Economic Instruction

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PAUL GRIMES, Section Editor

Child Safety Seats on Commercial Airliners: A Demonstration of Cross-Price Elasticities

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Abstract: The cross-price elasticity concept can be difficult for microeconomics students to grasp. The authors provide a real-life application of cross-price elasticities in policymaking. After a debate that spanned more than a decade and included input from safety engineers, medical personnel, politicians, and economists, the Federal Aviation Administration (FAA) recently announced that it would not mandate the use of child safety seats on commercial airliners. The FAA's analysis revealed that if families were forced to purchase additional airline tickets, they might opt to drive rather than fly, and driving represents a far more dangerous mode of travel. Given the relatively high cross-price elasticity between automobile travel and air travel, the FAA concluded that the mandatory child safety seat policy failed to pass the cost-benefit test—the policy would lead to a net increase in the number of fatalities. The authors review the FAA's decision-making process and highlight the role of economic analysis in developing public policy.

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The concept of a cross-price elasticity is important in microeconomics, and our collective experience is that students frequently have difficulty understanding and applying this concept. In addition, students tend to treat cross-price elasticities as merely a theoretical concept that is of limited practical value. We examine the child safety seat (CSS) mandate proposal on commercial airplanes as a real-life example that illustrates the use of cross-price elasticities in policymaking. A CSS mandate would raise the price of flying for passengers with children because seats would then have to be purchased separately for infants less than two years of age. This increase in price reduces the quantity of air travel demanded and increases the quantity of automobile travel, a riskier substitute for air travel. If the substitution effect—that is, the cross-price elasticity—is sufficiently large, mandatory CSS may increase the number of fatalities. Through this example, we demonstrate that the cross-price elasticity concept is not only an important one in microeconomics but also an important tool for policy analysis.

On August 25, 2005, the FAA announced that it would not mandate the use of CSSs on airplanes. The FAA (2005) analyses indicated that, if families were forced to purchase additional airline tickets, they might opt to drive rather than fly, and driving represents a far more dangerous mode of travel. In other words, given the effective cross-price elasticities, the increase in the price of airfare for families would cause them to substitute relatively risky automobile travel for relatively safe air travel. Fatalities per 100 million passenger miles traveled were approximately 0.03 for air travel and 0.97 for highway travel during the period from 1995 through 2003[1] (Tables 1 and 2; see also Figure 1). It is estimated that a CSS mandate would save 0.3 infant lives per year in the air. Specifying demand functions for air travel and highway travel and adopting the cross-price elasticity estimate used in Windle and Dresner (1991), we estimated that a CSS mandate would cause an additional 11.5 deaths per year on the nation's roadways. Thus, a mandatory CSS policy would be expected to lead to a net increase in the number of fatalities.

To the casual observer, it may seem that a policy mandating CSSs on commercial airliners is a no-brainer. After all, if CSSs are mandated in automobiles traveling 60 miles per hour, it stands to reason that they should also be required on airplanes traveling 600 miles per hour. Yet, as Thomas Sowell (1995) previously observed,

TABLE 1. U.S. Highway Fatalities per 100 Million Passenger Miles

	Year								
	1995	1996	1997	1998	1999	2000	2001	2002	2003
Rate	1.0811	1.0600	1.0274	0.9880	0.9692	0.9555	0.9087	0.9215	0.9082

Note. Calculated using U.S. highway fatalities and U.S. highway passenger miles for each year.
Source. U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, annual.

TABLE 2. U.S. Air Carrier Fatalities per 100 Million Passenger Miles

	Year								
	1995	1996	1997	1998	1999	2000	2001	2002	2003
Rate	0.0416	0.0874	0.0018	0.0002	0.0025	0.0178	0.1091	0.0000	0.0044

Note. Calculated using U.S. air carrier fatalities and U.S. air carrier passenger miles for each year.
Source. U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, annual.

whether mandating CSSs on commercial aircraft constitutes good public policy, in the sense that it results in a net reduction in fatalities, is first and foremost an empirical issue. To wit, if the cross-price elasticity between automobile travel and air travel is sufficiently large, the effective higher price of air travel will induce a large number of families to substitute risky automobile travel for relatively safe air travel, resulting in a net increase in the number of fatalities.

