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ESTIMATING DEMAND FOR CIGARETTES AND ALCOHOL WITH ZERO OBSERVATIONS: A CENSORED SYSTEM

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Abstract

Consumption of cigarettes, beer and wine by individuals is investigated, using a multivariate sample selection model. Empirical results suggest that the proposed model performs better than the restricted specifications. Gender differences are also present.

Key Words: sample-selection model; censored dependent variables

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The use of micro survey data in modeling health-care demand has become increasingly popular during the last two decades. One data feature frequently encountered in micro-level demand analysis is the presence of zero values in the dependent variables. The popular econometric procedures in accommodating such censoring in the dependent variables include the sample selection model (SSM, see, e.g., [1]) and two-part model (TPM, e.g., [2, 3, 4]). The SSM is characterized by a mechanism in which the stochastic processes governing the binary (e.g., whether or not to consume or participate) and level (e.g., how much to consume) outcomes can influence each other. This model, characterized by a latent binary equation and a latent level equation, is typically based on the bivariate normal distribution of the error terms in empirical applications and can be estimated by maximum-likelihood or by a two-step procedure [1]. The TPM reflects a decision process that is sequential in nature, and is usually estimated by a logit or probit model for the probability of observing a positive value of the dependent variable, along with OLS based on the truncated sample with positive values for the dependent variables. While not relying on the bivariate normality assumption, the TPM can be treated as a parametrically restricted version of the SSM in which the error correlation is zero.

Although the SSM and TPM have been popular, these models by nature are appropriate for modeling demand for a single good or service. Besides a lack of behavioral appeal, this 'single-equation' approach also suffers from loss of statistical efficiency. We address statistical efficiency by considering a system of censored equations in the current paper. This is accomplished by specifying a set of level equations with correlated errors, each subject exclusively to a binary selection rule. The resulting framework, which we called multivariate sample selection model (MSSM), is a multi-equation extension of Heckman's [1] SSM in that demand for multiple goods or services are considered. It is also a generalization of the Tobit system of Amemiya [5] in that censoring of each good is subject to a separate selection rule governing the discrete (zero/positive) outcomes. The proposed model thus nests the SSM and TPM, and is a more efficient (maximum-likelihood) alternative to a two-step estimator by Shonkwiler and Yen [6] for a similar multi-equation model. The procedure is applied to consumption of cigarettes, beer and wine by individuals in the United States.

A Multivariate sample selection model

We consider a system of *n* equations with outcome variables y_i each of which is governed by a sample-selection rule with binary outcome d_i:

$$
\begin{aligned}
d_i &= 1 && \text{if } z'\alpha_i + u_i > 0 \\
&= 0 && \text{if } z'\alpha_i + u_i \le 0 \\
\log y_i &= x'\beta_i + v_i && \text{if } d_i = 1 \\
&= 0 && \text{if } d_i = 0, \qquad i = 1,\ldots,n,
\end{aligned}
$$

where z and x are column vectors of exogenous variables, α_i and β_i are conformable parameter vectors, and u_i and v_i are random errors. Assume the error terms $[u', v']' \equiv [u_1,\ldots,u_n,\ v_1,\ldots,v_n]'$ are distributed as (2*n*)-variate normal with zero mean and covariance matrix Σ with (*i*,*j*)th elements $\rho_{ij}\sigma_i\sigma_j$, where ρ_{ij} are error correlation coefficients and σ_i are error standard deviations such that $\sigma_i = 1$ for $i = 1,\ldots,n$. The model extends Heckman's [1] SSM to one with multiple outcome variables

(y_i, $i = 1,...,n$); it is also an extension of the multivariate Tobit model [5] in that censoring of each dependent variable is not determined by a Tobit mechanism $x'\beta_i + v_i$ but by a separate stochastic process $z'\alpha_i + u_i$.

Data and sample

Our application involves a system of equations for cigarettes, beer and wine consumed by individuals in the United States. Consideration of cigarettes and alcohol in a system is motivated by previous findings that interactions between cigarette and alcohol consumption are important [9]. The data are compiled from the 1994-96 Continuing Survey of Food Intakes by Individuals, conducted by the US Department of Agriculture [10]. The dependent variables are the number of cigarettes and amounts of beer and wine consumed per day.

