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Controlling for individual heterogeneity in longitudinal models, with applications to student achievement

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Abstract

Longitudinal data tracking repeated measurements on individuals are highly valued for research because they offer controls for unmeasured individual heterogeneity that might otherwise bias results. Random effects or mixed models approaches, which treat individual heterogeneity as part of the model error term and use generalized least squares to estimate model parameters, are often criticized because correlation between unobserved individual effects and other model variables can lead to biased and inconsistent parameter estimates. Starting with an examination of the relationship between random effects and fixed effects estimators in the standard unobserved effects model, this article demonstrates through analysis and simulation that the mixed model approach has a ``bias compression'' property under a general model for individual heterogeneity that can mitigate bias due to uncontrolled differences among individuals. The general model is motivated by the complexities of longitudinal student achievement measures, but the results have broad applicability to longitudinal modeling.

Keywords: longitudinal data analysis, random effects models, fixed effects models, omitted variables.

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References

[1] Aaronson, D., Barrow, L., and Sander, W. (2003). Teachers and student achievement in the chicago public high schools. Tech. rep., Federal Reserve Bank of Chicago.

[2] Ahn, S., Lee, Y., and Schmidt, P. (2001). Gmm estimation of linear panel data models with time-varying individual effects. Journal of Econometrics 101, 219–255. MR1820251

[3] Allison, P. (1994). Using panel data to estimate the effects of events. Sociological Methods and Research 23, 2, 174–199.

[4] Anderson, T. (1984). An Introduction to Multivariate Statistical Analysis, Second ed. John Wiley & Sons. MR0771294

[5] Arellano, M. (2003). Panel Data Econometrics. Oxford University Press. MR2060514

[6] Ballou, D., Sanders, W., and Wright, P. (2004). Controlling for student background in value-added assessment of teachers. Journal of Educational and Behavioral Statistics 29, 1, 37–66.

[7] Bellman, R. E. (1960). Introduction to Matrix Analysis. McGraw-Hill, New York.

MR0122820

[8] Bifulco, R. and Ladd, H. (2004). The impact of charter schools on student achievement: Evidence from north carolina. Tech. rep., University of Connecticut and Duke University. August.

[9] Braun, H. (2005). Using student progress to evaluate teachers: A primer on value-added models. Tech. rep., Educational Testing Service, Policy Information Center. September.

[10] Diggle, P., Heagerty, P., Liang, K., and Zeger, S. (2002). Analysis of Longitudinal Data. Oxford University Press. MR2049007

[11] Doran, H. and Cohen, J. (2005). The confounding effects of linking bias on gains estimated from value-added models. In Value Added Models in Education: Theory and Applications, R. Lissitz, Ed. JAM Press, Maple Grove, Minnesota.

[12] Ejrnaes, M. and Holm, A. (2006). Comparing fixed effects and covariance structure estimators for panel data. Sociological Methods & Research 35, 61–83. MR2247151

[13] Frees, F. (2004). Longitudinal and Panel Data: Analysis and Applications in the Social Sciences. Cambridge University Press. MR2087947

[14] Gill, B., Zimmer, R., Christman, J., and Blanc, S. (2007). State Takeover, School Restructuring, Private Management, and Student Achievement in Philadelphia (MG-533-ANF/WPF/SDP). RAND, Santa Monica, CA. Available from http://www.rand.org/pubs/monographs/MG533.

[15] Goldhaber, A. and Anthony, E. (2004). Can teacher quality be effectively assessed? Unpublished manuscript.

[16] Halaby, C. (2004). Panel models in sociological research: Theory into practice. Annu. Rev. Sociol. 30, 507–544.

[17] Hamilton, L., McCaffrey, D., and Koretz, D. (2006). Validating achievement gains in cohort-to-cohort and individual growth-based modeling contexts. In Value Added Models in Education: Theory and Applications, R. Lissitz, Ed. JAM Press, Maple Grove, Minnesota.

[18] Han, C., Orea, L., and Schmidt, P. (2005). Estimation of a panel data model with parametric temporal variation in individual effects. Journal of Econometrics 126, 241–267. MR2155625

[19] Hanushek, E., Kain, J., and Rivkin, S. (2002). The impact of charter schools on academic achievement. Tech. rep., Hoover Institute.

[20] Harris, D. and Sass, T. (2006). Value-added models and the measurement of teacher quality. Unpublished manuscript.

[21] Hedeker, D. and Gibbons, R. (2006). Longitudinal Data Analysis. John Wiley & Sons. MR2284230

[22] Hsiao, C. (2003). Analysis of Panel Data, Second ed. Cambridge University Press. MR1962511

[23] Jacob, B. and Lefgren, L. (2006). When principals rate teachers. Tech. Rep. 2, Education Next.

[24] Kane, T., Rockoff, J., and Staiger, D. (2006). What does certification tell us about teacher effectiveness? Evidence from New York City. Unpublished manuscript.

[25] Koedel, C. and Betts, J. (2005). Re-examining the role of teacher quality in the educational production function. Tech. rep., Department of Economics, UCSD.

[26] Le, V., Stecher, B., Lockwood, J., Hamilton, L., Robyn, A., Williams, V., Ryan, G., Kerr, K., Martinez, J., and Klein, S. (2006). Improving Mathematics and Science Education:

A Longitudinal Investigation of the Relationship between Reform-Oriented Instruction and Student Achievement (MG-480-EDU). RAND, Santa Monica, CA.

