Impact of Mathematics Course Taking during High School on Earnings: Evidence from a Two-Sample Instrumental Variables Strategy. Third Year Paper Economics

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Abstract

This study examines the effects of taking advanced mathematics courses during high school on education and labor market outcomes. Following Goodman (2012), I exploit variation in the timing of state-level mathematics reforms aimed to increase the number of credits of mathematics that students earn in order to receive a high school diploma as an instrument for course taking. For the estimation of the effects of coursework on education and labor market outcomes I use a Two Sample Instrumental Variables (TSIV) approach. The results indicate that, when the sample is restricted to high school graduates, each additional Carnegie unit of advanced mathematics[1] increases yearly earnings by around 3.7 percent. The impact of an additional year of math courses on the raw measure or yearly earnings is around \$3,200. When the sample includes both high school graduates and dropouts, the corresponding estimates are 2.9 and \$3,700 respectively. However, the impact on ln(earnings) is imprecisely estimated. The impacts of advanced math courses on other outcomes such as college access, bachelors degree and associates degree attainment, and employment are also reported.

I also examine heterogeneous effects of the instrument (reforms) on mathematics course taking and high school graduation decisions. To to so, I propose an economic model drawn from consumer choice theory. This model helps understanding the heterogeneity (by academic ability) in effects on course taking and high school graduation rates. The results indicate that, overall there is a strong and positive impact of mathematics curricular reforms on course taking behavior. When the sample is broken down by quartile of academic ability, the impact of the reforms follows a non-linear pattern in which the top and second quartiles are the groups that benefit the most from the reforms. In terms of the probability of graduating from high school, the results show a strong and negative relationship; less able students experience higher negative impact of the reforms on their high school graduation probabilities.

1 Motivation

Starting during the early 1980's, and fueled by concerns about whether students were learning enough for meeting the challenges of a global economy, many states enacted a series of reforms aimed to improve student outcomes in the K-12 education system. In particular, states promulgated major curricular reforms that increased the total number of credits, as well as the number of credits in specific subjects such as mathematics, science, social studies and English that students

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[1]The sum of Algebra I, Algebra II, Geometry, Trigonometry, Pre-Calculus and Calculus

had to take in order to receive a high school diploma.

These curricular reforms have been the object of an intense policy work during the last decades. There was a movement away from the comprehensive high school curriculum towards requiring students to take more challenging courses (Lee, Croninger & Smith, 1997). By 1982, most states allowed high school students to graduate with zero or one completed math courses[2], whereas only a few states required two math courses and no state required three. The most commonly adopted reform was to increase from one to two math courses, whereas the second most common was to increase from two to three. By 1994, most states required to complete at least two math courses (Goodman, 2012). Between 1987 and 2004, the number of states requiring at least 2.5 credits in mathematics increased from 12 to 26 (Bozick & Ingels, 2008; Ingels & Dalton, 2008), and the number of states requiring at least 2.5 credits of science increased from 6 to 23 (Ingels & Dalton, 2008).

The movement of states towards a more rigorous set of high school graduation requirements is far from over. Recently, a coalition between the National Governors Association and the Council of Chief State School Officers has launched an effort to come up with one set of standards for all states called the *Common Core State Standards, CCSS*. Through the CCSS, the Council of Chief State Officers and the National Government Association seek to implement high standards that are consistent across states (www. ccsso.org). In short, even when states started implementing reforms aimed to increase the rigor of the high school curriculum during the decade of 1980's; work that continued during the 1990 and 2000's; nowadays it is still a ground of intense policy work. Therefore, it is critical, on the one hand, to measure the impact of these reforms on education and labor market outcomes, and, on the other hand, understanding the mechanisms through which these reforms impact course taking and high school graduation decisions across different groups of the population of students.

1.1 Changes in course taking patterns

Course-taking behavior, especially in mathematics and science, at public US high schools has changed dramatically during the last three decades, (Hoffer, Rasinski & Moore, 1995). For instance, between 1990 and 2000, the overall number of credits taken by students rose from 23.6 to 26.2. In the core academic subjects (mathematics, science, English and social studies), in the same period, the number of credits earned increased from 13.7 to 15.0. In contrast, in computer-vocational subjects, the average credits earned increased only from 0.4 to 0.7 (Perkins, Kleiner & Roey, 2004).

In mathematics, between 1982 and 2009, the average number of mathematics courses (Carnegie units) completed by public high school graduates increased from 2.6 to 3.9; the corresponding

[2]One math course is equivalent to one Carnegie unit = 1 year of instruction

figures for science are 2.2 and 3.5. Impressively, in the same period, the percentage of students completing the Five New Basics curriculum[3], increased from 10 percent in 1982 to 62 percent in 2009 (NCES, 2011).

Ingels & Dalton (2008) analyzed changes between 1982 and 2004 in the number of courses taken by seniors during the last year of high school. They found that, the percentage of students enrolling in calculus, rose from 6 to 13 percent and the percentage of students taking non-mathematics courses during their senior year declined from 57 to 34 percent over the same period. In addition, the percentage of students enrolling in advanced science courses such as chemistry II, physics II, and advanced biology increased from 12 to 25 percent. As shown, the academic reforms of the last decades have been accompanied with a dramatic change in course-taking patterns of high school students.

2 Research Questions

The ultimate research question of this paper is, what is the effect of taking advanced math courses during high school on earnings. I define *advanced mathematics* as Algebra I, Algebra II, Geometry, Trigonometry, PreCalculus and Calculus. Operationally, I define advanced math as the sum of the credits earned in these subjects. In addition, this paper addresses the following research questions. First, what is the causal effect of the reforms aimed to increase the number of math credits as high school graduation requirement on advanced math course taking? Second, what is the effect of the aforementioned reforms on the probability of graduation from high school?, Third, how the above effects -on course taking and high school graduation - vary by academic ability?

The contributions of this paper to the literature that examines the impact of math course taking during high school on different outcomes are the following. First, even when I follow Goodman (2012)'s lead in terms of the methodological approach, I propose a slightly different way to determine whether the impact of math courses on earnings is statistically significant. Whereas, Goodman estimates the first stage and second stage sequentially, in other words, he estimated the first stage, then he estimated the impact of the *predicted* course taking on the natural logarithm of earnings, he does not provide, at least in the paper, an adjustment for the standard errors. Instead, I estimated the first stage and reduced form equations separately, and bootstrapped the ratio of the coefficients. I use Biased-corrected confidence intervals to report the results. Second, unlike the previous literature on the effects of course taking during high school, I propose an economic model of how students' coursework choices, vary by academic ability. The model includes the decision of drooping out from high school if the student perceives that it is optimal for him/her to do so. An important feature of the model is that it allows to predict the impact of math curricular reforms

[3] The Five New Basics curriculum was proposed in the report *A Nation at Risk* and consisted in taking: four years of English, three years of mathematics, three years of science, three years of social studies, and, one-half year of computer science.

on coursework and high school graduation decisions across different groups of students defined by academic ability.

3 Review of the Literature

Many studies in many different countries have demonstrated that better-educated individuals earn higher wages, experience less unemployment and work in more prestigious occupations than their less-educated counterparts (Card, 1999). Most of these studies have focused on the number of years of education as the variable of interest. Less attention has been given to the study of which components of the education black box have an impact on the labor market. In particular, studies aimed to examine the economic effects of mathematics course taking are scarce.

