The Application of Big Data in Education Effectiveness Evaluation Based on the Value-Added Approach

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Abstract: Over recent years, much research has been undertaken on big data in many fields. Meanwhile, addressing the challenges of globalization, the Chinese government has emphasized the improvement of education quality as a major priority. In this context, education assessment and evaluation reform have been accelerated. One of the functions of big data is to drive the improvement of education quality through continuous collection and various data mining approaches. In line with the existing theoretical and empirical researches in developed and developing countries, this paper provides a demonstration of how big data can be applied in school effectiveness evaluation. Thus, in this paper, a value-added approach used for school effectiveness evaluation will be introduced and the multilevel modelling for measuring and analyzing value-added data will be discussed.

Keywords: Big Data; Education Effectiveness Evaluation; Value Added; Multilevel Modelling

1. Introduction

The past few decades have witnessed the rapid development of information technology, the essential role of big data is being gradually recognized and widely used in many fields. As for the conception of big data, it is a contested term defined by different groups. From the lens of technology, big data is defined in terms of volume, velocity, and variety. In other words, it consists of a huge volume of information with diverse variety and is collected at extreme velocity [1]. Williamson (2017) notes that big data is simultaneously technical and social. It can be understood as an emerging social phenomenon. There are people behind big data who work in specific organizational settings and seek to utilize big data systems for their variety purpose. Therefore, as a source of knowledge, big data has the power to change how and what people know about society and the people and institutions that occupy it [2]. In the educational landscape, big data has attained critical importance. Application of big data can drive the scientization of national education policy, development of education equity, improvement of education quality, optimization of curriculum system and teaching, and personalization of students [3].

As mentioned above, one of the functions of big data is to drive the improvement of education quality. In terms of the increasing attention of education quality worldwide, Chinese researchers claimed that high education quality is essential to narrow the education quality gap between China and other developed countries [4]. In this sense, the Chinese government has been emphasizing school evaluation and pupil assessment as a key aspect of improving education quality [5]. Therefore, regarding the big data in gearing up education quality, how it can be applicated to explore education institutions' effectiveness, teachers' performance, and students' achievement is a focus point in the research.

The purpose of this study is to demonstrate how big data can be applicated in school effectiveness evaluation through a value-added approach. It will begin with a description of the category and characteristics of big data from the lens of education effectiveness evaluation. This followed by the demonstration of the value-added model in school effectiveness evaluation. After that, how multilevel modelling can be employed to measure and analyze value-added data will be discussed. Finally, some limitations and challenges associated with the research and practice of the value-added data application for policymakers and school leaders will be discussed as well.

2. Categories and Characteristics of Big Data in Education

2.1 Hierarchically Structured Data Sets

According to the dynamic theory of education effectiveness of Creemers and Kyriakides (2008), the data will be looked simultaneously at the different levels of the education system, for example, the student, the classroom, the school, and the context [6]. Factors at each level are considered having both direct and indirect effects on student outcomes. The data sets associated with those levels are often hierarchically structured. In this sense, two or more levels can be distinguished and the units at the lower levels nested within the higher-level units. For example, a data set of students is nested within the classroom within schools. This hierarchical structure can be extended to the contextual levels such as local communities, regions or nations [7].

Data set at the student level involves students' characteristics such as gender, age, minority status; policymakers' status; intelligence and prior attainment; family background such as parental education, parental occupation, and family wealth; students' cognitive and non-cognitive achievement and so on. As for the classroom level, data is related to curriculum time and content as well as curriculum teaching and learning [8]. For example, the amount of instructional time, the number of classroom textbooks, teacher diaries, student-centered approaches, problem-solving approaches, the amount of teacher-supervised study, and the classroom climate. Data at school level include school demographics, school infrastructure and services, school culture, and school climate and so on [9]. Contextual data is often associated with the socio-economic status of the student body, grade phase of schooling, school residential community type, school governance structure, and country context.

2.2 A time sequence determined data sets

From the lens of the economics concepts of educational effectiveness, the data is related to the production process of an organization. There are inputs to the school, through the transformation process, and outputs will be attained at the end of schooling. In this sense, data can be classified with the time sequence into intake, process, and outcome.