[27] Lissitz, R., Ed. (2005). Value Added Models in Education: Theory and Applications. JAM Press: Maple Grove, MN.

[28] Lockwood, J. and McCaffrey, D. (2007). Controlling for student heterogeneity in longitudinal achievement models. RAND WR-471-IES, Santa Monica, CA.

[29] Lockwood, J., McCaffrey, D., Hamilton, L., Stecher, B., Le, V., and Martinez, J. (2007). The sensitivity of value-added teacher effect estimates to different mathematics achievement measures. To appear, Journal of Educational Measurement.

[30] Lockwood, J., McCaffrey, D., Mariano, L., and Setodji, C. (2006). Bayesian methods for scalable multivariate value-added assessment. To appear, Journal of Educational and Behavioral Statistics.

[31] Martineau, J. (2006). Distorting value added: The use of longitudinal, vertically scaled student achievement data for value-added accountability. Journal of Educational and Behavioral Statistics 31, 35–62.

[32] May, H., Supovitz, J. A., and Perda, D. (2004). A longitudinal study of the impact of america's choice on student performance in rochester, new york, 1998-2003. Tech. rep., Consortium for Policy Research in Education, University of Pennsylvania, Graduate School of Education.

[33] McCaffrey, D., Lockwood, J., Koretz, D., Louis, T., and Hamilton, L. (2004). Models for value-added modeling of teacher effects. Journal of Educational and Behavioral Statistics 29, 1, 67–101.

[34] McCaffrey, D. F., Lockwood, J. R., Koretz, D. M., and Hamilton, L. S. (2003). Evaluating Value-Added Models for Teacher Accountability, (MG-158-EDU). RAND, Santa Monica, CA.

[35] Morrison, D. F. (1990). Multivariate Statistical Methods, Third ed. McGraw-Hill, New York. MR0212946

[36] Nye, B., Konstantopoulos, S., and Hedges, L. (2004). How large are teacher effects? Educational Evaluation and Policy Analysis 26, 3, 237–257.

[37] Raudenbush, S. and Bryk, A. (2002). Hierarchical Linear Models: Applications and Data Analysis Methods, Second ed. Sage Publications, Newbury Park, CA.

[38] Rivkin, S. G., Hanushek, E. A., and Kain, J. F. (2005). Teachers, Schools and Academic Achievement. Econometrica 73, 2, 417–458.

[39] Rockoff, J. (2004). The impact of individual teachers on student achievement: Evidence from panel data. AEA Papers and Proceedings 94, 2 (May), 247–252.

[40] Rowan, B., Correnti, R., and Miller, R. (2002). What large-scale survey research tells us about teacher effects on student achievement: Insights from the Prospects study of elementary schools. Teachers College Record 104, 1525–1567.

[41] Sanders, W., Saxton, A., and Horn, B. (1997). The Tennessee Value-Added Assessment System: A Quantitative Outcomes-Based Approach to Educational Assessment. In Grading Teachers, Grading Schools: Is Student Achievement a Valid Evaluational Measure?, J. Millman, Ed. Corwin Press, Inc., Thousand Oaks, CA, 137–162.

[42] Schacter, J. and Thum, Y. M. (2004). Paying for high and low-quality teaching. Economics of Education Review 23, 411–430.

[43] Schmidt, H., Houang, R., and McKnight, C. (2005). Value-added research: Right idea but wrong solution? In Value Added Models in Education: Theory and Applications, R. Lissitz, Ed. JAM Press, Maple Grove, Minnesota, 272–297.

[44] Searle, S., Casella, G., and McCulloch, C. (1992). Variance Components. John

Wiley & Sons, New York. MR1190470

[45] Singer, J. and Willett, J. (2003). Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence. Oxford University Press.

[46] Teachman, J., Duncan, G., Yeung, W., and Levy, D. (2001). Covariance structure models for fixed and random effects. Sociological Methods & Research 30, 271–288. MR1862537

[47] Theil, H. (1971). Principals of Econometrics. John Wiley and Sons, New York.

[48] Thum, Y. (1997). Hierarchical linear models for multivariate outcomes. Journal of Educational and Behavioral Statistics 22, 77–108.

[49] Todd, P. and Wolpin, K. (2004). The production of cognitive achievement in children: Home, school and racial test score gaps. Tech. rep., Department of Economics, University of Pennsylvania. April.

[50] Wooldridge, J. (2001). Econometric Analysis of Cross Section and Panel Data. MIT Press.

[51] Zellner, A. (1962). An efficient method of estimating seemingly unrelated regression equations and tests for aggregation bias. Journal of the American Statistical Association 57, 348–368. MR0139235

[52] Zimmer, R., Buddin, R., Chau, D., Daley, G., Gill, B., Guarino, C., Hamilton, L., Krop, C., McCaffrey, D., Sandler, M., and Brewer, D. (2003). Charter School Operations and Performance: Evidence from California. RAND: Santa Monica, CA.

[53] Zvoch, K. and Stevens, J. (2003). A Multilevel, Longitudinal Analysis of Middle School Math and Language Achievement. Education Policy Analysis Archives 11, 20. http://epaa.asu.edu/epaa/v11n20/.