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Since Start Of The Vaccines For Children Program, Uptake Has Increased And Most Disparities Have Decreased

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Abstract

The Vaccines for Children program is a US government intervention aimed at increasing vaccination uptake by removing financial barriers that may prevent American children from accessing vaccinations. This study examined the impact that this intervention had on race- and ethnicity-related and income-related disparities for diphtheria-tetanus-acellular pertussis, measles-mumps-rubella, and polio vaccinations using data from the National Immunization Survey, 1995–2013. Vaccination rates increased across all races, ethnicities, and income groups following the introduction of the Vaccines for Children program. Disparities among race and ethnic groups narrowed considerably over time since the introduction of the vaccine program, although income-related disparities changed at different rates within race and ethnic groups and in some cases increased. Government interventions aimed solely at reducing certain financial barriers to vaccination may fail to address other important aspects of cost or perceived benefits that influence vaccination uptake, especially among poorer children.

Childhood vaccines for common communicable diseases are among the most beneficial health care interventions used worldwide. In the United States alone, it is estimated that childhood vaccinations will prevent an estimated 322 million bouts of illness and 732,000 deaths over the course of the lifetimes of children born between 1994 and 2013, benefitting under the Vaccines for Children program (VFC).[1] It is estimated that three vaccines in particular, diphtheria-tetanus-acellular pertussis (DTaP), measles-mumps-rubella (MMR), and polio will prevent 210 million bouts of illness and 600,000 deaths.[1]

The VFC program is cited as a successful example of a federally funded initiative established to widen access to vaccinations (currently vaccines for sixteen diseases designated by the Advisory Committee on Immunization Practices are eligible) and to ameliorate the impact of low income on access to vaccines. The VFC program specifically seeks to improve access for children who are uninsured, whose insurance fails to cover vaccinations, who have Medicaid, or who are American Indian or Native Alaskan. Prior to the vaccine program, children from poorer, often non-white families had lower vaccination rates and higher rates of vaccine-preventable illnesses than those who were white and/or more well-off.[1,2] By 1997, 74 percent of all childhood vaccinations were received from providers enrolled in the program.[3]

The VFC program is widely credited with reducing or removing cost barriers that contributed to disparities in vaccination rates across households differentiated by race and ethnicity,[2,4,5] and households differentiated by income.[6] No study, however, has examined income-related disparities in vaccination coverage between and within race and ethnic groups, nor what policy implications such an examination might offer. In this study, we examined income-related disparities in vaccination uptake within and between race and ethnic groups since the implementation of the program on October 1, 1994, until the most recent period where data is

available (2013). The study sought to use differences in the impact of the VFC program on income-related disparities within groups differentiated by race and ethnicity to assess the role of federally funded programs targeted at financial barriers to access. The study focused particular attention on the relative success of the program in respect of children from lower socioeconomic-status families.

Survey Data And Methods

Data from the National Immunization Survey were used in this study. The survey was established partly in response to the introduction of the Vaccines for Children program, and data from it are used as an official source of information on vaccination rates in the United States by the Centers for Disease Control and Prevention and other government agencies.[7] Data from 1995 to 2013 were available from the survey, which allowed us to examine vaccination uptake at the beginning of the VFC program (1995–97) up to the most recent period available (2011–13). In order to examine vaccination uptake over time, six time periods were created by merging data from separate years in order to boost sample size and avoid the potential impact of an aberration in any one year upon results.[8] Apart from information on vaccination uptake, the survey includes a range of sociodemographic information on the child and family including race/ethnicity, family size, and household income.

The National Immunization Survey gathers data on children ages 19–35 months using a random-digit-dialing phone survey of households across the fifty states and the District of Columbia (information on Guam and the US Virgin Islands are also gathered, although not included in this study).[9,10] The survey also uses a mail version to collect data from providers

on the types of vaccinations administered, the number of doses, and the dates the vaccines were given.[11] The provider data is gathered after parental or guardian consent is given.

The three vaccinations seen to have prevented the majority of vaccine-preventable bouts of illness and deaths,[1] DTaP, MMR, and polio vaccinations, are the primary vaccinations examined in this study. Analysis on Haemophilus influenzae type b (Hib), hepatitis B (HepB), and varicella (chickenpox), which are also recommended by the Advisory Committee on Immunization Practices and are included in the National Immunization Survey from the earliest period, are presented in the online Appendix.[12]

Analyses undertaken in this study included unadjusted vaccination rates, adjusted vaccination rates (multivariate probit analyses controlling for a range of covariates), and concentration index analyses for the estimation of relative disparities in vaccination usage across income groups. Concentration indices (C) are an established method for quantifying socioeconomic-related disparities in health care utilization,[13-16] which allows for robust comparative analysis of income-related disparities (in this case) across race and ethnic groups. Concentration indices have been used in a variety of contexts including earlier studies of childhood vaccination uptake.[17-22] The disparity measured by concentration indices are bounded between -1 (extreme pro-poor disparities, that is, only the poorest are vaccinated) and +1 (extreme pro-rich disparities, that is, only the richest are vaccinated), with a concentration index equal to 0 denoting vaccination rates that do not differ across children with different incomes. In this analysis, we used the concentration index advocated by Adam Wagstaff for use with a binary dependent variable (whether the child had up-to-date vaccination uptake).[22]

Equivalized household income is used to measure income-related disparities. Equalizing income accounts for household size that will affect the consumption potential (for example,

$50,000 in a two-person household should not be treated the same as $50,000 in a four-person household). Household income in the National Immunization Survey is provided in categorical ranges with a different number of categories used at different times. Eleven categories are included between 1995 and 1998, fifteen categories between 1999 and 2004, and fourteen categories between 2005 and 2013.[23] To adjust for the multiple categories in the survey, equivalized income was estimated by taking the mid-point for each category and dividing it by the square root of the number of people in the household (Organization for Economic Cooperation and Development square root equivalence scale).[24]

