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Genetic Risk Factors and Offsetting Behavior: The Case of Skin Cancer

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Abstract

This paper analyzes the extent of offsetting behavior using survey data on risk beliefs about skin cancer and precautionary actions that people can take to avoid this disease. The perspective taken is that, at conception, people are "installed" with differing genetic characteristics, such as skin type and complexion, which affect the likelihood of contracting skin cancer. The main issue addressed deals with how people's risk beliefs respond to the "safety features" reflected in their own genetic characteristics. Empirical results presented suggest that precautions against solar radiation exposure are chosen so as to partially offset genetic skin cancer protection.

Key words: Offsetting behavior, skin cancer, risk beliefs

JEL Classification: Q2, J2

Effectiveness of public policies concerning safety depends critically on how people respond to changes in risk. Technologists implicitly predict that government-mandated safety improvements in workplaces, vehicles, and other consumer products will be fully effective because no behavioral changes will be induced. Peltzman (1975) hypothesizes that people respond to installation of safety devices by engaging in riskier behavior, thus at least partially offsetting effects of government action. Wilde (1982a, 1982b) argues that people seek target levels of risk (risk homeostatis) and adjust their behavior so as to exactly offset the technological effect of mandated safety improvements. Additionally, Viscusi (1984) suggests the possibility of a lulling effect in which people use safer products so carelessly that they may actually end up at greater risk of injury. Recent empirical results from analyses of vehicle and traffic safety (Blomquist, 1988, Evans and Graham, 1990, 1991, Traynor, 1993, and Keeler, 1994), child-resistant bottle caps for over-the-counter medications (Viscusi, 1985), and cigarette lighters (Viscusi and Cavallo, 1994) can be cited in support of each of these points of view. In consequence, debates concerning the ultimate outcome of safety legislation and administrative rule-making continue to inspire controversy.

This paper analyzes the extent of offsetting behavior using survey data on risk beliefs about skin cancer and precautionary actions that people can take to avoid this disease. Motivations for offsetting behavior considered here, however, do not stem from public policy changes in safety regulations. Instead, the perspective taken is that at conception, people are "installed" with differing and easily measurable genetic characteristics, such as skin type and complexion. These characteristics have been shown in epidemiological studies (see, for example, Gallagher et al., 1995a, 1995b) to be important in determining the likelihood of contracting skin cancer at given levels of solar radiation exposure. The main issue addressed, then, deals with how people's beliefs respond to their own "safety features." In particular, this paper presents for the first time a direct calculation of the magnitude of offsetting behavior in a situation that: (1) makes use of measures of both risk and precautionary actions and (2) avoids the need to deal with complications such as noncompliance with or exceptions to government regulations. The influence of genetic characteristics turns out to be similar in analytic structure to the role of household characteristics considered by Viscusi and Magat (1987); however, those authors did not look at offsetting behavior. In any case, results presented here suggest that people with greater amounts of genetic protection against skin cancer do take fewer precautions, however, overall effects of behavioral changes on risk beliefs may be small.

Also, empirical estimates developed can be used to assess the role of education, age and gender, as well as information about and experience with skin cancer in determining both precautions taken and beliefs about risk. Although these factors have been extensively examined in prior studies of cigarette smoking (Farrell and Fuchs, 1982, Viscusi, 1990, 1991) radon exposure (Johnson and Luken, 1987, Doyle et al., 1991, and Smith, Desvousges, and Payne, 1995), and use of seatbelts, child safety seats, and motorcycle helmets (Blomquist, 1991), unique features of the survey data employed allow the present study to shed additional light on their relative importance and interpretation. For example, behavior changes are found to be at least partly responsible for decreased perceptions of skin cancer risk that occur as people age. Thus, the relationship between years of age and risk perception may reflect more than just different weights applied to information and experience as suggested by Viscusi.

The remainder of the paper is organized into three sections. Section 1 highlights necessary theoretical background. Section 2 describes the survey data and presents empirical results. Implications and conclusions are summarized in Section 3.

1. Model

This section applies a model of utility maximization that shows how to calculate the magnitude of offsetting behavior that occurs when people face different skin cancer risk levels. The model is similar to others in the literature (e.g., Courant and Porter 1981); in consequence, discussion is abbreviated and is aimed mainly at providing a reference point for empirical work presented in the next section.

People are assumed to maximize the lifetime utility (U) function

$$U = U(X, T_{LS}, T_{LN}, R, S) \tag{1}$$

where X denotes a composite good, T_{LS} denotes leisure time spent in direct sunlight, T_{LN} denotes leisure time spent out of the sun (including indoors), R denotes perception of lifetime skin cancer risk, and S denotes perception of more immediate effects of exposure to sunlight such as suntanning or sunburning. Specifying U as lifetime utility means that the model ignores dynamic issues such as the timing of occurrence or recurrence of skin cancer, but is consistent with how risk is measured in the data examined. Also, including both R and S in the model recognizes that exposure to sunlight jointly produces both immediate and long-term effects.

