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Accounting for the Change in the Gradient:

Health Inequality Among Infants*

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ABSTRACT

This study investigates changes in the relationship between maternal education and infant health using American Vital Statistics from 1983 to 2000. I find that, over the past two decades, the infant mortality disparity between babies born to mothers with different education levels has remained constant over time, while the disparity of infant health at birth, as measured by Apgar scores, has narrowed over time. While the convergence in Apgar scores is observed in all regions of the U.S., the convergence was particularly large in the Southern states, where access to medical care increased most because of the Medicaid expansion.

In order to better understand the narrowing disparity of infant health at birth, it is important to examine what accounts for this closing trend. A simple decomposition reveals that the dominant factor in explaining the closing gap is an increase in access to medical care. Given that Hispanic women tend to have favorable birth outcomes, while African-Americans tend to have worse-than-average infant outcomes, the gap has also declined because an increasing number of infants in the less educated population are being born to Hispanics rather than to African-Americans. There are also several behavioral factors which have had an important impact. Namely, the gap in Apgar scores has decreased because smoking among less-educated women has declined, although this improvement is partially offset by an increase in the number of less-educated women who gain excessive gestational weight. Finally, the gap has decreased because an increasing number of college-educated women are delaying fertility, seeking fertility treatments, and, consequently, having plural births which tend to have lower Apgar scores.

JEL: I10, I18, I12

INTRODUCTION

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* to health and labor economists. For example, as shown in figure 1, in the United States babies born to women without a high school diploma are twice as likely to die before their first birthday as babies born to college graduates[2]. While many people may be prepared to accept inequality in income as a necessary evil, inequality in health outcomes among infants is arguably less acceptable. 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 U.S. 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 major goals is "to eliminate health disparities among different segments of the population[3]." These health disparities can be analyzed in multiple dimensions, such as race, income and education. In this paper, I focus on infant health disparities based on maternal education because education is a more permanent measure of socioeconomic status than income and because education attainment is collected for all mothers, not only to those who are employed. In doing so, I examine one poorly understood aspect of the inequality in health: the evolution of the infant health gradient by maternal education over time.

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[2] From 1983 to 2000, the average infant death rate was12 per 1000 births for women without a high school diploma but only 5 per 1,000 births for women who graduated from college.

[3] *Healthy People 2010* is designed to achieve two overarching goals: The first goal is to help individuals of all ages increase life expectancy and improve their quality of life. The second goal is to eliminate health disparities among different segments of the population (*Healthy People 2010*. Washington, DC: U.S. Dept. of Health and Human Services, Office of Public Health and Science.).

One of the most impressive social achievements of the twentieth century is the vast improvement in physical health. For example, life expectancy at birth in the United States in 1901 was 49 years old; by the end of the 20th century, it was 77 years, an increase of over 50%. Although health has improved, the gradient in health status has worsened among adults (see e.g., Crimmins and Saito 2001; Pappas et al. 1993), reflecting more rapid health gains for people at the high end of the socioeconomic spectrum. Although some researchers have studied the adult health gradient over time, to my knowledge, no study has examined changes in the infant health gradient. This paper expands this line of research to include the evolution in the gradient in infant health, an issue that is of relevance to public policy makers and researchers alike.

In this paper, I use individual-level data from U.S. birth and death certificates from 1983 to 2000 to examine the evolution of inequality among infant health outcomes. I explore the change in the infant health gradient using logistic regressions. My primary measures of infant health outcomes are low Apgar[4] scores and infant deaths. The former is a summary measure of an infant's condition at birth. The later refers to the death of an infant before his or her first birthday.

In sharp contrast to the increasing health gradient among adults, the main findings of this paper suggest that (1) the gradient in infant death has remained constant over time and (2) the gradient in low Apgar scores has indeed narrowed. To reconcile my findings on infant health at birth with that on infant death rates, it must be the case that the gap in infant health between less and highly educated households increased from age 0 to 1 at a faster rate in 2000 than in 1983. We can see that because the health at birth for these two populations had almost equalized by

[4] The Apgar score is designed to quickly evaluate a newborn's overall physical condition after delivery. A perfect Apgar score of 10 means an infant is in the best possible condition. In this paper, an infant with an Apgar score less than or equal to 8 is defined as having a low Apgar score; consequently, 10% of infants fall into the low Apgar score group.

2000, the constant gap in health at age one over time implies that the increased slope of health deterioration with age became more rapid over the study period.

After finding this surprising result with respect to Apgar scores, the natural question to ask is what accounts for this narrowing gap. I implement a decomposition technique that focuses on three main factors: first, changes in behavior (e.g., reduction in smoking, increase in fertility treatment); second, demographic changes (e.g., an increasing number of infants in the less educated population are being born to Hispanics rather than to African-Americans.); and third, access to medical care, which is linked to the rapid increase in public health insurance coverage that took place during the late 1980s and early 1990s.

I find that access to medical care and changes in maternal behavior are the two most important factors accounting for the reduction of the gradient. Specifically, access to medical care accounts for 40% of the decrease in the gradient of low Apgar scores. Maternal behavior changes such as delays in pregnancy, fertility treatments (inferred from an increase in multiple births), unhealthy gestational weight gain, and reduction in smoking, together explain 30% of the closing gap. Demographic changes explain 12% of the gap.

In summary, although babies born to better educated mothers are healthier than those born to less-educated mothers, the infant health gradient has been narrowing over the past two decades. This finding may be comforting to those concerned with health inequality. For example, in 1983, if babies born to less-educated mothers had instead been born to highly educated mothers, approximately 21,365 fewer newborns would have had low Apgar scores. By 2000, this "excess" had declined to approximately 4,121[5]. My findings suggest that the rapid

[5] In 1983, there were 577,440 babies born to mothers with less education. In 1983, the percentage of low Apgar score babies among mothers with less education was 14.4 while the

Medicaid expansion in the late 1980s and early 1990s is the most important factor in accounting for the narrowing gap. However, this work also highlights the importance of maternal behaviors and demographic changes in driving trends in infant health. Finally, this paper calls for attention that the infant health for the highly educated households is deteriorating because of advanced maternal age and increasing fertility treatment.

