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# Teacher quality and teacher salaries: the case of Pennsylvania

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## Abstract

Both teacher quality and teacher salaries are endogenously correlated in the teacher labor market. Therefore, due to endogeneity, we develop three econometric simultaneous-equation models to examine the link between teacher quality and teacher salaries. A total of 500 school districts in the state of Pennsylvania during the school years 1999-2000 to 2001-2002 are selected for a case study. Results reveal a positive and significant relationship between these two.

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# I. Introduction

Teacher quality is tied to salary, with salary levels affecting a school district's probability of hiring a highly qualified teacher. On the other hand, a highly qualified teacher is more likely to receive higher pay in the market. In other words, teacher salary is also tied to quality, with quality levels affecting a school authority's decision to pay a high salary. For that reason, both teacher quality and teacher salaries may be endogenously correlated. Although portions of the economics and education literatures are devoted to investigations of the issue (e.g., Figlio, 1997 and 2002; Ballou and Podgursky, 1997; Darling-Hammond, 2000; Ascher and Fruchter, 2001; Hess, 2004; and Hanushek, Kain, and Rivkin, 2004), no previous studies have examined the endogenous relationship between teacher quality and teacher salaries. Therefore, we attempt to develop three econometric simultaneous-equation models to address the link between teacher quality and teacher salaries.

This paper is organized as follows. First, we present three econometric simultaneous-equation models and describe data measurement. Second, we report the empirical results. Third, an interesting question is raised for discussion. Conclusion may be found in the final section.

# II. Econometric Models and Data Measurement

A qualified education product is determined by both the school authority and teachers jointly. Therefore, due to endogeneity, teacher quality and teacher salaries are jointly determined simultaneously. Hence, a simple simultaneous-equation model can be specified as follows:

*Teacher Quality = f* (*Teacher salaries*, *School quality*, *Ethnicity*, *Student dropout rate*), and

*Teacher Salaries = f* (*Teacher quality*, *Community quality*, *Student-teacher ratio*, *Male-female teacher ratio*, *Urbanization*).

A total of 500 school districts in the state of Pennsylvania for 3 school years (1999–2000, 2000–2001, and 2001–2002) were selected for a case study. The data used in this study are district-level and can be found at the *Pennsylvania Department of Education* website and the *National Center for Education Statistics* website. Table 1 presents means and standard deviations for all variables used in the study.

Two important factors mainly determine a teacher's quality (*Q*): educational level (*E*) and years of teaching experiences (*Y*). Therefore, it is measured as the average education level of full-time teachers multiplied by average total years of teaching (i.e., $Q = E \times Y$) (see Note 1). The proxy for public school quality is instructional expenditures per pupil. It should be noted that the instructional expenditures do not include teacher salaries. In addition, ethnicity may have an impact on teacher quality, because different ethnic groups reflect different socio-economic characteristics. In this study, we focus on three minority ethnic groups. They are: Asian, Hispanic/American-Indian, and African-American. We use the proportion of each ethnic enrollment as a proxy. The quality of community is measured by median household income. Urbanization is measured according to codes (see Note 2). Student dropout rate is measured as total students who dropout from schools divided by total student enrollments. Student-teacher ratio is measured as total student enrollments divided by total full-time teachers in a school district. Male-female teacher ratio is measured as total full-time male teachers divided by total full-time female teachers.

Based upon the simple simultaneous-equation model, we can develop the following three regression functions: (1) the linear function; (2) the Cobb-Douglas function; and (3) the transcendental function. These three econometric models can be expressed as follows.

**Model 1:**

$$ATQ_{it} = a_0 + a_1 ATS_{it} + a_2 INS_{it} + a_3 PBE_{it} + a_4 PAE_{it} + a_5 PHE_{it} + a_6 PSD_{it} + \varepsilon_{1t} \quad (1.1)$$

and

$$ATS_{it} = b_0 + b_1 ATQ_{it} + b_2 MHI_{it} + b_3 INS_{it} + b_4 STR_{it} + b_5 MFR_{it} + b_6 URB_{it} + \varepsilon_{2t} \quad (1.2)$$

**Model 2**:

$$ATQ_{it} = C_0 \left(ATS_{it}\right)^{c_1} \left(INS_{it}\right)^{c_2} \left(PBE_{it}\right)^{c_3} \left(PAE_{it}\right)^{c_4} \left(PHE_{it}\right)^{c_5} \left(PSD_{it}\right)^{c_6} \quad (2.1)$$

and

$$ATS_{it} = D_0 \left(ATQ_{it}\right)^{d_1} \left(MHI_{it}\right)^{d_2} \left(INS_{it}\right)^{d_3} \left(STR_{it}\right)^{d_4} \left(MFR_{it}\right)^{d_5} \left(URB_{it}\right)^{d_6} \quad (2.2)$$