Perceptions about effects of sunlight exposure differ from, but are related to, actual effects as shown in the household production functions

$$R = R(R^*, \theta) \tag{2}$$

$$S = S(S^*, \eta)$$

where R^* denotes actual risk of skin cancer, S^* denotes actual suntanning/sunburning, and θ and η denote vectors of attitudes toward and knowledge of effects of sunlight exposure. R^* and S^* are, in turn, determined by

$$R^* = R^*(G, T_{LS}, T_{WS}; \Omega) \tag{3}$$

$$S^* = S^*(G, T_{LS}, T_{WS}; \Omega)$$

where G denotes a good that can be purchased to reduce harmful effects of sunlight,[1] T_{WS} denotes time spent working in direct sunlight[2], and Ω denotes an index of genetic protection against skin cancer. Consumption of G and spending less work and leisure time in direct sunlight, then, are the precautionary actions envisioned in the model. Choices of goods and time allocations are constrained by full income (V)

$$V = q_x X + q_G G + W T_L \tag{4}$$

where V denotes total time available (Π) valued at the wage rate (W) and $q_i (i = X, G)$ denote full, time inclusive prices (see Becker, 1965 for details).[3] Also, the derivation of the budget constraint makes use of the inequalities $T_W - T_{WS} \geq 0$ and $T_L - T_{LS} = T_{LN} \geq 0$, where T_W denotes total time spent working and T_L denotes total leisure time.

This model suggests that links between skin cancer risk and behavior can be explored empirically from four perspectives. First, after substituting for R^*, the household production function for R can be expressed as

$$R = f(G, T_{LS}, T_{WS}, \Omega, \theta)\,. \tag{5}$$

Estimating this equation is useful in testing for possible interaction between risk beliefs and precautionary behavior and in identifying partial effects of genetic factors, information and attitudes (Ω, θ) on R, holding precautionary actions (G, T_{LS}, T_{WS}) constant.

Notice that if precautionary actions do not affect risk beliefs, then: (1) R would depend only on Ω and θ and (2) changes in precautionary actions could not offset genetic risk factors. Second, the model can be solved for each of the three precautionary actions as functions of variables people take as exogenous. For example, G can be expressed as

$$G = g(W, q_X, q_G, \theta, \eta, \Omega, \Pi)\,. \tag{6}$$

Corresponding equations can be written for T_{LS} and T_{WS}. Estimates of these equations are of interest because they show how attitudes, information, genetic characteristics, and economic and demographic factors affect precautions taken. Third, equations for G, T_{LS}, and T_{WS} can be substituted into equation (5) to re-express R as

$$R = h(W, q_X, q_G, \theta, \eta, \Omega, \Pi)\,. \tag{7}$$

Equation (7) focuses on total effects, rather than behavior-constant partial effects, of variables shown in determining beliefs about skin cancer risk. Also, because η appears as an argument in equation (7), total effects determined net out influences of attitudes and information concerning immediate effects of solar radiation exposure, such as suntanning.

Fourth, a measure of the extent to which behavior offsets any of the exogenous variables in determining risk beliefs can be obtained by comparing estimates of equations (5) and (7). For example, consider the case of genetic risk factors. Denote the total effect of Ω on R from equation (7) as $dR/d\Omega$, denote the corresponding partial effect from equation (5) as $\partial R/\partial\Omega$, and define the difference between the two as $\Delta = dR/d\Omega - \partial R/\partial\Omega$. Assume that $\partial R/\partial\Omega < 0$. If precautionary behavior: (1) does not offset genetic protection (the technologist's prediction), $\partial R/\partial\Omega = dR/d\Omega$ and $\Delta = 0$, (2) partially offsets genetic protection, $\partial R/\partial\Omega < dR/d\Omega$ and $\Delta > 0$, (3) exactly offsets genetic protection (risk homeostatis) $dR/d\Omega = 0$ and $\Delta > 0$, and (4) more than offsets genetic protection (the lulling effect in the extreme), $dR/d\Omega > 0$ and $\Delta > 0$.[4]

2. Data and empirical results

2.1. Survey data

Data used in this study, described more fully in Dickie and Gerking (1996), were collected by in-person interviews conducted in Laramie, Wyoming and San Diego, California. The sampling plan for each city involved surveying 12 males and 12 females in each of six age groups (21–30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years and 71 years and older).[5] This design was used to over-sample older people in an effort to obtain respondents who have had personal experience with skin cancer.[6] Sample members were selected by dialing telephone numbers at random at various times during daytime and evening hours on both weekdays and weekends and were added to the sample if they agreed to participate and if their age-gender cell was not already filled.

In the interview, questions were sequenced as follows. First, general knowledge was assessed by asking respondents whether they had ever heard or read about skin cancer, whether they ever had been diagnosed by a physician as having this disease, and whether they knew of public figures, acquaintances, or relatives who had been treated for skin cancer. Second, respondents made an initial assessment of their own risk of contracting skin cancer (or getting it again if they already had been treated for it) using an illustration of a ladder with steps numbered from 0 to 20.[7] Respondents chose the step on the ladder that best reflected their own chance in 20 of contracting skin cancer during the remainder of their lifetime, while ignoring the issue of how severe their case might be. An important feature of this approach is that it measures risk beliefs held at the time of the survey, rather than asking respondents to report risk beliefs held at an earlier time (as in Smith and Johnson 1988 and Bernknopf, Brookshire, and Thayer 1990) or telling them what to believe about risk in a specific hypothetical situation (as in Viscusi, Magat, and Huber, 1987).