Intake data involves enrolment, school resources, students' expectations, students' attitudes, prior skills and behaviors, and prior attainment. Process data is associated with students' attendance, resource allocation, students' experiences, teaching and learning processes aimed at the behavior outcomes or academic outcomes. As for outputs, data is related to the completion rates, school costs and benefits, students' satisfaction, skills, and raw achievement.

3. The value-added approach in an educational context

Value-added originally is an economic concept referring to the difference between inputs and final outputs. It has come to be used in education with the political preoccupation of standards and quality in education in many countries. The concept rests on the assumption that schools add 'value' to the achievement of students, and students' progress is measured in either cognitive outcomes or non-cognitive outcomes. Scheerens et al. (2003) defined that the term value-added refers to the extra value that is added by schools to student achievement over and above the progress that might be expected in a normative sense [10].

The value-added approach seeks to relative effectiveness among schools. It attempts to adjust factors that are associated with student performance but are not or little controlled by schools. By collecting data describing inputs, process, outputs, and context about individual schools, a contextual value-added model will control for various intake achievement and indicates the relative effectiveness that a school effects on a student's prior attainment in comparison to a similar student in other schools over a specific period of time. By calculating the value-added component, a positive value-added score (residual) reflects that a school may be performing above expectations [11,12].

Although there are the limitations of the value-added model, it is still be considered as an outstanding approach in school effectiveness research. It offers a fairer way of presenting school examination results; it provides detailed and summary data that a school can apply to its self-evaluation; the results can be contrasted against other types of data available in schools such as views and affective outcomes.

4. Multilevel Modelling for measuring value-added

Goldstein (1997) noted that the most important issue related to useful measurement is its acceptable validity and replicability. Applying an appropriate statistical methodology for measuring value-added as an indicator of school effectiveness is important, otherwise, the conclusion will be suspect [13].

4.1 Single level models

In the 1970s, major researches were about relationships among student-level variables [14,15,16]. Multiple regression was used to calculating the residual difference between an observed and expected score. The observed score is a student's actual prior attainment and the expected score is the predicted achievement based on his or her previous attainment. As a result, the residual score can be interpreted in terms of whether a student performs above or below expectations. In this sense, the residual score provides the statistical measure of value-added or a student's relative progress. In short, this analysis employs several factors, such as baseline, students' characteristics that provide an estimate of value-added. However, as mentioned above, students level data set nested within the school-level units. Using a single-level model means that very little can be said about the influence of schools on students. On top of that, the resulting statistical inferences may bias and over-optimistic [13]. Therefore, the main challenge is to develop models that allow the statistical analysis to separate the effect of the school on individual pupil outcomes and the extent to which pupil intake factors, such as prior attainment, their socio-economic background affect pupil outcomes.

4.2 Multilevel models

In the 1980s, Murray Aitkin and Harvey Goldstein have developed more statistical techniques, in particular, the multilevel analysis that enables the data to be treated in an appropriate manner [17,18,19]. Thus, instead of aggregating all levels data together arbitrarily, differences between classes, year groups and schools can be analyzed separately. It employs the same principle of calculating a residual value-added score as of multiple regression and is now widely recognized as a sophisticated approach to analyzing data that derive from multistage sampling.

Taking a two-units (student and school) multilevel modeling as an example, first, multistage sampling is applied. A random school sampling is drawn in the first stage and a sample of students within the schools will be selected in the second stage. In this case, the issue of the interdependence of observation within sampling units will be taken into account, as a result, the overestimation of the statistical significance of the findings under a simple random sampling design can be avoided to a large extent [20].

Starting with the multilevel modelling, if Y_{ij} is an individual score on the ith student in the jth school the simple model can be presented as follows

$$Y_{ij} = \beta_j + r_{ij} \quad (1)$$
$$= \beta_0 + u_j + r_{ij}$$

This means that the individual score (Y_{ij}) can be broken down into a school contribution (β_j) and a deviation (r_{ij}) from school average for student i in school j. in the second line the school contribution is decomposed into average score across schools and students (β_0) and deviation from that mean for school j (school 'residuals'). In this sense, $Y_{ij} = \beta_0 + u_j + r_{ij}$ can be expressed as a 'zero model', which includes no explanatory variables and involves the partitioning of variance in the outcome measure into the student and the school level. This model indicates that an individual score can be seen as the sum of the average score and the school and student-specific deviations.

