

WHY HAS THE HEALTH INEQUALITY AMONG INFANTS IN THE US DECLINED? ACCOUNTING FOR THE SHRINKING GAP

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SUMMARY

Given that wealthier people are healthier, the increase in income inequality over the past two decades has led to fears that inequalities in health have also increased. Indeed, some papers have found that health disparities have become more salient among some adult populations. Using the US Vital Statistics 1983–2000, this paper presents a new stylized fact: the infant health disparity, as measured by Apgar score, neonatal mortality and infant mortality, has been narrowing over the past two decades. This is in sharp contrast to the increasing disparities in health among adults of different educational backgrounds. Using a decomposition method, I find that the most important factor in explaining the closing gap is an increase in access to medical care. All else being equal, access to proper medical care is the most important factor in explaining the narrowing infant health gap. Demographic shifts and maternal behavior changes are also significant factors, together explaining 42.2% of the closing gap in low Apgar score, 41.4% of the closing gap in neonatal death, and 45.6% of the closing gap in infant death. Copyright © 2008 John Wiley & Sons, Ltd.

Received 29 June 2007; Revised 20 June 2008; Accepted 11 July 2008

JEL classification: I10; I18; I12

Keywords: health inequality; infant health

1. INTRODUCTION

Wealthier people are healthier; differences in health are apparent in some key health indicators such as infant mortality and life expectancy. Increases in income inequality over the past two decades combined with rising labor returns to schooling (Autor *et al.*, 2005) have led to fears that inequalities in health have also increased. Indeed, despite improvements in health for the population as a whole, some papers have found that health disparities have become more salient among certain adult populations.¹

Economists have long recognized the phenomenon in which people with higher socioeconomic status have better health and longevity than people with low socioeconomic status; this phenomenon is known as the gradient in health status. These health disparities have received attention from researchers and policymakers alike; they are now systematically monitored in many countries throughout the world. One of the World Health Organization's stated targets in its *Health for All 2000* report is to eliminate social inequalities in health. Policy goals in the United States also reflect a strong desire to eliminate such disparities; in its *Healthy People 2010* report, the Public Health Service proclaims that one of its two primary goals is to eliminate health disparities among different segments of the population.

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¹See e.g. Crimmins and Saito (2001), Pappas *et al.* (1993), Goesling (2007), Meara *et al.* (2008).

This paper presents a new stylized fact: the infant health disparity in the US, as measured by Apgar score, neonatal mortality and infant mortality, has been narrowing over the past two decades. I chose mortality rates because they are objective and serious events that both policymakers and researchers care about; however, infant death is also very rare. Apgar score is an overall measure of infant health at birth. It provides details on infants that are not terminally ill, and thus without a high probability of death. It was designed to quickly evaluate a newborn's physical condition after delivery and to determine any immediate need for extra medical or emergency care. Apgar assesses the health conditions of a newborn based on heart rate, respiration, muscle tone, skin color, and response to stimuli. The maximum score for each of the five health factors is 2; hence a perfect Apgar score is 10.

This narrowing is in sharp contrast to the increasing disparities in health among adults of different educational backgrounds.² After observing such patterns over time, the natural question to ask is what accounts for the narrowing gap in the educational-based infant disparity. I utilize a decomposition technique to focus on three main factors: maternal behavioral changes, demographic changes, and changes in access to medical care. Changes in maternal behavior include delays in pregnancy, fertility treatments (inferred from an increase in multiple births), unhealthy gestational weight gain, and reduction in smoking. Demographic changes include, for example, the fact that an increasing number of infants born to less-educated mothers are being born to Hispanics rather than African-Americans. Finally, access to medical care is linked to the rapid increase in public health insurance coverage that took place during the late 1980s and early 1990s.

I find that the most important factor in explaining the closing gap is an increase in access to medical care. However, demographic shifts and maternal behavior changes are also critical. For example, research shows that foreign-born Hispanic women on average have better infant health outcomes than African-Americans. Given these racial differences in birth outcomes, the gap in infant health decreased because an increasing number of infants whose mothers are less-educated are born to Hispanic immigrants rather than to African-Americans. There are also several behavioral factors that have had an important impact. Namely, the infant health gap has decreased because smoking among less-educated women has declined, though this improvement is partially offset by an increase in the number of less-educated women who gain excessive weight during pregnancy. Finally, the gap has decreased because an increasing number of college-educated women are delaying fertility and are seeking fertility treatment, which often leads to multiple births; such behaviors are usually associated with less healthy infants.

The rest of the paper proceeds as follows: Section 2 discusses the underlying mechanisms of changes in infant health over time. Sections 3 and 4 provide an overview of the data and methods. Results appear in Section 5 and Section 6 presents some specification checks. Section 7 concludes.

2. A FRAMEWORK FOR EXPLORING INFANT HEALTH OVER TIME

This paper extends the line of research that examines the evolution of the gradient in infant health to a more recent period (1983–2000).³ I first document the trend in the infant health gap – finding that the

²For example, Pappas *et al.* (1993) suggest that in 1986, the differences in mortality across educational groups were larger than those in 1960 in the United States. Crimmins and Saito (2001) also find large and growing educational differences in healthy life expectancy in the United States from 1970 to 1990.

³Previous research has found increasing health disparities in mortality and life expectancy both in Europe and in the United States. For example, Pappas *et al.* (1993) suggest that in 1986, the differences in mortality across educational groups were larger than those in 1960 in the United States. Crimmins and Saito (2001) also find large and growing educational differences in healthy life expectancy in the United States from 1970 to 1990. We also see increasing health disparities among adults when examining other measures of health such as self-reported health (Goesling, 2007) and old-age disability rates (Schoeni *et al.*, 2001, 2005). For example, Schoeni *et al.* (2001, 2005) find that educational differences in old-age disability rates have been declining since the early 1980s but that the gains have been concentrated among the most educated.

infant health gaps with respect to various infant health measures have narrowed over time. I then ask why, in the face of increasing income inequality, these infant health gaps decrease dramatically.

Three factors related to infant health have witnessed substantially different trends among the highly educated and low-educated groups over the past two decades. They have the potential to account for most of the rapid narrowing that we observe in the infant health gaps. These three mechanisms are as follows: (1) maternal behavior changes, (2) demographic changes, and (3) access to medical care. In this section, I discuss in more detail how these three mechanisms affect infant health.

2.1. Maternal behavior changes

The measures of maternal behavior, which I use are maternal age, marital status, whether the mother smokes, gestational weight gain, and whether the mother undergoes fertility treatments. This last element is unobserved, but I infer the use of such treatments through the prevalence of multiple births (see discussion below).

Advanced age, being unmarried, and maternal smoking all adversely affect infant health outcomes. A number of studies have shown that advanced maternal age increases the probability of chromosomal abnormality, Down's syndrome, low birth weight, preterm delivery, and small size for gestational age at delivery. Similarly, out-of-wedlock birth has also long been recognized as one of the demographic risk factors associated with infant mortality and other adverse infant health outcomes (Bennett, 1992). In this paper, I show that the infant death rate for unmarried mothers was 1.9 times higher than that of married mothers during the sample period. Lastly, as is well known and well studied, maternal smoking adversely affects the health of both mother and child.