Table 1, which presents a frequency distribution of these risk responses, shows that all steps on the ladder were chosen at least three times, except for the seventeenth which was never selected. Possible concerns about these data are: (1) the disproportionately large number of responses at steps 5, 10, 15, and 20 indicating that some people may have been unable or unwilling to precisely estimate their own skin cancer risk and (2) the relative uncertainty that some sample members expressed about the risk level selected (for more

Table 1. Frequency distribution of risk responses

STEP	NUMBER OF RESPONSES
0	21
1	22
2	20
3	17
4	12
5	39
6	9
7	18
8	15
9	3
10	51
11	3
12	8
13	3
14	5
15	17
16	4
17	0
18	5
19	4
20	15
TOTAL RESPONSES	291
MEAN STEP CHOSEN	7.6

details, see Dickie and Gerking, 1996). Also, whether people over- or under-estimated skin cancer risks is difficult to assess because prevalence of this disease varies widely by skin type and complexion, data on nonmelanoma skin cancers (the overwhelmingly predominant type) are weak, and recurrence is common among those who have already had this disease.

Third, after collecting risk assessment data, interviewers asked respondents about their behavior and personal characteristics that may affect their chances of getting skin cancer. Information obtained included: (1) amount of time regularly spent in direct sunlight both at work and at leisure, (2) goods purchased to avoid perceived short- and long-term consequences of solar radiation exposure (i.e., sunburning and/or skin cancer) such as sun protection products, (3) extent of previous skin damage in addition to possible previous diagnosis of skin cancer, such as severe sunburns, (4) complexion, and (5) sensitivity of skin to sunlight. Fourth, data were collected on respondents' socioeconomic and demographic characteristics including age, gender, marital status, household income, schooling, and employment.

2.2. Determinants of precautionary actions

This subsection analyzes determinants of precautions taken to reduce skin cancer risk from solar radiation exposure (see equation (6)). Table 2 presents regression results as well as sample means and definitions of all explanatory variables used. Precautionary actions are measured in three ways. The binary variable LOTION indicates whether a respondent ever uses sun protection products, and LEISURE and WORK measure the leisure and work hours in a typical week spent in direct sunlight between 11:00 am and 3:00 pm, during warm weather months. Explanatory variables measure respondents' attitudes toward and awareness of possible skin damage from sunlight, genetic attributes, and socioeconomic status. Prices of market goods and total time available per day are assumed to be the same for all sample members. The equation for sun protection product use is estimated by binomial probit and the equations for time spent outdoors are estimated by least squares. Summary statistics for each equation show that coefficients of explanatory variables are jointly significant using standard tests.

Equations for sunscreen use and outdoor hours provide evidence of offsetting behavior: People with greatest genetic protection from skin cancer tend to take fewest precautions. For example, those with medium natural skin color are less likely to use sun protection products than those with fair skin. Calculation of marginal effects (see Greene, 1993, p. 639) based on coefficients presented in Table 2 suggests that estimated probability of sunscreen use by people with medium skin is about 37 percentage points lower than for people with fair skin when all other explanatory variables are held constant at their sample means. Coefficients of MODERATE and DARK are negative, but are not significantly different from zero in the LOTION equation. Also, people who have medium natural skin color spend, on average, about three more leisure hours per week in direct sunlight than those with fair skin. People with medium and dark skin spend about two more work hours per week in direct sunlight than those with fair skin. Whether skin is especially sensitive to exposure to sunlight does not appear to be an important determinant of any of the three precautionary actions considered, net of effects of complexion.

Additionally, as shown in Table 2, younger, married respondents with higher household incomes, greater concerns about effects of solar radiation exposure, and who have had experience with skin cancer were more likely to have reported using sun protection

Table 2. Determinants of time outdoors and sunscreen use[a]