The literature that examines the effect of high school coursework on wages is limited not only in the number of studies that attempt to explore this relationship but also in terms of the approaches they take. Three of the four studies (Altonji, 1995; Levine & Zimmerman, 1995; Rose & Betts, 2004) use an arguably imperfect instrument proposed by Altonji (1995): the high school average number of courses taken in each subject. This instrument might likely violate the exclusion restriction because, there might be mechanisms through which the mean courses by high school-subject can be correlated with earnings, regardless of the courses student take. For instance, economic conditions may increase the value of the instrument (mean courses by high school-subject) and increase the earnings at the same time, holding coursework fixed. In addition, this instrument leaves out within high school variation in course-taking, and only takes variation across high schools as a source as identification. The fourth study, (Goodman, 2012), uses a better instrument - the timing of state level reforms aimed to increase math graduation requirements. This instrument follows the tradition of using state/national level policy changes as natural experiments which are arguably exogenous to students coursework decisions. Since the instrument considers within state variation on math requirements this differences out any potential endogeneity problem.

The evidence from these studies is mixed. Altonji (1995) finds small and insignificant effects of coursework (across all subjects) on wages; Levine & Zimmerman (1995), find statistically significant effects only for female college graduates; they found that each additional year of mathematics coursework rises wages between 2.9 and 5.4 %[4]. Rose & Betts (2004) found that credits earned in algebra and geometry increase earnings by 8%. Finally, Goodman (2012) finds only positive and statistically significant effects for black males (between 5-9%).

Altonji (1995) uses data from the National Longitudinal Survey of the High School Class of 1972 (NLS72) to identify the effect of high school curriculum on wages. As instrument of course-taking in each subject he uses the high school mean of the number of courses taken in that subject. He

[4]These effects were estimated by OLS since IV effects were statistically insignificant

also includes high school fixed effects to control for observed and unobserved characteristics at the high school level that might be correlated with the course-taking variables that are time-invariant. He finds that one more year of science, math, English, social studies and foreign language leads to an increase of wages of only 0.3 percent. Thus, the effect of a year equivalent of courses is much smaller than the value of one year of high school.

Levine & Zimmerman (1995) examined whether taking more high school math and science classes leads to higher wages. They used two data sources: the National Longitudinal Survey of Youth (NLSY-79) and the 1980 cohort of the High School and Beyond (HSB) survey. As instrument, they followed Altonji's (1995) lead and used the high school mean number of math and science courses taken. They estimated wage regressions in which the log wages is the outcome and the vector of the number of courses taken in math and science is the question predictor while controlling for background characteristics. They estimate wage regressions by gender (men and women) and educational attainment (high school graduates, some college, and college graduates). All the IV models led to statistically insignificant effects. By using OLS models that control for ability through test scores, they find that female college graduates increase earnings between 2.9% and 5.4% for each additional half-year course in math. Additional courses in science do not conduce to statistically significant increases in wages for any group. In math, no statistically significant effects are found for men and for all persons with less than college education.

By using the sophomore cohort (1980) of the High School and Beyond (HSB) data, Rose & Betts (2004) estimated the effect of high school mathematics courses on earnings. In particular they examined the effect of Vocational Math, Pre-algebra, Algebra/geometry, Intermediate algebra, Advanced algebra and Calculus on earnings nearly a decade after graduation from high school. This study is the first in providing a discussion of the mechanisms through which high school courses have the potential to increase earnings. They included controls for the highest level of education attained, college major and occupation. In order to control for the endogeneity of the course-taking variables, they utilized Altonji's (1995) high school mean of math courses as instrument. They also estimated some OLS models including high school fixed effects. Their IV estimates indicate that vocational math credits have a statistically significant and negative effect on earnings of around 8%. Credits earned in algebra/geometry increase earnings by 8%. No statistically significant effects were found for intermediate algebra, advance algebra and calculus. The high school fixed effects models are simply OLS models with the inclusion of high school fixed effects; these models indicate that each unit (year) of vocational math decreases earnings by 2% whereas algebra/geometry, intermediate algebra and advanced algebra increase earnings between 3-4%.

By using a two-sample instrumental variables (TSIV) approach, Goodman (2012) identified the impact of mathematics courses taken during high school on earnings using the differential timing of state-level increases in high school graduation requirements as a source of exogenous variation. In order to measure the impact of the reforms on mathematics coursework he constructed a panel of cross sections of transcript studies from the National Center for Education Statistics (NCES). He used the graduating class of 1982 from the HSB[5], and for the graduating classes of 1987, 1990 and 1994, he used transcripts studies associated with NAEP[6]. He also used Census data to gauge the effect of the reforms on earnings. He finds that each additional year of math increases black males' earnings by 5-9 %. The impact on white males are around the same magnitude but statistically insignificant. The results for black and white women are also statistically insignificant.

This study advances the current literature because of the following reasons. First, it is the first study that relies, at least indirectly, on an economic model that helps understanding, first, how students choose their optimal number of years of mathematics during high school; second, what are the effects of math curricular reforms on coursework and high school graduation decisions; finally, how these effects vary by academic ability. Most studies cited here examine the relationship between math coursework and earnings; even when this paper examines exactly that, the main difference is that, I present a deeper analysis of how curricular reforms influence coursework and high school graduation decisions and how these effects vary by academic ability. This is relevant since, by understanding the mechanisms through which the math curricular reforms influence course taking patterns and high school graduation decisions we can, in turn, predict, at least indirectly, the differential effects of coursework on earnings.

4 Choice model of Course taking behavior

In this section I present a choice model of course taking behavior. In this economy, high school students obtain utility from two sources: the future earnings from taking x units of advanced math courses, and from leisure, defined as the time devoted to all other activities unrelated with taking and learning advanced mathematics. Let $y(x)$ be the present discounted value of earnings from taking x units of mathematics; and let l be the measure of leisure.

Assume that students' utility function is Cobb-Douglas given by:

$$u[y(x), l] = [y(x)]^{\alpha} l^{1-\alpha} \tag{1}$$

Let t_m be the time devoted to take and learn advanced mathematics during high school and T be the total endowment of time during the entire high school enrollment. Therefore, the time constraint faced by students is:

$$t_m + l = T$$

Assume that it takes t_m to successfully complete x units of math and these variables are linearly related through the following equation:

[5]High School and Beyond

[6]National Assessment of Educational Progress

$$x = \nu t_m \tag{2}$$

It is noteworthy that, ν can be thought as a measure of academic ability since $\nu = \frac{x}{t_m}$, thus, more able students take less time in order to complete the same number of math credits x. This relationship provides the heterogeneity in effects that it critical for the model. For simplicity assume that $y(x) = x^\delta$ where $0 < \delta < 1$; $y(x)$ is the concave and increasing.

