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Review

Value-added modeling: A review

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ABSTRACT

This article reviews the literature on teacher value-added. Although value-added models have been used to measure the contributions of numerous inputs to educational production, their application toward identifying the contributions of individual teachers has been particularly contentious. Our review covers articles on topics ranging from technical aspects of model design to the role that value-added can play in informing teacher evaluations in practice, highlighting areas of consensus and disagreement in the literature. Although a broad spectrum of views is reflected in available research, along a number of important dimensions the literature is converging on a widely-accepted set of facts.

1. Introduction

Value-added modeling has become a key tool for applied researchers interested in understanding educational production. The “value-added” terminology is borrowed from the long-standing production literature in economics – in that literature, it refers to the amount by which the value of an article is increased at each stage of the production process. In education-based applications, the idea is that we can identify each student’s human capital accumulation up to some point, say by the conclusion of period *t-1*, and then estimate the value-added to human capital of inputs applied during period *t*.

Value-added models (VAMs) have been used to estimate value-added to student achievement for a variety of educational inputs. The most controversial application of VAMs has been to estimate the effects of individual teachers. Accordingly, this review focuses on the literature surrounding teacher-level VAMs.[1] The attention on teachers is motivated by the consistent finding in research that teachers vary dramatically in their effectiveness as measured by value-added (Hanushek & Rivkin, 2010). In addition to influencing students’ short-term academic success, access to high-value-added teachers has also been shown to positively affect later-life outcomes for students including wages, college attendance, and teenage childbearing (Chetty, Friedman, & Rockoff, 2014b). The importance of access to effective teaching for students in K-12 schools implies high stakes for personnel policies in public education. Chetty, Friedman, and Rockoff (2014b) and Hanushek (2011) monetize the gains that would come from improving the quality of the teaching

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[1] Other applications of value-added include evaluations of teacher professional development and coaching programs (Biancarosa, Byrk, & Dexter, 2010; Harris & Sass, 2011), teacher training programs (Goldhaber, Liddle, & Theobald, 2013; Koedel, Parsons, Podgursky, & Ehlert, in press; Mihaly, McCaffrey, Sass, & Lockwood, 2013), reading reform programs (Betts, Zau, & King, 2005) and school choice (Betts & Tang, 2008), among others.

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workforce – using value-added-based evidence – and conclude that the gains would be substantial.

The controversy surrounding teacher value-added stems largely from its application in public policy, and in particular the use of value-added to help inform teacher evaluations. Critics of using value-added in this capacity raise a number of concerns, of which the most prominent are (1) value-added estimates may be biased (Baker et al., 2010; Paufler & Amrein-Beardsley, 2014; Rothstein, 2009, 2010), and (2) value-added estimates seem too unstable to be used for high-stakes personnel decisions (Baker et al., 2010; Newton, Darling-Hammond, Haertel, & Thomas, 2010). Rothstein (2015) also raises the general point that the labor-supply response to more rigorous teacher evaluations merits careful attention in the design of evaluation policies. We discuss these and other issues over the course of the review.

The remainder of the paper is organized as follows. Section 2 provides background information on value-added and covers the literature on model-specification issues. Section 3 reviews research on the central questions of bias and stability in estimates of teacher value-added. Section 4 combines the information from Sections 2 and 3 in order to highlight areas of emerging consensus with regard to model design. Section 5 documents key empirical facts about value-added that have been established by the literature. Section 6 discusses research on the uses of teacher value-added in education policy. Section 7 concludes.