Taking natural logarithms of both sides of Equations (2.1) and (2.2), teacher quality (*ATQ*) and teacher salaries (*ATS*) functions become linear. Hence, the econometric models can be created as follows.

$$\log ATQ_{it} = c_0 + c_1 \log ATS_{it} + c_2 \log INS_{it} + c_3 \log PBE_{it} + c_4 \log PAE_{it} + c_5 \log PHE_{it} + c_6 \log PSD_{it} + \varepsilon_{3t}, \quad (2.3)$$

and

$$\log ATS_{it} = d_0 + d_1 \log ATQ_{it} + d_2 \log MHI_{it} + d_3 \log INS_{it} + d_4 \log STR_{it} + d_5 \log MFR_{it} + d_6 \log URB_{it} + \varepsilon_{4t}, \quad (2.4)$$

**Model 3:**

$$ATQ_{it} = F_0 \left(ATS_{it}\right)^{f_1} \left(INS_{it}\right)^{f_2} e^{f_3(PBE_{it}) + f_4(PAE_{it}) + f_5(PHE_{it}) + f_6(PSD_{it})} \quad (3.1)$$

and

$$ATS_{it} = G_0 \left(ATQ_{it}\right)^{g_1} \left(MHI_{it}\right)^{g_2} \left(INS_{it}\right)^{g_3} e^{g_4(STR_{it}) + g_5(MFR_{it}) + g_6(URB_{it})} \quad (3.2)$$

Taking natural logarithms of both sides of Equations (3.1) and (3.2), teacher quality (*ATQ*) and teacher salaries (*ATS*) functions become linear. Thus, the econometric models can be developed as follows.

$$\log ATQ_{it} = f_0 + f_1 \log ATS_{it} + f_2 \log INS_{it} + f_3 PBE_{it} + f_4 PAE_{it} + f_5 PHE_{it} + f_6 PSD_{it} + \varepsilon_{5t}, \quad (3.3)$$

and

$$\log ATS_{it} = g_0 + g_1 \log ATQ_{it} + g_2 \log MHI_{it} + g_3 \log INS_{it} + g_4 STR_{it} + g_5 MFR_{it} + g_6 URB_{it} + \varepsilon_{6t}, \quad (3.4)$$

where $i$ = 1, 2, 3,…, 500; $t$ = 1999 – 2000, 2000 – 2001, 2001 – 2002; $\log C_0 = c_0$; $\log D_0 = d_0$; $\log F_0 = f_0$; $\log G_0 = g_0$; *ATQ* = average teacher quality; *ATS* = average teacher salaries; *INS* = instructional expenditures per pupil; *PBE* = proportion of African-American enrollments; *PAE* = proportion of Asian enrollments; *PHE* = proportion of Hispanic/American Indian enrollments; *PSD* = public school student dropout rates; *MHI* = median household income; *STR* = student-teacher ratio; *MFR* = male-female teacher ratio; *URB* = urbanization; and $\varepsilon_{1t},\ldots,\varepsilon_{6t}$ = stochastic disturbance (with a mean 0 and a variance $\sigma^2$).

## III. Empirical Results

To correct for simultaneous equations bias, the Two-Stage Least Squares (2SLS) procedure is used to obtain unique estimates that are consistent and asymptotically efficient. The results from estimations of equations (1.1), (1.2), (2.3), (2.4), (3.3), and (3.4) are presented in Table 2. First, let's take a look at the estimations of teacher quality. As Table 2 shows, teacher salaries (*ATS*) exert a positive and significant effect at the 1% level on teacher quality (*ATQ*) in all three models, meaning that higher teacher salaries will attract more highly qualified teachers. In addition, the elasticity of teacher quality with respect to wages is estimated by 1.247 in Model 2 and 1.093 in Model 3. The elasticity is elastic, implying that a 1% increase in wages is estimated to lead to an increase in teacher quality by 1.247% in Model 2 and 1.093% in Model 3. Moreover, instructional expenditures per pupil also provide a positive and significant effect at the 1% level on teacher quality in all three models, which implies that a good quality school provides better facilities and environments for teaching and thus attracts more highly qualified teachers and improves a teacher's teaching quality. However, minority student enrollments (Hispanic/American Indian, African-American, and Asian) exert a negative and significant effect on teacher quality in all three models at the 1% level, implying that the higher the minority student enrollments the less qualified the teachers. A possible explanation for the result is that racial distribution positively reflects income distribution and in turn affects community quality. A higher community quality is more likely to attract more highly qualified teachers due to higher pay. Finally, public school student dropout rates provide a positive and significant effect at the 5% or 10% level on teacher quality in all three models, meaning that the greater the number of low-performing and marginal students withdrawing from schools, the greater the number of highly qualified teachers remaining at the school.