The explanatory variables include education, age, income and dummy variables indicating urbanization (city, suburban), region (Northeast, Midwest, West), race (White, Black), ethnicity (Hispanic), home ownership, self-evaluated health status, social status (white collar), employment status, and whether the individual had been diagnosed of cancer or blood pressure/heart problem(s). In the context of demand theory, these demographic variables play the roles of preference and demand shifters and are commonly used in the cigarette and alcohol demand literature [11,12,13]. Individuals with better education may be more cognizant of the risks of cigarette smoking and alcohol consumption than others. Individuals residing in urban areas may be subject to more peer pressure and other metropolitan influences such as advertising. White, Black and Hispanic are racial and ethnic factors which may reflect cultural and taste differences, while employment and social status may reflect lifestyle. Age is relevant as previous studies suggest a life-cycle pattern for smoking [14] and such pattern is also likely to exist for beer and wine. Self-evaluated health status is often found to play significant roles in the consumption of cigarettes [15] and alcohol. Cancer is included because of its potential deterring effects on the consumption of cigarettes. Finally, regional dummies are included because individuals in some regions may be more tolerant of smoking and drinking as a mode of social behavior and also because, in the absence of prices, these variables may serve as proxies for regional price differentials.

We use a sample of 4313 men and another sample of 4166 women. Among the men, 1186 (or 27.5 percent of sample) reported smoking of cigarettes, 913 (21.2 percent) reported drinking beer and 300 (6.9 percent) reported consuming wine. For the women sample, the corresponding figures are 979 (23.5 percent), 266 (6.4 percent) and 306 (7.3 percent), respectively. The high proportions of zero consumption for these products suggest that it is important to accommodate censoring in the dependent variables. Among the consuming men, the mean number of cigarettes smoked per day is 20.8, while the mean amount of beer is 796.8 grams and the mean amount of wine is 171.5 grams per day. Among the consuming women, the corresponding numbers are 17.3 cigarettes, 455.6 grams of beer and 173.2 grams of wine per day. Thus men on average tend to smoke more cigarettes and drink more beer than women but consume about the same amount of wine as women. Detailed definitions and sample statistics for all variables are presented in Table 1.

Results

To determine the appropriateness of merging the male and female samples, we test for equality of all parameters between men and women. The test, similar to the Chow test in more traditional models, is carried out by estimating the full model for the men, women and merged samples. Using the log-likelihood values of these samples, result of a likelihood-ratio test suggests rejection (p-value < 0.00001) of equal parameters between men and women, calling for estimation with separate samples.

Maximum-likelihood estimates of the full model for both genders are presented in Table 2. (All results for the full model with pooled sample and parameter estimates for the SSM and TPM with gender-segmented samples are available upon request.) For both men and women, more than half of the correlation coefficients are significant at the 5% level of significance. For men, significance of ρ_{41} and ρ_{52} suggests that it is important to correct for sample selectivity for cigarettes and beer. The significance of other correlation coefficients (e.g., ρ_{21}, ρ_{32}, ρ_{42}, ρ_{51}, and ρ_{54}) also justifies estimation of the equations in a system. Similar results are also suggested by the significance of correlation coefficients for the women sample.

For men, over half of the parameter estimates for cigarettes are significant but have opposite signs in the selection and level equations. Such opposite signs are observed in the coefficients of White, homeowner, health, white collar, cancer, blood pressure/heart problems, education, and age. For beer, opposite effects are also observed in education, although the directions of effects on selection and level are the same for a number of other variables (i.e., South, White, home owner, employed, and age). For wine, the effects of variables are significant mainly in the selection equation, whereas significance in the level equation is more sparse, with only Northeast significant in the level equation. These differentiated effects of variables on the selection and level equations suggest it is important to model the consumption of cigarettes, beer and wine with a MSSM, rather than the Tobit model [5], in which case the differentiated effects are likely to be masked by the Tobit parameterization.

Similar opposite effects of variables are also observed in the cigarette equation for women (e.g., Black, homeowner, blood pressure/heart problems, education, and age). However, unlike in the men sample, significance of variables for wine appears in both the selection and level equations. Although South, White, Black, blood pressure/heart problems and age are significant in the selection equation, none of these variables are significant in the level equation for beer. These different effects of variables between genders highlight the importance segmenting the sample by gender.