4.1 Optimal choice of x^* and l^* with no math graduation requirements

While in high school students choose the combination of x and l that maximizes their utility function. They solve the following problem:

$$\begin{aligned} \underset{x,l}{\text{Max}} \quad & x^{\delta\alpha} l^{1-\alpha} \\ \text{s.t.} \quad & \frac{1}{\nu}x + l = T \end{aligned}$$

The Lagrangian is:

$$\mathcal{L}(x, l, \lambda) = x^{\delta\alpha} l^{1-\alpha} + \lambda[T - \frac{1}{\nu}x - l] \tag{3}$$

The first order conditions are:

$$\partial x: \ \delta\alpha x^{\delta\alpha-1} l^{1-\alpha} = \frac{\lambda}{\nu} \tag{4}$$

$$\partial l: \ (1-\alpha) x^{\delta\alpha} l^{-\alpha} = \lambda \tag{5}$$

$$\partial \lambda: \ \frac{1}{\nu}x + l = T \tag{6}$$

Solving for x^* and l^* we have:

$$x^* = \frac{\delta\alpha}{1 - (1-\delta)\alpha} T\nu \tag{7}$$

$$l^* = \frac{1-\alpha}{1 - (1-\delta)\alpha} T \tag{8}$$

The no graduation requirements model of choice predicts the following:

- Students with a higher ability take more math courses than their lower ability counterparts. Since the model assumes a constant ν, the predicted relationship between x^* and ν is linear.
- The optimal l^* is independent of ν. This implies that there is no correlation between academic ability and the amount of leisure the student demands.

- If students were given more time T, they will increase both x^* and l^*.

4.2 Optimal choice of x^{**} and l^{**} with math graduation requirements

Now let's solve the same problem but this time imposing a minimum number of mathematics units the student must obtain in order to receive a high school diploma (R). Students solve this constrained optimization problem.

$$\begin{aligned} \underset{x,l}{\text{Max}} \quad & x^{\delta\alpha} l^{1-\alpha} \\ \text{s.t.} \quad & \frac{1}{\nu}x + l = T \\ \text{and} \quad & x - R \geq 0 \end{aligned}$$

Again the Lagrangian is:

$$\mathcal{L}(x, l, \lambda, \mu) = x^{\delta\alpha} l^{1-\alpha} + \lambda[T - \frac{1}{\nu}x - l] + \mu(x - R) \tag{9}$$

This Lagrangian must be solved by the Kuhn-Tucker method because the second constraint is an inequality. The first order conditions are:

$$\partial x: \; \delta\alpha x^{\delta\alpha-1} l^{1-\alpha} = \frac{1}{\nu}\lambda - \mu \tag{10}$$

$$\partial l: \; (1-\alpha) x^{\delta\alpha} l^{-\alpha} = \lambda \tag{11}$$

$$\partial\lambda: \; \frac{1}{\nu}x + l = T \tag{12}$$

$$x - R \geq 0 \tag{13}$$

$$\mu \geq 0 \tag{14}$$

$$\mu(x - R) \geq 0 \tag{15}$$

Let's x^{**} and l^{**} be the optimal choice of courses and leisure when there are high school graduation requirements. From the last condition there are three cases.

Case 1. If $x^{**} > R$ then $\mu = 0$. Therefore, adding the math graduation requirements constraint does not change anything; $x^* = x^{**}$.

Case 2. If $x^{**} = R$, then $\mu > 0$. Using the interpretation of the multipliers, i.e., being the increase in the objective function given a marginal relaxation of the constraint we know that $\mu = \frac{\partial u}{\partial(-R)} > 0$ which is equivalent to say that, $\frac{\partial u}{\partial(R)} < 0$. Thus, given that $x^{**} = R$ an increase in the number of math required to obtain a high school graduation will reduce the utility. Consequently, cases 1 and 2 summarize the fact that, students on or above the minimum number of required units of math, will suffer no change in their optimal choices because of the imposition of the requirement.

Case 3. If $x^{**} < R$ then $\mu < 0$ which is a contradiction. If $x^* < R$ then, the student will be forced to take a sub-optimal choice (from his/her perspective). If the student chooses to take $x^{**} = R$, because of the time constraint, he/she will be forced to decrease leisure, thus, $l^{**} < l^*$ and reduce his/her utility further.

4.3 Including the outside option: dropping out from high school

The students have the option of dropping out from high school if the value of the utility from attending and graduating high school is less than the value of the outside option which is working and earning the mean salary of high school dropouts. Students first, solve the maximization problem and decide whether or not to continue enrolled in high school and graduate or to dropout and work.

Formally, once they have solved the problem above, they know x^{**} and l^{**}. The value of attending school is then $V^s = u[y(x^{**}), l^{**}]$. Let V^w the value of working as a high school dropout, therefore, they also solve:

$$V = max\{V^s, V^w\}$$

Based on this, they decide whether or not to continue enrolled in high school and graduate. Thus, for a student whose optimal choice of coursework is x^* (with no graduation requirements), the probability of dropping out from high school is proportional to $Pr(x^* < R)$. Recall that,

$x^* = \frac{\delta\alpha}{1-(1-\delta)\alpha} T\nu = \xi(\delta, \alpha)T\nu$ where $\xi(\delta, \alpha)$ is a constant.

The probability of dropping out from high school is:

$$Pr(HSdropout) = \kappa Pr(x^* < R) = \kappa Pr(\xi(\delta, \alpha)T\nu < R) = \kappa Pr\left(\nu < \frac{R}{\xi(\delta,\alpha)T}\right).$$

From the last expression it is clear that the probability of dropping out increases if R increases. Assume, ν has the c.d.f $G(\nu)$, then,

$$Pr(HSdropout) = \kappa G\left(\frac{R}{\xi(\delta,\alpha)T}\right)$$

Thus, from the last expression, it is possible to conduct policy simulations of the effect of graduation requirements on dropout from high school. First, we have to estimate the vector of structural parameters (κ, δ, α); then assume the value of T. Assuming that $G(\cdot)$ is Normal[7], I can predict the probability of drooping out from high school given different values of R[8].

4.4 Testable implications

The model provides testable implications.

1. High ability students, i.e., high values of ν, take more math courses than students with lower levels of ability.

2. As a consequence, the probability of graduating from high school is proportional to academic ability. Abler students graduate from high school at higher rates than their lower ability counterparts.

3. In the presence of a high school graduation requirement that imposes a minimum number of math credits, students with the highest ability are the least likely to change their course taking behavior, whereas students in the margin - middle ability levels - are those that might experience the biggest change in course taking behavior.

4. In the presence of curricular reforms like the ones described in (3), all types of students are more likely to dropout from high school. However, students with higher ability experience the least impact.

4.5 How the model informs on the causal effect of mathematics course-taking on earnings

The main research question this paper addresses is, what is the causal effect (or economic return) of taking advanced math courses during high school on earnings. The model predicts that higher ability students take more courses and are more likely to graduate from high school. Therefore, even when the parameter identified in this paper is the average causal effect of coursework on earnings, it might mask heterogeneous effects. Based on the exclusion restriction assumption that the only reason through which the reforms influence earnings is through its impact on course taking, if there is heterogeneous effects in the first stage, if follows that it must be heterogeneous impacts on the reduced form. In addition, the mechanism through which acquiring more math courses leads to higher earnings might be explained by the differential response - by academic ability - to the reforms in terms of coursework and high school graduation decisions. If the reforms induce high ability individuals to take more courses and low ability students to drop out from high school, this creates a sorting mechanism through which the market gets more information of the potential employees, and consequently, increases earnings.

[7] A very credible assumption given that ν is a measure of ability

[8] I hope to do this in future versions of this paper

5 Empirical Strategy

Following Goodman (2012), I estimate the returns to advanced math courses by using a Two Sample Instrumental Variables (TSIV) approach. This method exploits variation in the timing of the implementation of mathematics curricular reforms at the state level. These changes in high school graduation requirements are arguably exogenous to students' choices of courses. In order to understand what the instrument is, and how the TSIV method works in this paper, it is convenient to describe first the structure of the data.

