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There is limited existing evidence justifying the economic case for state education policy. Using newly-developed measures of the human capital of each state that allow for internal migration and foreign immigration, we estimate growth regressions that incorporate worker skills. We find that educational achievement strongly predicts economic growth across U.S. states over the past four decades. Based on projections from our growth models, we show the enormous scope for state economic development through improving the quality of schools. While we consider the impact for each state of a range of educational reforms, an improvement that moves each state to the best-performing state would in the of long-run economic gains of over four times current GDP.

Economic Gains for U.S. States from Educational Reform*

Eric A. Hanushek, Jens Ruhose, and Ludger Woessmann†

Abstract

There is limited existing evidence justifying the economic case for state education policy. Using newly-developed measures of the human capital of each state that allow for internal migration and foreign immigration, we estimate growth regressions that incorporate worker skills. We find that educational achievement strongly predicts economic growth across U.S. states over the past four decades. Based on projections from our growth models, we show the enormous scope for state economic development through improving the quality of schools. While we consider the impact for each state of a range of educational reforms, an improvement that moves each state to the best-performing state would in the aggregate yield a present value of long-run economic gains of over four times current GDP.

Education policy is largely the province of individual U.S. states. And to this end, it is common for people campaigning to be governor to proclaim a dedication to being the "education governor." Yet from the standpoint of state economic development, it is not entirely clear what improving a state's schools might mean. Most discussions, particularly in the post-NCLB era of U.S. schools, focus policy attention on student achievement, but most of the evidence on economic outcomes of schooling does not do so. This paper evaluates the economic implications of improved educational achievement and provides projections for individual states of how economic development would be altered by school improvement.

A variety of existing studies provide suggestive implications of educational improvement, but on closer inspection few are directly related to the policy discussions going on across U.S. states. Extensive analysis addresses the role of human capital in determining individual incomes.

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Other studies delve into how human capital affects growth and development from an international macroeconomic perspective. Yet a vast majority of this work takes the expedient of measuring human capital simply by school attainment – the amount of time spent in school. Notwithstanding some discussion of high school and college completion, the vast majority of policy discussions are about achievement and the quality of schooling. These discussions implicitly underscore the fact that what students know and can do at any point in the schooling process varies dramatically and in important ways.

Two conclusions follow from recognizing that human capital is measured imperfectly and incompletely by school attainment. First, the existing justifications for many policy actions, while widely accepted, are not entirely appropriate and may even point policy in the wrong directions. For example, an over-emphasis on high school completion, such as through promotion of GED diplomas, could lead to ignoring more fundamental learning objectives. Second, the standard evidence on the economic returns to human capital does not provide a viable way of calculating the economic benefits related to the relevant school improvement programs found in the current policy debates. Economic analyses based just on whether a program affects school completion can distort both costs and benefits of programs, leading to incorrect decisions.[1]

This paper makes two contributions to the literature on economic benefits of education. First, we develop and analyze more refined measures of educational achievement for workers across U.S. states, which in the aggregate we call knowledge capital to distinguish it from the standard years of school measures. These measures allow us to estimate how state growth and

[1] For example, various analyses in Belfield and Levin (2007) evaluate programs in terms of their impact on high school graduation rates without regard to quality considerations. But, as we show below, the variations in observed state achievement imply differences of three or more quality-equivalent years of schooling for individuals with the same nominal school attainment.

development is related to the quality of schools and of workers. Second, using these estimates, we develop state-by-state projections of the future benefits of various educational reforms.

Estimation of the impact of achievement differences across states is complicated. The common reliance on school attainment measures reflects in many ways the availability of data – across individuals, across states, and across countries. Going beyond school attainment generally requires using specialized data sets that often do not suit the purposes of the analysis. Moreover, when focused on U.S. states, it is important to understand the high degree of mobility of the U.S. population, implying that policies of one state may have significant implications for others as workers move and take their human capital with them. A portion of this analysis must therefore address construction of appropriate workforce measures of knowledge capital that are relevant to consideration of state policies.

This analysis of state economic development builds directly on the analysis of international development and is best considered as an extension of that work to U.S. states. Using estimates of skill differences measured by achievement scores of nations or states –the knowledge capital of nations – we estimate growth regressions. We find that there is a strong relationship between growth of U.S. states and the quality of their workforce with parameter estimates that are virtually identical to those found across countries. This consistency of underlying growth forces is important for our interpretation of results, because investigating the causal structure of growth is more feasible within the framework of country differences in growth rates than state differences in growth rates.

Our measures of the knowledge capital in each state directly link the productive skills of the workforce to the quality of schools in the state. From this, using our state growth results, we project the economic value of improving schools in each state. Our results suggest that feasible quality improvements are associated with very large economic returns that could exceed the *total* spending on K-12 education in each state. For example, the value of a reform that would lift each state to the currently top-performing state would amount in present value to an aggregate $76 trillion for the United States, some four times current GDP.

Because of the close interrelationships among states brought about by the mobility of the population, it is very much in the interest of all states jointly to improve on the quality of schools. Nonetheless, our results show that, while state rewards are reduced, rewards remain large even with individual state improvements in the face of outmigration of its students.

Section 2 reviews the existing research on the impact of human capital on economic growth that forms the foundation for this study. Section 3 describes how we develop cognitive skills measures for each U.S. state. Section 4 presents results of growth regressions across U.S. states. Section 5 introduces the projection model. Section 6 presents results on the projected economic gains from a number of educational reforms for each U.S. state. Section 7 concludes.

2. Some Foundational Research

For state policy, two kinds of economic impacts of education are relevant. The first is simply the impact on individual citizens: How different are economic outcomes if an individual has more human capital? The second involves the macroeconomic outcomes for the state: How is state economic development altered by changing the human capital of the state? This analysis focuses on the second topic of the aggregate effects of schooling on state economic development, a topic that has received relatively little analysis. The impact of education on individuals has been extensively studied and is largely subsumed in the consideration of aggregate outcomes.[2]

While policy discussions of state economic development often range over a variety of

[2] See Mincer (1974), Card (2001), Heckman, Lochner, and Todd (2006), and Hanushek et al. (2015).

topics, a primary policy instrument is invariably the nature and performance of the public schools. Unfortunately, the existing analysis frequently suffers from poor and indirect measures of schooling outcomes. Instead of actually measuring the skills of individuals, these studies rely on a simple proxy – school attainment, or the average years of schooling of the population. This measure has prima facie support, because a primary purpose of schooling is increasing the skills of citizens. It also proves convenient, because of its ready availability in individual data and in aggregate state and national data.

Nonetheless, measurement issues are severe and compromise investigations of the growth implications of educational improvements.[3] The inappropriate measurement of skills introduces significant analytical problems. More importantly, it also removes the analysis from the key policy issues surrounding school quality.

The most relevant prior research comes from cross-country analyses that focus on the impact of knowledge capital, or the aggregate skills of countries, on international growth. This cross-country analysis is far more extensive than analysis of within-country growth, and it is relevant to development across regions of the U.S.[4] This research not only provides the motivation for our subsequent state analysis but also indicates how to interpret our state estimates found in this analysis.

2.1 Knowledge Capital and Economic Growth

Prior theoretical and empirical work – largely developed in an international context – has

[3] Similar measurement problems affect analyses of the individual returns to schooling; see Hanushek et al. (2015).

[4] Note that historically, empirical growth analysis focused on the time-series patterns for the U.S. as a whole; see Denison (1985) and Jorgenson and Griliches (1967).

pursued a variety of specifications of the underlying growth process.[5] A simple characterization of this, however, is that growth rates can be considered as a function of workers' skills along with other systematic factors.

$$growth = \alpha_1 \; human\ capital + \alpha_2 \; other\ factors + \varepsilon \qquad (1)$$

This formulation suggests that nations or states with more human capital tend to continue to make greater productivity gains than nations or states with less human capital, although it is possible that any induced growth in productivity disappears over time.[6]

The empirical macroeconomic literature focusing on cross-country differences in economic growth has overwhelmingly employed measures related to school attainment, or years of schooling, to test the human capital aspects of growth models. This approach has been emulated in cross-state analyses. And, empirical applications have tended to find a significant positive association between quantitative measures of schooling and economic growth.

Nevertheless, these formulations introduce substantial bias into the picture of economic growth. Average years of schooling is a particularly incomplete and potentially misleading measure of education for comparing the impacts of human capital on the economies of different countries or states. It implicitly assumes that a year of schooling delivers the same increase in knowledge and skills regardless of the education system. For example, a year of schooling in Brazil is assumed to create the same increase in productive human capital as a year of schooling in Korea or that a year of schooling in Mississippi is the same as a year in Massachusetts. Formulations relying on this measure of human capital also assume that formal schooling is the

[5] See the reviews in Hanushek and Woessmann (2008, (2015a).

[6] A major difference of perspective in modeling economic growth rests on whether education should be thought of as an input to overall production, affecting the level of income but not the growth rate in the long run (augmented neoclassical models, as in Mankiw, Romer, and Weil (1992)) or whether education directly affects the long-run growth rate (endogenous growth models as in Lucas (1988), Romer (1990), and Aghion and Howitt (1998)). See Aghion and Howitt (2009) for a textbook introduction.

only source of education and that variations in non-school factors have negligible effects on education outcomes and skills. This neglect of differences in the quality of schools and in the strength of family, health, and other influences is probably the major drawback of such a quantitative measure of schooling.

The role of other influences is in fact acknowledged in a standard version of an education production function as employed in a very extensive literature (see Hanushek (1986, (2002) for reviews). This formula expresses skills as a function of a range of factors (expressed linearly for expositional purposes):

$$\textit{human capital} = \beta_1 \textit{ schools} + \beta_2 \textit{ families} + \beta_3 \textit{ ability} + \beta_4 \textit{ health} + \beta_5 \textit{ other factors} + \upsilon \qquad (2)$$

In general, human capital combines both school attainment and its quality with the other relevant factors, including education in the family, health, labor-market experience, and so forth.

Thus, while school attainment has been a convenient measure to use in empirical work because the data are readily available across individuals, across time, and across countries, its use ignores differences in school quality in addition to other important determinants of people's skills.

A more satisfying alternative is to consider variations in cognitive skills as a direct measure of the human capital input into empirical analyses of economic growth. Focus on cognitive skills has a number of potential advantages. First, it captures variations in the knowledge and ability that schools strive to produce and thus relates the putative outputs of schooling to subsequent economic success. Second, by emphasizing total outcomes of education, it incorporates skills from any source – including families and innate ability as well as schools. Third, by allowing for differences in performance among students whose schooling differs in quality (but possibly not in quantity), it acknowledges – and invites investigation of – the effect of different policies on school quality.

2.2 International Growth

The analysis of state growth in this paper has its foundation in cross-country growth analysis, and the interpretation of results for state growth builds on basic international models. To set the stage, we present an overview of basic results on long-term international growth.[7]

Table 1 presents the basic results for the association between educational outcomes and economic growth in 1960-2000 for the sample of 50 countries for which both economic growth data and measures of cognitive skills, or knowledge capital, are available from international assessments of math and science.[8] The inclusion of (log) initial GDP per capita in all specifications simply reflects the fact that it is easier to grow more rapidly when farther from the technology frontier, because it is only necessary to imitate others rather than invent new things.[9]

When knowledge capital is ignored (column 1 of Table 1), years of schooling is significantly associated with average annual growth rates in real GDP per capita in 1960-2000. However, once the test measure of human capital is included (column 2), cognitive skills are highly significant and years of schooling becomes statistically insignificant, as the estimated coefficient drops to close to zero. Furthermore, the variation in cross-country growth explained by the model increases from 21 percent to 67 percent when human capital is measured by cognitive skills rather than years of schooling.

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[7] See Hanushek and Woessmann (2012, (2015a) for a more complete description of the data, the estimation, and the interpretation of the international growth models.

[8] The specific cognitive skill measure used here averages the standardized country scores on all international student achievement tests that have been performed between 1964 and 2003 in math and science at the primary through end of secondary level. During this period, twelve separate international tests were administered that produce 36 different scores for subject-year-age combinations. The scores from the different tests were combined on a common metric through empirical calibration (Hanushek and Woessmann (2015a)).

[9] As discussed further in terms of state growth in section 6.6 below, putting initial GDP per capita in logarithmic form permits assessment of alternative forms of the growth model that have been suggested in the prior literature; see Hanushek and Woessmann (2015a).

The estimated coefficient on cognitive skills implies that an increase of one standard deviation in educational achievement yields an average annual growth rate over the 40 years of observation that is two percentage points higher. This historical experience suggests a very powerful response to improvements in educational outcomes, particularly when compared to the average 2.3 percent annual growth within the sampled countries over the past two decades.

The final column of Table 1 includes two measures of the economic institutional structure of countries. There is an extensive literature indicating that good economic institutions foster faster growth and may also affect the returns to cognitive skills.[10] To deal with the effect of institutions, in column 3 we simply add two common (and powerful) institutional measures related to the quality of the underlying economic environment: openness of the economy and security of property rights. The results show that cognitive skills continue to exert a positive and highly significant effect on economic growth independent of the measures related to the quality of institutions, although the estimated impact of cognitive skills is reduced from 2 to around 1.4 on average.

These last estimates are particularly relevant to the growth experience of U.S. states. The U.S. as a nation is generally regarded to have among the best economic institutions in the world, on these and other dimensions. Looking into the future for the U.S., given its well-established institutions, the impact of cognitive skills found in column 3 seems most appropriate, and we can judge our state estimates below in relation to this international benchmark.

