$\sigma_T = 0.2$; $\phi = 0.13$; and $\theta = 0.3$. It is useful to see how the specific baseline parameters affect the results when we use alternative but plausible values.

The impact of the different parameters is straightforward. A lower depreciation rate (higher persistence of achievement), a wider distribution of the teacher effectiveness distribution, and a larger labor market payoff to skill lead to a larger economic value of teacher effectiveness. All of the prior estimates were based on rather conservative estimates of σ_T, the variation in teacher effectiveness; one standard deviation in teacher effective translates into 0.2 standard deviations in annual student growth. As indicated, a plausible upper bound on the variations in effectiveness would be 0.3 standard deviations in annual student growth, which would be consistent both with the larger estimates in Table 1 and with a more significant between-school variation in effectiveness. Additionally, the return to skill of $\phi = 0.13$ most closely mirrors the labor market estimates for young workers and for time periods in the past when the demand for skill was less. More recent estimates and consideration of the full age range of workers yields larger estimates, suggesting that $\phi = 0.2$ is a plausible upper bound on the estimates. The baseline estimates do use a depreciation rate of 0.3, whereas a subset of existing production function estimates suggest larger depreciation, particularly of achievement gains induced by the teacher. We thus also look at $\theta = 0.6$, or a depreciation rate that is twice as large.

Table 3 presents alternative estimates of marginal impacts evaluated at one point in the teacher distribution—one standard deviation above the mean, or the 84th percentile. Compared to the baseline, a higher depreciation rate on achievement obviously lessens the impact of teacher quality on earnings, because this effectively reduces the impact of different teachers. Nonetheless, even at the lower bound in column (1) of the table defined by the previous quality and earnings parameters (σ_T and ϕ) but higher depreciation (θ), a good teacher with a class of 15 annually produces \$182,000 more in present value than the average teacher. If we scan across the marginal annual economic value of a good teacher (compared to the average) evaluated at a given class size – say 20 students per class – we see that the parameters do make a large difference in the estimated impact. The annual economic value with class size of 20 ranges from a quarter of a million dollars to a million dollars at the top of the range for the three parameters together. (The final column is an upper bound on estimates based on current empirical work.)

While the difference in estimates across the parameters is large, the more striking feature of the table is the magnitude of the lower bound. A teacher in the top 15 percent with a class of 20 or more students yields at least \$240,000 in economic surplus each and every year compared to an average teacher.

As suggested, the persistence of the annual teacher effects implied by these estimates is an open question. All of the calculations in Fig. 1 presume that 70 percent of a teacher's addition to knowledge carries over permanently (except as modified by subsequent school and family inputs). In reality, maybe all carries over, or maybe only a small part carries over. A host of unknown factors—including compensatory behavior of parents and schools, the cumulative nature of skills, the specific attributes valued in the labor market, and the nature of peer-classroom interactions come into play in determining the long run impact of specific teachers. But even twice the depreciation of achievement that was used in the baseline yields very large estimates of the value of an effective teacher—say, \$150,000 per year present value for a 75th percentile teacher with a class of 20 students.

4.2. The demand side based on aggregate economic growth

An alternative way of estimating the derived demand for effective teachers focuses on the impact of student performance on economic growth. Recent analysis has demonstrated a very close tie between cognitive skills of a country's population and the country's rate of economic growth (see the review in Hanushek and Woessmann, 2008). In particular, countries that perform better on international math and science tests have stronger growth of their economies. These analyses suggest that the aggregate impact of increased skills is noticeably larger than the individual impact from the prior calculations.[35]

The magnitude of the effects is truly large. For the United States, Hanushek and Woessmann (2011) calculate that the present value of increased Gross Domestic Product (GDP) from improving scores by 0.25 standard deviations would be \$44 trillion.[36] To get some idea of what a difference of 0.25 s.d. on the international tests means in substantive terms, it is useful to note that Canada is approximately 0.4 s.d. ahead of the U.S. and that Finland – the current world leader – is approximately 0.58 s.d. ahead.[37]

Now consider what would be possible if we could eliminate the bottom end of the teacher quality distribution and replace these teachers with average teachers. Following the estimates in Hanushek (2009), it is possible to bound the increases in overall performance that could be expected

[35] The precise reasons for the larger estimates of aggregate effects compared to the micro effects from individual earnings are not clear. These estimates are consistent with substantial externalities from higher cognitive skills, but independent estimates of these are unavailable. The macro estimates reported here assume an endogenous growth formation such that increased cognitive skills translate into permanently higher rates of long run growth in GDP per capita. An alternative neoclassical version would relate increased skills to increased factor endowments, leading to movement to a higher level of income but one with the pre-reform rate of long run growth. This latter model yields somewhat smaller estimates of the economic gains, but they remain at 70 percent of endogenous growth model and still considerably above what would be estimated from the individual earnings parameters. The alternative approaches to estimation are discussed in Hanushek and Woessmann (2008, 2011).

[36] The key assumptions, described in detail in Hanushek and Woessmann (2011), are that future growth follows the patterns of growth for 1960–2000, that school improvement takes 20 years and that the higher skilled people replace existing workers as they retire after a 40 year career, and that present values are calculated through 2090 using a 3 percent discount rate.

[37] These variations come from math performance on the 2006 tests in the Programme for International Student Assessment, or PISA (see summary data in Organisation for Economic Co-operation and Development, 2010). There are some variations in average country scores over time and across subjects, but these do not affect the calculations here.