EXPLANATORY VARIABLE	DEFINITION	SAMPLE MEAN	DEPENDENT VARIABLE		
			LOTION	LEISURE	WORK
CONSTANT			−1.069 (−1.264)	1.617 (0.625)	2.737 (1.385)
CANCER	= 1 if have been diagnosed with skin cancer	0.15	1.290 (2.773)	−1.319 (−0.910)	−0.320 (−0.289)
BLISTERS	= 1 if ever have had a sunburn with blisters	0.56	−0.169 (−0.567)	0.784 (0.780)	.0843 (1.098)
EXPOSURE	= 1 if have spent a lot of time in sun during lifetime	0.77	0.140 (0.407)	1.111 (0.951)	1.599 (1.792)
KNOW	= 1 if know of acquaintance, relative, or public figure who has had skin cancer	0.87	0.366 (0.862)	0.970 (0.672)	1.295 (1.175)
FAIR	= 1 if natural skin color is fair	0.21	—[b]	—[b]	—[b]
MODERATE	= 1 if natural skin color is moderately fair	0.38	−0.732 (−1.559)	0.202 (0.152)	0.330 (0.326)
MEDIUM	= 1 if natural skin color is medium	0.29	−1.166 (−2.471)	2.993 (2.056)	1.888 (1.698)
DARK	= 1 if natural skin color is dark	0.12	−0.630 (−1.170)	1.939 (1.069)	2.298 (1.659)
RESPONSE	= 1 if skin's response to 2 hrs. in direct sunlight without special protection is not always burn	0.62	0.080 (0.243)	−0.530 (−0.485)	−1.167 (−1.397)
TWENTY	= 1 if age 21–30	0.17	—[b]	—[b]	—[b]
THIRTY	= 1 if age 31–40	0.17	−1.093 (−1.673)	−0.554 (−0.332)	−0.517 (−0.406)
FORTY	= 1 if age 41–50	0.17	−1.350 (−2.135)	−1.869 (−1.069)	−3.856 (−2.889)
FIFTY	= 1 if age 51–60	0.16	−2.665 (−3.665)	−0.439 (−0.242)	−2.542 (−1.837)
SIXTY	= 1 if age 61–70	0.16	−2.308 (−3.505)	0.390 (0.218)	−6.049 (−4.434)
SEVENTY	= 1 if age 71 or older	0.16	−2.803 (−4.529)	0.956 (0.533)	−5.539 (−4.040)

Table 2. Continued

EXPLANATORY VARIABLE	DEFINITION	SAMPLE MEAN	DEPENDENT VARIABLE LOTION	LEISURE	WORK
MALE	= 1 if male	0.50	−0.007 (−0.025)	0.088 (0.092)	1.445 (1.964)
LARAMIE	= 1 if live in Laramie; =0 if live in San Diego	0.50	−0.471 (−1.674)	4.330 (4.380)	−0.332 (−0.440)
COLLEGE	= 1 if college graduate or advanced degree	0.39	0.473 (1.528)	−0.116 (−0.111)	1.018 (1.268)
BLUE	= 1 if blue collar occupation	0.25	−0.427 (−1.199)	0.121 (0.104)	1.820 (2.049)
LOW INCOME	= 1 if household income <$25,000 per year	0.30	—[b]	—[b]	—[b]
MIDDLE INCOME	= 1 if household income >$25,000 but <$45,000 per year	0.38	0.462 (1.264)	−0.967 (−0.748)	0.309 (0.312)
HIGH INCOME	= 1 if household income > $45,000 per year	0.32	0.695 (1.682)	0.109 (0.075)	0.653 (0.589)
MARRIED	= 1 if married	0.56	0.570 (1.795)	−0.430 (−0.400)	1.000 (1.219)
AVOID CANCER	= 1 if avoiding skin cancer not unimportant	0.71	0.955 (1.857)	−0.208 (−0.093)	−1.755 (−1.032)
AVOID BURN	= 1 if avoiding sunburn not unimportant	0.73	2.805 (5.061)	−0.117 (−0.051)	0.120 (0.068)
TAN	= 1 if think look healthier or more attractive with suntan	0.59	0.395 (1.418)	2.705 (2.626)	0.299 (0.380)
	SUMMARY STATISTICS				
	Mean of Dependent Variable		0.64	7.10	4.00
	Number of Observations		291	291	291
	R^2		—	0.141	0.216
	$F(23, 267)$		—	1.90	3.20
	Log-Likelihood		−62.18	—	—
	$\chi^2(23)$		257.33	—	—
	Estimation method		Probit	OLS	OLS

[a] *t*-statistics shown in parenthesis beneath coefficients
[b] denotes omitted dummy variable

products. Coefficients of these variables, however, were not different from zero at conventional levels of significance in the LEISURE and WORK equations with the exception that older respondents appear to spend significantly less work time in direct sunlight than younger respondents. Effects of level of schooling completed appear to be weak in all three precautionary action equations estimated.[8] This result is somewhat surprising in light of prior findings by Grossman (1975), Farrell and Fuchs (1982), Viscusi and Evans (1990), Blomquist (1991), and Keeler (1994) that people with more formal education are more likely to engage in health producing activities such as not smoking, wearing seatbelts, and using safety seats for young children. Finally, residents of Laramie appear to be more likely to spend leisure time outdoors during warm weather months and less likely to use sun protection products than residents of San Diego. Although merely speculation, this result may reflect differences in climate or may suggest that people in rural areas are less likely to take precautionary actions than their counterparts in urban areas.[9] Alternatively, Laramie residents may recognize that because of their more northerly latitude, precautions against solar radiation exposure are not as important. Coefficients of most other explanatory variables are not significantly different from zero.