Unlike maternal smoking, both inadequate and excessive weight gain have not yet been well studied, though these are important risk factors. Some studies show that both of these factors are associated with maternal complications. One limitation of previous studies on the effects of excessive weight gain is the use of small hospital data sets lacking information on Apgar scores. In contrast, I use the US Vital Statistics data that include information on Apgar scores and have a large sample size. In Lin (2006), a discussion paper version of this paper, I show that both inadequate and excessive weight gain are associated with negative infant health outcomes.

The last factor related to maternal behavior that I investigate is the effect of fertility treatments. Although I do not have data on fertility treatments, the sharp increase in the number of multiple births in certain groups can be used to infer the prevalence of such procedures. Compared with singleton births (i.e. only one child born to a mother), children from multiple births are usually smaller and have more complications. As a result, children from multiple births are more likely to die. If highly educated mothers use fertility treatments more than less-educated mothers, then multiple births may reduce the health gap by worsening infant health among highly educated women.

2.2. Demographic changes

Research on ethnic differences in the United States demonstrates that despite a socioeconomic profile comparable to African-Americans and a lower socioeconomic profile compared with the non-Hispanic white population, Hispanics are healthier than African-Americans and similar in health to non-Hispanic whites. This phenomenon is observed in several important health indicators such as mortality and birth weight, and has come to be termed an 'epidemiologic paradox'.⁴ This pattern is partly explained by some health-related behaviors such as lower rates of smoking and drinking among Hispanics.

⁴See for example Elo *et al.* (2004), Hummer *et al.* (2000), Morales *et al.* (2002), Palloni and Arias (2004), Kington and Nickens (2001), Collins and Shay (2002).

However, when maternal nativity is examined, these positive effects are restricted to immigrant (foreign-born) Hispanics, and do not extend to American-born Hispanic women. For example, Collins and Shay (2002) show that in very low-income (less than \$10 000/year) census tracts, the incidence of low birth weight infants among American-born Hispanics and African-Americans is equivalent. In contrast, foreign-born Hispanic infants have a low birth weight rate that is far less than that of African-Americans and is 40% less than that of non-Hispanic whites. There are various hypotheses that have been proposed to explain Hispanics' favorable health outcomes. The most prevalent hypotheses include the healthy migrant effect, which argues that Hispanic immigrants are selected for their good health and robustness.

Historically, infant mortality among blacks in the United States has been approximately twice that of whites.⁵ Numerous studies have argued that the lower average relative birth weight of African-American babies to Caucasian babies is the primary reason for the persistence of black–white infant mortality differentials, for example, Lu and Halfon (2003). Since an increasing number of infants in the less-educated population are now being born to foreign-born Hispanics rather than to African-Americans and foreign-born Hispanic women in general have favorable birth outcomes while African-Americans have worse outcomes, we can expect this change in demographic composition to improve infant health among the less educated during the sample period.

2.3. Access to medical care

In an effort to increase the use of prenatal care, the late 1980s and early 1990s has witnessed a rapid expansion in the eligibility of pregnant women for Medicaid, a federal-state matching entitlement program that provides health insurance for the poor. Until the early 1980s, the eligibility for Medicaid was tied to the receipt of cash welfare payments under the Aid to Families with Dependent Children (AFDC) program. This linkage had the effect of limiting eligibility to very low-income women in single-parent households. However, since the inception of the Medicaid program, states have had the option of extending Medicaid benefits to some groups of pregnant women who were not on AFDC. Starting from the late 1980s, Medicaid eligibility for pregnant women has increased dramatically. As a result, by 2000, Medicaid covered medical expenses for nearly 40% of all US births.

It is widely believed that expanding medical care can improve infant health. For example, Currie and Gruber (1996) show that broader eligibility for Medicaid increased the utilization of medical care and lowered the incidence of infant mortality.⁶ By improving access to medical care, primarily among less-educated women, the rapid Medicaid expansion may cause the gap in the infant health disparity to narrow significantly.

In this paper, adequate prenatal care is constructed using the Kessner Criteria, defined by the National Center for Health Statistics (NCHS), which uses the month in which prenatal care was initiated, the number of prenatal visits, and the gestation weeks to evaluate whether prenatal care is adequate. Specifically, NCHS defines adequate prenatal care as having one's first prenatal visit with a health professional within the first trimester of pregnancy and having an adequate number of follow-up visits based on gestational weeks.

3. DATA AND VARIABLES

The main source of data used in this study comes from the Linked Birth and Infant Death files (LBID) released by the NCHS. The data are publicly available for periods 1983–1991 and 1995–2000. These data contain linked information from birth to death certificates. Unfortunately, this linkage is not provided for 1992, 1993, or 1994, so for these years the Vital Statistics Detailed Natality data are used

⁵National Vital Statistics Reports, Volume 50, Number 15, NCHS 2002.

⁶Currie and Gruber (1996) find that a 30%-point increase in eligibility would lead to a 8.5% reduction in infant mortality rate.

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Table I. Distribution of Apgar scores and its relationship with infant death

Apgar scores	Percentage	Infant death			
		All	HS dropouts	HS graduates/some college	College graduates
0	0.07	0.575 [0.0099]	0.531 [0.0199]	0.585* [0.0129]	0.612* [0.0246]
1	0.20	0.814 [0.0046]	0.809 [0.009]	0.815* [0.0058]	0.815* [0.0127]
2	0.10	0.550 [0.0082]	0.551 [0.0162]	0.551* [0.0106]	0.54* [0.0222]
3	0.11	0.325 [0.0074]	0.346 [0.0142]	0.316* [0.0096]	0.319* [0.0198]
4	0.16	0.214 [0.0054]	0.232 [0.0108]	0.21* [0.007]	0.195* [0.0133]
5	0.28	0.143 [0.0034]	0.150 [0.0069]	0.144* [0.0045]	0.128* [0.0085]
6	0.64	0.084 [0.0018]	0.093 [0.0039]	0.083* [0.0023]	0.074* [0.0043]
7	1.62	0.039 [0.0008]	0.047 [0.0018]	0.037* [0.001]	0.032* [0.0017]
8	7.66	0.011 [0.0002]	0.016 [0.0005]	0.011* [0.0003]	0.008* [0.0004]
9	76.64	0.003 [0]	0.006 [0.0001]	0.003* [0]	0.002* [0.0001]
10	12.52	0.003 [0.0001]	0.005 [0.0002]	0.002* [0.0001]	0.001* [0.0001]

Notes: 1. Data are from US Vital Statistics, 1983–2000. A low Apgar score is defined at 8 to below –10.84% of infants have low Apgar scores. 2. Standard errors in brackets, with asterisks (*) denote that the differences between HS dropout group and other groups are significant at 5% level.

instead. Although infant mortality information is not available in the Natality data, it contains several other infant health measures like Apgar scores, which are of interest to this study.