2.3 A Brief Discussion of Causality

The fundamental question such analysis raises is whether the tight relationship between cognitive skills and economic growth can be interpreted as a causal one that supports direct

[10] See North (1990), Murphy, Shleifer, and Vishny (1991), and Acemoglu, Johnson, and Robinson (2005).

policy actions. In other words, if achievement were raised, would growth rates be expected to go up by a commensurate amount? Work on differences in growth among countries, while extensive over the past two decades, has been plagued by legitimate questions about whether any truly causal effects have been identified, or whether the estimated statistical analyses simply pick up a correlation that emerges for other reasons.

Knowing that the relationship is causal, and not simply a byproduct of some other factors, is clearly very important from a policy standpoint. Policymaking requires confidence that by improving academic achievement, countries and states will bring about a corresponding improvement in the long-run growth rate. If the relationship between test scores and growth rates simply reflects other factors that are correlated with both test scores and growth rates, policies designed to raise test scores may have little or no impact on the economy.

We present a summary of the investigation of causality in the international results, because we largely rely upon these results in interpreting our subsequent state growth models.[11] While it is difficult to address the key identification issues conclusively, the combined evidence from a variety of complementary analyses strongly supports a causal interpretation of the effect of cognitive skills on economic growth.

The early studies that found positive effects of years of schooling on economic growth may well have been suffering from reverse causality. They correctly identified a relationship between improved growth and more schooling, but incorrectly saw the latter as the cause and not the effect (e.g., Bils and Klenow (2000)). As nations become richer, they buy more of all goods, including schooling.

There is *a priori* less reason to think that higher student achievement is caused by economic

[11] This section summarizes the detailed analysis found in Hanushek and Woessmann (2015a), chapter 4.

growth. For one thing, scholars have found little impact of additional education spending on achievement outcomes, in particular in the cross-country setting, so it is unlikely that the relationship comes from growth-induced resources lifting student achievement.[12] But this observation can be extended to investigate further the primary issues of identification that have been previously discussed.

First, specification tests show that the models in Table 1 are quite insensitive to different measures of cognitive skills, various groupings of countries (including some that eliminate regional differences), specific sub-periods of economic growth, and the inclusion of other proposed factors including measures of geographical location, political stability, capital stock, and population growth. These specification tests rule out some basic problems attributable to hypothesized omitted causal factors that have been noted in prior growth work.

Second, the most obvious reverse-causality issues arise because growth rates over the period 1960 to 2000 are related to test scores for roughly the same period. But for a sample of 25 countries where test performance up to 1984 can be related to economic growth in the period 1985-2009, the estimation shows a positive effect of early test scores on subsequent growth rates that is almost twice as large as that displayed above. Indeed, this fact itself may be significant, because it is consistent with the possibility that skills have become even more important for the economy in recent periods.

Third, the important international differences in test scores may not reflect school policies but instead might arise because of health and nutrition differences in the population or simply because of cultural differences regarding learning and testing. However, instrumental variable estimates based on institutional characteristics of each country's school system (exit

[12] See the review of international evidence in Hanushek and Woessmann (2011). For the U.S., see Hanushek (2003).

examinations, autonomy of school decision making, relative teacher salaries, and private schooling) yield essentially the same results as presented in Table 1. This finding supports a causal interpretation of the effect of cognitive skills as well as the conclusion that schooling policies can have direct economic returns.

Fourth, it is possible that countries with good economic institutions also have good school systems but that schools themselves do not directly affect growth. To circumvent this problem, we consider the implications of differences in measured skills within a single economy (the U.S.) by comparing immigrants to the U.S. who have been educated in their home countries with immigrants from the same countries but educated just in the U.S. This comparison finds that the cognitive skills of the immigrant's home country lead to higher incomes, but only if the immigrant was in fact educated in the home country. These results, which also hold when Mexicans (the largest U.S. immigrant group) are excluded and when only immigrants from English-speaking countries are included, rule out the possibility that test scores simply reflect cultural factors or economic institutions of the home country.

Finally, perhaps the toughest test of causality is relating *changes* in test scores over time to *changes* in growth rates, essentially introducing country fixed effects. For 12 OECD countries, the magnitude of trends in educational performance can be related to the magnitude of trends in growth rates over time. Indeed, the gains in test scores are very closely related to the gains in growth rates over time, a result consistent with a causal interpretation of the impact of test scores.[13]

Each approach to determining causation is subject to its own uncertainty, but the combined evidence consistently points to the conclusion that differences in cognitive skills lead to

[13] It is very unlikely that the changes in growth rates suffer the same reverse causality concerns suggested previously, because a change in growth rate can occur at varying income levels and varying rates of growth.

significant differences in economic growth. Establishing the case of the international evidence on causality provides considerable support for a causal interpretation of our subsequent state growth models, where comparable investigations to address causality directly are more difficult.

3. Stocks of Cognitive Skills of U.S. States

The approach that we pursue in this paper is to duplicate the cross-country growth regressions for U.S. states. We view this estimation as a natural extension of the international estimation, but one that amplifies the international work. Specifically, given the commonly held view that the operations of U.S. labor and capital markets are superior to those found in most other countries, the U.S. growth results tend to show what the growth frontier looks like.

Duplicating the international models, however, requires developing measures of the state knowledge capital for each state – something that has not previously been available.[14] The fundamental difficulty is that no direct measures of cognitive skills for the labor force in each state exist. We have measures of skills of the student body by state from the National Assessment of Educational Progress (NAEP), but the students are not the same as the adults in the workforce because of the large amount of mobility across states.

Our analysis of deriving state human capital measures proceeds in three steps. First, we construct mean test scores of the students of each state in order to estimate the cognitive skills of those students who remain in the state and become part of the relevant labor force (section 3.1). Second, we adjust state test scores for migration between states, assuming that migration is not selective (section 3.2). Third, we adjust these scores for selectivity of the interstate migration flows as well as for selective international migration (section 3.3). This discussion provides an

[14] Some prior analysis has considered growth and income differences across states, but the measures of human capital have focused on school attainment. See, for example, Tamura (2006) and Turner, Tamura, and Mulholland (2013).

overall summary. The details of the data development can be found in a companion paper (Hanushek, Ruhose, and Woessmann (2015), Appendix B). In our analysis of state growth models below, we show the impact of each of these adjustments.

3.1 Construction of Average State Test Scores

The NAEP provides reliable U.S. state-level test score data (see National Center for Education Statistics (2014)), and we start by combining all available state test score information into one average score for each state.[15] We focus on the NAEP mathematics test scores in grade eight.[16] For most states, NAEP started to collect eighth-grade math test scores on a representative sample at the state level in 1990 and repeated testing every two to four years. From 2003 forward, these test scores are consistently available for all states. We use all available state NAEP data through 2011. Note that an eighth-grader in 1990 would be age 35 in 2011, implying that the majority of workers in the labor force would never have participated in the testing program.

The NAEP state-level test results, however, prove to be quite stable over time. An analysis of the variance of grade eight math tests shows that 88 percent of test variation lies between states and just 12 percent represents variation in state-average scores over the two decades of observations due to changed performance or to test measurement error. Thus, we begin by calculating an average state score using all available NAEP observations for each state. These

[15] Throughout our analysis, our state sample for the growth analysis refers to 47 states. Alaska, Delaware, and Wyoming are excluded from the analysis because of their GDP's dependence on natural resources or finance; see Hanushek, Ruhose, and Woessmann (2015) for details. In the later projections, we include all states.

[16] If we use reading test scores in grade eight, which are available only from 1998 onwards, the results are very similar. NAEP also tests students in grade four but these are not available by parental education, which is vital information for our adjustment for selective migration. We did construct mean state test scores for the different grades and subjects, however, and they turn out to be very highly correlated. The correlations range from 0.87 between eighth-grade math and fourth-grade reading to 0.96 between eighth-grade reading and fourth-grade reading, indicating that each of the test scores provides similar information about the position of the state in terms of student achievement.

are estimated as state fixed effects in a regression with year fixed effects on scores that were normalized to a common scale that has a U.S. mean of 500 and a U.S. standard deviation of 100 in the year 2011.

Our primary analysis relies on these estimates of skills for students educated in each of the states. Ranking states by their average test score, Minnesota, North Dakota, Massachusetts, Montana, and Vermont make up the top five states, whereas Hawaii, New Mexico, Louisiana, Alabama, and Mississippi constitute the bottom five states. The top-performing state over the two decades (Minnesota) surpasses the bottom-performing state (Mississippi) by 0.87 standard deviations. Various analyses suggest that the average learning gain from one grade to the next is roughly equivalent to one-quarter to one-third of a standard deviation in test scores. That is, in eighth-grade math, the average achievement difference between the top- and the bottom-performing state amounts to some three grade-level equivalents, underscoring the importance of attention to the skill differences of workers.

3.2 Adjustment for Non-Selective Interstate Migration

The second step of our derivation involves adjusting for migration between U.S. states. We start by assuming that migration is not selective and turn to a consideration of selectivity in the migration process in the next section.

Obviously, not all current workers in a state were educated in that state. From the Census data, we know the state of birth of all workers in each state who were born in the United States. On average, just 54 percent of the working-age population in 2010 is living in their state of birth (see Appendix Figure A1), indicating that many were unlikely to have been educated in their current state of residence. But there is also substantial variation across states. For example, in Nevada, only 17 percent of the state's residents in 2010 report having been born there. At the other extreme, 77 percent of the population in Louisiana was born there. These numbers indicate that interstate migration is a major issue when assessing the cognitive skills of a state workforce.

To adjust for interstate migration, we start by computing the birthplace composition of each state from the Census data. For each state, we break the state working-age population into state locals (those born in their current state of residence), interstate migrants from other states (those born in the U.S. but outside current state of residence), and international immigrants (those born outside the U.S.). For the U.S.-born population, we construct a state-by-state matrix of the share of each state's working-age population born in each of the other states. For the purposes of the growth models, the adjustments are based on state population shares for the year 1970, which is the starting period of our growth analysis below.

Assuming that interstate migrants have not left their state of birth before finishing grade eight, we can then combine test scores for all U.S.-born workers of a state according to the separate birth-state scores.[17] This adjusted skill measure thus assigns all state locals and all interstate migrants the mean test score of their state of birth – which only for the state locals will be equivalent to the mean test score of students in their state of residence.

3.3 Adjustment for Selective Interstate and International Migration

The next step in our analysis is to take into consideration that interstate migration is, in fact, selective and to adjust for international migration.

Adjustment for Selective Interstate Migration

The previously derived skill measure implicitly assumes that the internal migrants from one

[17] This approach parallels that of Card and Krueger (1992), except our focus is on achievement in birth states as opposed to resources. Across the United States as a whole, 86 percent of children aged 0-14 years still live in their state of birth, so that any measurement error introduced by this assumption should be limited. With the exception of Washington, DC (34 percent) and Alaska (53 percent) – neither of which is used in our analysis – the share is well beyond 70 percent in each individual state (own calculations based on the 2010 U.S. Census data (Ruggles et al. (2010)).

state to another are a random sample of the residents of their state of origin. This obviously need not be the case, as the interstate migration pattern may be very selective. For example, Ohio university graduates might migrate to a very different set of states than Ohioans with less education might migrate to – and it would be inappropriate to treat both flows the same.[18]

The NAEP scores of population subgroups by educational background provide an overall suggestion of the potential importance of selective migration. Comparing the NAEP scores of students from families where at least one parent has some kind of university education with students from families where the parents do not have any university education, we find an average difference of over 0.6 standard deviations for the U.S. as a whole.

Against this background, to account for selective interstate migration we allow for different migration patterns across states by education levels. In particular, we make the assumption that we can assign to the working-age population with a university education the test score of children with parents who have a university degree in each state of birth, and equivalently for those without any university education. That is, from the Census data we first compute separate population shares of university graduates and non-university graduates by state of birth for the working-age population of each state. With these population shares, we then assign separate test scores by educational category. This adjustment is done for interstate migrants to deal with selectivity of in-migration, but also for state locals because of selective outmigration and differential fertility which generate differences in the cohort composition between those in the workforce and those taking the NAEP tests.

Adjustment for Selective International Migration

A remaining topic is how to treat immigrants – those educated in a foreign country. On

[18] This selective migration was one of the fundamental critiques of Heckman, Layne-Farrar, and Todd (1996) about the analysis of Card and Krueger (1992).

average, international migration is less frequent than interstate migration, with more than 90 percent of U.S. workers born in the United States. However, recent years show large state variation in this percentage: in 2010, 99 percent of the working-age population in West Virginia was born in the United States, but only 70 percent of the working-age population in California (see Hanushek, Ruhose, and Woessmann (2015), Figure 5).

Immigrants also require attention. From the Census data, we know the country of origin of each immigrant. So for each country of origin, we can combine information from the major international tests – PISA, TIMSS, and PIRLS[19] – and rescale these test scores to the NAEP scale (Hanushek, Peterson, and Woessmann (2013)).[20] We determine whether a person was educated in his or her home country by information on age of immigration into the United States. These data allow us to add in scores for the foreign-born and foreign-educated working-age population of each state.

