NORTHWESTERN UNIVERSITY
TRANSPORTATION CENTER

Leon N. Moses Distinguished
Lecture in Transportation

The Economics of Transportation Safety

Ian Savage

Leon N. Moses 1924-2013

1950s	PhD Harvard, 1952 Harvard Economic Research project Northwestern University, 1959	Input-Output Analysis Transportation and industrial location
1960s		
1970s		
1980s		
1990s		
2000s		

Leon N. Moses 1924-2013

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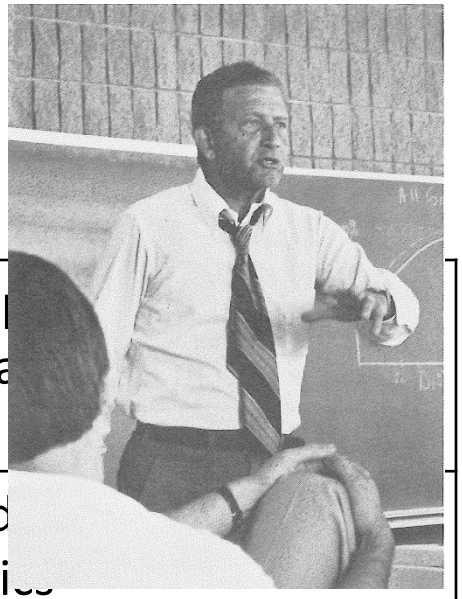
1960s	NUTC Director of Research 1960-64	Urban and regional economics Inland waterways study 65-70
1970s		
1980s		
1990s		
2000s		

Leon N. Moses 1924-2013



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1960s	NUTC Director of Research 1960-64	Urban and economi Inland waterways study 65-70
1970s	Chair, Dept of Economics 1970-72 President, Regional Science Assoc, 1972 NUTC Director 1974-79	Urban area structure Production in time and space 5 deregulation conferences
1980s		
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2000s		

Leon N. Moses

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1970s	Chair, Dept of Economic President, Regional Science Assoc, 1972 NUTC Director 1974-79	Production in time and space 5 deregulation conferences
1980s		Deregulation and safety
1990s		HazMat transportation Truck safety
2000s	Retires, 2005	

"The risks of bodily harm are not unreasonable when consumers understand that risks exist, can appraise their probability and severity, know how to cope with them and voluntarily accept them to get benefits that could not be obtained in less risky ways“

Corwin D. Edwards

National Commission on Product Safety

Final Report (1970)

Part 1

What are the risks?

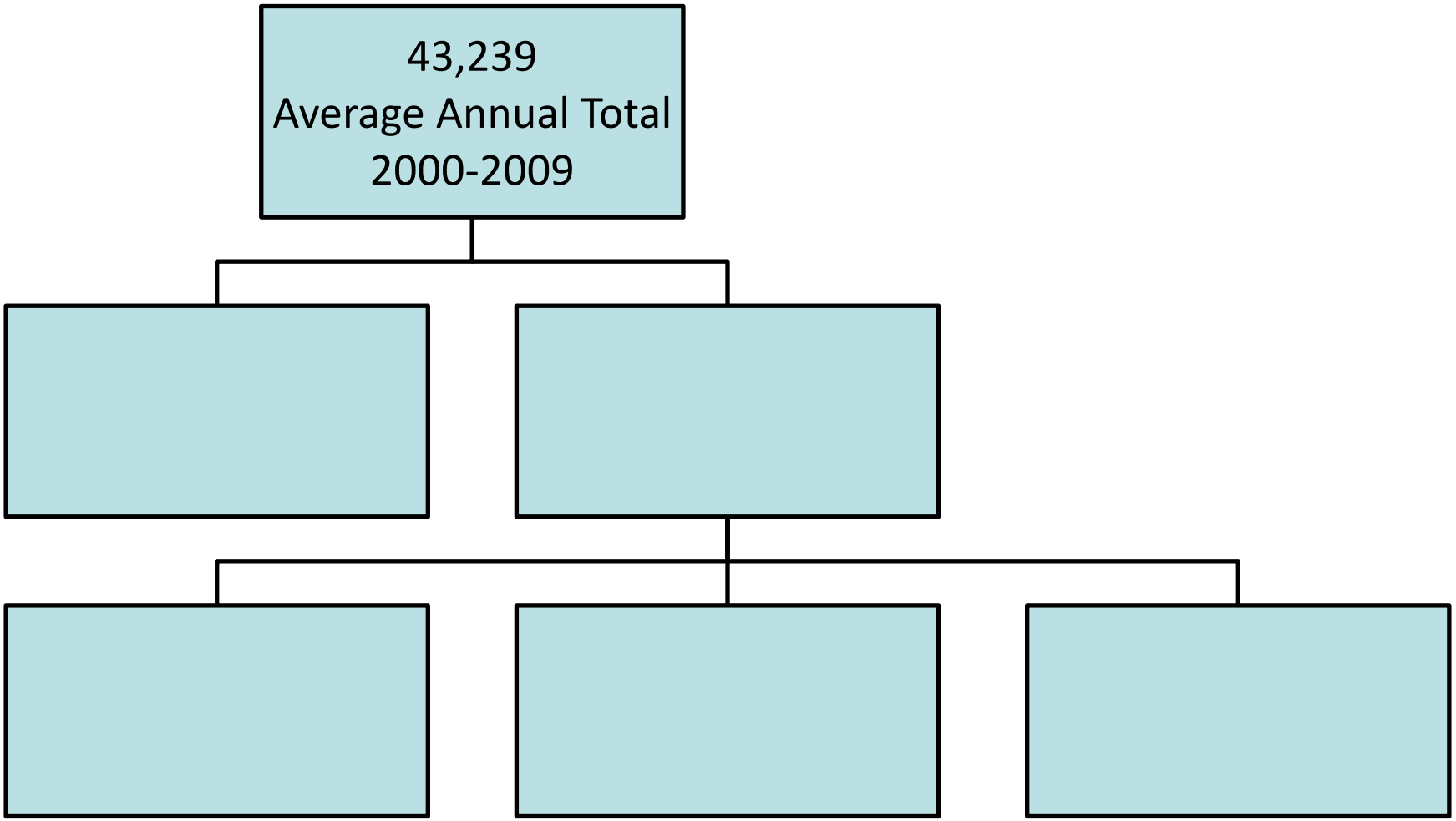
Clean up your language

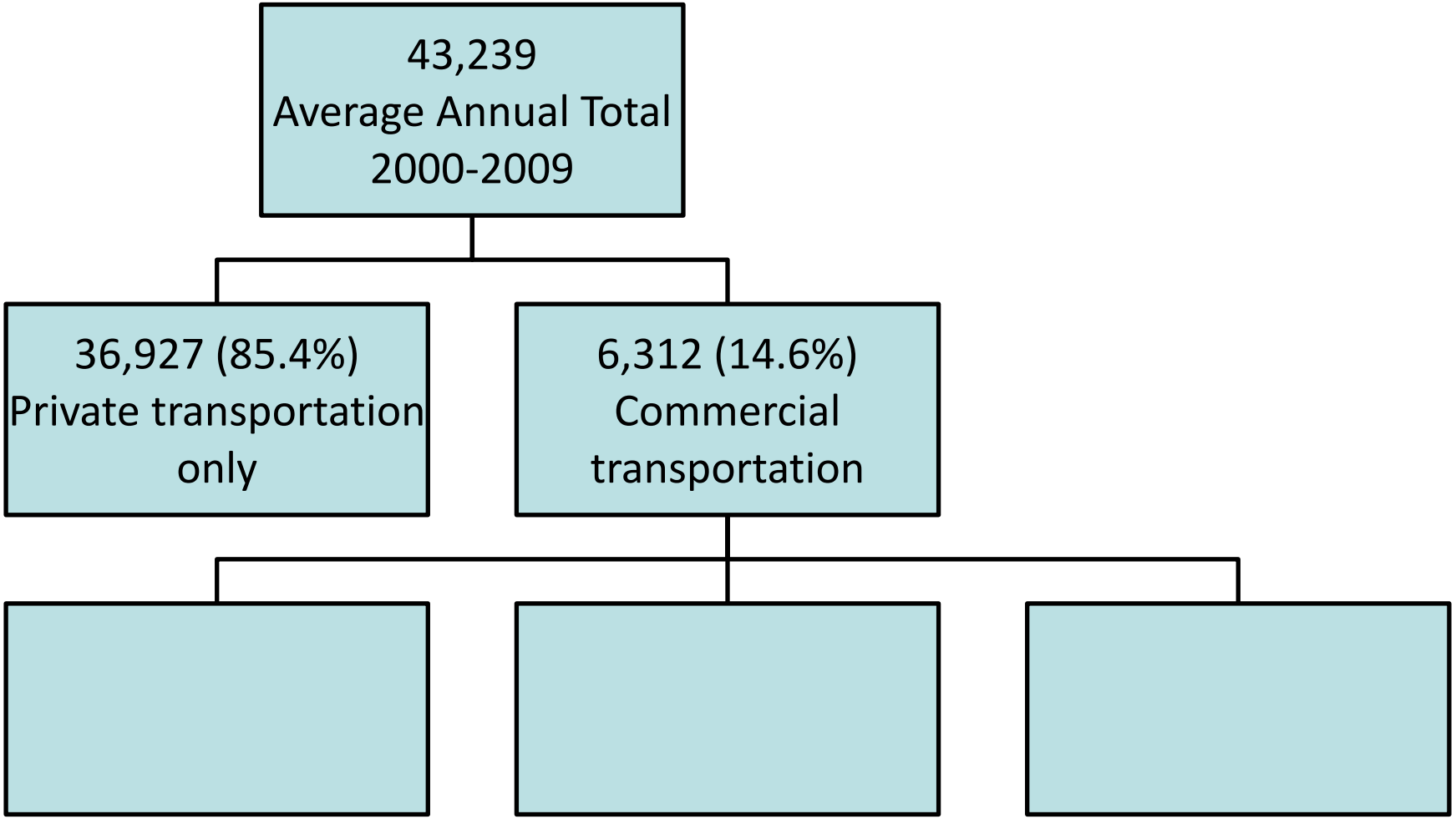
Accidents Crashes

Incidents

Magnitude of the risk

- Transportation related fatalities are 1 in every 56 deaths in the United States (average over period 2000-2009)
- But are 38% of all “unintentional injury deaths”
- Equivalent to the sum of the 2nd and 3rd most prevalent causes (falls and poisonings)
- Over the 2000-09 decade annual average fatalities were 43,239

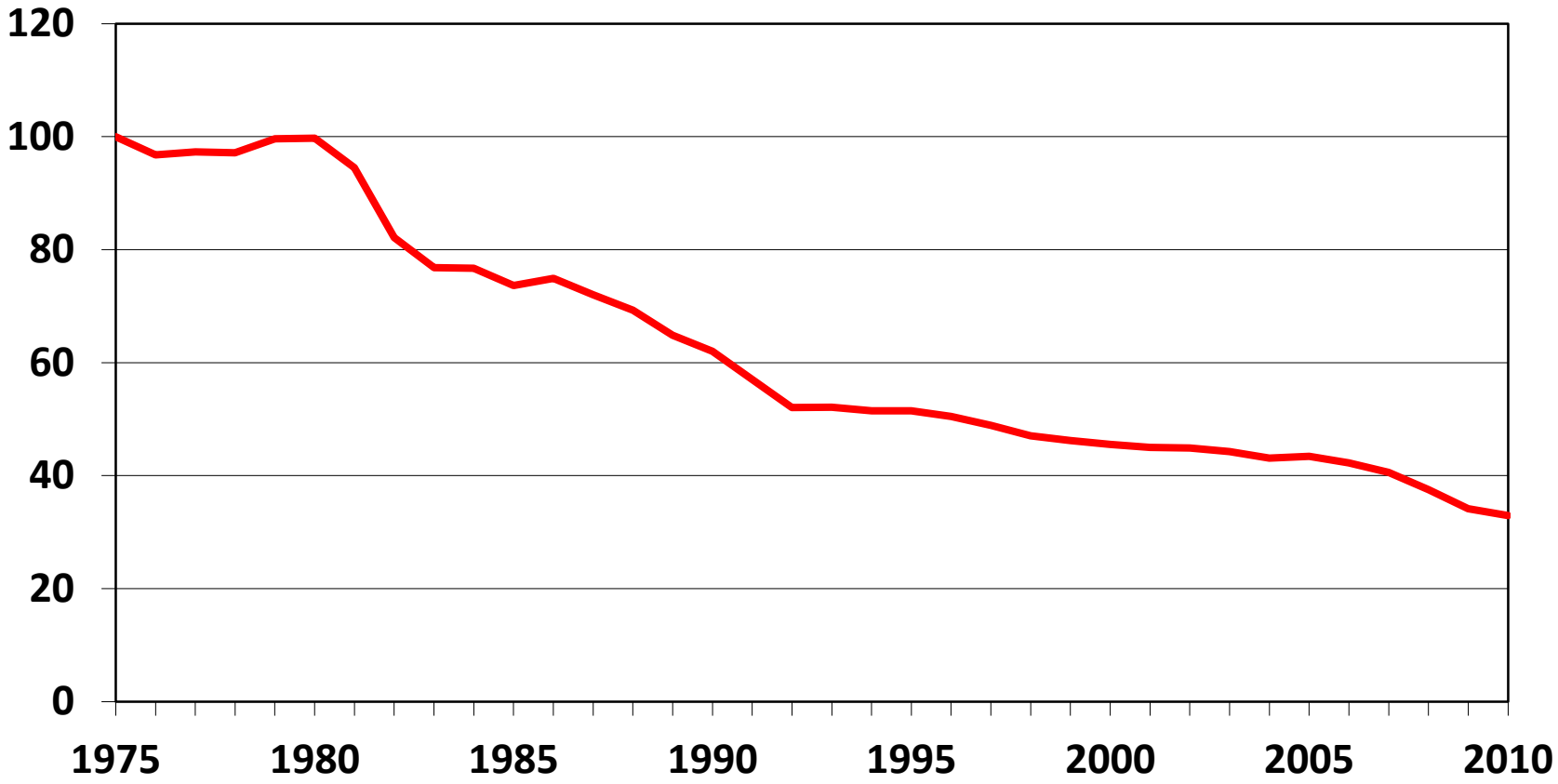

43,239
Average Annual Total
2000-2009


43,239
Average Annual Total
2000-2009
36,927 (85.4%)
Private transportation only
6,312 (14.6%)
Commercial transportation

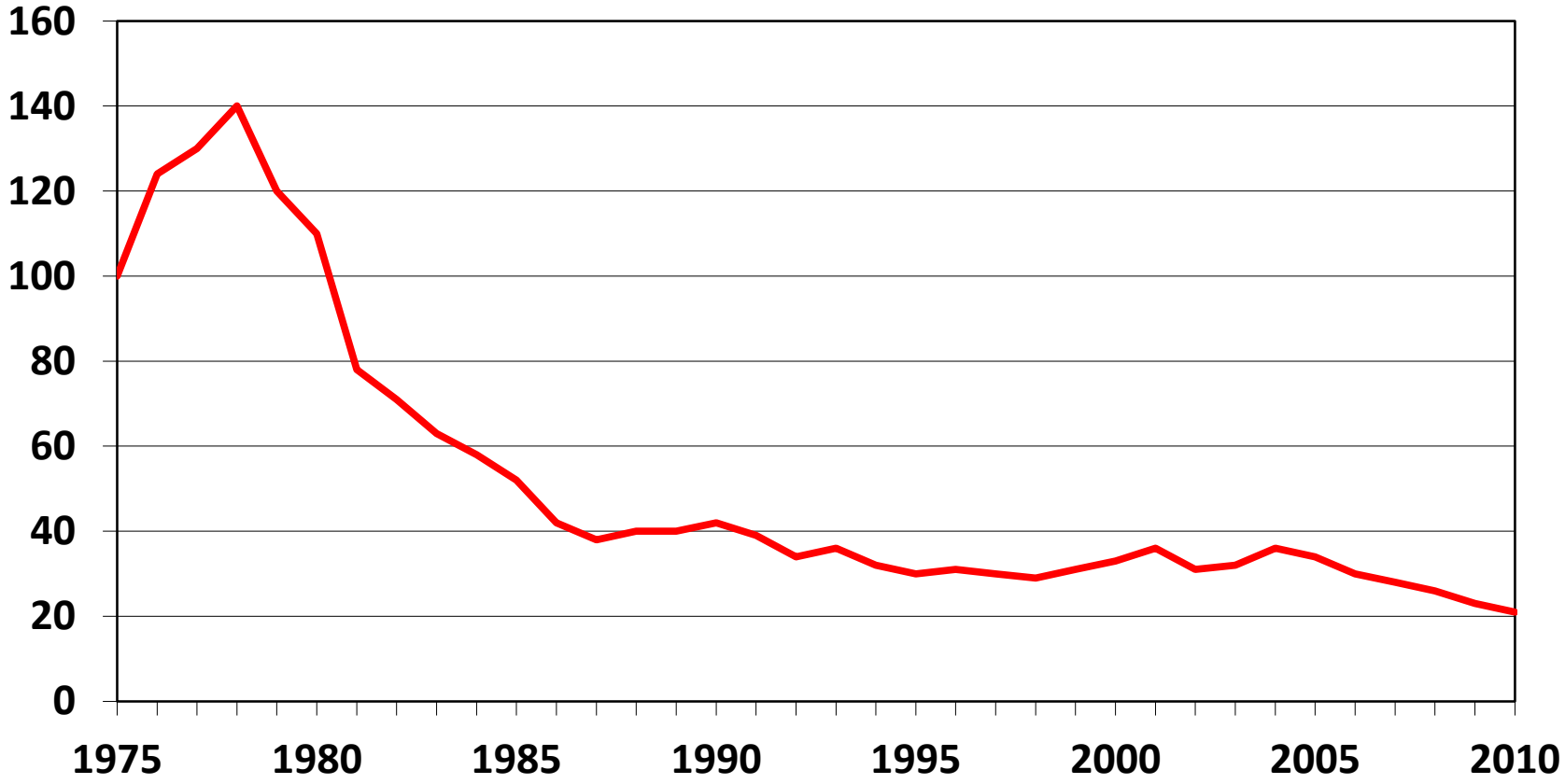
Passenger fatalities per billion passenger miles 2000-09

Riding a motorcycle	212.57
Driving or passenger in car and light truck	7.28
Passenger on a local ferry boat	3.17
Passenger on commuter rail and Amtrak	0.43
Passenger on urban mass transit rail	0.24
Passenger on a bus (holding more than 10 passengers – transit, intercity, school, charter)	0.11
Passenger on commercial aviation	0.07

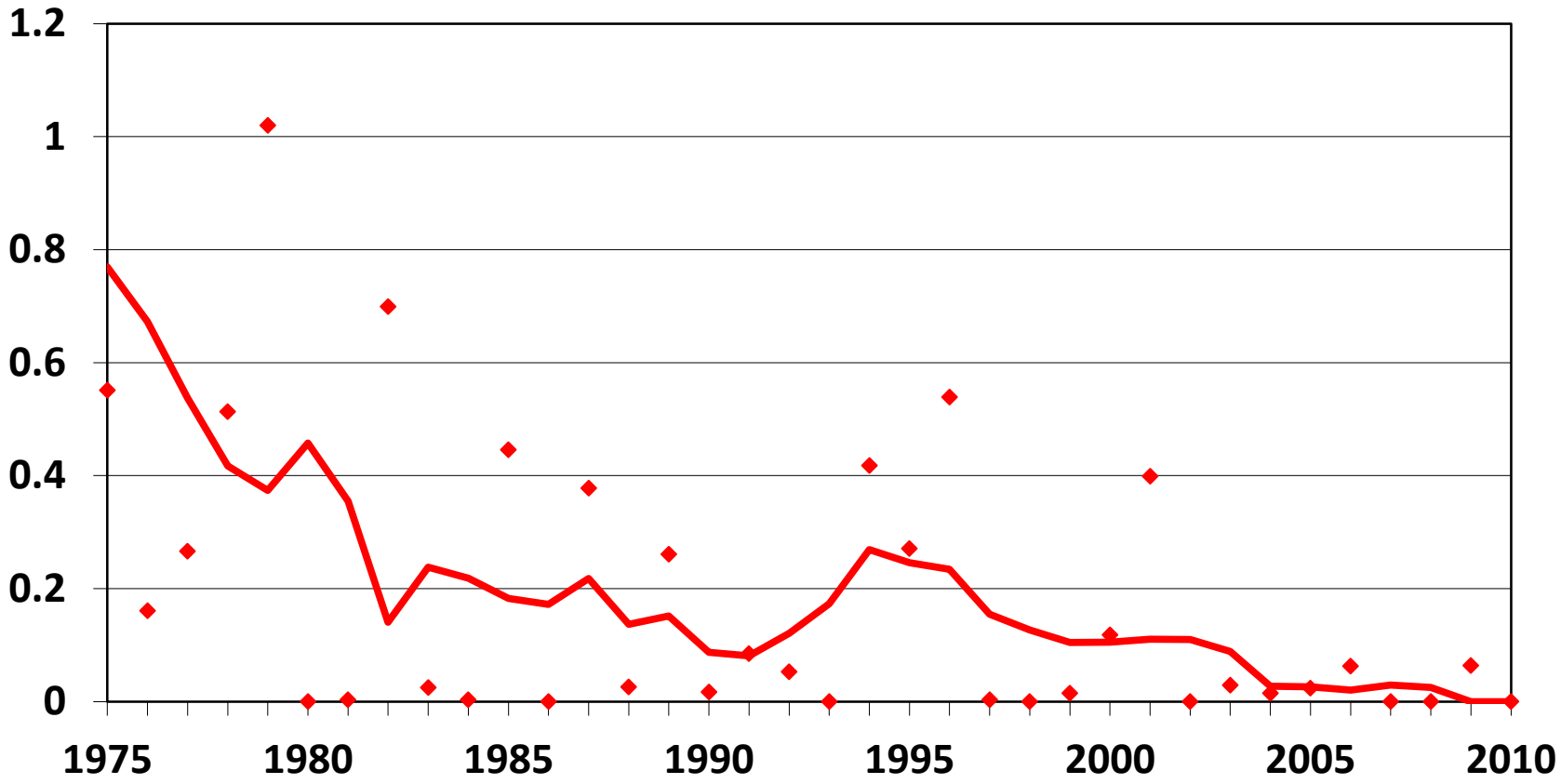
Highway fatalities per vehicle mile (index with 1975=100)

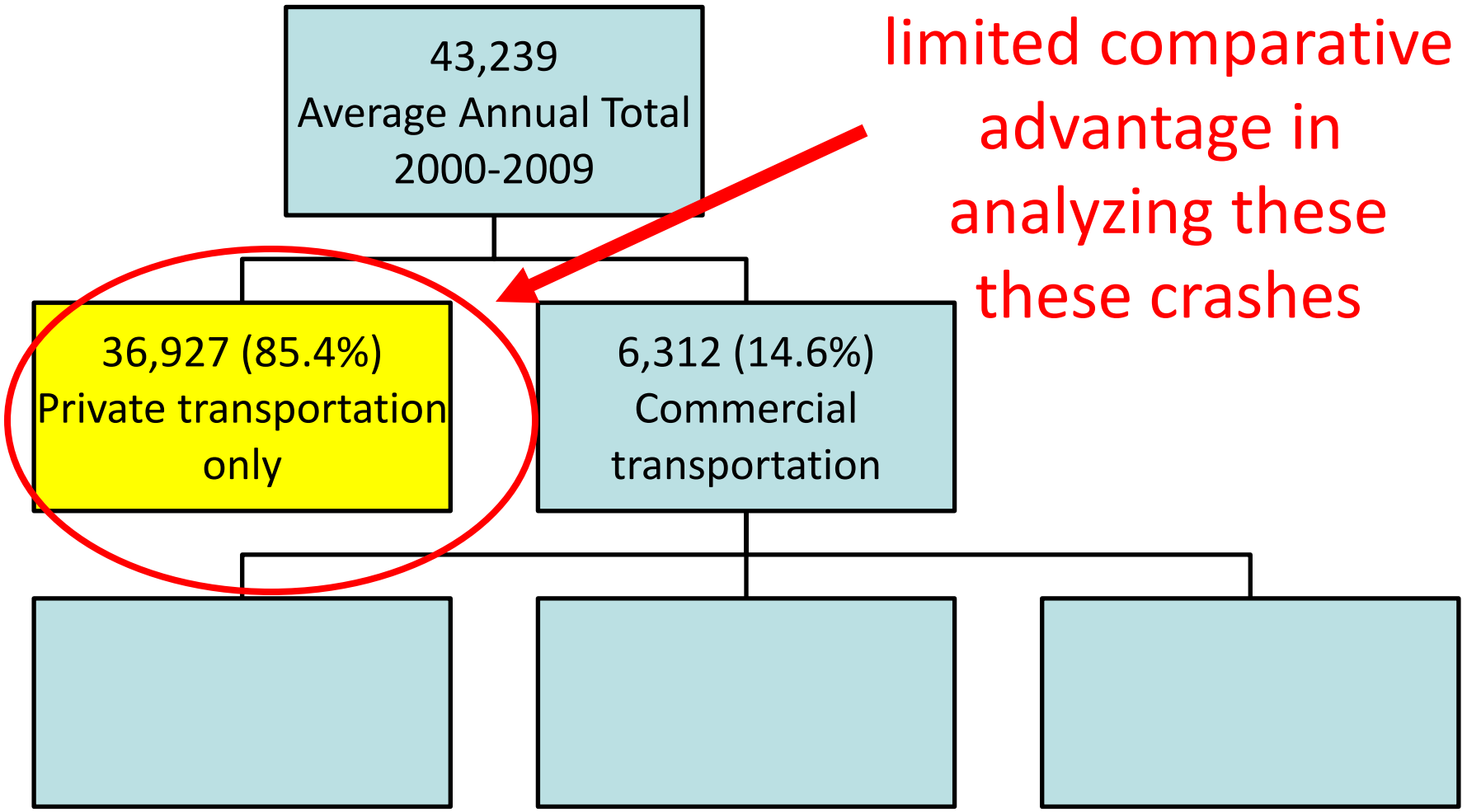


Railroad collisions and derailments per train mile (index with 1975=100)



Commercial aviation passenger fatalities per million enplanements (with 5yr m.a.)

