cross sectional roadside study in which 582 motorcyclists exchanged their current helmet for a new helmet (Le and Blum 2013).
Average direct acute-care cost of non-fatal RTI with a helmet (US$)	$436 ($366 – $506)	Estimate from a 2010 prospective study of 477 RTI admissions that stratified hospital mean costs by principal injured region and helmet use, converted to US$ (Hoang and others 2008). Lower and upper bounds represent the 95% confidence intervals and were derived from the listed standard deviations (Hoang and others 2008).
Average direct acute-care cost of non-fatal RTI without a helmet (US$)	$559 ($416 - $702)	Estimate from a 2010 prospective study of 477 RTI admissions that stratified hospital mean costs by principal injured region and helmet use, converted to US$. Lower and upper bounds represent the 95% confidence intervals and were derived from the listed standard deviations (Hoang and others 2008).
Change in treatment cost for 10$ change in income	1%	Hoang and others 2008
Income lost	32 weeks	Pham and others 2008
Per capita income distribution by quintile (US$)	$308, $558, $835, $1244, $2847	Nguyen and others 2013b
Motorcycle ownership by income quintile (%)	20%, 35%, 54%, 73%, 94%	General Statistics office (GSO 2010) Used to estimate the burden of motorcycle RTI injury and death within each quintile.
Relative risk of death, helmet versus no helmet	0.58 (0.50 – 0.79)	Point estimate and lower bound are derived using the odds ratio point estimate and lower 95% confidence interval from a 2008 meta-analysis (GSO 2006). Given the low absolute risk of death or injury among motorcycle riders, the odds ratio was assumed to be a reasonable estimate of the relative risk. Upper bound estimated by assuming a 50% relative reduction in population-level helmet effectiveness in the Vietnamese context (see Figure 11A.9).
Relative risk of injury, helmet versus no helmet	0.31 (0.25 – 0.66)	Point estimate and lower bound are derived using the odds ratio point estimate and 95% confidence interval from a 2008 meta-analysis (GSO 2006). Given the low absolute risk of death or injury among motorcycle riders, the odds ratio was assumed to be a reasonable estimate of the relative risk. Upper

		bound estimated by assuming a 50% relative reduction in population-level helmet effectiveness in the Vietnamese context (see Figure 11A.9).
Per capita cost of policy implementation (US$)	$0.29	Liu and others 2008
Pre-policy registered motorcycles	21.2 million	Chisholm and others 2012
Pre-policy registered motorcycles	25.2 million	Chisholm and others 2012
Pre-policy revenue from helmet infringements (US$, millions)	Unknown	No data. Fines US$2-5 per offence.

Table 11A.2 Values Used for the Distributional Sensitivity Analysis[1]

	Income Quintile					Mean	Q5:Q1 Ratio
	I	II	III	IV	V		
Distribution of motorcycle RTI deaths and non-fatal injuries (proportion borne by each income quintile)[2]							
Input for main analysis (severely inequitable)[3]	7%	13%	20%	26%	34%	-	4.6
Moderately inequitable	15%	18%	20%	23%	25%	-	1.7
Perfectly equitable	20%	20%	20%	20%	20%	-	1
Distribution of pre-policy helmet use							
Input for main analysis (mildly inequitable)[4]	24%	27%	30%	33%	36%	30%	1.5
Moderately inequitable	10%	20%	30%	40%	50%	30%	5
Severely inequitable	6%	12%	24%	48%	60%	30%	10
Distribution of post-policy helmet use							
Input for main analysis (perfectly equitable)	93%	93%	93%	93%	93%	93%	1
Mildly inequitable	88%	90%	93%	95%	97%	93%	1.1
Moderately inequitable	84%	88%	93%	97%	100%	93%	1.2

[1] Distributions estimated using plausible values except where specified as having been derived from a specific source.
[2] Values listed here were used to create weights to distribute the total pre-policy motorcycle RTI deaths and injuries among quintiles.
[3] For the main analysis, motorcycle RTI deaths and injuries were assumed to have a distribution among quintiles corresponding to probability of household motorcycle ownership (GSO 2010).
[4] Approximated using the relationship between helmet ownership and income (Ackaah and others 2013).

Table 11A.3 Calculating the Proportion of Non-Fatal Motorcycle RTIs with Head Injury

Symbol	Definition
G_0, G_1	Number of motorcycle crashes resulting in non-fatal injury (pre-intervention, post-intervention)
E_0, E_1	Proportion of motorcycle crash injuries with head injury (pre-intervention, post-intervention)
H_0, H_1	Proportion of motorcycle riders wearing helmets (pre-intervention, post-intervention)
I_0, I_1	Number of head injuries (pre-intervention, post-intervention)
AR_H, AR_{NH}	Absolute risk of head injury (with helmet, without helmet)
RR	Relative risk of injury, helmet vs. no helmet ($RR = AR_H/AR_{NH}$)