5.1 Data

Reforms data

By using a number of issues of the Digest of Education Statistics from NCES, I built a panel dataset where the unit of observation is the state-class (cohort). The panel includes information about the high school graduation requirements, as well as other economic and education controls for the years 1992, 1996, 1998, 2000, 2004 and 2005. The variables included are: cohort (graduating class), state, total number of high school graduation requirements, credits required in mathematics, science, English and social studies; it also includes, the variable $MathReform$ which turns from 0 to 1[9] at the time the state implements a mathematics curricular reform and stays in 1 after that. As education policy controls, I included the pupil-teacher ratio and the per-pupil expenditure in 2013 USD. The economic controls are the unemployment rate and poverty rate.

Transcripts data

Following Goodman's lead I put together a dataset that includes transcript information from NCES of four graduating classes. Unlike Goodman who followed two graduation classes in the 80's and two of the 90's, I include the most recent two decades of data (1990's and 2000's); in particular, I include the graduating classes of 1992, 1998, 2000, and 2005. I use the NELS:88 study to obtain the data of the 1992 cohort; and for the graduating classes of 1998, 2000 and 2005, I use the HSTS. From each graduating class, I pull a number of variables such as the high school exit status, the number of credits in different subjects of mathematics such as Algebra I, Algebra II, Geometry, Trigonometry PreCalculus, Calculus and non-advanced math courses as well; state, race, gender, gpa and high school class rank were also included. By stacking all the graduation classes in one dataset, I compiled a panel of cross sections of transcript information that spans between 1992 to 2005. In order to measure the impact of the reforms on advanced mathematics course taking I merged the reforms data onto the transcripts dataset. In order to be consistent with the data from the Census, the analytic sample only includes White and Black students.

[9]Some states changed more than once, mostly increasing the number of math years required for graduation

In addition to the aforementioned variables, for the graduating class of 1992, I used the mean of the standardized test scores in math, reading, social studies and history as a measure of academic ability. For the graduating classes of 1998, 2000 and 2005 I used the gpa. Within each graduating class, I created a variable measuring the quartile of academic ability. These measures are convenient for the following reasons. For the graduating class of 1992, the standardized scores were obtained in the sophomore year; and for the graduating classes of 1998, 2000 and 2005 the gpa is calculated using the available courses in each student's transcript; therefore, this measure is always there regardless of when the student decided to dropout of high school.

Census data

I use the 2012-3[10] year version of the American Community Survey (ACS) to extract the sample of individuals and variables needed for the analyses. The sample includes White and Black individuals who turned 18 between 1992 and 2005 and the variables used are gender, race, age, state, education, wages, worked last week, weekly hours worked during the last 12 months, and weeks worked during the last 12 months. In order to measure the impact of the reforms on earnings I merged the reforms data onto the ACS dataset.

In addition to measuring the impact of the reforms on earnings, I also use the ACS data to gauge the impact of the reforms on high school graduation. To this end, I created two outcome variables: the first one indicates which individuals attained at least a high school diploma and the second one indicates which students attained exactly a high school diploma. In this case, I used the 2011-1 year ACS survey.

5.2 TSIV

In order to measure the impact of the reforms on advanced math course taking I estimate the following equation in the baseline specification:

$$Courses_{isc} = \alpha_1 + \alpha_2 MathReform_{sc} + \mu_c + \nu_s + \epsilon_{isc} \tag{16}$$

This is the first stage regression utilized in the IV framework. The reduced form equation, i.e., the one that measures the impact of the reforms on the natural logarithm of earnings is:

$$Ln(earnings)_{isc} = \beta_1 + \beta_2 MathReform_{sc} + \mu_c + \nu_s + \epsilon_{isc} \tag{17}$$

Equation (16) is estimated with the transcripts data. Here $Courses_{isc}$ represents the number of Carnegie units taken by student i from the graduating class $c \in \{1992, 1998, 2000, 2005\}$ attending a high school at state $s \in \{AL, ...WY\}$; $MathReform \in \{0, 1\}$ is a variable with a value of 1

[10] This version surveys 3% of the population in the US and includes the years 2010, 2011 and 2012

if the state s has implemented the reform in time c and 0 otherwise; for example, if a student of the graduating class of 1998, attended a high school located in a state that implemented the reform by 1998, the variable $MathReform_{sc}$ will take the value of 1 for this state for the values of $c \in \{1998, 2000, 2005\}$; before that, for this specific state, the variable $MathReform_{sc}$ will take the value of 0 for $c \in \{1992\}$. Given that the process of implementing a curricular reform is highly political - the governor of each state signs the curricular reform into Law -, it is likely that students in each state know what high school graduation requirements they are required to meet in order to obtain the high school diploma as well as whether there has been a recent change in these requirements.

The class and state fixed effects are μ_c and ν_s and ϵ_{isc} is a random error. In additional specifications of (16) and (17), I include state level education controls such as the per-pupil expenditures and pupil-teacher ratio, as well as economic controls such as the unemployment rate and poverty rate for state s and class c. Class and time are used interchangeably. **Identification** comes from within-state changes in math coursework controlling for year-specific statewide shocks.

Equation (17) is estimated using the ACS data; $Ln(earnings)_{isc}$ is the natural logarithm of the last year earnings of respondent i of the "cohort" $c \in \{24, ..., 36\}$ at state s. As mentioned, given that equation (16) is the first stage relationship and equation (17) is the reduced form, it is possible to recover the two sample 2SLS estimator; thus,

$$\hat{\beta}_{TSIV} = \frac{\hat{\beta}_2}{\hat{\alpha}_2} \tag{18}$$

Empirically, in order to estimate $\hat{\beta}_{TSIV}$, I stacked the American Community Survey data onto the Transcripts dataset. I created a variable that identifies which source the records come from. I bootstrapped the first stage regression, the reduced form, and the ratio of the coefficients of math reform 100[11] times.

5.3 Testable implications - Empirical Evidence

In order to test the implications of the economic model I have created dummies of within graduating class quartiles of academic ability. These ability dummies as well as their interactions with the reform variable are included in the following equations:

$$Courses_{isc} = \beta_1 + \sum_{q=2}^{q=4} \delta_q Ability_{qsc} + \sum_{q=2}^{4} \lambda_q Ability_{qsc} \times MathReform_{sc} + \mu_c + \nu_s + \epsilon_{isc} \tag{19}$$

[11] I did not do the recommended 250 repetitions because of timing constraints

$$HSgrad_{isc} = \beta_1 + \sum_{q=2}^{q=4} \delta_q Ability_{qsc} + \sum_{q=2}^{4} \lambda_q Ability_{qsc} \times MathReform_{sc} + \mu_c + \nu_s + \epsilon_{isc} \quad (20)$$

The model prediction/implication (1) and (3) are tested by using equation (19) and implications (2) and (4) are tested using (20). For example, the first prediction states that higher ability students take more courses; this can be analyzed by examining the coefficients δ_2, δ_3 and δ_4. The model predicts that $\delta_2 < \delta_3 < \delta_4$. The same is true for the second prediction, which states that higher ability students have higher probability of graduating from high school.

Implications (3) and (4) predict heterogeneous effects of math reforms across levels of academic ability. Given that this is a fully interacted model, the effect of reforms on course taking for students in the second quartile would be $\beta_1 + \lambda_2$; similarly, the effects of reforms for groups 3 and 4 are $\beta_1 + \lambda_3$ and $\beta_1 + \lambda_4$ respectively.