The elasticities of probabilities, conditional level and unconditional level with respect to the continuous variables for the men sample are presented in Table 3. Despite results of the statistical tests which reject the SSM and TPM, the elasticities are extremely close, in reference to corresponding standard errors, among the three models. Income does not have a significant effect on the consumption probability or level for any of the three commodities. According to the full model (and the two restricted models), education and age both have significant and negative effects on the probability, while the effect of age is positive and the effect of education is insignificant on the conditional level of cigarette consumption. Overall, the elasticities of unconditional level suggest that education has a negative effect on the level of consumption while the effect of age is insignificant. As to beer, education plays a positive role and age plays a negative role on probability, while both variables have negative effects on the conditional level. The net effects of these two variables are both negative on the unconditional level. The effects of age on beer consumption are particularly notable, with an unconditional elasticity of −1.17. Turning to wine, education and age both have positive and large effects on the probability of consumption, while their effects on the conditional level are insignificant. The net effects of these variables, according to the unconditional elasticities, are both positive as the probability effects obviously dominate the conditional level effects.

Table 4 reports the elasticities for women. As in men, education and age both play significant and negative roles in the probabilities of cigarette and beer consumption. Unlike in men, however, these variables do not have significant effects on the conditional level of cigarette or beer consumption. The roles of these variables are different on wine, with positive effects on the probability of wine consumption. In addition, education also increases the conditional level of wine consumption. Overall, the unconditional elasticities suggest that both education and age increase wine consumption. As in men, income does not affect the consumption of cigarettes, beer or wine.

Concluding remarks

We extend the bivariate SSM to accommodate censoring in multiple outcome variables. We reject the hypothesis of equal parameters between genders, and consequently estimate the models with separate men and women samples. The proposed multivariate model is found to perform better than the nested bivariate SSM and TPM, both of which have been used extensively in microeconometric modeling, notably in health-care demand. However, the calculated elasticities are very similar across these models. In view of the extensive debates among users of the SSM and TPM, our empirical results are fascinating.

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Table 1. Sample statistics

		Men (n = 4313)		Women (n = 4166)	
Variable	Definition	Mean	S.D.	Mean	S.D.
Dependent variables					
Cigarettes	Number of cigarettes per day	5.71	11.50	4.06	9.03
	Consuming (1186 men, 979 women)	20.76	12.98	17.27	10.91
Beer	Amount of beer per day (grams) ÷ 10	16.87	50.85	2.91	15.97
	Consuming (913 men, 266 women)	79.68	84.94	45.56	45.36
Wine	Amount of wine per day (grams)	11.93	56.24	12.72	56.32
	Consuming (300 men, 306 women)	171.45	134.82	173.20	124.23
Explanatory variables (continuous)					
Educ	Education in years	12.85	3.08	12.71	2.90
Age	Age in years	48.69	16.04	48.42	15.88
Income	Per-capita income (thousands)	16.56	13.32	15.35	12.36
Explanatory variables (binary; yes = 1)					
City	Resides in central city	0.28		0.31	
Suburban	Resides in suburban area	0.46		0.44	
Rural	Resides in rural area (reference)	0.26		0.25	
Northeast	Resides in the Northeast	0.18		0.18	
Midwest	Resides in the Midwest	0.24		0.25	
South	Resides in the South	0.36		0.37	
West	Resides in the West (reference)	0.22		0.20	
White	Race is White	0.83		0.80	
Black	Race is Black	0.10		0.13	
Other race	Race is other (reference)	0.07		0.07	
Hispanic	Is of Hispanic origin	0.04		0.04	
Homeowner	Is a homeowner	0.72		0.70	
Health	Self-evaluated health fair or better	0.84		0.82	

White collar	Is a white-collar worker	0.28	0.24
Cancer	Has been diagnosed with cancer	0.06	0.06
BP_heart	Had blood pressure or heart problems	0.29	0.28
Employed	Is employed	0.66	0.51

Source: Compiled from the Continuing Survey of Food Intakes by Individuals, US Department of Agriculture, 1994–96.