The combined LBID and Natality data sets provide a census of virtually all of the approximately four million births that occur in the United States each year. Beginning in 1989, the Vital Statistic files include self-reported data on maternal smoking during pregnancy and gestational weight gain. My decomposition analyses, therefore, focus on the period between 1989 and 2000 when these two measures of maternal behavior are available. For consistency, I exclude states that do not report maternal education, Apgar scores, and relevant explanatory variables for all of the sample years.⁷ To ease computation time, I then take a sample of 10%.⁸ After these exclusions I am left with a sample of 4357908 observations from 43 states. This large sample size allows the analysis of relatively rare outcomes, such as infant deaths, with high precision and enables me to conduct detailed analysis by maternal education groups.

My primary measures of health outcomes are two infant mortality rates – infant death rates and neonatal death rates, and low Apgar scores.⁹ Infant and neonatal death rates are important because they are objective and severe measures that policymakers, the public, and researchers care about. Apgar scores are important

⁷California, Texas, Washington, and New York do not report mother's education. California, Indiana, and South Dakota do not report maternal smoking. California and Texas do not report Apgar scores. Louisiana, Nebraska, and Oklahoma do not report gestational weight gain.

⁸The results in this paper are robust to different samples.

⁹Besides Apgar score and infant death rates, I also examine the changes in the gradient with respect to birth weight. I find that birth weight has not changed much over time either in terms of its distribution or in terms of the incidence of low birth weight (i.e. birth weight less than 2500 g). Specifically, from 1983 to 2000, the overall mean of the birth weight distribution has decreased by 46 g while the standard deviation has increased by 24 g, which is a minute change given that the mean birth weight distribution is around 3300 g. Furthermore, the incidence of low birth weight has not changed much for singleton births. There has, however, been an increasing incidence of low birth weight, but only among the college graduate group. This observation is mainly due to the increasing incidence of multiple births, which is most likely a result of increasing fertility treatments.

Table II. Summary statistics by maternal education (percentages reported)

Variables	Low education	Middle education	High education
<i>Infant outcomes</i>			
Low Apgar score	12.07 [0.0004]	10.90* [0.0002]	9.48* [0.0003]
Infant death (Death <1 year)	1.32 [0.0001]	0.85* [0.0001]	0.54* [0.0001]
Neonatal death (Death <1 Month)	0.75 [0.0001]	0.57* [0.0001]	0.39* [0.0001]
<i>Maternal behavior</i>			
Multiple births	2.01 [0.0002]	2.49* [0.0001]	3.27* [0.0002]
Mother smokes during pregnancy	28.33 [0.0006]	16.46* [0.0003]	3.05* [0.0002]
Weight gain less than 15 pounds	10.02 [0.0004]	8.04* [0.0002]	4.30* [0.0002]
Weight gain greater than 60 pounds	3.15 [0.0002]	2.67* [0.0001]	1.48* [0.0001]
Teenage mother	40.54 [0.0005]	7.96* [0.0002]	0.00* [0]
Maternal age over 40	0.76 [0.0001]	1.07* [0.0001]	2.65* [0.0002]
Married mother	42.36 [0.0005]	73.54* [0.0003]	95.36* [0.0002]
<i>Demographic variables</i>			
Hispanic	15.79 [0.0004]	5.35* [0.0001]	2.79* [0.0002]
African-American	26.84 [0.0005]	17.98* [0.0002]	7.08* [0.0003]
White	53.84 [0.0005]	73.78* [0.0003]	85.52* [0.0004]
Other races	3.53 [0.0002]	2.89* [0.0001]	4.61* [0.0002]
Foreign-born mother	15.44 [0.0004]	7.75* [0.0002]	10.69* [0.0003]
<i>Access to medical care</i>			
Adequate prenatal care	49.55 [0.0005]	72.31* [0.0003]	85.50* [0.0004]
Intermediate Prenatal Care	36.77 [0.0005]	22.86* [0.0003]	13.12* [0.0003]
Inadequate prenatal care	13.68 [0.0004]	4.83* [0.0001]	1.38* [0.0001]
Observations	874 774	2 632 968	904 444

Notes: 1. Low education: less than 12 years of schooling completed; Middle Education: 12–15 years of schooling completed; High Education: 16 or more years of schooling completed. 2. Data are from US Vital Statistics, 1983–2000. 3. Standard errors in brackets, with asterisks (*) denote that the differences between HS dropout group and other groups are significant at 5% level.

because research has shown that they are good predictors of future child health. For example, using the National Maternal and Infant Health Survey (NMIHS) data, Almond *et al.* (2005) find that after controlling for family background variables and infant birth weight, the Apgar score is a significant predictor for measures of health, cognitive ability, and behavioral problems of children at age three.

Table I reports the distribution of Apgar scores as well as their relationship with infant mortality. Column 3 shows that for Apgar 1–10, every one-point increase in the Apgar score leads to a decrease in the probability of infant death.¹⁰ This shows that the Apgar scores do well in terms of assessing different

¹⁰There might be some errors in recording an Apgar score of 0. It is odd that the death rate for Apgar score 0 babies is only 54%, whereas all of the other infant death rates decrease monotonically with the Apgar score. However, since I use Apgar score as a binary variable, with a 'low' Apgar score being set at Apgar less than or equal to 8. This makes any potential problems with zero Apgar scores irrelevant.

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Table III. The effects of education on poor infant health (linear probability model)

	All births			Singleton births		
	Low Apgar score	Infant mortality (death < 1 year)	Neonatal death (death < 1 Month)	Low Apgar score	Infant mortality (death < 1 year)	Neonatal death (death < 1 Month)
Low education	4.276 [0.280]**	0.953 [0.057]**	0.430 [0.037]**	4.189 [0.281]**	0.916 [0.052]**	0.401 [0.031]**
Middle education	1.941 [0.177]**	0.278 [0.026]**	0.160 [0.020]**	1.903 [0.172]**	0.265 [0.026]**	0.149 [0.020]**
Time trend*	-0.188	-0.022	-0.010	-0.168	-0.019	-0.007
low education	[0.012]**	[0.004]**	[0.003]**	[0.012]**	[0.004]**	[0.002]**
Time trend*	-0.064	0.001	0.000	-0.054	0.002	0.001
middle education	[0.008]**	[0.002]	[0.001]	[0.007]**	[0.002]	[0.001]
Observations	4 357 908	3 667 295	3 667 295	4 247 436	3 573 785	3 573 785

Notes: This table reports coefficients and standard errors (in brackets) from linear probability model. To save space, the coefficients are scaled up by 100. A full set of year dummies are not reported for brevity. Except year dummies, regressions do not include any other controls. *Significant at 5%; **significant at 1%. Data are from US Vital Statistics, 1983–2000.

infant health levels. Column 3 also shows that the relationship between Apgar score and infant death rate is not linear. For example, the effect of a one-point increase in the Apgar score from 9 to 10 has a very small effect on infant death, but a one-point increase, from 3 to 4 for example, has a very large effect on infant death. In the analysis that follows, I define a low Apgar score as less or equal to 8. I use a dichotomous variable because the effect of Apgar score on infant health is not linear. By choosing a cutoff point at 8, 10.84% of infants fall in low Apgar group.