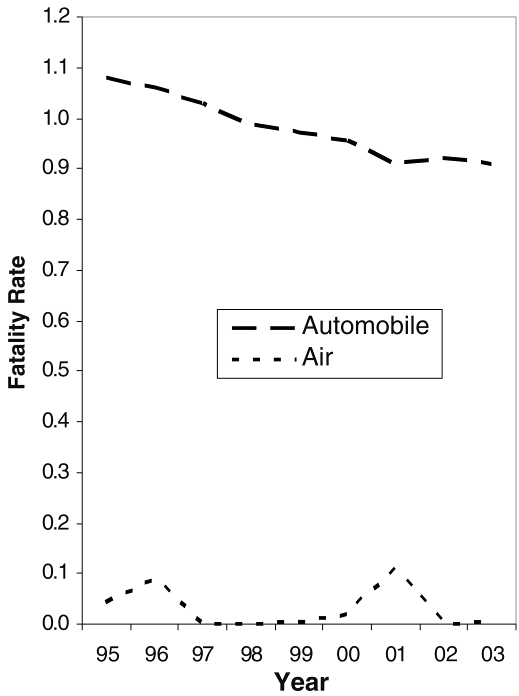

FIGURE 1. Fatalities per 100 million passenger miles by mode.

We use the mandatory CSS policy proposal as an avenue through which to highlight the importance of cross-price elasticities and their role in developing public policy. To illustrate the relevant tradeoffs, we first review the cost-benefit analysis conducted by the FAA in arriving at its decision not to implement the CSS policy. We then develop the key demand concepts underlying the relevant tradeoffs. To further underscore the instructional nature of this material, we provide classroom discussion questions and quantitative exercises, to enhance student learning.

OVERVIEW OF FAA ANALYSIS

From the time of its inception in 1958, the FAA has permitted children under 2 years of age on commercial flights to sit on the lap of an accompanying adult.[2] From a safety standpoint, the practice was noncontroversial over most of its history because of the absence of effective CSSs for airplanes. This technological constraint dissipated over the ensuing decades, however, to the point that in 1982 the FAA issued its first regulation defining performance standards for CSSs used on airlines. This regulation essentially approved those safety seats that pass the FAA's dynamic test.[3] In 1985, the FAA updated standards to ensure that approved CSSs performed satisfactorily in a rollover test.

By 1990, three econometric studies had been undertaken to explore the overall safety implications should the FAA require use of CSSs on commercial aircraft (McKenzie and Lee 1990; Windle and Dresner 1991; U.S. Department of Transportation 1990). Each of these studies, including one commissioned by the FAA itself, concluded that such a policy would result in a net loss of lives. The basis for this result was that some families, if required to purchase an extra seat for their young child, would substitute highway travel for air travel.[4] Because the highway mortality rate per passenger mile is significantly greater than the corresponding mortality rate for air travel, the FAA's 1990 study estimated a net loss of 8.2 lives during the ensuing 10 years should CSSs be mandated on commercial aircraft (U.S. Department of Transportation 1990). In addition, the study projected 52 more serious injuries and 2,300 more minor injuries over the same period if a CSS mandate were enacted. The essence of this result, that such a policy would have negative overall safety consequences, was further corroborated by an updated 1993 econometric study prepared for the FAA (Apogee Research 1993).

Notably, the central conclusions of these studies formed the basis for the FAA's *de facto* decision during the early 1990s not to mandate CSS on commercial airlines despite strong pressure from the National Transportation Safety Board, members of the U.S. Congress, and the Association of Flight Attendants.[5]

Reacting to a 1997 recommendation from the White House Commission on Aviation Safety and Security that the FAA create such a mandate, the FAA issued an Advanced Notice of Proposed Rulemaking on February 18, 1998, concerning the requirement of CSSs on commercial airplanes (Child Restraint Systems 2005). This notice allowed a period in which the public could voice opinions on the issue. After years of public feedback, the FAA officially withdrew the notice on August 26, 2005, "to pursue other options that will mitigate the risk of child injuries and fatalities in aircraft" (Child Restraint Systems 2005, 50226). The FAA justified this policy decision with essentially the same argument that it had provided when the issue first became public in 1990.

During the early years of the CSS debate, major U.S. airlines, as represented by the Air Transport Association (ATA), supported an FAA mandate on CSSs. On February 22, 1990, the ATA issued a petition to the FAA requesting that the FAA enact such a mandate. Following the FAA's 1995 Report to Congress, which departed from previous studies in predicting an adverse market outcome for the airline industry should a CSS mandate take effect, the ATA relinquished its initial position by withdrawing the 1990 petition (U.S. Department of Transportation). Subsequently, the ATA has publicly supported a nonregulatory solution to the child safety issue (U.S. Congress, House of Representatives, Committee on Transportation and Infrastructure 1996). (For further discussion of this topic, see Appendixes.)