5.4 Impact of reforms on high school graduation using ACS

The model predicts that all students, in the presence of a mathematics curriculum reform will experience a decrease in the probability of high school graduation (*Testable implication 4*). In addition to using the transcript data to measure the impact of the reform on the graduation from high school I use the ACS data to provide another set of estimates that prove this prediction.

I used two different samples and two different measures of high school graduation. The first sample includes students who reached at least 9^{th} grade. The second sample includes all individuals who turned 18 between 1992 and 2005 with no regard to their educational attainment. The first measure of high school graduation is **at least high school** reported by the individuals in the ACS; therefore, individuals with high school diploma and beyond have a value of 1 whereas students who did not attain a high school diploma have the value of zero in this variable. The second measure of high school graduation refers to individuals whose *highest degree attained* is a high school diploma. Thus, for every combination of sample and outcome I estimate the following equation using the ACS data.

$$HSgrad_{isc} = \beta_1 + \beta_2 MathReform_{sc} + \mu_c + \nu_s + \epsilon_{isc} \quad (21)$$

I also add education policy and economic controls to this equation.

6 Results

6.1 Impact of reforms on course taking and high school graduation using Transcripts (NCES)

Impact on course taking

Table 1 includes the parameter estimates of the impact of math reforms on course taking. The analytic sample includes both high school graduates and dropouts. In the first specification (M1) the only predictor was the dummy variable of math reform. M2 adds the education policy controls, i.e., Pupil teacher ratio and Per pupil expenditure; M3 adds economic controls such as Poverty rate and Unemployment rates. Finally, M4 includes dummies for ability quartile and interaction of these with the dummy math reform.

After controlling for academic ability (M4), the impact of reforms on course taking is positive, statistically significant and large; around one fourth of a Carnegie unit increase. The coefficients for the Ability quartiles 2, 3 and 4, follow a monotonically increasing pattern, 0.602, 1.176 and 1.68 respectively. This proves the first testable assumption of the model which states that, higher ability students take more math courses than their lower ability counterparts.

The third testable implication states that the impact of the reforms would be larger for middle ability students; those more likely to be influenced by the reforms because they might be already close to the new minimum number of math credits. However, the coefficients for each group, (which in the table are the values of $\beta + \lambda_2$, $\beta + \lambda_3$ and $\beta + \lambda_4$) indicate a pattern no predicted by the model. The highest impact of the reforms was experienced by the highest ability group (0.175), the second highest was experienced by the second ability quartile (0.137) and the least impact was for the third ability quartile (0.0774). Later in the paper I provide a theoretical explanation of why this happen based on the Spence (1973) model of job market signaling.

The table also includes the F value for the test of the significance of the instrument. Across all specifications, the F value is always greater than 10 and statistically significant. This suggest that there is a strong association between the reforms and course taking.

In table 3, I included only high school graduates and estimated the effect of the reforms on course taking. The specifications are exactly the same as in table 1. Again, based on (M4) the impact of the reforms on course taking is positive, statistically significant and large (0.2633). This is almost the same value as in table 1. The parameter estimates of the ability quartiles 2,3 and 4 also follow a monotonically increasing pattern, 0.57, 1.132 and 1.64 respectively. This confirms the first testable implication as well. The impact of the reforms on each ability quartile follows the same pattern as in table 1. The impact is almost the same for ability quartiles 2 and 4 whereas the third ability quartile experiences a smaller impact. Again, the F statistic is large and statistically significant across all specifications.

The baseline means of math courses taken by the 1992, 1998, 2000 and 2005 graduating classes are 1.76, 2.58, 2.56 and 2.74 respectively. Among the students with ability information, the baselines measures of math courses for the quartiles 1, 2, 3 and 4 are 1.72, 2.3, 2.88 and 3.44, correspondingly.

Impact of reforms on high school graduation

Table 2 includes the parameter estimates of the impact of the reforms on high school graduation using the Transcripts data. Overall, from M3, there is a decrease of around 1.6 percentage points due to the reforms. The model predicts that (testable implication no 2) there is a positive relationship between ability the probability of graduation from high school. The parameters of the ability quartiles 2, 3 and 4 , reveal exactly this; compared with students in the first ability quartile, students in the second quartile 2 are 1.5 percentage points more likely to graduate from high school. Similarly, students in the third and fourth quartiles are 2.0 and 2.13 percentage points more likely to graduate from high school.

The testable implication 4, states that, higher ability students will experience less impact on high school graduation due to the imposition of higher requirements when compared with their lower ability classmates. M4 provides estimates of how different ability quartiles were impacted by the reforms; whereas the students in the second ability quartile experienced an impact of -1.57 percentage points, students in the third and fourth experienced -1.2 and -0.73 percentage points respectively. Indeed, as predicted by the model, there is a inverse relationship between ability and the negative impact on high school graduation due to the reforms.

To put this in context, I calculated the mean of high school graduation using the transcripts data; overall, 91 percent of the students in the pooled sample graduate from high school. Among the students for whom the ability information is available, the overall high school graduation rate is 95 percent; the graduation rates for the four ability quartiles are 91, 95, 97 and 98 percent correspondingly.

6.2 Impact of reforms on high school graduation using the American Community Survey (ACS)

In order to complement the estimates of the impact of the reforms on high school graduation , I used the American Community Survey (ACS) 2011. As mentioned, the sample includes White and Black individuals who turned 18 years old between 1992 and 2005. I merged the reforms data onto the ACS data using the graduating classes and states as the common variables. I used two different samples: 1) the first sample includes only individuals whose reported educational level is at least 9^{th} grade; 2) the second sample includes all the individuals. I also defined two different outcomes: the first outcome, **At least high school diploma** equals 1 for all the individuals whose educational levels were high school diploma and further; 0 otherwise. The second outcome, **Exactly high school diploma** was equal to 1 only for those individuals who reported high school diploma as their current educational level attained.

Table 4 includes the estimates of the impact of math reforms on **At least high school diploma** using the sample of individuals who attained at least 9^{th} grade. Across all specifications, the impact is negative, statistically significant and large, around 1.15 percentage point decrease. When using the outcome **Exactly high school diploma** in this sample (Table 5), the impact was also negative, statistically significant and even larger: around 1.3 percentage points decrease.

For the entire sample, when using the outcome **At least high school diploma**, (Table 6) the impact was also negative, statistically significant and around 1.8 percentage points decrease. Finally, the estimates for **Exactly high school diploma** in table 7 are around 1.4 percentage points decrease. It is noteworthy that the results for the entire sample were larger than those that condition on being a high school student; there might be aspiration effects of the reforms for persons who are not in high school yet. Across the two samples and the two definitions of high school graduation, the results are strikingly similar to those obtained using the transcripts data.

6.3 Reduced Form estimates

Tables 8 through 13 include the reduced form estimates of the impact of the reforms on education and labor market outcomes conditional on high school graduation. For example, table 8 indicates, that reforms increased earnings of high school graduates by around 1 percent; this estimate is statistically significant at the 10 percent level. Furthermore, as shown in table 9, reforms are associated with an increase in earnings (in real $2012 dollars) of around $880. In addition, when examined the impact of reforms on the variable *some college* I found that it decreases by around 0.6 percentage points; again, statistically significant only at the 10 percent. For the outcomes of whether the student obtained a Bachelors degree, an Associate degree or whether the individual was employed, the impacts of the reforms were small and statistically insignificant.