PREVIOUS LITERATURE

In this paper, educational attainment, rather than income, is used as an indicator of socioeconomic status. There are findings showing that education has a causal impact on health (e.g., Berger and Leigh 1989, Sander 1995ab, Leigh and Dhir 1997, Goldman and Lakdawalla 2001). In addition, Currie and Moretti (2003) find that maternal education increases infant health. A mother's education level can affect the health of children not only by changing the household budget constraint but also by changing the mother's behaviors. Namely, education may affect the budget constraint both directly through higher earnings for the woman (Card 1999)[6] and indirectly through an improvement in her marriage market prospects (Behrman and Rosenzweig 2002). In addition, even holding the budget constraint constant, a mother's education may improve child health if it induces her to behave in a healthier way (e.g., reduction in smoking), to make better decisions (e.g., eat healthier, gain adequate gestational weight), or to

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percentage of low Apgar score babies among the highly educated group was 10.7. Therefore, the number of "excess" low Apgar score babies was 21,365 (577,440*(0.144 - 0.107) =21, 365). In 2000, these percentages were 10.1 and 9.4 among the less educated and highly educated groups, respectively. Taken together with the fact that 588,770 babies were born to less educated mothers in the year 2000, we find that the number of "excess" low Apgar score babies in 2000 was 4,121 (588,770*(0.101-0.094)=4,121).

[6] The private returns to schooling in the United States in the 1990s are believed to be about 8-12%: each extra year of schooling appears to be associated with an 8-12% increase in earnings. See Card (1999) for a comprehensive survey of the evidence on the private returns to schooling.

alter her preferences (e.g., education may increase one's patience (Becker and Mulligan 1997) or risk aversion).

There are two main advantages of using education as an indicator of socioeconomic status. First, education is a more permanent and stable measure of socioeconomic status than income. For example, income may be affected by the health of the unborn child through reductions in maternal labor supply or high medical bills. Second, data on educational attainment is collected for all mothers, not only those who are employed.

Extensive research concerning the social determinants of health has revealed that education is strongly associated with a broad range of health measures (see Marmot 2004 for a review), but little is known about the evolution of educational-related disparities over time. Moreover, all the previous studies on these disparities over time are centered on *adults*[7]. As there is no literature on the evolution of the infant health disparity, I instead draw from the literature on the evolution of health inequalities of adults. This provides information on health inequalities at a different phase of human life. It is important to recognize that the trends for adults and for infants do not necessarily need to match each other. In fact, the trend in adults offers a sharp contrast to the trends among infants.

Research on adults has shown that the gradient in health status has steepened over time, in the sense that the same difference in years of education is now associated with a larger difference in the probability of death than twenty years ago. For example, Koskinen (1985) showed that socioeconomic differentials in life expectancy have reportedly widened in England and Wales. Using a series of Decennial Supplement on Occupational Mortality data, he showed that age-

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[7] A few researchers have investigated trends in infant mortality by race (Collins and Thomasson 2002; Culter and Meara 2003), but not by income or education.

adjusted mortality rates have declined in all social classes, but differences between classes are persistent. Later, using the same data, Pamuk (1985) confirmed that social-class inequality in mortality among employed and retired males declined in the 1920s, then increased during the 1950s and 1960s so that by the early 1970s it was greater than it had been in the early part of the century. For married women, using husband's social class as a socioeconomic indicator, a similar increase in inequality with respect to mortality rates occurred from the 1950s to the 1970s.

More recent studies in the United States further support these findings. For example, Feldman et al. (1989) suggested that in 1960, there was little difference in mortality by educational level among middle-aged and older men. Since 1960, however, death rates among men declined more rapidly for the more-educated than the less-educated, resulting in a substantial educational differential in mortality from 1971 to 1984. Pappas et al. (1993) suggested that in the 1980s, the differences in mortality across educational groups were larger than those in 1960. Specifically, they found that the age-adjusted mortality rate for white men who had attended college declined from 5.7 to 2.8 per 1000, while the rate declined only from 9 to 7.6 for those who had not graduated high school. Their analysis, however, was limited to a comparison of two selected dates, 1960 and 1986. Preston and Elo (1995) later confirmed that educational inequality in mortality was greater between 1979 and 1985 than in 1960 for white men[8]. Crimmins and Saito (2001) also found large and growing educational differences in healthy life expectancy in the United States from 1970 to 1990. Similarly, Schoeni et al. (2001, 2005) found that educational differences in old-age disability rates have been declining since the early 1980s but the gains have been concentrated among the most educated. Overall, research on

[8] For white women, however, mortality differentials based on education have narrowed rather than expanded since 1960; these findings contradict those of Pappas et al. (1993).

adults finds that the health inequality by education has increased over the past few decades in the U.S.

Thus, this line of research concludes that over the twentieth century general health status among Americans has strikingly improved. But at the same time, important and persistent health differences based on socioeconomic status have grown. This paper expands this line of research to include the evolution in the gradient in infant health, an issue that is of relevance to public policy makers and researchers alike.

A FRAMEWORK FOR EXPLORING INFANT HEALTH

The regressions used in this paper are guided by a simple model in which the likelihood of an adverse infant outcome is influenced by three mechanisms: (1) maternal behavior, such as smoking, unhealthy weight gain, delaying fertility or seeking fertility treatment, (2) demographic changes (for example, an increasing number of infants in the less educated population are being born to Hispanics rather than to African-Americans), and (3) access to medical care. Variables associated with these mechanisms can be viewed as inputs into a health production function; the function captures the means through which variables related to infant health translate into various infant health outcomes. Understanding these mechanisms provides guidance as to which controls are necessary in reduced form estimates and facilitates the interpretation of the decomposition implemented later in this paper.

Maternal Behavior Changes

Maternal behavior during pregnancy is important in producing healthy babies. For example, Currie and Moretti (2003) find that maternal education improves infant health through increasing the probability that a mother is married, through reducing parity[9], through increasing use of prenatal care and through reducing smoking. The measures of maternal behavior which I use are maternal age, marital status, whether the mother smokes, and gestational weight gain. Another interesting component of maternal behavior is the use of fertility treatment which is unobserved, but I infer the use of such treatments through the prevalence of multiple births (see discussion below).