This study distinguishes between three education groups: high school dropouts (less than 12 years of schooling completed, also referred to as the less-educated group), high school graduates (12–15 years of schooling completed, also referred to as the middle-educated group), and college graduates (16 or more years of schooling completed, also referred to as the highly educated group). The striking differences across education groups can be seen in Table II, which provides key summary statistics. High school dropout mothers are 1.27 times more likely to give birth to a low Apgar score baby. Compared with college graduated mothers, they are also 1.92 times more likely to have children who die within the first month and 2.44 times more likely to have children who die before age one.

Besides differences in Apgar score and infant mortality rates, there are also substantial differences in maternal characteristics by education group. As we see in Table III, mothers who are college graduates are 3.48 times more likely to give birth after age 40 than high school dropout mothers. College graduate mothers are also more likely to have multiple births, more likely to be married, less likely to smoke during pregnancy, and less likely to have excessive gestational weight gain (over 60 pounds) or inadequate weight gain (less than 15 pounds). Demographically, college graduate mothers are more likely to be white and less likely to be Hispanic or African-American. Finally, college-educated mothers are twice as likely to report having received adequate prenatal care.

Figures 1 and 2 plot the trends in maternal behavior, demographic composition, and access to medical care by maternal education group – a first step to interpreting and understanding the decomposition results below. Figure 1(A) shows that from 1983 to 2000, the percent of multiple births among college-graduated mothers doubled. At the same time, the percentage of mothers over 40 years old increased fourfold (Figure 1(D)). In addition, there is a more rapid decline in smoking among less-educated women than among highly educated women (where the rates were already low). Figure 2 shows that the percentage of women who dropped out of high school who are Hispanic increased from 7 to 29%, whereas the percentage of those who dropped out of high school who are African-American decreased from 26 to 23%. We also see an increasing percentage of less-educated foreign-born women,

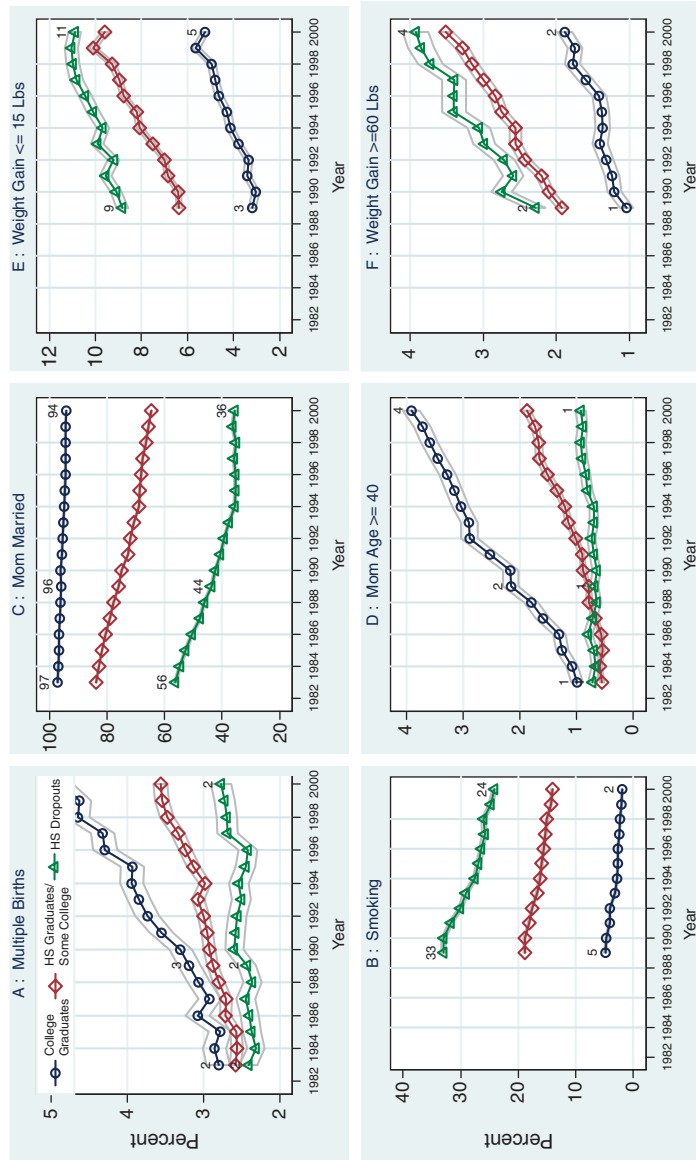
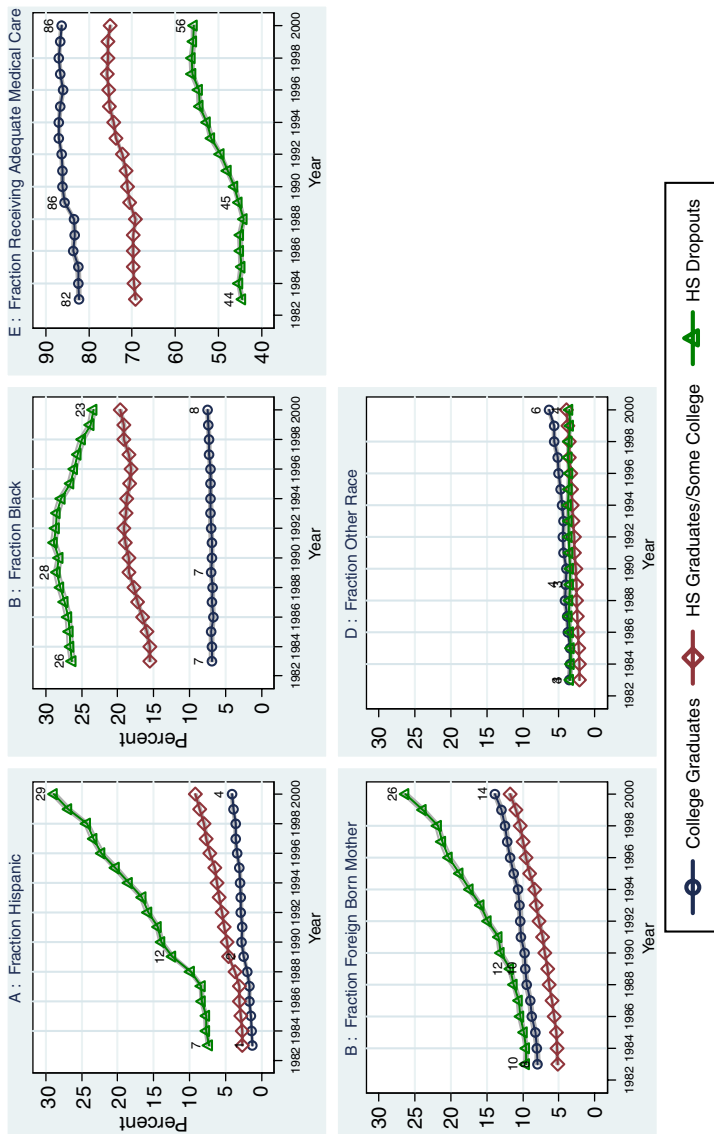


