Economic Gains from Educational Reform by US States,*

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Journal of Human Capital

* We gratefully acknowledge comments from the editor Lars Lefgren and two anonymous referees. This research was supported by the Kern Family Foundation and by the Hewlett Foundation.

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Online Appendix B. Projection Model and Detailed Results

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 (2011, 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).

To put this total value in perspective, we can express it in percent of current GDP:

$$Value\ of\ the\ reform\ in\ \%\ of\ current\ GDP = \frac{Total\ value\ of\ reform}{GDP_{no\ reform}^{2015}} * 100$$

We can also relate it to the total discounted future GDP over the same period:

$$Value\ of\ the\ reform\ in\ \%\ of\ discounted\ future\ GDP = \frac{Total\ value\ of\ reform}{\sum_{t=2015}^{t=2095} GDP_{no\ reform}^{t} * (1 + discount\ rate)^{-(t-2015)}} * 100$$

Alternatively, we can also calculate by how much GDP is higher due to the reform in any given year, such as 2095:

$$GDP\ increase\ in\ year\ 2095\ (in\ \%) = \frac{GDP_{reform}^{2095} - GDP_{no\ reform}^{2095}}{GDP_{no\ reform}^{2095}} * 100$$

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	43,561	242	5.2	19.8	0.33	0.25
Alabama	514	242	5.2	19.8	0.33	0.25
Alaska	145	242	5.2	19.8	0.33	0.25
Arizona	747	242	5.2	19.8	0.33	0.25
Arkansas	307	242	5.2	19.8	0.33	0.25
California	5,607	242	5.2	19.8	0.33	0.25
Colorado	767	242	5.2	19.8	0.33	0.25
Connecticut	642	242	5.2	19.8	0.33	0.25
Delaware	184	242	5.2	19.8	0.33	0.25
District of Columbia	307	242	5.2	19.8	0.33	0.25
Florida	2,175	242	5.2	19.8	0.33	0.25
Georgia	1,213	242	5.2	19.8	0.33	0.25
Hawaii	203	242	5.2	19.8	0.33	0.25
Idaho	163	242	5.2	19.8	0.33	0.25
Illinois	1,946	242	5.2	19.8	0.33	0.25
Indiana	836	242	5.2	19.8	0.33	0.25
Iowa	427	242	5.2	19.8	0.33	0.25
Kansas	389	242	5.2	19.8	0.33	0.25
Kentucky	485	242	5.2	19.8	0.33	0.25
Louisiana	681	242	5.2	19.8	0.33	0.25
Maine	150	242	5.2	19.8	0.33	0.25
Maryland	889	242	5.2	19.8	0.33	0.25
Massachusetts	1,130	242	5.2	19.8	0.33	0.25
Michigan	1,121	242	5.2	19.8	0.33	0.25
Minnesota	825	242	5.2	19.8	0.33	0.25
Mississippi	284	242	5.2	19.8	0.33	0.25
Missouri	724	242	5.2	19.8	0.33	0.25
Montana	113	242	5.2	19.8	0.33	0.25
Nebraska	279	242	5.2	19.8	0.33	0.25
Nevada	374	242	5.2	19.8	0.33	0.25
New Hampshire	181	242	5.2	19.8	0.33	0.25
New Jersey	1,422	242	5.2	19.8	0.33	0.25
New Mexico	226	242	5.2	19.8	0.33	0.25
New York	3,375	242	5.2	19.8	0.33	0.25
North Carolina	1,276	242	5.2	19.8	0.33	0.25
North Dakota	129	242	5.2	19.8	0.33	0.25
Ohio	1,426	242	5.2	19.8	0.33	0.25
Oklahoma	450	242	5.2	19.8	0.33	0.25
Oregon	556	242	5.2	19.8	0.33	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	1,682	242	5.2	19.8	0.33	0.25
Rhode Island	142	242	5.2	19.8	0.33	0.25
South Carolina	493	242	5.2	19.8	0.33	0.25
South Dakota	119	242	5.2	19.8	0.33	0.25
Tennessee	775	242	5.2	19.8	0.33	0.25
Texas	3,911	242	5.2	19.8	0.33	0.25
Utah	365	242	5.2	19.8	0.33	0.25
Vermont	76	242	5.2	19.8	0.33	0.25
Virginia	1,248	242	5.2	19.8	0.33	0.25
Washington	1,051	242	5.2	19.8	0.33	0.25
West Virginia	194	242	5.2	19.8	0.33	0.25
Wisconsin	732	242	5.2	19.8	0.33	0.25
Wyoming	108	242	5.2	19.8	0.33	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	69,697	387	8.3	32.9	0.50	0.38
Alabama	1,687	794	17.0	70.2	0.97	0.74
Alaska	176	293	6.3	24.2	0.39	0.30
Arizona	1,476	478	10.2	40.6	0.62	0.47
Arkansas	792	624	13.4	54.0	0.79	0.60
California	15,225	657	14.0	57.1	0.82	0.62
Colorado	645	203	4.3	16.6	0.28	0.21
Connecticut	502	189	4.1	15.4	0.26	0.20
Delaware	285	374	8.0	31.3	0.49	0.38
District of Columbia	1,953	1,537	32.9	147.7	1.66	1.26
Florida	4,725	525	11.2	44.9	0.67	0.51
Georgia	2,756	549	11.8	47.1	0.70	0.53
Hawaii	565	674	14.4	58.7	0.84	0.64
Idaho	146	217	4.6	17.8	0.30	0.23
Illinois	2,887	359	7.7	29.9	0.48	0.36
Indiana	795	230	4.9	18.8	0.31	0.24
Iowa	218	124	2.6	10.0	0.17	0.13
Kansas	222	138	3.0	11.1	0.19	0.15
Kentucky	927	462	9.9	39.1	0.60	0.46
Louisiana	2,175	772	16.5	68.1	0.95	0.72
Maine	94	151	3.2	12.2	0.21	0.16
Maryland	1,191	324	6.9	26.9	0.43	0.33
Massachusetts	185	40	0.8	3.2	0.06	0.04
Michigan	1,646	355	7.6	29.6	0.47	0.36
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	1,089	927	19.8	83.3	1.10	0.84
Missouri	980	327	7.0	27.2	0.44	0.33
Montana	27	59	1.3	4.7	0.08	0.06
Nebraska	194	168	3.6	13.7	0.23	0.18
Nevada	926	599	12.8	51.7	0.76	0.58
New Hampshire	76	101	2.2	8.1	0.14	0.11
New Jersey	883	150	3.2	12.2	0.21	0.16
New Mexico	659	707	15.1	61.8	0.88	0.67
New York	5,127	367	7.9	30.7	0.49	0.37
North Carolina	1,969	373	8.0	31.2	0.49	0.38
North Dakota	15	27	0.6	2.2	0.04	0.03
Ohio	1,405	238	5.1	19.5	0.32	0.25
Oklahoma	875	470	10.1	39.8	0.61	0.46
Oregon	529	230	4.9	18.8	0.31	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	1,726	248	5.3	20.4	0.34	0.26
Rhode Island	270	459	9.8	38.8	0.60	0.45
South Carolina	912	447	9.6	37.8	0.58	0.44
South Dakota	61	125	2.7	10.1	0.17	0.13
Tennessee	1,971	615	13.2	53.1	0.77	0.59
Texas	5,108	316	6.8	26.2	0.42	0.32
Utah	417	276	5.9	22.8	0.37	0.28
Vermont	28	90	1.9	7.2	0.13	0.10
Virginia	1,327	257	5.5	21.1	0.35	0.26
Washington	876	201	4.3	16.4	0.28	0.21
West Virginia	495	617	13.2	53.3	0.78	0.59
Wisconsin	391	129	2.8	10.4	0.18	0.14
Wyoming	88	198	4.2	16.1	0.27	0.21