Presumably, selectivity is an even greater concern for international immigrants than for interstate migration. We know that international migration in particular is a highly selective process (Borjas (1987); Grogger and Hanson (2011)), implying that the mean test score of the country of birth is unlikely to represent accurately the cognitive skills of the migrant group.[21] The United States has rather strict immigration laws, and skill-selective immigration policies represent a substantial hurdle for potential immigrants (Bertoli and Fernández-Huertas Moraga (2015); Ortega and Peri (2013)). In addition, individuals self-select into migration (McKenzie,

[19] PISA stands for Programme for International Student Assessment, TIMSS for Trends in International Mathematics and Science Study, and PIRLS for Progress in International Reading Literacy Study.

[20] For countries of origin that did not participate in the international achievement tests, we imputed values by regional averages; see Hanushek, Ruhose, and Woessmann (2015).

[21] While not directly comparable, others considering the degree of self-selection do, however, argue that it might not be as strong; see Hendricks (2002) and Schoellman (2012), both of whom are using immigrant wages in the U.S. to consider the magnitude of income differences across countries. Schoellman also addresses differentials for Mexican immigrants.

Gibson, and Stillman (2010)). Thus, for example, only the most skilled and motivated are able to gather information on possible destination countries, and only they possess skills that are rewarded in a foreign country. While generally framed only in terms of school attainment, the existing research on international migration mostly indicates that historically migrants who go to developed countries are better educated, on average, than those they leave behind (Borjas (1987); Chiswick (1999); Grogger and Hanson (2011)).

While we do not have detailed information on the selectivity of migration from each country, a first variant to adjust for selective immigration – parallel to the treatment of locals and interstate migrants – would be to adjust international scores by the educational distribution of the immigrant workforce in each state of current residence.[22] But it is reasonable to expect that immigrants are further self-selected within schooling attainment categories. If this is true, then average test scores of the source country – either simple averages or averages by parental background – may not describe actual migrant skill levels very well. Their true skill level may exceed the home country mean test score, and even the mean test score within each educational category.

To account for this selection, we use the 90th percentile of the source-country skill distribution. In this adjustment, we thus assume that the migrants are positively selected from the source-country population – i.e., that they are much more skilled than those left behind. Note that under this assumption, immigrants from a low-performing country would still be assumed to score below immigrants from a high-performing country on average, as well as below better-educated U.S. workers.

The assumption of a positive selection may not hold for all source countries. In particular,

[22] While not reported here, results based on such an adjusted measure are very similar to the results reported below.

given the close geographic proximity and the substantial income differences, Mexicans – the largest immigrant group into the U.S. at roughly one quarter of all immigrants – may constitute a special group of immigrants that shows different selection patterns than the migrant population from most other countries.[23] We therefore also consider an alternative adjustment for the possibility that the character of immigrants from Mexico differs from that of immigrants from other countries. Specifically, based on evidence in Kaestner and Malamud (2014) that Mexican migrants to the U.S. are not a selected subgroup of their home country population, the alternative measure assesses the skills of Mexican immigrants at the national Mexican mean (while continuing to assess other immigrants at the 90th percentile).[24]

4. Growth Models across U.S. States

The basis for our subsequent projection analysis is estimation of growth models that duplicate the international growth models for U.S. states. Further, we show the importance of more accurate estimates of the human capital stock of each state.

Looking across states is obviously different from the international comparisons earlier. Looking across countries introduces assumptions that all countries are operating on the same production function – even though GDP per capita in Uganda is only one-thirtieth that in the U.S. Because the U.S. states can be more readily presumed to be operating on the same production function, it is more natural to look at how human capital and other input differences affect state incomes. At the same time, one might expect interstate movement of people and of capital to erode differences in economic advantages.

[23] Existing research on the selectivity of Mexican migrants comes to very different conclusions about the extent to which they are selected from their home-country population (e.g., Chiquiar and Hanson (2005); Fernández-Huertas Moraga (2011); Kaestner and Malamud (2014)).

[24] There may be other heterogeneity in the migrants from individual countries, but we have no way to incorporate this into our estimates.

In this analysis, we focus on the average annual growth rate in real per capita state GDP for the period 1970-2010.[25] This is related to (the log of) the initial level of GDP per capita in 1970, (the log of) physical capital per worker,[26] school attainment,[27] and our cognitive skills measures. Appendix Table A1 provides descriptive statistics.

Table 2 duplicates the growth models in Table 1 except it now applies to U.S. states. The overall results are remarkably similar. The first column provides the simple growth model based just on school attainment as the measure of human capital. Without regard for quality, attainment is significantly related to state growth rates. Nonetheless, as with the international models, these estimates are quite misleading: any trace of the impact of pure school attainment disappears when the measure of quality is included.

The remaining columns investigate the alternative test measures of the knowledge capital in each state. Column 2 takes average test scores with no adjustment for interstate migration or immigration, a measure that we believe is quite imperfect. We then adjust for the scores of interstate migrants between U.S. states (column 3). This adjustment brings us closer to our preferred adjustment, but it ignores the selectivity on internal migration along with the character of international immigration to each state.

Our preferred measure of a state's cognitive skills adjusts the internal U.S. migrants for selectivity based on education levels and introduces the quality of the immigrants into each state,

[25] Real state GDP per capita of each state is constructed following the approach of Peri (2012), using nominal GDP data at the state level from the Bureau of Economic Analysis (2013b). Nominal GDP are deflated to the base year 2005 by the nation-wide implicit GDP price deflator (Bureau of Economic Analysis (2013c)). For real GDP per capita, we divide total real GDP by total population from the Bureau of Economic Analysis (2013a).

[26] Data on physical capital per worker in 1970 are provided in Turner, Tamura, and Mulholland (2013).

[27] The U.S. Census micro data permit a calculation of school attainment for the working-age population of each state (Ruggles et al. (2010)). We focus on the population aged 20 to 65 not currently in school. The transformation of educational degrees into years of schooling follows Jaeger (1997). Due to their relatively weak labor-market performance (Heckman, Humphries, and Mader (2011)), GED holders are assigned 10 years of schooling.

again assuming that immigrants fall in the 90th percentile of the cognitive skill distribution for their home country.

The results of the preferred specification (column 4) reinforce our view that state growth is very consistent with international growth. The estimate of the growth parameter of 1.42 is essentially identical to the relevant international coefficient of 1.43 (column 3, Table 1), allowing us to rely on the extensive robustness analysis, sensitivity testing, and causality analysis of the international work.[28]

The final column (column 5) reports results of the alternative measure that assesses the skills of Mexican immigrants at the national Mexican mean (while continuing to assess other immigrants at the 90th percentile). Even given the relative importance of Mexican immigrants, particularly for some states, the estimated growth coefficient is virtually unchanged.

The marginal impact of knowledge capital on growth rates across states (using the estimates in column 4 of Table 2) are shown in Figure 1. The remarkable consistency of the state growth model with the international growth model lends confidence to basing projections of future state growth on these results.

5. A Basic Framework for Growth Projections

The focus of this paper is understanding what school improvement would mean for state incomes. For this, we assume that our baseline model of growth (column 4, Table 2) holds into the future. By this, a one standard deviation improvement in skills would imply a 1.4 percentage point faster growth in state income in the long run. Of course, a one standard deviation improvement in state average scores is a huge change – more than today's range across states.

[28] The preferred comparison of coefficients relies on the estimates adjusted for economic institutions, since the U.S. already has high-quality institutions and the institutions are mostly constant across states.

Therefore, we consider a range of alternative achievement goals that appear quite feasible.

An important aspect of education policy is how it affects dynamic changes over time. Education policy is not instantaneous, and it takes some time before the effects of any education policy are fully felt. We consider a series of state changes that occur over ten years; i.e., current students only move fully to higher achievement after ten years of reform.[29] We assume that the pace of student improvement is linear so that ten percent of the ultimate gain accrues each year.

Of course, improvement of students is also not the same as improvement in the labor force. The labor force improves only as new, more skilled students replace retiring less skilled workers. We calculate how the average quality of the labor force changes by assuming that 2.5 percent of the labor force retires each year and is replaced by better educated workers. This implies that the labor force does not fully reach its ultimate quality for 50 years (10 years of reform followed by 40 years of retirements).

We project the annual growth of each state in each year based on the average quality of the labor force in each given year.[30] The projections assume that the mobility patterns across states will hold in the future but that the size of the state populations will remain constant. In other words, the mix of the workforce by state of education remains constant into the future. We look at the implications for state GDP growth over an 80 year period, reflecting the expected lifetime of somebody born today. Given the extended period of labor force reform, the largest impacts clearly appear in the more distant future. In recognition of this, we weight early gains more heavily than later gains. Specifically, we calculate present values by discounting future years at three percent per year (implying that gains in 2095, after 80 years, are weighted only 9 percent as

[29] Details of the projections are described in Appendix B.

[30] As indicated above, economists have used different models to characterize long-run growth. In the robustness section 6.6 below, instead of having growth rates directly dependent on the level of cognitive skills, we also consider the possibility that growth rates depend just on the amount of change in cognitive skills.

heavily as initial year gains).[31]

With these parameter choices, we project how the GDP of each state would develop with and without the modeled reform.[32] The economic gain of each reform is then calculated as the difference in discounted future GDP between a situation with and without reform. Appendix A describes the different steps of this projection model in detail.

6. Economic Gains of Alternative School Improvement Programs

We provide economic calculations for various plausible state improvement scenarios. The scenarios differ in the magnitude of the improvement from reform and in the actions that other states take toward reform. In particular, the interrelationships among states through migration imply that individual state actions have a muted impact on economic growth when not accompanied by complementary actions by other states.

For perspective, between 1992 and 2011 Maryland, Florida, Delaware, and Massachusetts each were able to gain over 60 percent of a standard deviation on NAEP over the past two decades.[33] Our baseline reform scenario below considers an improvement of one-quarter standard deviation over a ten year period. Each of the fourteen most improved states were able to obtain average gains at a rate sufficient to bring scores up by this amount. (State variations in achievement growth are found in Appendix Figure A3).

[31] A standard value of the social discount rate used in long-term projections on the sustainability of pension systems and public finance is 3 percent (e.g., Börsch-Supan (2000)), a precedent that is followed here. As a practical value for the social discount rate in cost-benefit analysis (derived from an optimal growth rate model), Moore et al. (2004) suggest using a time-declining scale of discount rates for intergenerational projects that do not crowd out private investment, starting with 3.5 percent for years 0-50, 2.5 percent for years 50-100. By contrast, the influential Stern Review report that estimates the cost of climate change uses a discount rate of only 1.4 percent, thereby giving a much higher value to future costs and benefits (Stern (2007)).

[32] The growth of the economy with the current level of skills is projected to be 1.5 percent, consistent with the projected growth in labor productivity from the Congressional Budget Office or the rough average of OECD growth over the past two decades.

[33] For a discussion of these calculations, see Hanushek, Peterson, and Woessmann (2013). Note that data are available for only 41 states because not all states participated in the state-representative samples before 2003.

6.1 Scenario I: Improvement by a Quarter of a Standard Deviation

Our baseline economic projections consider the impact on each state of having its workers improve by one-quarter standard deviation. This is consistent with a variety of underlying changes: a state improves its own students by ¼ standard deviation and keeps all of them in the state; or a state improves its own students sufficiently more to make up for the fact that some will leave; or the workers migrating into the state show the same improvement. In all three cases, the aggregate effect is simply a ¼ standard deviation improved score of future workers in the state. (Subsequently, we also consider the isolated improvement by each state that is not compensated by improved immigrants).

One-quarter standard deviation does not have much natural appeal, but it can be interpreted readily from the current state distribution of NAEP scores (eighth-grade math in 2015). A gain of ¼ standard deviation implies that the lowest ranked state (Alabama) would move up to being 41^{st} in the ranking (currently California). Or alternatively, ¼ standard deviations would move the 8^{th}-ranked state (Virginia) to the top.

This improvement translates into a uniform gain across states of a 0.35 percentage point faster growth rate in the long run. This improvement, while seemingly modest, yields future increases in state GDP that have a present value of 2.6 times current state GDP. There are a variety of ways to understand this, but it effectively amounts to a level increase of (discounted) GDP of 5.6 percent on average – considerably above the current total spending on education across the states. By the end of our projection period (2095), state GDP would be more than 20 percent above that expected with the current level of achievement in each state.

The absolute magnitude of the increase of course depends on the size of the state. (Individual state projections are found in Appendix Table B1). Because California's economy is the largest, it would see a present value of reform of more than $6 trillion. New York would see gains of more than $3.5 trillion.

6.2 Scenario II: Improvement to Top-Performing State

An alternative reform would be bringing each state up to the best state over the past two decades: Minnesota. This improvement clearly has varying impacts, depending on how far each state is from Minnesota. Minnesota, by this scenario, stays the same, and another 20 states have gains of less than the baseline scenario of 0.25 standard deviations. (See Appendix Table B2 and Figure 3, below). Nonetheless, the overall improvement for the nation is larger than the baseline scenario by fifty percent.

Again, this scenario is meant to match a feasible scenario where the schools across the nation are sufficient to bring up all students to high standards. Of course, since the schools are not the only factor in achievement, this requires the schools in states with more disadvantaged populations to improve even more than those with less disadvantaged populations.

The average growth improvement in the long run for the U.S. would be one-half percentage point higher with this improvement than with current skill levels. The overall present value of gain is more than four times current U.S. GDP – or the equivalent of an average increase of 9 percent over the next 80 years.