Table 2. ML estimation of the full model (MSSM)

	Men (log$L$ = –16514.33)						Women (log$L$ = –10668.51)					
	Selection equations			Level equations			Selection equations			Level equations		
Variable	Cig.	Beer	Wine	Cig	Beer	Wine	Cig.	Beer	Wine	Cig	Beer	Wine
Constant	2.36‡	0.62	–6.79‡	–0.04	6.50‡	5.72	0.91‡	–0.35	–9.57‡	2.09‡	3.91‡	15.53‡
	(0.37)	(0.41)	(0.68)	(0.52)	(0.58)	(15.86)	(0.37)	(0.62)	(0.86)	(0.53)	(1.46)	(1.99)
City	–0.18‡	0.01	0.45‡	0.03	–0.04	0.08	–0.09	0.12	0.26‡	–0.03	0.06	–0.25
	(0.06)	(0.07)	(0.11)	(0.08)	(0.09)	(0.94)	(0.06)	(0.10)	(0.11)	(0.09)	(0.21)	(0.19)
Suburban	–0.12	–0.01	0.29‡	0.07	–0.17‡	0.12	–0.11‡	0.02	0.23‡	0.08	–0.06	–0.20
	(0.05)	(0.06)	(0.10)	(0.07)	(0.08)	(0.64)	(0.06)	(0.09)	(0.10)	(0.08)	(0.16)	(0.18)
Northeast	–0.07	0.01	–0.02	0.05	–0.22‡	–0.32‡	–0.11	–0.13	–0.18†	–0.01	–0.11	0.09
	(0.07)	(0.07)	(0.10)	(0.10)	(0.10)	(0.17)	(0.07)	(0.10)	(0.10)	(0.10)	(0.22)	(0.18)
Midwest	0.00	0.04	–0.40‡	0.06	–0.02	–0.49	0.07	–0.10	–0.48‡	0.04	0.22	0.37‡
	(0.07)	(0.07)	(0.10)	(0.09)	(0.09)	(0.83)	(0.07)	(0.10)	(0.10)	(0.10)	(0.18)	(0.19)
South	–0.05	–0.21‡	–0.44‡	0.13	–0.23‡	–0.43	0.03	–0.27‡	–0.46‡	0.10	–0.02	0.35‡
	(0.06)	(0.06)	(0.09)	(0.09)	(0.10)	(0.93)	(0.06)	(0.10)	(0.10)	(0.09)	(0.26)	(0.18)
White	–0.14†	0.27‡	0.55‡	0.59‡	0.55‡	–0.27	0.41‡	0.67‡	0.93‡	–0.06	0.36	–0.59
	(0.08)	(0.10)	(0.19)	(0.11)	(0.14)	(1.20)	(0.10)	(0.20)	(0.26)	(0.15)	(0.67)	(0.47)

Black	−0.01	0.12	0.05	0.05	0.36‡	−0.60	0.37‡	0.55‡	0.63‡	−0.42‡	0.06	−0.40
	(0.10)	(0.13)	(0.25)	(0.15)	(0.18)	(0.67)	(0.12)	(0.22)	(0.29)	(0.17)	(0.65)	(0.47)
Hispanic	−0.32‡	0.24†	−0.10	−0.06	−0.10	−0.09						
	(0.12)	(0.12)	(0.25)	(0.16)	(0.16)	(0.74)						
Homeowner	−0.29‡	−0.10†	0.12	0.19‡	−0.21‡	0.17	−0.24‡	0.01	0.14	0.22‡	−0.14	−0.14
	(0.05)	(0.05)	(0.09)	(0.07)	(0.07)	(0.32)	(0.05)	(0.08)	(0.09)	(0.07)	(0.15)	(0.17)
Health	−0.18‡	0.15‡	0.29‡	0.19‡	0.11	−0.02	−0.19‡	0.15	0.46‡	0.08	−0.13	−0.70‡
	(0.06)	(0.07)	(0.12)	(0.08)	(0.11)	(0.70)	(0.06)	(0.11)	(0.15)	(0.08)	(0.23)	(0.29)
White collar	−0.31‡	−0.06	0.33‡	0.28‡	−0.14†	0.15	−0.09	0.04	0.10	0.01	−0.01	−0.23
	(0.06)	(0.06)	(0.09)	(0.08)	(0.08)	(0.67)	(0.06)	(0.09)	(0.09)	(0.09)	(0.17)	(0.17)
Employed	0.13‡	0.15‡	0.11	−0.07	0.15†	−0.12	0.05	−0.04	0.08	−0.11	0.22	0.08
	(0.05)	(0.06)	(0.10)	(0.08)	(0.09)	(0.28)	(0.05)	(0.08)	(0.09)	(0.07)	(0.14)	(0.17)
Cancer	−0.18†	0.14	0.05	0.26†	−0.08	−0.15	0.10	−0.07	−0.04	−0.17	−0.08	0.07
	(0.10)	(0.11)	(0.14)	(0.15)	(0.16)	(0.32)	(0.09)	(0.15)	(0.15)	(0.13)	(0.33)	(0.25)
BP_heart	−0.13‡	−0.12‡	−0.06	0.13†	−0.07	−0.01	−0.12‡	−0.27‡	−0.08	0.15†	−0.33	0.22
	(0.05)	(0.06)	(0.08)	(0.07)	(0.09)	(0.18)	(0.06)	(0.11)	(0.09)	(0.08)	(0.31)	(0.17)
log(Educ)	−0.49‡	0.23‡	0.70‡	0.45‡	−0.54‡	−0.12	−0.31‡	0.20	1.88‡	0.31‡	−0.05	−1.64‡
	(0.08)	(0.09)	(0.12)	(0.11)	(0.15)	(1.50)	(0.09)	(0.16)	(0.24)	(0.12)	(0.29)	(0.46)