DEMAND CONCEPTS

In this section, we develop the basic demand concepts required for students to understand the economic analysis that the FAA conducted in arriving at its public policy decision not to mandate CSSs.

Suppose the demand functions for air travel and automobile travel are given, respectively, by

$$\ln(Q^A) = \beta_1 + \beta_2 \ln(P^A) + \beta_3 \ln(P^M) + \beta_4 \ln(I), \quad \text{and} \tag{1}$$

$$\ln(Q^M) = \gamma_1 + \gamma_2 \ln(P^M) + \gamma_3 \ln(P^A) + \gamma_4 \ln(I), \tag{2}$$

where P^A and Q^A are prices and quantities of family travel units (FTUs) by air travel, P^M and Q^M are prices and quantities of FTUs by automobile travel, I is income, and $\ln(\cdot)$ is the natural logarithm function. A typical FTU consists of four members, including one child under 2 years of age and one between 2 and 5 years of age.[6] Given the double-log functional form, the coefficients in the demand equations represent elasticities. According to the law of demand, we expected the own-price elasticities, β_2 and γ_2, to be negative. Generally, air travel and automobile travel are considered to be substitute modes of long-distance travel, so β_3 and γ_3 were expected to be positive. Because both goods are generally considered to be normal goods, β_4 and γ_4 were expected to be positive.

The demand function for automobile travel in equation (2) is of particular interest for the CSS policy. The cross-price elasticity of Q^M with respect to P^A is γ_3. This represents the percentage change of FTUs that will choose to travel by automobile if the price of air travel rises by 1 percent, *ceteris paribus*. If the cross-price elasticity is 0 ($\gamma_3 = 0$), the adoption of the CSS policy would reduce the number of fatalities associated with air travel without increasing the number of fatalities associated with automobile travel. Conversely, if the cross-price elasticity is positive, the implementation of the CSS policy would reduce the risk associated with air travel but would simultaneously increase the number of families who choose to drive and thereby increase the number of families at risk through automobile travel.

We adopted the assumptions of Windle and Dresner (1991) in our numerical analysis. The mortality rate for air travel is 0.264 per billion passenger miles, and that of auto travel is 12.80 per billion passenger miles. The price of air travel per FTU is $295.75 before the CSS policy is implemented and $357.90 afterwards, a 21 percent increase in price. The cross-price elasticity (γ_3) is 0.356. This implies that a 1 percent increase in the price of air travel leads to a 0.356 percent increase in FTUs by automobile, *ceteris paribus*. Hence, a 21 percent increase in the price of air travel leads to a 7.48 percent increase in FTUs by automobile, which translates into 300,000 FTUs. The increase in automobile fatalities induced by the CSS policy is 11.5 fatalities per year. It is estimated that 0.3 lives can be saved in air travel per year from the CSS policy. The implementation of the CSS policy would divert many FTUs to travel by automobile, a far more dangerous mode of travel, and thus increase the net number of fatalities. It was on the basis of just such an analysis that the FAA declined to implement the CSS policy.

To further demonstrate the relationship between the cross-price elasticity and the change in fatalities, Figure 2 illustrates the additional fatalities from automobile travel and the decrease in fatalities by air travel when the CSS policy is implemented. The flat line shows the reduced number of air-travel fatalities resulting from the CSS policy—0.3 per year. The dotted line shows the relationship between the additional automobile-travel fatalities and the cross-price elasticity on

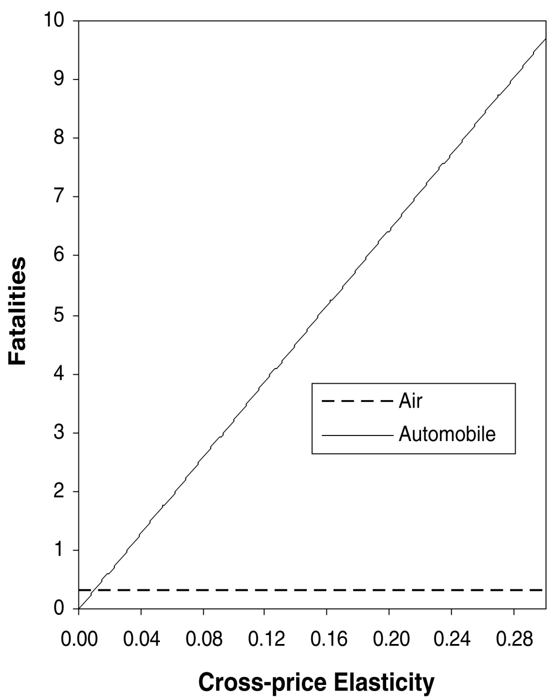

FIGURE 2. Relationship between fatalities and cross-price elasticity.