Equations 11A.1 & 11A.2

(11A.1)

$$I0 = G_0 \times \mathrm{H0} \times \mathrm{AR}H + G_0 \times (1 - \mathrm{H0}) \times \mathrm{AR}_{NH}$$

$$I0 = G_0 \times \mathrm{H0} \times \mathrm{AR}H + G_0 \times (1 - \mathrm{H0}) \times \frac{\mathrm{AR}_H}{\mathrm{RR}}$$

$$I0 = G_0 \times \mathrm{AR}H \times [\mathrm{H0} + (1 - \mathrm{H0}) \times \frac{1}{\mathrm{RR}}]$$

Similarly

$$I1 = G_1 \times \mathrm{AR}H \times [\mathrm{H1} + (1 - \mathrm{H1}) \times \frac{1}{\mathrm{RR}}]$$

(11A.2) Assuming helmet use reduces the risk of head injury in the event of a crash but has no influence on overall crash risk and no influence on the risk of additional non-fatal injuries to other body parts in the event of a crash (ie $G_0 = G_1$):

$$E_0 = \frac{I_0}{G}$$

$$E_0 = E_1 \times (\frac{I_0}{I_1})$$

$$E_0 = E_1 \times (\frac{[\mathrm{H}_0 + (1 - \mathrm{H}_0) \times \frac{1}{\mathrm{RR}}]}{[\mathrm{H}_1 + (1 - \mathrm{H}_1) \times \frac{1}{\mathrm{RR}}]})$$

Using equations 11A.1 and 11A.2, we are able to estimate the proportion of motorcycle crashes that result in head injury in the pre-policy period. Using the total RTI injuries, the proportion of RTI injuries attributable to motorcycles, and the proportion of motorcycle crashes that result in head injuries allows estimation of I_0.

Table 11A.4 Calculating the Number of Post-Policy Head Injuries

Symbol	Definition
P	Population at risk
H_0, H_1	Helmet use pre-intervention, post-intervention
I_0, I_1	Head injuries pre-intervention, post-intervention
AR_H, AR_{NH}	Absolute risk of injury with helmet, without helmet
RR	Relative risk of injury, helmet vs no helmet ($RR = AR_H/AR_{NH}$)

Equations 11A.3 and 11A.4

(11A.3)

$$I_0 = \mathrm{P} \times \mathrm{H}_0 \times \mathrm{AR}_H + \mathrm{P} \times (1 - \mathrm{H}_0) \times \mathrm{AR}_{NH}$$

$$I_0 = \mathrm{P} \times [\mathrm{H}_0 \times \mathrm{AR}_H + (1 - \mathrm{H}_0) \times \mathrm{AR}_{NH}]$$

$$I_0 = \mathrm{P} \times [\mathrm{H}_0 \times \mathrm{AR}_H + (1 - \mathrm{H}_0) \times \frac{\mathrm{AR}_H}{\mathrm{RR}}]$$

$$\mathrm{AR}_H = I_0 \div \left(\mathrm{P} \times \left[\mathrm{H}_0 + \frac{(1-\mathrm{H}_0)}{\mathrm{RR}}\right]\right)$$

(11A.4)

$$I_1 = \mathrm{P} \times [\mathrm{H}_1 \times \mathrm{AR}_H + (1 - \mathrm{H}_1) \times \mathrm{AR}_{NH}]$$

$$I_1 = \mathrm{P} \times [\mathrm{H}_1 \times \mathrm{AR}_H + (1 - \mathrm{H}_1) \times \frac{\mathrm{AR}_H}{\mathrm{RR}}]$$

$$I_1 = \mathrm{P} \times \mathrm{AR}_H \times [\mathrm{H}_1 + \frac{(1-\mathrm{H}_1)}{\mathrm{RR}}]$$

$$I_1 = \mathrm{P} \times [\frac{I_0}{\left(\mathrm{P}\times\left[\mathrm{H}_0+\frac{(1-\mathrm{H}_0)}{\mathrm{RR}}\right]\right)}] \times [\mathrm{H}_1 + \frac{(1-\mathrm{H}_1)}{\mathrm{RR}}]$$

$$I_1 = [\frac{I_0}{\left(\left[\mathrm{H}_0+\frac{(1-\mathrm{H}_0)}{\mathrm{RR}}\right]\right)}] \times [\mathrm{H}_1 + \frac{(1-\mathrm{H}_1)}{\mathrm{RR}}]$$

Using equations 11A.3 and 11A.4, we are able to estimate the number of head injuries in the post-policy period.