2.3. Determinants of risk beliefs and offsetting behavior

Table 3 presents estimates of equations for RISK and TIME and calculations of the extent of offsetting behavior. The first two columns of Table 3 estimate determinants of risk from the household production function (equation (5)) in the model presented in Section 1 as well as determinants of TIME (= WORK + LEISURE). Estimates reported were obtained by full information maximum likelihood (see Davidson and MacKinnon 1993, pp. 638–40). Joint estimation was pursued on efficiency grounds and to facilitate hypothesis testing (see below). The risk production function, a structural equation including TIME as an explanatory variable, is identified by excluding measures of income, occupational status (which is associated with earning power), marital status, and attitudes toward immediate effects of sunlight exposure (compare equation (5) to equation (7)). The dependent variable is measured as the step on the risk ladder chosen by each respondent and coefficients are interpreted as partial effects of a variable on RISK, holding TIME constant. The specification shown was selected, in part, because in preliminary estimates (available from the authors on request), use of sunscreen did not affect perceived risk at conventional levels of significance and the null hypothesis that coefficients of WORK and LEISURE are identical was not rejected ($p = 0.81$). In consequence, the household production function reported in Table 3 excludes LOTION and replaces WORK and LEISURE with TIME. The equation for TIME, a reduced form, was specified identically to equations reported in Table 2. Coefficients of explanatory variables in the two equations jointly differ from zero at conventional significance levels; individual equation and systemwide χ^2 statistics exceed 1% critical values.

As expected, estimates of the TIME equation are similar to those reported in Table 2 for WORK and LEISURE and do not require further discussion. Coefficient estimates in the household production function for RISK, interpreted as partial effects, indicate that an additional weekly hour outdoors in direct sunlight raises perceived risk by slightly more than 1 percentage point, and a prior diagnosis of skin cancer boosts perceived risk by about 30 percentage points. People who have moderately fair, medium or dark natural skin color see themselves at significantly lower risk than persons who have fair skin. Remaining coefficient estimates do not differ significantly from zero at the 10 percent level in a two-

Table 3. Determinants of Risk, Time, and Δ[a]

EXPLANATORY VARIABLE	MAXIMUM LIKELIHOOD ESTIMATES		IMPLIED TOTAL EFFECTS	$\hat{\Delta}_i$
	TIME	RISK	RISK	
CONSTANT	−0.582	5.702	5.567	−0.135
	(−0.148)	(2.910)	(2.792)	(−0.149)
CANCER	−2.439	6.235	5.668	−0.567
	(−1.111)	(6.395)	(5.868)	(−1.016)
BLISTERS	1.590	0.786	1.156	0.369
	(1.185)	(1.131)	(1.878)	(0.987)
EXPOSURE	2.850	1.146	1.808	0.662
	(1.694)	(1.375)	(2.435)	(1.275)
KNOW	2.515	1.267	1.851	0.584
	(1.211)	(1.002)	(1.619)	(1.067)
FAIR	—[b]	—[b]	—[b]	—[b]
MODERATE	0.314	−2.108	−2.035	0.073
	(0.177)	(−2.331)	(−2.418)	(0.177)
MEDIUM	4.984	−3.609	−2.450	1.159
	(2.938)	(−2.841)	(−2.265)	(1.693)
DARK	3.787	−2.627	−1.746	0.880
	(1.517)	(−2.047)	(−1.490)	(1.236)
RESPONSE	−1.336	−0.359	−0.670	−0.311
	(−0.934)	(−0.464)	(−0.925)	(−0.860)
TWENTY	—[b]	—[b]	—[b]	—[b]
THIRTY	−1.896	−1.456	−1.896	−0.441
	(−0.909)	(−1.164)	(−1.594)	(−0.827)
FORTY	−5.856	0.297	−1.064	−1.361
	(−2.480)	(0.228)	(−1.069)	(−1.671)
FIFTY	−2.038	−1.772	−2.246	−0.474
	(−0.785)	(−1.307)	(−1.884)	(−0.709)
SIXTY	−2.084	−1.262	−1.746	−0.484
	(−0.792)	(−0.839)	(−1.310)	(−0.724)
SEVENTY	−0.538	−2.622	−2.747	−0.125
	(−0.197)	(−1.855)	(−1.967)	(−0.195)
MALE	1.102	−0.848	−0.591	0.256
	(0.842)	(−1.149)	(−0.904)	(0.782)
LARAMIE	4.281	−0.973	0.022	0.995
	(3.241)	(−1.068)	(0.033)	(1.725)
COLLEGE	0.679	0.113	0.271	0.158
	(0.502)	(0.167)	(0.411)	(0.480)
BLUE	2.202	—[b]	0.334	—[c]
	(1.600)		(0.400)	
LOW INCOME	—[b]	—[b]	—[b]	—[b]
MIDDLE INCOME	−0.234	—[b]	0.512	—[c]
	(−0.138)		(1.303)	
HIGH INCOME	1.057	—[b]	−0.054	—[c]
	(0.635)		(−0.138)	
AVOID CANCER	−0.401	0.427	0.246	−0.093
	(−0.148)	(0.546)	(0.614)	(−0.148)

Table 3. Continued

EXPLANATORY VARIABLE	MAXIMUM LIKELIHOOD ESTIMATES		IMPLIED TOTAL EFFECTS	$\hat{\Delta}_i$
	TIME	RISK	RISK	
AVOID BURN	−1.535 (−0.593)	—[b]	−0.357 (−0.565)	—[c]
MARRIED	1.113 (0.770)	—[b]	0.259 (0.737)	—[c]
TAN	2.656 (2.174)	—[b]	0.617 (1.601)	—[c]
TIME	—[b]	0.232 (2.065)	—[b]	—[c]
SUMMARY STATISTICS NUMBER OF OBSERVATIONS	291	291	291	
$\chi^2(23)$	55.092	—	93.755	
$\chi^2(18)$	—	87.941	—	
$\chi^2(41)$	181.059			

[a] *t*-statistics shown in parentheses beneath coefficient estimate
[b] denotes omitted variable
[c] denotes calculation not applicable

tail test, with the exception of those for the dummy variable for persons aged 70 years and older.