2. Model background and specification

2.1. Background

Student achievement depends on input from teachers and other factors. Value-added modeling is a tool that researchers have used in their efforts to separate out teachers' individual contributions. In practice, most studies specify linear value-added models in an *ad hoc* fashion, but under some conditions these models can be formally derived from the following cumulative achievement function, taken from Todd and Wolpin (2003) and rooted in the larger education production literature (Ben-Porath, 1967; Hanushek, 1979):

$$A_{it} = A_t[X_i(t), F_i(t), S_i(t), \alpha_{i0}, \varepsilon_{it}] \quad (1)$$

Eq. (1) describes the achievement level for student i at time t (A_{it}) as the end product of a cumulative set of inputs, where $X_i(t)$, $F_i(t)$ and $S_i(t)$ represent the history of individual, family and school inputs for student i through year t, α_{i0} represents student i's initial ability endowment and ε_{it} is an idiosyncratic error. The intuitive idea behind the value-added approach is that to a rough approximation, prior achievement can be used as a sufficient statistic for the history of prior inputs and, in some models, the ability endowment. This facilitates estimation of the marginal contribution of contemporaneous inputs, including teachers, using prior achievement as a key conditioning variable.

In deriving the conditions that formally link typically-estimated VAMs to the cumulative achievement function, Todd and Wolpin (2003) express skepticism that they will be met. Their skepticism is warranted for a number of reasons. As one example, in the structural model parental inputs can respond to teacher assignments, allowing for increased (decreased) parental inputs that are complements (substitutes) for higher teacher quality. VAM researchers cannot measure and thus cannot control for parental inputs, which means that unlike in the structural model, value-added estimates of teacher quality are inclusive of any parental-input adjustments. More generally, the model shown in Eq. (1) is flexible along a number of dimensions in ways that are difficult to emulate in practical modeling applications (for further discussion see Sass, Semykina, & Harris, 2014).

Sass et al. (2014) directly test the conditions linking VAMs to the cumulative achievement function and confirm the skepticism of Todd and Wolpin (2003), showing that they are not met for a number of common VAM specifications. The tests performed by Sass et al. (2014) give us some indication of what value-added *is not*. In particular, they show that the parameters estimated from a range of commonly estimated value-added models do not have a structural interpretation. But this says little about the informational value contained by value-added measures. Indeed, Sass et al. (2014) note that "failure of the underlying [structural] assumptions does not necessarily mean that value-added models fail to accurately classify teacher performance" (p. 10).[2] The extent to which measures of teacher value-added provide useful information about teacher performance is ultimately an empirical question, and it is this question that is at the heart of value-added research literature.

2.2. Specification and estimation issues

A wide variety of value-added models have been estimated in the literature to date. In this section we discuss key specification and estimation issues. To lay the groundwork for our discussion consider the following linear VAM:

$$Y_{isjt} = \beta_0 + Y_{isjt-1}\beta_1 + X_{isjt}\beta_2 + S_{isjt}\beta_3 + T_{isjt}\theta + \varepsilon_{isjt} \quad (2)$$

In Eq. (2), Y_{isjt} is a test score for student i at school s with teacher j in year t, X_{isjt} is a vector of student characteristics, S_{isjt} is a vector of school and/or classroom characteristics, T_{isjt} is a vector of teacher indicator variables and ε_{isjt} is the idiosyncratic error term. The precise set of conditioning variables in the X-vector varies across studies. The controls that are typically available in district and state administrative datasets include student race, gender, free/reduced-price lunch status, language status, special-education status, mobility status (e.g., school changer), and parental education, or some subset therein (examples of studies from different locales that use control variables from this list include Aaronson, Barrow, & Sander, 2007; Chetty, Friedman, & Rockoff, 2014a; Goldhaber & Hansen, 2013; Kane, McCaffrey, Miller, & Staiger, 2013; Koedel & Betts, 2011; Sass, Hannaway, Xu, Figlio, & Feng, 2012). School and classroom characteristics in the S-vector are often constructed as aggregates of the student-level variables (including prior achievement). The parameters that are meant to capture teacher value added are contained in the

[2] Guarino, Reckase, and Wooldridge (2015) perform simulations that support this point. Their findings indicate that VAM estimators tailored toward structural modeling considerations can perform poorly because they focus attention away from more important issues.

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