Table 11A.5 Calculating Costs Averted and Financial Risk Protection

Symbol	Definition
I_0, I_1	Number of head injuries (pre-intervention, post-intervention)
⍰0,⍰1	*Proportion of riders wearing helmets* *(pre-intervention, post-intervention)*
D_0, D_1	Number of deaths (pre-intervention, post-intervention)
C_0, C_1	Average treatment cost (pre-intervention, post-intervention)
C_H, C_{NH}	Cost of injury (helmet, no helmet)
P	Population
n	Simulated number of individuals
y	Average Income
L	Poverty Line
FRP_P, FRP_C	Financial risk protection (Cases of poverty averted, catastrophic health expenditures averted)
I_0, I_1	Number of head injuries (pre-intervention, post-intervention)
H_0, H_1	Proportion of riders wearing helmets (pre-intervention, post-intervention)

Equations 11A.5 and 11A.6

(11A.5)

$$C_{0,1} = C_H \times H_{0,1} + C_{NH} \times (1 - H_{0,1})$$

$$OOP\ Direct\ Acute\ Care\ Costs\ Averted = C_0 \times I_0 - C_1 \times I_1$$

(11A.6)

$$FRP_P = \left(I_0 \times \frac{\sum_{i=1}^{P} \begin{cases} 1\ if\ y - C_0 < L \\ 0\ if\ y - C_0 > L \\ 0\ if\ y < L \end{cases}}{P} \right) - \left(I_1 \times \frac{\sum_{i=1}^{P} \begin{cases} 1\ if\ y - C_1 < L \\ 0\ if\ y - C_1 > L \\ 0\ if\ y < L \end{cases}}{P} \right)$$

$$FRP_C = \left(I_0 \times \frac{\sum_{i=1}^{P} \begin{cases} 1\ if\ .25 \times y < C_0 \\ 0\ if\ .25 \times y > C_0 \end{cases}}{P} \right) - \left(I_1 \times \frac{\sum_{i=1}^{P} \begin{cases} 1\ if\ .25 \times y < C_1 \\ 0\ if\ .25 \times y > C_1 \end{cases}}{P} \right)$$

Using equations 11A.5 and 11A.6 we are able to quantify the change in income and thus catastrophic expenditure from motorcycle accidents.

Table 11A.6 Estimating the Influence of Poor Quality and Inadequately Fastened Helmets

	Standard Helmets	Poor Quality and Inadequately Fastened Helmets (estimates)
Injury		
Relative Risk	0.31	0.66
Relative Risk Reduction	0.69	0.35
Death		
Relative Risk	0.58	0.79
Relative Risk Reduction	0.42	0.21

Yu and colleagues performed a case-control study in Taiwan to estimate the influence of improper use on helmet efficacy ("Policy struggle to identify substandard helmets 2014). Compared to non-helmeted motorcyclists, helmeted motorcyclists were less likely to have head injuries (odds ratio 0.22). Compared to motorcyclists wearing full-coverage helmets, those with half-coverage helmets were about twice as likely to have head injuries (odds ratio 2.57). Compared to motorcyclists with appropriately fastened helmets, those with loosely or unfastened helmets were also about twice as likely to have head injuries (odds ratio 1.94).

In Vietnam in 2007, we estimate that 80% of helmets were substandard, 25% had less safe designs (half-head, open-faced, or cap style), and 21.5% were inadequately applied or secured ("Policy struggle to identify substandard helmets 2014; Le and Blum 2013). These deficiencies are not mutually exclusive and may co-exist in any given helmet.

To estimate the influence of substandard and improperly applied helmets on the results of our simulation, we assumed that Vietnamese helmets, on average, provided half the relative risk reduction of helmets in high-income countries (See Table 11A.2). The resulting values were used as in the univariate sensitivity analysis that varied the relative risk describing the efficacy of helmets.