Advanced age[10], unmarried status and maternal smoking all aversely affect infant health outcomes. With more women postponing childbearing until their later reproductive years, there is increased awareness and concern about advancing maternal age and infant health. Some studies have shown babies born to older mothers have an increased risk of low birth weight (e.g., Cnattingius et al. 1993; Cnattingius et al., 1992), of preterm delivery (e.g., Astolfi and Zonta 2002; Cnattingius et al. 1992) and of being small for gestational age (SGA) (e.g., Dildy et al. 1996; Dollberg et al. 1996). Similarly, out-of-wedlock birth has long been recognized as one of the demographic risk factors associated with infant mortality and other adverse infant health outcomes (Bennett 1992). Data used in this study show that the infant death rate for unmarried mothers was 1.9 times higher than that of married mothers during the sample period[11]. As is well known and well studied, maternal smoking also adversely affects the health of both mother and child[12].

[9] Parity is defined as the number of times that a mother has given birth to a fetus with a gestational age of 24 weeks or more, regardless of whether the child was born alive or was stillborn.
[10] For example, young adolescents (12-17 years) have long been related to higher infant mortality rates (Cook 2005).
[11] The infant death rate was 6.9 per 1000 births for married mothers, while it was 12.9 for unmarried mothers during the sample period (Author's calculation from U.S. Vital Statistics, 1983 to 2000).
[12] For example, Lien and Evans (2005) find that states that adopted large cigarette tax hikes had a

Unlike the well studied effects of maternal smoking on infant health outcomes, both inadequate and excessive weight gain are important risk factors, which have not been well studied. Inadequate gestational weight gain has been reported to increase the risk of preterm delivery and the risk of having an infant that is small-for-gestational-age (SGA) (Abrams 1989). On the other hand, excessive weight gain is associated with complications in pregnancy such as higher rates of hypertension, C-sections, induction of labor, and large-for-gestational-age infants (Jensen 2005; Thorsdottir 2002; Wanjiku and Raynor 2004). One limitation of previous studies on the effects of excessive weight gain is that they use small hospital data sets without information on Apgar scores rather than using the Vital Statistics data, which includes information on Apgar scores and has a large sample size. Thus my work is able to present a new finding: a positive relationship between excessive weight gain and low Apgar scores.

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 fertility treatments[13]. Compared with singleton births (i.e., only one child born to a mother), children from multiple births usually have more complications, such as increased risk of miscarriage, pre-eclampsia, growth retardation, and preterm delivery. For example, Schieve (2002) shows a positive relationship between (very) low birth weight and multiple births. Almond, Chay and

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corresponding decrease in the percentage of pregnant women who smoke. Meara (2001) documents a strong correlation between smoking during pregnancy and the probability of having a low birth weight infant. Almond et al. (2005) find significant negative effects of smoking on birth weight and Apgar score. Chomitz et al. (1995) shows that if all women stopped smoking when they became pregnant, at least 20 percent of all low birth weight infants could be avoided.

[13] Fauser (2005) shows that although an association between older females and multiple gestations is clear, the delay in childbearing accounts for no more than 30% of the recorded overall increase in multiple pregnancies. Furthermore, the rate of triplet and higher-order multiple pregnancies has increased four-fold over the same time period, a trend that can be attributed almost entirely to fertility treatment.

Lee (2005) find that compared to singletons, twins are more likely to die within one day, one week, one month, and one year of birth. Twins have lower Apgar scores and they have higher incidences of breech birth, abnormal conditions and congenital anomalies. Given that twins tend to be less healthy at birth than singletons, the increase in the number of multiple births is important in explaining the change in infant health disparity. This is because 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.

Demographic Changes

Since an increasing number of infants in the less educated population are being born to Hispanics rather than to African-Americans, it is important to address differences in health outcomes among various racial groups. Hispanics and African-Americans have very different average infant outcomes as compared to whites. For example, Forbes (1991) shows that despite a higher level of risk factors such as low socioeconomic status, delayed use of prenatal care, and higher parities, Hispanic women tend to have favorable birth outcomes, a phenomenon that has come to be termed an "epidemiologic paradox". However, research also shows that these positive effects are restricted to those who are foreign-born, not to American-born Hispanic women. For example, Collins and Shay (1994) show that in very low-income (less than $10,000/year) census tracts, the incidence of low birth weight babies born to Mexican and other Hispanic, US-born mothers were 14% and 15%, respectively. In contrast, Mexican and other Hispanic infants with foreign-born mothers who resided in these areas had low birth weight rates of 3 and 7%, respectively.

Infant mortality among blacks in the U.S. has historically been approximately twice that of whites (National vital statistics reports, NCHS 2002). Numerous studies have argued that the lower average relative birth weight of African-American babies relative to Caucasian babies is the primary reason for the persistence of black-white infant mortality differentials (e.g., Lu and Halfon 2003)[14].

Because foreign born Hispanic women in general have favorable birth outcomes while African-Americans in general have worse infant health outcomes, and because, from 1983 to 2000, there has been an increase in less educated foreign born Hispanic women and a decrease in less educated African-American women, we can expect to see this demographic composition change to improve infant health among the less educated during the sample period.

Access to Medical Care

It is widely believed that expanding medical care can improve infant health. For example, Currie and Gruber (1996) show that increased eligibility for public health insurance increased the utilization of medical care and lowered the incidence of infant mortality[15]**.** In this paper, I use adequate prenatal care, measured by the onset of prenatal care and the number of prenatal care visits, as a proxy for access to medical care. By improving access to medical care primarily among less-educated women, the rapid expansions in Medicaid[16] in the late 1980s and early

[14] However, there is no consensus in the literature as to whether genetic factors are responsible for the lower average birth weight of African-American babies. Race may possibly reflect genetic differences but it may also be a proxy for health habits, familial support, exposure to stress, or maternal health endowments – factors that are not easily observable by researchers. Therefore, when drawing causal inferences, it is necessary to be aware of key factors that may be correlated with race and which may significantly influence infant outcomes.

[15] Currie and Gruber (1996) find that a 30-percent-point increase in eligibility would lead to a reduction of 8.5 percent in infant mortality rate.

16 Medicaid is a public health insurance program for poor women and children.

1990s may have caused a narrowing in the infant health inequality gap. In addition, since Medicaid is a means-tested public health insurance program, it can be expected to improve infant health more in the Southern states because they are generally poorer. Therefore, if access to medical care is important for closing the infant health gap, we should see a faster rate of convergence in the Southern states.