log(Age)	−0.28‡	−0.61‡	0.63‡	0.62‡	−0.68‡	−0.21	−0.22‡	−0.61‡	0.50‡	0.31‡	−0.39	−0.64‡
	(0.08)	(0.08)	(0.13)	(0.11)	(0.15)	(1.31)	(0.08)	(0.11)	(0.12)	(0.11)	(0.45)	(0.24)
log(Income)				−0.00	−0.01	0.06				0.03	−0.09	−0.05
				(0.02)	(0.04)	(0.09)				(0.03)	(0.08)	(0.07)
std. dev. (σ_i)				1.35‡	1.12‡	0.86				1.31‡	0.95‡	1.44‡
				(0.04)	(0.13)	(0.64)				(0.05)	(0.47)	(0.14)
Correlation (j = 1,…,5)												
ρ_{21}	0.16‡						0.27‡					
	(0.03)						(0.04)					
ρ_{3j}	−0.06	0.19‡					0.05	0.21‡				
	(0.05)	(0.04)					(0.05)	(0.06)				
ρ_{4j}	−0.98‡	−0.11‡	0.02				−0.96‡	−0.21‡	−0.08			
	(0.00)	(0.03)	(0.05)				(0.01)	(0.04)	(0.05)			
ρ_{5j}	0.21‡	0.77‡	−0.01	−0.11‡			0.27‡	0.64	0.02	−0.18†		
	(0.04)	(0.10)	(0.06)	(0.04)			(0.09)	(0.56)	(0.20)	(0.10)		
ρ_{6j}	−0.05	−0.02	0.30	−0.02	−0.04		−0.00	−0.20‡	−0.94‡	0.07	0.06	
	(0.17)	(0.46)	(2.62)	(0.15)	(0.09)		(0.06)	(0.07)	(0.03)	(0.07)	(0.24)	

Note: Asymptotic standard errors in parentheses. Daggers ‡ and † denote significance at the 5% and 10% levels, respectively.

Table 3. Elasticities with respect to continuous variables: men

	Cigarettes			Beer			Wine		
	Prob.	Cond. level	Uncond. level	Prob.	Cond. level	Uncond. level	Prob.	Cond. level	Uncond. level
					MSSM				
Education	–0.63‡	–0.11	–0.74‡	0.33‡	–0.68‡	–0.35†	1.43‡	–0.28	1.15‡
	(0.10)	(0.09)	(0.15)	(0.13)	(0.13)	(0.18)	(0.25)	(0.33)	(0.44)
Age	–0.36‡	0.30‡	–0.06	–0.88‡	–0.30‡	–1.17‡	1.28‡	–0.35	0.93‡
	(0.10)	(0.07)	(0.13)	(0.12)	(0.10)	(0.15)	(0.26)	(0.23)	(0.34)
Income	–	–0.00	–0.00	–	–0.01	–0.01	–	0.06	0.06
	–	(0.02)	(0.02)	–	(0.04)	(0.04)	–	(0.09)	(0.09)
					SSM				
Education	–0.68‡	–0.07	–0.75‡	0.31‡	–0.71‡	–0.40‡	1.48‡	–0.16	1.33‡
	(0.10)	(0.09)	(0.15)	(0.13)	(0.13)	(0.19)	(0.25)	(0.32)	(0.39)
Age	–0.33‡	0.33‡	0.00	–0.84‡	–0.26‡	–1.10‡	1.27‡	–0.22	1.05‡
	(0.10)	(0.07)	(0.12)	(0.12)	(0.10)	(0.15)	(0.26)	(0.22)	(0.34)
Income		–0.01	–0.01		–0.03	–0.03		0.06	0.06
		(0.02)	(0.02)		(0.04)	(0.04)		(0.09)	(0.09)