See notes to Online 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	32,810	182	3.9	15.2	0.24	0.18
Alabama	580	273	5.8	22.5	0.37	0.28
Alaska	50	84	1.8	6.7	0.12	0.09
Arizona	1,262	408	8.7	34.3	0.54	0.41
Arkansas	341	269	5.8	22.1	0.36	0.28
California	9,645	416	8.9	35.0	0.55	0.41
Colorado	447	141	3.0	11.4	0.20	0.15
Connecticut	390	147	3.1	11.9	0.20	0.16
Delaware	80	105	2.2	8.4	0.15	0.11
District of Columbia	1,448	1,139	24.4	104.9	1.31	1.00
Florida	2,155	240	5.1	19.6	0.33	0.25
Georgia	1,309	261	5.6	21.5	0.35	0.27
Hawaii	362	432	9.2	36.4	0.56	0.43
Idaho	104	155	3.3	12.5	0.21	0.16
Illinois	1,744	217	4.6	17.7	0.30	0.23
Indiana	329	95	2.0	7.6	0.13	0.10
Iowa	218	124	2.6	10.0	0.17	0.13
Kansas	222	138	3.0	11.1	0.19	0.15
Kentucky	0	0	0.0	0.0	0.00	0.00
Louisiana	1,120	398	8.5	33.4	0.52	0.40
Maine	68	109	2.3	8.8	0.15	0.12
Maryland	220	60	1.3	4.8	0.08	0.06
Massachusetts	0	0	0.0	0.0	0.00	0.00
Michigan	989	213	4.6	17.4	0.29	0.22
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	448	382	8.2	32.0	0.50	0.38
Missouri	980	327	7.0	27.2	0.44	0.33
Montana	0	0	0.0	0.0	0.00	0.00
Nebraska	194	168	3.6	13.7	0.23	0.18
Nevada	813	526	11.3	44.9	0.67	0.51
New Hampshire	45	60	1.3	4.8	0.09	0.06
New Jersey	0	0	0.0	0.0	0.00	0.00
New Mexico	588	631	13.5	54.6	0.79	0.60
New York	2,833	203	4.3	16.6	0.28	0.21
North Carolina	548	104	2.2	8.3	0.15	0.11
North Dakota	15	27	0.6	2.2	0.04	0.03
Ohio	608	103	2.2	8.3	0.14	0.11
Oklahoma	250	134	2.9	10.8	0.19	0.14
Oregon	60	26	0.6	2.1	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	637	92	2.0	7.3	0.13	0.10
Rhode Island	242	412	8.8	34.6	0.54	0.41
South Carolina	346	170	3.6	13.8	0.23	0.18
South Dakota	61	125	2.7	10.1	0.17	0.13
Tennessee	403	126	2.7	10.1	0.18	0.13
Texas	0	0	0.0	0.0	0.00	0.00
Utah	320	212	4.5	17.3	0.29	0.22
Vermont	16	49	1.1	3.9	0.07	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	258	321	6.9	26.6	0.43	0.33
Wisconsin	0	0	0.0	0.0	0.00	0.00
Wyoming	60	136	2.9	11.0	0.19	0.14