implementation of the CSS policy. For example, if the cross-price elasticity is 0.20, the increase in automobile fatalities is 6.5. The breakeven cross-price elasticity is $\gamma_3 = 0.01$. Hence, when $\gamma_3 < 0.01$, the number of air-travel fatalities avoided as a result of the CSS policy exceeds the increased number of automobile fatalities, and vice versa.

On the basis of the demand function for air travel in equation (1), the own-price elasticity for air travel is β_2. According to Windle and Dresner (1991), $\beta_2 = -0.381$, which implies that a 1 percent increase in price of air travel leads to a 0.381 percent decrease in FTUs. Because the price of air travel would be expected to increase by 21 percent, the number of FTUs by air travel will decrease by 8 percent or 321,000 FTUs.[7] If the own-price elasticity is sufficiently large in absolute value, implementing the CSS policy would result in lower profits for the airlines.[8]

CLASSROOM DISCUSSION QUESTIONS

In this section, we briefly outline a series of discussion questions that instructors may use to facilitate classroom discussion and promote active learning.

1. Would the FAA have likely reached a different conclusion if air travel and automobile travel were independent goods?
2. Suppose that the government subsidized the additional cost associated with the use of mandatory CSSs on commercial aircraft. How would this have influenced the FAA's cost-benefit analysis?
3. In light of the rationality axiom in economics, what position would you expect the automakers Chrysler, Ford, and GM to take on the issue of mandating CSSs on commercial aircraft?
4. When considering whether to raise the terrorism threat warning levels at airports, should the Transportation Safety Administration (TSA) take into account the fact that some individuals may respond by substituting automobile travel for air travel?[9]
5. The antitrust laws in the United States prohibit the airlines from colluding with one another for purposes of jointly setting prices, but the airlines are not prohibited from communicating with one another for purposes of deciding whether to support particular regulatory policies. How might the airlines use their discretion to communicate with one another on the issue of mandatory CSSs as an instrument of collusion?

CONCLUSION

This discussion highlights the role of economic analysis, and cross-price elasticities in particular, in informing the FAA's decision making concerning the merits of the CSS policy. After extensive analysis over more than a decade, the FAA concluded that the mandatory CSS policy failed to pass the cost-benefit test in that the expected number of lives saved in the air from the implementation of the CSS policy was considerably less than the number of lives that would be lost as a result of diverting families to the nation's relatively risky highways. In this case, cross-price elasticities, given their prominent role in developing public policy, are indeed a matter of life and death.

NOTES

1. The two values, each derived from Bureau of Transportation Statistics data, reveal a large safety differential between the two modes. Observing prior years in Tables 1 and 2, we see that this large differential is persistent.
2. Note that the Civil Aviation Board, which handled aviation safety prior to the creation of the FAA, also allowed for this practice. Source: Nancy Claussen, FAA Flight Standards Office.
3. Specifically, CSSs must pass what the FAA technically refers to as a "16g longitudinal aircraft deceleration test."
4. The study assumes infant tickets are offered at a 50% discount.
5. Although refusing to bow to pressure from these groups, the FAA continued to improve safety standards for CSSs on airlines throughout the 1990s. A series of 1994 safety tests, performed by the FAA Civil Aeromedical Institute in preparation for the FAA's 1995 Report to Congress, identified the overall superiority of aft-facing CSSs in protecting infants under 20 pounds. See U.S. Department of Transportation. *Report to Congress: Child Restraint Systems.* Washington, DC: May 1995.
6. U.S. Department of Transportation (1990) simulated the CSS policy impact under various assumptions about the size and the composition of FTUs.
7. To be consistent, all of the above parameter values are taken from Windle and Dresner (1991). Different results would be obtained and possibly different conclusions would follow if alternative parameter values were used. This is particularly likely to be the case given that the number of fatalities preventable by the CSS policy is subject to large error.
8. In this discussion, we use double-log demand functions to illustrate the basic demand concepts. Note that the simulations and policy analysis do not rely on a specific functional form of the demand functions—only the elasticities. Although some demand functions, such as the Linear Expenditure System and the Almost Ideal Demand System, are more reasonable to describe consumer behavior, they are less tractable for undergraduate and MBA students in microeconomics courses and thus are not adopted in this article. See, for example, Deaton (1997) and Varian (1992) for more details.
9. We are grateful to an anonymous referee for suggesting this question.