Figure 11A.1 Sensitivity of Deaths Averted to Univariate Model Inputs

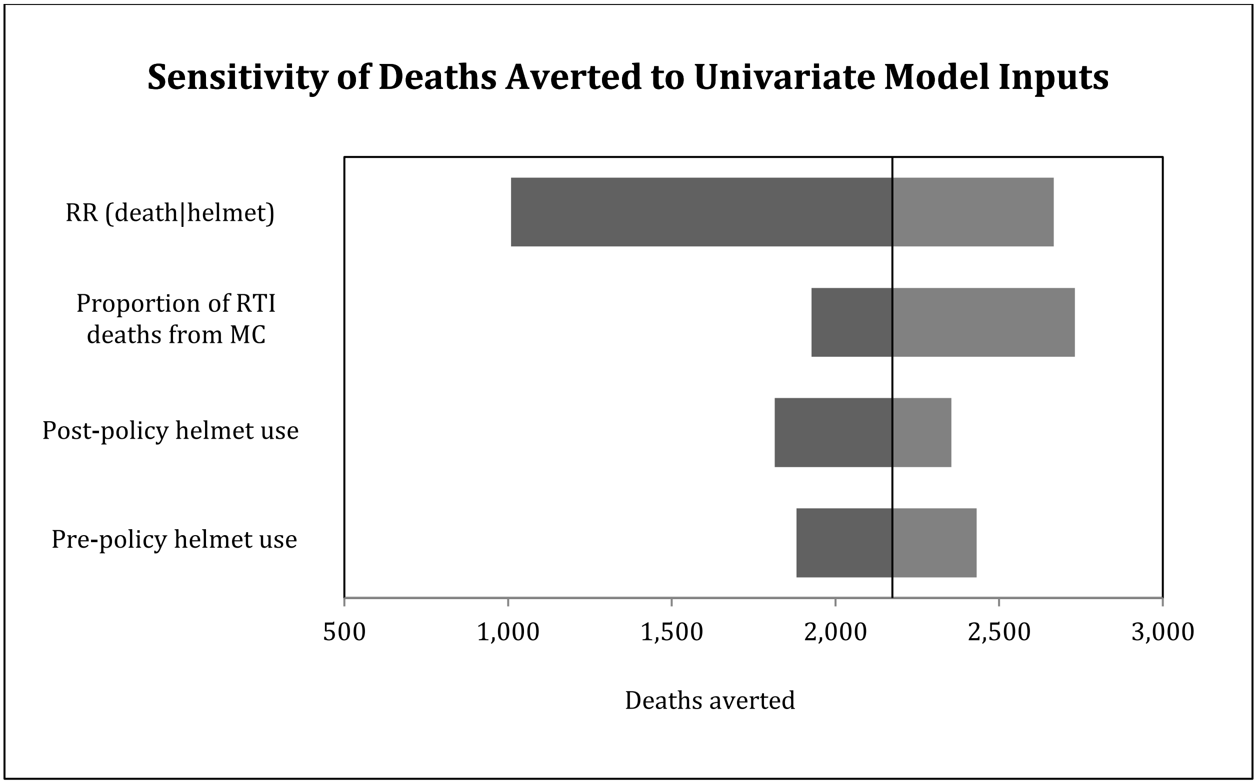


Figure 11A.2 Sensitivity of Injuries Averted to Univariate Model Inputs

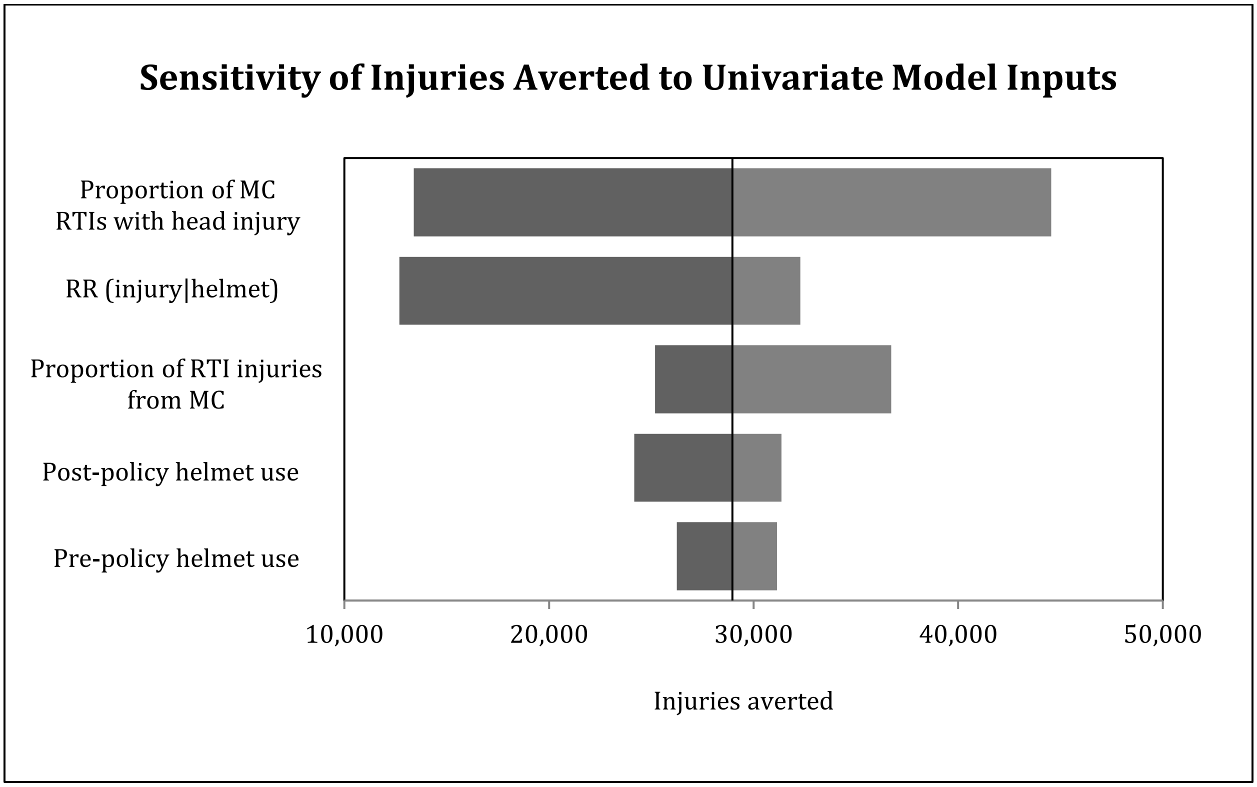


Figure 11A.3 Sensitivity of Direct Acute-Care Costs Averted to Univariate Model Inputs