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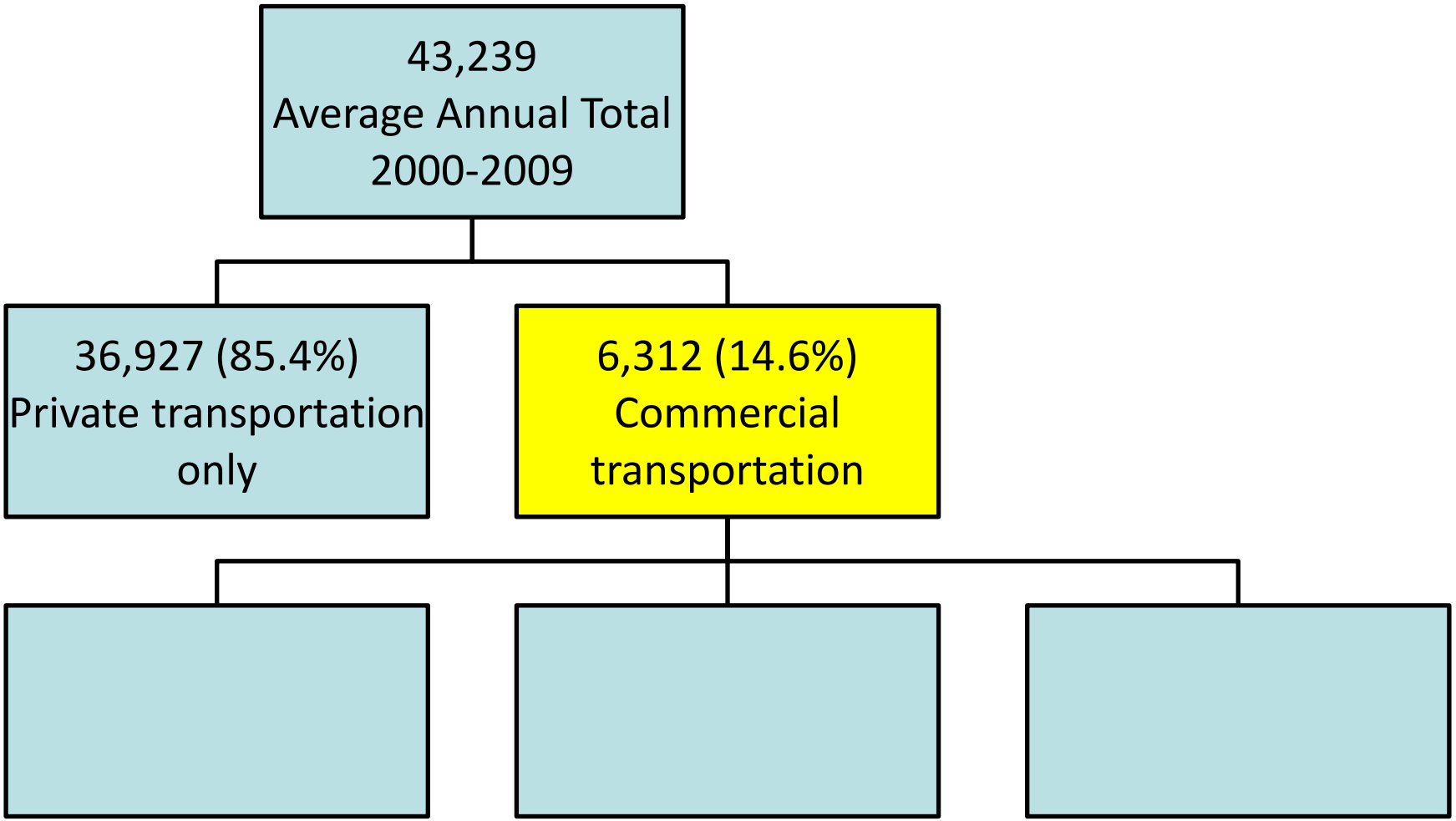
Economists have limited comparative advantage in analyzing these these crashes

1. 55% of occupant-fatalities in single-vehicle crashes
2. 30% of occupant-fatalities are passengers
3. 10% of fatalities are motorcyclists
4. Third of fatal crashes involve alcohol
5. Elevated risk for men in general (3 X), and those under the age of 24 (2 X)
6. Human frailties such as inattention, cognitive overload and poor judgment abound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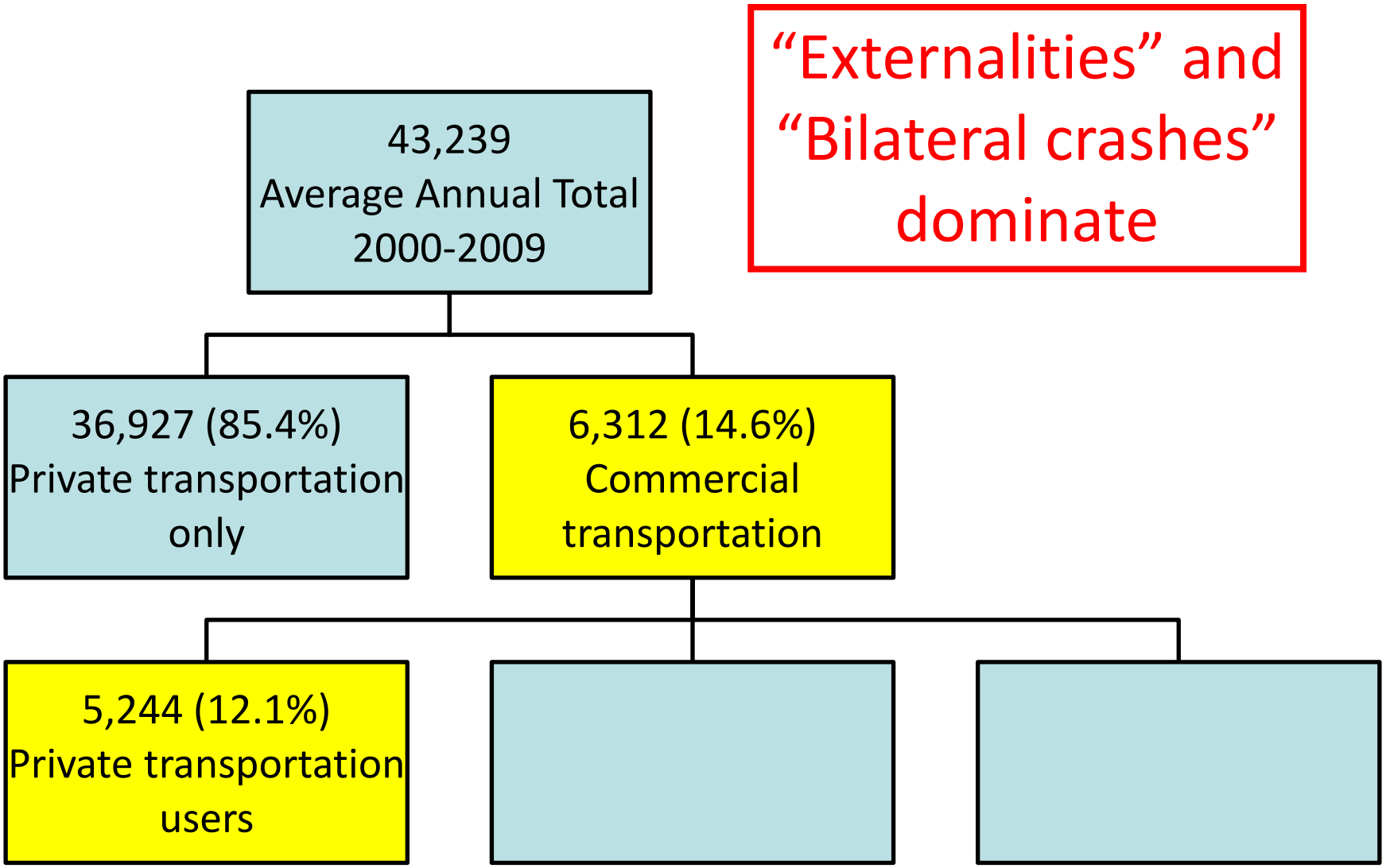
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Average Annual Total
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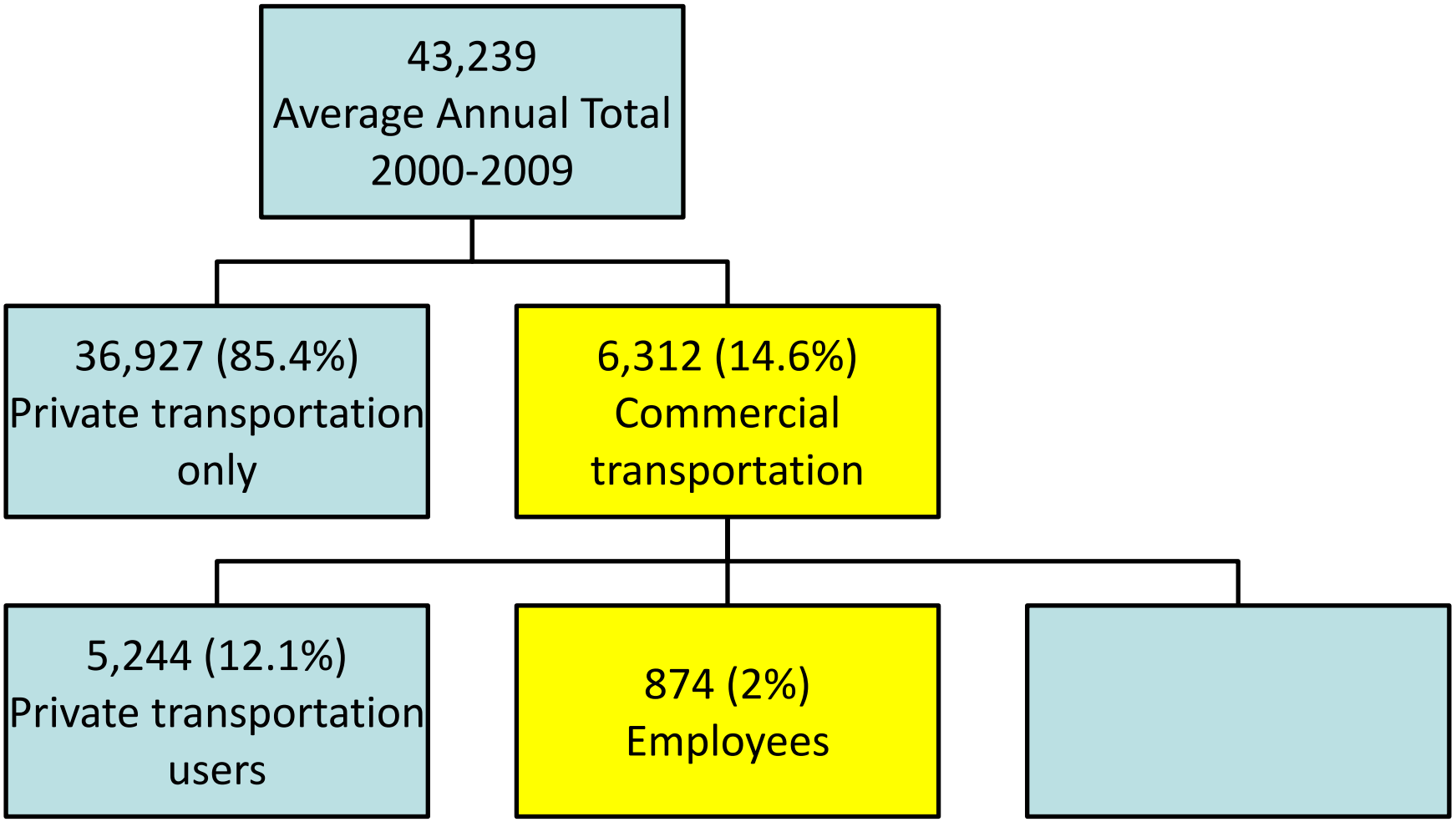
Commercial transportation
5,244 (12.1%)
Private transportation users
"Externalities" and "Bilateral crashes" dominate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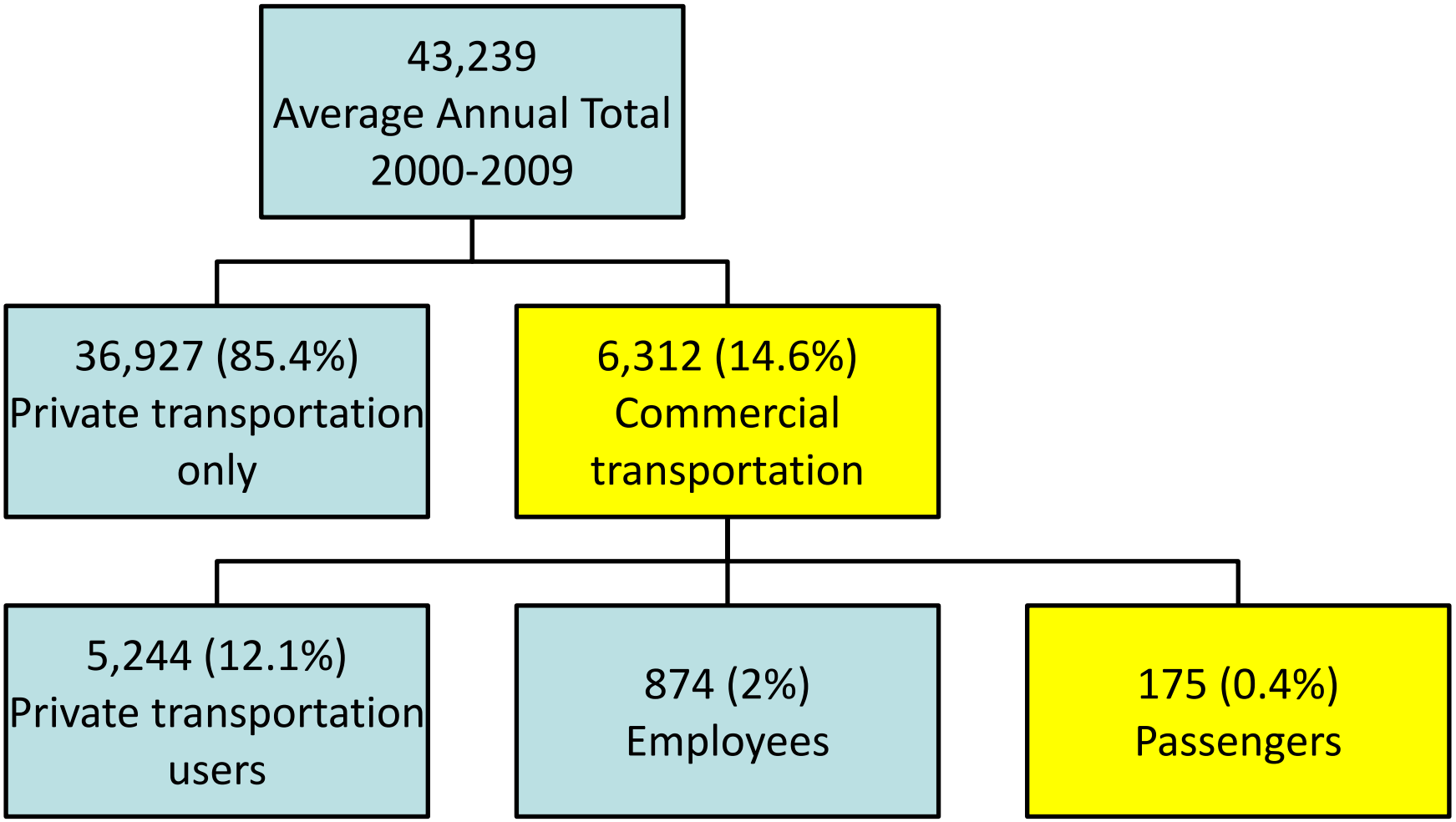
Private transportation
users
874 (2%)
Employees

Rates per 1,000 Employees 2009

	Fatality	Non-fatal Injury
Fishing	8.81	15
Agriculture	*0.76*	*53*
Taxi and limousine	0.62	37
Truck transportation	0.29	57
Water transportation	0.24	33
Construction	*0.12*	*47*
Pipeline transportation	0.10	15
Rail transportation	0.06	23
Air transportation	0.06	71
Utilities	*0.03*	*31*
Bus transportation	0.03	33-48
Manufacturing	*0.03*	*50*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Private transportation only
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Commercial transportation
5,244 (12.1%)
Private transportation users
874 (2%)
Employees
175 (0.4%)
Passengers

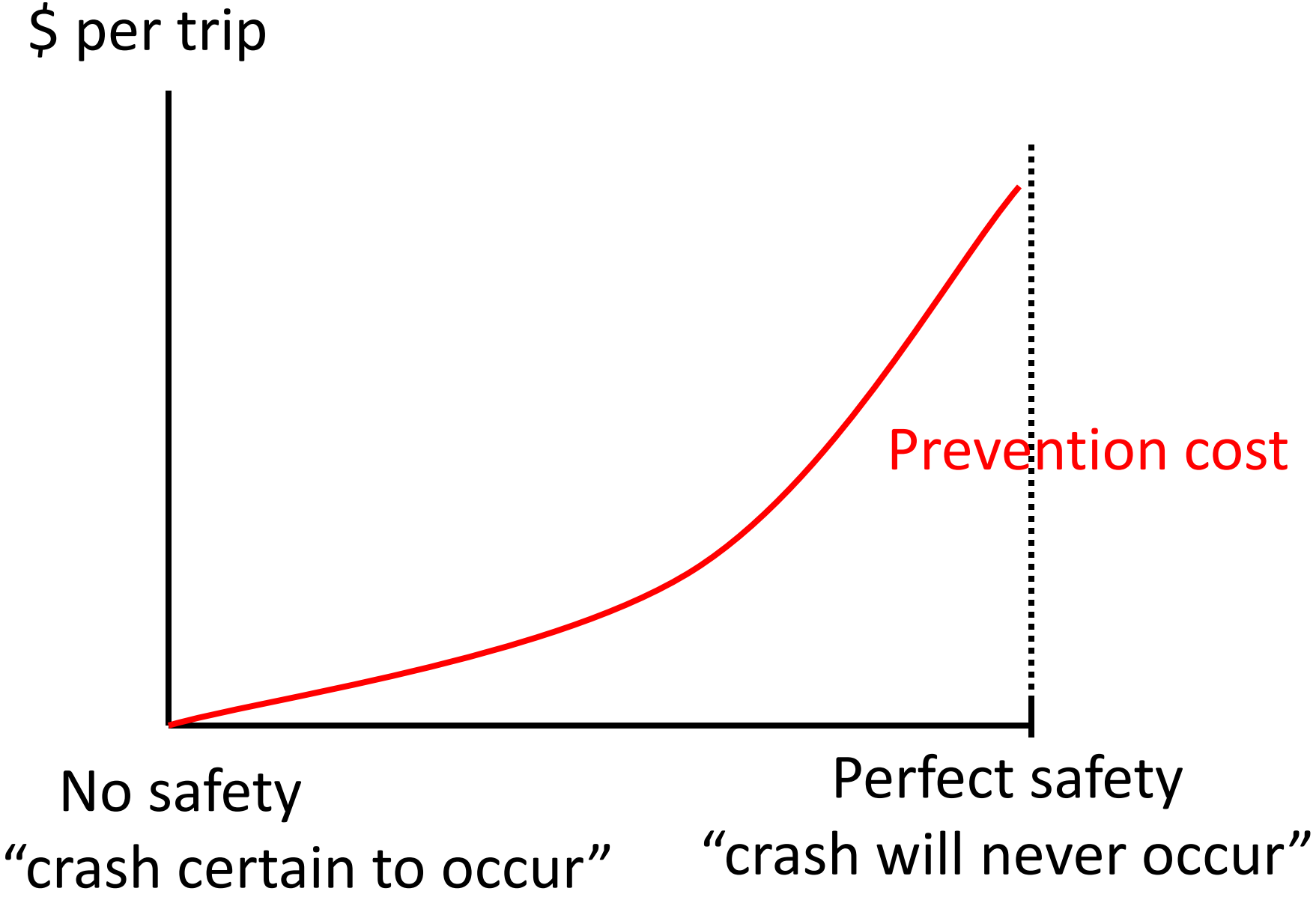
Part 2

How much safety?, or
How safe is “safe enough”?

$ per trip

No safety
"crash certain to occur"

Perfect safety
"crash will never occur"


$ per trip
Prevention cost
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Air New Zealand Flight 901, November 28, 1979

Chief Inspector of air accidents blamed the pilots

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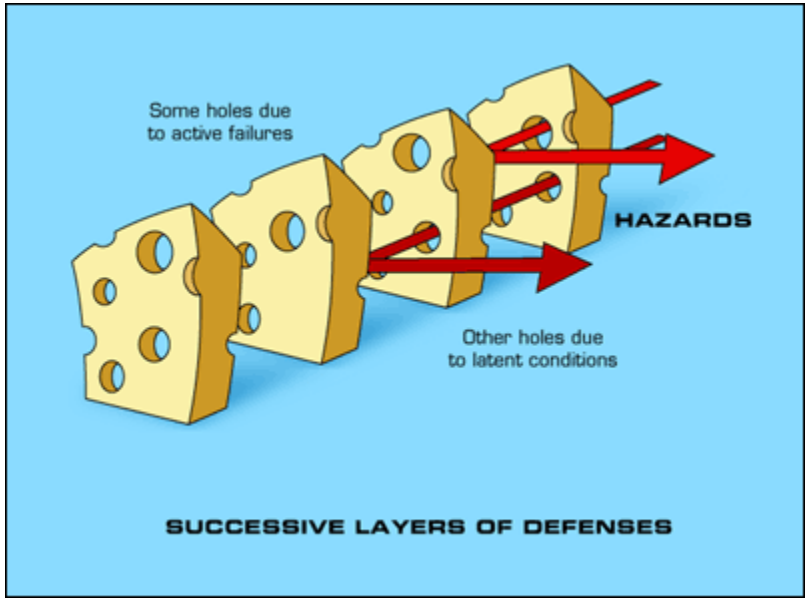
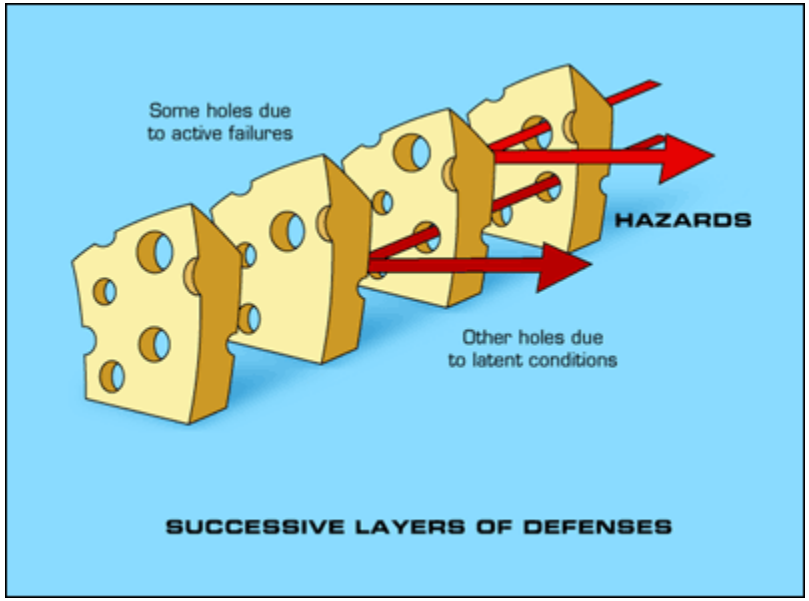
Royal Commission of Inquiry by Justice Peter Mahon accusing Air NZ management of a cover-up and conspiracy and "an orchestrated litany of lies"

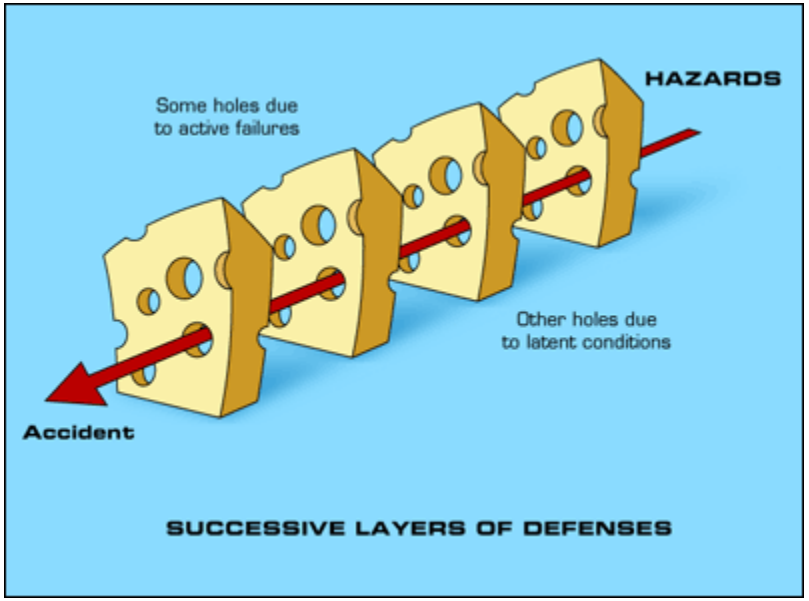
James T. Reason

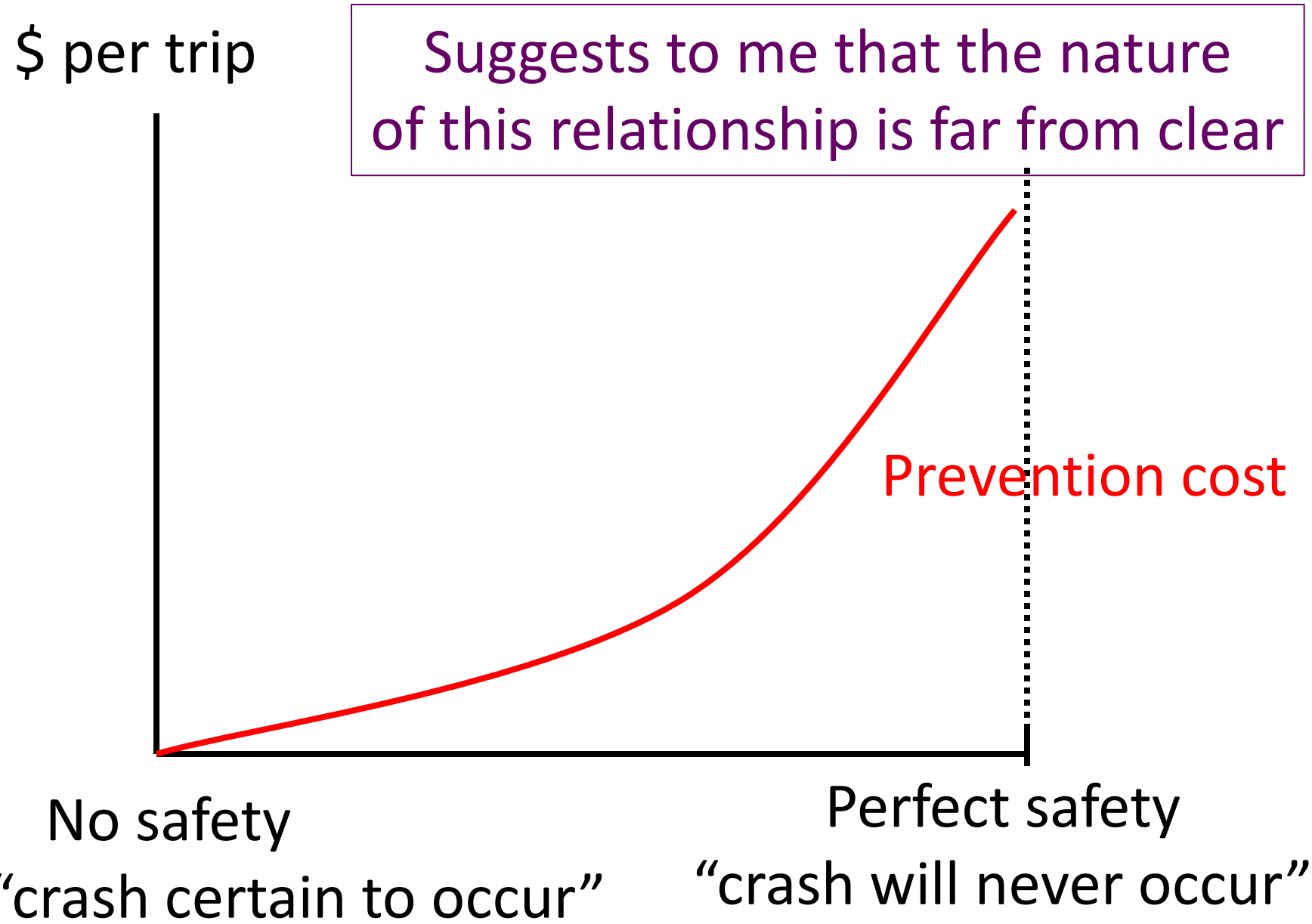


- Professor of Psychology, University of Manchester
- Daniel Maurino, James Reason, Neil Johnson and Rob Lee *Beyond Aviation Human Factors: Safety in High Technology Systems* (Ashgate, 1995)

“Swiss cheese theory”