Figure 1. Changes in characteristics – maternal behavior, with 95% confidence intervals. Data are from US vital statistics, 1983–2000. This figure shows behavior change variables by maternal education over time

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Data are from U.S. Vital Statistics, 1983 to 2000. This figure shows time trends for demographic composition variables and access to medical care

Figure 2. Changes in characteristics – demographic composition and access to medical care, with 95% confidence intervals. Data are from US Vital Statistics, 1983–2000. This figure shows time trends for demographic composition variables and access to medical care by maternal education

of whom 80% are Hispanics. Finally, Figure 2(E) shows that the percentage of infants born with adequate prenatal care increased dramatically for the less educated, going from 44% in 1983 to 55% in 2000, whereas it increased only 4% for the highly educated group.

4. METHODS

4.1. Regression analysis

In order to investigate the development of the gradient over time, I begin by graphing the relationship between infant health measures and maternal education over time. Figure 3 plots the conditional expectation, based on maternal education, of low Apgar scores, neonatal mortality, and infant death rates as a function of time.

As shown in Figure 3(A), the incidence of low Apgar scores is higher for infants born to less-educated mothers (line indexed by triangles) than for infants born to highly educated mothers (line indexed by circles). Although there is a good deal of variation in the incidence of low Apgar scores, it is obvious that the gap between the less-educated and highly educated groups has narrowed over time. Figure 3(B, C) plot the number of infant deaths and neonatal deaths per 1000 births over time by maternal education groups. These two figures show that although infants born to less-educated mothers always have higher death rates, similar to a low Apgar score, the differences have been declining over time.

In order to further investigate the gradient, I estimate a linear probability model where the probability of a negative infant health outcome is a linear combination of the independent variables

$$P_{it} = \beta_0 + \beta_1 L_{it} + \beta_2 M_{it} + \beta_3 [L * yeartrend]_{it} + \beta_4 [M * yeartrend]_{it} + \beta_5 [year]_t + \beta_6 X_{it} + \epsilon_{it} \quad (1)$$

P_{it} is the probability of an infant with a low Apgar score or who dies within the first month (neonatal mortality) or first year (infant mortality). L and M are dummy variables for mothers who are in the less-educated group and in the middle-educated group, respectively. The year trend is a linear index of the sample year where 0 represents 1983 and 19 represents 2000¹¹; year includes a full set of year dummies to control for national trends in infant health outcomes. The vector X_{it} represents measured at the individual level, which includes dummies for adequate prenatal care, inadequate prenatal care (the omitted group is intermediate prenatal care), mother's ethnic background (African-Americans, Whites, Hispanics, others), whether a mother is foreign-born, whether a mother is married, whether a child is a part of a multiple birth, whether a mother is a teenager, whether a mother is over 40, whether a mother smoked during pregnancy, and dummies for gestational weight gain.

In this model, the main coefficients of interest are β_3 and β_4 , which represent the changes in the gradient over time for the low and the middle education groups, respectively. For example, a positive β_3 indicates an increasing difference in infant health between the less- and highly educated groups, while a negative coefficient indicates that this gap actually narrows.

4.2. Decomposition analysis

In order to examine the factors that account for the evolution of the gradient, I implement a decomposition method, the same as that proposed by Smith and Welch (1989) and Heckman *et al.* (2000).

To understand this decomposition, let x refer to the following three sets of variables: (1) maternal behavior: married, multiple births, smoking, unhealthy weight gain, advanced maternal age; (2)

¹¹The results presented are robust to the specification of a full set of year dummies.

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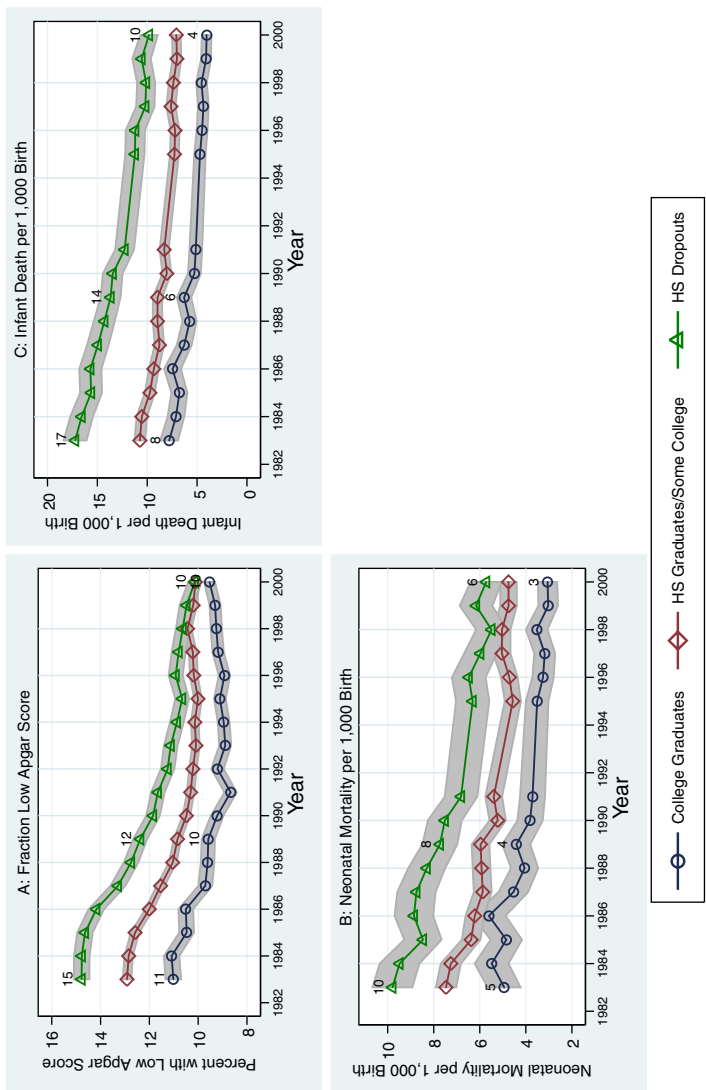


Figure 3. Infant health over time by maternal education groups, with 95% confidence intervals. Data are from US Vital Statistics, 1983–2000. Numbers in Figure 4 refer to the unconditional means

demographics: black, Hispanic, other races (other than white, black, and Hispanic), foreign-born; and (3) access to medical care: adequate prenatal care and inadequate prenatal care.