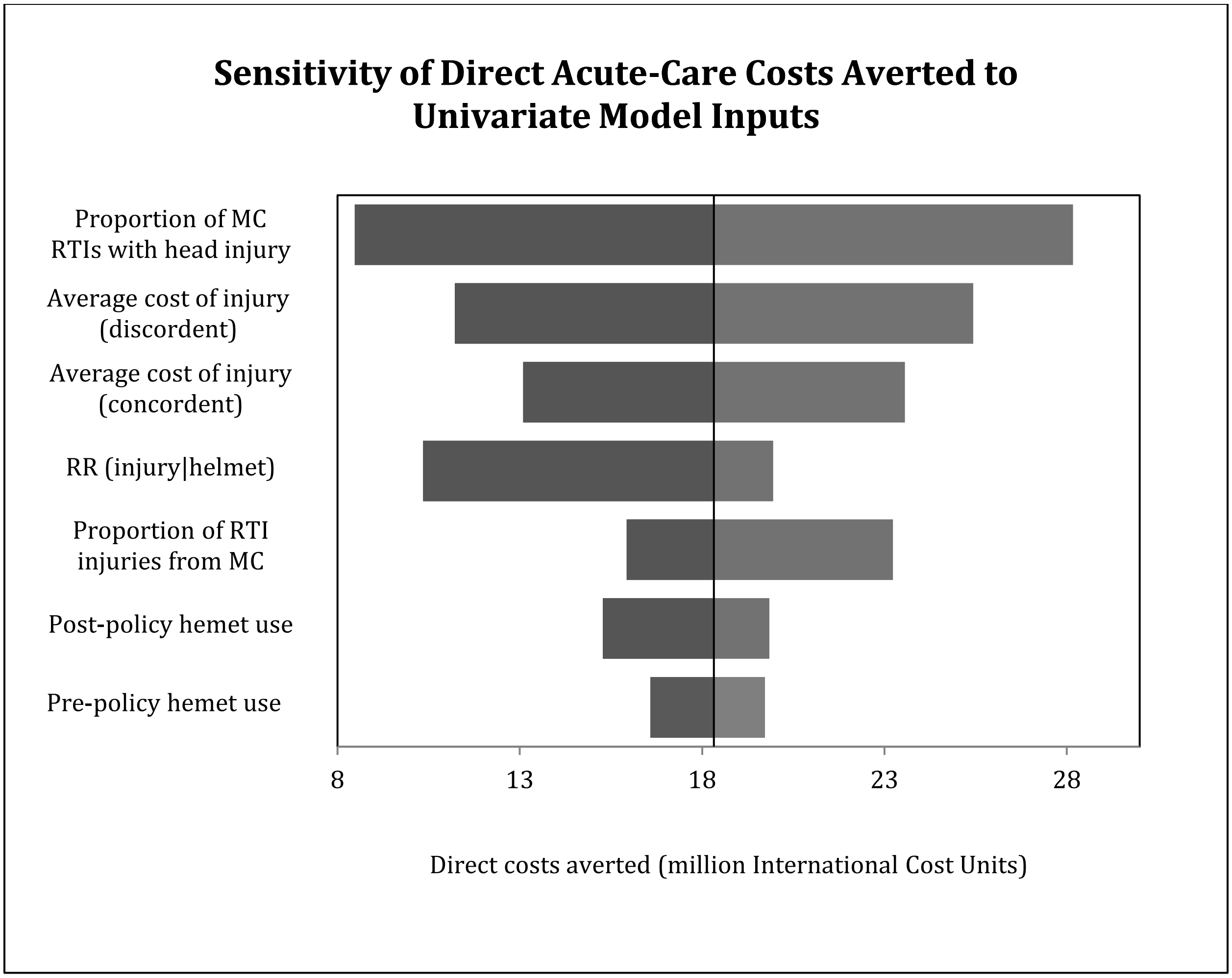


Figure 11A.4 Sensitivity of Cases of Poverty Averted to Univariate Model Inputs

