ADOLESCENT CIGARETTE USE: EFFECTS OF SCHOOL QUALITY AND STUDENT AND PARENTAL INVOLVEMENT

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1. Introduction. Research on adolescent cigarette use has been concerned mainly with the effects of individual and family variables. Many studies document associations between cigarette use and family attachment, school involvement, peer smoking, and other individual and family variables (e.g., Akers and Lee 1996; Ennett and Bauman, 1993). Recent research suggests cigarette use also varies by type of school (Ennett et al. 1997; Skager and Fisher 1989).

A drawback is the failure to link school with individual and family explanatory variables. To reduce omitted-variables bias, factors operating at the different levels need to be included in the same model. School variables may also condition the effects of variables operating at the individual and family levels. For example, one might expect the effects of student and parental involvement in schools to be intensified in high quality schools, including schools with a small ratio of students to teachers. If school involvement reduces the risk of cigarette use (MacBride et al., 1995; Jenkins, 1995), then quality schools may reinforce this effect by offering a normative climate in opposition to cigarette use, an example of a "cross-level interaction effect" (Bryk and Raudenbush, 1992).

The multilevel modeling approach applied in this paper (Bryk and Raudenbush 1992; Goldstein 1995; Kreft and De Leeuw 1999) has a number of advantages, including variance estimates that take into account the data hierarchy, such as clustering of sample students within schools. For our purposes– and those of public policy research generally– the most important advantage is that multilevel models can yield consistent estimates of cross-level interaction effects (see the next section).

We applied multilevel models to the National Educational Longitudinal Study (NELS) to explore how individual, family, and school characteristics affect adolescent cigarette use. The response variable is cigarette initiation (first use), coded "1" if the adolescent initiated daily cigarette use (at least one cigarette per day) during the interval between the baseline NELS interview and the reinterview conducted two years later; and coded "0" if the adolescent did not smoke on a daily basis at either wave. The final model used 18 explanatory variables– including 7 individual, 4 family, and 7 school variables– and incorporated cross-level interaction effects– interactions between school and family/individual variables– and variance components gauging differences among schools in the effects of individual and family variables. This paper reports findings about the effects of school quality and student and parental involvement in the schools. Full results are presented in Johnson (1999).

The following sections discuss the advantages of multilevel models for policy research, the data and methods of our application, and results on the effects of school quality and student and parental involvement on adolescent cigarette use.

2. Multilevel models in policy research. The standard single-level regression model has long been the model of choice in policy-oriented research. Let y_{ij} be a continuous response measured for the i-th student in the j-th school; x_{ij} an individual-level explanatory variable measured for the same student; and z_j a school-level variable measured for the j-th school. The model can be written

$$y_{ij} = a + bx_{ij} + cz_j + d\,(x_{ij} z_j) + \varepsilon_{ij}\,, \qquad (1)$$

where ε_{ij} is student-level error with zero mean; and a, b, c, and d are regression coefficients. The error ε_{ij} represents student-level variables that are not included in the model and that affect y_{ij}.

It is instructive to write the single-level model as a "pseudo two-level model" by defining a school-specific intercept a_j equal to $(a + cz_j)$:

$$\text{Level 1 (students): } y_{ij} = a_j + b\,x_{ij} + d\,(x_{ij} z_j) + \varepsilon_{ij}$$

$$\text{Level 2 (schools): } a_j = a + c\,z_j \qquad (1')$$

But (1′) is not a true multilevel model because there is no random error at Level 2. The single-level model allows unmeasured variables at the student level, but not at the school level.

The multilevel approach introduces the idea of separate regressions in each school or context:

$$\text{Level 1 (students): } y_{ij} = a_j + b_j x_{ij} + \varepsilon_{ij}$$

$$\text{Level 2 (schools): } a_j = a + cz_j + \mu_{1j}$$
$$b_j = b + d\,z_j + \mu_{2j} \qquad (2)$$

The key property of the level-1 equation is that the regression intercept and slope of y_{ij} on x_{ij} each have a subscript "j," which implies these parameters can vary across schools. The level-1 regressions are linked by a level-2 model, where regression coefficients of the level-1 model are themselves regressed on the school explanatory variable z_j. As in the single-level model, additional assumptions are needed to estimate the model, the main ones being that the level-1 error (ε_{ij}) and level-2 errors (μ_{1j} and μ_{2j}) are uncorrelated with each other and with the explanatory variables.