See notes to Online 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	29,738	165	3.5	13.4	0.23	0.17
Alabama	591	278	6.0	22.9	0.37	0.29
Alaska	93	155	3.3	12.6	0.21	0.16
Arizona	656	213	4.5	17.4	0.29	0.22
Arkansas	220	174	3.7	14.1	0.24	0.18
California	6,704	289	6.2	23.9	0.39	0.30
Colorado	326	103	2.2	8.3	0.14	0.11
Connecticut	354	134	2.9	10.8	0.19	0.14
Delaware	109	143	3.1	11.6	0.20	0.15
District of Columbia	596	469	10.0	39.8	0.61	0.46
Florida	1,736	193	4.1	15.7	0.26	0.20
Georgia	947	189	4.0	15.4	0.26	0.20
Hawaii	178	212	4.5	17.3	0.29	0.22
Idaho	79	118	2.5	9.5	0.16	0.12
Illinois	1,237	154	3.3	12.4	0.21	0.16
Indiana	402	116	2.5	9.4	0.16	0.12
Iowa	218	123	2.6	9.9	0.17	0.13
Kansas	150	93	2.0	7.5	0.13	0.10
Kentucky	310	154	3.3	12.5	0.21	0.16
Louisiana	633	225	4.8	18.4	0.31	0.23
Maine	70	113	2.4	9.1	0.16	0.12
Maryland	565	154	3.3	12.4	0.21	0.16
Massachusetts	304	65	1.4	5.2	0.09	0.07
Michigan	793	171	3.7	13.9	0.24	0.18
Minnesota	278	82	1.7	6.5	0.11	0.09
Mississippi	325	276	5.9	22.8	0.37	0.28
Missouri	464	155	3.3	12.5	0.21	0.16
Montana	39	83	1.8	6.6	0.12	0.09
Nebraska	157	136	2.9	11.0	0.19	0.14
Nevada	313	203	4.3	16.5	0.28	0.21
New Hampshire	66	88	1.9	7.1	0.12	0.09
New Jersey	538	91	2.0	7.3	0.13	0.10
New Mexico	199	213	4.6	17.4	0.29	0.22
New York	2,423	174	3.7	14.1	0.24	0.18
North Carolina	727	138	2.9	11.1	0.19	0.15
North Dakota	34	65	1.4	5.2	0.09	0.07
Ohio	603	102	2.2	8.2	0.14	0.11
Oklahoma	280	151	3.2	12.2	0.21	0.16
Oregon	370	161	3.4	13.0	0.22	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	1,062	153	3.3	12.4	0.21	0.16
Rhode Island	92	157	3.3	12.7	0.22	0.16
South Carolina	358	176	3.8	14.3	0.24	0.18
South Dakota	40	82	1.7	6.5	0.11	0.09
Tennessee	734	229	4.9	18.7	0.31	0.24
Texas	1,353	84	1.8	6.7	0.12	0.09
Utah	230	152	3.3	12.3	0.21	0.16
Vermont	29	93	2.0	7.4	0.13	0.10
Virginia	613	119	2.5	9.6	0.17	0.13
Washington	595	137	2.9	11.0	0.19	0.14
West Virginia	170	211	4.5	17.2	0.29	0.22
Wisconsin	335	111	2.4	8.9	0.15	0.12
Wyoming	41	92	2.0	7.4	0.13	0.10