$ per trip
Suggests to me that the nature of this relationship is far from clear
Prevention cost
No safety
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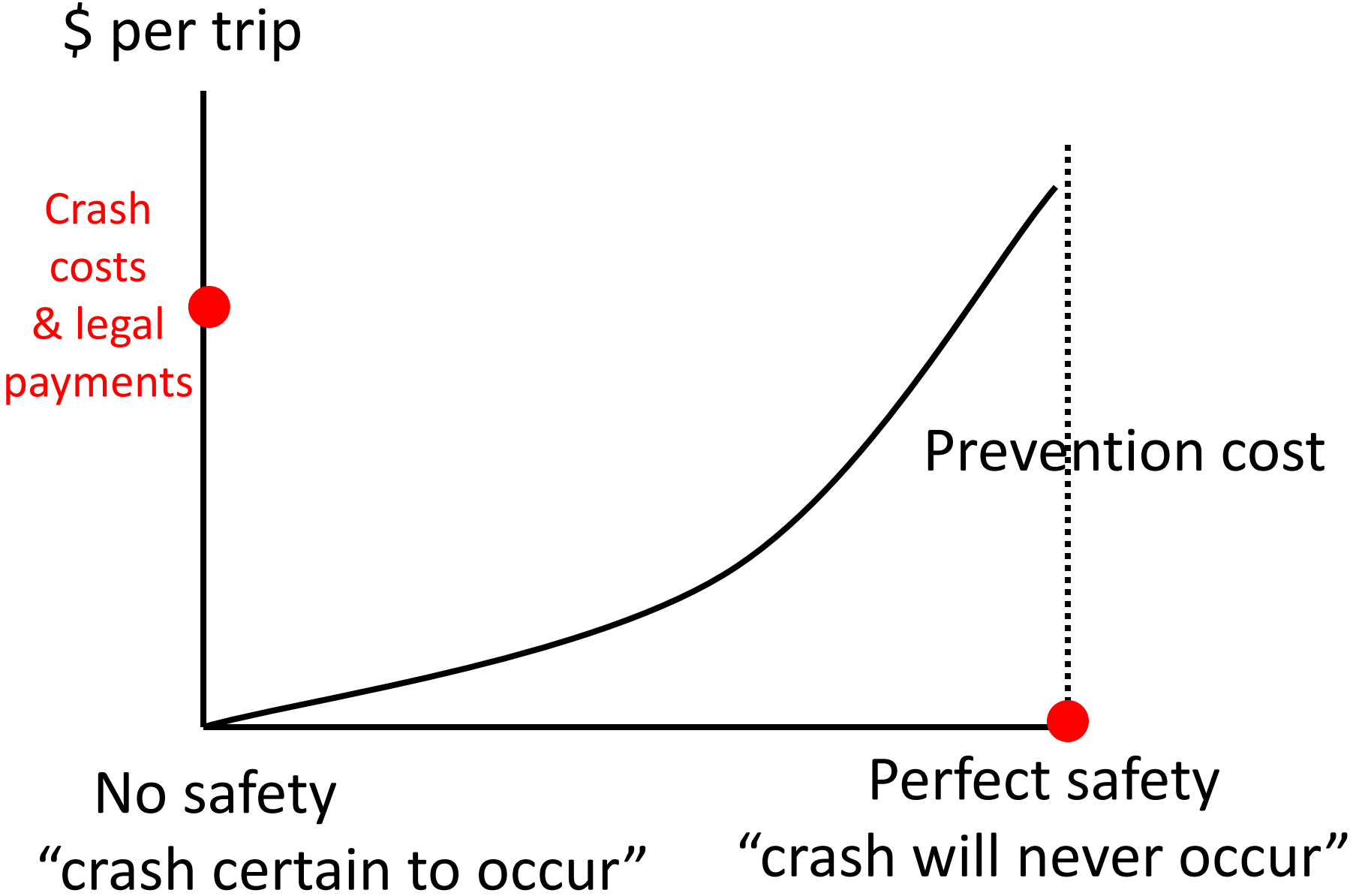
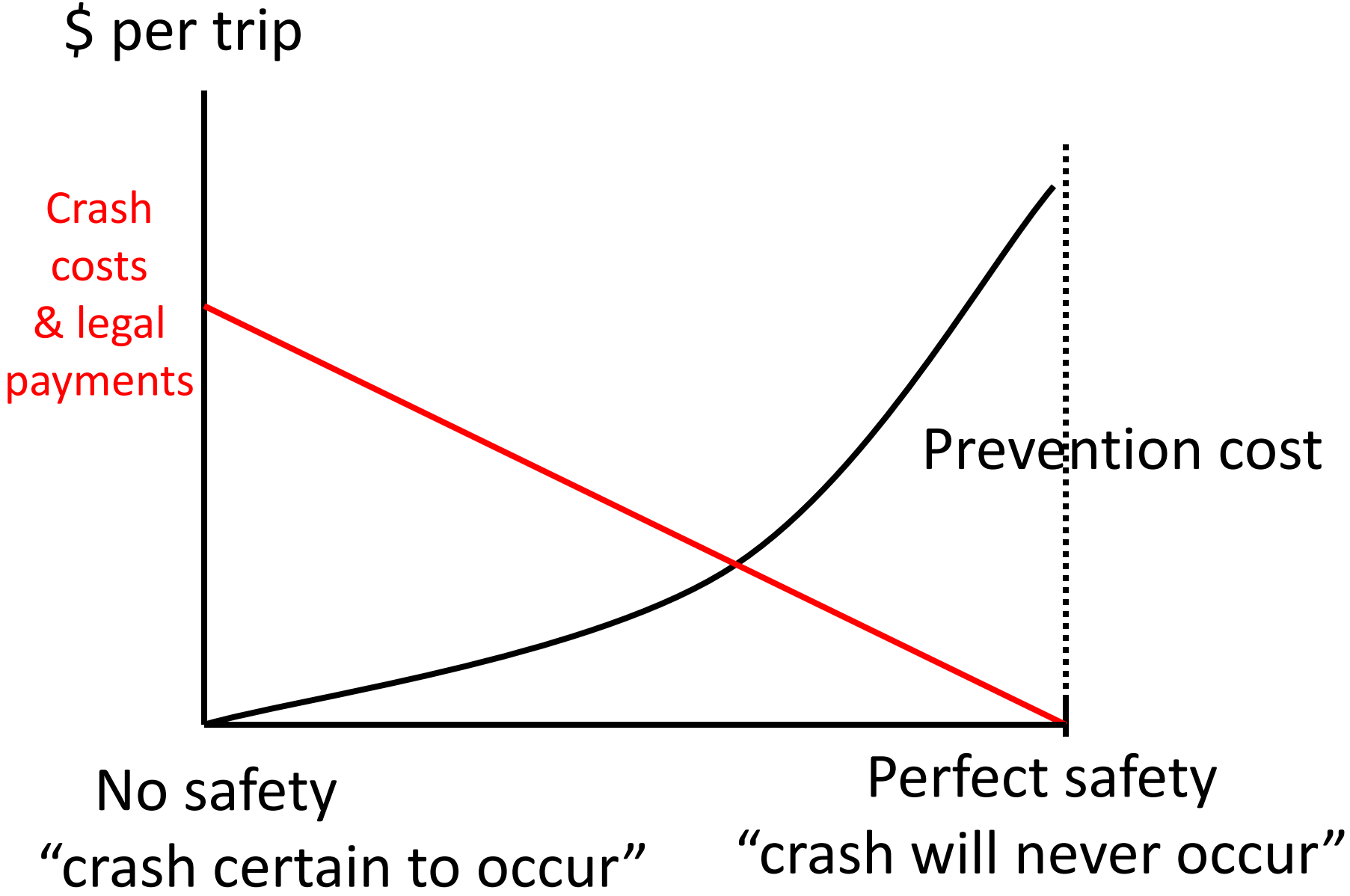

$ per trip
Crash costs & legal payments
Prevention cost
No safety
"crash certain to occur"
Perfect safety
"crash will never occur"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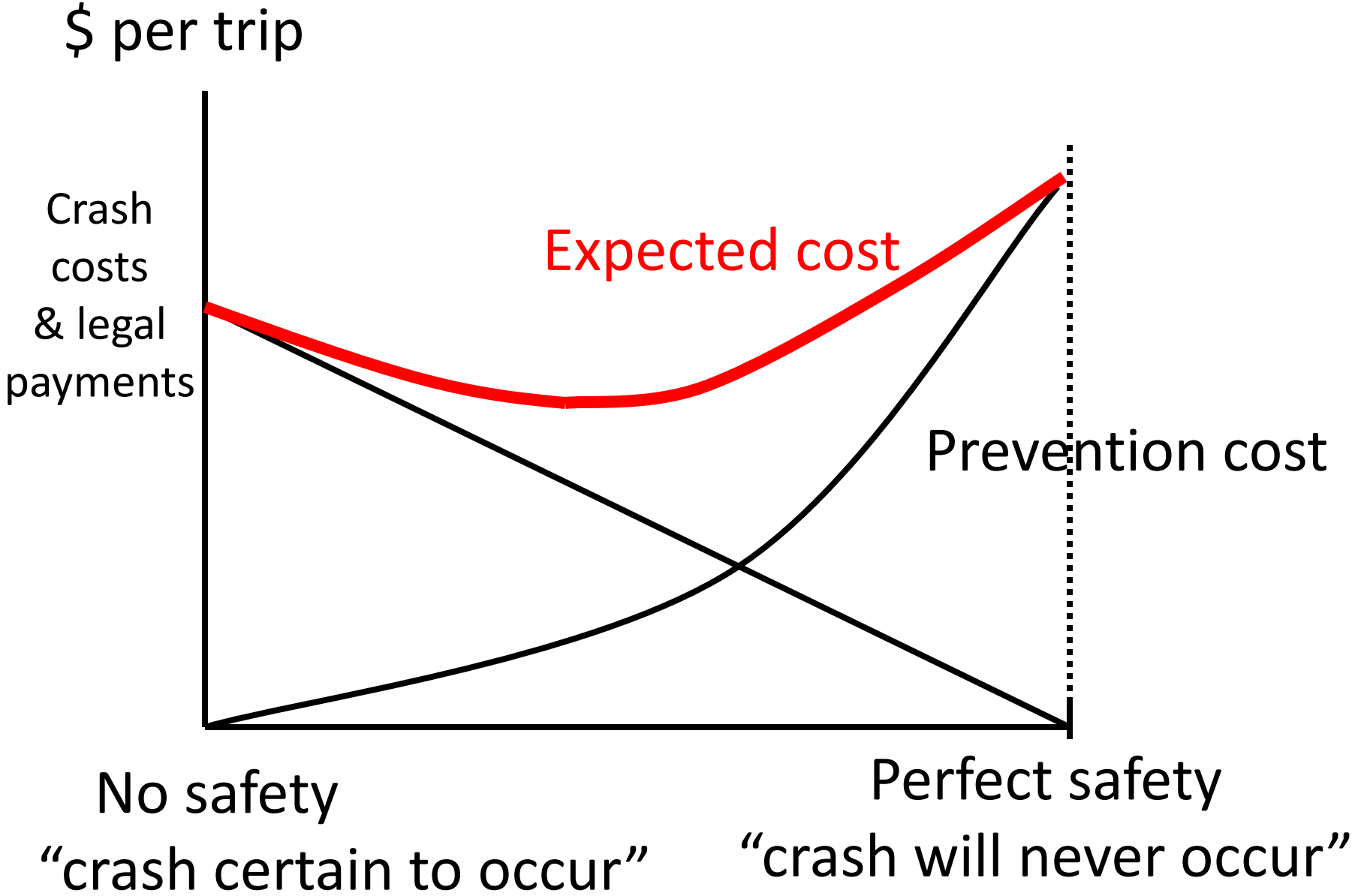
$ per trip
Crash costs & legal payments
Expected cost
Prevention cost
No safety
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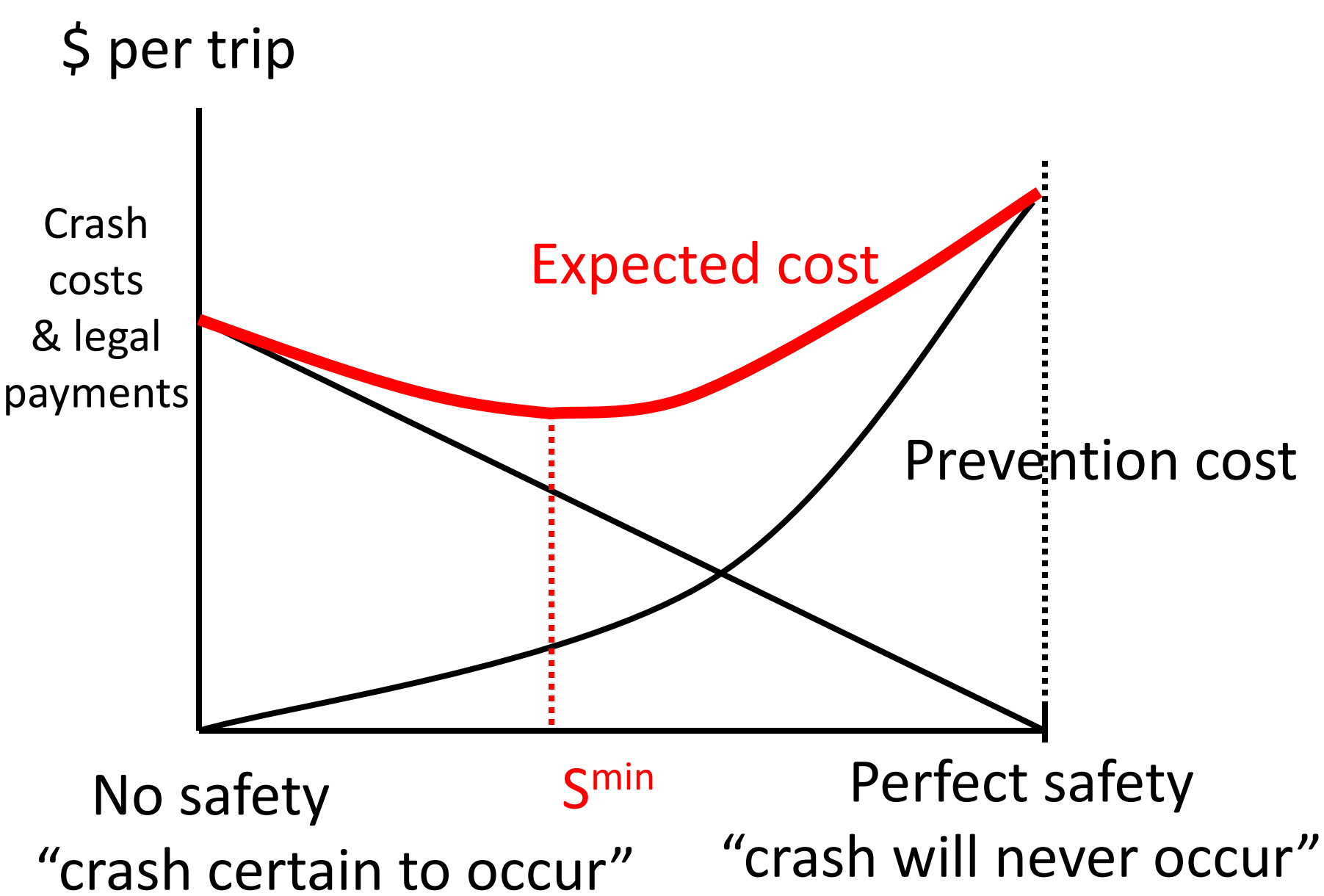
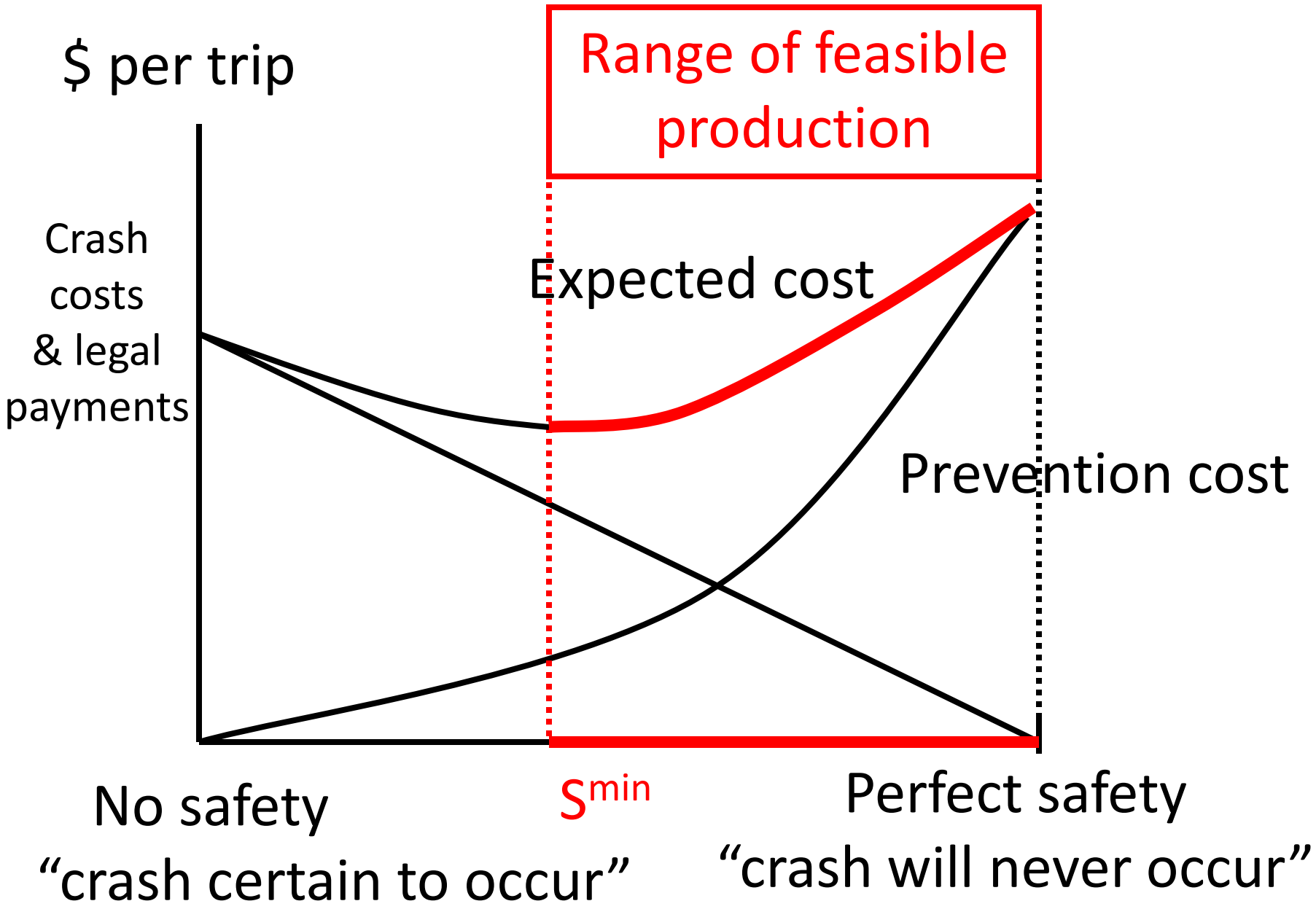

$ per trip
Crash costs & legal payments
Expected cost
Prevention cost
No safety
"crash certain to occur"
S^min
Perfect safety
"crash will never occur"


$ per trip
Range of feasible production
Crash costs & legal payments
Expected cost
Prevention cost
No safety
"crash certain to occur"
S^min
Perfect safety
"crash will never occur"

Benchmark model of consumers

- Many consumers
- Each buys at most one unit of travel per period of time
- Net value of non-safety attributes of transportation relative to next best consumption option varies across consumers (gives a downward sloping demand curve and a buy / don't buy decision)

Consumers' valuation of safety

- S = safety probability where $0 \leq S \leq 1$
  - 0 = crash certain to occur
  - 1 = crash will never occur

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- S = safety probability where $0 \leq S \leq 1$
  - 0 = crash certain to occur
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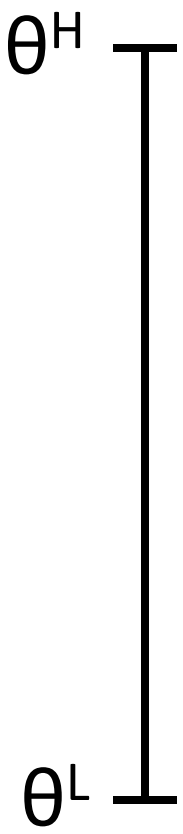
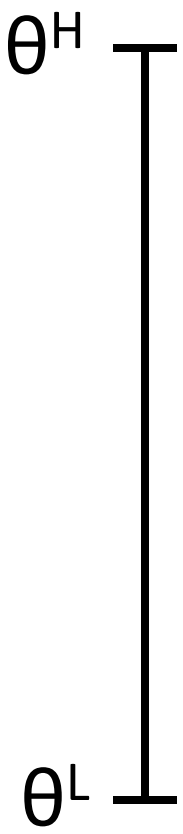
- $\theta_i S$ = value of safety attribute by consumer i
- $\theta_i > 0$ – everyone agrees more safety is better than less safety
- But some consumers value it more than others


Valuation (θ_i)
θ^H
θ^L

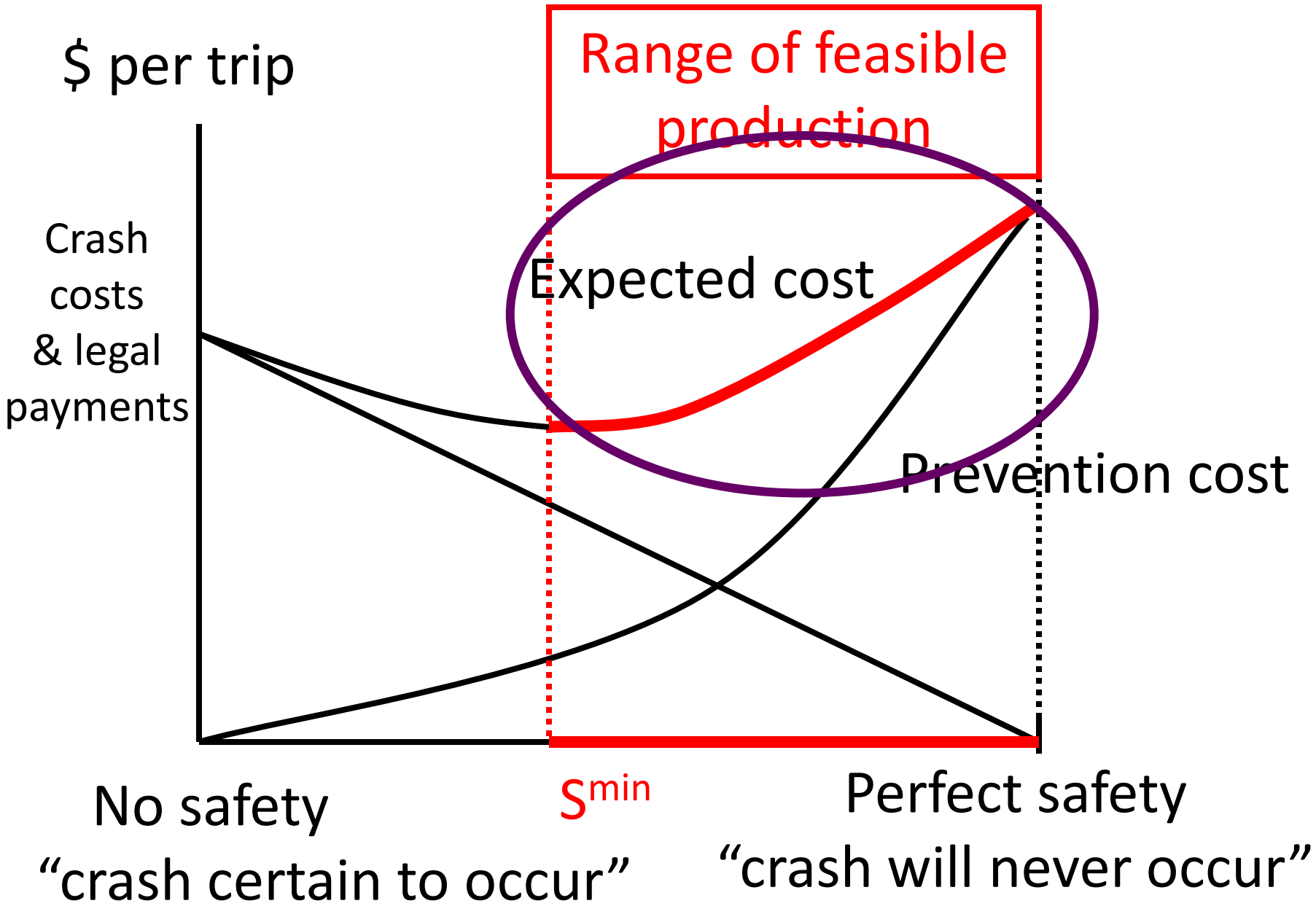


We don't know the range or distribution of θ_i

- For passengers (excepting some measure of central tendency – Value of a Statistical Life)
- Or for freight

Benchmark model

- Obtain a marginal cost of safety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Range of feasible production
Crash costs & legal payments
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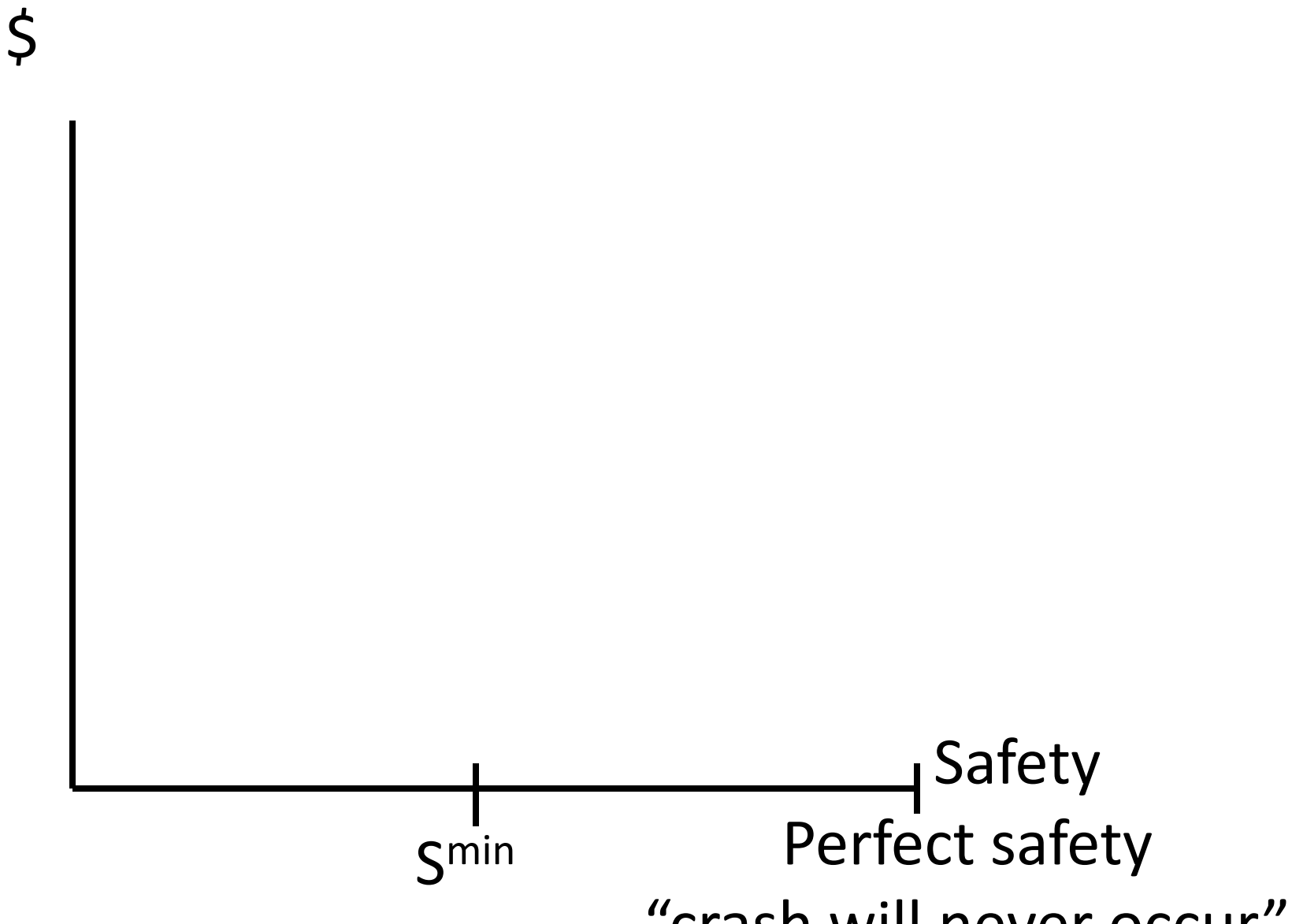
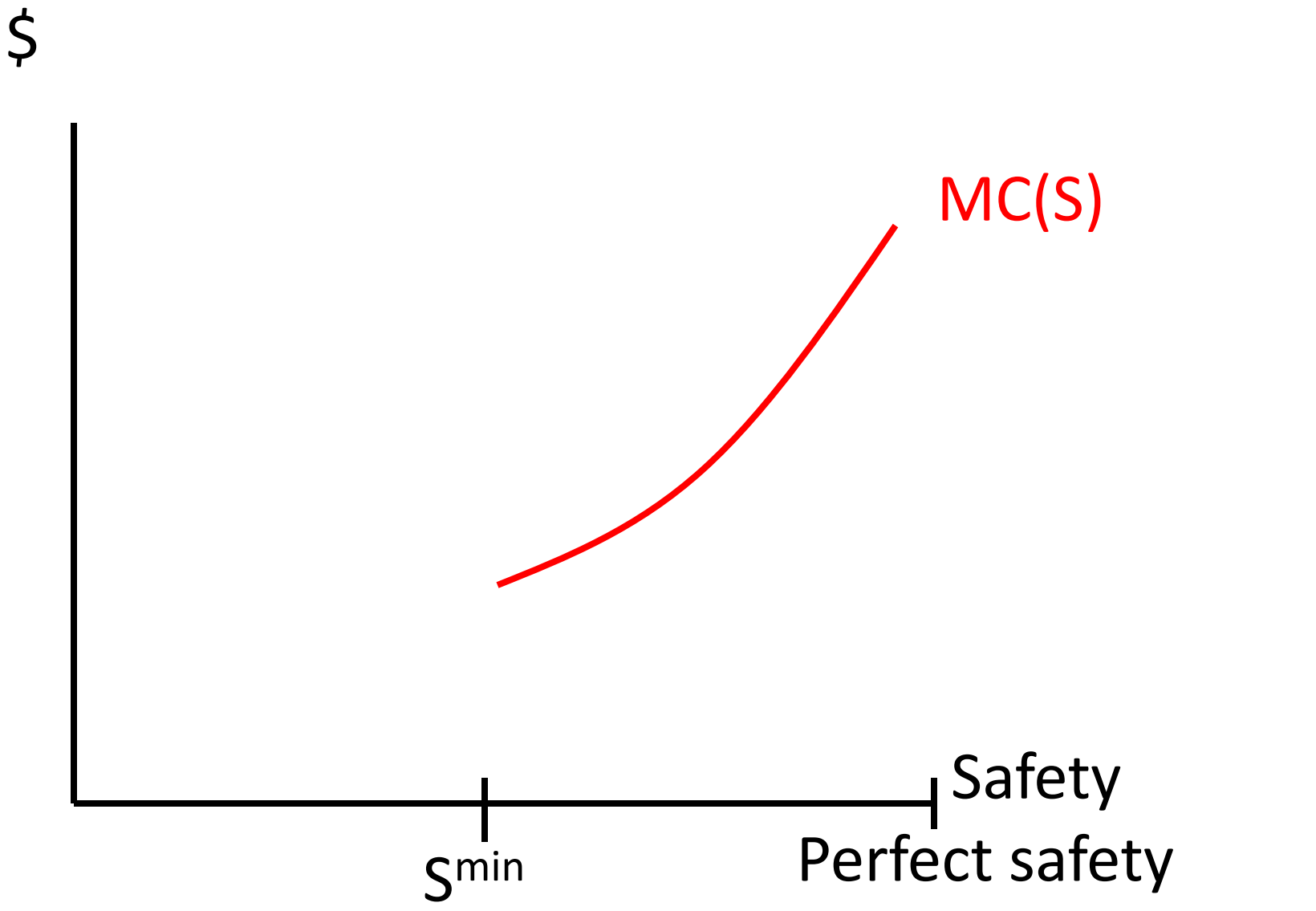