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APPENDIX A

FURTHER READING

Interested readers can find additional discussion on this topic in Windle and Dresner (1991), McKenzie and Warner (1987), and U.S. Department of Transportation (1990). It should be noted, however, that the last two articles are technical in nature and may only be appropriate for undergraduate students with a strong quantitative background. For other applications of cross-price elasticities, see Bask and Melkersson (2003) and Ault et al. (2005) for an interesting exchange on cross-price elasticities and the cessation of smoking. See Davis and Wohlgenant (1993) for the first estimate of the cross-price elasticity of natural Christmas trees with respect to artificial Christmas trees. See Abraham, Vogt, and Gaynor (2002) for estimates of cross-price elasticities of different health insurance plans. See Decker and Schwartz (2000) for an interesting analysis of the asymmetrical demand relationship between cigarettes and alcohol. See Diamond and Fayed (1998) for an analysis of the substitutability between adult labor and child labor.

APPENDIX B

STUDENT EXERCISES

1. The airlines have estimated that the average price of an airline ticket would rise by $40 if the government mandated the CSS policy. The government believes this policy would reduce fatalities on airplanes by 400 per year. The demand for automobile travel is $Q^M = 200 - P^G + I + 0.75P^A$, where Q^M is quantity of miles driven per year (in units of 100,000 miles), P^G is the price per gallon of gasoline, I is per-capita income (in thousands of dollars), and P^A is the average price of an airline ticket (in dollars). The government estimates that there are 10 automobile fatalities for each 100,000 miles driven.

a) How many additional miles will be driven as a result of the \$40 increase in the average price of an airline ticket?
b) How many additional fatalities on the highways will result from the \$40 increase in the average price of an airline ticket?
c) Determine whether mandating the CSS policy will save lives. Provide the economic rationale for your answer.

2. Suppose that the demand for air travel is given by $Q^A = 20 - P^A + I$, where Q^A is quantity of miles flown per year, P^A is the price, and I is per-capita income. In addition, the supply of air travel is given by $Q^A = P^A - S$, where S is an index of airport/airplane security.
   a) Solve for the equilibrium price and quantity of air miles.
   b) Determine precisely how the equilibrium price of air miles varies with S and I.
   c) Suppose that the demand for automobile travel is given by $Q^M = 64 - 6P^G + 5P^A$, where Q^M is the quantity of miles driven annually (in millions of miles), and P^G is the price per gallon of gasoline. The government has proposed that the airlines double S from 4 to 8. Using your findings from part a), determine how many additional miles will be driven as a result of the proposed increase in S.
   d) The government estimates that there are 10 automobile fatalities for each 1,000,000 miles driven. How many lives must be saved as a direct result of the proposed increase in S for there to be a net reduction in the number of lives lost? Provide the economic rationale for your answer.
3. Suppose that the demand function for annual automobile travel is given by $\ln(Q^M) = \gamma_1 + \gamma_2 \ln(P^M) + \gamma_3 \ln(P^A) + \gamma_4 \ln(I)$, where P^M and Q^M are prices and quantities of family travel units (FTUs) by automobile travel, P^A is the price of FTUs by air travel, I is income, and $\ln(\cdot)$ is the natural logarithm function.
   a) Prior to the implementation of the CSS policy, $P^A = \$300$ and $Q^M = 3{,}000{,}000$ FTUs. After the implementation of the CSS policy, $P^A = \$360$, and $Q^M = 3{,}300{,}000$ FTUs. What is the cross-price elasticity of automobile travel with respect to air travel (i.e., γ_3)?
   b) On the basis of your estimate of the cross-price elasticity in part a), determine whether air travel and automobile travel are complements, substitutes, or neither.
   c) Suppose that on average there are 4 highway fatalities for every 100,000 FTUs and that mandating the CSS policy results in a 20 percent increase in P^A. On the basis of your estimate of the cross-price elasticity in part a), determine how many air travel fatalities must be reduced by the CSS policy to justify its implementation.