DATA

The main source of data used in this study comes from the Linked Birth and Infant Death files (LBID) released by the National Center for Health Statistics (NCHS). The data are publicly available for periods 1983-1991 and 1995-2000. These data contain linked information from birth and death certificates. Unfortunately, this linkage is not provided by NCHS for the years 1992, 1993 and 1994. For these three years, the Vital Statistics Detailed Natality data are used instead. Although infant morality 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 4 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. States that do not report maternal education, Apgar scores, and relevant explanatory variables for all of the sample years are excluded for consistency. States that do not report smoking behavior and gestational weight gain after 1989 are also excluded[17]. To ease computation time, I then take a sample of

[17] California, 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

10%. After these exclusions I am left with a sample of 4,357,908 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 low Apgar scores and infant death rates[18]. The Apgar score is an overall measure of an infant's health at birth. 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 is a system of assessing 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[19]. In this study, a low Apgar score is defined as 8 or below; consequently, 10% of infants fall into the low Apgar score group[20].

I chose Apgar scores as a measure of infant health because Apgar scores provide more details on infant health than infant death rate. Infant death is quite rare, for example in 2000 the average infant death rate was 6 per 1000 births. Because of this, Apgar scores are a necessary and useful tool for assessing health among infants that are not terminally ill. In addition, Apgar

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Apgar scores. Louisiana, Nebraska and Oklahoma do not report gestational weight gain.

18 In this paper, I focus on Apgar score and infant death rates as infant health measures. However, I have also looked at the changes in the gradient with respect to birth weight. What I found is that the distribution of birth weight has not changed much over time. Specifically, from 1983 to 2000, the mean of the birth weight distribution has decreased by 46 grams while the standard deviation has increased by 24 grams, which is really a minute change given that the mean birth weight distribution is around 3,300 grams. Furthermore, the incidence of low birth weight has also not changed much for singleton births. We have seen an increasing incidence of low birth weight, but only from the college graduate group. This observation is mainly due to the increasing incidence of multiple births, which is probably the result of increasing fertility treatments.

19 For detail on scoring, see Appendix Table 1.

20 Refer to Appendix Table 2 for the full distribution of Apgar scores.

scores are important predictors for future child health. For example, using the National Maternal and Infant Health Survey (NMIHS) data, Almond, Chay and Lee (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.

It is important to point out that while Apgar scores measure health at birth only, infant death depends on how healthy the baby is at birth and on the medical care received after birth and parental behavior during the first year. In other words, even if there are no health disparities at birth, that doesn't guarantee that there will be no health disparity at age one. This is because infants born to different socioeconomic households may receive different treatment during their first year and so their health levels at age one may differ. Therefore, Apgar score, a measure of infant health at birth, will not necessarily match up with infant mortality rate, a measure of infant health at age one. If we assume that infants born to less educated mothers are subject to worse than average home environments, then the health disparity with respect to Apgar scores and with respect to infant mortality will be different due to poorer treatment after birth in the less educated families.

This study distinguishes between three education groups: high school dropouts (less than 12 years of schooling completed), high school graduates (12 to 15 years of schooling completed), and college graduates (16 or more years of schooling completed). The striking differences across education groups can be seen in Table 1 which provides key summary statistics. High school dropout mothers are 2.53% more likely to have children with low Apgar scores and 2.26 times more likely than college graduate mothers to have children who die before age one.

Besides differences in the two infant health measures above, there are also substantial differences in maternal characteristics by education group. Table 1 provides summary statistics related to measures of maternal behavior. Mothers who are college graduates are three 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, less likely to gain unhealthy gestational weight (more than 60 pounds or 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[21], both in terms of the timing of prenatal care initiation and the number of visits.

Figures 2, 3 and 4 further plot various variables regarding different hypotheses over time, including maternal behavior changes, demographic composition changes, and access to medical care changes. Understanding these trends by maternal education helps us to better interpret the decomposition results later.

In Figure 2, I find that while the probability of multiple births remains constant among high school dropouts, there is an increasing trend towards multiple births among college-educated mothers. The probability of having multiple births for highly educated women has doubled over the past two decades; specifically, it increased from 2% in 1983 to 4% in 2000. We also see that (1) among the high education group the percentage of mothers over 40 years old has gone up steadily over time, (2) an increasing number of less-educated women gain over 60 pounds during their pregnancies, and (3) there is a more rapid decline in smoking among less-educated women than among highly educated women (where rates were already low).

[21] The criterion for adequacy of prenatal care is based on Kessner criteria. The month in which prenatal care was initiated, the number of prenatal visits, and gestation are used to evaluate whether prenatal care is adequate.

Figure 3 shows that there were large demographic changes over the study period for all education groups. With the influx of Hispanic immigrants over the past two decades, the increasing fraction of Hispanic mothers should come as no surprise. More specifically, from 1989 to 2000, the percentage of women that dropped out of high school who are Hispanic increased from 7 to 29%, while the percentage of African-American decreased from 26 to 23%. From 1983 to 2000, the percentage of African-American women that graduated from college showed relatively little change over time, while that of Hispanic women increased from 1% to 4%. Given differences in average birth outcomes between different ethnic groups, one would expect this shift in demographic composition to improve health among infants of less-educated women, and thus narrow the gap in infant health outcomes between less-educated and more-educated women, which is indeed what we see in the decomposition results.

Figure 4 shows the changes in female college graduates and high school dropouts receiving adequate prenatal care between 1983 and 2000. In line with the expansion of Medicaid eligibility that occurred in the late 1980s and early 1990s, we see an increasing fraction of babies born to less-educated mothers who have adequate prenatal care. The percentage increased from 45% in 1989 to 55% in 2000. In contrast, there was only a 1 % increase in adequate prenatal care for highly educated mothers, from 85% in 1989 to 86% in 2000. Given the positive effect of the Medicaid expansion on mothers with little education, improvements in medical care can be expected to close the infant inequality gap and, hence, are expected to positively contribute to the closing gradient.

METHODS

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. Figures 5a and 5b plot the conditional expectation of low Apgar scores and infant death rates as a function of time based on maternal education. The health gradient is immediately apparent – over time, infants born to college educated mothers always have both a smaller probability of low Apgar scores and a lower infant death rate.