$
Safety
^{min}
Perfect safety
“crash will never occur”

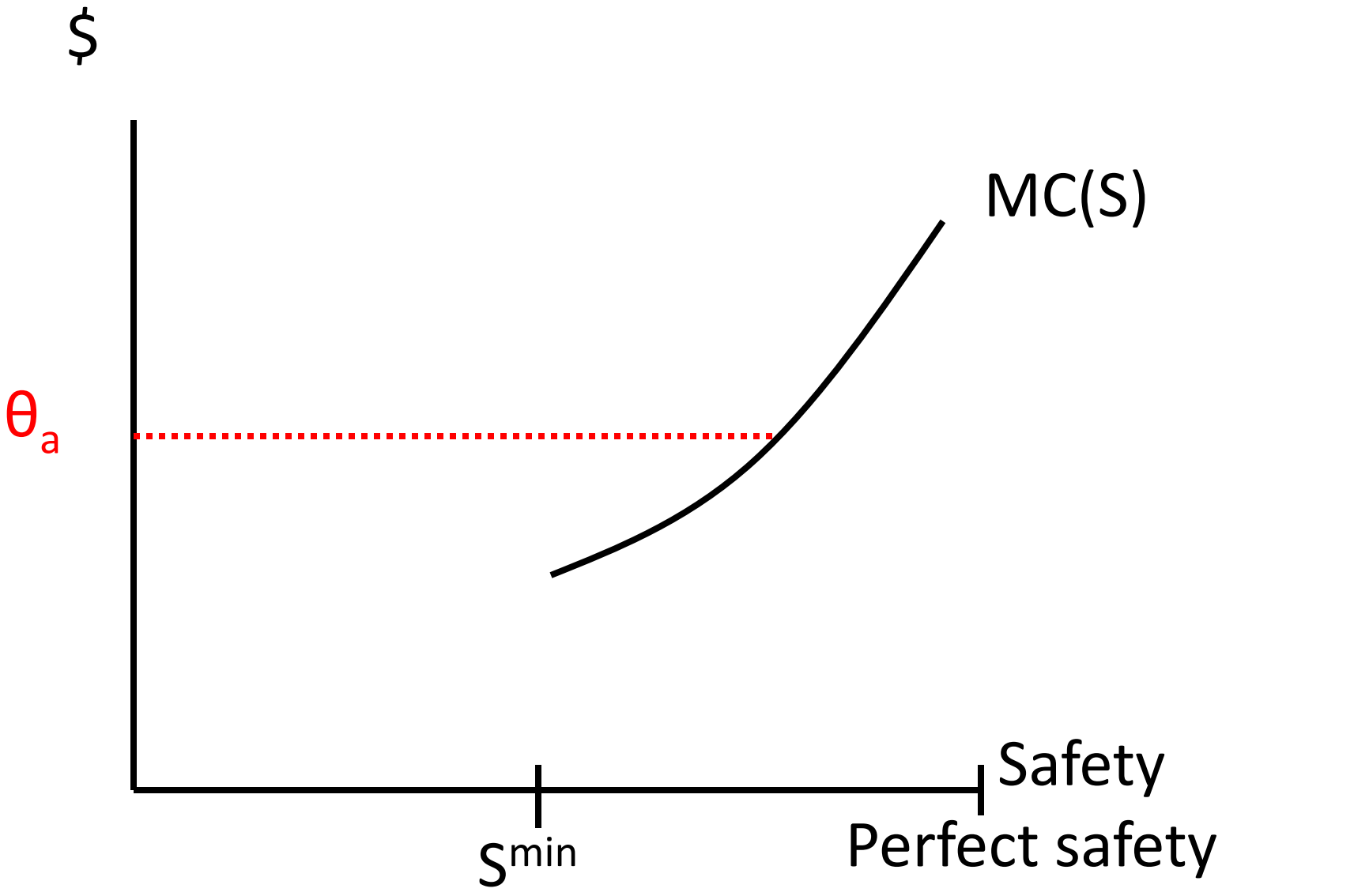

$
MC(S)
Safety
S^{min}
Perfect safety
“crash will never occur”

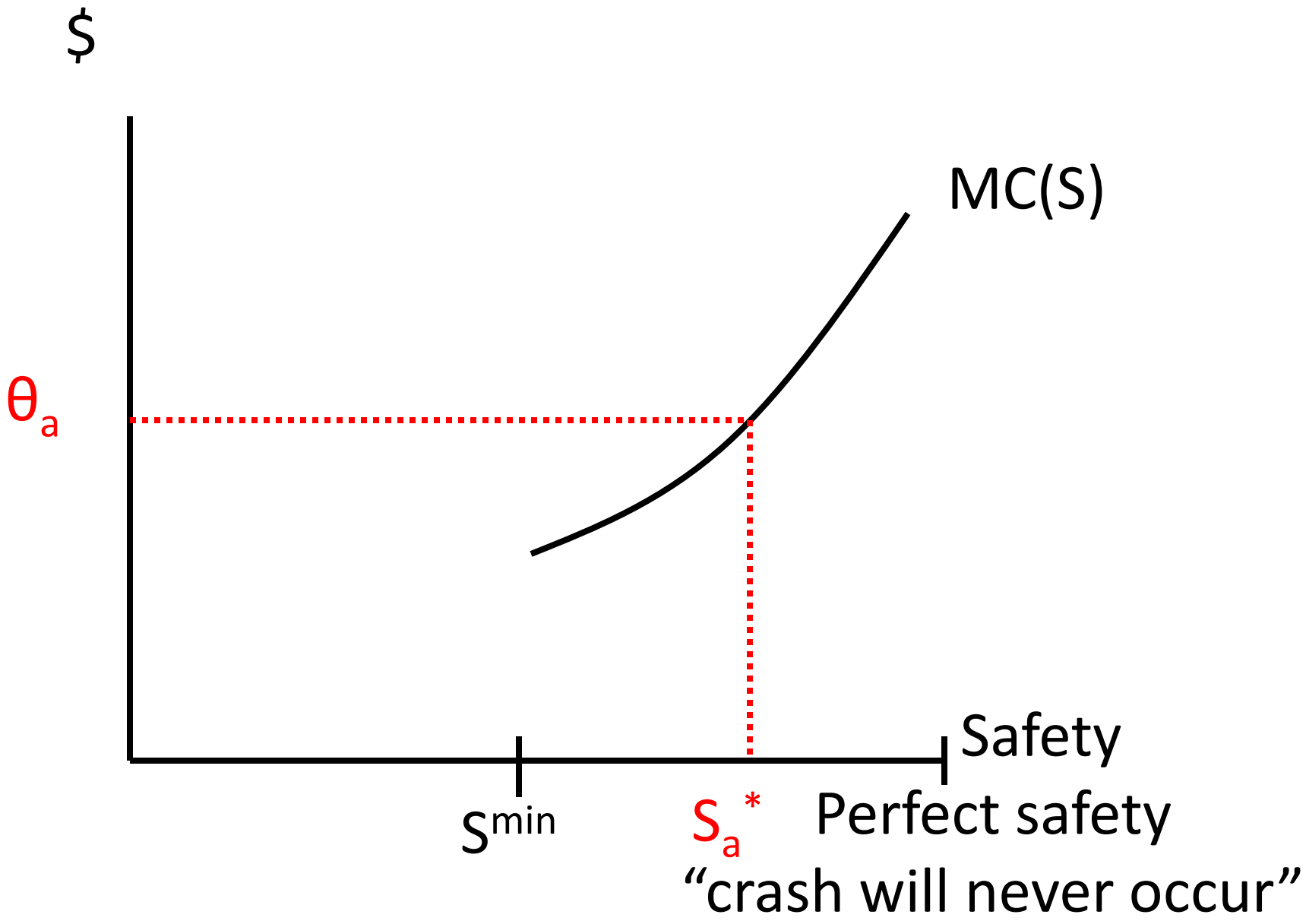
Benchmark model

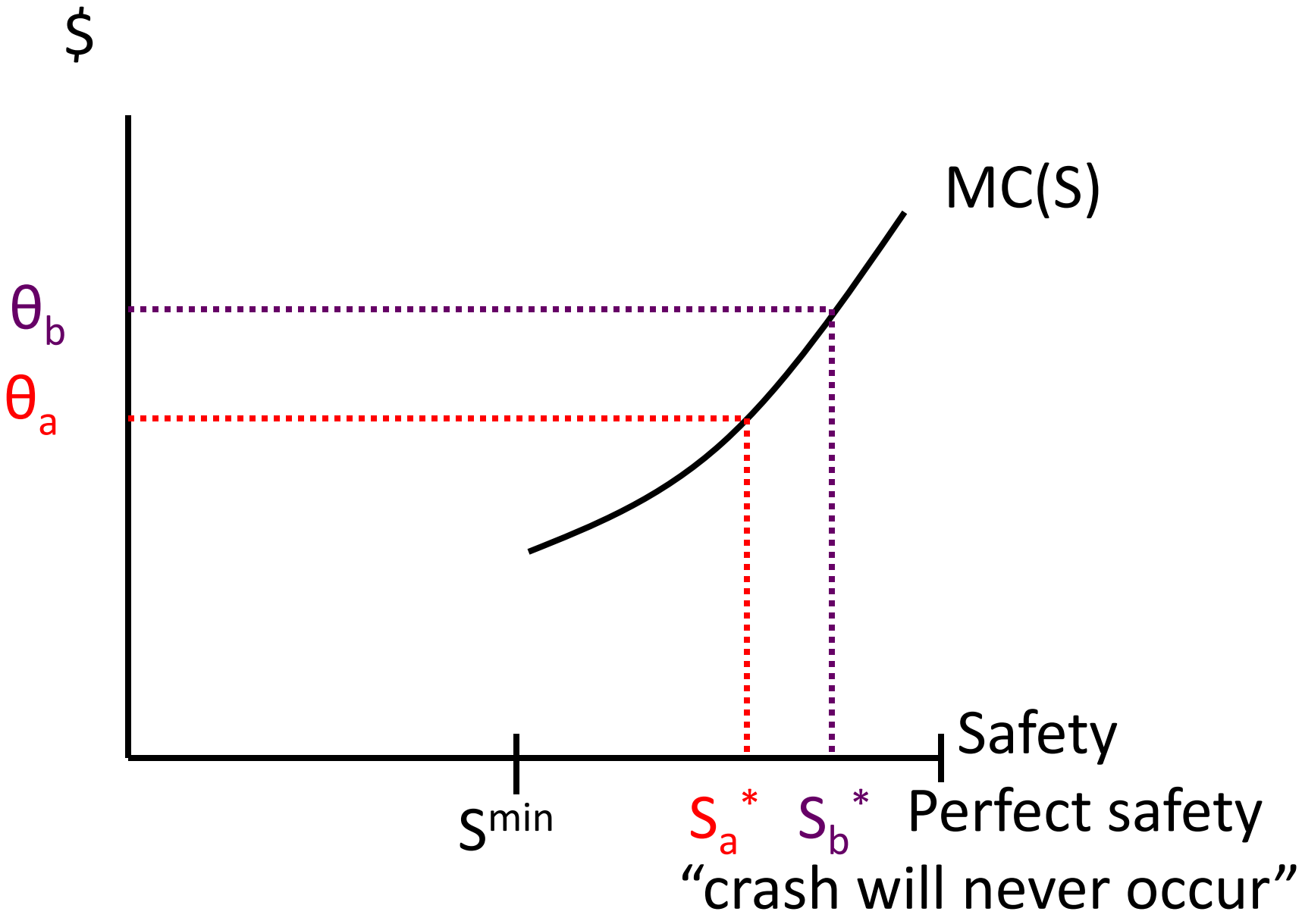
- Obtain a marginal cost of safety
- Benchmark model has price competed downward to marginal cost

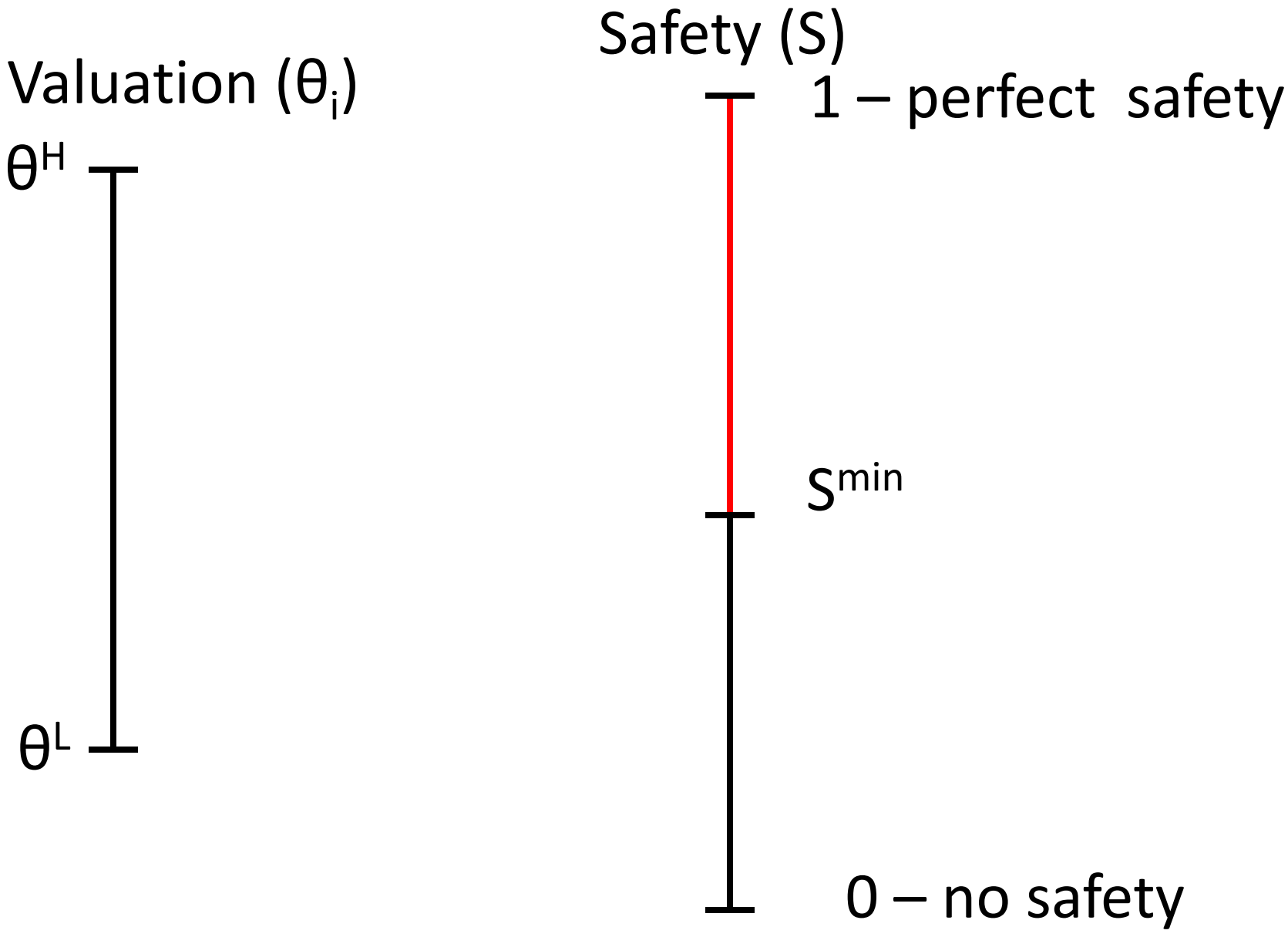
Benchmark model

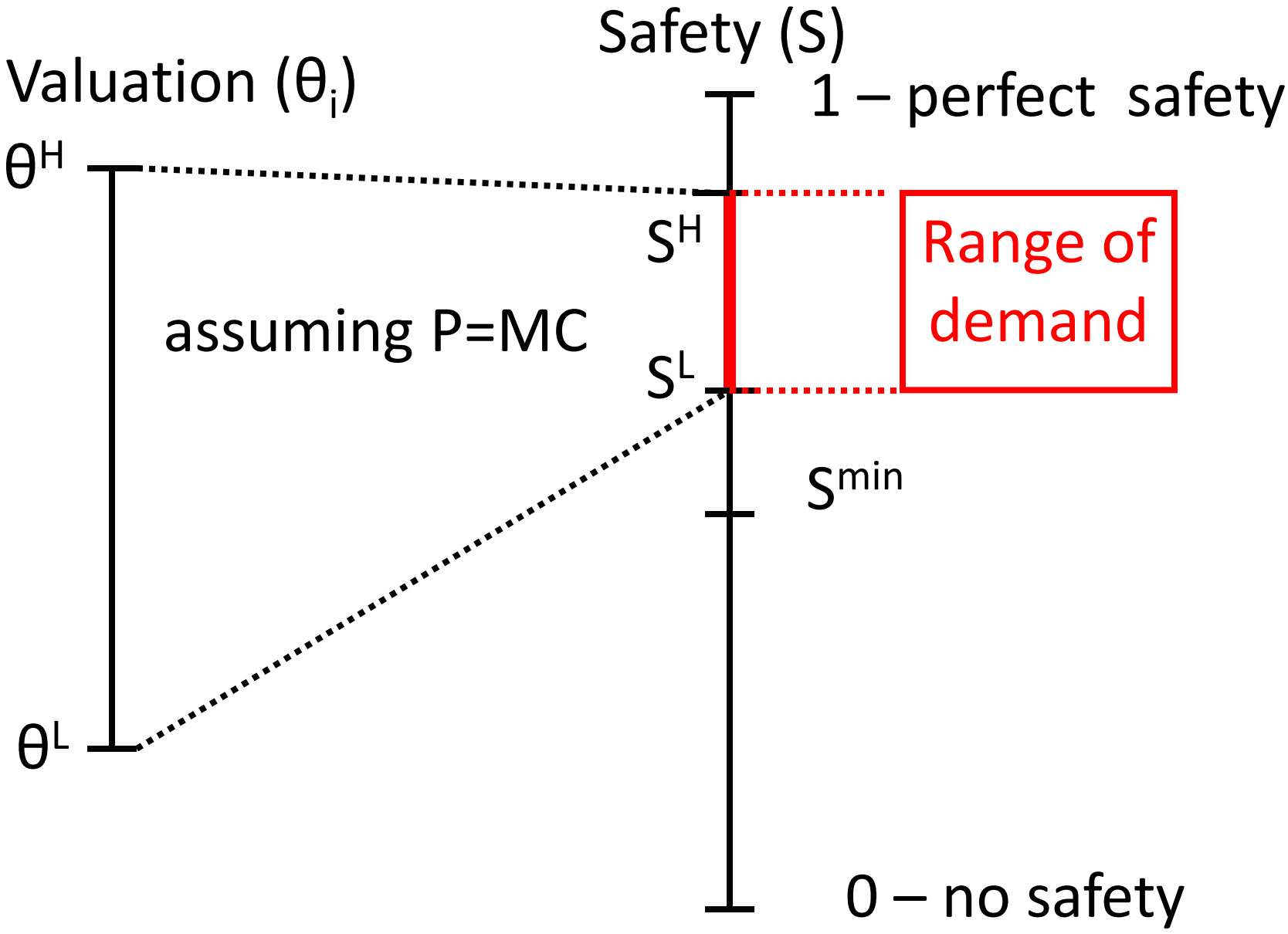
- Obtain a marginal cost of safety
- Benchmark model has price competed downward to marginal cost
- Consumers will purchase more safety until their θ_i just equals the "marginal price" of the increment of safety


$
MC(S)
θa
Safety
Smin
Perfect safety
“crash will never occur”

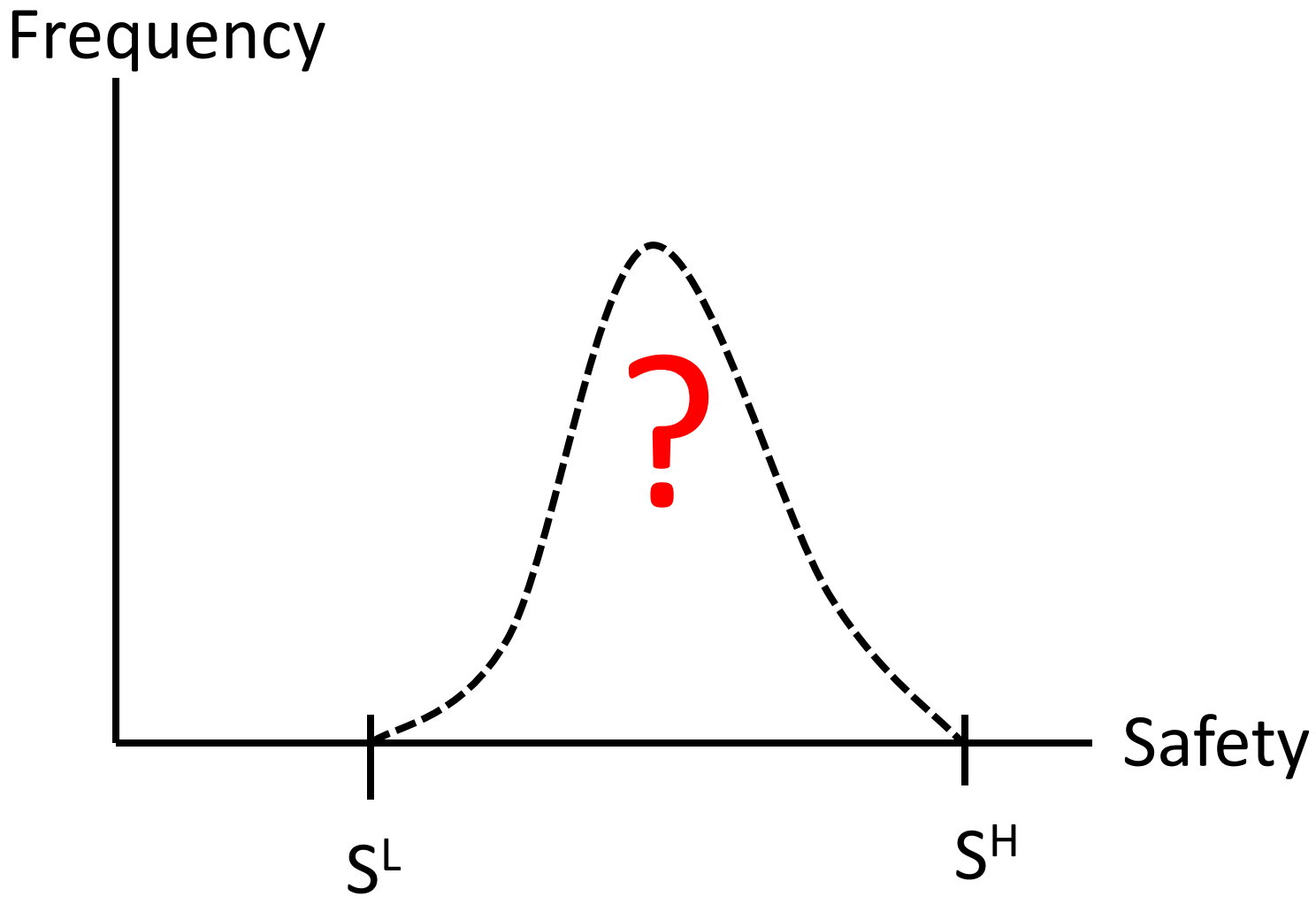

$
MC(S)
θa
Safety
Smin
Sa*
Perfect safety
"crash will never occur"


$
MC(S)
θb
θa
Safety
Smin
Sa*
Sb*
Perfect safety
"crash will never occur"

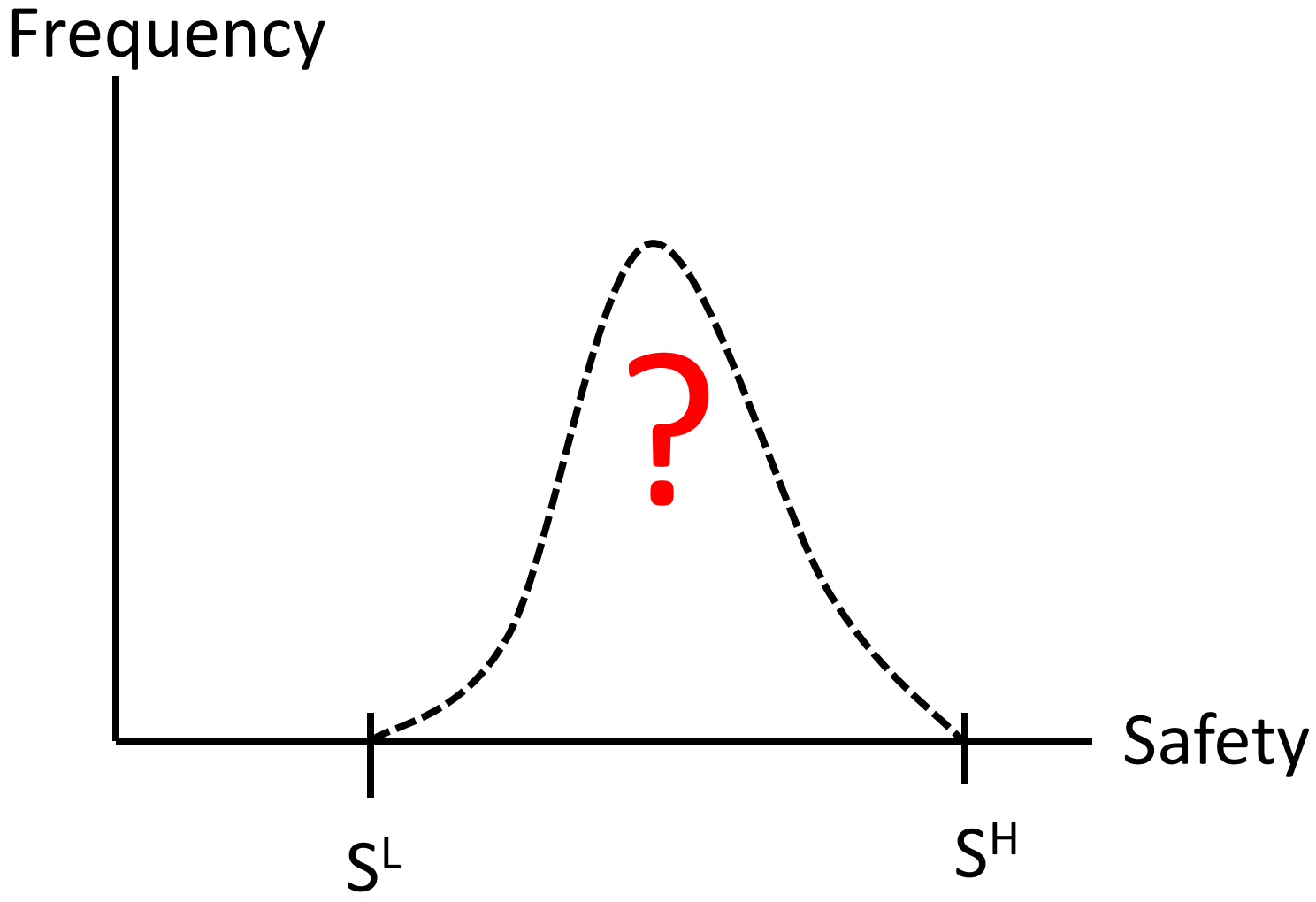

Valuation (θ_i)
θ^H
θ^L
Safety (S)
1 – perfect safety
S^{min}
0 – no safety


Safety (S)
Valuation (θ_i)
1 – perfect safety
θ^H
S^H
Range of demand
assuming P=MC
S^L
S^{min}
θ^L
0 – no safety