See notes to Online 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	42,469	236	5.0	19.5	0.32	0.24
Alabama	1,078	508	10.9	43.2	0.65	0.50
Alaska	60	100	2.1	8.0	0.14	0.11
Arizona	899	291	6.2	24.0	0.39	0.30
Arkansas	449	354	7.6	29.5	0.47	0.36
California	9,782	422	9.0	35.5	0.55	0.42
Colorado	355	112	2.4	9.0	0.16	0.12
Connecticut	282	106	2.3	8.5	0.15	0.11
Delaware	145	191	4.1	15.6	0.26	0.20
District of Columbia	212	167	3.6	13.6	0.23	0.18
Florida	2,952	328	7.0	27.3	0.44	0.33
Georgia	1,902	379	8.1	31.7	0.50	0.38
Hawaii	291	347	7.4	28.9	0.46	0.35
Idaho	73	109	2.3	8.7	0.15	0.12
Illinois	1,660	206	4.4	16.8	0.28	0.21
Indiana	498	144	3.1	11.6	0.20	0.15
Iowa	121	69	1.5	5.5	0.10	0.07
Kansas	112	70	1.5	5.6	0.10	0.08
Kentucky	600	299	6.4	24.7	0.40	0.31
Louisiana	1,360	483	10.3	41.0	0.62	0.48
Maine	53	85	1.8	6.8	0.12	0.09
Maryland	689	187	4.0	15.3	0.26	0.20
Massachusetts	109	23	0.5	1.8	0.03	0.03
Michigan	1,070	231	4.9	18.9	0.31	0.24
Minnesota	0	0	0.0	0.0	0.00	0.00
Mississippi	589	502	10.7	42.7	0.65	0.49
Missouri	607	203	4.3	16.5	0.28	0.21
Montana	14	29	0.6	2.3	0.04	0.03
Nebraska	101	88	1.9	7.0	0.12	0.09
Nevada	434	280	6.0	23.1	0.38	0.29
New Hampshire	41	54	1.2	4.3	0.08	0.06
New Jersey	475	81	1.7	6.5	0.11	0.09
New Mexico	335	360	7.7	30.0	0.48	0.36
New York	2,761	198	4.2	16.1	0.27	0.21
North Carolina	1,401	266	5.7	21.9	0.36	0.27
North Dakota	7	12	0.3	1.0	0.02	0.01
Ohio	899	153	3.3	12.3	0.21	0.16
Oklahoma	519	279	6.0	23.0	0.38	0.29
Oregon	308	134	2.9	10.8	0.19	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	1,120	161	3.4	13.1	0.22	0.17
Rhode Island	133	227	4.9	18.6	0.31	0.24
South Carolina	603	296	6.3	24.5	0.40	0.30
South Dakota	29	59	1.3	4.7	0.08	0.06
Tennessee	1,290	402	8.6	33.8	0.53	0.40
Texas	3,864	239	5.1	19.6	0.32	0.25
Utah	270	179	3.8	14.5	0.25	0.19
Vermont	15	48	1.0	3.8	0.07	0.05
Virginia	795	154	3.3	12.5	0.21	0.16
Washington	562	129	2.8	10.4	0.18	0.14
West Virginia	245	305	6.5	25.2	0.41	0.31
Wisconsin	269	89	1.9	7.1	0.12	0.09
Wyoming	32	71	1.5	5.7	0.10	0.08

See notes to Online Appendix Table B1.

Online 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.

Online 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.

[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.

Online Appendix E. Data Appendix

This Appendix is from Hanushek, Ruhose, and Woessmann (2017).

E.1: Construction of Years of Schooling Measures by State

We compile average years of educational attainment for each U.S. state from the Integrated Public Use Microdata Series (IPUMS) data of the Minnesota Population Center (Ruggles et al. (2010)). We concentrate on the working-age population between 20 and 65 years. We also drop all respondents who are still in school at the time of the survey.

For the years 1970 to 2000, we use the 1 percent (1970) and 5 percent (1980, 1990, and 2000) random samples of the American population. The 1 percent sample has about 4 million observations, the 5 percent samples have about 13 to 14 million observations. Beginning in the year 2001, we use census data from the American Community Survey (ACS). The ACS provides annual 1 percent random population samples (with smaller sample sizes between 2001 and 2004). The approximate sample size is 3 million observations each year. Survey weights in the census and the ACS allow us to calculate measures that are representative for the U.S. population.

Until 1980, the Census reported directly the years of schooling or highest grade level completed of each individual. Beginning with the 1990 Census, the Census Bureau has changed the coding of educational categories and reports degrees (Bachelor, Master, etc.) instead. To translate the degree information into years of schooling, we use the estimates of average years of schooling of each degree provided by Jaeger (1997).[5]

Substantial differences in the labor-market performance between GED holders and standard high school graduates (Heckman, Humphries, and Mader (2011)) warrant a special treatment of GED holders. Due to the weak labor-market position of GED holders, we assign them 10 rather than 12 years of schooling.

Only the most recent survey waves identify GED holders in the Census data. We therefore estimate a constant share of GED holders among all high-school graduates from the pooled ACS 2008-2010 samples. The pooled sample is restricted for each year to get approximately the same age cohort of people aged 20-65. For example, for the year 2007, we use all people aged 21-66 in

[5] Some Census years only report educational categories that cover several years of schooling. For these years, we assume the same fraction for this educational category as in the closest survey with full information.

ACS 2008, 22-67 in ACS 2009, and 23-68 in 2010; for the year 1990, we use all people aged 38-83 in ACS 2008, 39-84 in ACS 2009, and 40-85 in ACS 2010. Note that 1940 is not adjusted because the GED was introduced in 1942.

Overall, the GED adjustment affects the average years of schooling only very little, though. In 2007, for example, 15 percent of those who would have received 12 years of schooling otherwise are now assigned 10 years of schooling, reducing the mean of the average years of schooling from 12.33 to 12.27 years. Put differently, accounting for GED holders raises the mean share of those with less than 12 years of schooling from 22.6 percent to 26.7 percent.