When looking at the impact of the reforms on education and labor market outcomes including both high school graduates and dropouts the results are the following (tables 14-19). Earnings increase by around 0.5 percent, but this effect is statistically insignificant. When the outcome in the estimated reduced form equation is the raw measure of yearly earnings, the impact is around $700; this estimate is statistically significant at the 5 percent level. There is a reduction on the probability of getting some college by around 0.7 percent points. There is a statistically significant and negative effect on whether or not individuals attain an Associate degree by around 0.3 percentage points. The impacts on Bachelors degree attainment and employment were also small and statistically insignificant.

In summary, I found a strong and positive effect for both samples on earnings; a small and statistically significant effect of reforms on ln(earnings) only for the sample of high school graduates, and a small and statistically significant effect of the reforms on college access measured through the variable *some college*. For this reason, the TSIV estimates below only include these three outcomes: ln(earnings), earnings and the variable *some college*.

6.4 TSIV estimates

Table 20 includes the bootstrap estimates of the first stage, reduced form and TSIV for three outcomes: ln(earnings), earnings and *some college*. I present the 95 and 90 percent Biased-corrected confidence intervals. Given that I restricted the repetitions to 100, I don't expect that the first stage and reduced form estimates to match exactly the numbers presented in previous tables. However, the results are very similar. The TSIV estimates (column 3) indicate that, for the sample of high school graduates, each additional Carnegie unit of advanced mathematics (i.e., year of advanced math instruction) increases earnings by around 3.7 percent. This estimate is statistically significant at the 10 percent level. Furthermore, each additional Carnegie unit of advanced math increases yearly earnings by around $3,200 dollars[12]; this estimate is significant at the 5 percent level. Finally, the results also indicate that, each additional year of advanced math reduced the probability of reporting some college as the highest degree attained by around 2 percentage points; this estimate is also significant at the 5 percent level.

Table 21 includes the TSIV estimates for the sample of high school students. The impact of the an additional unit of advanced math on ln(earnings) is still positive and around 3 percent but statistically insignificant. However, the impact on earnings is large, positive and statistically significant, around $3,700 yearly increase for each unit of advanced math taken during high school. Finally, the impact on *some college* is negative and around 3 percentage points but statistically insignificant.

In summary, taking additional advanced math courses increases earnings. However, as pointed out by Professor Susan Dynarski, given that I am using the 2005 high school graduating class, any estimate of the impact of the reforms on earnings is likely to be biased downwards since most of these students would be still at school in 2012. Consequently, the impacts presented here are a lower bound for the impact of mathematics course taking on earnings.

[12] 2012 real dollars

7 A theoretical explanation of the differential effect of math reforms on course taking across ability quartiles

The choice model in this paper predicts that students with the highest ability are the least impacted by the reforms given that, most likely their optimal choice of coursework is above the new requirement. However, as we can see in tables 1 and 3, the students with the highest ability are the most impacted by the reforms. In this section, I present a theoretical explanation of why this might be the case, based on the model of job market signaling of Spence (1973). I consider only high school graduates.

Assume there are two types of individuals, Low and High ability. High school graduates, depending on their type choose the optimal x; they obtain utility from the earnings $y(x)$ and dis-utility from having to take x units of math. As in the Spence model, assume the single cross condition in which the utility functions of both types cross only once.

Since the market does not know the type of the high school graduates, it learns about it by looking at which x the high school graduate actually chose. Let α be the proportion of High type individuals in the population. Assume that the employer pays $y^L(x)$ to low types and $y^H(x)$ to high types. The employer offers then

$$w(x) = \alpha y^H(x) + (1 - \alpha)y^L(x)$$

The Spence (1973) model of job market signaling allows both types of equilibria: pooling and separating. However, among high school graduates, when the reforms induce lower ability students to take more math courses, the higher ability counterparts have now the incentive to take even more math courses than their before-reform optimal. If the market cannot identify low and high types among the group of high school graduates, there is a loss in the earnings for the highest ability group; they receive now $w(x) = \alpha y^H(x) + (1 - \alpha)y^L(x)$ instead of $w(x) = y^H(x)$ and since, $y^H(x) > \alpha y^H(x) + (1 - \alpha)y^L(x)$ they have the incentive to separate themselves from the lower ability group; inducing them to take more courses.

8 Conclusions

As a summary, one section of the paper was concerned with the identification and estimation of the causal effect of math coursework on earnings. The average causal effect of an additional year of advanced math courses during high school on yearly earnings was between 3 and 4 percent (between \$ 3,200 and \$3,700 USD). The first stage estimates revealed that the math curricular reforms increased coursework by around one quarter of a Carnegie unit (one academic year) and the reduced form estimates indicate that the aforementioned reforms increased earnings between 0.6 and 1 percent. Nevertheless, as suggested by the model proposed in this paper, there are important differences in coursework by academic ability.

The next part of the paper focused on the analyses of the first stage relationship: how the impact of the reforms on course-taking and high school graduation vary by academic ability? This section informs the previous analyses since, as the model and the empirical evidence suggest, there is a strong heterogeneity in the first stage relationship by academic ability. Higher ability students take more courses and their probability of high school graduation is higher when compared with their lower ability counterparts. These results lead to at least two important conclusions. First, there must necessarily be heterogeneous impacts of coursework on earnings, and, second, perhaps of higher relevance, the results provide evidence of a potential mechanism through which coursework influences earnings. Given that the reforms induce higher ability students to take more courses and lower ability individuals to dropout from high school, this might create a screening or sorting effect of the population of high school graduates in which the market can identify the high ability students better than before the reform and pays a higher premium. A similar situation occurs in the literature of the impact of the minimum wage laws; whereas the minimum wage benefits some individuals, there is another group that is unemployed because of these laws.

9 Next steps

Given that different instruments induce different groups of people to act, the next step is to examine the characteristics of the compliant population. This is relevant, especially during the current debate around the Common Core State Standards. Having the knowledge about which students are induced to take more courses because of the math curricular reforms would help to make the case for expanding these types of policies. Even when it was my intention to include this section on this paper, due to timing constraints it was not possible. Nevertheless, since I expect this paper to be part of my dissertation, I will work on this topic during the summer.

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10 Appendix

Table 1: First Stage: Impact of reforms on advanced course taking - including high school dropouts

	(1)	(2)	(3)	(4)
Reform	0.1188***	0.1574***	0.1978***	0.2464***
	(0.036)	(0.0384)	(0.0391)	(0.0421)
Pupil-teacher ratio		-0.0285	-0.0256	0.0047
		(0.0173)	(0.0179)	(0.0152)
Per-pupil expenditure		-0.0001***	-0.0001***	-0.0001***
		(0.00002)	(0.00002)	(0.00002)
Poverty rate			-0.0067	0.0023
			(0.007)	(0.006)
Unemployment rate			-0.0538***	-0.0862***
			(0.0131)	(0.0113)
Ability quartile 2				0.602***
				(0.0166)
Ability quartile 3				1.1764***
				(0.0158)
Ability quartile 4				1.6832***
				(0.0151)
$Reform \times Ability_2$				-0.109***
				(0.0405)
$Reform \times Ability_3$				-0.169***
				(0.0387)
$Reform \times Ability_4$				-0.0715**
				(0.0352)
$\beta_1 + \lambda_2$				0.1374***
$\beta_1 + \lambda_2$				0.0774**
$\beta_1 + \lambda_2$				0.1749***
F (Reform = 0)	10.9***	16.81***	25.62***	34.28***
N	63,798	63,798	63,798	60,768