Distribution of consumers



In a functioning competitive market carriers position themselves to satisfy consumer tastes



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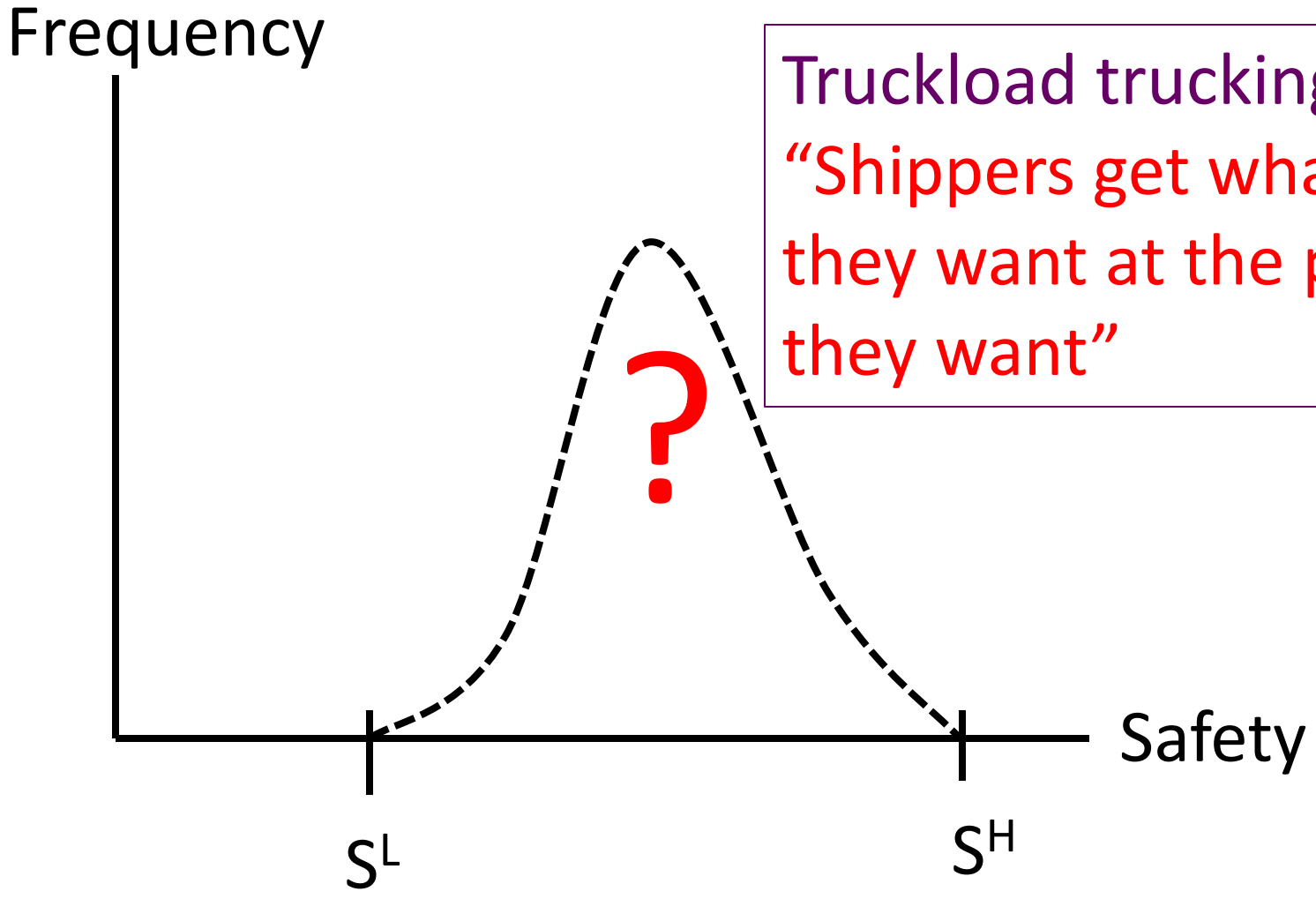

Truckload trucking:
"Shippers get what they want at the price they want"

Imperfect competition

- In many modes “economies of density” limit the number of competitors

Imperfect competition

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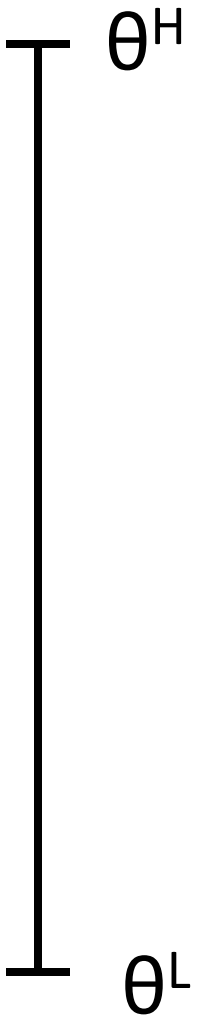
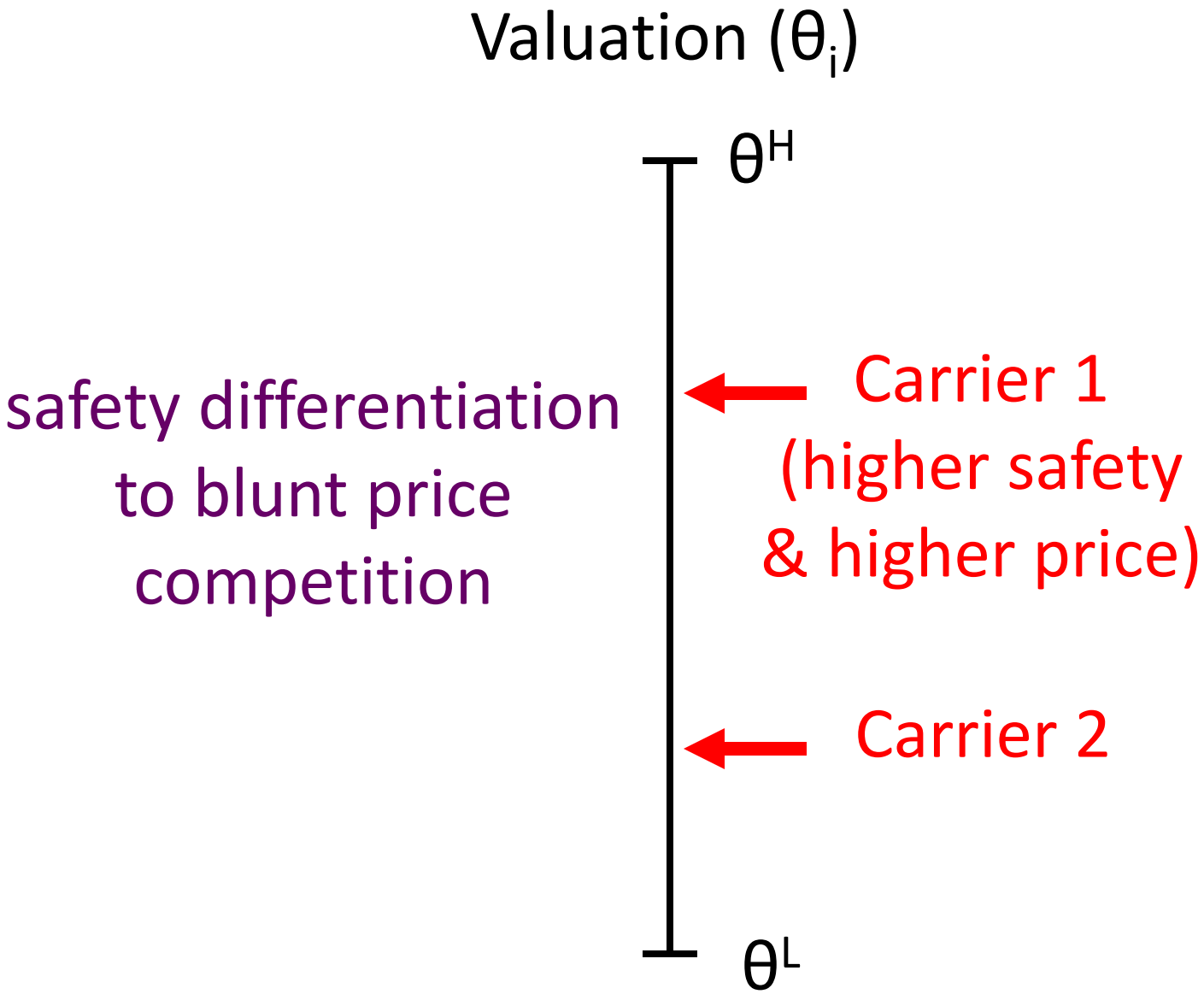
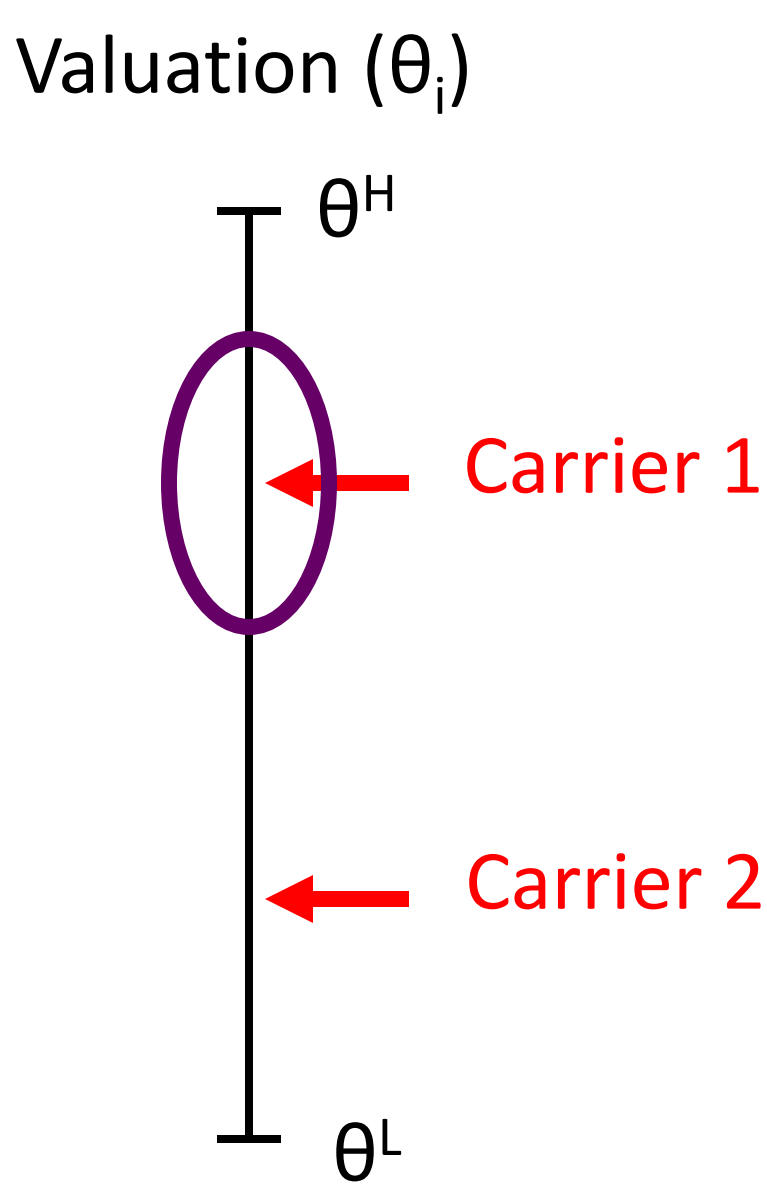
- “Lumpy” supply means that many passengers and also shippers with varied tastes have to share the same vehicle/train/plane/ship

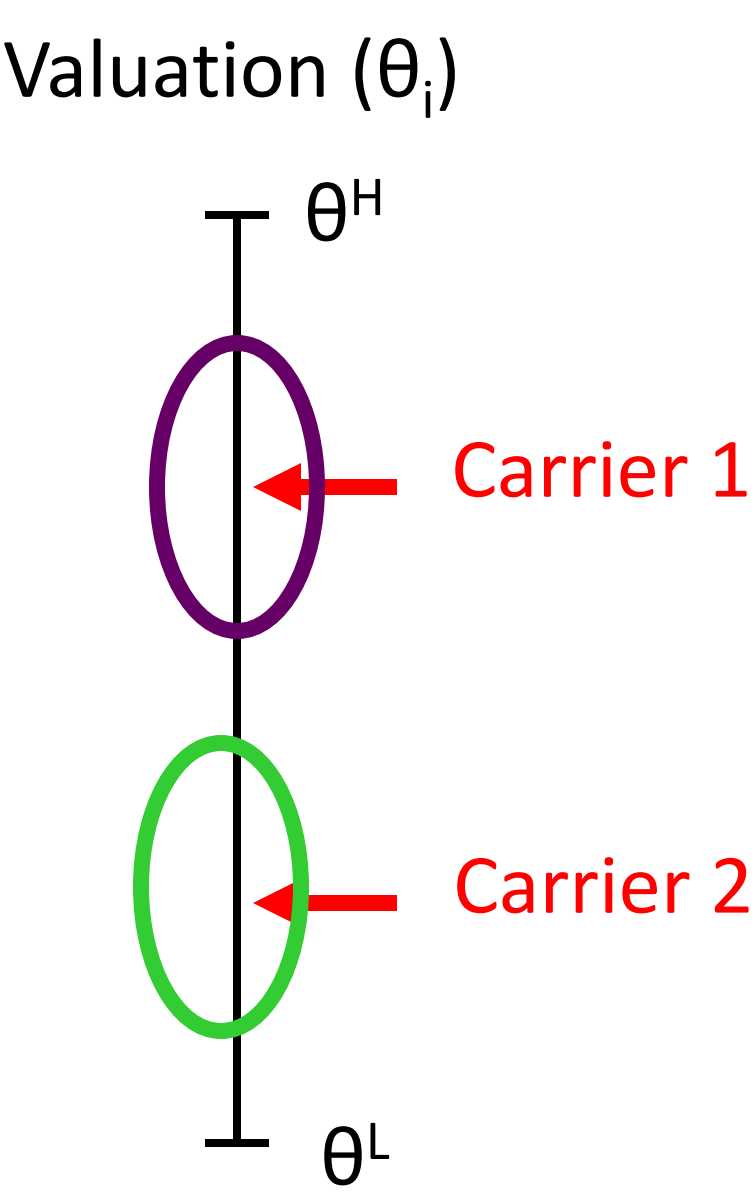
Imperfect competition

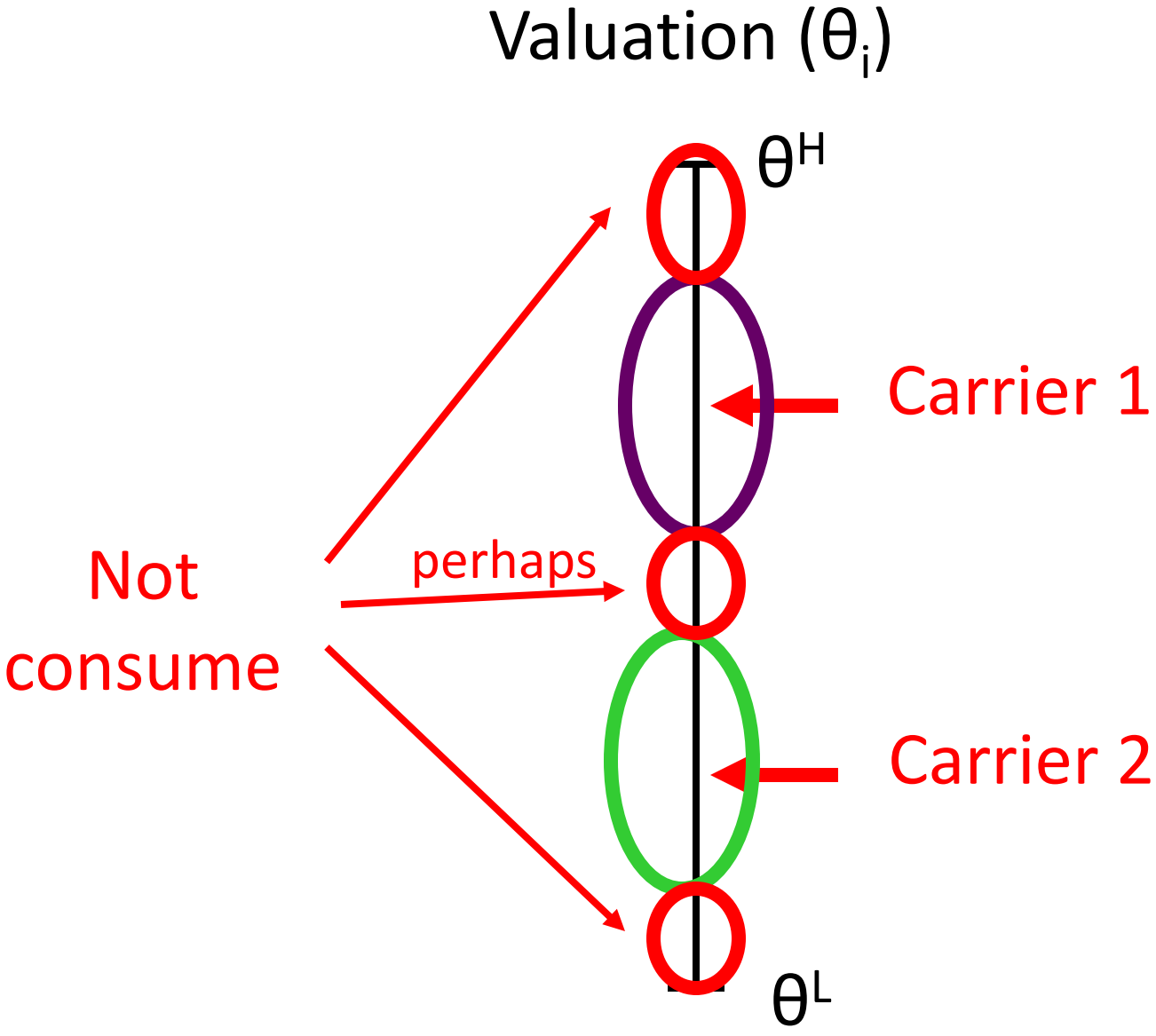
- In many modes “economies of density” limit the number of competitors
- “Lumpy” supply means that many passengers and also shippers with varied tastes have to share the same vehicle/train/plane/ship
- Implies limited safety choices – “one size fits all”


Valuation (θ_i)
θ^H
θ^L


Valuation (θ_i)
θ^H
safety differentiation to blunt price competition
Carrier 1 (higher safety & higher price)
Carrier 2
θ^L


Valuation (θ_i)
θ^H
Carrier 1
Carrier 2
θ^L


Valuation (θ_i)
θ^H
Carrier 1
Carrier 2
θ^L


Valuation (θ_i)
θ^H
Carrier 1
Not consume
perhaps
Carrier 2
θ^L

Implications

- Consumers may rationally choose less than perfect safety

Implications

- Consumers may rationally choose less than perfect safety
- Higher-safety and lower-safety options may optimally co-exist

Implications

- Consumers may rationally choose less than perfect safety
- Higher-safety and lower-safety options may optimally co-exist
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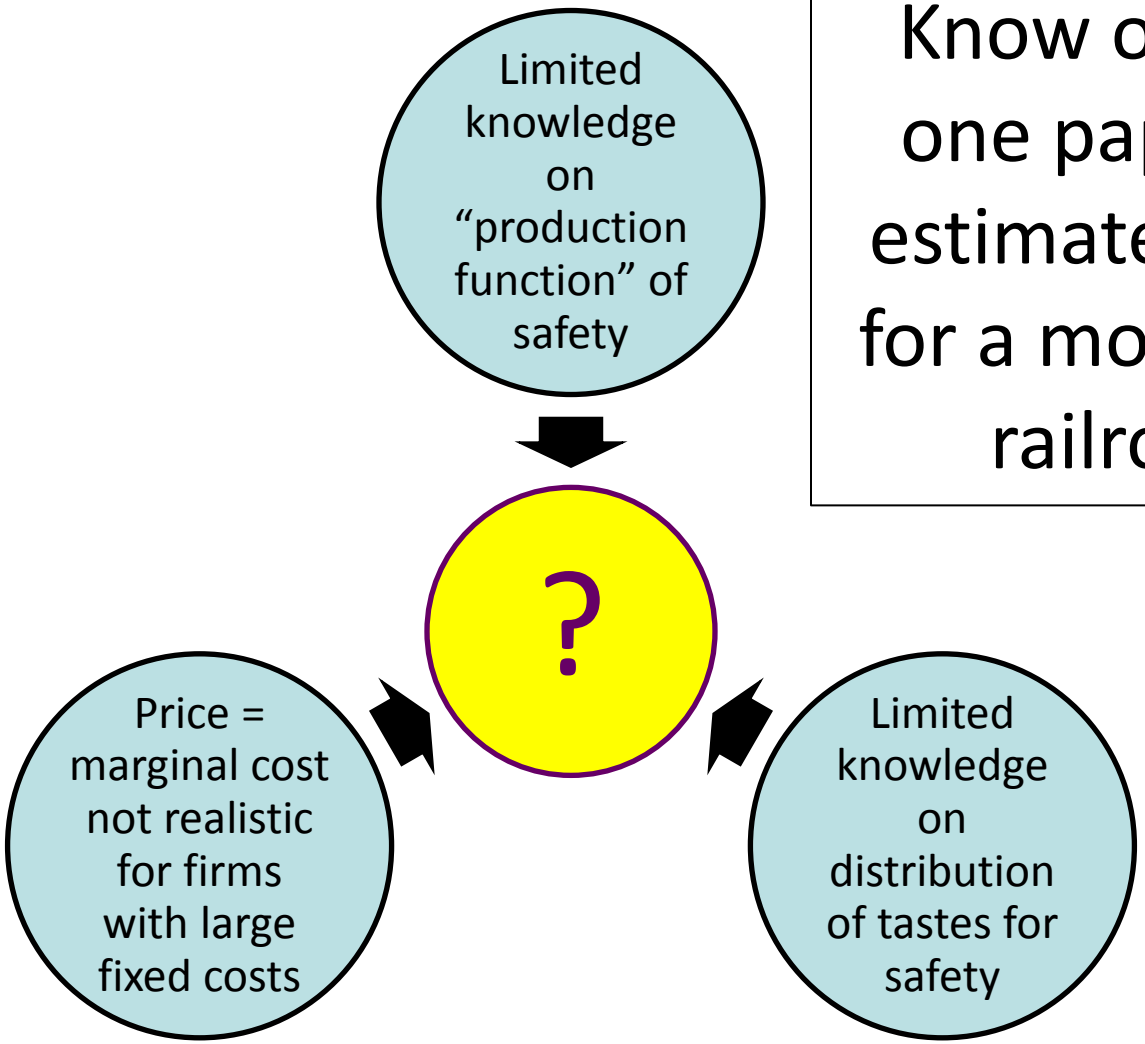
Implications

- Consumers may rationally choose less than perfect safety
- Higher-safety and lower-safety options may optimally co-exist
- Diversity of safety offerings may be a sign that the market works not a sign of market failure
- Lower safety offerings reflect lower taste for safety by some shippers and passengers

How much safety?

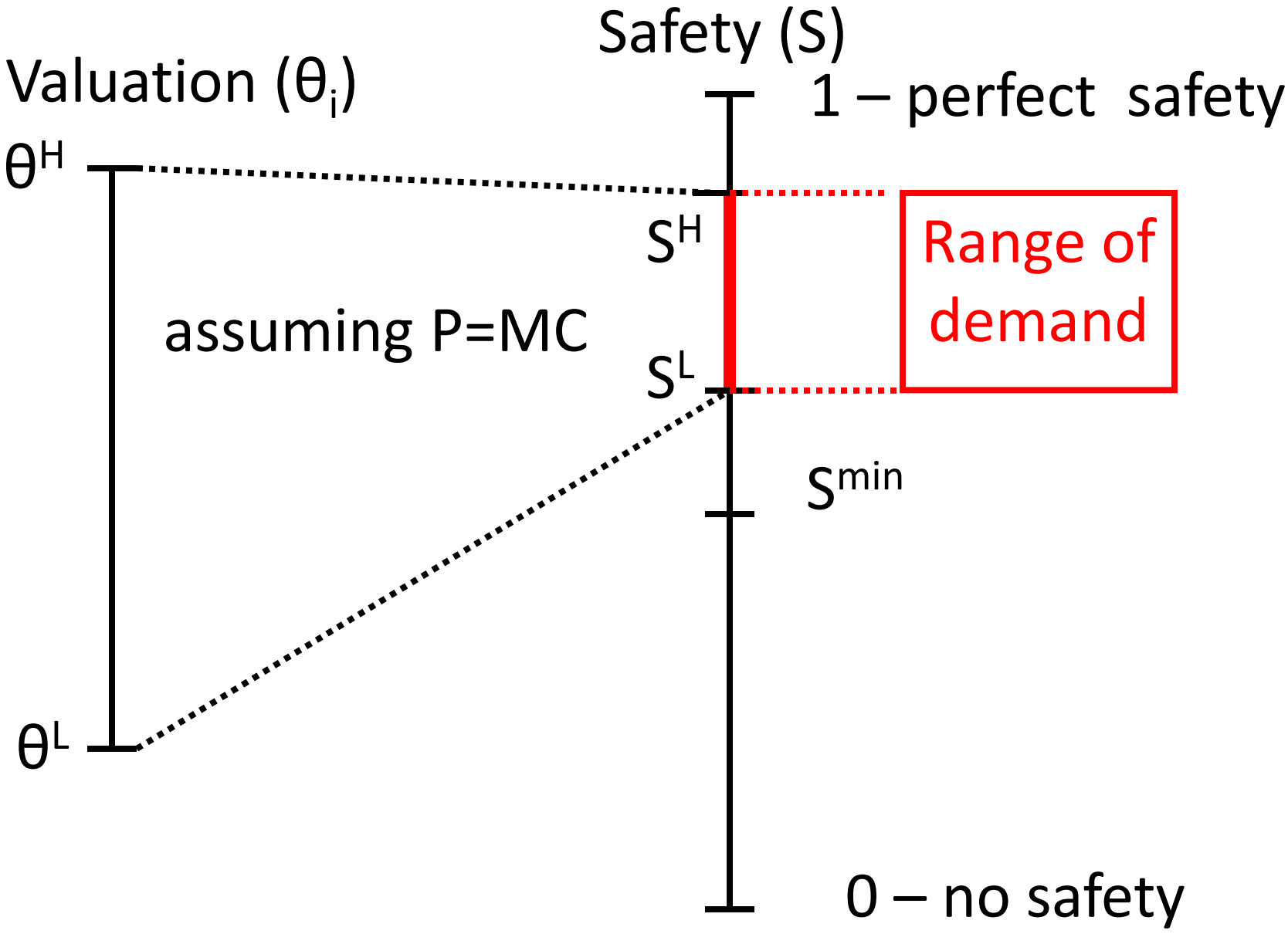
How much safety? - who knows!