A key new finding of this study is that the gap in infant mortality has stayed relatively constant over time while the gap in low Apgar scores has decreased over the past two decades. As shown in Figure 5a, the incidence of low Apgar scores is higher for infants born to less-educated mothers (line with triangles) than for infants born to highly educated mothers (line with circles). While there is a good deal of variation in the incidence of low Apgar scores, it is obvious that the gap between the less and highly educated groups has narrowed over time. In 1983, infants from the less-educated groups were 3.8 percent more likely to have a low Apgar score than infants from the highly educated group. By 2000, however, this percentage had decreased to 0.5 percent. Although there appears to be a slightly increase of low Apgar score babies for the highly educated group from 1996 to 2000, it appears that the narrowing gap is primarily due to a decrease in the incidence of low Apgar scores among infants born to less-educated mothers.

Figure 5b plots the number of deaths per 1000 births based on maternal education groups. This figure shows that infants born to less-educated mothers always have higher death rates, and that the differences in death rates have stayed relatively constant over time.

In order to further investigate the gradient, I estimate a logistic regression model where the logarithm of odds is a linear combination of the independent variables.

(1)

$$\ln\left(\frac{\Pr(y_{it}=1)}{1-\Pr(y_{it}=1)}\right)=\beta_0+\beta_1 L_{it}+\beta_2 M_{it}+\beta_3[L*yeartrend]_{it}+\beta_4[M*yeartrend]_{it}+\beta_5[year]_t+\beta_6 X_i+\varepsilon_{it}$$

$\Pr(y_{it}=1)$ is the conditional probability of an infant with a low Apgar score or of an infant who dies before its first birthday. L and M are dummy variables for mothers who are in the low education group (less than 12 years of schooling completed) and in the middle education group (12 to 15 years of schooling completed), respectively; the *yeartrend* is a linear index of the sample year where 0 represents 1983 and 19 represents 2000; *year* includes a full set of year dummies. The vector X_i includes time-invariant covariates measured at the individual level.

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 low and high education groups, while a negative coefficient indicates that this gap actually narrows.

In order to test whether the results of the model are robust to the specification of a linear time trend I re-estimate the model using a full set of year dummies rather than a linear year trend. In Appendix Figures 1a and 1b, I plot the coefficients of the interaction terms between low and middle education dummies and the year dummies to show that the results are consistent.

In order to examine the factors that account for the evolution of the gradient, I implement a decomposition method similar to that proposed by Smith and Welch (1989) and Heckman et al. (2000). Specifically, I examine the influence of three broad sets of factors: 1) maternal behavioral changes, as measured by whether a mother is married, whether she gives birth after age 40, experiences inadequate weight gain, has multiple births, or smokes during pregnancy; 2) demographic composition changes, including four dummy variables for whether a mother is Hispanic, African-American, other races, and foreign born; and 3) access to medical care, consisting of a dummy for adequate prenatal care and a dummy for inadequate prenatal care.

To understand this decomposition, let x refer to the three sets of variables mentioned above with the associated vector of coefficients $\hat{\beta}$. Let t be the current year and τ be the base year, while H denotes high education group and L denotes low education group.

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. Then, the change in the low education group infant outcome minus the high education group infant outcome between time periods t and τ is decomposed in the following way:

$$
\begin{aligned}
&\left[\left(\bar{x}_t^L \hat{\beta}_t^L - \bar{x}_t^H \hat{\beta}_t^H\right) - \left(\bar{x}_\tau^L \hat{\beta}_\tau^L - \bar{x}_\tau^H \hat{\beta}_\tau^H\right)\right] = \\
&\left[\left(\bar{x}_t^L - \bar{x}_t^H\right) - \left(\bar{x}_\tau^L - \bar{x}_\tau^H\right)\right]\hat{\beta}_\tau^H \text{..............}(a) \\
(2) \quad &+\left(\bar{x}_t^L - \bar{x}_\tau^L\right)\left(\hat{\beta}_\tau^L - \hat{\beta}_\tau^H\right)\text{.......................}(b) \\
&+\left(\bar{x}_t^L - \bar{x}_t^H\right)\left(\hat{\beta}_t^H - \hat{\beta}_\tau^H\right)\text{......................}(c) \\
&+\bar{x}_t^L\left[\left(\hat{\beta}_t^L - \hat{\beta}_t^H\right) - \left(\hat{\beta}_\tau^L - \hat{\beta}_\tau^H\right)\right]\text{...........}(d)
\end{aligned}
$$

The first two terms of (2) measure the contribution of changes in characteristics, valued at base-year coefficients. Term (a) measures the change in the infant health inequality predicted by changes in the characteristics of the two groups over time. These changes are valued using base-year high education group parameters. 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. Term (b) measures the additional change in the infant health gradient predicted by the change in the characteristics among the low education group, taking into account that the base-year coefficients of the high and low education groups differ. For example, if returns to medical care (in the base year) are higher among the highly educated group, then an increase in the overall mean values of medical care leads to an increase in the infant health disparity because the highly educated benefit disproportionately.

The last two terms measure the contribution of changes in coefficients. Term (c) measures the effect of a change in the infant health gap due to a change in the returns to a specific characteristic taking into account the fact that low and high education group mean characteristics differ in the current year. In other words, if the less-educated are less likely to have a characteristic for which the return decreases, then the gradient decreases. 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. Term (d) measures the predicted change in the infant health disparity that occurs because highly educated women and less-educated women become more similar in terms of coefficients, valued at current-year low education group characteristics. This term implies that if the coefficients of the less-educated improve more than the coefficients of the highly educated, the gap decreases due to a convergence in coefficients.

RESULTS

The Trend in Health Inequality

Table 2 displays the effects of maternal education on infant health outcomes as well as the evolution of the gradient over time. Since the coefficients of logistic regressions are not directly interpretable, the marginal effects of the regressions are reported. The first column shows the estimated coefficients where the dependent variable is an indicator of whether the infant had a low Apgar score from 1983 to 2000. There are two main findings from the first column. The first finding is the salient infant health differences between different maternal education groups. The marginal effect of low education dummy is 4 percentage points and the marginal effect of middle education dummy is 2 percentage points. In other word, the probability of being a low

Apgar score baby is 4 percentage points higher for a baby born to a less-educated mother versus a highly educated mother. Likewise, the probability of being a low Apgar score baby is 2 percentage points higher for a baby born to a middle educated mother versus a highly educated mother.