Table 3
Sensitivity of demand based on earnings to key parameters (marginal annual economic value of teacher one standard deviation above mean).

Class size	$\theta = 0.6$				$\theta = 0.3$			
	$\sigma_T = 0.2$		$\sigma_T = 0.3$		$\sigma_T = 0.2$		$\sigma_T = 0.3$	
	$\phi = 0.13$	$\phi = 0.2$	$\phi = 0.13$	$\phi = 0.2$	$\phi = 0.13$	$\phi = 0.2$	$\phi = 0.13$	$\phi = 0.2$
5	$60,652	$93,573	$91,215	$140,923	$106,556	$164,741	$160,566	$248,858
10	$121,303	$187,145	$182,430	$281,847	$213,113	$329,482	$321,132	$497,715
15	$181,955	$280,718	$273,645	$422,770	$319,669	$494,223	$481,698	$746,573
20	$242,607	$374,290	$364,860	$563,693	$426,225	$658,964	$642,264	$995,431
25	$303,259	$467,863	$456,075	$704,617	$532,781	$823,706	$802,831	$1,244,288
30	$363,910	$561,435	$547,290	$845,540	$639,338	$988,447	$963,397	$1,493,146

Note: θ, depreciation rate; σ_T, standard deviation of teacher quality; ϕ, labor market return to one standard deviation higher achievement.

from school improvement. Using the reasonable estimates (above) of variations in teacher effectiveness as measured by achievement growth – specifically, 0.20–0.30 s.d. – it is possible to see the impact of the least effective teachers.

Fig. 2 plots the impact on overall student learning of “deselecting” (i.e., moving out of the classroom) varying proportions of ineffective teachers and replacing them with an average teacher. These calculations come from using the prior variance estimates to judge the impact of truncating the distribution. The analysis applies to all teachers, so it can be thought of improving the effectiveness of teachers throughout the system. As such, it is assumed that the quality of teachers reinforces any gains that students make and the impacts of good instruction are not assumed to die out as the student progresses to a higher grade. Instead later teachers build upon the stronger average achievement of all children and set their instruction accordingly.

The figure shows upper and lower bounds on the improvements corresponding to standard deviations of 0.3 and 0.2, respectively. The wider the distribution of teacher effectiveness the greater is the improvement from eliminating the bottom tail of the distribution. As an example, consider what would happen to average student performance if we could eliminate the least effective 5 percent of teachers from the distribution. The estimates of the impact of teachers on student achievement indicate that students would on average gain 0.28–0.42 s.d. of performance by the end of their schooling, depending on the bounds of the teacher quality estimates.

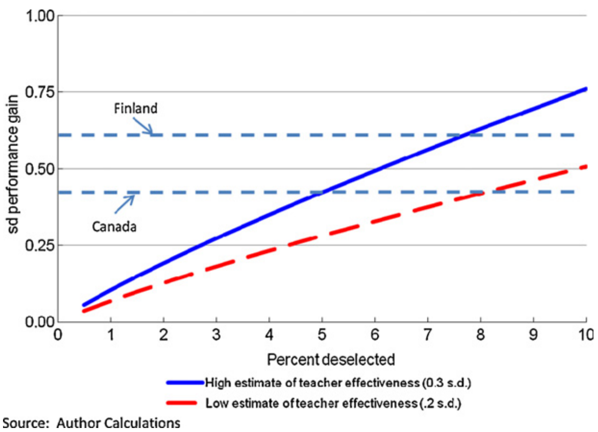

Fig. 2. Alternative estimates of how removing ineffective teacher affects student achievement.
Source: Author calculations.

These estimates of the importance of teacher quality permit some calculations of what would be required to yield various improvements in student performance. To begin with, consider what magnitude of teacher deselection might yield an improvement in student performance to the level of Canada (0.4 s.d. of student achievement). Fig. 2 shows that eliminating the least effective 5–8 percent of teachers would bring student achievement up by 0.4 s.d. If the upper bound on teacher effectiveness, corresponding to larger differences in effectiveness, is appropriate, replacing the bottom 8 percent of teachers with an average teacher would bring the U.S. up to the level of Finland.

The estimates of the growth impacts of bringing U.S. students up to Finland imply astounding improvements in the well being of U.S. citizens. The present value of future increments to GDP in the U.S. would amount to $112 trillion (Hanushek & Woessmann, 2011). These returns dwarf, for example, all of the discussions of U.S. economic stimulus packages related to the 2008 recession ($1 trillion).

The estimates are so large for two reasons—the U.S. is currently far from Finland in achievement and the U.S. economy is very large. The increase in achievement for the U.S. would, according to historic growth patterns, lift the annual U.S. growth rate by over one percent.[38]

5. Costs and the timing of benefits

It is clear from the prior calculations that improvements in teacher effectiveness would lead to very large economic gains. The estimates of the economic gains are all put in terms of present values, but they do not accrue for some years into the future. The estimates of individual earnings gains cover the entire work life of a current student. The estimates of the economic gains to the nation consider gains across the entire lifetime for somebody born today.

But it is not appropriate to presume that these changes occur without cost. At a very simple level, if 5–10 percent

[38] These estimates, particularly for the U.S., are sensitive to the assumptions about the form of the growth model. Under the neoclassical model, the low achievement of the U.S. is consistent with its currently being above its long run income level. The U.S. is presumed to be one of the prime contributors to the growth of the technological frontier, but the lower implied growth under this model would still yield a present value of economic improvement from achievement at the Finnish level of $62 trillion.