Turning now to the estimations of teacher salaries, as Table 2 shows, teacher quality exerts a positive and significant effect on teacher salaries at the 1% level, which implies that teacher salary is also tied to quality, with quality levels affecting a school authority's decision to pay a high salary. That is, a highly qualified teacher would be more likely to get higher pay. Moreover, the elasticity of teacher salaries with respect to teacher quality is estimated by 0.87515 in Model 2 and 0.93996 in Model 3. The elasticity is inelastic, meaning that a 1% increase in teacher quality is estimated to lead to increase in teacher salaries by 0.87515% in Model 2 and 0.93996% in Model 3. In addition, median household income exerts a positive and significant effect on teacher salaries, meaning that a higher-quality community collects more taxes that will then be used to pay higher salaries to teachers. In other words, the higher the quality of the community (identified by median household income), the better the teacher pay in the community. Moreover, instructional expenditure per pupil, student-teacher ratio, and urbanization all exert a positive and significant effect at the 1% level on teacher salaries in all three models. Nevertheless, male-female teacher ratio does not provide a significant effect at the 1%, 5%, or 10% level. The above results imply the following facts: (1) the better the quality of the school (identified by instructional expenditure per pupil), the better able it is to pay higher salaries to teachers; (2) the higher the student-teacher ratio, the more likely it is that each teacher may receive more pay; (3) the more urbanized the school district, the higher the teacher salaries; and (4) no strong evidence shows that gender discrimination exists in the teacher labor market, because male-female teacher ratio does not exert a significant effect on teacher salaries.

## IV. Discussion

Since teacher quality and teacher salaries are endogenously correlated, this implies that the level of salaries positively reflects the level of quality. For that reason, an interesting question may be raised for discussion: do school authorities want to offer higher salaries to hire highly qualified teachers? In discussing this question, we attempt to apply a simple supply-demand framework to the teacher labor market.

Suppose that there are two teachers, *A* and *B*. Teacher *A* holds a master degree in education and has been teaching at a high school for ten years; while Teacher *B* holds a bachelor degree in education and has been teaching at a high school for one year. According to our measure of teacher quality, obviously teacher *A*'s quality is higher than teacher *B*'s quality. Therefore, teacher *A* will have a higher marginal cost than teacher *B*. That is, teacher *A*'s labor is more expensive than teacher *B*'s labor. For that reason, as shown in Figure 1, teacher *A*'s supply curve for labor is higher than teacher *B*'s supply curve for labor. Given $L^*$ units of labor (see Figure 1), Teacher *A* is supposed to get paid at $W_2$ per unit of labor while teacher *B* is supposed to get paid at $W_1$ per unit of labor.

However, as shown in Figure 2, given salary schedule *D* (i.e., the demand curve for the school authority), the school authority will only want to pay $W_3$ per unit of labor to teacher *A* (note: $W_1 < W_3 < W_2$). According to salary schedule *D*, teacher *A* will only want to supply *L'* units of labor rather than *L** units of labor; while teacher *B* will supply *L** unites of labor although he/she may get lower pay at $W_1$ per unit of labor (note: *L'* < *L**). If the school authority requires *L** units of labor for each teacher, the school authority will have two options: (1) to hire teacher *A*, the school authority has to raise the salary schedule from *D* to *D*' and pay $W_2$ per unit of labor to teacher *A*; or (2) they just hire teacher *B* and pay $W_1$ per unit of labor to teacher *B* and save some budgetary funds although teacher quality may be lower.

How does the school authority make a choice? It depends on the primary goal and budget. Given the budget, if the primary goal is to improve student achievement, the authority may adopt the first option. But the question is whether or not teacher education/experience has a positive and significant impact on student achievement. In 2003, Hanushek showed that a majority of the studies through 1994 in the United States found no statistically significant link between teacher education/experience and student outcomes. However, Lin (2008) had a different result. He used Pennsylvania as a case study and found a positive and statistically significant relationship between teacher education/experience and student performance.