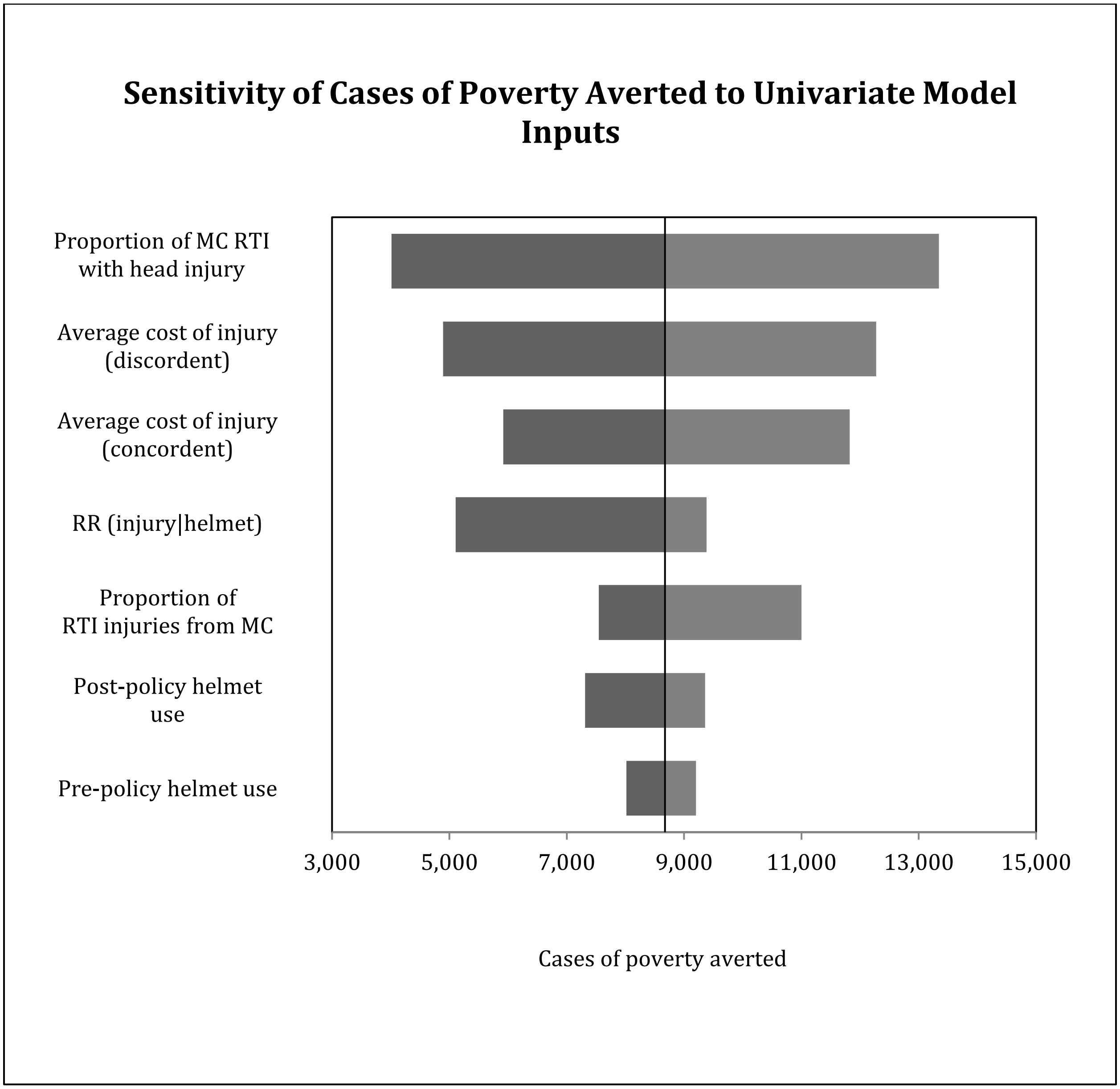


Figure 11A.5 Sensitivity of Catastrophic Health Expenditures Averted to Univariate Model Inputs