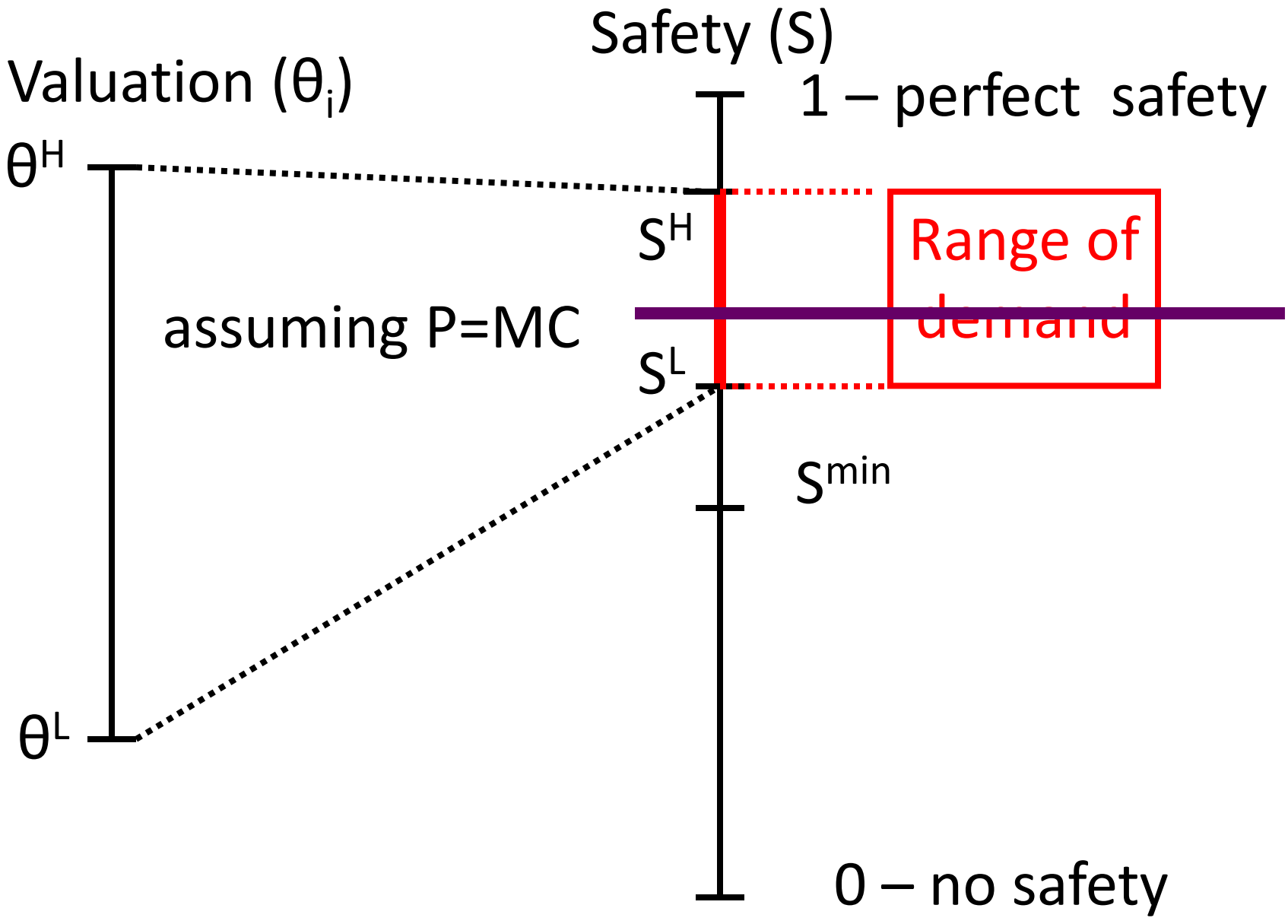


Know of only one paper to estimate this – for a monopoly railroad

Part 3

“Intolerable risk”


Safety (S)
Valuation (θ_i)
1 – perfect safety
θ^H
S^H
Range of demand
assuming P=MC
S^L
S^{min}
θ^L
0 – no safety


Safety (S)
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Range of demand
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S^L
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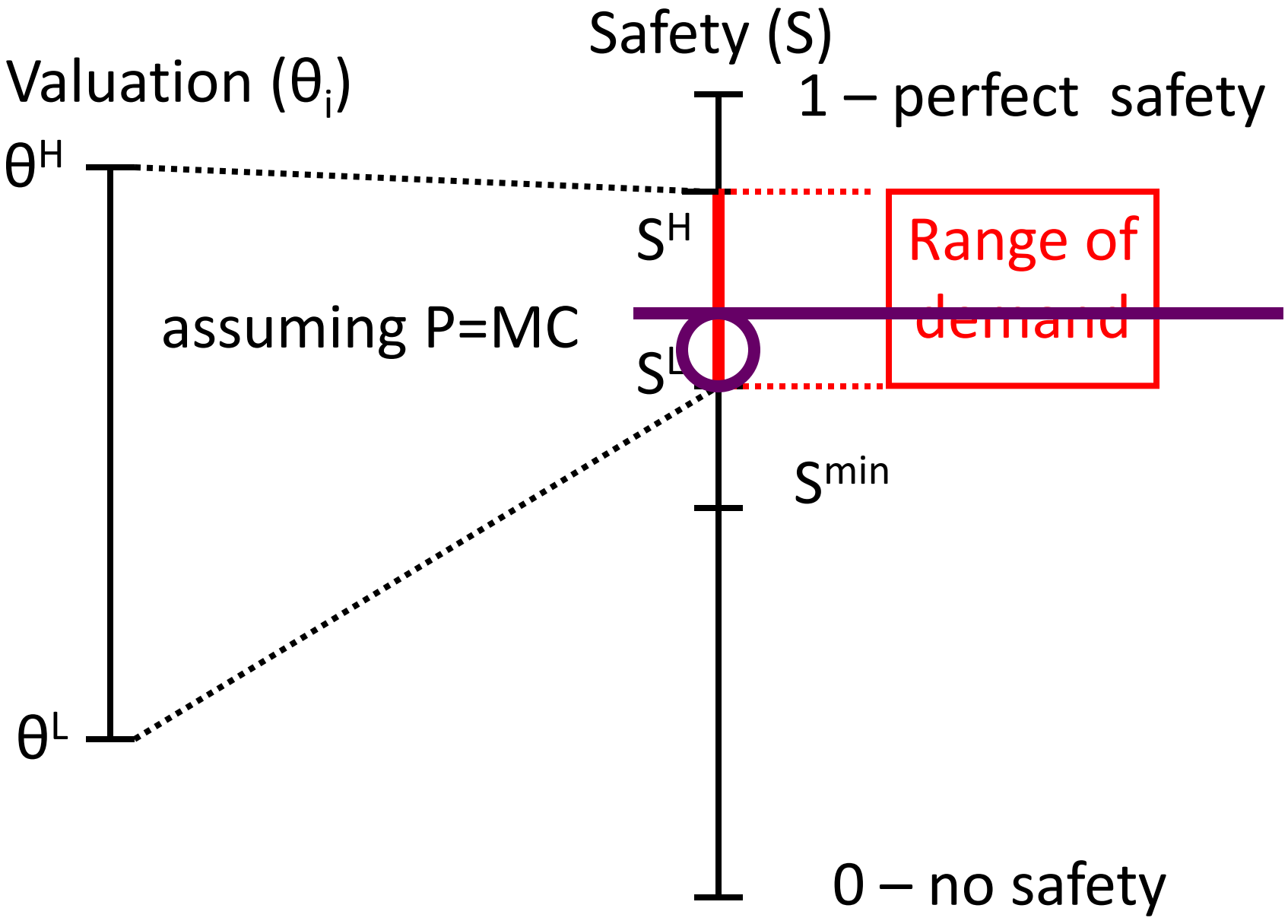
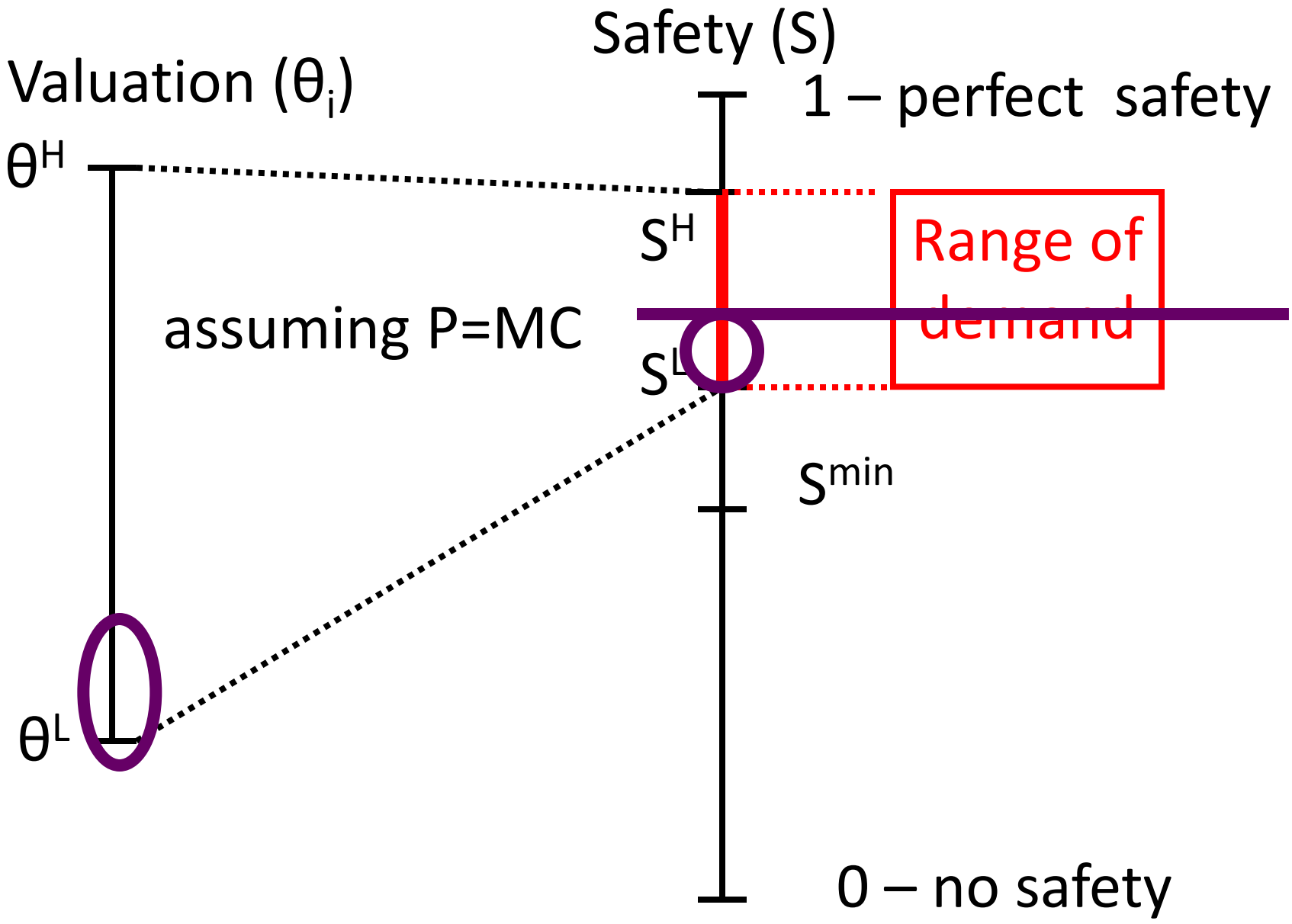
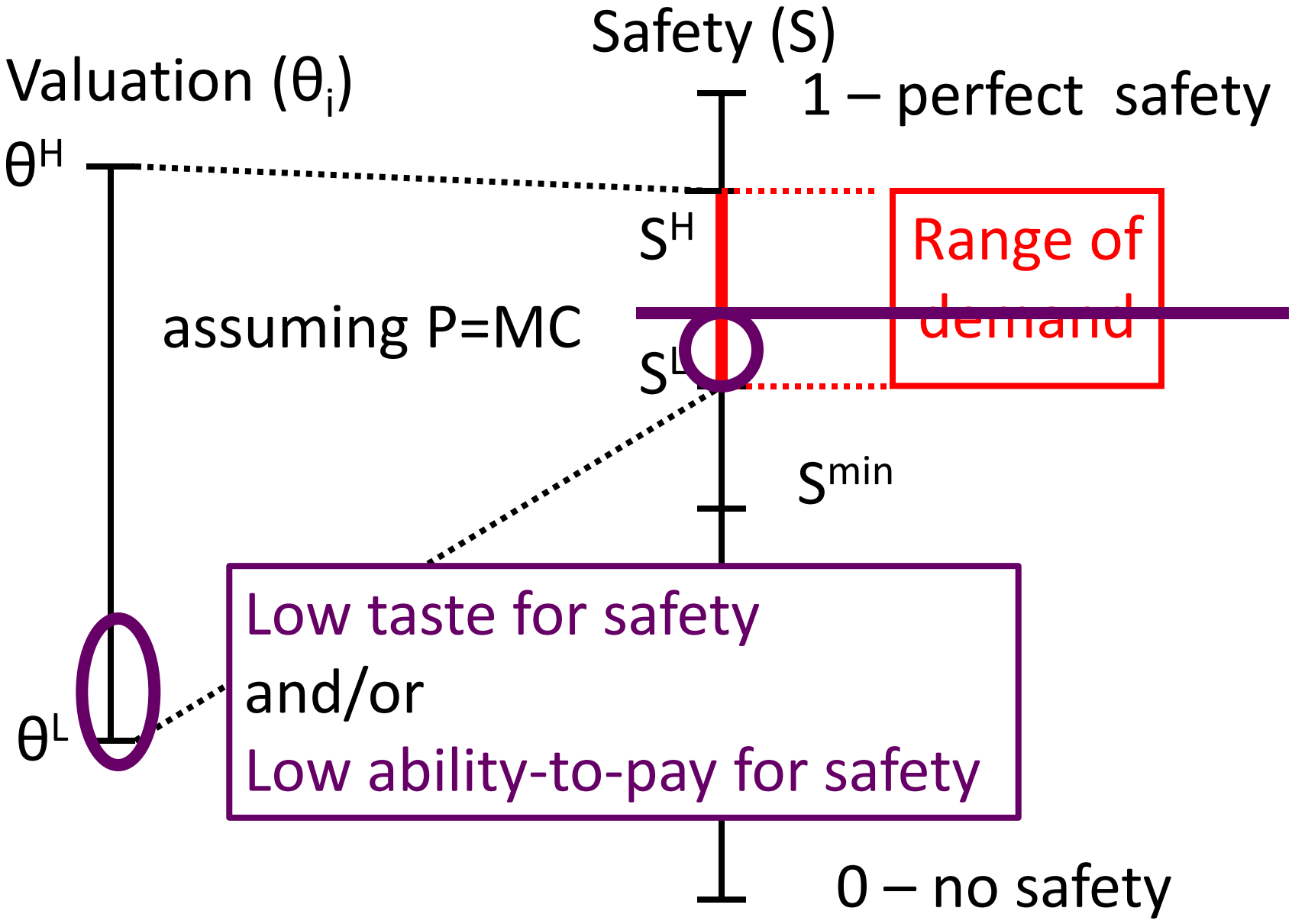

Safety (S)
Valuation (θ_i)
1 – perfect safety
θ^H
S^H
Range of demand
assuming P=MC
S^L
S^{min}
θ^L
0 – no safety


Safety (S)
Valuation (θ_i)
1 – perfect safety
θ^H
S^H
Range of demand
assuming P=MC
S^L
S^{min}
θ^L
0 – no safety


Safety (S)
Valuation (θ_i)
1 – perfect safety
θ^H
S^H
Range of demand
assuming P=MC
S^L
S^{min}
Low taste for safety
and/or
Low ability-to-pay for safety
θ^L
0 – no safety

Part 4

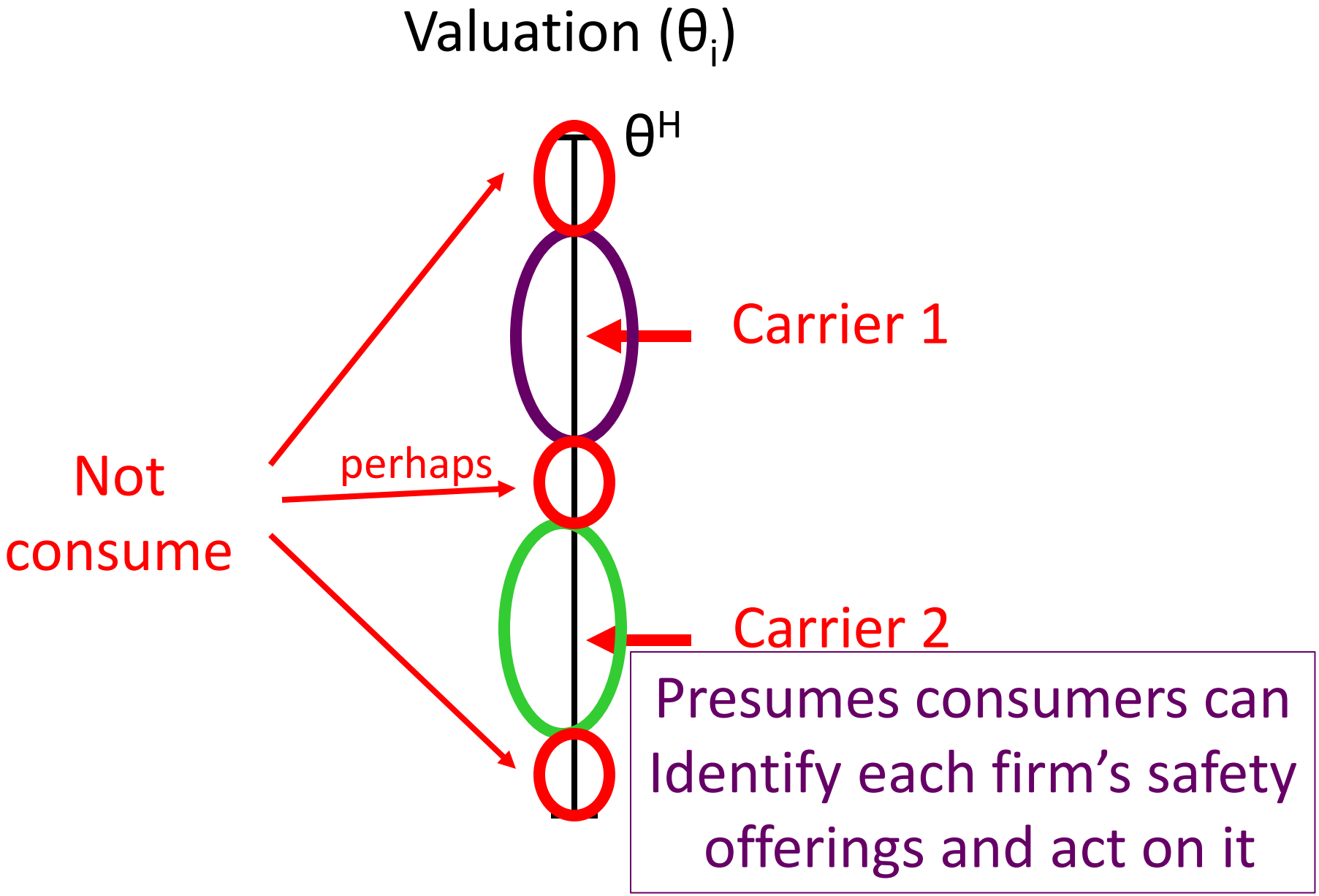
Deviations from the (unknown) optimal level(s)

Assumptions for ideal marketplace

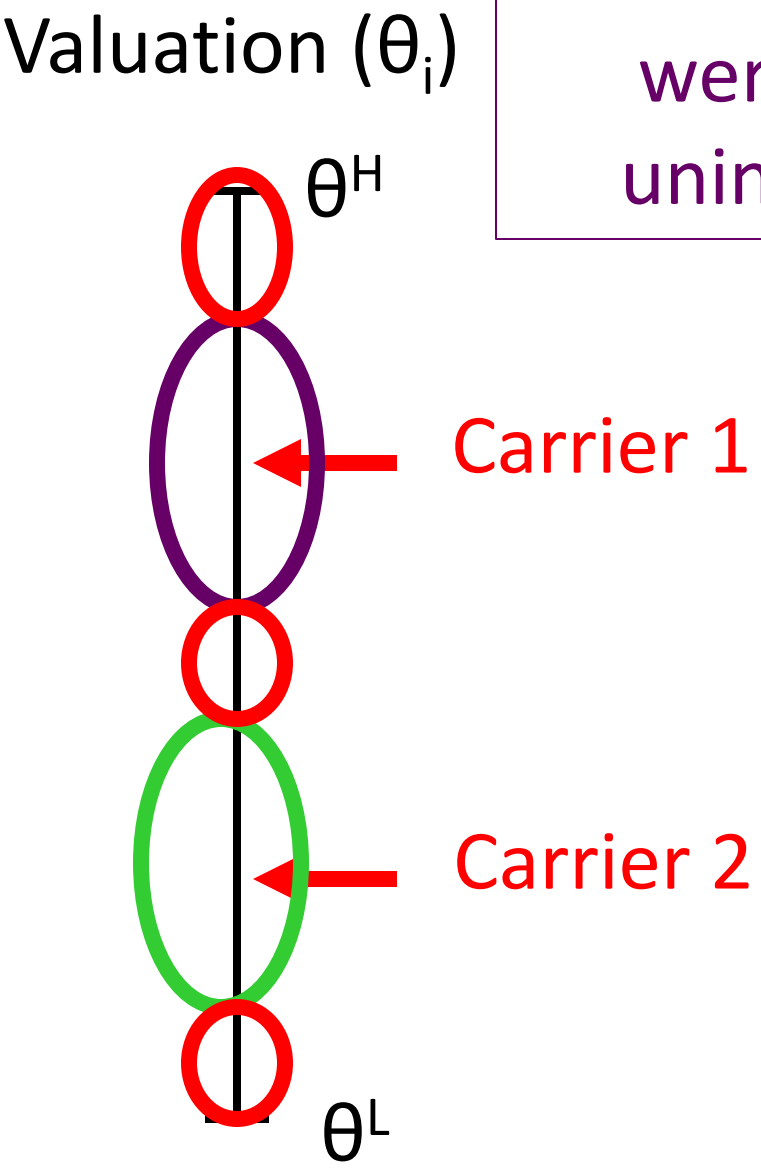
- Many carriers and P=MC

Assumptions for ideal marketplace

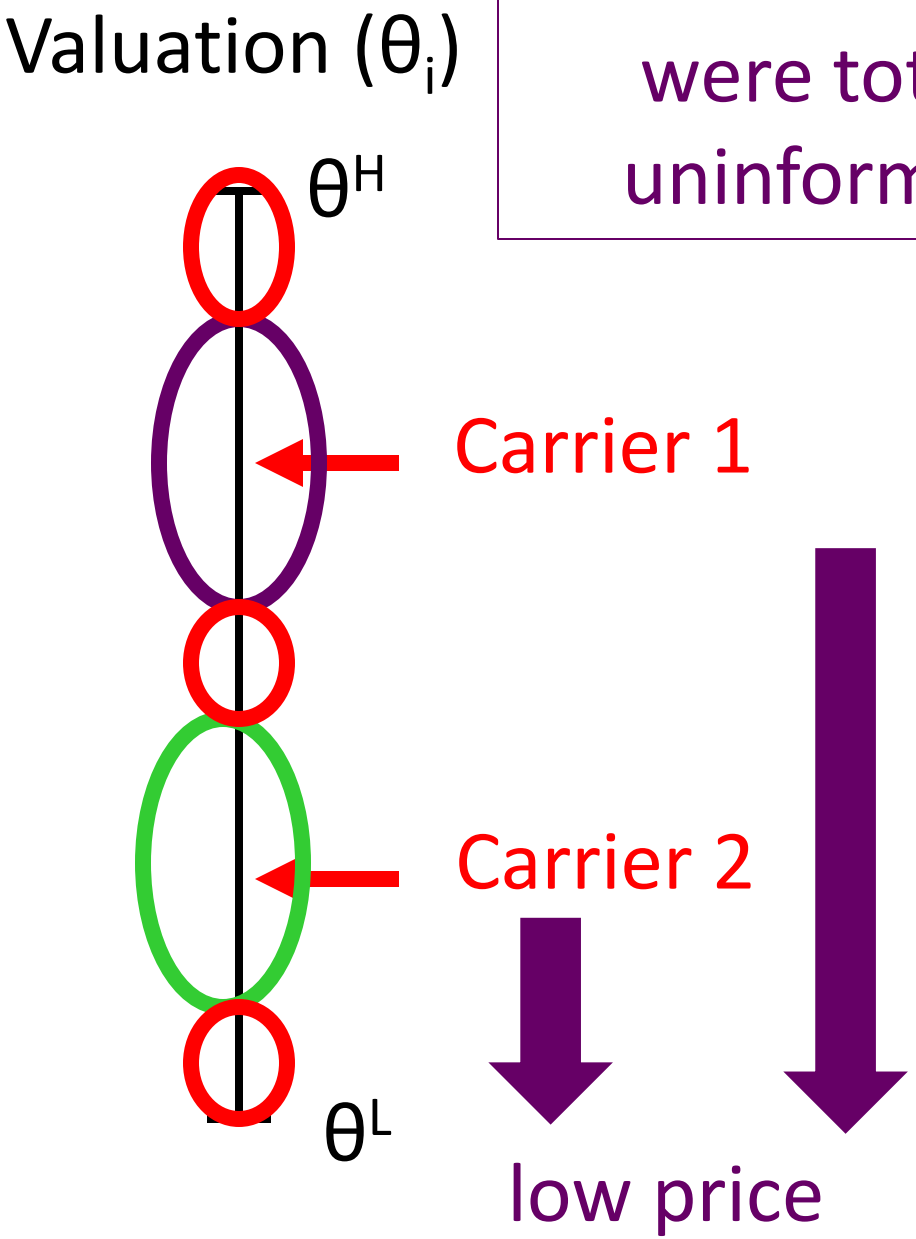
- Many carriers and P=MC
- Consumers are fully informed
- Consumers can make rational choices


Valuation (θ_i)
θ^H
Carrier 1
Not consume
perhaps
Carrier 2
Presumes consumers can Identify each firm's safety offerings and act on it

What if consumers were totally uninformed?



What if consumers were totally uninformed?



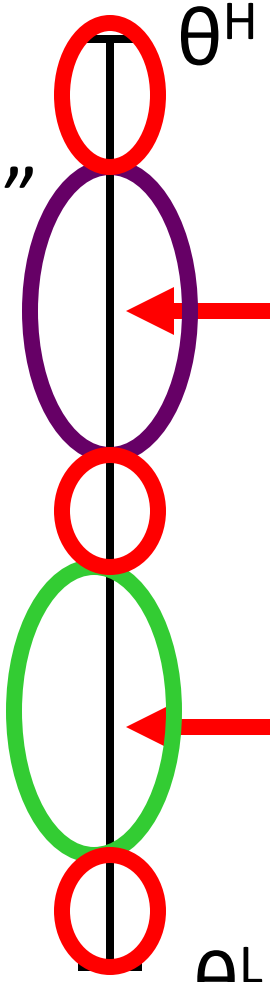
What if consumers were totally uninformed?

Valuation (θ_i)

Constrained if consumers can identify "notorious" carriers

But how and what do consumers learn?

How do carriers signal "high safety"?