But there is considerable heterogeneity of the effects of such a reform across U.S. states. States that perform close to the level of Minnesota such as North Dakota, Massachusetts, and Montana would see relatively modest economic gains of less than 2 percent of discounted future GDP on average. By contrast, states whose performance is rather distant from the top-performing state such as Mississippi, Alabama, Louisiana, New Mexico, Hawaii, and California (as well as the District of Columbia) would all see gains that exceed 15 percent of discounted future GDP on average – or more than seven times their current GDP. Obviously, however, having the lowest performing states move to equal those at the top within ten years is a very ambitious, and perhaps unrealistic, scenario.

6.3 Scenario III: Improvement to Best State in the Region

The ambition of the prior scenario is documented by the fact that the seven enumerated states would have to improve by more than 0.6 standard deviations. This is the rate of improvement seen by Maryland, the fastest improving state over the past two decades – feasible but difficult in twenty years and likely unattainable in ten years.

Therefore, we next consider a more modest scenario where each state improves to the best state in its division.[34] The largest required improvements (except for Washington, DC) are now New Mexico (0.6 standard deviations) and Nevada (0.5 standard deviations) which are rising to the level of the State of Washington. The overall average improvement in worker skills is now 0.18 standard deviations for the nation.

This more modest improvement in worker skills still implies a present value of improved GDP that averages twice current GDP (Appendix Table B3). This gain is worth 4 percent of discounted future GDP.

Again, the projected reform gains vary greatly across states. States such as New Mexico, Nevada, Hawaii, California, Rhode Island, Arizona, Louisiana, and Mississippi (and Washington, DC) would gain more than four times their current GDP, whereas by construction all nine division leaders would see no improvement in achievement and thus no economic gain.

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[34] The division leaders in achievement are Wisconsin (East North Central), Kentucky (East South Central), New Jersey (Mid-Atlantic), Montana (Mountain), Massachusetts (New England), Washington (Pacific), Virginia (South Atlantic), Minnesota (West North Central), and Texas (West South Central).

6.4 Scenario IV: Getting Every Student at least to the Basic Level

The prior scenarios imagine improvements across the full range of schooling. An alternative, which is essentially a more limited variant of No Child Left Behind, is to bring all students (and subsequent workers) at least up to the "basic skill level" as defined by NAEP (for calculations, see Appendix C). According to NAEP, the basic level implies "partial mastery of prerequisite knowledge and skills that are fundamental for proficient work at each grade."[35] In 2011, 27 percent of students in the U.S. fell below the basic level. Implemented across the United States, this reform would raise average achievement by 17 percent of a standard deviation.

Note, however, that this projection is a rather artificial policy change, because it assumes no spillovers in quality to anybody starting with basic or above achievement. Not only is it difficult to understand what kind of policies might produce such a pattern of gains but also it does not match historical evidence across the NCLB era (Hanushek, Peterson, and Woessmann (2013)).

One thing that this policy does promise is more inclusive growth. Specifically, it is designed to bring up those with the lowest skill levels – just the group that has found it increasingly difficult to participate effectively in the labor market. Given the strong relationship between skills and individual earnings in the U.S. economy (Hanushek et al. (2015)), enhancing the skills at the bottom would have a noticeable impact on the distribution of earnings, and ultimately income, in the U.S.

In terms of aggregate income, this reform would raise the level of future GDP by 3.8 percent on average (Appendix Table B4). In 2095, GDP would be 15 percent higher than without the

[35] See https://nces.ed.gov/nationsreportcard/achievement.aspx, accessed April 18, 2015. Note that there is confusion about various achievement levels. NAEP basic level corresponds roughly to the achievement level that the average state chose to define as proficient under the federal NCLB (Hanushek and Lindseth (2009)). The achievement level of PISA level 1 used in international projections is quite close to NAEP basic (Hanushek and Woessmann (2015b)).

reform. Some states with few current students falling below the basic level such as North Dakota, Massachusetts, Minnesota, South Dakota, Montana, Texas, and New Hampshire would see reform gains that are somewhat less than their current GDP (Figure 2). But some other states with large numbers of students below the basic level such as California, Alabama, and Mississippi (as well as the District of Columbia) would see gains exceeding three times their current GDP.

6.5 Scenario with Single-State Improvement and Outmigration

The prior estimates provided a picture of the results of simultaneous improvement of schools across the states. As a result, any locally educated student who subsequently moves to another state is replaced by a student who has been on a similar path of skill improvement. What would it mean for each state to be the only improving state?

The implications of this alternative scenario are easiest to see in terms of the baseline projections of Scenario II – all states improve up to the best state. But now on a state-by-state basis, we assume that educational improvement applies just to the students who are both educated in the state and remain in the state. In other words, the quality of education for in-migrants does not improve. We also assume that the historical proportion of students educated within each state that migrated out continues to be the same in the future. At the extremes, only 23.1 percent of the people born in Texas migrated out and are no longer living in the state, but as many as 64.5 percent of the people born in Alaska migrated out (See Appendix Figure A2).[36] Other states where more than half of the people born in the state migrated out are Wyoming,

[36] Note that because of changes in the size of the state population, the share of the state-born population that still lives in the state can differ markedly from the share of the *current* state population that was born in the state (as depicted in Appendix Figure B1). For example, Texas has the lowest rate of outmigration as a share of the state-born population, but is a middling state in terms of the share of the current population born in the state. By contrast, Nevada has the lowest fraction of the current population born in the state, but not the highest share of outmigration.

North and South Dakota, Montana, and Nevada.

Given these historical rates of interstate mobility, the skill increase of the workforce that is ultimately seen in each state is 0.24 standard deviations on average, instead of 0.38 standard deviations when all states are moving to the best state. As a result, the gains for each state fall, on average, from four times current GDP to on average 2.6 times.

But the specific difference for each individual state is very important, because it shows how the incentives change when states operate in their own local interest (Appendix Table B5). This difference varies greatly across states (Figure 3).[37] In states such as Texas, North Carolina, Georgia, Wisconsin, Minnesota, South Carolina, and Tennessee with relatively little outmigration, results are not much affected. By contrast, in states with substantial outmigration such as Alaska and Wyoming, results decline dramatically.

To be sure, the more skilled workers that migrate out of state will help the economy in other states to which they move. It is just that the state making the investment sees a noticeably smaller improvement if the state is the only reformer. And this presumably lessens the interest in school investment for each state.

6.6 Alternative Parameter Choices

The projections obviously depend upon the specific model and parameter. Economists have debated the correct way to specify the growth model; the leading alternative (see Appendix D) describes human capital as affecting the level of income instead of its growth rate as assumed here. Additionally the projections make a series of assumptions that affect the results. The rows of Table 3 present summaries of how varying parameter choices affect the estimates of the aggregate economic gains as variants of Scenario I. Using a neoclassical projection reduces the

[37] Detailed results are shown in Appendix Table A2.

present value of gains by just 11 percent. Shortening the time horizon from 2095 to 2075 reduces the overall gain by nearly half, indicating that the strongest gains accrue once the reform has reached the whole labor force. Assuming that the educational reform takes 20 years rather than 10 years reduces the overall gains by 18 percent.

Given that the growth coefficient is estimated with some statistical uncertainty, the next two rows report results when using a growth coefficient that is greater or smaller by one standard error of the coefficient estimated in the underlying growth model in Table 2. That is, the growth coefficient is taken at 1.96 and 0.88, respectively, as opposed to the best estimate of 1.42. The final two rows use a discount rate of 2 and 4 percent, respectively, rather than the 3 percent of the baseline model.

Both parameter variations obviously have a substantial effect on the projected economic value of improvement. But, the key element of the different parameter variations is that the gains are uniformly very large.

6.8 Overall Summary and Extension

We have presented a wide range of improvement scenarios. Table 4 provides an overall summary of the aggregate effects. The overall effects of the various scenarios for the United States as a whole range from $32 trillion for bringing just the lowest performing students up to a basic level to $76 trillion from bringing all states up to the best performing state.

But it is also clear that the different results vary greatly across the different U.S. states. As indicated by the large standard deviations of the reform results across the U.S. states (reported in parentheses), some states stand to gain even more from the specific reforms, whereas other states (that are already at a higher achievement level) gain less than the modal state.

Our projections so far have stayed within the limits of feasible reform scenarios based on achievement levels and growth that have been observed inside the United States. In a final set of projections, we can recognize the possibilities for improvement that can be seen in international data (Hanushek and Woessmann (2015b)). Two straightforward comparison groups of students are Canadian and Finnish students. Canada is an obvious comparison because of its proximity to the U.S., both geographically and economically. Finland is included because of its demonstrated improvement in international tests, making it a top performing country and one that the U.S. might try to emulate.[38]

As indicated by the bottom two entries in Table 4, projections of economic growth for reaching the Canadian level are very similar to those in Scenario II, because the top-performing U.S. state over the last 20 years (Minnesota) is roughly at the level of the average Canadian student. Finnish students, however, on average achieve 6 percent of a standard deviation above Minnesota, or 44 percent of a standard deviation above the U.S. average. The aggregate economic impact of bringing all students up to Finnish levels would be $89 trillion in present value or 10.5 percent of the discounted future GDP, again with substantial variation across the U.S. states.

7. Conclusions

We have shown feasible ways to estimate the human capital stock for each U.S. state in a way that is consistent with current policy discussions. In particular, we have assessed the cognitive skills of the workforce in each state, reflecting the historically high rates of labor mobility across states. Once done, we then are able to estimate state growth models which interestingly align perfectly with the more extensive existing work on cross-country growth

[38] The Canadian and Finnish achievement levels are taken from the available international tests, rescaled to the NAEP scale in the same way as used to adjust the immigrants in our analysis in section 3.3 above.

models.

These growth models permit explicit consideration of how policies to improve school quality can be expected to affect the future income of each state. This consideration is importantly based on the dynamics of improving the labor force including the time to improve the schools and the deferred impact of school improvement on the quality of the future labor force.

The growth projections have a simple interpretation. According to past patterns of growth in state GDP, there is a huge economic incentive for each state to improve its schools. Improved schools lead naturally to higher skilled workforces, and the impact of skills of the workforce is clear and strong.

Past performance also shows that improving performance is possible. For example, our baseline scenario of improving student performance by one-quarter standard deviation within ten years is consistent with the historical gains in 14 states.

The gains of such an improvement scenario over the lifetime of somebody born today are enormous. An improvement of 0.25 standard deviations would yield gains (in present value terms) that are 2.6 times current GDP, or 5.6 percent of discounted future GDP. To put this into perspective, education spending on K-12 education by states and localities accounts for roughly four percent of GDP in 2010.[39] Thus, our estimated gains would on average pay for all of the K-12 education in the states and yield extra returns that could both deal with any current fiscal problems of the states and make the citizens better off.

The baseline gains assume that all states are moving simultaneously toward improvement. If instead we considered only individual state improvements, the gains would fall by about 39

[39] Education spending at all levels by states and localities accounts for 5.9 percent of GDP in 2010 (U.S. Department of Education (2013), Tables 30-33). Two-thirds of that total goes to K-12 education.

percent on average. The U.S. states are very interconnected through migration, and this has immediate implications for the future of each state.

The impacts of educational improvements clearly take a considerable time to be realized. Improving the performance of today's students does not lead to an improved labor force until these students have left school and entered into employment and until more skilled workers become a significant portion of the labor force. As a result, the economic gains come in the future – beyond the normal election cycles for current politicians. To some, this discrepancy between terms in office and the economic returns to improved schools implies that politicians will not take optimal actions but instead will underinvest in improved schools. But, there are clear other examples where politicians take long-run actions that far exceed election cycles: actions of climate change or actions on procurement of new weapon systems for defense, for example. The future economic well-being of the U.S. depends on improvement of the American schools, and it seems overly cynical to presume that the elected leadership is incapable or unlikely to take actions that are distinctly in the long-run interest of their country.