The other key finding is that the trend in the health inequality gap, measured by a low Apgar score, 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, we see that the education-based infant health gap between college-graduate and high school dropout mothers has decreased by 4 % (-0.166/4.012) per year.

The coefficient estimates of the regression of infant death are shown in column 2. The estimated effects on the interaction terms suggest that the gradient has stayed relatively constant over time. That is, the interaction terms between the time trend and education levels are small in magnitude and not precisely estimated. Therefore, I conclude that the gap with respect to infant death has stayed constant over time. In the appendix, I show that the results (i.e., the gradient decreasing with respect to low Apgar scores and the gradient remaining constant with respect to infant death rates) from Table 2 are robust to using year dummies rather than time trends.

To summarize, we observe that the less educated households are catching up to the high educated households in terms of Apgar scores from 1983 to 2000. But this does not translate into a closing of the infant mortality gap. As a matter of fact, the infant mortality gap has remained roughly constant from 1983 to 2000, at around 6 per 1000 deaths. The paper by Case, Lubotsky and Paxson (2002) provides a possible way to reconcile the observation of a narrowing gap in Apgar scores with the observation of a constant gap in infant death rate. They find that the health gap between low and high socioeconomic status children becomes larger as children grow older. From this finding, we can infer that the health gap between less and highly educated households at age 1 is larger than the gap at age 0.

To reconcile my findings on infant health at birth with that on infant death rates, it must be the case that this gap in infant health between less and highly educated households increased from age 0 to 1 at a faster rate in 2000 than in 1983. We can see that because the health at birth for these two populations had almost equalized by 2000, the constant gap in health at age one over time implies that the increased slope of health deterioration with age became more rapid over the study period.

Table 3 shows the estimated effects of the other covariates included in model (1). Columns 1 and 2 report the regression results for all years (1983~2000) while columns 3 and 4 report the regression results for years 1989 to 2000, the period when information on gestational weight gain and smoking behavior is available. As discussed previously, the effects of maternal age and weight gain on infant health outcomes are highly non-linear. I, therefore, include a dummy for teenage mothers and a dummy for mothers older than 40 to capture the non-linear effect of maternal age on infant outcomes. The effects of weight gain on infant health are also non-linear. To capture the non-linear effects, I include a dummy for weight gain less than 15 pounds and a dummy for weight gain over 60 pounds.

From Table 3, consistent with our expectations, Hispanics, foreign-born mothers, and married mothers are less likely to have babies born with low Apgar scores. Furthermore, children born in multiple births, born to high school dropouts, and born to a mother smoker are more likely to have low Apgar scores. The effect of multiple births on low Apgar scores is particularly large -- a multiple birth baby is 11 % more likely to have a low Apgar score than a singleton birth baby (i.e., only one child born to a mother). Among the various factors, the effect of multiple births is the most salient.

The marginal effects of the dummies for weight gain during pregnancy, as shown in column 2 in Table 3, are particularly interesting. I find a positive effect of inadequate weight gain on a low Apgar score, a finding that was not previously documented in the literature. Mothers with weight gain of less than 15 pounds are 3.14 percentage points more likely to have low Apgar score babies. A new finding of this paper is that babies whose mothers gain weight over 60 pounds also have a higher probability of a low Apgar score; the effect is 0.43 percentage points. As for the effects of weight gain on infant death, I find that inadequate weight gain results in higher infant death rates; however, excessive weight gain does not seem to have similar negative effects on infant death.

In order to assess how much of the gap is accounted for by different groups of covariates, Figure 6 plots the conditional expectation of low Apgar scores for high and low education groups controlling for the different sets of covariates based on the hypotheses described previously. More specifically, the solid line is the unconditional expectation, which for comparison is the same as in Figure 5a. The dashed line is the conditional expectation when demographic variables are controlled. The dotted line is the conditional expectation when I add in controls for demographic variables as well as access to medical care. The dotted-dashed line is the conditional expectation controlling for all three sets of variables: the demographic variables, the access to medical care variables, and the maternal behavior change variables.

Figure 6 illustrates that as each set of control is added to the regression, the gap between the high and low education groups narrows; this implies that different control variables can account for a large portion of the gap. However, from this graph alone, assessing how much of the gradient each set of variables explains is difficult because the order in which the control variables are added effects the results. Furthermore, this gap does not take into account the effects of changes in coefficients .

For a more rigorous analysis, I use the aforementioned decomposition method. This decomposition method assesses the contribution of each control variable and differentiates between the changes in gradient that are due to changes in characteristics verses changes in coefficients (i.e., the returns to certain characteristics). For example, if the coefficient from a linear regression model associated with adequate prenatal care is -0.03 and the dependent variable is whether a baby has a low Apgar score, then this implies that having adequate prenatal care is associated with a 3% lower probability of having a baby with a low Apgar score. In other words, having adequate prenatal care has a negative 3% return with respect to low Apgar scores. Therefore, if a coefficient changes over time, we then interpret this as a change in the return to a certain characteristic over time. For example, increases in the return to medical care over time means that having adequate prenatal care is associated with a larger gain in Apgar scores in the present than in past years. In other words, the health differences between babies who receive adequate prenatal care and those who do not receive prenatal care increases over time.

Decomposition Results

Table 4 shows the results of the decomposition[22]. Overall, access to medical care is the dominant factor in explaining the closing infant health gradient as measured by a low Apgar score. All else being equal, access to proper medical care accounts for 39.5% of the closing infant health gradient. However, although access to medical care is certainly a driving factor, it explains less than half of the closing gradient. Maternal behavior changes and demographic

[22] In 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.

changes also contribute significantly, explaining 29% and 12%, respectively. The remaining 18% is not explained by the variables I include in my decomposition[23].

As seen in Table 4, the four most important factors in explaining the reduction of the infant health gradient are adequate prenatal care, foreign-born mothers, married mothers and multiple births. In what follows, I briefly discuss each of these factors.