Multivariate probit regressions were used to examine between-group differences in disparities by interacting race or ethnicity (white, black, and Hispanic; children of other race or ethnicity were excluded) and equivalized household income (partitioned into tertiles to produce low-, middle-, and high-income households). This allowed us to include nine race and income dummies in our analyses to estimate vaccination uptake disparities, with high-income white children used as the base category in all cases. While poverty status of the household may be a more appropriate measure of socioeconomic deprivation, the categories in the 1995–97 period do not correspond to the categories in the later periods and could not therefore be used consistently across time. Other characteristics of the child and the household that were included in the regression analyses were mother's education, parents' marital status, child's sex, state of residence (including the District of Columbia) fixed effects, and year fixed effects to account for differences in vaccination policies across states and over time. Other variables available in the 2005–07, 2008–10, and 2011–13 periods were whether the child was the first born, whether the child was breastfed for six months after birth, the mother's age, and insurance status. Separate analyses were undertaken in these later periods with these additional variables for confirmatory

purposes with no material differences observed with the results presented here. Results are presented as marginal effects instead of odds ratios to allow for comparability of results across vaccines and time periods.[25,26]

To enhance the precision of estimates, and to allow for results to be nationally representative, all results were estimated using the random-digit-dialing weights. The accuracy of the estimates using these weights has been shown to allow for a total error of less than 1.72 percent from the true population estimate.[27]

A total of 342,062 children ages 19–35 months (51,950 in 1995–97; 61,178 in 1998–2000; 81,416 in 2001–04; 51,529 in 2005–07; 49,191 in 2008–10; and 46,798 in 2011–13) were included in our study after observations without household income information (35,626) were dropped.[28]

Study Results

Unadjusted Vaccination Rates

Vaccination rates increased since introduction of the Vaccines for Children program (1995–97) (Exhibit 1). More details on the vaccination rates for Hib, HepB, and varicella along with concentration indices for those vaccinations are available in the Appendix.[12] Exhibit 1 shows that for DTaP and MMR overall, however, a slight reduction occurred between the two most recent periods included in 2008–13. Vaccination rates also changed at different rates across race/ethnic and income groups over time. At the beginning of the VFC program, significant racial- and ethnicity-related disparities in vaccination rates were observed. Higher vaccination rates were observed among white children with almost a 5 percentage-point difference in uptake of the DTaP between whites and blacks and almost a 9 percentage-point difference between

whites and Hispanics and smaller, but noticeable, differences in the MMR and polio vaccines. Vaccination rates converged between income and ethnic groups over time, especially in the 2008–10 period. Hispanic children had the highest uptake rate of MMR (and HepB and varicella, see Appendix Exhibit A2[12]) in the latest period. In the 2011–13 period, income differences had increased slightly.

With respect to income, significant income-related disparities were observed at the start of the VFC program. Higher-income children had vaccination rates greater than low-income children (DTaP: 88.0 percent versus 74.6 percent; MMR: 94.0 percent versus 86.4 percent; polio: 93.5 percent versus 86.9 percent). Absolute differences in vaccination rates across income groups reduced considerably in the 2008-10 period for MMR and polio but remained large for DTaP (90.2 percent for high income versus 80.8 percent for low income).

Income-related disparities in vaccination uptake differed across race and ethnicity (Exhibit 2). For additional details, see Appendix Exhibit A2.[12] And it is clear that income-related disparities have changed over time at different rates among white, black, and Hispanic children.[12] At the beginning of the vaccine program, high-income white children were more likely to be vaccinated relative to high-income black and Hispanic children. However, the latest period's vaccination rates among high-income children, regardless of race, were similar. The highest uptake of MMR and polio vaccinations was seen among high-income black children in 2011–13.

Among white children, differences in vaccine uptake rates have decreased overtime between high- and low-income children, halving for MMR and polio, although remaining similar for DTaP. Among black children, vaccination rates among high-income families increased at a much greater rate than that observed for low-income families. While in 1995–97, there was an

approximately 8 percentage-point difference in DTaP vaccination rates between high- and low-income black children, in the latest period this had increased to approximately 13 percentage points. Increases in disparities between high-income and low-income black children were also seen for MMR and polio over time.

The largest increase in overall vaccination rates over time was observed among low-income Hispanic children. While low-income Hispanic children consistently had the lowest vaccination rates of all groups at the beginning of the VFC program, this was not the case in later periods. Differences in vaccination rates between high- and low-income Hispanic children were reduced (for DTaP) or were eliminated (for MMR and polio) by 2008–10, although disparities in rates of uptake for the DTaP and polio vaccines reemerged in 2011–13, with small declines in uptake among low-income Hispanics and small increases in uptake among high-income Hispanics.

Concentration Indices

Income-related disparities measured using concentration indices discussed below and in Appendix Exhibit A3[12] illustrate that while pro-rich income-related disparities ($C > 0$) were large in 1995–97, income-related disparities were reduced between 1995–97 and 2008–10 but again trend upwards in 2011–13. This confirms what is shown in Exhibit 2, where in the most recent period children in high-income households increased vaccination while poorer children did not.

The largest reduction in overall US income-related disparities was observed for MMR vaccinations ($C = 0.20$ in 1995–97; $C = 0.09$ in 2011–13) (Exhibit 3). Income disparities went down among white and Hispanic children (where no statistically significant disparity was

observed in the two most recent periods) but went up among black children (C = 0.06 in 1995–97; C = 0.16 in 2011–13).

The largest income disparities among the ethnic groups was observed for DTaP (Exhibit 4). While income disparities decreased in the 2008–10 time period, they increased once more in the latest period. Disparities remained relatively constant over time for white and Hispanic children. Black children once more saw an increase in income disparities in the two most recent periods.

Compared to 1995-97 there was a reduction in income disparities up to the 2008–10 period for polio vaccination uptake but an increase in the 2011–13 period (Exhibit 5). Disparities remained fairly constant for whites and Hispanics, although a slight increase in disparities were seen in 2011–13 for the latter group. For black children, income disparities were more than twice as high in 2011–13 (C = 0.22) as they were at the beginning of the VFC program (C = 0.09).

Multivariate Analysis

Marginal effects from multivariate analyses illustrate that the likelihood of vaccination uptake has changed considerably over time (Appendix Exhibit 4).[12] Results show that at the beginning of the vaccine program, vaccination rates among high-income white children were greater than in all other groups. The largest differences were observed relative to low-income black and Hispanic children.

Differences between high-income white children and the other groups decreased over time for MMR and polio vaccinations, with differences between high-income whites and low-income Hispanics in particular having a large reduction with a not statistically significant difference observed in 2011–13.

However, disparities remained as large for DTaP vaccination uptake in the latest period as they were in the earliest period. In 2011–13, controlling for a range of other characteristics, high-income white children had DTaP vaccination rates 13 and 16 percentage-points higher than low-income white and low-income black children, respectively, and rates approximately 8 percentage-points higher than middle- and low-income Hispanics.