The decomposition results focus specifically on the infant health gaps between the highly educated group and the less-educated group. Let t be the current year and τ be the base year, and let H denote the highly educated group while L denotes the less-educated group. Let $\hat{\beta}$ be the associated vector of coefficients estimated from regressions where the dependent variables are various infant health measures and the independent variables are the three set of x variables mentioned above. Regressions are estimated separately for both high and low education groups, in the current year and in the base year. Let $\bar{x}_t H$, $\bar{x}_t L$, $\bar{x}_\tau H$, $\bar{x}_\tau L$ denote the mean vectors of high and low education group characteristics at different points in time. Thus, the change in the low-education group infant outcome minus the high-education group infant outcome between time periods t and τ can be decomposed in the following way:

$$[(\bar{x}_t^L \hat{\beta}_t^L - \bar{x}_t^H \hat{\beta}_t^H) - (\bar{x}_\tau^L \hat{\beta}_\tau^L - \bar{x}_\tau^H \hat{\beta}_\tau^H)] \quad (2)$$

$$= [(\bar{x}_t^L - \bar{x}_t^H) - (\bar{x}_\tau^L - \bar{x}_\tau^H)] \hat{\beta}_\tau^H \quad (a)$$

$$+ (\bar{x}_t^L - \bar{x}_\tau^L) (\hat{\beta}_\tau^L - \hat{\beta}_\tau^H) \quad (b)$$

$$+ (\bar{x}_t^L - \bar{x}_t^H) (\hat{\beta}_t^H - \hat{\beta}_\tau^H) \quad (c)$$

$$+ \bar{x}_t^L [(\hat{\beta}_t^L - \hat{\beta}_t^H) - (\hat{\beta}_\tau^L - \hat{\beta}_\tau^H)] \quad (d)$$

The first two terms ((a) and (b)) measure the contribution of changes in characteristics, valued at base-year coefficients. For example, if differences between the characteristics of highly educated and less-educated mothers had diminished over time, then this component of the infant health gradient would have decreased. The last two terms ((c) and (d)) measure the contribution of changes in coefficients. For example, if the return to medical care decreases over time, we can expect the infant health disparity to decrease because the highly educated groups have more adequate medical care than the less-educated groups. For brevity, in what below, I sum up terms (a)–(d) and only report the totally contribution of each variable.

5. RESULTS

5.1. Trends in infant health inequality

Table III displays the effects of maternal education on infant health outcomes as well as the evolution of the gradient over time using a linear probability model. Further analyses indicate the results in this paper are robust to logistic regressions. The coefficients of low Apgar scores are shown in Column 1. The probability of being a low Apgar score baby is 4.27 percentage points higher for a baby born to a less-educated versus a highly educated mother. Likewise, the probability of being a low Apgar score baby is 1.94 percentage points higher for a baby born to a middle-educated versus a highly educated mother.

The other key finding, also shown in Column 1, is that the gap with respect to low Apgar scores has actually been *decreasing* over time. The interaction terms between the time trend and education levels are negative and significant, indicating that the differences in low Apgar scores between the highly and less-educated groups have decreased since the early 1980s. As a gauge of the size of the change in the gap, the education-based infant health gap between college-graduate and high school dropout mothers has decreased by 4.4% per year.

Column 2 and 3 show the results with respect to infant death rates. The estimated effects on the interaction terms of the time trend and low education dummy suggest that the gradient between the

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Table IV. Decomposition results -contributions to convergence of infant health

	Low Apgar score	Neonatal death (death < 1 month)	Infant mortality (death < 1 year)
Adequate prenatal care	37.0%	25.6%	25.4%
Inadequate prenatal care	2.5%	3.6%	3.0%
Total effects of access to medical care	39.5%	29.3%	28.4%
Mom black	4.8%	5.2%	6.2%
Mom hispanic	-5.9%	-4.6%	-2.4%
Mom other races	1.0%	1.0%	1.0%
Mom foreign-born	12.1%	14.6%	15.6%
Total effects of demographic changes	12.0%	16.2%	20.5%
Mom married	12.1%	11.2%	10.5%
Multiple births	11.1%	10.9%	11.2%
Weight gain < = 15 Pounds	9.9%	2.3%	1.2%
Weight gain > = 60 Pounds	-3.1%	-1.3%	-0.8%
Mother smokes During pregnancy	3.6%	4.9%	5.9%
Mom age > = 40	-3.4%	-2.8%	-2.9%
Total effects of behavior changes	30.2%	25.2%	25.1%
Unexplained	18.4%	29.3%	26.1%
Total	100.0%	100.0%	100.0%

Notes: 1. The text describes the decomposition.

highly educated and less educated has become flatter over time. As a gauge of the size of the change in the gap, the education-based infant mortality gap between college-graduate and high school dropout mothers has decreased by 2.32 % per year for neonatal death and by 2.30% per year for infant death within the first year.

Since a narrowing of the gap due to increase in multiple births among the highly educated group is not very optimistic, as a robustness check, Columns 4–6 of Table III report coefficients for singleton births only. Consistent with results in Columns 1–3, when deleting multiple births from the sample, we still see convergence of the education-based infant health gradient. The magnitude of the convergence is similar to that from all births.

5.2. Decomposition results

Table IV shows the results of the decomposition between the highly educated group and the less-educated group.¹² Overall, access to medical care is the most important factor in explaining the narrowing infant health gap. Although access to medical care is certainly a driving factor, it explains less than half of the narrowing in the gap over time. Maternal behavior changes and demographic changes together also contribute to more than 40% of the closing gap. Specifically, demographic shifts and maternal behavior changes together explain 42.2% of the closing gap in low Apgar score, 41.4% of the closing gap in neonatal death, and 45.6% of the closing gap in infant death. Depending on each specific dependent variable, there is around 20% of the closing gap that is not explained by the variables that I include in my decomposition.

Within these categories, the three most important factors in explaining the reduction of the infant health gradient are adequate prenatal care, foreign-born mothers, and multiple births. In what follows, I briefly discuss each of these factors.

¹²In the decomposition, I use 1989 as the base year and 2000 as the current year. 1989 is the first year that data on weight gain and smoking behavior is available and 2000 is the latest year of this study. The decomposition results are robust to use 1983 and 2000 except when using 1983, the effects of maternal smoking and inadequate weight gains are not available, which makes the model less interesting. The decomposition results are also robust to exclusion of multiple births except when using only singleton births, the effect of multiple births is of course not available.

The single largest component is adequate prenatal care.¹³ This finding suggests that the increases in access to medical care, perhaps caused by the rapid Medicaid expansion in the late 1980s and early 1990s, played a significant role in closing the infant health gap. All else being equal, access to proper medical care accounts for 39.5% of the closing gap in low Apgar score, 28.4% of the closing gap in infant death, and 29.3% of the closing gap in neonatal death. Comparing across different measures of infant health, Table IV also shows that access to medical care contributes more to the closing of low Apgar score gap than to the closing of infant mortality gaps.