Robust standard errors in parentheses
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted using the cross sectional final usable weight of each data collection year
The sample includes only White and Black students

Table 2: First Stage: Impact of reforms on high school graduation

	(1)	(2)	(3)	(4)
Reform	-0.0067	-0.01*	-0.016***	-0.003
	(0.0057)	(0.006)	(0.0061)	(0.0058)
Pupil-teacher ratio		0.0144***	0.0146***	0.0138***
		(0.003)	(0.0031)	(0.0019)
Per-pupil expenditure		0.00001***	0.00002***	0.00001***
		(0.000004)	(0.000004)	(0.000002)
Poverty rate			0.0025**	0.0014*
			(0.0012)	(0.0008)
Unemployment rate			0.0089***	0.0034**
			(0.0022)	(0.0014)
Ability quartile 2				0.015***
				(0.0021)
Ability quartile 3				0.0206***
				(0.0019)
Ability quartile 4				0.0213***
				(0.0018)
$Reform \times Ability_2$				-0.0128**
				(0.005)
$Reform \times Ability_3$				-0.0098**
				(0.0043)
$Reform \times Ability_4$				-0.0043
				(0.0037)
$\beta_1 + \lambda_2$				-0.0157***
$\beta_1 + \lambda_3$				-0.0127**
$\beta_1 + \lambda_4$				-0.0073***
F (Reform = 0)	1.4	2.79*	6.85***	0.26
N	63,035	63,035	63,035	60,005

Robust standard errors in parentheses

*p<0.1, **p<0.05, ***p<0.001

Regressions are weighted using the cross sectional final usable weight of each data collection year

The sample includes only White and Black students

Table 3: First Stage: Impact of reforms on advanced course taking - conditional on high school graduation

	(1)	(2)	(3)	(4)
Reform	0.1669***	0.219***	0.2802***	0.2633***
	(0.0359)	(0.0381)	(0.0388)	(0.0429)
Pupil-teacher ratio		-0.0595***	-0.0552***	-0.0126
		(0.0169)	(0.0174)	(0.0157)
Per-pupil expenditure		-0.0001***	-0.0002***	-0.0001***
		(0.00002)	(0.00002)	(0.00002)
Poverty rate			-0.009	0.0087
			(0.0069)	(0.0062)
Unemployment rate			-0.0817***	-0.0988***
			(0.0127)	(0.0115)
Ability quartile 2				0.5712***
				(0.0171)
Ability quartile 3				1.1322***
				(0.0162)
Ability quartile 4				1.6425***
				(0.0154)
$Reform \times Ability_2$				-0.0742*
				(0.0399)
$Reform \times Ability_3$				-0.132***
				(0.0381)
$Reform \times Ability_3$				-0.0471
				(0.0347)
$\beta_1 + \lambda_2$				0.1891***
$\beta_1 + \lambda_3$				0.1313***
$\beta_1 + \lambda_4$				0.2162***
F (Reform = 0)	21.66***	32.99***	52.01***	37.63***
N	59,136	59,136	59,136	59,097

Robust standard errors in parentheses

*p<0.1, **p<0.05, ***p<0.001

Regressions are weighted using the cross sectional final usable weight of each data collection year

The sample includes only White and Black students

Table 4: Impact of reforms on ***At least high school diploma*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00996***	-0.0109***	-0.0115***
	(0.00316)	(0.00331)	(0.00333)
Pupil-teacher ratio		-0.00253	-0.00274
		(0.00181)	(0.00183)
Per-pupil expenditure		2.92e-07	4.71e-07
		(2.39e-06)	(2.42e-06)
Poverty rate			-0.000419
			(0.000788)
Unemployment rate			0.00158
			(0.00135)
N	210,619	210,619	210,619

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes only White and Black students
The sample includes students who at least reported 9^{th} grade.

Table 5: Impact of reforms on ***Exactly high school diploma*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.0129***	-0.0127**	-0.0130**
	(0.00486)	(0.00501)	(0.00507)
Pupil-teacher ratio		-0.00185	-0.00202
		(0.00275)	(0.00278)
Per-pupil expenditure		-1.64e-06	-1.44e-06
		(3.68e-06)	(3.73e-06)
Poverty rate			0.000215
			(0.00117)
Unemployment rate			0.000669
			(0.00210)
N	210,619	210,619	210,619

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes only White and Black students
The sample includes students who at least reported 9^{th} grade.

Table 6: Impact of reforms on ***At least high school diploma*** conditional on being in the sample. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.0161***	-0.0183***	-0.0180***
	(0.00358)	(0.00375)	(0.00377)
Pupil-teacher ratio		-0.00257	-0.00242
		(0.00209)	(0.00210)
Per-pupil expenditure		3.38e-06	3.22e-06
		(2.71e-06)	(2.74e-06)
Poverty rate			3.17e-05
			(0.000883)
Unemployment rate			-0.000834
			(0.00152)
N	217,395	217,395	217,395

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005.

Table 7: Impact of reforms on ***Exactly high school diploma*** conditional on being in the sample. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.0140***	-0.0143***	-0.0143***
	(0.00474)	(0.00488)	(0.00494)
Pupil-teacher ratio		-0.00183	-0.00190
		(0.00266)	(0.00269)
Per-pupil expenditure		-7.99e-07	-6.87e-07
		(3.59e-06)	(3.64e-06)
Poverty rate			0.000296
			(0.00114)
Unemployment rate			6.84e-05
			(0.00205)
N	217,395	217,395	217,395

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005.

Table 8: Reduced Form - Impact of reforms on ***ln(earnings)*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	0.00643	0.0110**	0.0103*
	(0.00508)	(0.00529)	(0.00536)
Pupil-teacher ratio		0.000792	0.000757
		(0.00292)	(0.00295)
Per-pupil expenditure		-1.01e-05***	-1.03e-05***
		(3.86e-06)	(3.90e-06)
Poverty rate			-0.00185
			(0.00122)
Unemployment rate			0.00199
			(0.00218)
N	430,022	430,022	430,022

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 9: Reduced Form - Impact of reforms on ***Earnings*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	699.0***	1,003***	877.5***
	(186.5)	(195.1)	(197.7)
Pupil-teacher ratio		84.86	50.55
		(110.2)	(110.7)
Per-pupil expenditure		-0.641***	-0.622***
		(0.143)	(0.144)
Poverty rate			-140.7***
			(46.08)
Unemployment rate			334.1***
			(80.19)
N	430,022	430,022	430,022

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 10: Reduced Form - Impact of reforms on ***Some College*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00578*	-0.00703**	-0.00615*
	(0.00300)	(0.00312)	(0.00315)
Pupil-teacher ratio		-0.000545	-0.000295
		(0.00170)	(0.00171)
Per-pupil expenditure		2.43e-06	2.26e-06
		(2.27e-06)	(2.29e-06)
Poverty rate			0.000875
			(0.000721)
Unemployment rate			-0.00228*
			(0.00129)
N	587,101	587,101	587,101