Discussion

The benefits of childhood vaccinations for communicable diseases in the United States and worldwide are widely acknowledged. They have been shown to be among the most cost-effective health care interventions[29,30] and are estimated to have contributed significantly to reductions in morbidity and mortality.[1] This study has echoed that of others in showing that the Vaccines for Children program coincided with increased uptake of common vaccinations and reductions in disparities in vaccine uptake rates across races and ethnic groups and families from different socioeconomic situations.[2,4,5] Additionally, this study has added to existing knowledge in three areas.

First, it has demonstrated the value and importance of examining within each group, as well as among groups, with groups being differentiated on the basis of race and ethnicity and income. Only by examining within-group disparities related to income, for example, is it possible to discern the very different experiences of black and Hispanic children in uptake of the MMR vaccination over time (Exhibit 3). As the VFC program developed, disparities between blacks and Hispanics relative to whites decreased. However, among blacks, income-related disparities increased, while those among Hispanics decreased. Similarly, the very different experiences within ethnic groups was evident (Exhibit 2). Here, it was seen that low-income Hispanics

increased uptake of virtually all vaccines to a greater extent, and in a more sustained manner over the duration of the vaccines program, than was the case among the other low-income groups. This provides a more nuanced insight into the experiences of different groups, calls for a more thorough investigation of the factors underlying variations in uptake, and perhaps a more nuanced policy response than simply reducing financial barriers to access that the VFC program (and lately the Affordable Care Act (ACA), which removed cost-sharing requirements from vaccines) has done.

Second, the study demonstrates that the reductions in disparities over the operation of the VFC program did not occur evenly over time, across vaccines, or among different groups. In the case of DTaP, MMR, and polio vaccines, much of the increase in uptake by disadvantaged groups can be seen to have occurred in 2005–07 instead of earlier. Indeed, as the analysis shows, in the last period observed in this study (2011–13), there has been a discernible if slight widening of income disparities in respect of several vaccines including DTaP and MMR. That the impact should change over time suggests that other factors complemented the impact the vaccines program had on changing disparities in vaccination uptake. As with the examination of within race and ethnic group differences, this again points to the need for a nuanced understanding of what and how factors other than the reduction in financial barriers to access affected uptake. Whether these changes related to health promotion activities, increased public awareness associated with disease outbreaks, or changes in other factors seemingly unrelated to the value of vaccines for children is unclear. What is clear is that only a more thorough investigation of the changes in other factors that coincided with changes in vaccine uptake will provide a fuller understanding of the contribution of the VFC program to the increases in uptake and reductions in disparities.

Third, changes in disparities occurred at different rates across vaccines. It is tempting to posit a relationship between the number of shots associated with a particular vaccine and its uptake specifically for the relatively low uptake and large disparities observed for DTaP. However, while uptake is lower and disparities higher with DTaP (which requires four shots for children of this age) than with MMR (which requires one shot for children of this age), uptake of polio (where three shots are recommended) and disparities in uptake, are of a similar order of magnitude as with MMR. One potential future avenue of research in this sense may be into the perceived benefit of some vaccines, the perceived severity of illness that vaccines prevent, and to what extent these perceptions influence the decision of parents and vaccination providers (that is, physicians) to request or suggest vaccination.

Among low-income Hispanics, both the extent of the reduction in income-related disparities and the patterns across vaccines are different to that among whites and blacks. Again, this suggests factors other than cost--whether financial or related to inconvenience associated with repeat practitioner office visits--underlie uptake and differences in uptake across groups. Similarly, it is also interesting that vaccination uptake among high-income black children increased at a greater rate than for low-income black children. These distinctions are important in the sense that while the increase in receipt of vaccines facilitated by the VFC program benefited all groups, it did not benefit them uniformly to eliminate all disparities between and within groups. Indeed, as the experience among black children shows, our findings suggest that broad instruments such as widening access by reducing financial barriers for all could serve to sharpen instead of reduce within-group income-related disparities by benefiting high-income families to a greater degree than poorer families.

As noted, results from this study also show that while income-related disparities decreased over time, there was an uptick in disparities in the latest period. This period corresponds to the introduction of the ACA, which required all new private insurance plans beginning September 23, 2010, to cover Advisory Committee on Immunization Practices' recommended vaccinations without any cost-sharing requirement. To what extent the ACA affected results in the most recent period is difficult to ascertain. However, it is reasonable to expect that the requirement of private insurance to wave all cost-sharing for vaccinations would benefit richer, insured families to a greater degree than poorer, uninsured families thereby increasing income-related disparities.

An important finding of this study is that while racial and ethnic disparities in vaccinations were large at the beginning of the vaccines program, vaccination rates across ethnicities have narrowed considerably, which is to be welcomed. Socioeconomic disparities, as measured by household income, however, remain. The question of why some children, specifically those from lower socioeconomic groups who prior to the establishment of the VFC program had greater incidence of vaccine-preventable disease,[1,2] still do not undergo vaccination, even after the removal of many financial barriers through the program, is one that requires greater scrutiny from both researchers and policy makers. It seems unlikely that the lower rates of uptake in poor children could be explained by laws allowing nonmedical exemption in many states, since the evidence from studies on the impact of nonmedical exemption laws also clearly indicates that those who fill out exemptions are more likely to be from richer families, not those from lower-income households.[31,32]

While this study has examined the impact of the VFC program on vaccination behavior, it is acknowledged that other factors and policies, such as state exemption changes,[33] removal

of insurance cost-sharing requirements,[34] and exogenous factors such as the specious linkage of the MMR vaccine to autism, may have affected vaccination behavior. Approximately 10 percent of children in the National Immunization Survey were dropped because of missing income information, which may lead to an underestimation of the disparities observed.[28] Furthermore, the lack of information on the insurance status of the child in each year of the survey prevented the examination of what impact the program had on children in different insurance statuses.

Conclusion

There was a significant increase in the uptake of many common vaccines and a reduction in disparities across ethnic and racial groups subsequent to the introduction of the Vaccines for Children program in the United States. These gains may well be attributable to the impact of the program in reducing financial barriers to access. The pattern of uptake, however, requires a more nuanced explanation, since it varied within groups differentiated by race and ethnicity over time. A deeper explanation might be required than just simply referring to a reduction in financial barriers to access. A failure to explore such patterns and seek a fuller explanation for the patterns of uptake observed not only means valuable insights may be missed that could inform policy but may fail to counter recent reversals in the reductions in disparities observed in respect of the uptake on many common vaccines.