Carrier 1

Carrier 2

low price

Much dispersion

- many carriers
- consumers have varied tastes
- consumers are not bundled together
- consumers are well informed
- “vertical differentiation”

Much dispersion

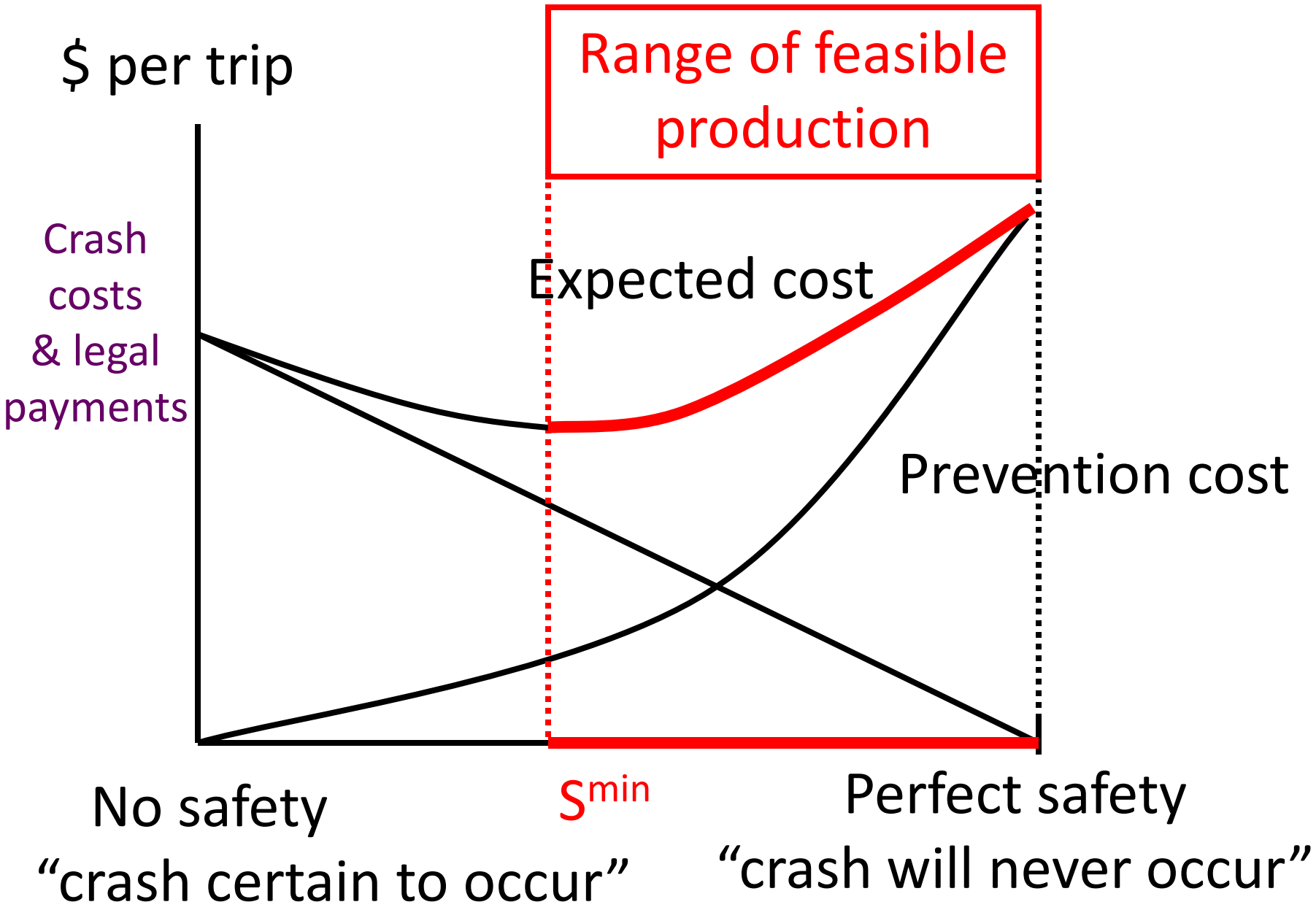
- many carriers
- consumers have varied tastes
- consumers are not bundled together
- consumers are well informed
- “vertical differentiation”

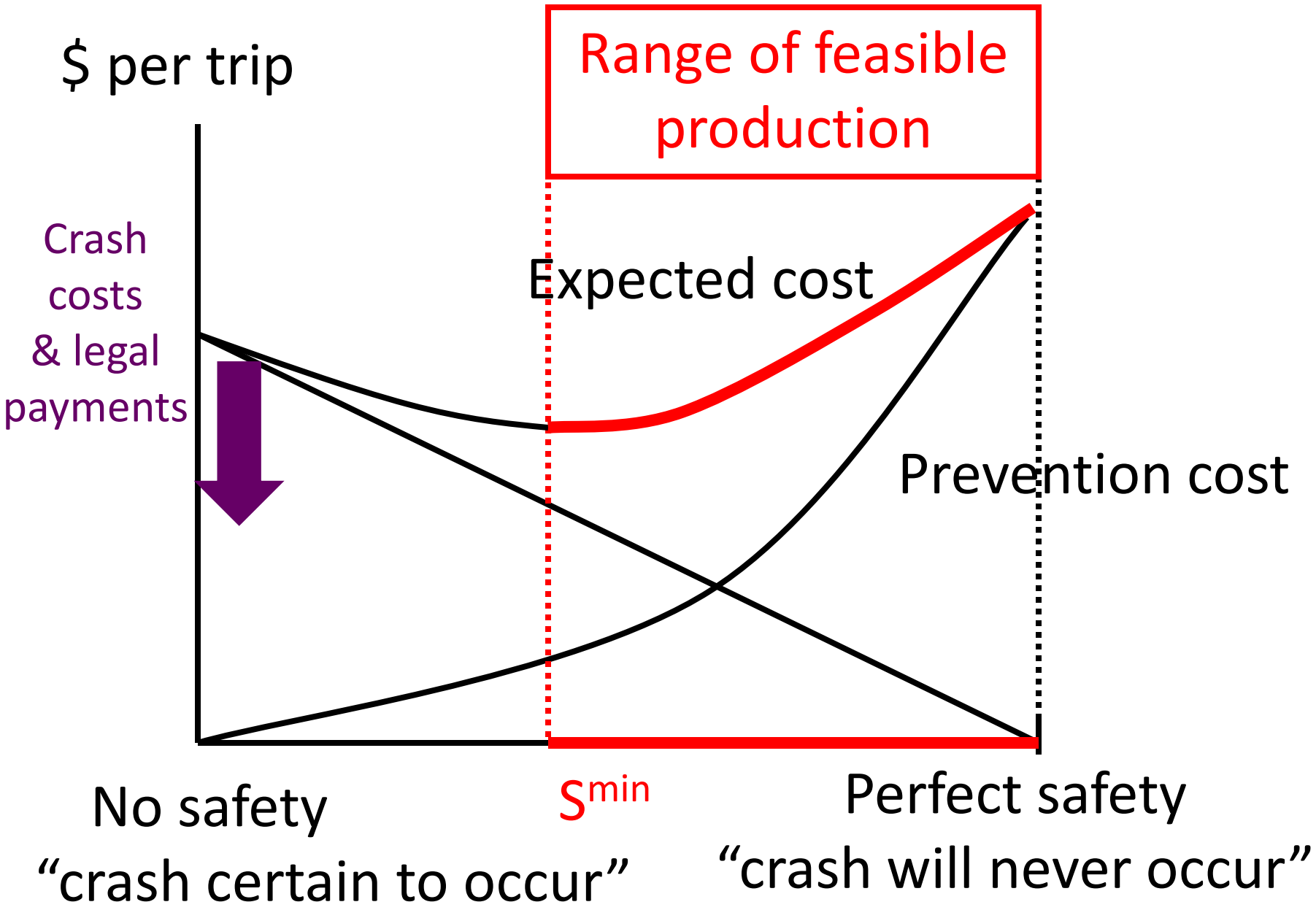
Little dispersion

- few carriers
- consumers have similar tastes
- consumers bundled together – “one size fits all”
- difficult to determine carriers’ safety or differentiate between them

Assumptions for ideal marketplace

- Many carriers and P=MC
- Consumers are fully informed
- Consumers can make rational choices
- All third party effects internalized by carrier
  - Externalities
  - Bilateral crashes


$ per trip
Range of feasible production
Crash costs & legal payments
Expected cost
Prevention cost
No safety
"crash certain to occur"
S^min
Perfect safety
"crash will never occur"


$ per trip
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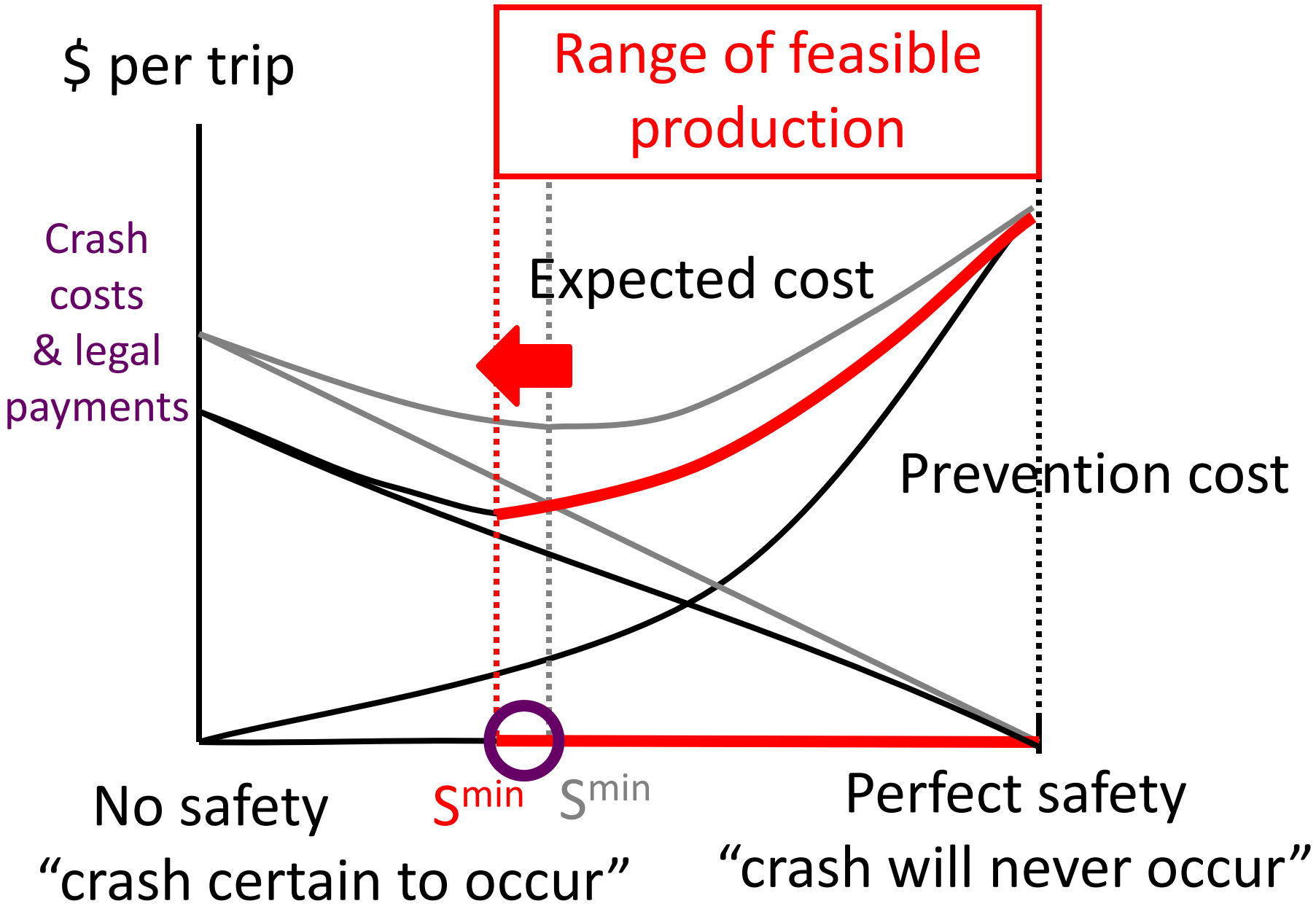
$ per trip
Range of feasible production
Crash costs & legal payments
Expected cost
Prevention cost
S^min
S^min
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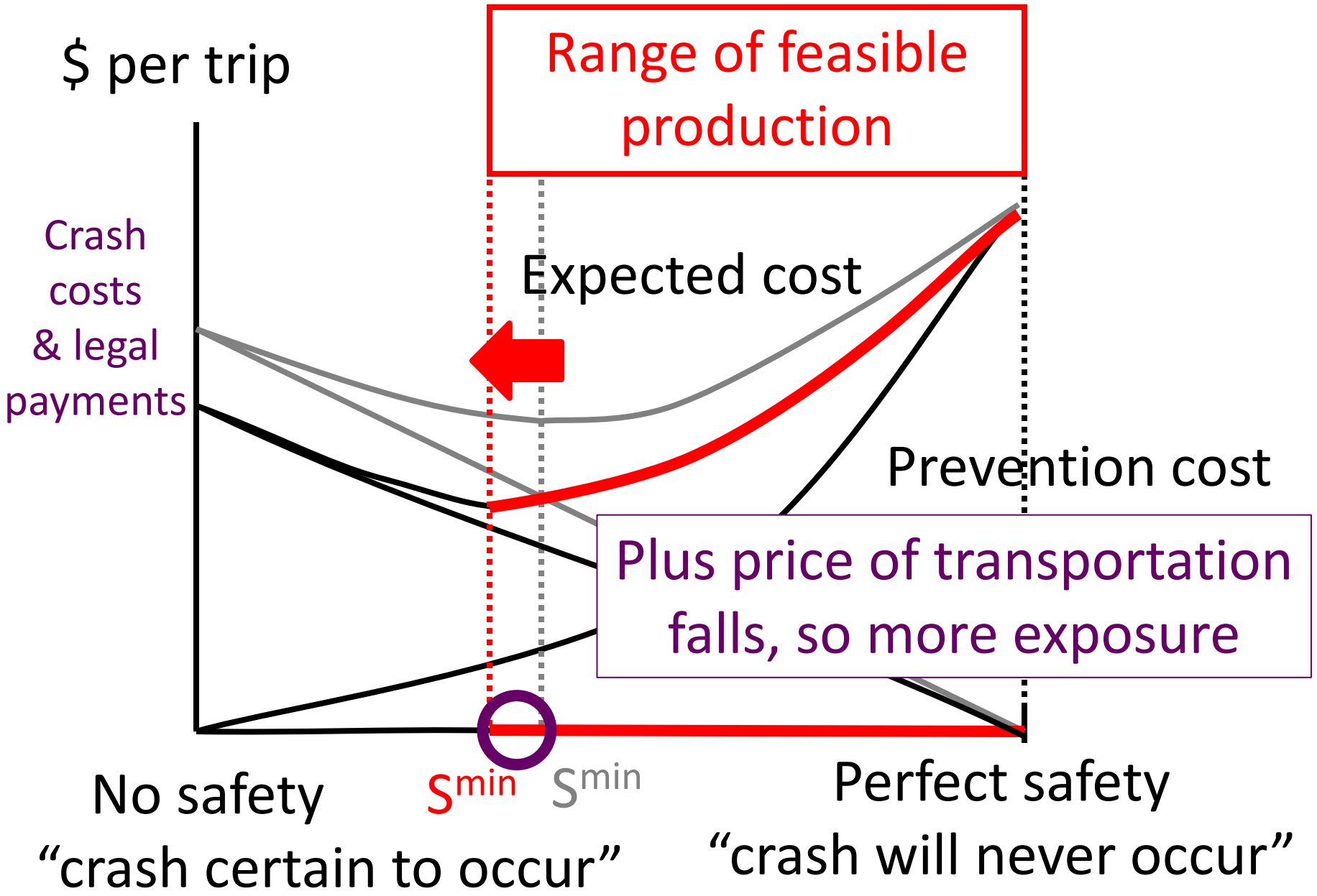
$ per trip
Range of feasible production
Crash costs & legal payments
Expected cost
Prevention cost
Plus price of transportation falls, so more exposure
No safety
"crash certain to occur"
Smin
Smin
Perfect safety
"crash will never occur"

Assumptions for ideal marketplace

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  - Externalities
  - Bilateral crashes
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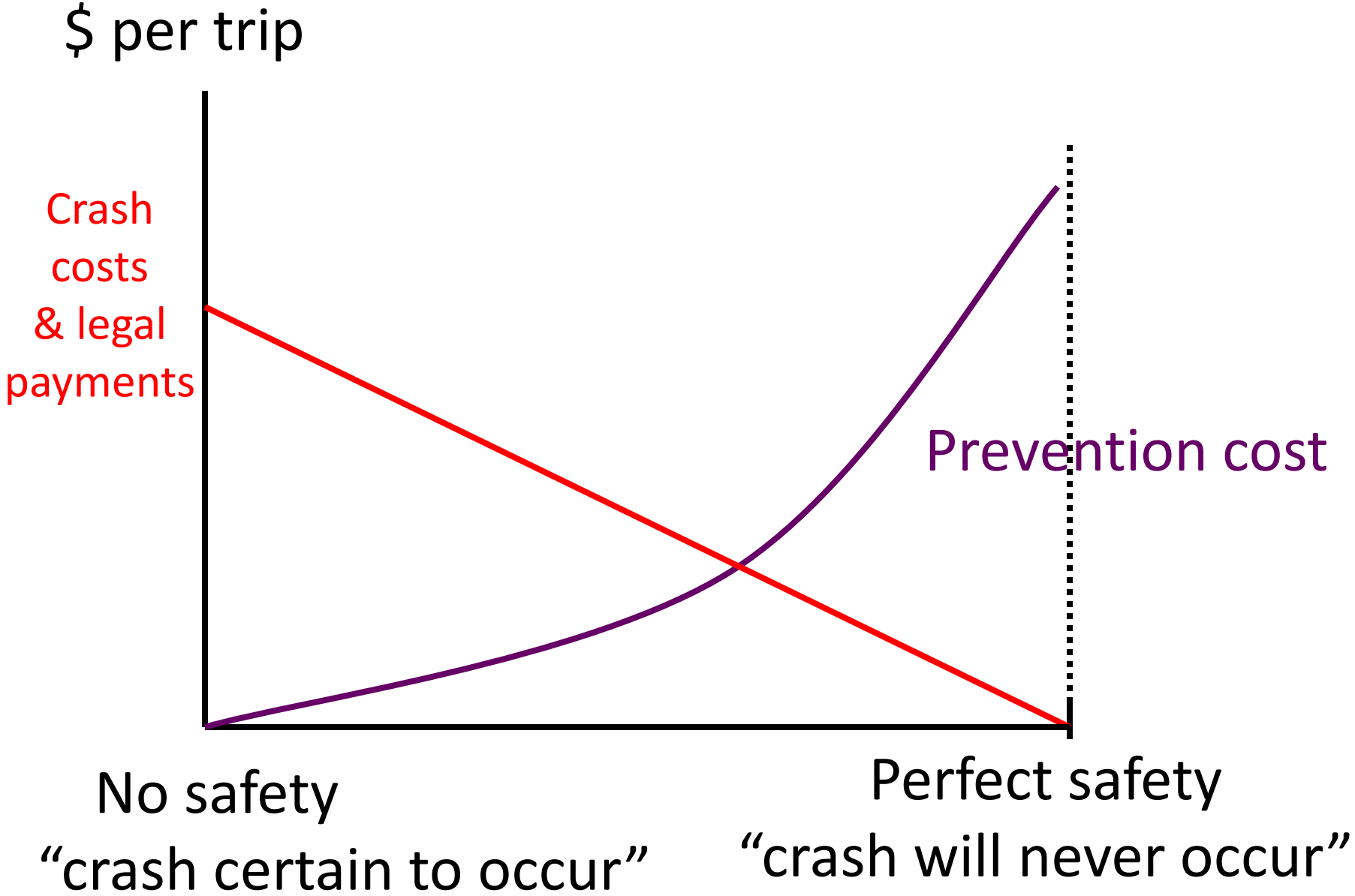
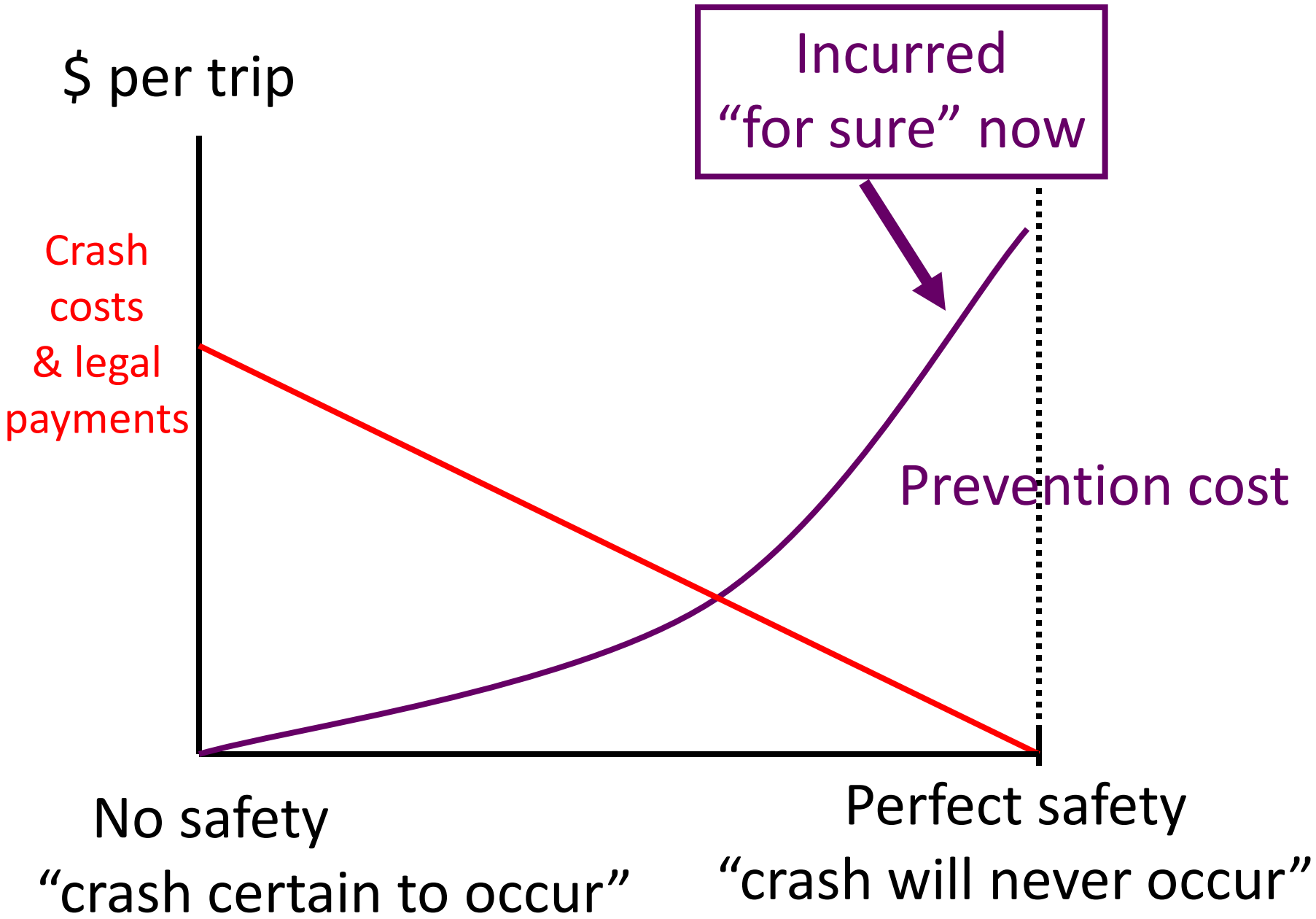
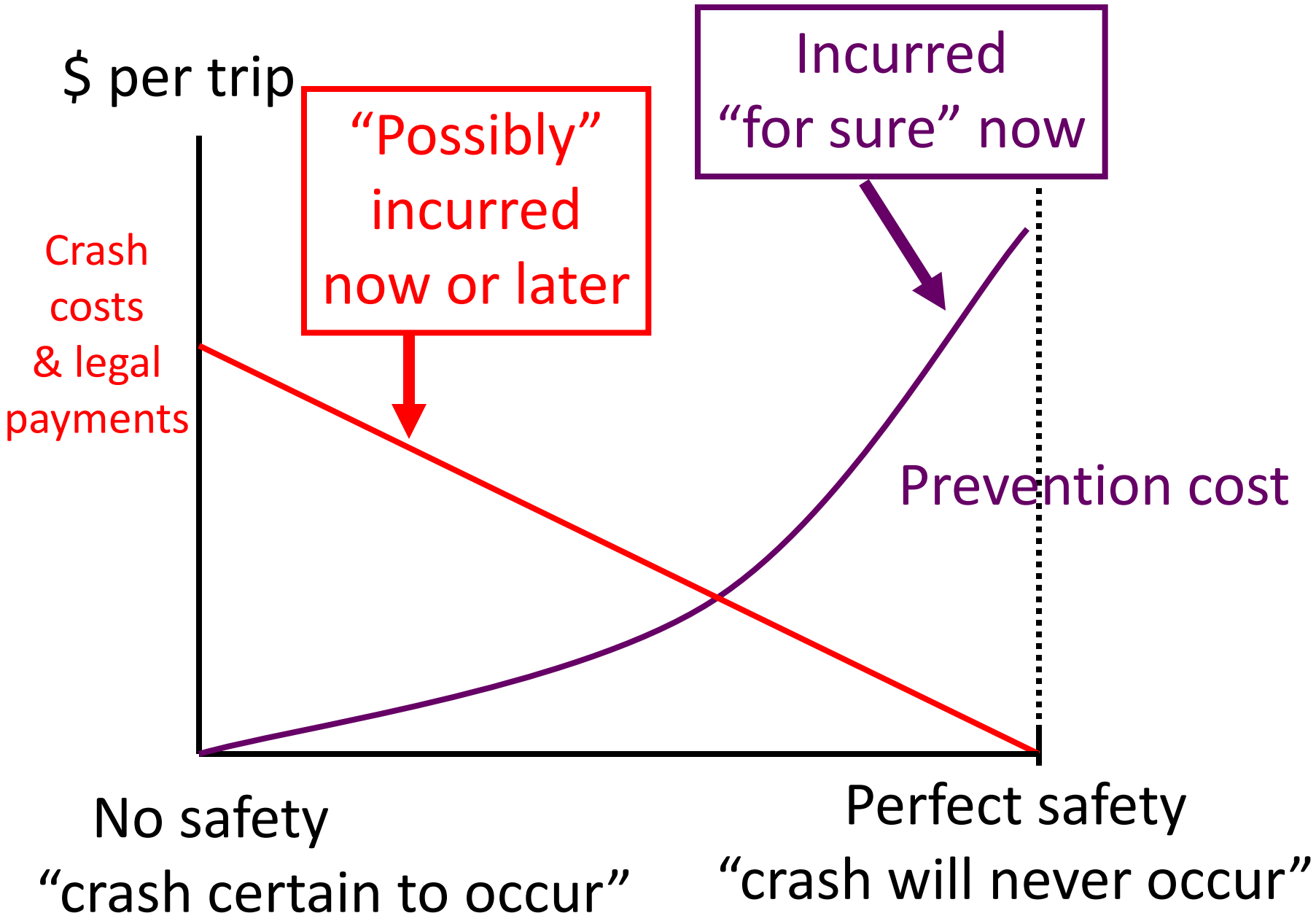
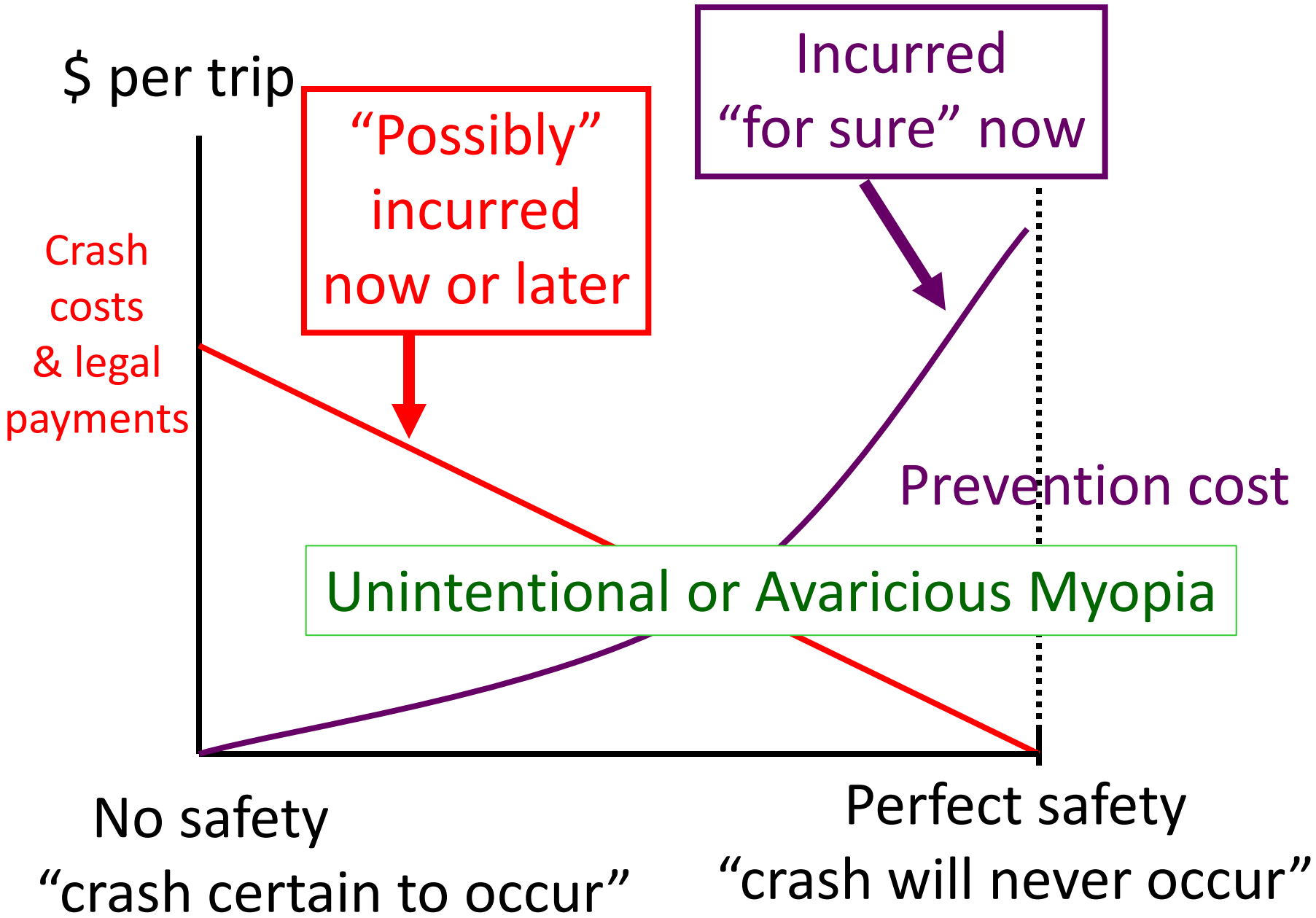
Interact for prevalent market failure