Implied total effects of determinants of risk beliefs, reported in Column 3 of Table 3, are obtained by deriving the reduced form equation for RISK from estimates of the RISK production and TIME equations just discussed.[10] Standard errors were computed using methods outlined in Greene (1993, pp. 218–220). Total effects can be compared to partial effects from Column 2 in order to test hypotheses outlined in Section 1. The main hypotheses to be tested concern the extent to which behavior offsets the effect of genetic protection in the formation of risk beliefs. However, it also is of interest to consider how precautionary behavior affects relationships between risk beliefs and other variables. In consequence, differences between total effects and partial effects are computed for all exogenous variables of the model. These differences, labeled $\hat{\Delta}_i$, are shown in the fourth column of Table 3.[11] Notice that

$$\hat{\Delta}_i = \hat{\alpha}_i - \hat{\beta}_i = \hat{\gamma}\hat{\pi}_i \tag{8}$$

where $\hat{\alpha}_i$ denotes the coefficient of a variable in the derived reduced form risk equation, $\hat{\beta}_i$ and $\hat{\pi}_i$ denote corresponding coefficients in the risk production function and reduced form TIME equation, respectively, and $\hat{\gamma}$ denotes the coefficient of TIME in the risk production function. Values of $\hat{\Delta}_i$ measure the extent to which changes in behavior (i.e., time spent outdoors) offset exogenous determinants of risk beliefs in units of risk ladder steps.

Casual inspection of estimates in Table 3 suggests that effects of behavior are not strong enough to completely offset effects of genetic protection in determining risk beliefs. Coefficients of MODERATE and MEDIUM in the reduced form RISK equation are negative with *t*-statistics exceeding 2 (in absolute value). Moreover, a Wald test of the null hypothesis that coefficients of MODERATE, MEDIUM, DARK, and RESPONSE jointly are zero in this equation is rejected at conventional significance levels ($\chi^2(4) = 12.706$, $p = 0.0128$). Thus, results presented are not consistent with the risk homeostatis hypothesis which, as indicated in Section 1, predicts that $\Delta > 0$ and $dR/d\Omega = 0$.

The conclusion of $dR/d\Omega < 0$ could be reconciled with a strong lulling effect, which predicts $dR/d\Omega > 0$, if people with greater genetic protection underestimate the risk they actually face. Individuals who underestimate risk, however, should tend to raise their risk assessment when provided with relevant risk information. Yet results presented in Dickie and Gerking (1996) do not support an association between greater genetic protection and upward revisions in risk beliefs. In that study, risk assessments made after receiving information were on average lower than initial risk beliefs in each complexion and skin type category. Moreover, the extent of downward revision did not appear to be smaller among those with greater genetic protection. Although people with moderately fair skin reduced their risk assessment by less than those with fair skin, people whose skin is less sensitive to sunlight (RESPONSE) made greater downward revisions than those with more sensitive skin. Other complexion categories had no significant association with the extent of revision. In summary, it does not appear that people with greater genetic protection systematically underestimate the risk they face and consequently the result that $dR/d\Omega < 0$ is inconsistent with the lulling effect.

At the other extreme, results presented in Table 3 do not lend support for the technologists' prediction that $\Delta = dR/d\Omega - \partial R/\partial\Omega = 0$. The coefficient of TIME in the household production function for RISK ($\hat{\gamma}$) is equal to 0.232 with a *t*-statistic of 2.065. Thus, H_0: $\gamma = 0$ would be rejected in favor of H_1: $\gamma \neq 0$ at the 5% level of significance. Also, a test that coefficients of MODERATE, MEDIUM, DARK, and RESPONSE are jointly zero in the TIME equation is rejected ($\chi^2(4) = 12.882$) at significance levels above $p = 0.0119$ and the hypothesis that γ and coefficients of these four variables are jointly zero is rejected at less than 1% ($\chi^2(5) = 16.79$, $p = 0.0049$). Therefore, because people with darker complexions appear to spend more time outdoors, which in turn is associated with increased perceptions of skin cancer risk, behavior does appear to partially but not totally offset the beneficial effects of greater genetic protection against this disease.

These results, however, should not be over-generalized. On the one hand, values of $\hat{\Delta}_i$ are not estimated precisely: a test that Δ_i are jointly zero for MODERATE, MEDIUM, DARK, and RESPONSE only would be rejected at significance levels exceeding $p = 0.534$ using a Wald statistic ($\chi^2(4) = 3.143$).[12] On the other hand, effects of behavior on actual risks faced may differ from effects on risk beliefs. If individuals overestimate small risks while underestimating large risks, then a given change in actual risk would lead to a smaller absolute change in perceived risk (Lichtenstein et al., 1978). Viscusi (1985) has shown that this pattern of risk assessments is consistent with a Bayesian learning model in which perceived risk is a weighted average of prior beliefs and the risk level implied by new information. If similar cognitive factors affect beliefs about risk changes produced by protective action, then protection will have a greater impact on actual than on perceived risk. Consequently, the actual risk effects of offsetting behavior will be absolutely larger than the perceived risk effects in Table 3.