It is clear that policies aimed at improving vaccination behavior warrants careful consideration and with a specific focus on poorer families. More nuanced and creative interventions are needed if the benefits of these highly effective interventions are to be shared by those who stand to benefit the most, specifically among poorer children.

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The income categories for 1999–2004: 0–$7,500; $7,501–$10,000; $10,001–$12,500; $12,501–$15,000; $15,001–$17,500; $17,501–$20,000; $20,001–$25,000; $25,001–$30,000; $30,001–$35,000; 35,001–$40,000; $40,001–$45,000; $45,001–$50,000; $50,001+.

The income categories for 2005–13: 0–$7,500; $7,501–$10,000; $10,001–$17,500; $17,501–$20,000; $20,001–$25,000; $25,001–$30,000; $30,001–$35,000; $35,001–$40,000; $40,001–$50,000; $50,001–$60,000; $60,001–$75,000; $75,001+.

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Table 1: Percentage Of US Children Ages 19–35 Months Vaccinated Across Race And Ethnicity And Household Income

	Race/ethnicity					Income tertiles		
Years	Total	White	Black	Hispanic	Other ethnicity	Highest income	Middle income	Lowest income
Observations								
1995–97	51,950	35,700	7,219	6,407	2,624	14,880	17,141	19,929
1998–2000	61,178	38,179	9,366	10,134	3,499	17,229	22,681	21,268
2001–04	81,416	48,601	10,784	15,559	6,472	25,244	28,853	27,319
2005–07	51,529	31,482	5,092	10,229	4,826	17,180	17,140	17,309
2008–10	49,191	31,052	4,774	8,494	4,871	15,772	16,944	16,475
2011–13	46,798	28,337	4,348	8,642	5,471	14,482	16,860	15,456
Vaccination rate: DTaP ≥ 4 doses								
1995–97	80.24%	82.24%	77.34%	73.64%	81.19%	87.97%	80.99%	74.61%
1998–2000	82.43	84.78	77.77	78.11	83.59	89.31	82.36	77.58
2001–04	82.36	84.85	76.86	79.39	81.61	89.92	82.41	77.37
2005–07	84.62	85.73	82.55	83.03	84.68	89.59	84.54	81.39
2008–10	83.65	85.04	80.69	82.86	84.46	90.24	83.47	80.80
2011–13	82.85	84.17	77.83	82.04	84.63	90.94	82.82	78.95
Vaccination rate: MMR ≥ 1 dose								
1995–97	89.72%	90.94%	88.00%	85.91%	91.05%	93.96%	90.49%	86.36%
1998–2000	90.70	91.68	88.47	89.17	90.95	94.18	90.59	88.32
2001–04	91.31	92.16	89.56	90.21	91.18	94.83	91.23	89.09
2005–07	92.56	92.53	92.28	92.45	93.47	95.16	92.11	91.18
2008–10	91.72	91.58	91.78	92.11	92.21	93.42	90.65	91.68
2011–13	91.68	91.26	90.73	92.51	92.54	94.47	90.38	91.11
Vaccination rate: Polio ≥ 3 doses								
1995–97	89.49%	90.62%	87.45%	86.74%	89.20%	93.46%	89.46%	86.92%
1998–00	89.30	90.49	86.32	87.61	89.52	92.17	89.49	87.05
2001–04	89.78	90.86	87.15	88.93	88.50	93.39	89.40	87.75
2005–07	91.95	92.07	91.02	92.00	92.21	93.73	91.58	91.05
2008–10	92.63	92.88	91.90	92.60	92.48	94.98	91.74	92.00
2011–13	92.65	93.19	92.01	92.27	91.92	95.67	92.09	91.53

Table 2: Percentage Vaccination Uptake Of US Children Ages 19–35 Months Partitioned By Race And Ethnicity And Household Income

Vaccination type	Years	White			Black			Hispanic		
		High income	Middle income	Low income	High income	Middle income	Low income	High income	Middle income	Low income
DTaP ≥ 4 doses	1995–97	88.83%	82.23%	75.49%	83.91%	77.29%	75.89%	83.75%	75.48%	71.48%
	1998–00	90.23	83.05	79.77	86.10	78.13	75.85	83.45	80.72	76.22
	2001–04	90.68	83.73	78.34	85.56	76.86	75.15	86.94	80.47	77.82
	2005–07	90.41	85.31	80.32	86.61	83.59	81.15	86.66	82.95	82.27
	2008–10	90.42	83.98	79.98	89.52	83.63	78.39	89.25	81.74	82.23
	2011–13	90.82	83.38	77.63	88.60	80.63	75.61	90.18	81.89	81.15
MMR ≥ 1 dose	1995–97	94.69	91.26	86.34	89.47	88.28	87.59	90.04	86.73	85.00
	1998–2000	94.47	90.77	89.14	91.35	90.16	87.10	93.53	89.83	88.21
	2001–04	95.01	91.73	88.78	93.21	89.19	88.99	94.73	90.43	89.41
	2005–07	95.15	92.24	89.57	94.19	90.93	92.28	94.63	92.05	92.10
	2008–10	93.80	90.51	90.34	93.79	92.75	91.16	91.13	90.66	92.58
	2011–13	94.23	90.00	89.45	95.50	90.91	90.05	95.11	90.91	92.63
Polio ≥ 3 doses	1995–97	93.91	90.14	87.52	89.47	88.17	86.76	93.24	85.99	85.88
	1998–2000	92.86	89.69	88.39	90.48	87.46	84.93	87.71	89.28	86.94
	2001–04	93.98	89.78	88.18	91.52	86.39	86.59	92.00	89.33	88.30
	2005–07	94.00	91.91	89.92	93.23	90.79	90.54	93.04	90.60	92.20
	2008–10	95.41	91.76	91.33	93.17	92.73	91.46	93.90	91.25	92.73
	2011–13	95.76	92.04	91.70	96.26	93.03	91.16	95.42	93.39	91.62

Figure 1: Concentration Indices For MMR Vaccination Of US Children Ages 19–35 Months Across Race And Ethnicity