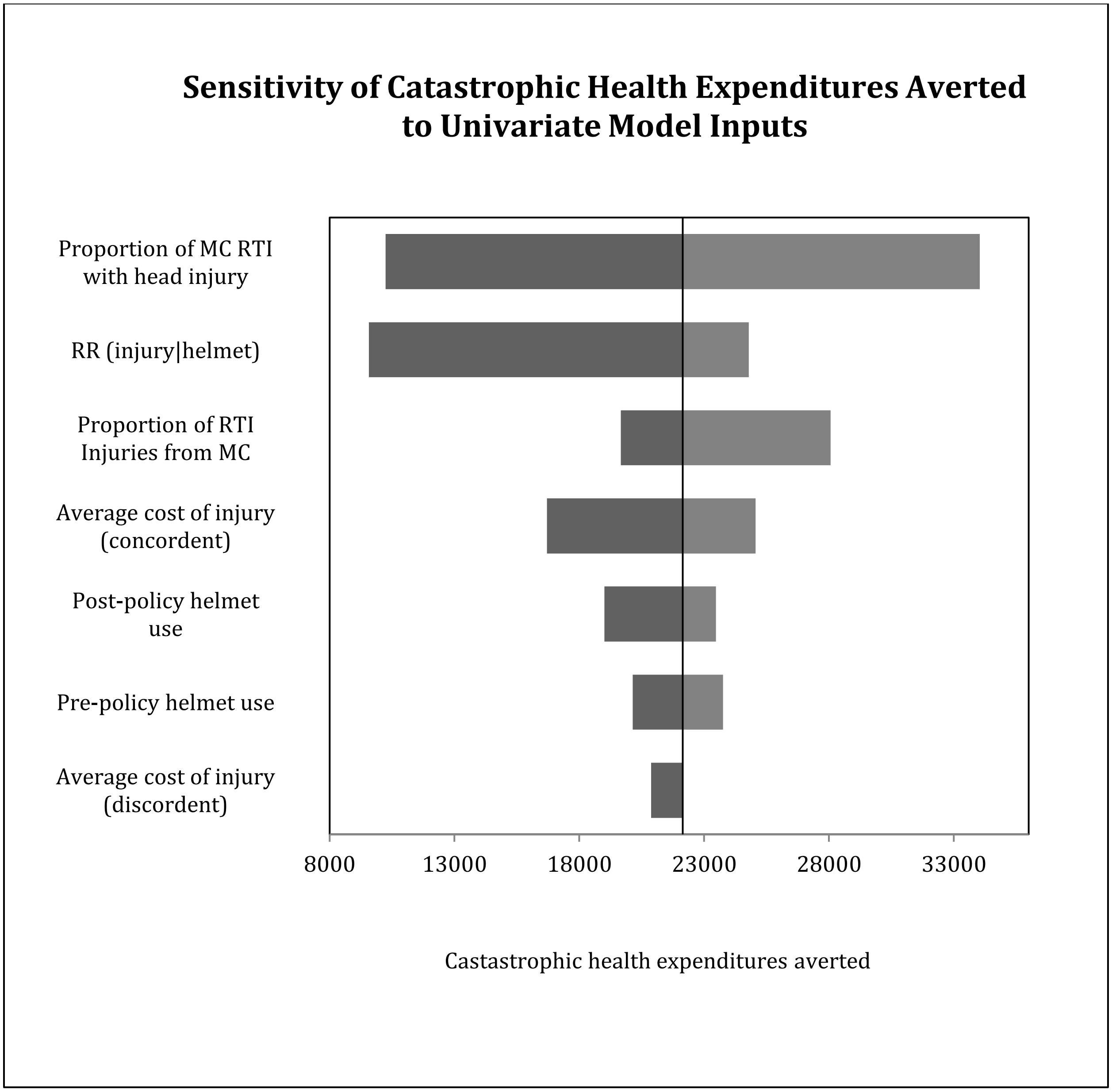
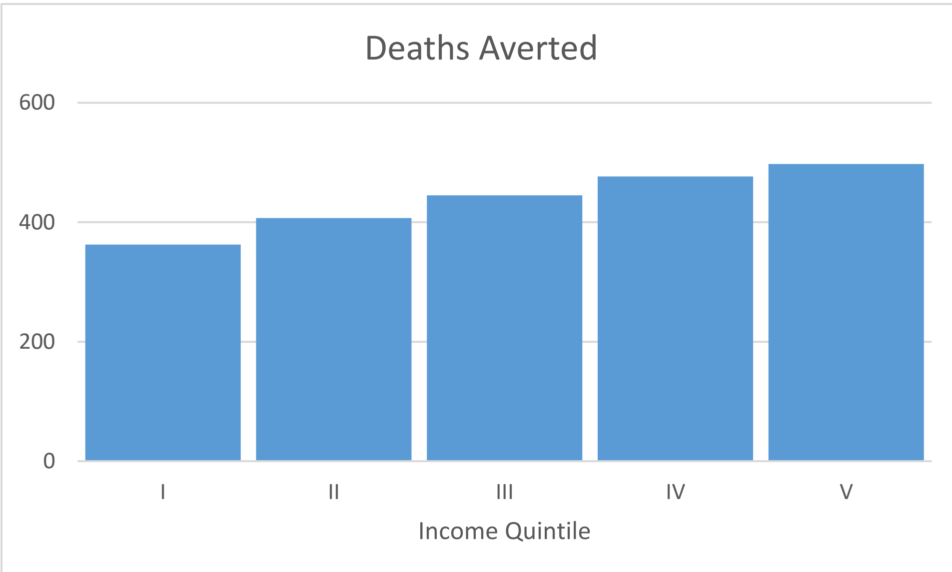


Figure 11A.6 Sensitivity Analysis Assuming Perfectly Equitable Motorcycle use Across Quintiles (I being poorest, V being richest).

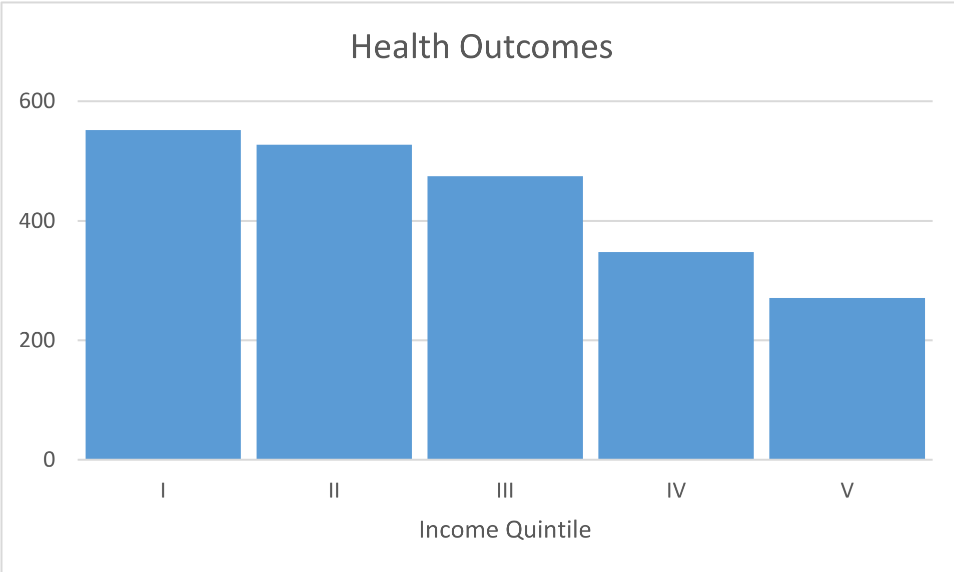
Note: See Table 11A.2 for moderately inequitable assumptions.