While it is difficult to test this explanation directly, it is possible to provide some supporting evidence. Let Δ and δ measure the effect of offsetting behavior on perceived and actual risk, respectively, let $b = \partial R/\partial R^*$ from equation (2) so that $\Delta = b\delta$. If perceived risk does not fully adjust to actual risk changes, then $0 < b < 1$, and Δ will be smaller absolutely than δ. One way of testing this possibility, then, is to determine whether sample evidence is consistent with $b < 1$. Dickie and Gerking (1996) show that, when provided with information about relevant risk factors, respondents made very limited revisions in their skin cancer risk assessments; most of the sample members did not change risk beliefs at all. These results suggest that risk beliefs about skin cancer are "sticky" and support a value of b, that is below unity. A second test rests on the observation that, if individuals differ in the responsiveness of perceived risk to actual risk changes as measured by b, then all else equal those with larger values of b should likewise have larger absolute values of Δ.[13] To perform this test, perceived risk effects of offsetting behavior were computed separately for two subsamples. The first group consists of 82 respondents whose risk beliefs changed in response to information in the previously-cited study. These individuals are assumed to have more responsive beliefs and correspondingly larger values of b than the second group, composed of 209 respondents whose risk beliefs did not change. Results (available from the authors on request) indicate that the measures of Δ associated with skin type and complexion are absolutely larger for the group assumed to have the larger b values and a likelihood ratio test for whether coefficients in the TIME and household production RISK equations are equal across groups is rejected at significance levels above $p = 0.0922$. Thus, both of these admittedly imperfect tests are consistent with the notion that actual risk effects of offsetting behavior may exceed the corresponding perceived risk effects.

The comparison of partial and total effects to examine the intervening role of precautionary behavior in determining risk beliefs also can be applied to other exogenous variables. The role of age is of particular interest in this context in light of Viscusi's (1991) conjecture that younger people pay more attention to recent publicity about risk than older people whereas older people weight experience with risky activities more heavily than younger people. Public warnings about skin cancer have escalated over the past 25 years; in consequence, an assessment of skin cancer risk by younger people may be expected to exceed that for older people. The pattern of coefficients of age in the total effects RISK equation is broadly consistent with this view. Nevertheless, an alternative interpretation suggested by Dickie and Gerking (1996) is that because skin cancer risks currently appear to be growing, younger people may face greater cumulative lifetime risks than older people. Thus, the total effects of age may indicate that respondents distinguished between marginal and cumulative hazards.

Table 3 presents evidence, although it is less than clear-cut, suggesting that changes in behavior may be at least partly responsible for observed alterations in risk perceptions that occur as people age. As previously indicated, γ is positive and significantly different from zero at 5%. Also, the coefficient estimates of the five age dummies in the TIME equation are all negative, but the null hypothesis that these coefficients are jointly equal to zero only can be rejected at significance levels exceeding $p = 0.18$ using the Wald test ($\chi^2(5) = 7.537$). The hypothesis that γ and the five coefficients of age are jointly zero is rejected for $p \geq 0.0316$ using a Wald test ($\chi^2(6) = 13.834$). In consequence, it appears that a portion of the difference in risk assessments between people in their twenties and those in older age groups may be attributed to differences in behavior, but the evidence on this point is weak. Nevertheless, the possibility remains that the role of age in determining risk beliefs may have a more complex, behavioral interpretation than the purely cognitive explanations suggested in earlier studies.

3. Conclusion

This paper has examined the concept of offsetting behavior and presented empirical evidence on this phenomenon using a measure of risk beliefs about skin cancer collected in a survey. In prior studies, the extent of offsetting behavior is indirectly measured in response to public policy changes in situations where direct measures of risk are unavailable. For example, traffic safety studies have considered whether people appear to adopt a riskier style of driving when cars are equipped with more safety equipment, but have not been able to consider the crucial link between behavioral changes and levels of risk that roadway users ultimately face. The main contribution of this paper rests on estimates of: (1) determinants of precautionary action that can be taken to reduce skin cancer risk (i.e. use of sun protection products and spending less time in direct sunlight) and (2) determinants of beliefs about risk of contracting skin cancer (i.e. precautionary action, genetic characteristics, and information about and experience with this disease). Results presented suggest that people with darker skin, and therefore more genetic protection against skin cancer, are less likely to use sun protection products and spend more work and leisure time in direct sunlight. These behavioral differences appear to partially, but not totally, offset the beneficial effects of dark complexion on reducing risk of skin cancer. Thus, the technologists' prediction of no offsetting behavior is rejected. Additionally, the risk homeostatis hypothesis (behavior changes exactly offset genetic protection) and the lulling effect hypothesis (behavior changes may more than offset genetic protection) are rejected. Of course, behavioral changes may offset *actual* risks to a greater or lesser extent than they offset people's beliefs about risk. This possible outcome warrants additional research, perhaps in an experimental framework, to further understanding of connections between risk and behavior in public policy settings.