					TPM				
Education	–0.74‡	–0.01	–0.75‡	0.32‡	–0.72‡	–0.41‡	1.48‡	–0.16	1.33‡
	(0.10)	(0.07)	(0.13)	(0.13)	(0.13)	(0.19)	(0.25)	(0.34)	(0.41)
Age	–0.33‡	0.40‡	0.07	–0.83‡	–0.26‡	–1.09‡	1.27‡	–0.22	1.05‡
	(0.10)	(0.09)	(0.14)	(0.12)	(0.10)	(0.15)	(0.25)	(0.23)	(0.34)
Income		–0.05	–0.05		–0.03	–0.03		0.06	0.06
		0.03	(0.03)		(0.04)	(0.04)		(0.09)	(0.09)

Note: Asymptotic standard errors in parentheses. Daggers ‡ and † denote significance at the 5% and 10% levels, respectively.

Table 4. Elasticities with respect to continuous variables: women

	Cigarettes			Beer			Wine		
	Prob.	Cond. level	Uncond. level	Prob.	Cond. level	Uncond. level	Prob.	Cond. level	Uncond. level
					MSSM				
Education	–0.42‡	–0.03	–0.45‡	0.41	–0.15	0.26	3.90‡	0.67‡	4.56‡
	(0.12)	(0.10)	(0.17)	(0.33)	(0.23)	(0.47)	(0.53)	(0.34)	(0.66)
Age	–0.29‡	0.07	–0.22	–1.26‡	–0.08	–1.34‡	1.03‡	–0.03	1.00‡
	(0.10)	(0.08)	(0.14)	(0.25)	(0.22)	(0.30)	(0.26)	(0.21)	(0.35)
Income		0.03	0.03		–0.09	–0.09		–0.05	–0.05
		(0.03)	(0.03)		(0.08)	(0.08)		(0.07)	(0.07)
					SSM				
Education	–0.44‡	0.01	–0.43‡	0.30	–0.13	0.17	3.90‡	0.63	4.53‡
	(0.12)	(0.10)	(0.17)	(0.35)	(0.24)	(0.47)	(0.52)	(0.34)	(0.66)
Age	–0.30‡	0.09	–0.21	–1.18‡	–0.01	–1.20‡	1.02‡	–0.04	0.99‡
	(0.11)	(0.09)	(0.14)	(0.25)	(0.29)	(0.33)	(0.26)	(0.20)	(0.35)
Income		0.01	0.01		–0.10	–0.10		–0.04	–0.04
		(0.04)	(0.04)		(0.08)	(0.08)		(0.07)	(0.07)

					TPM				
Education	–0.44‡	0.01	–0.43‡	0.30	–0.13	0.17	3.95‡	0.46	4.40‡
	(0.12)	(0.10)	(0.17)	(0.34)	(0.24)	(0.48)	(0.52)	(0.40)	(0.68)
Age	–0.30‡	0.09	–0.21	–1.18‡	–0.01	–1.20‡	1.02‡	–0.17	0.85‡
	(0.11)	(0.09)	(0.14)	(0.24)	(0.23)	(0.31)	(0.26)	(0.24)	(0.37)
Income		0.01	0.01		–0.10	–0.10		–0.05	–0.05
		(0.04)	(0.04)		(0.08)	(0.08)		(0.09)	(0.09)

Note: Asymptotic standard errors in parentheses. Daggers ‡ and † denote significance at the 5% and 10% levels, respectively.