Figure 11A.7 Sensitivity Analysis Assuming Moderately Inequitable Motorcycle use, Moderately Inequitable Pre-Policy Helmet Use, and Moderately Inequitable Post-Policy Helmet use Across Quintiles. (I being poorest, V being richest).



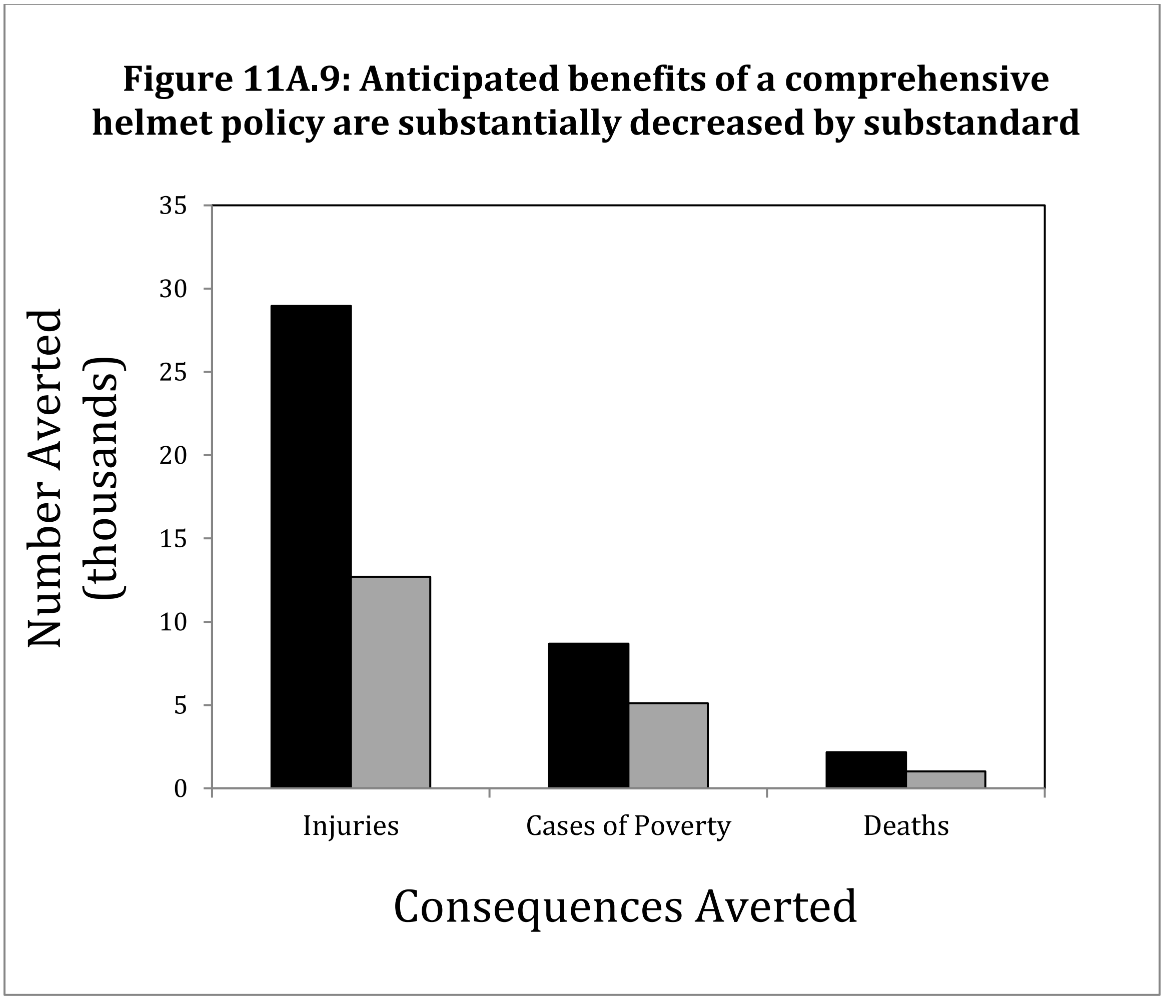
Note: See Table 11A.2 for moderately inequitable assumptions.

Figure 11A.8 Sensitivity Analysis Assuming Perfectly Equitable Motorcycle use, Severely Inequitable Pre-Policy Helmet Use, and Perfectly Equitable Post-Policy Helmet use Across Quintiles (I being poorest, V being richest).



Note: See Table 11A.2 for moderately inequitable assumptions.

Figure 11A.9 Anticipated Benefits of a Comprehensive Helmet Policy when Substantially Decreased by Substandard Helmets



Note: Simulation results from the main analysis shown in black. Simulation results from the sensitivity analysis assuming population-level helmet effectiveness reduced by the proliferation of substandard helmets shown in grey. Anticipated benefits from the comprehensive helmet policy are substantially decreased by substandard helmets.

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