Being a foreign-born mother is the most important demographic variable. Coupled with the fact that 80% of foreign-born less-educated mothers are Hispanic, this result is consistent with the current literature that claims that foreign-born Hispanic immigrants have better infant health outcomes. This finding suggests that if the flow of Hispanic immigrants continues, we may see further decreases.

The last important component is multiple births. This should not be surprising because the percentage of multiple births increased from 2% in 1989 to 4% in 2000 for highly educated women while the percentage of multiple births remains at approximately 2% for less-educated women. Kogan *et al.* (2000) find that while constituting only 3% of all births in the United States in 1997, twins accounted for 21% of all low birth weight babies, 14% of preterm births, and 13% of all infant deaths. Although a decrease in the infant health gap is generally perceived as a good outcome, the increase in multiple births closes the gap in a less desirable way – instead of improving infant health at the low end of the distribution, it worsens infant health at the high end.

6. SPECIFICATION CHECKS

6.1. Selection issues

When interpreting the changes in the gradient using fixed education groups, it is important to address the issues of selection because the observed differences may be driven by compositional changes. Over time, on average, an increasingly higher level of educational attainment has been achieved in the US. The crux of the selection problem is that people with the same characteristics were more likely to attain higher education levels in 2000 than in 1983. If we observe a narrowing of health gaps between college- and non-college-educated groups, this could be entirely due to changes in the way in which college and high school students are selected rather than due to policies, changes in behavior, or any of the other variables I have discussed above. Owing to the general improvement in educational attainment, there are two selection issues: selection of college graduates and selection of high school dropouts.

In 1983, only 16% of mothers had graduated from college; this number increases steadily to 26% in 2000. If we assume that there is a monotonic relationship between the probability of going to college and of giving birth to healthy babies, then the individuals who fall between the top 16% and the top 26% can be expected to have worse health than the top 16% of the distribution. This is because these 10% who are college graduates in 2000 would not have finished college in 1983; college graduates are now less favorably selected. As a result, the average infant health of the group as a whole in 2000 is worse than if we included only the top 16% of the sample.

Similarly, there is a constant decline in the number of high school dropouts; in 1983, 21% of mothers fell into this category, as opposed to 18% in 2000. This means that high school dropouts are more negatively selected over time. Again, we need to assume that the probability of completing high school is monotonically correlated with the probability of giving birth to healthy babies. Since 3% of

¹³In this paper, I use Kessner Criteria to define adequate prenatal care. However, the result is robust to using number of visits and prenatal care timing separately. Further analyses show that these two factors together still are the leading factors in explaining the closing gap.

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Table V. The effects of maternal education on infant health using relative education measures: a robustness check – the probability of going to college is held constant in order to address the selection issue

	All births			Singleton births		
	Low Apgar score	Infant mortality (death < 1 year)	Neonatal death (death < 1Month)	Low Apgar score	Infant mortality (death < 1 year)	Neonatal death (death < 1 month)
Low education	6.921 [0.390]**	1.467 [0.066]**	0.851 [0.057]**	6.690 [0.384]**	1.392 [0.057]**	0.787 [0.050]**
Middle education	2.941 [0.377]**	0.428 [0.026]**	0.266 [0.021]**	2.793 [0.371]**	0.409 [0.025]**	0.253 [0.021]**
Time trend*	-0.236	-0.036	-0.021	-0.214	-0.032	-0.018
low education	[0.024]**	[0.005]**	[0.004]**	[0.023]**	[0.005]**	[0.004]**
Time trend*	-0.098	-0.006	-0.003	-0.086	-0.004	-0.002
middle education	[0.027]**	[0.002]*	[0.002]	[0.027]**	[0.002]	[0.002]
Observations	4 357 908	3 667 295	3 667 295	4 247 436	3 573 785	3 573 785

Notes: See Table III.

those who would have been high school dropouts are now high school graduates, the rest of the high school dropout group is more negatively selected. As a result, the average health of the group has worsened.

If we account for these selection problems, both the corrected college-graduate and high school dropout groups would have better health than those observed in the data. This is due to the fact that the top members of the low-educated group move up to the middle-educated group, deteriorating infant health outcomes for the less-educated group. Likewise, members from the top of the middle-educated group move to the highly educated group, also deteriorating infant health outcomes for the highly educated group. It is, therefore, an empirical question as to whether my evidence of a narrowing infant health gap provides a lower or upper bound on the convergence of health outcomes when using the relative education groups in the results section above.

To overcome these selection issues, I weight the observations by the propensity score. The objective is to hold constant the probability that a person attends college, given their characteristics. I first estimate a logistic equation predicting the probability of a person attending college in 1983.¹⁴ Next I take the 1983 coefficients and estimate the probability of attending college for the rest of the sample years. Finally, in each year, I take the top 20% of the people as the high-education group and the bottom 20% of the people as the low-education group. I then re-estimate model (1) using these new relative education groups.

Table V shows the changes in the infant health gradient using these relative education groups. The same patterns of convergence emerge as before; that is, we see convergence in low Apgar score and two infant death rates. The interaction terms of the linear time trend and education levels are negative and significant, indicating that the differences in infant health have decreased since the early 1980s. Columns 4–6 show that the results are robust to inclusion of only singleton births. In summary, the results in this section show that the convergence in infant health shown in Table III is robust to possible selection issues.

¹⁴Variables used to predict the propensity score of attending college include dummies for adequate prenatal care, mother’s ethnic background, whether a mother is foreign-born, whether a mother is married, whether a child is a part of a multiple birth, whether a mother is a teenager, whether a mother is over 40, whether a mother smoked during pregnancy, and dummies for gestational weight gain.

Table VI. The effect of maternal education on low apgar score – by region (South, Non South)

	Low Apgar score		Infant death		Neonatal death	
	South	Non-South	South	Non-South	South	Non-South
Low education	3.834 [0.189]**	2.718 [0.152]**	0.78 [0.066]**	0.775 [0.047]**	0.379 [0.053]**	0.319 [0.038]**
Middle education	1.759 [0.162]**	1.311 [0.120]**	0.316 [0.057]**	0.248 [0.038]**	0.203 [0.046]**	0.107 [0.030]**
Time trend*low education	-0.244 [0.025]**	-0.142 [0.020]**	-0.019 [0.006]**	-0.016 [0.008]**	-0.011 [0.007]	-0.005 [0.005]
Time trend*middle education	-0.068 [0.021]**	-0.04 [0.016]**	0.001 [0.007]	0.002 [0.005]	-0.002 [0.006]	0.003 [0.004]
Observations	1,125,508	1,838,538	856,252	1,390,022	856,252	1,390,022

Notes: 1. The dependent variable is a dummy for low Apgar score. To save space, the coefficients are scaled up by 100. Robust standard errors in brackets. *Significant at 5%; **significant at 1%. Data are from US Vital Statistics, 1989–2000. 2. This table shows that the convergence in the southern states is larger than the convergence in the non-southern states.