Having computed the years of schooling of each individual *i*, the average years of schooling *S* in state *s* at time *t* is then given by combining individual years of schooling by the weighted share of individuals *i* with education level *e* in the state at the time:

$$S_{st} = \sum_e \frac{\sum_i person\ weights_{iest}}{\sum_i person\ weights_{ist}} * years\ of\ schooling_e \tag{E1.1}$$

This yields the average years of schooling by state over time.

E.2: Construction of Test Score Measures by State

Our construction of cognitive skill measures for each U.S. state proceeds in four steps. This appendix provides methodological details on each step. First, we construct a constant measure of the mean test scores of students of each state (Online Appendix E.2.1). Second, we adjust the test scores of the working-age population of each state for interstate migration, thereby placing particular emphasis on the fact that interstate migration is selective (Online Appendix E.2.2). Third, test scores are adjusted for immigration from other countries, again with a special focus on selectivity (Online Appendix E.2.3).

E.2.1 Construction of Mean State Test Scores

The National Assessment of Educational Progress (NAEP) studies the educational achievement of American students in grades four and eight in different subjects (National Center for Education Statistics (2014)). In our main analysis, we focus on the mathematics score in grade eight, on which we focus the following description. But as far as possible, we also computed test scores based on reading and grade four, as well as on a combination of subjects and grades.

Since 1990, NAEP math tests have been administered on a representative scale at the state level every two to four years for most states. By 2003, test scores are available for all states.

Adjustment of Pre-1996 Tests for Accommodation

Since 1996, NAEP allows students with disabilities and English language learners specific accommodations to facilitate test participation. The NAEP test scores before 1996 (in 1990 and 1992) did not permit such accommodation, so that they have to be adjusted in order to be on a common scale with the subsequent tests. Therefore, we rescale the pre-1996 tests as follows: For 1996, NAEP test scores and standard deviations are available for tests with and without accommodation at the national level. By subtracting the 1996 U.S. mean without accommodation from the state score and dividing by the 1996 U.S. standard deviation without accommodation, we standardize test scores to mean 0 and standard deviation of 1. By multiplying the 1996 U.S. standard deviation with accommodation and adding the 1996 U.S. mean with accommodation, we bring each test score before 1996 to the same scale as the tests that permitted accommodation.

That is, the pre-1996 waves are aligned to the post-1996 scale in the following way:

$$score_{st}^{adj} = \left(\frac{score_{st} - mean_{US,t=1996}^{same\ scale}}{sd_{US,t=1996}^{same\ scale}} \right) * sd_{US,t=1996}^{new\ scale} + mean_{US,t=1996}^{new\ scale} \qquad \text{(E2.1)}$$

where $score_{st}$ is the raw score (without accommodation) of state *s* at time *t*, *mean* refers to the U.S. national mean, *sd* refers to the U.S. standard deviation, *same scale* refers to scores without accommodation, and *new scale* refers to scores with accommodation.

Normalization of Scales to Base Year 2011

Next, we normalize each scale – eight-grade math, etc. – to have a mean of 500 and a standard deviation of 100 in the common base year 2011. This is done by subtracting from each test score the 2011 U.S. mean and dividing by the 2011 U.S. standard deviation and then multiplying by 100 and adding 500:

$$score_{st}^{standard} = \left(\frac{score_{st}^{adj} - mean_{US,\,t=2011}}{sd_{US,\,t=2011}} \right) * 100 + 500 \qquad \text{(E2.2)}$$

Regression-based Estimation of Mean State Scores by State Fixed Effects

Using the normalized scores, we estimate the average test score of each state over all test scores that are available until 2011. This is done by estimating state fixed effects in a regression with year fixed effects that take into account systematic differences over time, as well as – in estimations that combine tests across subjects and grades – grade-by-subject fixed effects that takes into account systematic differences between grades and subjects:

$$score_{sgut}^{standard} = \sum_{s=1}^{50} \alpha_s I_s + I_g * I_u + I_t + \epsilon_{sgut} \quad \text{(E2.3)}$$

I_s is the fixed effect of state *s* that we are interested in. I_t are time fixed effects and $I_g * I_u$ are grade-by-subject fixed effects. By leaving out the indicators that represent math, grade eight, and the year 2011, all state fixed effects refer to this subject, grade, and year. The same adjustments and estimations can also be performed for different subsamples of the population, e.g., by education category of the parents. In further analysis, we estimate average standard deviations by employing the same fixed effects regression framework.[6]

E.2.2 Adjustment for Interstate Migration

Adjusting for State of Birth

To be able to adjust the state skill measure for interstate migration, we start by computing the birthplace composition of each state from the Census data. In particular, we compute the population shares of people currently living in state *s* who were born in state *s* ("state locals"), those born in in another state *k* ("interstate migrants"), and those born in another country ("international immigrants"). Thus, the population share of individuals *i* from origin state/country *o* living in state *s* at time *t* is given by

$$population\ share_{ost} = \frac{\sum_i person\ weights_{iost}}{\sum_i person\ weights_{ist}} \quad \text{(E2.4)}$$