Therefore, school authorities' decision whether to offer higher salaries to hire highly qualified teachers depends on their primary goals, and whether they believe that teacher education/experience exerts a positive and significant impact on student achievement. In other words, different primary goals and beliefs may lead to different education outcomes and employment policies in the teacher labor market.

## V. Conclusion

In this paper, both teacher quality and teacher salaries are endogenously correlated in the market. Therefore, due to endogeneity, three econometric simultaneous-equation models were created to examine the linkage between teacher quality and teacher salary. Results revealed a significant and positive relationship between these two, implying that salary level positively reflects quality level.

Furthermore, a simple supply-demand framework in the teacher labor market was applied to discuss an interesting question – whether or not school authorities will want to offer higher salaries to hire highly qualified teachers. The answer would depend on school authorities' primary goals and beliefs regarding whether teacher education/experience exerts a positive and significant impact on student achievement.

## Notes

1. The level of education is measured via codes. These codes are: *1* = less than high school graduate; *2* = high school graduates; *3* = less than bachelor's degree; *4* = bachelor's degree; *5* = master's degree; and *6* = doctor's degree (see *Public School Professional Personnel*, Pennsylvania Department of Education).
2. These codes are: *1* = school district located in Rural, inside Core Based Statistical Area (CBSA); *2* = school district located in Rural, outside CBSA; *3* = school district located in Small Town; *4* = school district located in Large Town; *5* = school district located in Urban Fringe of a Mid-size City; *6* = school district located in Urban Fringe of a Large City; *7* = school district located in Mid-size City; and *8* = school district located in Large City. (Source: *Pennsylvania Department of Education* [www.pde.state.pa.us]).

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Table 1: Mean and Standard Deviation of Variables

| Variables | Mean | Standard Deviation |
|---|---|---|
| Median household income | 29181.2 | 8883.41 |
| Log value of median household income | 10.2404 | 0.279522 |
| Average educational level | 4.42367 | 0.142056 |
| Log value of average education level | 1.48646 | 0.0319795 |
| Average years of teaching experience | 16.6581 | 2.25981 |
| Log value of average years of teaching experience | 2.80353 | 0.137943 |
| Average teacher salaries | 47755.9 | 6018.73 |
| Log value of average teacher salaries | 10.7664 | 0.120978 |
| Instructional expenditures per student | 4961.37 | 746.562 |
| Log value of instructional expenditures per student | 8.49912 | 0.140950 |
| Proportion of low income families | 0.265127 | 0.164497 |
| Proportion of Asian student enrollments | 0.0111550 | 0.0161444 |
| Proportion of Hispanic and American Indian student enrollments | 0.0185550 | 0.0540464 |
| Proportion of African-American student enrollments | 0.0552983 | 0.127524 |
| City size (urbanization) | 4.056 | 1.77622 |
| Student-teacher ratio | 15.9049 | 1.91993 |
| Male-female teacher ratio | 0.482995 | 0.111982 |
| Public school dropout rate | 0.017054 | 0.0114023 |

Table 2: Estimates of *ATQ*, log *ATQ*, *ATS*, and log *ATS*

| Explanatory Variables | Model 1: **2SLS** Explained Variables: *ATQ* | *ATS* | Model 2: **2SLS** Explained Variables: log *ATQ* | log *ATS* | Model 3: **2SLS** Explained Variables: log *ATQ* | log *ATS* |
|---|---|---|---|---|---|---|
| Constant | -11.057*** (-3.20) | -40602*** (-25.91) | -10.441*** (-19.68) | 1.4236*** (9.20) | -8.2737*** (-16.50) | 1.9349*** (13.45) |
| *ATS* | 0.001714*** (24.18) | | | | | |
| log *ATS* | | | 1.247*** (25.83) | | 1.09319*** (23.61) | |
| *ATQ* | | 704.94*** (31.58) | | | | |
| log *ATQ* | | | | 0.87515*** (25.30) | | 0.93996*** (27.81) |
| *MHI* | | 0.09558*** (9.73) | | | | |
| log *MHI* | | | | 0.07927*** (11.92) | | 0.068654*** (10.44) |
| *INS* | 0.001186*** (3.34) | 4.1367*** (35.72) | | | | |
| log *INS* | | | 0.11410*** (4.62) | 0.47647*** (36.93) | 0.09761*** (3.82) | 0.44692*** (34.51) |
| *PBE* | -24.989*** (-12.28) | | | | -0.34777*** (-12.42) | |
| log *PBE* | | | -0.03938*** (-14.55) | | | |
| *PAE* | -169.17*** (-10.89) | | | | -2.3094*** (-10.91) | |
| log *PAE* | | | -0.036598*** (-11.79) | | | |
| *PHE* | -35.282*** (-8.23) | | | | -0.50257*** (-8.50) | |
| log *PHE* | | | -0.003224*** (-3.72) | | | |
| *PSD* | 54.06** (2.43) | | | | 0.777** (2.53) | |
| log *PSD* | | | 0.00826* (1.74) | | | |
| *STR* | | 629.21*** (15.43) | | | | 0.01395*** (15.92) |
| log *STR* | | | | 0.24146*** (17.07) | | |
| *MFR* | | -68.5 (-0.10) | | | | 0.00221 (0.16) |
| log *MFR* | | | | 0.001809 (0.25) | | |
| *URB* | | 769.73*** (17.73) | | | | 0.016415*** (17.55) |
| log *URB* | | | | 0.0429*** (14.66) | | |
| $R^2$ | 0.352 | 0.818 | 0.401 | 0.784 | 0.349 | 0.793 |
| $\overline{R}^2$ | 0.350 | 0.817 | 0.399 | 0.783 | 0.346 | 0.792 |
| *F*-Statistics | 135.35 | 1115.15 | 153.07 | 904.47 | 133.47 | 950.87 |
| Sample Size | 1500 | 1500 | 1500 | 1500 | 1500 | 1500 |