Table VII. Decomposition results – contributions to convergence of low Apgar score by region

Decomposition results	All	South	Non-South
Adequate prenatal care	37.0%	64.3%	21.3%
Inadequate prenatal Care	2.5%	2.2%	4.2%
Total effect of access to medical care	39.5%	66.5%	25.5%
Mother black	4.8%	18.6%	-11.7%
Mother hispanic	-5.9%	1.7%	-10.4%
Mother other races	1.0%	0.5%	0.2%
Mother foreign-born	12.1%	3.6%	14.8%
Mother married	12.1%	43.0%	-22.5%
Multiple births	11.1%	8.3%	14.5%
Weight gain < = 15 Pounds	9.9%	2.8%	17.5%
Weight gain > = 60 Pounds	-3.1%	-4.9%	-0.4%
Mother smoke during pregnancy	3.6%	6.7%	0.8%
Mother age > = 40	-3.4%	-0.9%	-6.2%
Unexplained	18.4%	-46.0%	78.0%
Total	100.0%	100.0%	100.0%

Notes: 1. Data are from US Vital Statistics, 1983–2000. 2. This table shows that compared with non-southern states, access to medical care in the southern states contributes more to the flattening of infant health gradient in the low Apgar score. 3. The text describes the decomposition.

6.2. Convergence by region

In order to further analyze the driving factor-access to medical care-in decreasing the gradient, I examine potential regional patterns, given that over the past two decades access to medical care has increased more in southern states than in non-Southern states. Thus, my third research question asks whether there is faster convergence in Southern or non-Southern states.¹⁵

The Medicaid expansion in the late 80s and early 90s might have been more important in the South than in the non-South because less-educated mothers in the South are, on average, poorer than their counterparts in the non-South. Therefore, a larger number of less-educated mothers are covered by Medicaid in the South than in the non-South.

¹⁵The South includes the following three census regions: West-South-Central, East-South-Central and South-Atlantic. West-South central include Texas, Oklahoma, Arkansas, Louisiana. East-South-Central includes Mississippi, Alabama, Tennessee, and Kentucky. South-Atlantic includes Florida, Georgia, South Carolina, North Carolina, Virginia, and West Virginia.

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Table VI shows the evolution of the gradient by region. For each of the three infant health measures, regressions are estimated separately for the South and non-South areas. For all of the three infant health measures, the coefficients of the interaction term between low education and a linear time trend for the South are larger than the coefficients for the non-South. However, a formal test shows that, for infant death and neonatal death, the coefficients of the interaction term between low education and a linear time trend for the southern states and non-Southern states are not significantly different from each other. Since the percentage of women receiving adequate prenatal care increased faster in the South than in the non-South, and since access to medical care is more important to the closing gap of low Apgar score than to the closing gap of infant death rates, it might not come as a surprise that a quicker convergence in South regions is only observed with respect to low Apgar score but not infant deaths.

By applying the decomposition method described above to low Apgar score by region, I show that the contribution of access to medical care to the closing gradient is greater in the South. This result is shown in Table VII. For comparison, Column 1 displays the results for the entire country as in Table IV. Columns 2 and 3 show the decomposition results for the South and for the non-South, respectively. From the table we see that access to medical care accounts for 39.5% of the reduction of the infant health gradient for the whole nation; however, the regional differences are quite stark. Access to medical care accounts for 66.5% of the reduction of the infant health gradient in the South, but only 25.5% of it in the non-South, further supporting the key finding of this section – that the infant health gap converges faster in the South with respect to low Apgar score is due to the relative importance of the Medicaid expansions.

7. DISCUSSION AND CONCLUSIONS

This paper shows that the gradient, as measured by low Apgar scores, neonatal deaths, and infant deaths, has decreased over time. A simple decomposition method reveals that increasing access to medical care is the most important factor in explaining the decrease in the infant health gradient. Demographic shifts and maternal behavior changes are also significant factors, together explaining around 40% of the closing gap.

There is a good deal of evidence indicating that other things being equal, differences in health at birth matter for future outcomes. For example, Elo and Preston (1992) show that cohorts who underwent high death rates in childhood also tend to show high death rates in adulthood, in part because of the direct effects of childhood health conditions on future health outcomes. Using Danish registry data, Linnet *et al.* (2006) showed that children who were born premature or with low birth weight and/or whose mothers smoked in pregnancy all had a much higher risk of ADHD when they grew older. In their study of the Health and Retirement Survey, a national survey of older adults done in the US, Luo and Waite (2005) find that the effect of a retrospective measure of childhood SES on future health, education, and income is attenuated by the inclusion of child health measures, suggesting that child health may explain some of the impact of low childhood SES on future outcomes. Together, this line of literature suggests that disparities in infant health are important because they help to predict differences in adult outcomes. Since I show that the infant health inequality gap has been narrowing over time in the US, I argue that if we were to observe these same infants later in life when they become adults, we would also observe a narrowing in the adult health inequality gap. This optimistic view assumes that the negative health insults that happen to the low SES infants later in life do not change over time.

Will the infant health gradient continue to decrease in the future? The results above highlight the fact that a part of the convergence is due to the influx of Hispanic immigrants. Since the positive effect of infant health is restricted to immigrants but not to native-born Hispanics, this suggests that if in the

future, the immigration influx stops, then health improvements in low SES babies might also slow or stop.

Predictions aside, this paper shows that Medicaid does have an effect on closing infant health inequality, lending some support to the fact that the large government expenditure on Medicaid has been effective. However, there has been relatively little money spent on advocating healthier maternal behavior. An obvious policy implication from this paper is to devote more resources to educating women about prenatal care and fertility decisions, for example, gaining adequate gestational weight gain, and recognizing the negative effects of delayed fertility and treatments.

The framework presented in this paper, which combines demographics, maternal behavior, and access to medical care, can provide a guide to addressing the complexities involved in infant health outcomes – policies aimed to further close the health gap thus need to incorporate these three key factors.

ACKNOWLEDGEMENTS

I am deeply indebted to my advisor, Janet Currie, for her advice and support throughout this project. Special thanks to Sandra Black for her suggestions and continual encouragement. I also thank Moshe Buchinsky, Jinyong Hahn, Joseph Hotz, Kathleen McGarry, Erica Field, Jason Schnittker, Phillips Brown, Alan Barreca, Hal Snarr and seminar participants in the 2006 NBER Summer Institute, the 2006 Society of Labor Economics annual meeting, the 2006 Population Association of America annual meeting, the UCLA Albert Family Fund Proseminar in Applied Microeconomics and Econometrics, the 2006 WEAI annual meeting and the 2006 Econometric Society Summer Meeting. All errors are my own.

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