For comparison with the single-level model, we can write the two-level model as a single equation by substituting the right-hand-sides of the level-2 equations for a_j and b_j in the level-1 equation:

$$y_{ij} = a + bx_{ij} + cz_j + d(x_{ij} z_j) + (\varepsilon_{ij} + \mu_{1j} + x_{ij}\mu_{2j}). \qquad (2')$$

Comparing (1) with (2') shows that the only difference is in the assumed error structure.

An important parameter for policy is d, the cross-level interaction. Individuals and families in the U.S. are afforded many legal protections, so schools are the principal lever of drug prevention policy. Cross-level interactions may be critical paths by which school policies can impact individual behavior. Yet, if d is estimated using (1) when the true error is that of (2'), the estimate is inconsistent, because the error in (2') is correlated with ($x_{ij} z_j$). Thus, if there exist unmeasured school variables– as there almost surely are– good estimates of cross-level interaction effects might not be possible using a single-level model.

3. Data and measures

a. Sample and data collection design. The longitudinal design of NELS (National Center for Educational Statistics, 1992) allows us to gauge changes in cigarette use between measurement waves and to control for whether or not respondents used cigarettes at the prior wave. Most research on cigarette use in the U.S. has used cross-sectional rather than longitudinal data, perhaps because the National Household Survey on Drug Abuse (NHSDA) and Monitoring the Future (MTF)–two major surveys designed to measure substance use–are cross-sectional in design. Yet retrospective reporting can bias responses about past drug use obtained from cross-sectional surveys (Johnson et al. 1998).

We split the NELS longitudinal file into two panels to investigate cigarette use separately among eighth graders in 1988 and tenth graders in 1990. Eighth grade panel members were first interviewed as eighth graders in Fall 1988 (Wave 1) and reinterviewed two years later (Wave 2). Tenth grade panel members were first interviewed as tenth graders in Fall 1990 (Wave 1) and reinterviewed two years later (Wave 2). Both panels followed up school drop-outs. About 6.8% of eighth grade panel members and 10.4% of tenth grade panel members dropped out before Wave 2. The adolescent interviews used traditional personal interviewing techniques. Personal interviews of parents and school administrators were also conducted at Wave 1 of each panel. Given positive correlation of cigarette use at different ages, the sample overlap between panels (about 90%) results in increased precision for comparing panels. The significance test results presented in this paper are conservative in that we treat the two panels as independent samples.

Both panels are based on a two-stage national probability sample of U.S. students: Stratified random sampling of schools was followed by random sampling of eligible students within schools. In our analysis, the Eighth grade panel consists of 17,424 adolescents in 1,014 schools who responded to both interviews. The tenth grade panel consists of 16,542 adolescents in 1,464 schools who responded to both interviews. We used standard NELS weights (NCES, 1992) to adjust for unit nonresponse and unequal selection probabilities. We used techniques described in Pfeffermann et al. (1997)– as implemented in the program MLWIN (www.ioe.ac.uk/mlwin)–to incorporate the NELS weights in the multilevel model estimation.

b. Measurement of daily cigarette use. Daily cigarette use at each wave of each panel was measured based on responses to the question "How many cigarettes do you usually smoke in a day?" We collapsed the response categories at each wave to form a binary variable: 1 = One or more cigarettes per day; 0 = Not a daily smoker. Item nonresponse was small, ranging from 2.3% at Wave 1 of the eighth grade panel to 7.1% at Wave 2 of the tenth grade panel.