Each state is composed of individuals educated in other states. To adjust, at least partially, for the differences in schooling that these individuals brought with them to their current state of residence, we construct a series of composite test scores. The idea is that each person who is

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[6] Standard deviations are also adjusted to be on the same scale by $sd_{st}^{standard} = \left(\frac{sd_{st}^{adj} - sd_{US,t=2011}}{sd_{US,t=2011}}\right) * 100 + 100.$

living in a state receives the test score of his home state. The baseline composite test score of state *s* at time *t* is then the weighted sum of test scores from all origin states *o* which are weighted by the fraction of people born in a particular origin *o* living in state *s* at time *t*:

$$score_{st}^{adj} = \sum_{o} population\ share_{ost} \times score_{o} \qquad \text{(E2.5)}$$

Thus, each person currently living in a state is assigned the test score from the respective state of birth.

The baseline composite test score thus assigns all locals the mean test score of the state of residence which is also their state of birth, assuming that the locals have not moved during their school career to another state. Assuming that internal migrants have not left their state of birth before finishing grade eight, all internal migrants receive the mean test score of their state of birth. In this variant, the international immigrants receive the mean score of their current state of residence.

Adjusting for Selective Interstate Migration based on Educational Background

To address selective interstate migration, we compute all population shares separately by educational background. We distinguish two educational categories: Persons with (at least some) university education and persons without university education. For each state, we also construct separate test scores by the education category of the parents (some university education or not).

We then assign separate test scores by educational background *e*:

$$score_{st}^{sel} = \sum_{oe} population\ share_{oest} \times score_{oe} \qquad \text{(E2.6)}$$

For state locals, this adjusted score replaces the average test score of the state of residence with the average test score of the state of residence by education category (university / no university). Likewise, for in-migrants it adjusts the average test scores of by education category. The assumption is that we can assign the population with a university education the test score of children with parents who have a university degree, and equivalently for those without a university education.

E.2.3 Adjustment for International Migration

Our adjustment for international migration combines data from international achievement tests with population shares of immigrants from different countries of origin.

International Test Score Data

We use international test score data from PISA, TIMSS, and PIRLS for international immigrants residing in one of the U.S. states.[7] As a first step, the international test data have to be rescaled onto a common scale with the national NAEP data (Hanushek, Peterson, and Woessmann (2012a)). To do so, we first standardize all international test scores by subtracting from each mean score on the international scale the U.S. mean value on the international scale by subject, grade, and year and divide this difference by the U.S. standard deviation on the international scale, also by subject, grade, and year. Next, we multiply the standardized value by the U.S. standard deviation of the NAEP score by subject, grade, and year and add the U.S. mean of the NAEP score by subject, grade, and year:

$$score_{sgut}^{adj} = \left(\frac{score_{sgut} - mean_{US,gut}^{int'l}}{sd_{US,gut}^{int'l}}\right) * sd_{US,gut}^{NAEP} + mean_{US,gut}^{NAEP} \quad \text{(E2.7)}$$

where $score_{sgut}$ is the raw international test score of country *s* at grade *g* in subject *u* in year *t*.

To compute average test scores for each country, we proceed in the same way as for the national test data. The regression design takes into account systematic differences between grades, subjects, and years. The final estimate of the country average test score is then a country fixed effect:

$$score_{sgut}^{standard} = \sum_s \alpha_s I_s + I_g * I_u * I_{test} + I_t + \epsilon_{sgut} \quad \text{(E2.8)}$$

where I_s is the fixed effect of country *s* that we are interested in. I_t are time fixed effects and $I_g * I_u * I_{test}$ are grade times subject times survey fixed effects. The survey fixed effects indicate whether we identify grade 4 in PIRLS or grade 4 in TIMSS. Thus, they are dummy variables for TIMSS, PIRLS, and PISA. Again, the same regression can be estimated for different subsamples of the population.[8]

[7] We draw the data from the International Data Explorer (IDE) of the National Center of Education Statistics (http://nces.ed.gov/surveys/international/ide/).

[8] When estimating separate scores by the education category of the father, in PISA we use a simple average of the test scores in ISCED categories 0-4 for non-university education and ISCED categories 5a and 6 for university education. In TIMSS 1995 and 1999, we use the average of the categories until "finished secondary" for non-university education and "finished university" for university education. In the subsequent TIMSS waves, we use ISCED categories 0-4 for non-university education and ISCED categories 5a and more than 5a for university education. The IDE does not report educational background variables for PIRLS and TIMSS grade 4.

Apart from the mean test score, we also estimate the performance of the 75th and the 90th percentile of students in each country. We also estimate the standard deviation.[9]

In cases where a source country did not participate in the international achievement tests, we impute values from neighboring countries or regions. Table E1 reports the respective imputations for the main source countries of immigrants in the United States.