The single largest component is adequate prenatal care; it reduces the gap by 37%. This finding suggests that the increases in access to medical care, perhaps caused by the rapid Medicaid expansion in the late 80s and early 90s, played a significant role in closing the infant health gap.

Being a foreign-born mother is perhaps the most important demographic variable, accounting for 12% of the closing gap. 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. When assessing the

23 There are two potentially important factors that I do not include in my decomposition exercises and thus may account for some of the unexplained 18%. The first factor is selective abortion. Over the study period, the legal abortion rate declined. For example, the abortion rate declined from 29.3 per 1,000 women aged 15-44 in 1980 and 27.4 in 1990 to 22.4 in 1996 (Finer and Henshaw, 2003). I am not aware of any data on whether the abortion rate decreased faster among the highly or less educated groups. If the number of unwanted babies decreased more for the less educated group compared with the highly educated group, this might have improved infant health relatively more for the less educated. The second factor is technological innovation. The 1980s and 1990s witnessed many medical innovations to improve critically ill newborns (Cutler and Meara 2000). Unfortunately, there is no information contained in the US Vital Statistics that can be used as a measure for medical technology change. In addition, it is uncertain which group would benefit the most from these improvements in medical technology. On the one hand it is possible that the Medicaid expansion helped the less educated mothers have access to high technology, which is in general expensive. Moreover, since infants born to less educated women have worse health than those born to highly educated women, then technological innovation will disproportionately improve infant health for the less educated. On the other hand, if only highly educated people have access to innovations, then these innovations will improve the health of the babies born to highly educated women.

effects of the influx of Hispanics on the infant health gradient, it is important to look not only at the effects of being Hispanic but also the effects of being foreign-born. Combining the positive effect of being foreign-born (12.1%) and the negative effect of being Hispanic (-5.9%), the net effect of the influx of Hispanic women over the past few decades accounts for approximately 6.2% (12%-5.9%)[24] of the closing of the infant health gap in low Apgar scores. This finding suggests that if the flow of Hispanic immigrants continues, we may see further decreases in the infant health gap.

Of the maternal behavior variables, whether a mother is married explains 12% of the reduction of the infant health gradient. Whether the effect of a mother's marriage status has a positive or negative effect on the infant health gap can be decomposed into changes in coefficients and changes in characteristics. On the one hand, changes in coefficients, the return to being married, have been decreasing over time. This can be seen from Figure 2 in the Appendix, which shows that the negative effect of being unmarried has been decreasing over time. Since there is a higher percentage of unmarried mothers in the low education group versus the high education group, and since the negative effect of being an unmarried mother has been decreasing over time, less-educated mothers benefit disproportionately, thus narrowing the infant health gap. Table 4 shows that changes in coefficients close the gap by 13.7% (the sum of terms (c) and (d)). On the other hand, changes in characteristics, the decreasing rate of being married among less-educated women, increase the gap by 1.6% (the sum of terms (a) and (b)). This is because being unmarried is associated with negative infant health outcomes, and over time we see a decreasing rate of being married among the less educated, therefore, the infant health among the less educated deteriorated and thus increased the infant health gap. If we take into account both

[24] 80% of the foreign born mothers are Hispanic.

changes in coefficient and changes in characteristic we see that over time the net effect of whether a mother is married explains 12% of the reduction of the infant health gradient.

The last important component is multiple births, accounting for 11% of the narrowing infant health gradient. This should not be surprising because the percentage of multiple births increase from 2 % in 1989 to 4% in 2000 for highly educated women while the percentage of multiple births remains at 2% for less educated women. Kogan et al. (2004) find that while constituting 3% of all births in the United States in 1997, twins accounted for 21% of all low birth weight babies, 14 percent of preterm births, and 13 percent 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, it worsens infant health at the high end of distribution.

SPECIFICATION CHECKS

Selection Issue

When interpreting changes in the gradient using fixed education groups, it is important to address issues of selection. Over time, on average, an increasingly higher level of educational attainment has been achieved in the U.S. 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 gaps in health between college and non-college, this could be entirely due to changes in the way the both college and high school students are selected rather than because of policies, changes in behavior etc. Because of this general improvement in education attainment, there are two selection issues: selection of college graduates and selection of high school dropouts.

Figure 7 shows that in 1983 only 16% of mothers had graduated from college; in 2000, this number reached 26%. If we assume that there is a monotonic relationship between the probability of going to college and of giving birth to healthy babies (which is supported by Figure 1), the additional 10% counted as college graduates in 2000, which would not have finished college in 1983, can be expected to have worse health than the top 16%. That is, 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%.

In addition to the increase in college attainment, Figure 7 also shows that in 1983, 21% of mothers were high school dropouts, as opposed to 18% in 2000. What this means is that the 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. The 3% of the people that would have been high school dropouts but now have become high school graduates have left the group, leaving the rest of the high school dropout group more negatively selected. As a result, the average health of the group has worsened.

If we correct 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 means that without correcting for selection into college would overestimate convergence, while without correcting for selection into high school dropouts gives an underestimate of convergence. 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 relative education groups.

To overcome these selection issues, I adopt a propensity score method. The objective is to hold constant the probability that a person would attend college, given their characteristics. I first estimate a logistic equation predicting the probability of a person attending college in 1983. 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 this new relative education group variable.

Table 5 shows the infant health gradient using these relative education groups. The results from Table 5 yield the same pattern of convergence as before (i.e., using high school dropout versus college graduate); that is, we still see convergence in low Apgar scores but not in infant death rates. The interaction terms of the linear time trend and education levels are negative and significant (by chance, the estimated coefficient -0.166 is exactly the same as it is in Table 2), indicating that the differences in low Apgar scores have decreased since the early 1980s. In summary, the results in this section show that the convergence in low Apgar scores shown in Table 2 is robust to possible selection issues.

Convergence by Region

Since I found that access to medical care is the most important factor in explaining the trend, and because access to medical care increased more in the southern states than in the non-southern states due to the rapid Medicaid expansion in the late 80s and early 90s, my third research question asks whether there is faster convergence in Southern states than in non-Southern states.