In the next stage, explanatory variables are added to the model and a multilevel model is presented as follows

$$Y_{ij} = \beta_0 + u_j + r_{ij} \quad (2)$$

It should be noted that just one explanatory variable (X) is measured at the student level. However, with the more complex data in practice, more complex models with multiple variables will be applied with both levels. The intercept reflects the expected score on the dependent variable for individuals with an average score on all explanatory variables. Therefore, this model can be fitted by taking a data set with students identified by the school they belong to and be used to estimate the required parameter values [13].

One of the main features of multilevel analysis is the identification of a distinct level of variance. Student level variables are the lower-level variables that may explain variance at a higher level (school level). For example, student's social-economic status may account for variation between schools in relating to student achievement, but school-level variables can only account for variation between schools. Sometimes, adding new explanatory variables at the student level to the model will result in more variance at a higher level. This means the difference between schools is larger than the difference without considering student background variables. Saunders (1998) stated that multilevel modelling is the appropriated statistical technique that deals with data sets that are hierarchically structured [21]. This means a student belongs to a certain class and he or she also attends a certain school. In some situations, this nesting may not be perfectly hierarchical. For example, if the nesting of schools within geographical units is included in the analysis, it should be noticed that some schools receive students from various districts and the students from the same district may attend different schools. However, these cross-classifications still can be analyzed through cross-classified multilevel models [22].

5. Limitations of value-added measurement

So far, we have outlined the value-added method and multilevel model analysis, it is essential to emphasize the statistical uncertainty and limitations of numerical data. Statistical uncertainty refers to the uncertainty in estimating any average numerical score from the sample of students in the school. This uncertainty may prevent any fine distinction to be made between the performance of schools [23]. On top of that, the issue of measurement error should be considered when interpreting data. Another issue associated with the data is accuracy and appropriateness. This remains that when we consider how to apply the big data into practice, it is crucial to notice whether the data is an appropriate indicator and is it difficult and cost to collect. All those limitations point to the importance of considering the statistical significance of each school's results and the stability of results over time.

6. Application of value-added data

One of the application areas of big data in education is the school effectiveness evaluation. Employing a value-added model, it is helpful to study the questions about the consistency of school effectiveness across schools over time, highlight differences within a school, and allow schools to compare themselves with other schools. To be more specific, value-added data at the individual student level can help students learn more and learn better by providing feedback on their measured progress. At the classroom level, teachers can track students' engagement and achievement by reviewing value-added data. At the school level, a value-added measurement can be employed to reflect the aim of schooling through using student attitudes and academic outcomes value-added measurement. Differential effectiveness for different groups of students, such as boys or girls, ethnic minority students, can be examined and implicate for equal opportunities. It can also help policymakers and school leaders evaluate institutional effectiveness and generate insights for future improvement [24].

7. Conclusion

Surrounding by digital data and new information technologies, it is required in the field of education to gain insight from these large volumes and variety of big data. With the increasing mobilization of new digital data technologies, education institutions are generating big data from cognitive to non-cognitive during the teaching and learning process. One of the application areas of big data in education is to increase education quality through the way of education effectiveness evaluation with the support of data mining and data analysis approaches. Thus, in this study value-added evaluation approach derived from economic perspectives is proposed and the multilevel modelling specifically employed for hierarchically structured data is demonstrated. Although the contribution of the value-added evaluation approach has been demonstrated, it should be emphasized that this approach is not the only criterion to judge school effectiveness. Moreover, the challenges such as the methodological limitations, the difficulties of data collection, how to involve teachers in action research so that teaching and learning processes in the classroom become the center of this area of research, and so on should also be noticed.

Reference

[1] Kalota, F. Applications of big data in education. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering* 2015, 9(5), 1602-1607.

[2] Williamson, B. Big data in education: The digital future of *learning, policy and practice*. Sage, 2017.