To impute the missing data, we used techniques for multilevel models described by Schafer (1996, 1997). Missing values on cigarette use were imputed after missing values on explanatory variables had already been imputed. For each panel, we first generated predicted values using a bivariate normal multilevel model with two response variables–daily cigarette use at waves 1 and 2–and twelve explanatory variables, including family structure, dropout status, parental support, school participation, negative peer associations, race/ethnicity, region, type of school, percent of minority students, student-teacher ratio, size of school, and teacher salary level. The effects of six individual/family variables were treated as random at the school level. The continuous imputed values were rounded to 0 or 1. We also generated three sets of imputations for each panel, and, using multiple imputation techniques (Schafer, 1997), found that the additional uncertainty contributed by the imputation amounted to less than

10% of each standard error reported in Table 1.

c. Measurement of student and parental involvement. We measured student involvement as the number out of nine activities, including music, athletics, and academic and vocational clubs, that the adolescent respondent reported participating at Wave 1. We measured parental involvement as the number of affirmative answers given by the adolescent respondent to ten questions about the respondent's parent(s) at Wave 1, e.g., whether a parent helped with home work or attended school meetings. Missing data rates of both scales were less than 3% in each panel. We imputed missing values of scale items using the mode of respondents with nonmissing values. Both scales have high internal reliability, with Cronbach's alpha greater than 0.65 in each panel.

d. Measurement of school quality. We measured school quality as the student-teacher ratio, the number of students per teacher in the school, as determined from interviews with school administrators conducted at Wave 1. Missing data rates equal 2% in the eighth-grade panel and 7% in the tenth-grade panel. The missing values were imputed using mean imputation within imputation cells defined by region, type of place, and type of school (public vs. Catholic vs. other private).

e. Measurement of other explanatory variables. There are six additional explanatory variables at the individual and family levels: gender; race/ethnicity; family income; two biological parents at home; school dropout (based on the Wave-2 follow up); and a negative peer relations scale (number of affirmative answers to five questions about how school peers viewed the respondent, e.g., as a poor student). There are six additional explanatory variables at the school level: region; type of place (central city v. other metro v. nonmetro); type of school (public v. Catholic v. other); school size; average beginning teacher salary; and school racial/ethnic composition. Details of these variables and descriptive statistics for all variables– means, variances, and intercorrelations– are in Johnson and Hoffmann (1999). Prior to analysis, continuous variables were "centered" by subtracting their means (Bryk and Raudenbush, 1992).

4. Models and results. We present results based on two multilevel models– called Model 1 and Model 2. Model 1 is a 2-level "variance-components model" with a logit-linked binary response and one fixed covariate. Multilevel parameter estimates reported in this paper are second-order penalized quasi-likelihood estimates ("PQL2"), as discussed in Goldstein (1995) and implemented in MLWIN. The estimates were corroborated using two alternative methods– bootstrap and Markov Chain Monte Carlo– also in MLWIN.

We use Model 1 to underscore the importance of cigarette initiation as a response variable. Let y_{ij} denote a binary (0-1) response variable indicating daily cigarette use at Wave 2 and let π_{ij} denote the corresponding probability of using cigarettes daily at Wave 2. Let x_{ij} denote a binary (0-1) response variable indicating daily use at Wave 1. Model 1 is written

$$\text{Level 1 (adolescents): } y_{ij} = \pi_{ij} + e_{ij}$$
$$\operatorname{logit}(\pi_{ij}) = \alpha_j + \beta x_{ij}$$

$$\text{Level 2 (schools): } \alpha_j = \alpha + u_j, \qquad (3)$$

where $\operatorname{logit}(\pi_{ij}) = \log(\pi_{ij}/(1 - \pi_{ij}))$; "log" denotes the natural logarithm; e_{ij} is a level-1 random error; and u_j is a level-2 random error. We assume that y_{ij} is distributed as an extra-Bernoulli variable with mean π_{ij}, so e_{ij} has mean 0 and variance $\sigma_e^2 = \kappa\, \pi_{ij}\,(1 - \pi_{ij})$. We also assume u_j is normal with mean 0 and variance σ_u^2 and that the level-1 and level-2 errors are independent. In both panels, κ was estimated to be close to 1.0. Inspection of residuals suggested the assumptions of normality and constant variance are reasonable for the level-2 errors of both models presented in this paper.