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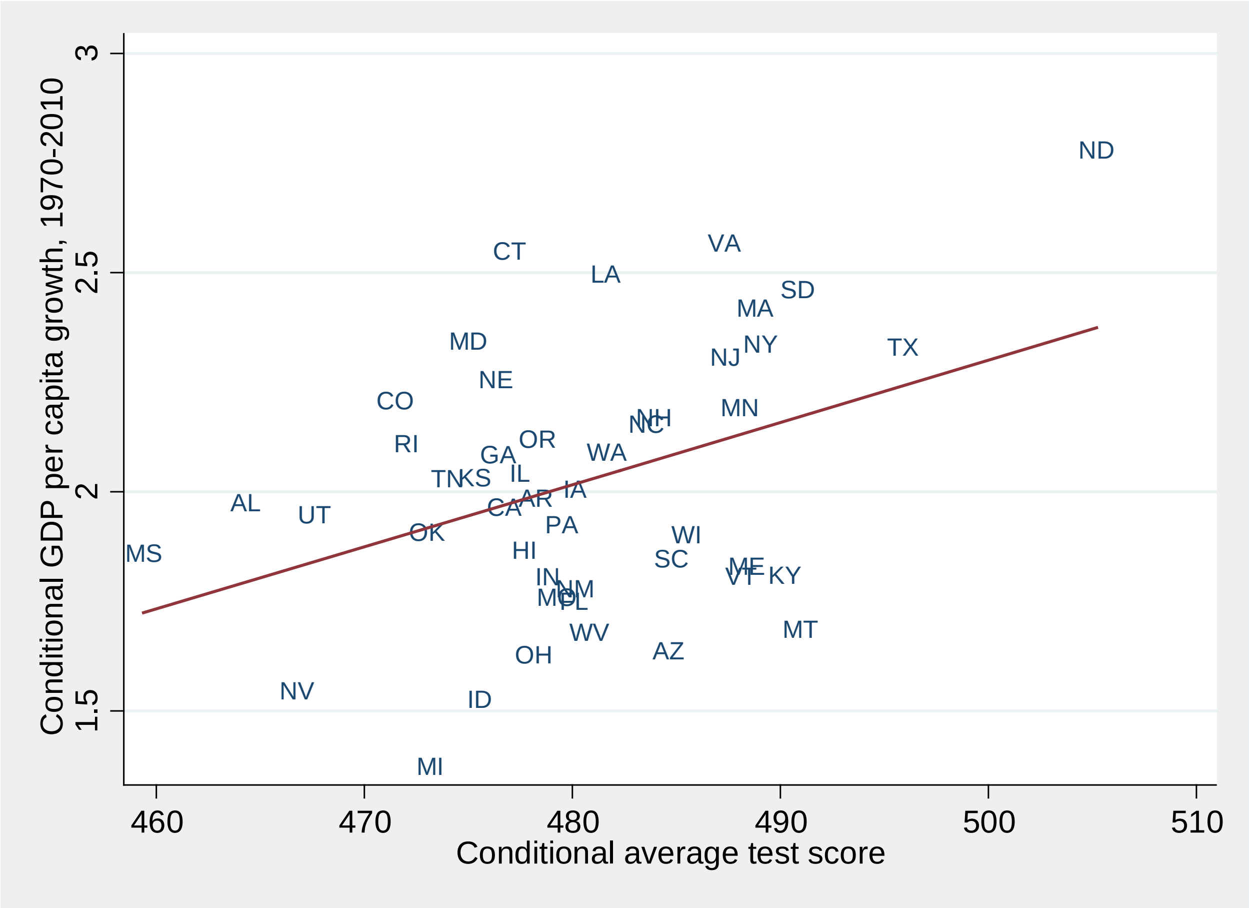
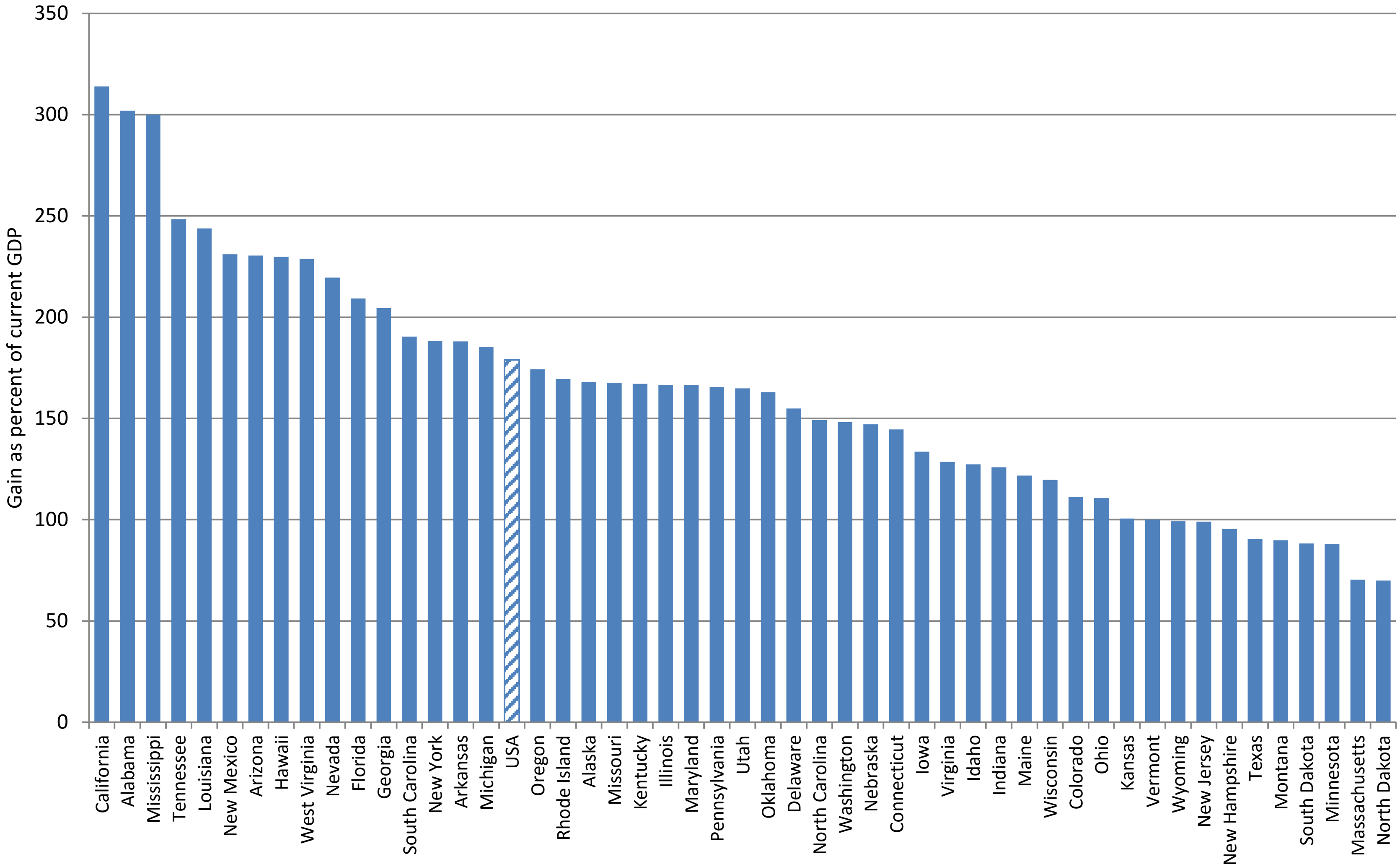
Figure 1: Test Scores and Economic Growth across U.S. States



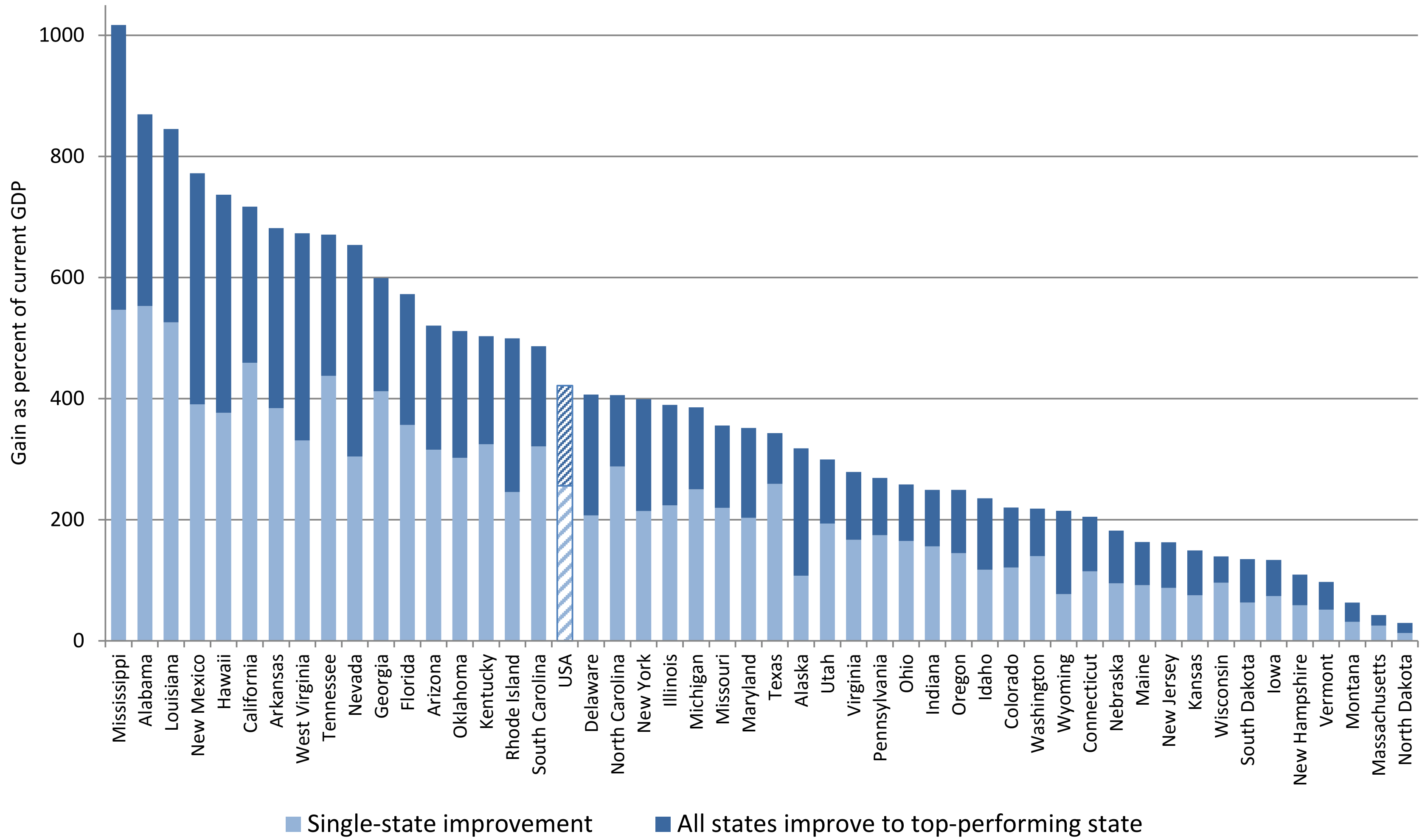
Notes: Added-variable plot of a regression of the average annual rate of growth (in percent) of real GDP per capita in 1970-2010 on the initial level of (log) real GDP per capita in 1970, average test scores adjusted for interstate migrants by education and for international migrants by the 90th percentile in country of birth in 1970, average years of schooling in 1970, and (log) real physical capital per worker in 1970 (mean of the unconditional variables added to each axis). See column 4, Table 2.

Figure 2: Effect on GDP of Scenario IV: Getting Every Student at least to the Basic Level



Notes: Present value of future increases in GDP until 2095 due to a reform that brings each student at least to the basic level, expressed as a percentage of current GDP. See Appendix Table B4for details. Washington, DC (511 percent) is missing for expositional purposes.

Figure 3: Difference in the Effect on GDP between Individual and Joint State Reform (Scenario II)



Notes: The figure shows the present value of the reform in percent of current GDP when all states improve to the top-performing state (Minnesota) and when each state improves individually (light parts of the bars). Washington, DC (181 percent for single-state improvement, 1,701 percent for all states improvement) is missing for expositional purposes.

Table 1: Basic Cross-Country Growth Regressions

	(1)	(2)	(3)
Cognitive skills		2.062***	1.426***
		(0.313)	*(0.446)*
Initial years of schooling (1960)	0.286**	-0.136	-0.145
	(0.110)	*(0.082)*	*(0.082)*
log (initial physical capital per capita (1960))	-.120	0.317	0.304
	(0.496)	*(0.342)*	*(0.313)*
log (initial GDP per capita (1960))	-1.197*	-1.154**	-1.343***
	(0.658)	*(0.460)*	*(0.422)*
Openness			0.816
			(0.499)
Protection against expropriation			0.243
			(0.239)
Constant	3.133***	-4.849***	-4.206***
	(0.348)	*(1.234)*	*(1.413)*
No. of countries	50	50	47
F (openness, protection)			5.11***
R^2	0.207	0.672	0.738

Notes: Dependent variable: average annual growth rate in GDP per capita, 1960-2000. Cognitive skill measure refers to average score on all international tests 1964-2003 in math and science, primary through end of secondary school. Robust standard errors in parentheses: statistical significance at * 10%, ** 5%, *** 1%. Source: Hanushek and Woessmann (2012, (2015a).

Table 2: State Growth Regressions, 1970-2010

	(1)	(2)	(3)	(4)	(5)
Cognitive skills (CS): average state test score		1.010***			
		(0.313)			
CS: adjusted for non-selective interstate migration			1.263***		
			(0.450)		
CS: adjusted for selective interstate and international migration				1.419**	
				(0.540)	
CS: adjusted for selective migration (Mexicans assessed at national mean)					1.465***
					(0.539)
Initial years of schooling (1970)	0.146*	-0.129	-0.140	-0.177	-0.187
	(0.083)	*(0.110)*	*(0.127)*	*(0.142)*	*(0.142)*
log (initial physical capital per worker (1970))	-0.209	0.369	0.297	0.147	0.175
	(0.313)	*(0.397)*	*(0.402)*	*(0.364)*	*(0.366)*
log (initial GDP per capita (1970))	-1.108**	-1.040**	-1.067***	-1.152***	-1.151***
	(0.474)	*(0.391)*	*(0.394)*	*(0.397)*	*(0.394)*
Constant	13.715***	4.250	4.211	6.724**	6.274*
	(3.314)	*(3.562)*	*(3.999)*	*(3.271)*	*(3.334)*
No. of states	47	47	47	47	47
R^2	0.235	0.392	0.360	0.352	0.359

Notes: Dependent variable: average annual growth rate in GDP per capita, 1970-2010. CS: average state test score: estimated average NAEP test score for the state over all available years (1992 to 2011) in eighth-grade math. CS: adjusted for non-selective interstate migration: average state test score adjusted by assigning interstate migrants the mean test score of their state of birth. CS: adjusted for selective interstate and international migration: test score assigns all U.S. born people the test score of their state of birth by educational level (high school or less vs. at least some college education) and international migrants the test score at the 90th percentile of the test score distribution in their country of birth. In all adjustments, state population shares for the year 1970 are used to weight the different test scores. Robust standard errors in parentheses: statistical significance at * 10%, ** 5%, *** 1%.