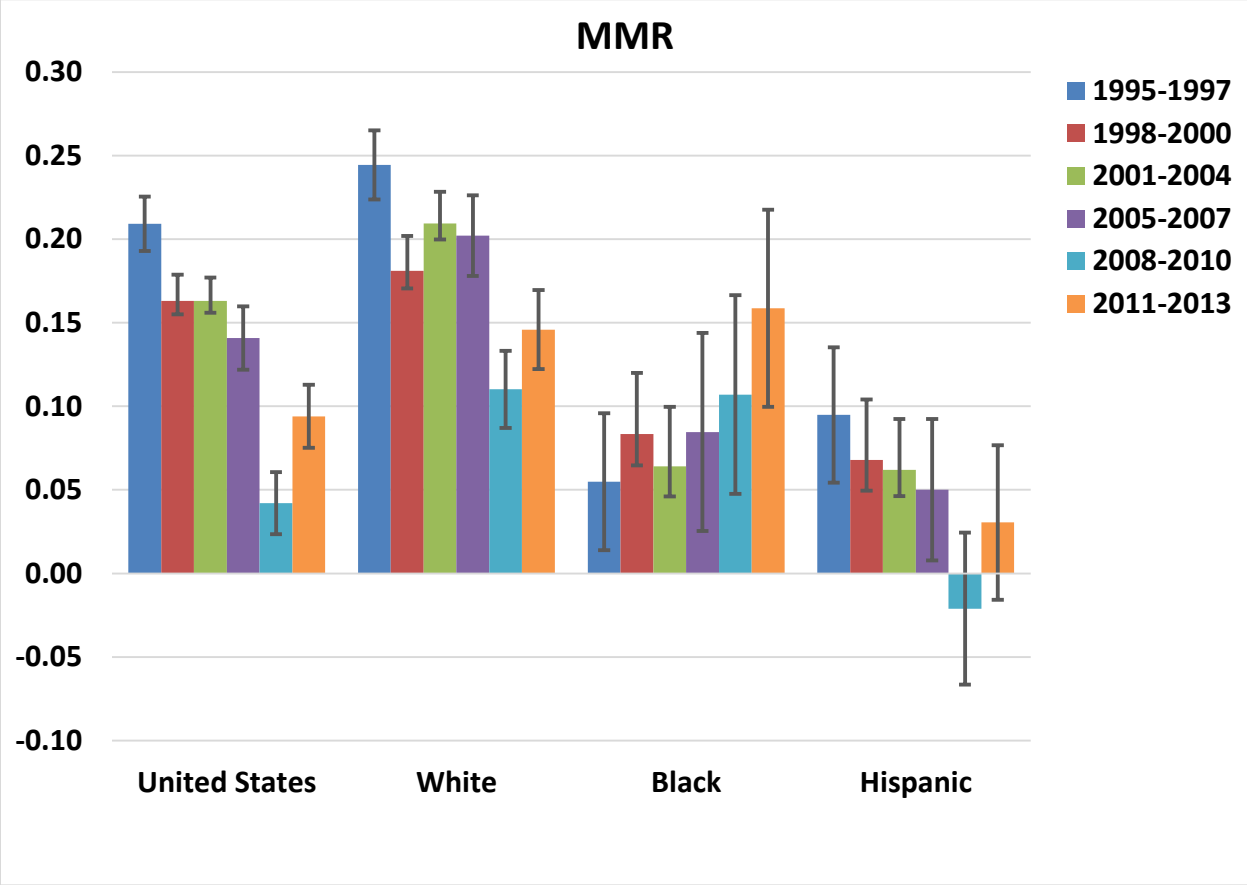


Figure 2: Concentration Indices For DTaP Vaccination Of US Children Ages 19–35 Months Across Race And Ethnicity