(*t*-value) *** Denotes statistical significance of the *t*-statistic at the 0.01 level; ** denotes statistical significance of the *t*-statistic at the 0.05 level; * denotes statistical significance of the *t*-statistic at the 0.10 level.

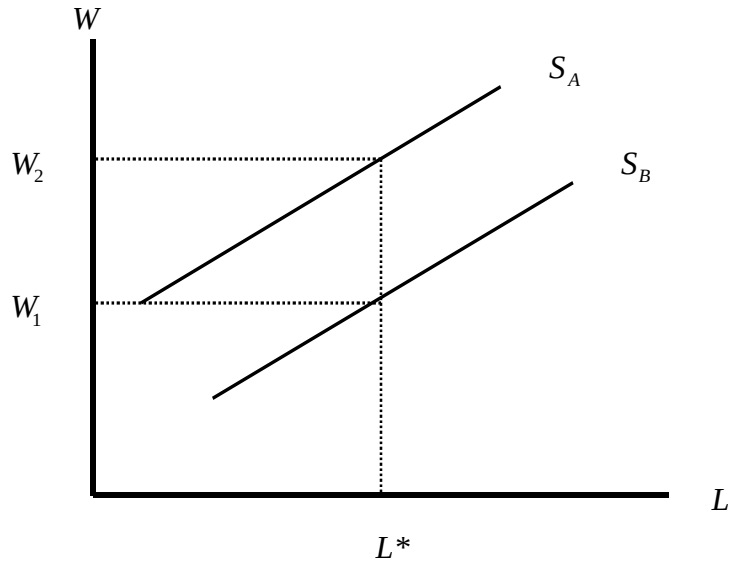


Figure 1: Supply Curves for Teacher *A* and Teacher *B*

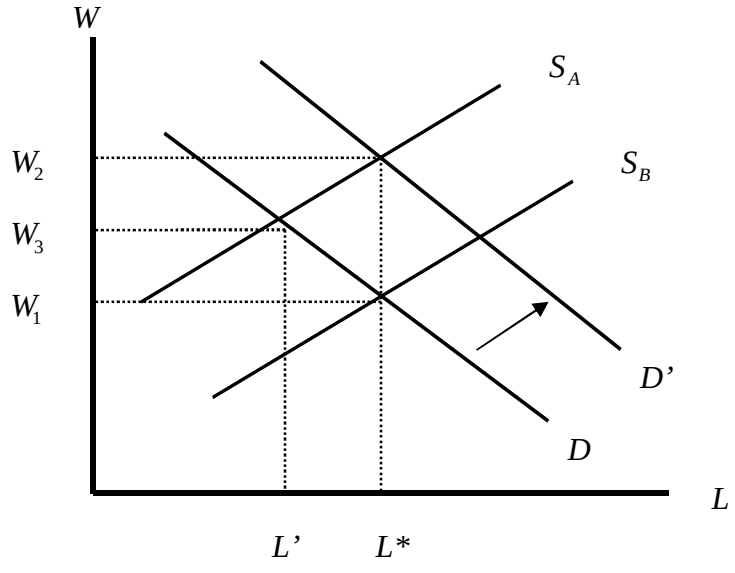


Figure 2: Teacher Labor Market for Teacher *A* and Teacher *B*