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Notes

1. Joint production arising because G may be a direct source of utility (or disutility) is ignored here, but is treated at length in Dickie and Gerking (1991).
2. It is implicitly assumed here that people are indifferent between outdoor and indoor work, apart from effects on skin damage. Of course, more complex formulations are possible (i.e., wages for the two types of work may differ or people may derive utility from outdoor work) but these are not pursued because the aim of the model only is to provide a basis for the empirical estimates presented in the next section.
3. The budget constraint makes the simplifying assumptions that: (1) the time required to consume one unit of X and G is fixed and (2) people cannot undertake more than one activity at a time.
4. More accurately, a strong lulling effect means that the actual risk effects of genetic protection are more than offset by behavioral changes, so that $dR/d\Omega > 0$. This point is addressed more fully in connection with empirical tests presented in Section 2.3.
5. This sampling plan called for a total sample of 288; however, interviewers unintentionally oversampled by three. The extra observations are used in the empirical analysis.
6. The median age of sample members was 50 years, whereas, median age of the US population was about 32 years.
7. The approach used here to collect risk belief information is similar to the one used in Gerking, de Haan, and Schulze (1988).
8. In a preliminary specification, equations for LOTION, WORK, and LEISURE were estimated using four schooling categories (all defined as highest attainment): (1) less than high school graduation (excluded category), (2) high school graduation, (3) college graduation, and (4) advanced degree. In the WORK and LEISURE equations, the null hypothesis that coefficients of the three dummy variables are jointly equal to zero is not rejected at conventional significance levels. In the LOTION equation, the corresponding hypothesis is rejected at the 5% level. In that equation, however, the coefficient of the college graduation dummy was significant at 10% using a two-tail test and coefficients of the other two schooling dummies were not significant at conventional levels. In light of these outcomes, only COLLEGE is used in the final specification reported in Table 2.
9. This result is similar to estimates of Evans and Graham (1990) who found that the car-occupant fatality rate for children under five years old was greater in states where a greater percentage of vehicle miles are traveled in rural areas.
10. These derived reduced form coefficients were obtained by substituting the estimated TIME equation in Column 1 into the RISK equation in Column 2. Additionally, direct single-equation estimates of the reduced form risk production function by fully censored regression previously were reported by Dickie and Gerking (1996). Although the two sets of reduced form risk estimates are closely related, the derived estimates are more appropriate for the purposes at hand because they take account of the over-identifying restrictions on the household production function for risk, whereas the direct estimates do not.
11. Standard errors for the estimates of Δ_i were found using the same approach as was applied to find standard errors for the derived reduced form coefficients.
12. Intuitively, the Δ_i are estimated imprecisely relative to γ or corresponding π_i coefficients because computing $\hat{\Delta}_i$ compounds uncertainty from estimation of both γ and π_i. To illustrate, note that since $\hat{\Delta}_i = \hat{\gamma}\hat{\pi}_i$,

estimated t-ratios for $\hat{\Delta}_i$ and $\hat{\pi}_i$ would be identical if var($\hat{\Delta}_i$) were equal to $\hat{\gamma}^2$ var($\hat{\Delta}_i$). But the approximate var($\hat{\Delta}_i$) is estimated by

$$\hat{\gamma}^2 \text{var}(\hat{\pi}_i) + \hat{\pi}_i^2 \text{var}(\hat{\gamma}) + 2\hat{\gamma}\hat{\pi}_i \text{cov}(\hat{\gamma}, \hat{\pi}_i).$$

Barring the unlikely occurrence that the covariance term is both (a) large absolutely relative to the variances and (b) opposite in sign to the product $\hat{\gamma}\hat{\pi}_i$, var($\hat{\Delta}_i$) will exceed both $\hat{\gamma}^2$var($\hat{\pi}_i$) and $\hat{\pi}_2^i$ var($\hat{\gamma}$). Then, Δ_i will have a smaller t-ratio than either $\hat{\gamma}$ or $\hat{\pi}_i$. In the present case the covariances tend to be an order of magnitude smaller than the variances, making a large difference in significance levels for tests of Δ compared to tests of γ or π. (For example, the standard error for the Δ coefficient of MEDIUM can be computed using the formula above and information in Table 3 together with the relevant covariance -0.00088.) The practical implication is that larger samples are required to estimate Δ than to estimate γ or π at conventional significance levels, a point that may be useful in designing future research.

13. This is an imperfect test because it is likely that optimizing individuals would change their behavior in response to changes in b, complicating comparisons between actual and perceived risk effects. Specifically, an increase in b with the overall level of perceived risk held constant raises the perceived risk effect of protective action, and thus leads the individual to increase protection. However, an increase in b also raises the perceived risk effect of genetic protection, which may lead to reduced protective action, leaving the total effect of the change in b ambiguous. Chirinko and Harper (1993) also discuss how discrepancies between actual and perceived risks may affect offsetting behavior.

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