Selectivity Adjustment of Home-Country Test Scores

As discussed in the paper, the skills of migrants are not random draws from the home-country skill distribution. To estimate the migrant selectivity for each country, we proceed in two steps. First, for each country of origin (country subscripts omitted), we calculate the selectivity parameter for school attainment as the percentile *p* of the home-country distribution from which the average immigrant to the U.S. is drawn:

$$p = s_{US}^{pri} * \frac{1}{2} s_{home}^{pri} + s_{US}^{sec} * \left(s_{home}^{pri} + \frac{1}{2} s_{home}^{sec} \right) + s_{US}^{ter} * \left(s_{home}^{pri} + s_{home}^{sec} + \frac{1}{2} s_{home}^{ter} \right) \qquad \text{(E2.9)}$$

where the respective educational degrees of the population are given by *pri* = primary, *sec* = secondary, and *ter* = tertiary, *s* refers to the shares of the population with the respective degrees (with $s^{pri}+ s^{sec}+ s^{ter}=1$), *home* refers to the population in the respective home country, and *US* refers to the immigrants from the specific home country living in the United States. Data are taken from Docquier, Lowell, and Marfouk (2009) and refer to the year 2000.

Second, to adjust for skill selectivity within educational degrees, our baseline estimate uses the country-specific attainment selection parameter *p* to calculate the percentile of the cognitive skill distribution for the average immigrant as $p^* = p + p * (1 - p)$. For each country, we know the mean and standard deviation of the test score distribution. Assuming a normal distribution, we can calculate the corresponding test score that is adjusted for international migrant selectivity:

$$score_{sgut}^{selectivity} = invnorm(p^*) * sd_{sgut}^{standard} + score_{sgut}^{standard} \qquad \text{(E2.10)}$$

where $invnorm(p^*)$ are draws of the p^*th percentile from a normal (0,1) distribution, $score_{sgut}^{standard}$ is the average international test score of country *s* at grade *g* in subject *u* in year *t*, and $sd_{sgut}^{standard}$ is the corresponding standard deviation. The comparison of $score_{s}^{selectivity}$ in

[9] Standard deviations are again adjusted to be on the same scale with NAEP.

math, grade 8, in the year 2007, using $p^* = 75$ and $p^* = 90$, respectively, with the available country-specific observed test scores at the 75th and 90th percentile, respectively, show that this prediction works well (correlations almost perfect with r = 99 percent in both cases).

Population Shares of Immigrants from Different Countries of Origin

Using Census data, we next calculate the population shares of those born outside the United States. Table E1 shows the main source countries of immigrants who came to the United States over the last 70 years.

In calculating the share of immigrants from different origin countries in the birthplace composition of each state, we take into account the age of immigration. In particular, immigrants arriving in the United States before the age of 6 are assumed to have spent their school career in the U.S. school system, so they are assigned the NAEP score of their state of residence. Those who immigrated after the age of 20 are assigned the test score of their country of origin. And those who immigrated between ages 6 and 20 are assigned a weighted average of the two.

Using the population shares of immigrants from different countries of origin as in equation (E2.4), we then basically proceed in the same way as with the national test score data. That is, we adjust the composite test score of each state by applying the selectivity-adjusted country-of-origin test scores for international immigrants.

Table E1: Main Source Countries

Country of Birth	Total Census Obser-vations, 1940-2010	Share of all immigrants (in percent)	Imputation of international test scores
Mexico	1,054,264	24.14	
Philippines	192,335	4.40	
Puerto Rico	184,529	4.22	NAEP
Germany	138,950	3.18	
India	136,515	3.13	Southeast Asia: Indonesia, Malaysia, Philippines, Singapore, Thailand + Iran
Canada	136,424	3.12	
Cuba	115,914	2.65	Central America: El Salvador, Panama, Honduras, Trinidad&Tobago
China	115,670	2.65	East Asia: Shanghai-China, Hong Kong, Macao-China, Mongolia, Taiwan (Chinese Taipei), Japan, Korea, Rep.
Vietnam	111,037	2.54	Southeast Asia: Indonesia, Malaysia, Philippines, Singapore, Thailand
Italy	102,190	2.34	
El Salvador	93,766	2.15	
Korea	87,184	2.00	South Korea
England	81,712	1.87	
USA, Unknown State	72,212	1.65	NAEP
Poland	71,464	1.64	
Dominican Republic	67,583	1.55	Central America
Japan	62,327	1.43	
Jamaica	58,633	1.34	Central America
Colombia	57,598	1.32	
Guatemala	55,451	1.27	Central America
Abroad, ns	52,545	1.20	Total Average
Other USSR/Russia	44,915	1.03	USSR: Russia, Moldova, Ukraine, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan
Taiwan	40,817	0.93	
Haiti	40,287	0.92	Central America
West Germany	36,231	0.83	Germany
Iran	34,117	0.78	
Ecuador	32,475	0.74	South America: Argentina, Brazil, Chile, Colombia, Peru, Uruguay
Peru	32,047	0.73	
Portugal	31,728	0.73	
Honduras	31,141	0.71	
Ireland	30,295	0.69	
Greece	29,979	0.69	
France	28,703	0.66	
Brazil	25,754	0.59	
United Kingdom	25,565	0.59	
Hong Kong	25,324	0.58	
Nicaragua	23,920	0.55	Central America
Pakistan	23,123	0.53	Southeast Asia + Iran
Guyana/British Guiana	22,425	0.51	South America
Laos	21,998	0.50	Southeast Asia
Trinidad and Tobago	21,731	0.50	

Notes: Main source countries/regions of immigrants living in the United States. Only countries with a share of the total immigrant inflow of at least 0.5 percent. Averages over all available Census years. Imputation: Countries/ region by which test scores are imputed in cases without international test score data. Source: Authors' calculations based on Ruggles et al. (2010).