Table 3: Alternative Models and Parameter Choices

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Baseline model	47,249	262	5.6	21.6	0.35	0.25
Neoclassical growth model	42,134	234	4.7	15.5	0.00	0.25
Time horizon: until 2075	24,832	138	3.5		0.35	0.25
Reform duration: 20 years	38,917	216	4.6	19.5	0.35	0.25
Growth coefficient +1 std. err.	66,705	370	7.9	31.0	0.49	0.25
Growth coefficient –1 std. err.	28,628	159	3.4	12.9	0.22	0.25
Discount rate: 2 percent	83,286	462	7.0	21.6	0.35	0.25
Discount rate: 4 percent	27,626	153	4.4	21.6	0.35	0.25

Notes: Effect on GDP of Scenario I (improvement by 1/4 standard deviation). See notes to Appendix Table B1.

Table 4: Summary of Results for the Different Scenarios of School Improvement

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Scenario I: 0.25 std. dev.						
U.S. total	47,249	262	5.6	21.6	0.35	0.25
Scenario II: Top-performing state						
U.S. total	75,938	422	9.0	36.1	0.54	0.38
Std. dev. across states		(306)	(6.6)	(28.8)	(0.34)	(0.24)
Scenario III: Best state in region						
U.S. total	35,648	198	4.2	16.5	0.26	0.18
Std. dev. across states		(223)	(4.8)	(20.1)	(0.27)	(0.19)
Scenario IV: Basic level						
U.S. total	32,229	179	3.8	14.6	0.24	0.17
Std. dev. across states		(77)	(1.6)	(6.5)	(0.10)	(0.07)
II with single-state improvement						
U.S. total	46,112	256	5.5	21.3	0.34	0.24
Std. dev. across states		(145)	(3.1)	(12.4)	(0.19)	(0.13)
Improvement to Canadian level						
U.S. total	77,313	429	9.2	36.8	0.55	0.39
Std. dev. across states		(307)	(6.6)	(29.0)	(0.34)	(0.24)
Improvement to Finnish level						
U.S. total	88,772	493	10.5	42.6	0.62	0.44
Std. dev. across states		(315)	(6.7)	(30.2)	(0.34)	(0.24)

Notes: Values for the U.S. as a whole and unweighted standard deviation across all U.S. states. Present value of future increases in GDP until 2095 due to reform, expressed in billion 2015 dollars, as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2095' indicates by how much GDP in 2095 is higher due to the reform (in percent). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in NAEP score' refers to the ultimate increase in educational achievement due to the reform. See text for parameters of the projection model.

Electronic Appendices

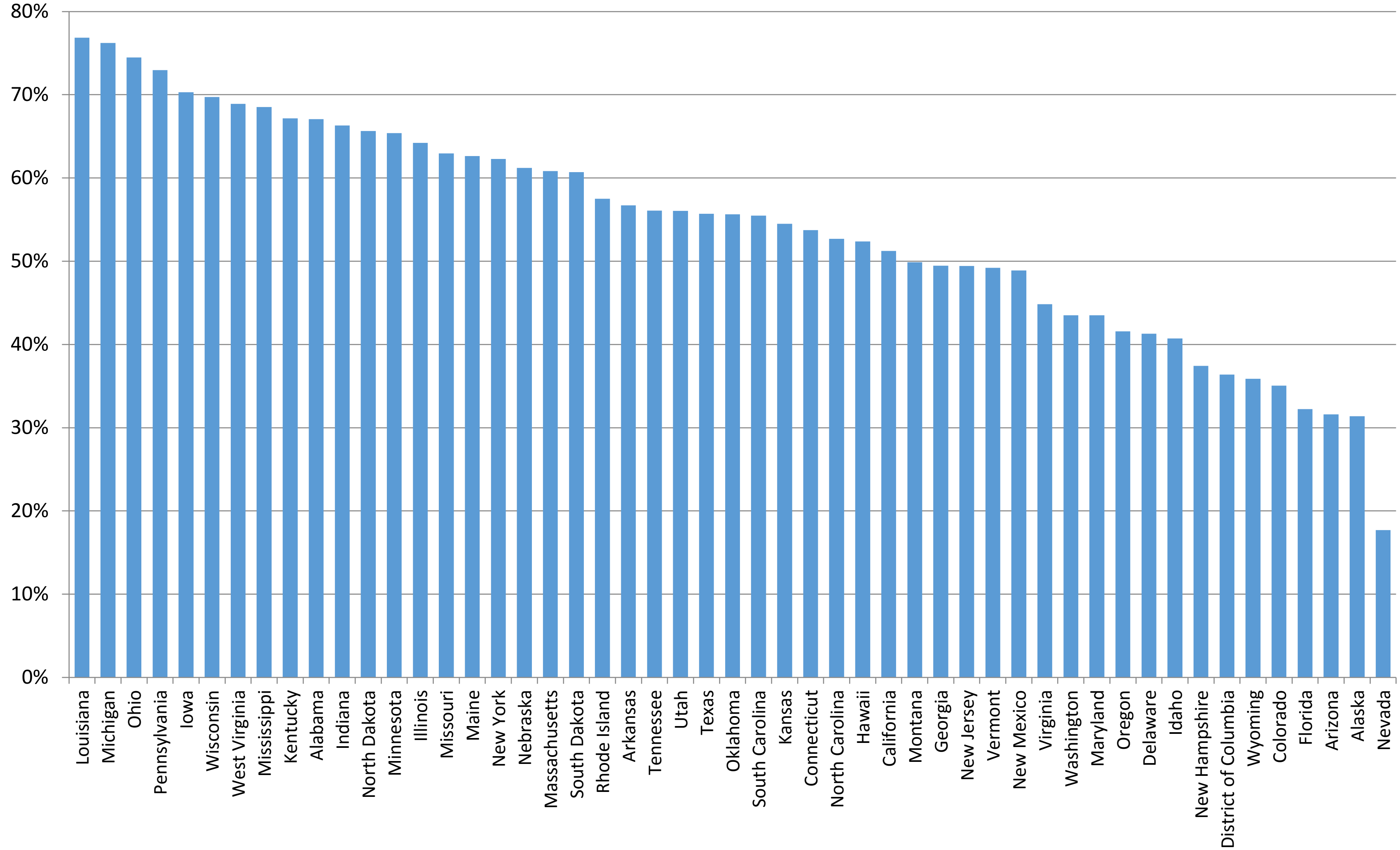
The following appendix material will appear in an electronic appendix. It is included here only for convenience.

Table A1: Summary State Statistics

	Mean	Std. dev.	Min	Max
GDP per capita annual growth rate, 1970-2010	2.240	0.307	1.561	2.893
Real GDP per capita, 1970	18,166	2,895	12,531	26,057
Real physical capital per worker, 1970	129,815	24,700	88,945	212,186
Years of schooling, 1970	11.08	0.578	9.999	12.05
Cognitive skills (CS):				
CS: average state test score	5.005	0.213	4.508	5.348
CS: adjusted for non-selective interstate migration	5.007	0.163	4.579	5.288
CS: adjusted for selective interstate and international migration	4.804	0.154	4.393	5.039
CS: adjusted for selective migration (Mexicans assessed at national mean)	4.802	0.154	4.393	5.038

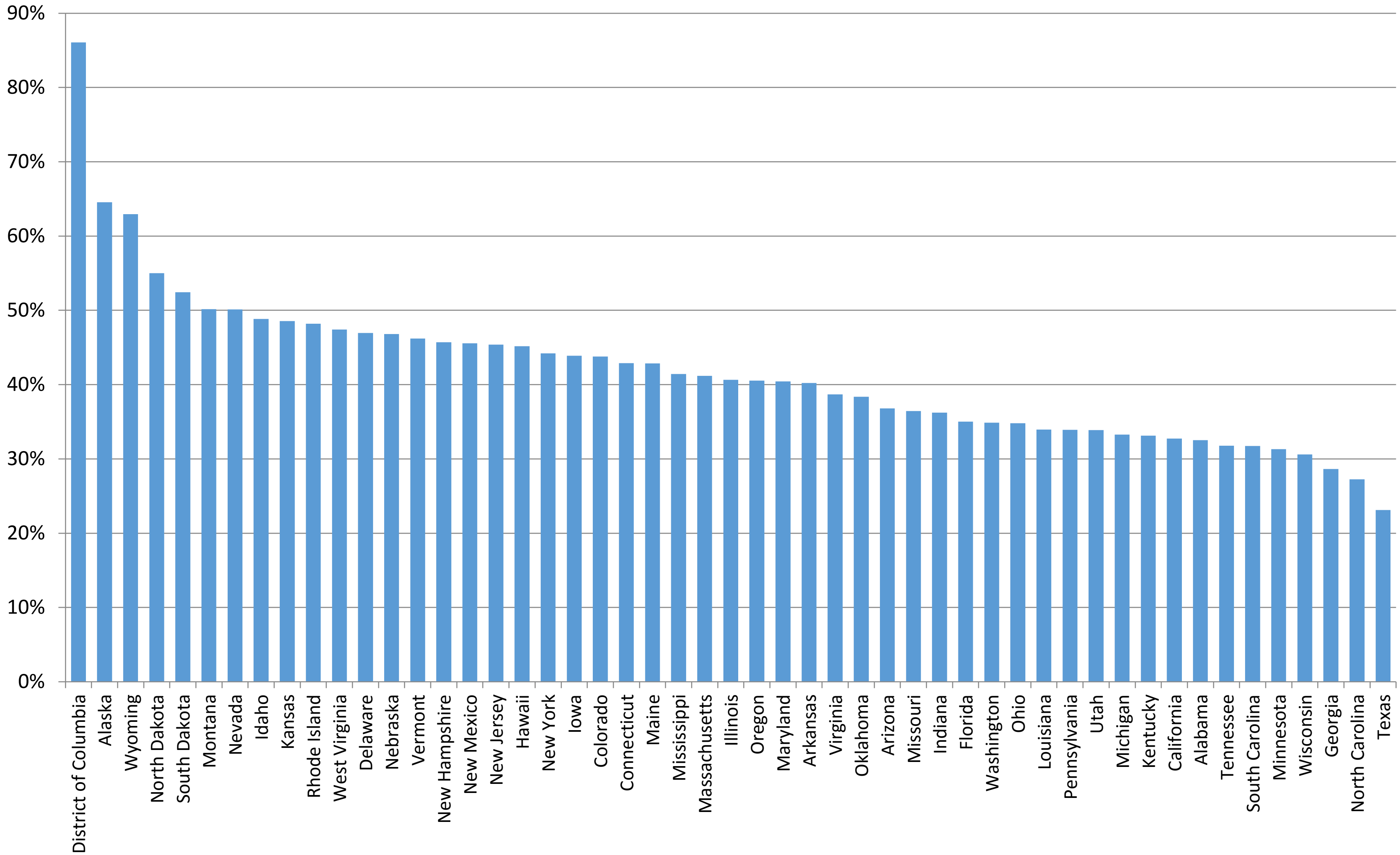
Notes: Data refer to 47 U.S. states (Alaska, Delaware, and Wyoming excluded).