Table 1 shows the Model 1 parameter estimates. The slope parameter β gauges the dependence of daily cigarette use on daily cigarette use two years earlier. For the eighth grade panel, the estimated β of 2.77 corresponds to an odds-ratio of current relative to past smoking of about exp(2.77) = 16. That is, an eighth grade panel member is about 16 times more likely to be a daily smoker if he (she) was a daily smoker two years ago than if he was not. For the tenth grade panel, the corresponding estimate equals about exp(2.99) = 20. The increase in the odds-ratio may reflect that addiction becomes more severe the longer an individual uses cigarettes. If so, it makes sense to try to prevent adolescents from ever using cigarettes for the first time.

Another finding of Table 1 is that the school variance in daily cigarette use– after controlling for past use– is much larger among eighth graders than among tenth graders– 0.09 vs. 0.03. This suggests that opportunities for school interventions to prevent cigarette use are greater in middle schools than in high schools.

Past cigarette use is such a strong predictor of current use that it might be misleading to include past smokers and nonsmokers in the same model. We examined separate models for initiation and cessation and found that most explanatory variables interact with past use. NELS data are more plentiful for initiation than cessation, so the sequel focuses on initiation.

Model 2 uses daily cigarette initiation between Waves 1 and 2 as the response variable. That is, y_{ij} equals 1 if the adolescent began daily cigarette use between Waves 1 and 2; and y_{ij} equals 0 if the adolescent was a daily nonsmoker at both waves. The analysis is restricted to daily nonsmokers at Wave 1, which reduces the sample size from 17,424 to 16,454 in the eighth grade panel and from 16,542 to 13,840 in the tenth grade panel. Model 2 also extends Model 1 by adding individual and family explanatory variables at level 1 and school explanatory variables at level 2. We assume P level-1 explanatory variables, denoted x_{pij}, p = 1,..., P; and Q level-2 explanatory variables, denoted w_{qj}, q = 1...,Q. Model 2 is written:

$$\begin{aligned}
&\text{Level 1 (adolescents): } y_{ij} = \pi_{ij} + e_{ij}\\
&\qquad\operatorname{logit}(\pi_{ij}) = \alpha_j + \textstyle\sum_p \beta_{pj}\, x_{pij}\\
&\text{Level 2 (schools): } \alpha_j = \alpha + \textstyle\sum_q \gamma_{0q}\, w_{qj} + u_{0j}\\
&\qquad\beta_{1j} = \beta_1 + \textstyle\sum_q \gamma_{1q}\, w_{qj} + u_{1j}\\
&\qquad\dots\\
&\qquad\beta_{Pj} = \beta_P + \textstyle\sum_q \gamma_{Pq}\, w_{qj} + u_{Pj}. \qquad (4)
\end{aligned}$$

where the summations extend from p = 1 to p = P at Level 1 and from q = 1 to q = Q at Level 2.

The first level of (4) is similar to (3), except that π_{ij} – the probability of initiation– depends upon a school-specific intercept– α_j – and upon school-specific slopes– β_{1j} through β_{Pj}. In the (P + 1) level-2 equations, the level-1 regression intercept and slopes are themselves treated as response variables. Each is regressed on Q school-level explanatory variables. For example, in the equation for β_{1j}, β_1 is the average across schools of the slope of logit(π_{ij}) on x_{1ij}; γ_{11} is the effect on β_{1j} of a unit increase in w_{1j}; and u_{1j} is the level-2 random error associated with β_{1j}. Model 2 also assumes that the level-1 random error e_{ij} is independent of the level-2 random errors– u_{0j} through u_{Pj}; that random errors are uncorrelated with explanatory variables; and that the vector of level-2 random errors– u_{pj} , p = 0, 1, ..., P– is multivariate normal with zero means; variances σ_{up}^2, p = 0, 1, ..., P; and covariances $\sigma_{upp'}$, where p and p′ each range from 0 to P and p does not equal p′.