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 11: Reduced Form - Impact of reforms on ***Bachelors degree attainment*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	0.00761***	0.00346	0.00311
	(0.00285)	(0.00296)	(0.00300)
Pupil-teacher ratio		-0.00120	-0.00152
		(0.00156)	(0.00158)
Per-pupil expenditure		8.58e-06***	9.11e-06***
		(2.17e-06)	(2.19e-06)
Poverty rate			0.00119*
			(0.000651)
Unemployment rate			0.000695
			(0.00119)
N	587,101	587,101	587,101

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 12: Reduced Form - Impact of reforms on ***Associate degree attainment*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00322	-0.00301	-0.00321
	(0.00200)	(0.00206)	(0.00209)
Pupil-teacher ratio		0.000716	0.000796
		(0.00113)	(0.00115)
Per-pupil expenditure		7.83e-08	-1.64e-07
		(1.50e-06)	(1.52e-06)
Poverty rate			-0.00111**
			(0.000472)
Unemployment rate			0.000634
			(0.000848)
N	587,101	587,101	587,101

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 13: Reduced Form - Impact of reforms on ***Employment*** conditional on high school graduation. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00385	-0.00104	-0.00206
	(0.00290)	(0.00300)	(0.00304)
Pupil-teacher ratio		0.000659	7.45e-05
		(0.00167)	(0.00168)
Per-pupil expenditure		-5.91e-06***	-5.11e-06**
		(2.23e-06)	(2.25e-06)
Poverty rate			0.000968
			(0.000691)
Unemployment rate			0.00238*
			(0.00124)
N	587,101	587,101	587,101

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 14: Reduced Form - Impact of reforms on ***ln(earnings)*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	0.00178	0.00599	0.00576
	(0.00500)	(0.00520)	(0.00528)
Pupil-teacher ratio		0.000344	0.000524
		(0.00286)	(0.00289)
Per-pupil expenditure		-9.64e-06**	-1.01e-05***
		(3.80e-06)	(3.83e-06)
Poverty rate			-0.00190
			(0.00120)
Unemployment rate			0.000806
			(0.00215)
N	452,483	452,483	452,483

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 15: Reduced Form - Impact of reforms on ***Earnings*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	535.6***	811.8***	703.8***
	(180.9)	(188.9)	(191.6)
Pupil-teacher ratio		60.04	33.56
		(106.4)	(107.0)
Per-pupil expenditure		-0.604***	-0.595***
		(0.138)	(0.139)
Poverty rate			-141.2***
			(44.62)
Unemployment rate			286.2***
			(77.77)
N	452,483	452,483	452,483

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 16: Reduced Form - Impact of reforms on ***Some College*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00630**	-0.00773***	-0.00680**
	(0.00280)	(0.00291)	(0.00295)
Pupil-teacher ratio		-0.00116	-0.000909
		(0.00158)	(0.00160)
Per-pupil expenditure		2.44e-06	2.29e-06
		(2.13e-06)	(2.15e-06)
Poverty rate			0.000996
			(0.000675)
Unemployment rate			-0.00239**
			(0.00121)
N	637,444	637,444	637,444

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 17: Reduced Form - Impact of reforms on ***Bachelors degree attainment*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	0.00620**	0.00223	0.00199
	(0.00265)	(0.00275)	(0.00279)
Pupil-teacher ratio		-0.00162	-0.00190
		(0.00145)	(0.00146)
Per-pupil expenditure		7.96e-06***	8.44e-06***
		(2.02e-06)	(2.04e-06)
Poverty rate			0.00119**
			(0.000606)
Unemployment rate			0.000398
			(0.00111)
N	637,444	637,444	637,444

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 18: Reduced Form - Impact of reforms on ***Associate degree attainment*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00334*	-0.00324*	-0.00338*
	(0.00185)	(0.00190)	(0.00193)
Pupil-teacher ratio		0.000397	0.000489
		(0.00104)	(0.00105)
Per-pupil expenditure		8.72e-08	-1.50e-07
		(1.39e-06)	(1.41e-06)
Poverty rate			-0.000985**
			(0.000436)
Unemployment rate			0.000452
			(0.000787)
N	637,444	637,444	637,444

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 19: Reduced Form - Impact of reforms on ***Employment*** conditional on being a high school student. Estimates from the American Community Survey (ACS)

	(1)	(2)	(3)
Reform	-0.00402	-0.00162	-0.00271
	(0.00286)	(0.00296)	(0.00300)
Pupil-teacher ratio		0.000249	-0.000335
		(0.00163)	(0.00165)
Per-pupil expenditure		-5.38e-06**	-4.62e-06**
		(2.20e-06)	(2.22e-06)
Poverty rate			0.000771
			(0.000682)
Unemployment rate			0.00252**
			(0.00123)
N	637,444	637,444	637,444

Robust standard errors in parentheses.
*p<0.1, **p<0.05, ***p<0.001
Regressions are weighted
The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.

Table 20: Two Sample IV estimates conditional on High School graduation

	(1)	(2)	(3)
	First Stage	Reduced Form	TSIV
ln(Earnings)	0.2802	0.0104	0.0372
95% BC -CI	[0.1445, 0.4023]	[-0.0023, 0.0206]	[-0.0053, 0.1058]
90% BC -CI	[0.1694, 0.3978]	[-0.0008, 0.0174]	[0.0006, 0.0794]
Earnings	0.2802	$903	$3,223
95% BC -CI	[0.1445, 0.4023]	[527.3597, 1258.745]	[1675.077, 7168.225]
90% BC -CI	[0.1694, 0.3978]	[531.6754, 1182.885]	[1786.723, 6089.87]
Some College	0.2802	-0.0061	-0.0219
95% BC -CI	[0.1445, 0.4023]	[-0.0113, 0.0013]	[-0.054, -0.0022]
90% BC -CI	[0.1694, 0.3978]	[-0.0101, -0.0007]	[-0.0474, -0.0031]

Bootstrap estimates of the first stage, reduced form and TSIV estimates conditional on high school graduation (100 repetitions).

The confidence intervales are Biased-Corrected reported by the Stata bootstrap post estimation commands.

Bootstrapping was conducted by stacking (appending) the transcripts and ACS datasets into one common datafile.

The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school graduates.

Table 21: Two Sample IV estimates conditional on being a High School student

	(1)	(2)	(3)
	First Stage	Reduced Form	TSIV
ln(Earnings)	0.1978	0.0059	0.0297
95% BC -CI	[0.06, 0.3412]	[-0.0073, 0.0156]	[-0.0341, 0.1213]
90% BC -CI	[0.1001, 0.3199]	[-0.0043, 0.0139]	[-0.0279, 0.1015]
Earnings	0.1978	$725.4	$3,666.7
95% BC -CI	[0.06, 0.3412]	[316.3, 1139.4]	[485.7, 8578.3]
90% BC -CI	[0.1001, 0.3199]	[417.4, 1073.3]	[1232.1, 7637.5]
Some College	0.1978	-0.0068	-0.0344
95% BC -CI	[0.06, 0.3412]	[-0.0124, 0.0004]	[-0.0988, 10.636]
90% BC -CI	[0.1001, 0.3199]	[-0.0119, -0.0007]	[-0.0705, 0.0014]

Bootstrap estimates of the first stage, reduced form and TSIV estimates conditional on high school graduation (100 repetitions).

The confidence intervales are Biased-Corrected reported by the Stata bootstrap post estimation commands.

Bootstrapping was conducted by stacking (appending) the transcripts and ACS datasets into one common datafile.

The sample includes White and Black individuals who turned 18 between 1992 and 2005 who were high school students.