Table E2: Selectivity of Migrant Sending Countries

Country	School-attainment selectivity		Country	School-attainment selectivity	
	Adjusted	Unadjusted		Adjusted	Unadjusted
Mongolia	0.997	0.948	England	0.938	0.752
Indonesia	0.989	0.894	Scotland	0.938	0.752
Macedonia	0.988	0.893	United Kingdom	0.938	0.752
Botswana	0.987	0.887	American Samoa	0.936	0.746
Ghana	0.985	0.877	Guam	0.936	0.746
Southern Africa	0.985	0.878	Japan	0.936	0.747
Africa	0.984	0.872	Overseas Territories	0.936	0.746
Algeria	0.984	0.872	U.S. Virgin Islands	0.936	0.746
Morocco	0.983	0.869	Israel/Palestine	0.934	0.751
South Africa	0.983	0.870	Kazakhstan	0.933	0.742
Egypt	0.982	0.867	Panama	0.933	0.741
Northern Africa	0.982	0.867	Colombia	0.932	0.738
Tunisia	0.981	0.861	Estonia	0.932	0.739
Bahrain	0.978	0.852	Baltic States	0.931	0.738
Iran	0.978	0.853	Denmark	0.931	0.737
Qatar	0.978	0.853	New Zealand	0.930	0.736
Saudi Arabia	0.978	0.852	Trinidad and Tobago	0.930	0.736
United Arab Emirates	0.978	0.853	Sweden	0.929	0.733
Singapore	0.977	0.850	Western Europe	0.929	0.741
Kuwait	0.974	0.839	Belgium	0.928	0.731
Liechtenstein	0.974	0.838	Former USSR without Russia	0.928	0.734
Switzerland	0.972	0.833	Chile	0.927	0.730
Taiwan (Chinese Taipei)	0.970	0.827	Former USSR	0.927	0.731
Southeast Asia + Iran	0.968	0.825	Kyrgyzstan	0.927	0.729
Brazil	0.966	0.816	Hungary	0.926	0.728
Turkey	0.966	0.817	Finland	0.925	0.725
Southeast Asia	0.965	0.820	South America	0.925	0.730
Palestinian Nat'l Auth.	0.963	0.809	Total Average	0.925	0.744
Thailand	0.962	0.806	Netherlands	0.923	0.723
Malaysia	0.956	0.790	Argentina	0.922	0.721
Asia	0.955	0.798	Lithuania	0.921	0.719
Middle East	0.955	0.798	Northern Europe	0.921	0.720
France	0.954	0.785	Ukraine	0.919	0.716
Georgia	0.953	0.784	Moldova	0.918	0.714
East Asia	0.950	0.791	Oceania	0.918	0.715
Lebanon	0.949	0.775	Syrian Arab Republic	0.918	0.713
Hong Kong	0.947	0.769	Europe	0.914	0.714
Macao-China	0.947	0.769	Iceland	0.914	0.708
Azerbaijan	0.944	0.763	Jordan	0.914	0.707
Spain	0.944	0.764	Antarctica	0.913	0.706
Philippines	0.943	0.760	Austria	0.912	0.704
Latvia	0.941	0.758	Montenegro	0.912	0.704
Bulgaria	0.938	0.750	Serbia	0.912	0.704

(continued on next page)

Table E2 (continued)

Country	School-attainment selectivity		Country	School-attainment selectivity	
	Adjusted	Unadjusted		Adjusted	Unadjusted
Slovak Rep.	0.912	0.703	Norway	0.894	0.674
Czechoslovakia	0.909	0.698	Central America	0.891	0.677
Romania	0.909	0.699	Bosnia and Herzegovina	0.889	0.666
Eastern Europe	0.907	0.698	Malta	0.885	0.660
Australia	0.906	0.693	Poland	0.885	0.661
Czech Rep.	0.906	0.693	Croatia	0.884	0.66
Yugoslavia	0.906	0.707	Ireland	0.879	0.652
Cyprus	0.905	0.692	Honduras	0.876	0.647
Oman	0.905	0.692	Germany	0.872	0.643
Peru	0.905	0.692	Portugal	0.865	0.633
Armenia	0.903	0.688	Italy	0.863	0.629
Korea, Rep.	0.902	0.688	Greece	0.850	0.613
Albania	0.901	0.685	El Salvador	0.827	0.584
Southern Europe	0.899	0.697	Canada	0.774	0.525
Uruguay	0.898	0.681	North America	0.774	0.525
Luxembourg	0.894	0.674	Mexico	0.710	0.461

Notes: Selectivity of U.S. immigrants based on their home-country distribution of school attainment. See section E2.3 for details.