[3] Yang, X.M.et al. Application Model and Policy Suggestion of Big Data in Education. *E-Education Research* 2015,36(09):54-61.

[4] Zhang, L., Lin, Z. H., Wang, J. Q. & Wang, M. China: revitalizing education in the twenty-first century, in: *Human right educations in Asian schools* (vol. 3) (Japan, Asia-Pacific Human Rights Information Center), 2000,103–113.

[5] Wen Jung Peng, Sally M. Thomas, Xijie Yang & Jianzhong Li Developing school evaluation methods to improve the quality of schooling in China: a pilot 'value added' study, *Assessment in Education: Principles, Policy & Practice*, 2006,13:2, 135-154

[6] Creemers, B. P. M., & Kyriakides, L.A theoretical based approach to educational improvement: Establishing links between educational effectiveness research and school improvement. *Yearbook on School Improvement. Weinhem/Munchen: Juventa Verlag*, 2008,41- 61.

[7] Creemers, B. P., Kyriakides, L., & Sammons, P. *Methodological advances in educational effectiveness research*. 2010, Routledge.

[8] David, R., Teddlie, C., & Reynolds, D. *The international handbook of school effectiveness research*. 2000, Psychology Press.

[9] Teodorović, J. Classroom and school factors related to student achievement: What works for students? *School Effectiveness and School Improvement*, 2011,22(2), 215-236.

[10] Scheerens, J., Glas, C. A., Thomas, S. M., & Thomas, S. (2003). *Educational evaluation, assessment, and monitoring: A systemic approach 2003, Vol. 13. Taylor & Francis.*

[11] Thomas, S. Value-added measures of school effectiveness in the United Kingdom. *Prospects*, 1998,28(1), 91-108.

[12] B. Muñoz-Chereau & S.M. Thomas, Educational effectiveness in Chilean secondary education: comparing different 'value-added' approaches to evaluate schools, *Assessment in Education: Principles, Policy & Practice*, 2016, 23:1, 26-52

[13] Goldstein, H. Methods in school effectiveness research. *School effectiveness and school improvement*, 1997,8(4), 369-395.

[14] Coleman, J. S., Campbell, E. Q., Hobson, C. J., McPartland, J., Mood, A. M., Weinfeld, F., & York, R. L. Equality of educational opportunity (Report No. OE-3800). *Washington, DC: National Center for Educational Statistics.* 1966.

[15] Jencks, C. Inequality: A reassessment of the effect of family and schooling in America. 1972.

[16] Rutter, M., Maughan, B., Mortimore, P., Ouston, J., & Smith, A. 15,000 hours: Secondary schools and their effects on children. *Shepton Mallet: Open Books*. 1979.

[17] Aitkin, M., Anderson, D., & Hinde, J. Statistical modelling of data on teaching styles. *Journal of the Royal Statistical Society: Series A (General)*, 1981,144(4), 419- 448.

[18] Goldstein, H. The methodology of school comparisons. *Oxford Review of Education*, 1984, 10(1), 69-74.

[19] Goldstein, H. Multilevel models in education and social research. *Oxford University Press*.1987.

[20] Muñoz-Chereau, B. *Value added measures of school performance in Chile* (PhD thesis). Bristol: University of Bristol.2013.

[21] Saunders, L. 'Value added' measurement of school effectiveness: an overview. Berkshire*: National Foundation for Educational Research*.1998.

[22] Timmermans, A. C., & Thomas, S. M. The impact of student composition on Schools' value-added performance: a comparison of seven empirical studies. *School Effectiveness & School Improvement*, 2014,26, 1–12.

[23] Goldstein, H., & Spiegelhalter, D. J. League tables and their limitations: statistical issues in comparisons of institutional performance. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 1996, 159(3), 385-409.

[24] Thomas, S., Salim, M., Muñoz-Chereau, B., & Peng, W.-J. Educational quality, effectiveness and evaluation: Perspectives from China, South America and Africa. In Ch. Chapman, P. Armstrong, A. Harris, D. Muijs, D. Reynolds, and P. Sammons (Eds.), *School effectiveness and school improvement research, policy and practice. Challenging the orthodoxy?* 2012, pp. 125–145. London: Routledge.