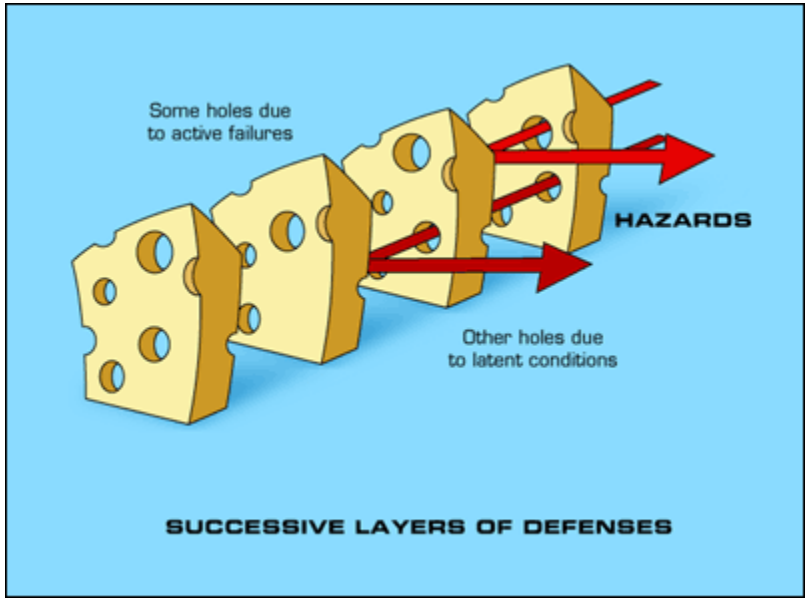

$ per trip
Crash costs & legal payments
Prevention cost
No safety
"crash certain to occur"
Perfect safety
"crash will never occur"


$ per trip
Incurred
“for sure” now
Crash
costs
& legal
payments
Prevention cost
No safety
“crash certain to occur”
Perfect safety
“crash will never occur”


$ per trip
"Possibly" incurred now or later
Incurred "for sure" now
Crash costs & legal payments
Prevention cost
No safety
"crash certain to occur"
Perfect safety
"crash will never occur"


$ per trip
Incurred
"for sure" now
"Possibly"
incurred
now or later
Crash
costs
& legal
payments
Prevention cost
Unintentional or Avaricious Myopia
No safety
"crash certain to occur"
Perfect safety
"crash will never occur"

“What is the harm in removing a few slices of cheese”



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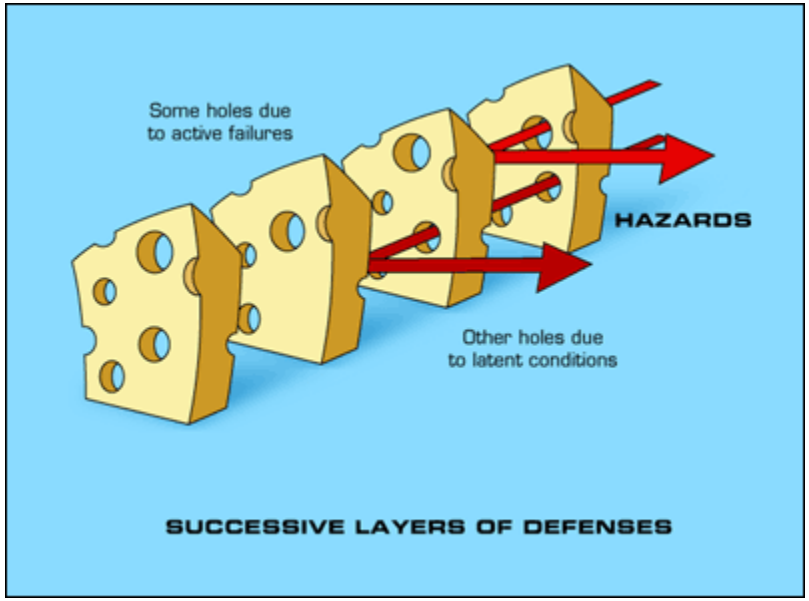

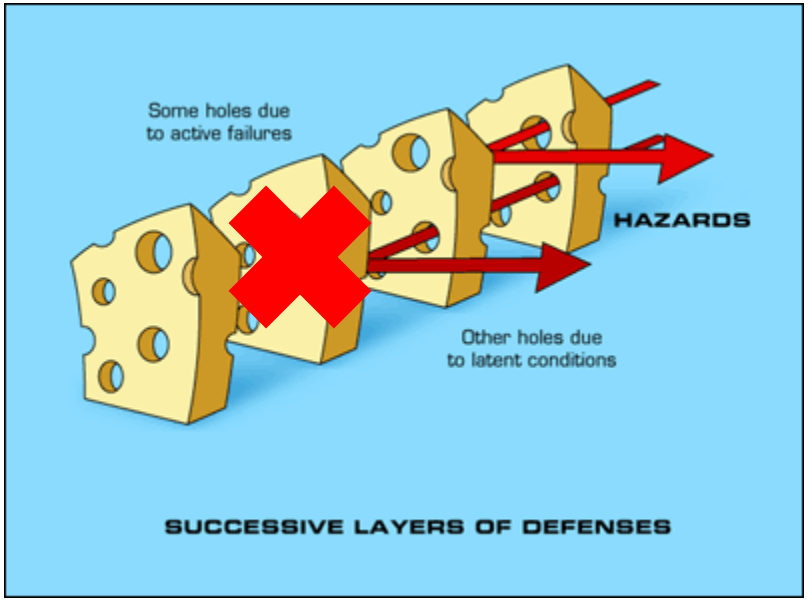

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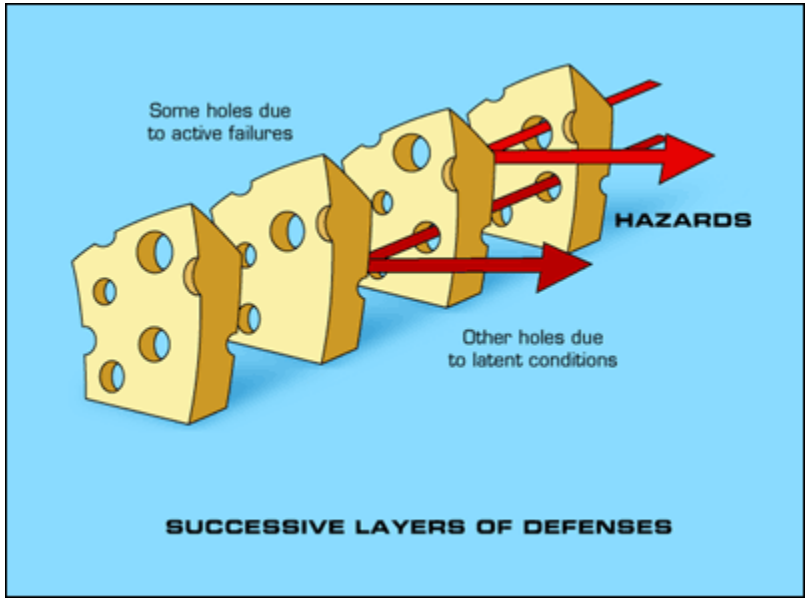
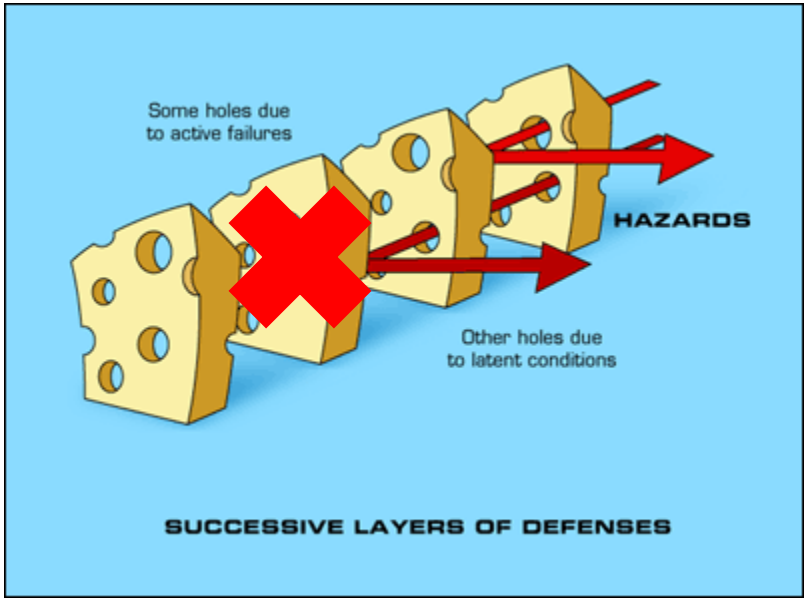




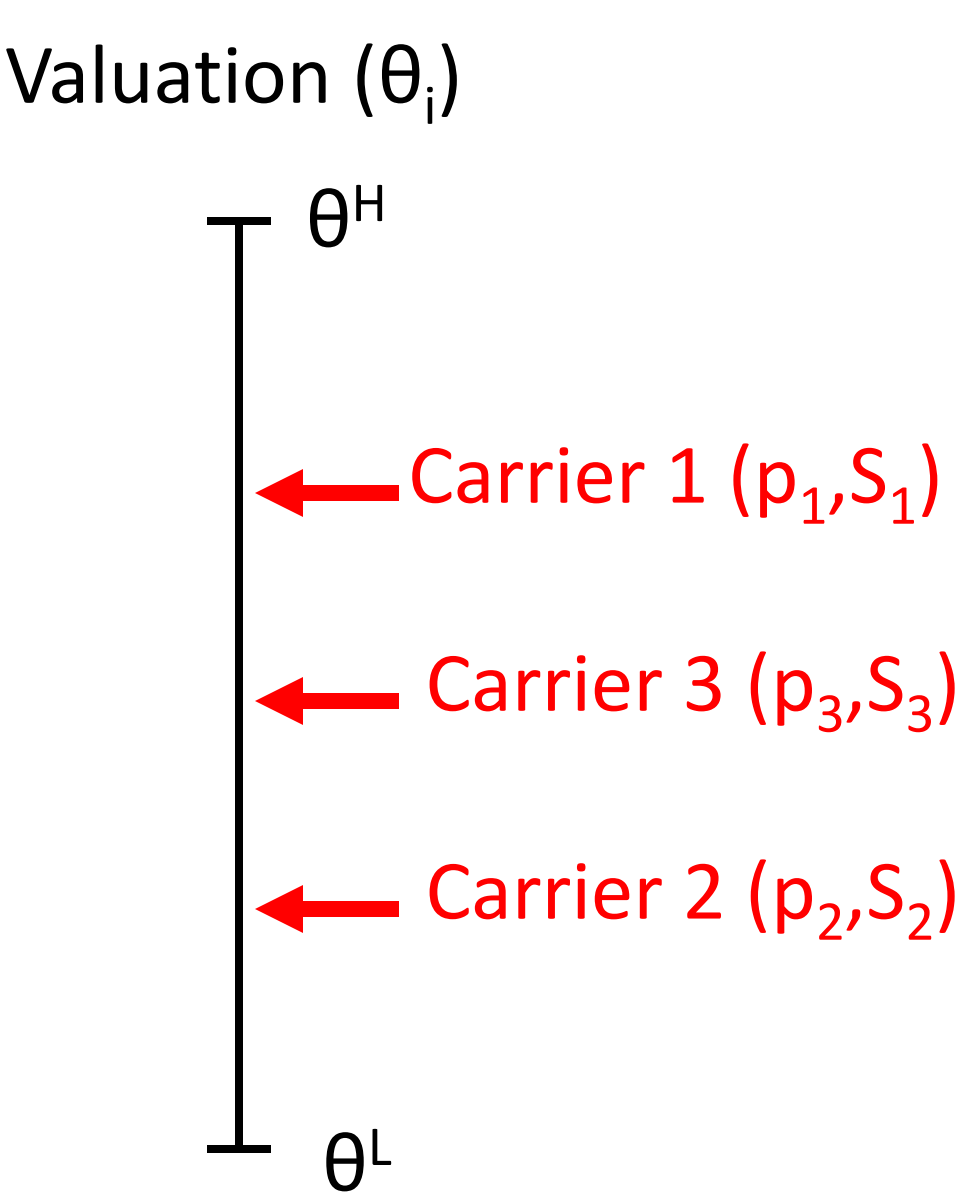
Unintentional or Avaricious Myopia requires consumers “not to notice”

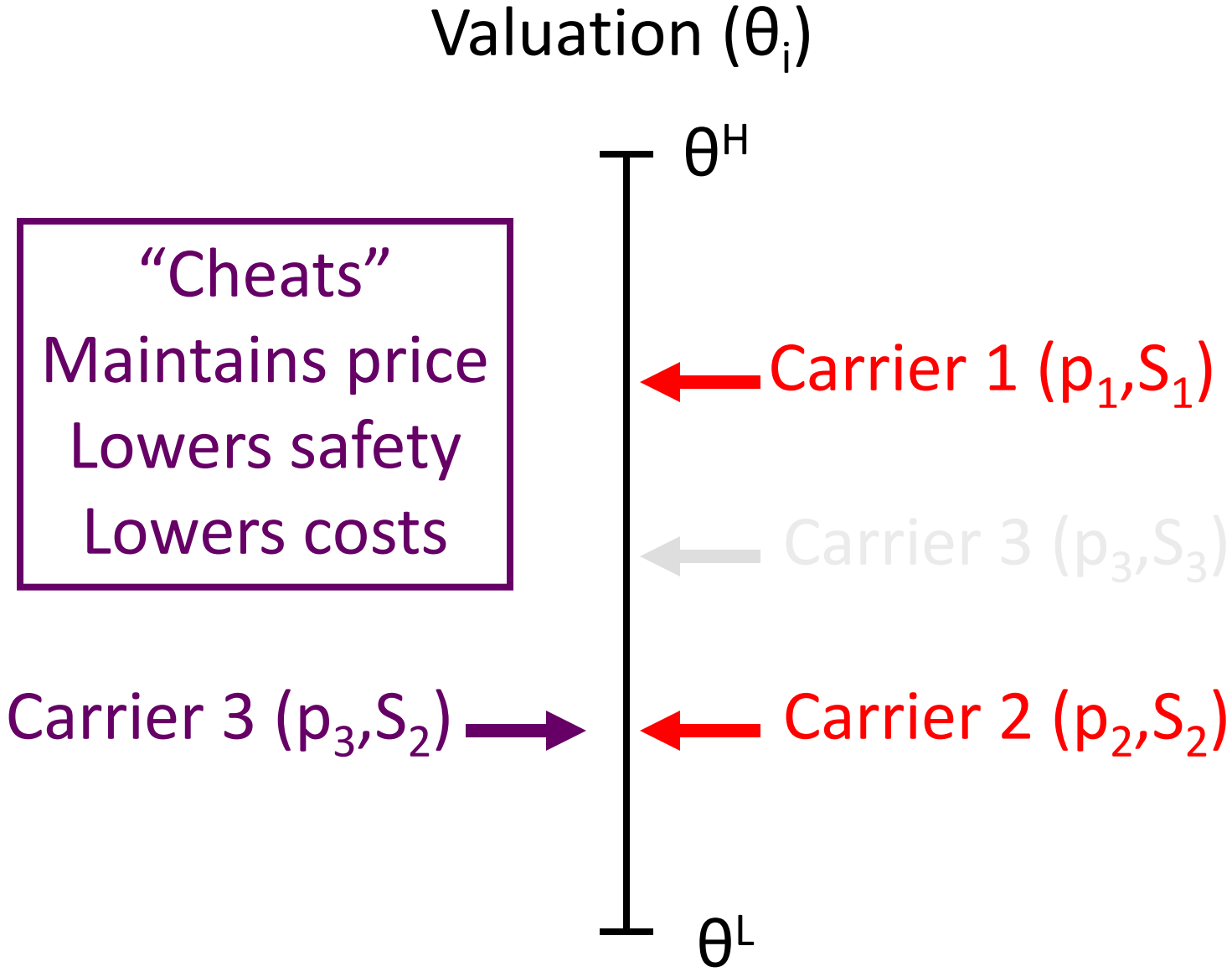
Unintentional myopia

- Primarily associated with inexperienced new entrants
- Basis of most safety regulation
- Initial certification of:
  - Carriers
  - Equipment
  - Employees
- Presumably consistent with S^{min}

Avaricious myopia – “cheating”

- Incumbent firm deviating from past performance
- We all can think of firms in all modes that we believe have engaged in this
- “Milking” or “burning” a reputation
- Generally associated with firms close to bankruptcy, or needing to “get through” a difficult period


Valuation (θ_i)
θ^H
Carrier 1 (p_1,S_1)
Carrier 3 (p_3,S_3)
Carrier 2 (p_2,S_2)
θ^L


Valuation (θ_i)
θ^H
"Cheats"
Maintains price
Lowers safety
Lowers costs
Carrier 1 (p_1,S_1)
Carrier 3 (p_3,S_3)
Carrier 3 (p_3,S_2)
Carrier 2 (p_2,S_2)
θ^L

Avaricious myopia – “cheating”

- Economists are perplexed by the existence of “cheating” in stable markets

- Why is this?

Economics of reputation

1. New “high quality” firm cannot initially charge a high price

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5. If you “burn your reputation” get one time gain but lose stream of future price premiums

Equilibrium competitive prices are such that there is no incentive to cheat

Part 5

How (relatively) important are these deviations?

Magnitude of failures varies by mode

	Few Carriers (limited choice)	Consumers Poorly Informed	Consumer Cognitive Failures	External Costs not Covered	Bilateral Crashes	Carrier Myopia
Private Driving	*	*	***	*	***	n/a
Private Aviation & Boating	Few failures					
Commercial Passenger	**	***	***	*	**	***
Road Freight	*	*	none	***	***	***
Maritime Freight	*	*	none	**	*	***
Rail Freight	***	*	none	**	***	**
Pipelines	***	*	none	***	none	**

Part 6

What (more) can we do about it?

Liability / legal reforms?

	Few Carriers (limited choice)	Consumers Poorly Informed	Consumer Cognitive Failures	External Costs not Covered	Bilateral Crashes	Carrier Myopia
Private Driving	*	*	***	*	***	n/a
Private Aviation & Boating	Few failures					
Commercial Passenger	**	***	***	*	**	***
Road Freight	*	*	none	***	***	***
Maritime Freight	*	*	none	**	*	***
Rail Freight	***	*	none	**	***	**
Pipelines	***	*	none	***	none	**

More extensive insurance holding?

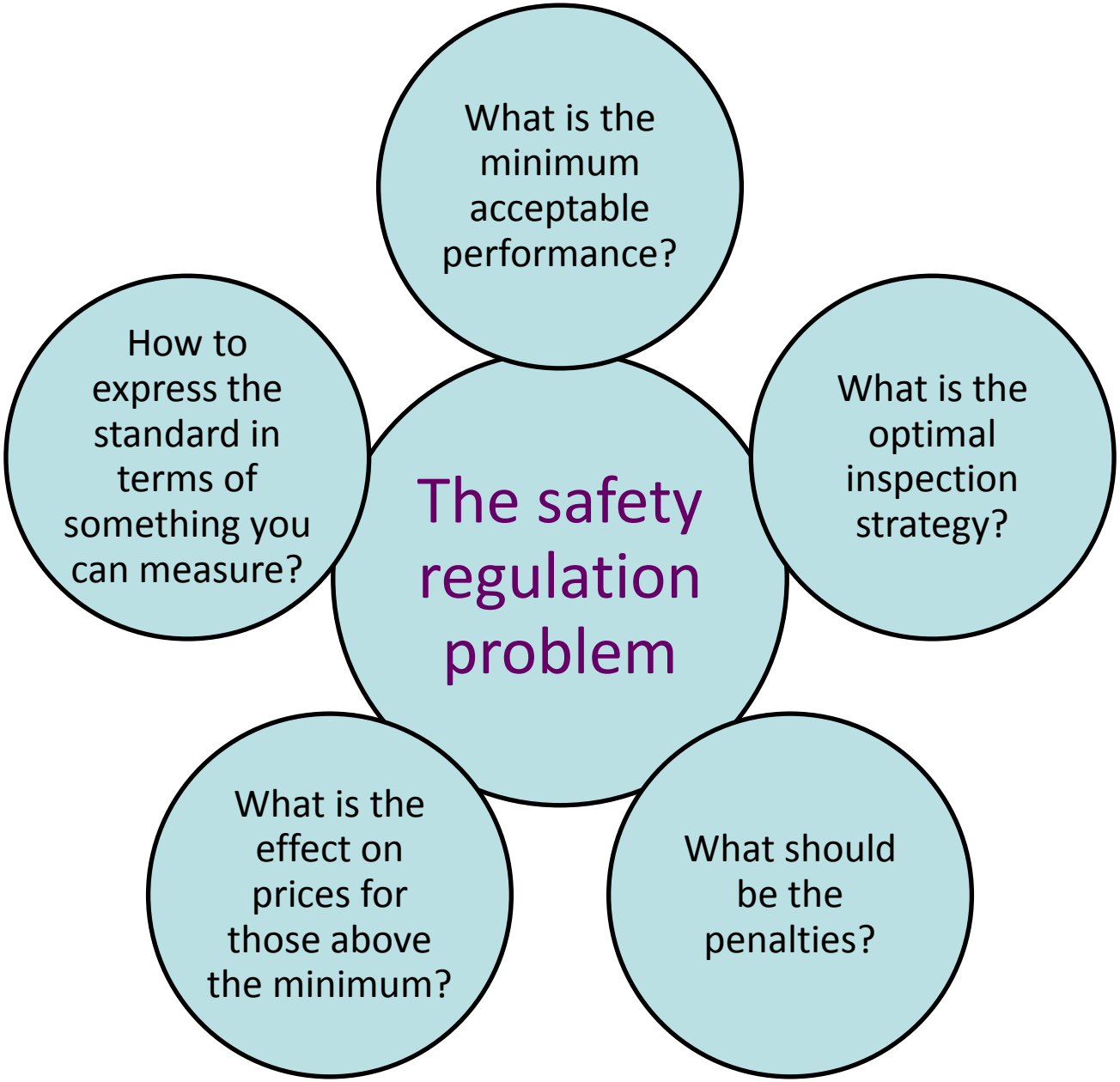
	Few Carriers (limited choice)	Consumers Poorly Informed	Consumer Cognitive Failures	External Costs not Covered	Bilateral Crashes	Carrier Myopia
Private Driving	*	*	***	*	***	n/a
Private Aviation & Boating	Few failures					
Commercial Passenger	**	***	***	*	**	***
Road Freight	*	*	none	***	***	***
Maritime Freight	*	*	none	**	*	***
Rail Freight	***	*	none	**	***	**
Pipelines	***	*	none	***	none	**

More information collection and dissemination in the Internet age?

	Few Carriers (limited choice)	Consumers Poorly Informed	Consumer Cognitive Failures	External Costs not Covered	Bilateral Crashes	Carrier Myopia
Private Driving	*	*	***	*	***	n/a
Private Aviation & Boating	Few failures					
Commercial Passenger	**	***	***	*	**	***
Road Freight	*	*	none	***	***	***
Maritime Freight	*	*	none	**	*	***
Rail Freight	***	*	none	**	***	**
Pipelines	***	*	none	***	none	**

The old standby - regulatory action to enforce some minimum standard

	Few Carriers (limited choice)	Consumers Poorly Informed	Consumer Cognitive Failures	External Costs not Covered	Bilateral Crashes	Carrier Myopia
Private Driving	*	*	***	*	***	n/a
Private Aviation & Boating	Few failures					
Commercial Passenger	**	***	***	*	**	***
Road Freight	*	*	none	***	***	***
Maritime Freight	*	*	none	**	*	***
Rail Freight	***	*	none	**	***	**
Pipelines	***	*	none	***	none	**


What is the minimum acceptable performance?
How to express the standard in terms of something you can measure?
The safety regulation problem
What is the optimal inspection strategy?
What is the effect on prices for those above the minimum?
What should be the penalties?

Final Thoughts

What can we conclude?

Take aways

- Difficult to quantify “optimal safety”
- It will likely involve higher and lower safety carriers coexisting

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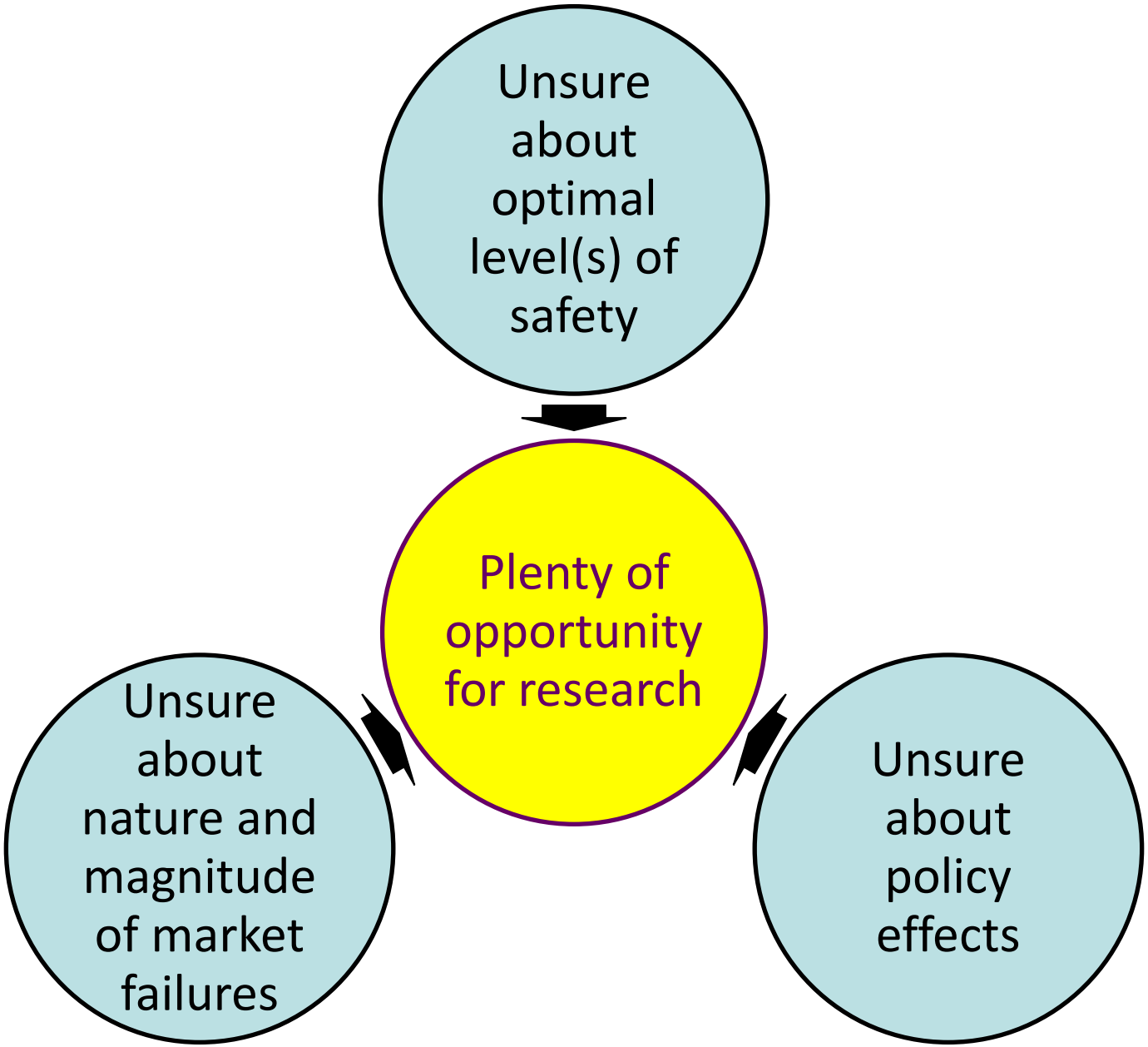
- Market failures are rife, but their nature and magnitude varies by mode

Take aways

- Difficult to quantify “optimal safety”
- It will likely involve higher and lower safety carriers coexisting
- Market failures are rife, but their nature and magnitude varies by mode
- Policy responses are numerous
  - Each have their pluses and minuses
  - Non-trivial to implement
  - Should be deployed in combination


Unsure about optimal level(s) of safety
Plenty of opportunity for research
Unsure about nature and magnitude of market failures
Unsure about policy effects

“Transportation econ. courses with Leon and his cigar were epic! . . . many of us had careers in transportation because of him.” Vicki Whamond Bretthauer

"When I arrived from Italy at NU I was a 25 year old young kid who did not know anything about the realities of American Life. It was [Prof.] Moses who helped me to adjust at NU's life, and motivate me when I was down, or when I could have done better on an exam. Yet these human qualities where coupled by a great professional rigor and vigor that were for me the ultimate example to imitate in action." Corrado Letta

“Leon was one of my favorites and I often tried to sit at the same table with him during Transportation Center BAC meetings.” Chuck Lounsbury

"There is no doubt in my mind that he was one of the few persons who had a very significant impact on me and my spirit. He was great as a scientist and very kind as a human being. I have not seen him for a long time but I always thought about him, now I will carry his memory in my heart."
Yossi Prashker

October 24, 1924 – October 12, 2013

- Friend
- Leader
- Scholar