Figure A1: Share of Current State Population Born in the State



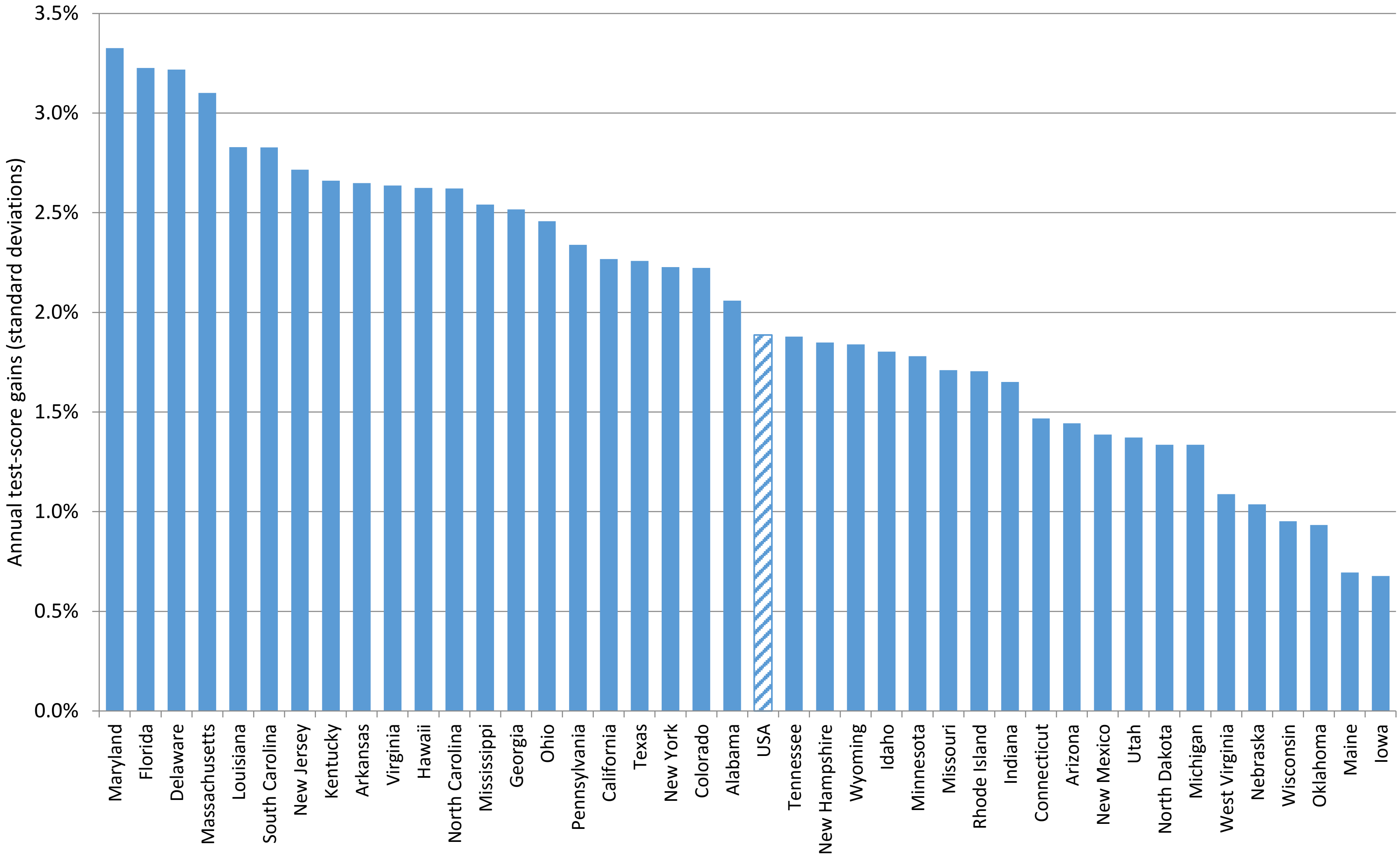
Notes: Share of the current working-age population (20 to 65 years old) who were born in the state. Three-year averages from 2010 to 2012. Source: Authors' calculations based on data from the American Community Survey (ACS), taken from the IPUMS – Integrated Public Use Microdata Series (Ruggles et al. (2010)).

Figure A2: Population Loss Rates: Share of State-Born Population Living in another State



Notes: Share of the current working-age population (20 to 65 years old) who were born in the state but are living in another state. Three-year averages from 2010 to 2012. Source: Authors' calculations based on data from the American Community Survey (ACS), taken from the IPUMS – Integrated Public Use Microdata Series (Ruggles et al. (2010)).

Figure A3: Historical Achievement Growth, 1992-2011



Notes: Estimated average annual test score gains in percent of a standard deviation based on NAEP achievement tests in math, reading, and science. Source: Hanushek, Peterson, and Woessmann (2013).

Appendix B. Projection Model

This appendix presents an overview of the projection model that is used to calculate the gains from a reformed education system. See Hanushek and Woessmann (2011b, 2015a) for a detailed description of projection models of educational reforms.

Reform Phases

The projection model follows four phases:

Phase 1 (2015-2025): Introducing the reform

In the first 10 years of the reform, the additional growth in GDP per capita is given by:

$$\Delta^t = growth\ coefficient * \Delta NAEP * \frac{1}{working\ life} * \frac{t - 2015}{10} + \Delta^{t-1}$$

The *growth coefficient* is obtained from the growth regressions in section 4 and is set to 0.0142 for the main results. $\Delta NAEP$ represents the growth in test score that is due to the reform. Each year, only a fraction of the workforce is replaced by younger workers who have obtained a better education. This is indicated by *1/working life*, with the working life set to 40 years. The term $\frac{t-2015}{10}$ indicates that it takes 10 years for the reform to be completely enrolled and fully effective.

Phase 2 (2026-2055): Replacing older workers by workers of the reform

After the first 10 years, the reform is fully effective and workers that join the workforce now bring with them the total benefit from the reformed education system. However, for the period of a working life, there will be still workers that have received their education under the old educational system. They will be replaced by the new workers. During the next 30 years, the additional growth can be described as follows:

$$\Delta^t = growth\ coefficient * \Delta NAEP * \frac{1}{working\ life} + \Delta^{t-1}$$

Phase 3 (2056-2065): Replacing workers who only partially obtained better education

After 40 years (the time span of a working life), all workers that have not gone through the reformed system are replaced by new workers. However, workers that obtained their education during the phase-in of the reform only partially profited from the new education system. They are now replaced by workers who received the benefits from the fully effective education system. The additional growth for the next 10 years is therefore:

$$\Delta^t = growth\ coefficient * \Delta NAEP * \frac{1}{working\ life} - (\Delta^{t-40} - \Delta^{t-41}) + \Delta^{t-1}$$

Phase 4 (after 2065): All workers have gone through the better education system

In this phase, the entire workforce has received the better education. The annual growth rate is now increased by the constant long-run growth effect:

$$\Delta = growth\ coefficient * \Delta NAEP$$

GDP with and without Reform

Our model assumes that without the reform GDP at time *t* would be:

$$GDP^t_{no\ reform} = GDP^{t-1}_{no\ reform} * (1 + potential\ growth)$$

Potential growth is set to 1.5 percent each year, based on the projected growth in labor productivity from the Congressional Budget Office.[1] With reform, the annual growth rate is increased by Δ^t:

$$GDP^t_{reform} = GDP^{t-1}_{reform} * (1 + potential\ growth + \Delta^t)$$

Cumulative Effect of the Reform

The total value of the reform is given by the discounted differences between GDP with and without reform. We calculate the gains from the improved system over 80 years, about the expected life span of a child that is born today. The discount rate in the baseline scenario is set to 3 percent.

$$Total\ value\ of\ the\ reform = \sum_{t=2015}^{t=2095} \left(GDP^t_{reform} - GDP^t_{no\ reform}\right) * (1 + discount\ rate)^{-(t-2015)}$$

[1] Congressional Budget Office. 2014. An Update to the Budget and Economic Outlook: 2014 to 2024 (August 2014), p. 47, Table 2-2. http://www.cbo.gov/publication/45653 (accessed 10/19/2014).

Table B1: Effect on GDP of Scenario I: Improvement by a Quarter Standard Deviation

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
USA	47,249	262	5.6	21.6	0.35	0.25
Alabama	557	262	5.6	21.6	0.35	0.25
Alaska	157	262	5.6	21.6	0.35	0.25
Arizona	810	262	5.6	21.6	0.35	0.25
Arkansas	333	262	5.6	21.6	0.35	0.25
California	6,082	262	5.6	21.6	0.35	0.25
Colorado	832	262	5.6	21.6	0.35	0.25
Connecticut	696	262	5.6	21.6	0.35	0.25
Delaware	199	262	5.6	21.6	0.35	0.25
District of Columbia	333	262	5.6	21.6	0.35	0.25
Florida	2,359	262	5.6	21.6	0.35	0.25
Georgia	1,316	262	5.6	21.6	0.35	0.25
Hawaii	220	262	5.6	21.6	0.35	0.25
Idaho	177	262	5.6	21.6	0.35	0.25
Illinois	2,110	262	5.6	21.6	0.35	0.25
Indiana	906	262	5.6	21.6	0.35	0.25
Iowa	463	262	5.6	21.6	0.35	0.25
Kansas	422	262	5.6	21.6	0.35	0.25
Kentucky	527	262	5.6	21.6	0.35	0.25
Louisiana	738	262	5.6	21.6	0.35	0.25
Maine	163	262	5.6	21.6	0.35	0.25
Maryland	964	262	5.6	21.6	0.35	0.25
Massachusetts	1,226	262	5.6	21.6	0.35	0.25
Michigan	1,216	262	5.6	21.6	0.35	0.25
Minnesota	895	262	5.6	21.6	0.35	0.25
Mississippi	308	262	5.6	21.6	0.35	0.25
Missouri	786	262	5.6	21.6	0.35	0.25
Montana	123	262	5.6	21.6	0.35	0.25
Nebraska	302	262	5.6	21.6	0.35	0.25
Nevada	405	262	5.6	21.6	0.35	0.25
New Hampshire	196	262	5.6	21.6	0.35	0.25
New Jersey	1,542	262	5.6	21.6	0.35	0.25
New Mexico	245	262	5.6	21.6	0.35	0.25
New York	3,661	262	5.6	21.6	0.35	0.25
North Carolina	1,384	262	5.6	21.6	0.35	0.25
North Dakota	140	262	5.6	21.6	0.35	0.25
Ohio	1,546	262	5.6	21.6	0.35	0.25
Oklahoma	489	262	5.6	21.6	0.35	0.25
Oregon	603	262	5.6	21.6	0.35	0.25

Table B1 (continued)

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Pennsylvania	1,824	262	5.6	21.6	0.35	0.25
Rhode Island	154	262	5.6	21.6	0.35	0.25
South Carolina	535	262	5.6	21.6	0.35	0.25
South Dakota	129	262	5.6	21.6	0.35	0.25
Tennessee	841	262	5.6	21.6	0.35	0.25
Texas	4,242	262	5.6	21.6	0.35	0.25
Utah	396	262	5.6	21.6	0.35	0.25
Vermont	83	262	5.6	21.6	0.35	0.25
Virginia	1,353	262	5.6	21.6	0.35	0.25
Washington	1,141	262	5.6	21.6	0.35	0.25
West Virginia	211	262	5.6	21.6	0.35	0.25
Wisconsin	794	262	5.6	21.6	0.35	0.25
Wyoming	117	262	5.6	21.6	0.35	0.25

Notes: Present value of future increases in GDP until 2095 due to reform, expressed in billion 2015 dollars, as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2095' indicates by how much GDP in 2095 is higher due to the reform (in percent). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in NAEP score' refers to the ultimate increase in educational achievement due to the reform. See text for parameters of the projection model.

Table B2: Effect on GDP of Scenario II: Improvement to Top-Performing State

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
USA	75,938	422	9.0	36.1	0.54	0.38
Alabama	1,847	869	18.6	77.6	1.05	0.74
Alaska	191	318	6.8	26.4	0.43	0.30
Arizona	1,608	521	11.1	44.4	0.67	0.47
Arkansas	864	682	14.6	59.4	0.85	0.60
California	16,630	717	15.3	62.8	0.89	0.62
Colorado	699	220	4.7	18.0	0.30	0.21
Connecticut	544	205	4.4	16.7	0.28	0.20
Delaware	309	407	8.7	34.2	0.53	0.38
District of Columbia	2,162	1701	36.4	166.2	1.79	1.26
Florida	5,149	573	12.3	49.2	0.73	0.51
Georgia	3,005	599	12.8	51.6	0.76	0.53
Hawaii	617	737	15.8	64.7	0.91	0.64
Idaho	159	236	5.0	19.3	0.32	0.23
Illinois	3,138	390	8.3	32.7	0.51	0.36
Indiana	862	249	5.3	20.5	0.34	0.24
Iowa	236	134	2.9	10.8	0.19	0.13
Kansas	240	149	3.2	12.1	0.21	0.15
Kentucky	1,010	503	10.8	42.8	0.65	0.46
Louisiana	2,380	845	18.1	75.2	1.02	0.72
Maine	102	164	3.5	13.3	0.23	0.16
Maryland	1,293	352	7.5	29.3	0.47	0.33
Massachusetts	200	43	0.9	3.4	0.06	0.04
Michigan	1,789	386	8.3	32.3	0.51	0.36
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	1,194	1017	21.8	92.4	1.19	0.84
Missouri	1,065	356	7.6	29.7	0.47	0.33
Montana	30	63	1.4	5.1	0.09	0.06
Nebraska	210	182	3.9	14.8	0.25	0.18
Nevada	1,011	654	14.0	56.8	0.82	0.58
New Hampshire	82	109	2.3	8.8	0.15	0.11
New Jersey	956	163	3.5	13.2	0.22	0.16
New Mexico	720	772	16.5	68.1	0.95	0.67
New York	5,573	399	8.5	33.5	0.52	0.37
North Carolina	2,141	406	8.7	34.1	0.53	0.38
North Dakota	16	30	0.6	2.4	0.04	0.03
Ohio	1,524	258	5.5	21.3	0.35	0.25
Oklahoma	953	512	11.0	43.6	0.66	0.46
Oregon	574	249	5.3	20.5	0.34	0.24

Table B2 (continued)

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Pennsylvania	1,872	269	5.8	22.2	0.36	0.26
Rhode Island	294	500	10.7	42.5	0.64	0.45
South Carolina	992	487	10.4	41.3	0.63	0.44
South Dakota	66	135	2.9	10.9	0.19	0.13
Tennessee	2,152	671	14.4	58.4	0.84	0.59
Texas	5,547	343	7.3	28.6	0.46	0.32
Utah	453	300	6.4	24.8	0.40	0.28
Vermont	31	97	2.1	7.8	0.14	0.10
Virginia	1,439	279	6.0	23.0	0.38	0.26
Washington	950	218	4.7	17.9	0.30	0.21
West Virginia	540	673	14.4	58.6	0.84	0.59
Wisconsin	423	140	3.0	11.3	0.19	0.14
Wyoming	95	215	4.6	17.5	0.29	0.21

See notes to Appendix Table B1.