Substituting the right-hand-side of each level-2 equation of (4) into Level 1 expresses logit(π_{ij}) in terms of x_{pij}'s, w_{qj}'s, and their products– the $x_{pij}w_{qj}$'s:

$$\begin{aligned}
\operatorname{logit}(\pi_{ij}) = {} & \alpha_j + \textstyle\sum_p \beta_{pj}\, x_{pij} + \sum_q \gamma_{0q}\, w_{qj}\\
& + \textstyle\sum_p \sum_q \gamma_{0q}\, (x_{pij}\, w_{qj}) + u_{0j} + \sum_p x_{pij}\, u_{pj}. \qquad (4')
\end{aligned}$$

The coefficients of the $x_{pij}w_{qj}$'s – the γ_{pq}'s – gauge the cross-level interaction effects, showing how school variables amplify or dampen the effects of individual and family variables. This paper presents results based on a simplified version of Model 2 in which interactions and school-level variances and covariances that were not statistically significant in either NELS panel were omitted from the model. In analyzing each panel, we tested each fixed and random parameter in the full model using Wald tests and found that only nine cross-level interactions and five school-level variance components were significant in one or both panels. Johnson and Hoffmann (1999) give details.

Table 2 presents Model 2 parameter on the logit scale of Eqs. (4). The table presents only the effects that involve one or more of the three variables of interest: student involevement, parental involvement, and the student/teacher ratio of the school. The question is, How does school quality– as measured by the student-teacher ratio– condition the effects of student and parental involvement on adolescent cigarette initiation? The effects of student and parental involvement estimate the reduction in the log-odds of cigarette initiation associated with a one standard deviation *increase* in the scale value. The effects of the student-teacher ratio estimate the reduction in the log-odds associated with a one standard deviation *decrease*. The standard deviations of student involvement, parental involvement, and the student-teacher ratio equal approximately 1.6, 1.6, and 7.8, respectively, in the eighth grade panel; and 1.2, 1.9, and 5.9 in the tenth grade panel.

Comparing parameter estimates with standard errors in Table 2 shows that each effect is statistically significant at the 0.05 level in one or both panels. Except for the intercept, the fixed effects of appear stable across panels, but the variance components gauging unexplained school variability in the intercept and the effect of student involvement decline between the eighth and tenth grade panels.

Table 3 presents Model 2 odds ratios gauging the effects of parental and student involvement in "good" and "bad" schools. The odds ratios are defined in terms of levels of student and parental involvement and school quality that are one standard deviation above and below the estimated means. Thus, the odds ratios for student involvement gauge the amount of reduction in cigarette initiation that is associated with an increase of two standard deviations in the student involvement scale. For example, in the eighth grade panel, the effect of student involvement is to multiply the odds on initiation by a factor of 1.14 in a "bad" school and by a factor of 0.93 in a "good" school. To a close approximation in both panels, 4 school activities out of a possible 9 is "good" (one standard deviation above the mean); one activity is "bad" (one standard deviation below the mean). For parental involvement, 9 activities out of 10 is "good"; 5

activities is "bad." For school quality, a student-teacher ratio of 13 is "good"; a ratio of 27 is "bad."

Table 3 suggests that increasing school quality– by reducing the student-teacher ratio– increases the deterrent effect of student involvement on cigarette use. It is reasonable that improving improving school quality increases the value of the investments that students make in schools. Yet, at least when parents alone are involved in the school, improving school quality *reduces* the deterrent effect of parental involvement. For example, in the eighth grade panel, parental involvement multiplies the odds on initiation by a factor of 0.92 in a bad school, but there is essentially no effect in a good school. Possibly there is a "substitution effect" operating between parents and teachers. Teachers can make their greatest positive contribution to childrens' welfare when parental support is low, and vice-versa. The strongly negative same-level interaction between student and parental involvement (Table 2) indicates the two kinds of involvement are mutually reinforcing in deterring cigarette use. Regardless of school quality, the greatest reduction in cigarette initiation arises when both adolescents and their parents are involved in the school. These findings are supported by results of both panels.