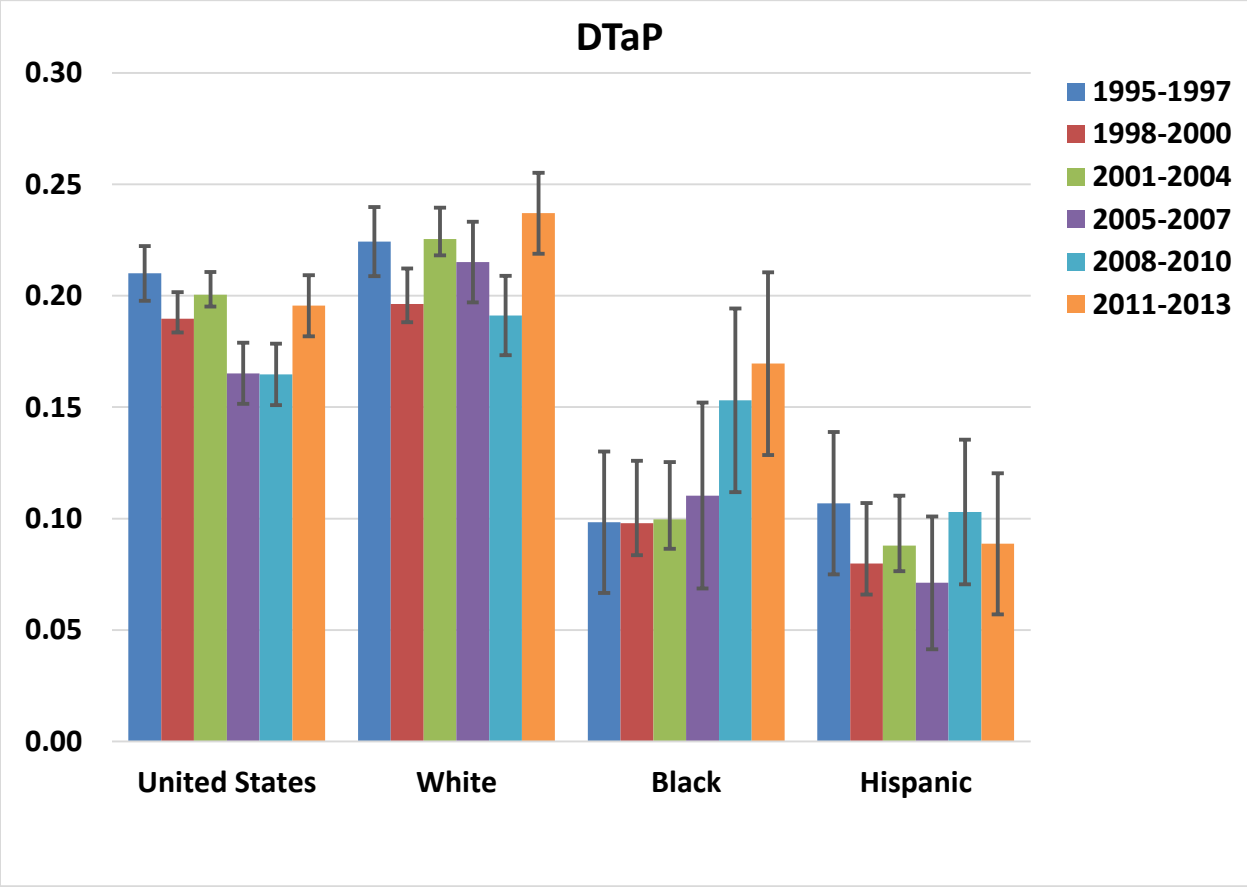
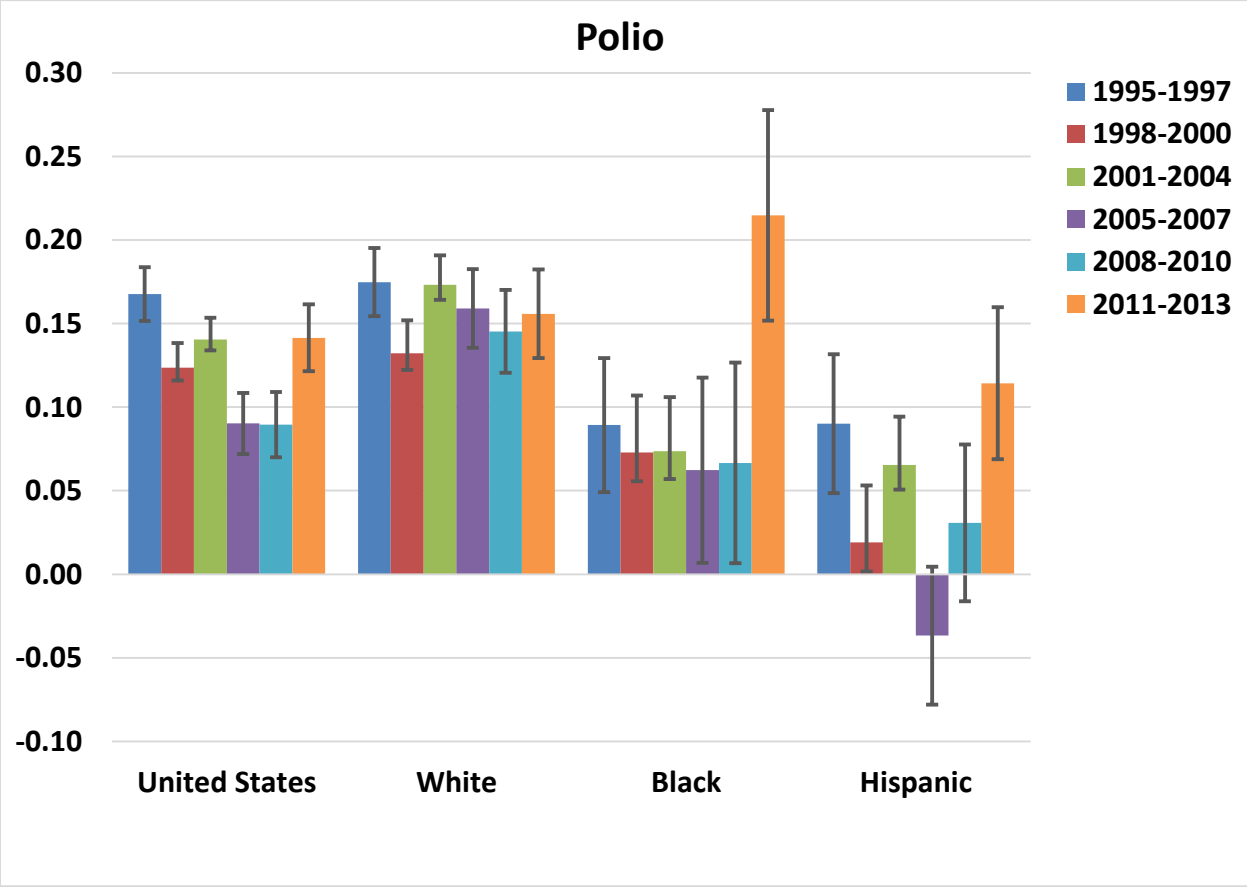


Figure 3: Concentration Indices For Polio Vaccination Of US Children Ages 19–35 Months Across Race And Ethnicity



Appendix

Table A1: Percentage Of US Children Ages 19–35 Months Vaccinated Across Race And Ethnicity And Household Income