Table B3: Effect on GDP of Scenario III: Improvement to Best State in the Region

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
USA	35,648	198	4.2	16.5	0.26	0.18
Alabama	629	296	6.3	24.5	0.40	0.28
Alaska	54	91	1.9	7.3	0.13	0.09
Arizona	1,372	444	9.5	37.5	0.58	0.41
Arkansas	370	292	6.2	24.1	0.39	0.28
California	10,494	453	9.7	38.3	0.59	0.41
Colorado	484	153	3.3	12.4	0.21	0.15
Connecticut	422	159	3.4	12.9	0.22	0.16
Delaware	86	113	2.4	9.1	0.16	0.11
District of Columbia	1,593	1254	26.8	117.0	1.41	1.00
Florida	2,337	260	5.6	21.4	0.35	0.25
Georgia	1,421	283	6.1	23.4	0.38	0.27
Hawaii	394	470	10.1	39.9	0.61	0.43
Idaho	113	167	3.6	13.6	0.23	0.16
Illinois	1,891	235	5.0	19.3	0.32	0.23
Indiana	356	103	2.2	8.3	0.14	0.10
Iowa	236	134	2.9	10.8	0.19	0.13
Kansas	240	149	3.2	12.1	0.21	0.15
Kentucky	0	0	0.0	0.0	0.00	0.00
Louisiana	1,218	433	9.3	36.5	0.56	0.40
Maine	73	118	2.5	9.5	0.17	0.12
Maryland	237	65	1.4	5.2	0.09	0.06
Massachusetts	0	0	0.0	0.0	0.00	0.00
Michigan	1,072	231	5.0	18.9	0.31	0.22
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	488	415	8.9	34.9	0.54	0.38
Missouri	1,065	356	7.6	29.7	0.47	0.33
Montana	0	0	0.0	0.0	0.00	0.00
Nebraska	210	182	3.9	14.8	0.25	0.18
Nevada	887	573	12.3	49.3	0.73	0.51
New Hampshire	49	65	1.4	5.2	0.09	0.06
New Jersey	0	0	0.0	0.0	0.00	0.00
New Mexico	642	689	14.7	60.1	0.86	0.60
New York	3,071	220	4.7	18.0	0.30	0.21
North Carolina	593	112	2.4	9.0	0.16	0.11
North Dakota	16	30	0.6	2.4	0.04	0.03
Ohio	658	112	2.4	9.0	0.16	0.11
Oklahoma	271	145	3.1	11.8	0.20	0.14
Oregon	65	28	0.6	2.2	0.04	0.03

Table B3 (continued)

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Pennsylvania	689	99	2.1	8.0	0.14	0.10
Rhode Island	264	448	9.6	37.8	0.58	0.41
South Carolina	375	184	3.9	15.0	0.25	0.18
South Dakota	66	135	2.9	10.9	0.19	0.13
Tennessee	436	136	2.9	11.0	0.19	0.13
Texas	0	0	0.0	0.0	0.00	0.00
Utah	347	230	4.9	18.8	0.31	0.22
Vermont	17	53	1.1	4.3	0.08	0.05
Virginia	0	0	0.0	0.0	0.00	0.00
Washington	0	0	0.0	0.0	0.00	0.00
West Virginia	280	349	7.5	29.0	0.46	0.33
Wisconsin	0	0	0.0	0.0	0.00	0.00
Wyoming	65	147	3.2	11.9	0.20	0.14

See notes to Appendix Table B1.

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Table B4: Effect on GDP of Scenario IV: Getting Every Student at least to the Basic Level

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
USA	32,229	179	3.8	14.6	0.24	0.17
Alabama	641	302	6.5	25.0	0.40	0.29
Alaska	101	168	3.6	13.6	0.23	0.16
Arizona	712	230	4.9	18.9	0.31	0.22
Arkansas	238	188	4.0	15.3	0.26	0.18
California	7,277	314	6.7	26.0	0.42	0.30
Colorado	353	111	2.4	8.9	0.16	0.11
Connecticut	384	145	3.1	11.7	0.20	0.14
Delaware	118	155	3.3	12.6	0.21	0.15
District of Columbia	649	511	10.9	43.6	0.66	0.46
Florida	1,882	209	4.5	17.1	0.29	0.20
Georgia	1,026	204	4.4	16.7	0.28	0.20
Hawaii	193	230	4.9	18.8	0.31	0.22
Idaho	86	127	2.7	10.3	0.18	0.12
Illinois	1,339	166	3.6	13.5	0.23	0.16
Indiana	435	126	2.7	10.2	0.18	0.12
Iowa	236	134	2.9	10.8	0.19	0.13
Kansas	162	101	2.2	8.1	0.14	0.10
Kentucky	335	167	3.6	13.6	0.23	0.16
Louisiana	686	244	5.2	20.0	0.33	0.23
Maine	76	122	2.6	9.8	0.17	0.12
Maryland	612	166	3.6	13.5	0.23	0.16
Massachusetts	329	70	1.5	5.6	0.10	0.07
Michigan	860	185	4.0	15.1	0.25	0.18
Minnesota	301	88	1.9	7.1	0.12	0.09
Mississippi	352	300	6.4	24.8	0.40	0.28
Missouri	502	168	3.6	13.6	0.23	0.16
Montana	42	90	1.9	7.2	0.13	0.09
Nebraska	170	147	3.2	11.9	0.20	0.14
Nevada	339	220	4.7	18.0	0.30	0.21
New Hampshire	71	95	2.0	7.7	0.13	0.09
New Jersey	582	99	2.1	7.9	0.14	0.10
New Mexico	215	231	4.9	18.9	0.31	0.22
New York	2,625	188	4.0	15.3	0.26	0.18
North Carolina	787	149	3.2	12.1	0.21	0.15
North Dakota	37	70	1.5	5.6	0.10	0.07
Ohio	652	111	2.4	8.9	0.15	0.11
Oklahoma	304	163	3.5	13.2	0.23	0.16
Oregon	401	174	3.7	14.2	0.24	0.17

Table B4 (continued)

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Pennsylvania	1,151	165	3.5	13.4	0.23	0.16
Rhode Island	100	170	3.6	13.8	0.23	0.16
South Carolina	388	190	4.1	15.5	0.26	0.18
South Dakota	43	88	1.9	7.1	0.12	0.09
Tennessee	796	248	5.3	20.4	0.34	0.24
Texas	1,463	91	1.9	7.3	0.13	0.09
Utah	249	165	3.5	13.4	0.23	0.16
Vermont	32	100	2.1	8.0	0.14	0.10
Virginia	663	129	2.8	10.4	0.18	0.13
Washington	644	148	3.2	12.0	0.21	0.14
West Virginia	184	229	4.9	18.7	0.31	0.22
Wisconsin	362	120	2.6	9.6	0.17	0.12
Wyoming	44	99	2.1	8.0	0.14	0.10

See notes to Appendix Table B1.

Table B5: Effect on GDP of Scenario II with Single-State Improvement

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
USA	46,112	256	5.5	21.3	0.34	0.24
Alabama	1,175	553	11.8	47.4	0.71	0.50
Alaska	65	108	2.3	8.7	0.15	0.11
Arizona	975	316	6.8	26.2	0.42	0.30
Arkansas	488	385	8.2	32.2	0.51	0.36
California	10,643	459	9.8	38.8	0.60	0.42
Colorado	384	121	2.6	9.8	0.17	0.12
Connecticut	305	115	2.5	9.2	0.16	0.11
Delaware	157	207	4.4	16.9	0.28	0.20
District of Columbia	230	181	3.9	14.7	0.25	0.18
Florida	3,206	356	7.6	29.7	0.47	0.33
Georgia	2,067	412	8.8	34.6	0.54	0.38
Hawaii	316	377	8.1	31.5	0.50	0.35
Idaho	79	117	2.5	9.5	0.16	0.12
Illinois	1,799	224	4.8	18.3	0.30	0.21
Indiana	539	156	3.3	12.6	0.22	0.15
Iowa	131	74	1.6	5.9	0.10	0.07
Kansas	122	76	1.6	6.1	0.11	0.08
Kentucky	651	325	6.9	26.9	0.43	0.31
Louisiana	1,481	526	11.3	44.9	0.67	0.48
Maine	57	92	2.0	7.4	0.13	0.09
Maryland	747	203	4.4	16.6	0.28	0.20
Massachusetts	117	25	0.5	2.0	0.04	0.03
Michigan	1,161	250	5.4	20.6	0.34	0.24
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	642	547	11.7	46.8	0.70	0.49
Missouri	658	220	4.7	18.0	0.30	0.21
Montana	15	31	0.7	2.5	0.04	0.03
Nebraska	110	95	2.0	7.6	0.13	0.09
Nevada	471	304	6.5	25.2	0.41	0.29
New Hampshire	44	59	1.3	4.7	0.08	0.06
New Jersey	514	87	1.9	7.0	0.12	0.09
New Mexico	365	391	8.4	32.8	0.51	0.36
New York	2,992	214	4.6	17.5	0.29	0.21
North Carolina	1,520	288	6.2	23.8	0.39	0.27
North Dakota	7	13	0.3	1.1	0.02	0.01
Ohio	974	165	3.5	13.4	0.23	0.16
Oklahoma	563	302	6.5	25.0	0.41	0.29
Oregon	334	145	3.1	11.7	0.20	0.14

Table B5 (continued)

	Value of reform (bn $)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2095 (in %)	Long-run growth increase	Increase in NAEP score
Pennsylvania	1,213	174	3.7	14.2	0.24	0.17
Rhode Island	145	246	5.3	20.2	0.33	0.24
South Carolina	655	321	6.9	26.7	0.43	0.30
South Dakota	31	63	1.4	5.1	0.09	0.06
Tennessee	1,403	438	9.4	36.9	0.57	0.40
Texas	4,191	259	5.5	21.3	0.35	0.25
Utah	293	194	4.2	15.8	0.27	0.19
Vermont	16	52	1.1	4.1	0.07	0.05
Virginia	862	167	3.6	13.5	0.23	0.16
Washington	608	140	3.0	11.3	0.19	0.14
West Virginia	266	331	7.1	27.5	0.44	0.31
Wisconsin	291	96	2.1	7.7	0.13	0.09
Wyoming	34	77	1.7	6.2	0.11	0.08

See notes to Appendix Table B1.

Appendix C. Computation of Test Score Gains for Scenario IV

From NAEP, we know the percentage of students who perform below basic level for each state. Knowing that the Basic Level for eight grade math requires at least 262 points (on the original NAEP scale)[2] and assuming that test scores are distributed normally (with $\mu = 283.85, \sigma^2 = 36.20$), we can calculate the average test score for students performing below basic level. The first step is to rescale the cutoff, so that it can be used with the adjusted NAEP scores, which have a standard deviation of 100 and a mean of 500 in 2011:

$$cutoff_{rescaled} = \frac{262 - 283.85}{36.20} * 100 + 500 = 439.64 \approx 440$$

Using this cutoff, the average test score for students below basic level is computed by $\frac{\sum_{x=0}^{440} f(x) * x}{\sum_{x=0}^{440} f(x)}$, with $f(x)$ as the normal density function, which is parameterized with the state-specific mean test score and the state-specific standard deviation. The gain for bringing each student up to the basic level is then computed by $s*(B–A)$, where s is the share of students who perform below basic level, B is the threshold level for the basic level ($B = 440$), and A is the average test score for those below B.

[2] http://nces.ed.gov/nationsreportcard/mathematics/achieveall.aspx.

Appendix D. Results for the Neoclassical Growth Model

As noted above, in the economics literature on growth there have been differences of opinion on the best way to categorize the long-run growth pattern. A fundamental distinction is whether improved skills of the labor force lead to improved long-run growth rates or whether the improved skills lead to some increased growth in the short to medium run while economies move to a new steady state level, but no change in long-run growth rates. In the former (endogenous growth), the more skilled labor force is instrumental in continuing productivity improvements. This is the model underlying our growth projections reported so far. In the later (augmented neoclassical growth), there is an immediate gain since skills are one of the inputs determining GDP, but then growth converges back to the steady state rate.

We can use our estimated growth models to project what would happen to future GDP in each state under the neoclassical growth path. In particular, we take the growth of the production frontier as 1.5 percent per year. The frontier is assumed to be what happens in the three states with the highest rate of U.S. patents – California, New York, and Texas.[3] Other states will grow faster in the short run as they converge to the frontier states, but then will settle into the 1.5 percent long-run growth.

For this alternative projection, we again consider the baseline model of Scenario I of a 0.25 standard deviation improvement. With the 80 year projection, the gains are only slightly smaller at 2.3 times current GDP as opposed to 2.6 times under the endogenous growth projections (Table 3).[4] The impact of this alternative clearly happens near the end of our projection period, so that GDP for the country in 2095 is 15.5 percent higher than the no-reform GDP, as opposed to 21.6 percent greater with endogenous growth.

In sum, the neoclassical projections are somewhat smaller, but they do not change the overall conclusion of huge gains from skill improvement. This conclusion holds similarly across all of the scenarios.

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[3] From 1963 to 2013, California (18.7 percent), New York (8.2 percent), and Texas (6 percent) account for one third of all patents in the U.S. Source: TAF database maintained by the U.S. Patent and Trademark Office [http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm].

[4] Detailed state-by-state results are available from the authors upon request.