5. Discussion. Multilevel models hold promise for policy research because the outcomes that policies seek to change and the factors manipulable by policy are often at different levels of society. Much statistical research emphasizes that failing to model the data hierarchy– such as clustering of students within schools in the NELS sample design– results in standard errors that are typically too small. This paper emphasizes that failing to model the social hierarchy– the different levels of policy inputs and outputs such as schools and individuals– can lead to biased and inconsistent estimates of policy-relevant effects.

The results on cigarette initiation illustrate the importance of cross-level interaction effects in policy evaluations. Decreasing the student-teacher ratio of a school reduces cigarette risk by strengthening the deterrent effect of the student's involvement in the school. Sufficient teachers per pupil is especially important in reducing cigarette initiation among students whose parents are not involved. Parental involvement is especially important when the number of teachers per pupil is low.

6. References

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Table 1. Model 1 estimates. Daily cigarette use at Wave 2. α = average school intercept. β = slope of Wave 1 cigarette use. σ_u^2 = school-level variance. National Educational Longitudinal Study (NELS).											
Eighth grade panel						*Tenth grade panel*					
α	(se)	β	(se)	σ_u^2	(se)	α	(se)	β	(se)	σ_u^2	(se)
-1.77	(.03)	2.77	(.08)	0.09	(.02)	-1.95	(.03)	2.99	(.06)	0.03	(.01)

Table 2. Model 2 estimates. Initiation of daily cigarette use between Waves 1 and 2. NELS.			
*Parameter**	*8th grade panel*	*10th grade panel*	*Change between panels*
1. Main effects			
Intercept	-1.35 (.06)	-1.85 (.07)	Base %: 21% to 14%**
Student involvement (+ 1 SD)	-0.05 (.04)	-0.12 (.05)	Odds ratio: 0.95 to 0.89
Parent involvement (+ 1 SD)	-0.11 (.04)	-0.08 (.04)	Odds ratio: 0.90 to 0.92
Student-teacher ratio (- 1 SD)	-0.06 (.03)	-0.02 (.03)	Odds ratio: 0.94 to 0.98
Urban place (1if yes, 0 otherwise)	-0.08 (.07)	-0.18 (.09)	Odds ratio: 0.92 to 0.84
2. Interaction effects			
Student by Parent involvement	-0.07 (.03)	-0.04 (.03)	Odds ratio: 0.93 to 0.96
Student involvement by S/t ratio	-0.05 (.02)	-0.02 (.02)	Odds ratio: 0.95 to 0.98
Parental involvement by S/t ratio	0.02 (.02)	0.07 (.03)	Odds ratio: 1.02 to 1.07
Parental involvement by Urban place	0.03 (.01)	0.02 (.01)	Odds ratio: 1.03 to 1.02
3. Random effects– Unexplained variability among schools			
Variance(Intercept)	0.23 (.04)	0.08 (.02)	Difference = -0.15 (.04)**
Variance(Student involvement effect)	0.09 (.02)	0.05 (.01)	Difference = -0.04 (.02)**
Variance(Parental involvement effect)	0.09 (.02)	0.08 (.01)	Difference = -0.01 (.02)

*Parameter estimates are on the logistic scale. Since continuous explanatory variables are centered at their means, the intercept pertains to a non-minority female with one or no parents at home who attended a non-Western, non-Catholic school and did not drop out between waves. Johnson and Hoffmann (1999) give details.

**Significant change based on two-sample two-tail t-test assuming independent samples, a = .05

Table 3. Model 2 estimates. Odds ratios gauging the deterrent effects on adolescent cigarette initiation of student and parental involvement in good and bad schools.* Adolescents in urban schools. NELS.				
	8th grade panel		**10th grade panel**	
Effect*	**bad school**	**good school**	**bad school**	**good school**
Student involvement alone	1.14	0.93	0.90	0.81
Parent involvement alone	0.92	1.01	0.83	1.11
Both student and parent	0.80	0.72	0.64	0.78

*Good (bad) schools are defined as schools with student-teacher ratios one standard deviation below (above) the mean. The student and parental involvement effects are odds ratios gauging the amount of reduction in the odds of initiation associated with an increase of two standard deviations in the scale value. See text.