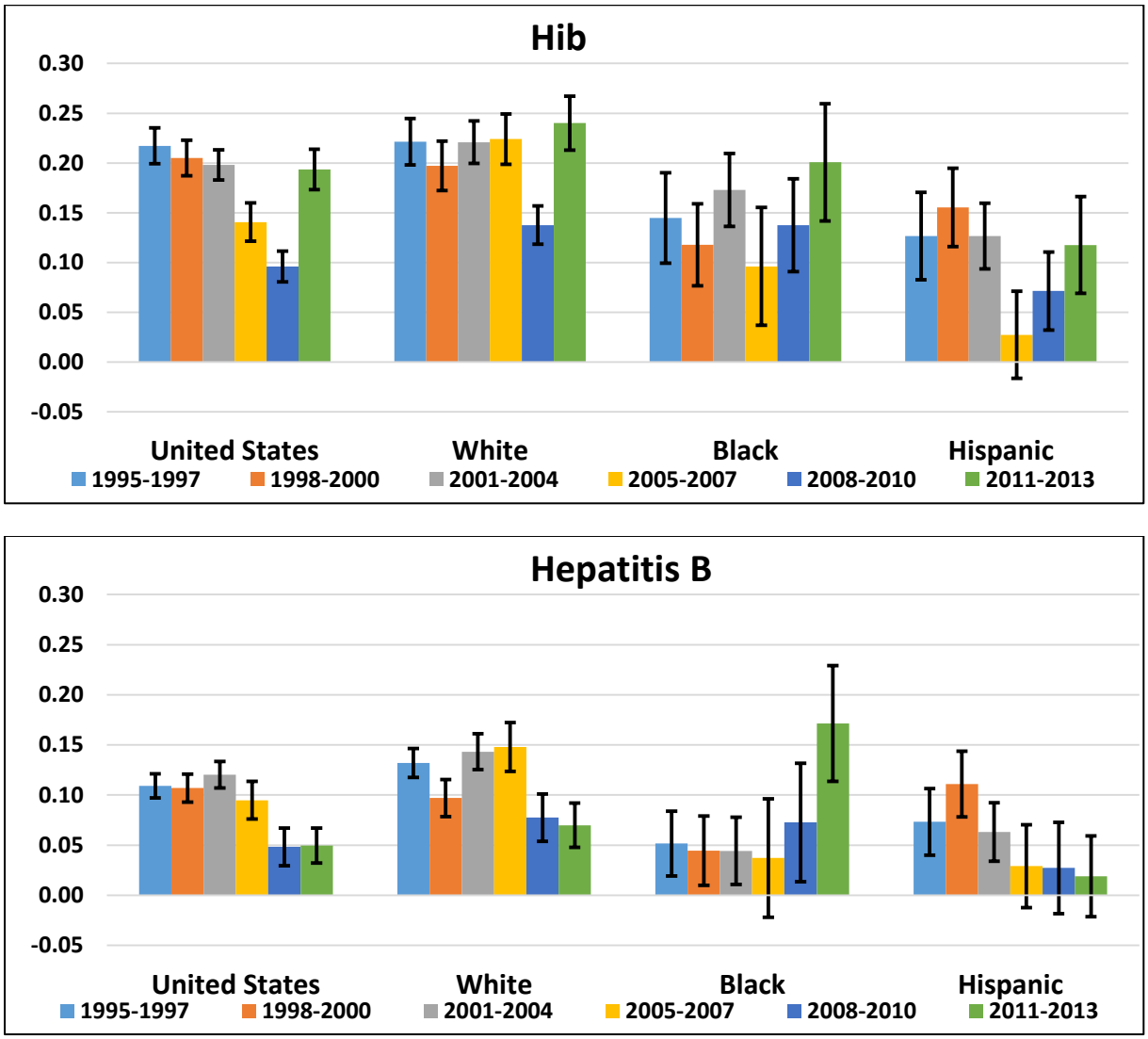
	Race/ethnicity					Income tertiles		
Years	**Total**	**White**	**Black**	**Hispanic**	**Other ethnicity**	**Highest income**	**Middle income**	**Lowest income**
Observations								
1995–97	51,950	35,700	7,219	6,407	2,624	14,880	17,141	19,929
1998–2000	61,178	38,179	9,366	10,134	3,499	17,229	22,681	21,268
2001–04	81,416	48,601	10,784	15,559	6,472	25,244	28,853	27,319
2005–07	51,529	31,482	5,092	10,229	4,826	17,180	17,140	17,309
2008–10	49,191	31,052	4,774	8,494	4,871	15,772	16,944	16,475
2011–13	46,798	28,337	4,348	8,642	5,471	14,482	16,860	15,456
Vaccination rate: Hib ≥ 3 doses								
1995–97	91.82%	93.05%	90.53%	88.29%	90.45%	95.39%	92.38%	89.03%
1998–2000	93.09	94.33	91.18	91.15	90.86	95.94	93.51	90.65
2001–04	92.72	93.93	90.31	91.86	90.09	95.79	93.14	90.35
2005–07	93.86	93.26	92.24	92.95	90.78	95.21	92.64	91.46
2008–10	87.61	87.50	85.81	88.95	86.66	90.53	87.29	86.28
2011–13	92.93	93.50	90.71	93.27	92.08	96.80	92.53	91.30
Vaccination rate: HepB ≥ 3 doses								
1995–97	78.54%	78.86%	78.30%	76.41%	82.51%	83.27%	78.21%	75.62%
1998–2000	88.11	88.96	86.84	86.47	87.68	90.47	88.49	86.05
2001–04	90.16	91.08	88.04	89.21	89.61	93.06	89.97	88.41
2005–07	92.43	92.68	92.21	92.07	92.16	94.16	92.20	91.45
2008–10	92.04	91.98	91.62	92.15	92.64	93.44	91.29	91.78
2011–13	89.96	89.71	90.30	89.89	90.80	92.07	88.98	89.52

Vaccination rate: Varicella ≥ 1 dose								
1995–97	20.88%	22.67%	16.20%	16.38%	25.85%	31.39%	21.47%	13.49%
1998–00	57.62	56.68	57.21	59.79	61.51	65.10	55.31	54.51
2001–04	82.86	82.13	82.55	84.10	85.09	87.88	81.25	80.95
2005–07	89.50	88.71	90.96	89.93	91.49	91.62	88.86	88.56
2008–10	90.52	89.89	90.66	91.48	91.15	92.78	89.21	90.10
2011–13	90.77	89.82	90.97	91.95	91.81	93.40	89.18	90.45

Table A2: Percentage Vaccination Uptake Of US Children Ages 19–35 Months Partitioned By Race And Ethnicity And Household Income

Vaccination type	Years	White			Black			Hispanic		
		High income	Middle income	Low income	High income	Middle income	Low income	High income	Middle income	Low income
Hib ≥ 3 doses	1995–97	95.79%	93.16%	89.84%	94.06%	91.27%	89.50%	93.48%	89.15%	87.20%
	1998–00	96.48	93.61	92.41	95.59	91.35	90.18	93.68	94.23	89.52
	2001–04	96.29	93.65	91.01	95.50	91.57	88.78	95.51	93.02	90.87
	2005–07	95.91	93.06	90.07	94.87	92.45	90.74	95.73	91.78	92.88
	2008–10	90.55	87.03	84.45	90.89	88.87	84.07	91.10	88.94	88.66
	2011–13	96.89	92.58	90.79	94.48	93.24	89.44	97.59	93.58	92.70
HepB ≥ 3 Doses	1995–97	83.67%	77.98%	74.55%	79.33%	80.12%	77.45%	82.27%	77.84%	75.04%
	1998–00	90.86	88.31	87.29	88.31	87.87	86.07	90.05	89.09	84.86
	2001–04	93.41	90.61	88.50	91.02	87.33	87.73	92.47	88.85	88.82
	2005–07	94.70	92.49	90.48	94.77	91.26	91.92	95.65	90.59	92.12
	2008–10	93.69	91.02	91.21	93.29	92.45	91.10	91.70	91.52	92.35
	2011–13	91.95	88.24	88.97	94.55	91.70	89.33	89.52	90.52	89.77
Varicella* ≥ 1 dose	1995–97	31.46%	21.32%	14.06%	27.21%	21.62%	12.07%	30.11%	20.37%	13.03%
	1998–00	64.76	53.10	51.06	66.05	59.68	54.22	62.61	61.39	58.70
	2001–04	87.61	80.06	77.67	87.41	83.38	81.26	88.66	83.66	83.54
	2005–07	91.99	88.20	85.69	93.20	91.05	90.33	91.30	88.69	90.24
	2008–10	92.90	89.04	87.39	93.04	91.85	89.92	92.01	89.95	91.77
	2011–13	93.23	88.28	87.83	91.12	91.18	90.89	93.72	90.63	92.09

Figure A1: Concentration Indices For Hib, HepB, and Varicella Vaccination Of US Children Ages 19–35 Months Across Race And Ethnicity



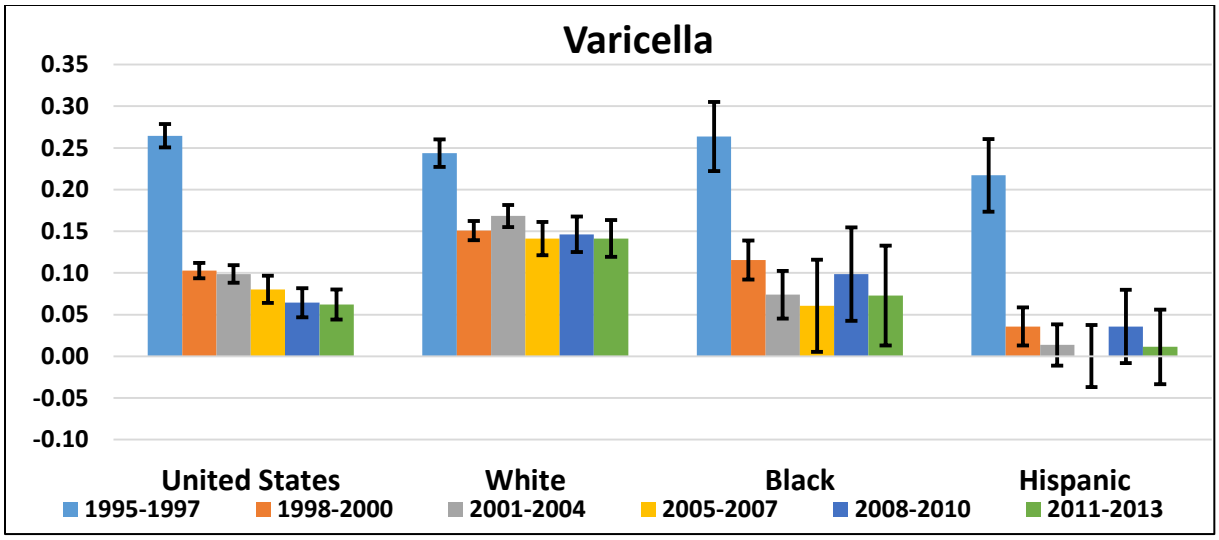

Varicella
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
United States
White
Black
Hispanic
1995-1997
1998-2000
2001-2004
2005-2007
2008-2010
2011-2013

Table A3: Multivariate Analyses for DTaP, MMR, and Polio Vaccination of US Children Ages 19–35 Months

	1995-97	1998-2000	2001-04	2005-07	2008-10	2011-13
DTaP ≥ 4 doses						
White High Income	Base	Base	Base	Base	Base	Base
White Mid Income	-0.072***	-0.076***	-0.079***	-0.063***	-0.071***	-0.087***
White Low Income	-0.129***	-0.093***	-0.125***	-0.094***	-0.100***	-0.132***
Black High Income	-0.056*	-0.047**	-0.072**	-0.087**	-0.017	-0.037
Black Mid Income	-0.126***	-0.128***	-0.166***	-0.058***	-0.076***	-0.123***
Black Low Income	-0.124***	-0.131***	-0.169***	-0.081**	-0.119***	-0.161***
Hispanic High Income	-0.039	-0.067***	-0.027**	-0.010	-0.002	0.001
Hispanic Mid Income	-0.119***	-0.076***	-0.084***	-0.072***	-0.074***	-0.085***
Hispanic Low Income	-0.140***	-0.103***	-0.099***	-0.053***	-0.048***	-0.077***
MMR ≥ 1 dose						
White High Income	Base	Base	Base	Base	Base	Base
White Mid Income	-0.040***	-0.035***	-0.038***	-0.032***	-0.033***	-0.044***
White Low Income	-0.085***	-0.042***	-0.068***	-0.057***	-0.030***	-0.041***
Black High Income	-0.069**	-0.038**	-0.026*	-0.022	-0.003	0.013
Black Mid Income	-0.077***	-0.042**	-0.075***	-0.038**	-0.008	-0.040**
Black Low Income	-0.072***	-0.064**	-0.072***	-0.035**	-0.026	-0.040**
Hispanic High Income	-0.052	-0.005	0.006	0.011*	-0.024**	0.013
Hispanic Mid Income	-0.080***	-0.037*	-0.037***	-0.033***	-0.021*	-0.026*
Hispanic Low Income	-0.087***	-0.045***	-0.043***	-0.020**	0.003	-0.004
Polio ≥ 3 doses						
White High Income	Base	Base	Base	Base	Base	Base
White Mid Income	-0.044***	-0.030***	-0.048***	-0.037***	-0.042***	-0.047***
White Low Income	-0.073***	-0.033***	-0.062***	-0.052***	-0.046**	-0.044***
Black High Income	-0.064**	-0.023**	-0.034**	-0.029	-0.037	0.004
Black Mid Income	-0.080***	-0.050***	-0.095***	-0.037**	-0.035**	-0.039**
Black Low Income	-0.096***	-0.069***	-0.086***	-0.042***	-0.054***	-0.055**
Hispanic High Income	0.003	-0.043*	-0.013	-0.005	-0.008	0.000
Hispanic Mid Income	-0.080****	-0.013	-0.035***	-0.040***	-0.033***	-0.019
Hispanic Low Income	-0.075***	-0.027***	-0.040***	-0.003	-0.012*	-0.032***

SOURCE Authors' analysis of National Immunization Survey data. NOTES DTaP is diphtheria-tetanus-acellular pertussis. MMR is measles-mumps-rubella.

Results presented as Marginal Effects. Regression controls for state of residence, year of survey, mother's education, mother's marital status, and gender of child. Results of other variables are suppressed

* Statistically significant difference ($p<0.10$). ** Statistically significant difference ($p<0.05$). *** Statistically significant difference ($p<0.01$)