Table 6 shows the evolution of the gradient by region. Columns 2 and 3 show the convergence in the South and the non-South areas, respectively. The coefficient of the interaction term between low education and a linear time trend for the South is -0.20 percentage points while the coefficient for the non-South is -0.160 percentage points, indicating a faster convergence in the South. If we focus on columns 5 and 6 where I restrict the sample period from 1989 to 2000, we also see that the South converged faster than the non-South. The estimated effect of convergence is -0.23 for the South, while it is only -0.14 for the non-South. Overall, the estimated coefficients show that the effect in other regions in the county is much smaller than in the South.

A natural question to ask is why the gradient in the South converges faster than the gradient in the non-South. A possible answer to this question is that the Medicaid expansion was much more important in the South than in the non-South. Figure 10 supports this hypothesis; it shows the percentage of mothers who have adequate prenatal care over time by region and by maternal education. From this graph we can see that although the percentage of women receiving adequate prenatal care has increased over time in both regions, the percentage increases more rapidly for less-educated women in the South. Before 1990, less-educated women in the South had, on average, less adequate prenatal care than their counterparts in other regions. However, after 1990, less-educated women in the South actually had a higher probability of receiving adequate prenatal care than their counterparts in the non-South. The timing of the rapid increase in adequate prenatal care among less-educated women in the South corresponds exactly with the rapid Medicaid expansion of the late 1980s and early 1990s. Moreover, Medicaid expansion might be more important in the South than in the non-South because less-educated mothers in the South are, on average, poorer than the less-educated women in the non-South. Therefore, more less-educated mothers are covered by Medicaid in the South than in the non-South.

Table 7 shows the decomposition results by region. For comparison, Column 1 displays the results for the whole nation as in Table 4. Columns 2 and 3 are the decomposition results for the South and for the non-South, respectively. From the table we see that access to medical care accounts for 40% 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 65% of the reduction of the infant health gradient in the South, but only 25% of it in the non-South, further supporting the key finding of this section – the faster rate of convergence in the South is due to the relative importance of Medicaid expansions.

DISCUSSION AND CONCLUSIONS

Using Vital Statistic in America from 1983 to 2000, I examine two important questions regarding the evolution of the inequality (or gradient) in infant health over time. First, has the infant health gradient increased or decreased over time? After finding that the gradient has indeed decreased over time, I ask what accounts for the decreasing gradient. This study represents a first attempt at looking into the evolution of the infant health gradient. The major findings of this paper are that when this disparity is measured by low Apgar scores, we observe a narrowing of the gradient over the last two decades of the twentieth century, but when this disparity is measured by the infant death rate, the gradient has remained relatively constant over time.

The convergence in the Apgar score health disparity and the lack of convergence in the infant mortality rate suggests that the even though infants born to mothers of various socioeconomic backgrounds are born under nearly identical initial conditions today, infants born into lower socioeconomic households are not receiving the same care that their counterparts receive during that first year of life. As a result, the health gap between less and highly educated households at age 1 is larger than the gap at age 0. Furthermore, because the health at birth for the highly educated and for the less educated populations had almost equalized by 2000, the constant gap in health at age one over time implies that the increased slope of health deterioration with age became more rapid over the study period.

To address the second question, I use a simple decomposition which reveals that the increasing access to medical care is the dominant factor in explaining the decrease in the infant health gradient, as measured by a low Apgar score. All else being equal, the greater likelihood is that less-educated women now have access to proper medical care narrows the low Apgar score gap by 39%. However, even though increasing medical care is the most important factor, it explains less than half of the reduction of the infant health gradient. Maternal behavior changes and demographic changes also contribute significantly; maternal behavioral changes explain 29% and demographic changes, especially the increasing share of births to foreign-born Hispanics, explain 12%. When I re-analyze the results by region, I find that access to medical care is more important in the South than in the non-South. This finding is consistent with the fact that over time, the percentage of mothers receiving adequate prenatal care increased more rapidly in the South than in the non-South. Taken together, these findings suggest that the Medicaid expansion was more important in the South than in the non-South regions and that this drives the more rapid convergence of the gradient in the South.

Finally, this paper calls attention to the fact that the gradient converges not only because infant health among low education groups has increased but also because infant health among the highly educated group has deteriorated in some respects. The delaying pregnancy age and the increasing number of multiple births among highly educated mothers are worsening the infant health distribution at the high end of the distribution.

APPENDIX

In Table 2, I use a linear time trend to estimate whether the education-based infant health gap has decreased over time. We see that infant health as measured by a low Apgar score has decreased; however, infant health as measured by infant death rate has stayed constant over time. The linear time trend, however, may mask the effects of different years. In order to check the robustness of a linear time trend, I estimate the same model using a full set of year dummies.

The marginal effects of education*year dummies are plotted in Appendix Table 1. The line with triangles (circles) plot the marginal effects of low (middle) education dummy *year dummies from 1984 to 2000. The omitted year category is 1983. The red line is a horizontal line representing zero. The difference between the line with circles (triangles) and the red line measures the degree to which the gradient has converged between highly and less (middle) educated women. For example, the coefficient for low education*year 1999 dummy is -0.02, which means that a baby born to a less-educated mother in 1999 is 2 percentage points less likely to have a low Apgar score than a baby born to a less-educated mother in 1983. Since the gap between the blue and red lines has increased over time, the gradient has decreased. Combined with the regression results using a linear time trend, we see that the decreasing gradient is robust to using a linear time trend specification or a full set of year dummies. Figure 1b in the Appendix plots the same results as Figure 3a but using the infant death rate measure instead of the Apgar score. Since the gap between the green line and the red line is basically zero, consistent with previous regression results from Table 2, this graph shows that the gradient has stayed relative constant over time and that the results are robust to using a linear time trend or a full set of year dummies.

Appendix Table 1: Apgar Scoring for Newborns.

	0	***1***	***2***
Activity (muscle tone)	Limp; no movement	Some flexion of arms and legs	Active motion; movement of extremities
Pulse (heart rate)	By stethoscope – No heart rate	By stethoscope – Fewer than 100 beats per minute	By stethoscope – At least 100 beats per minute
Grimace (reflex irritability)*	No response	Some motion	Cry
Appearance (color)	The baby's whole body is completely bluish-gray or pale	Good color in body with bluish hands or feet	Good color all over
Respiration (breathing)	Not breathing	Weak cry; may sound like whimpering, slow or irregular breathing	Good, strong cry; normal rate and effort of breathing

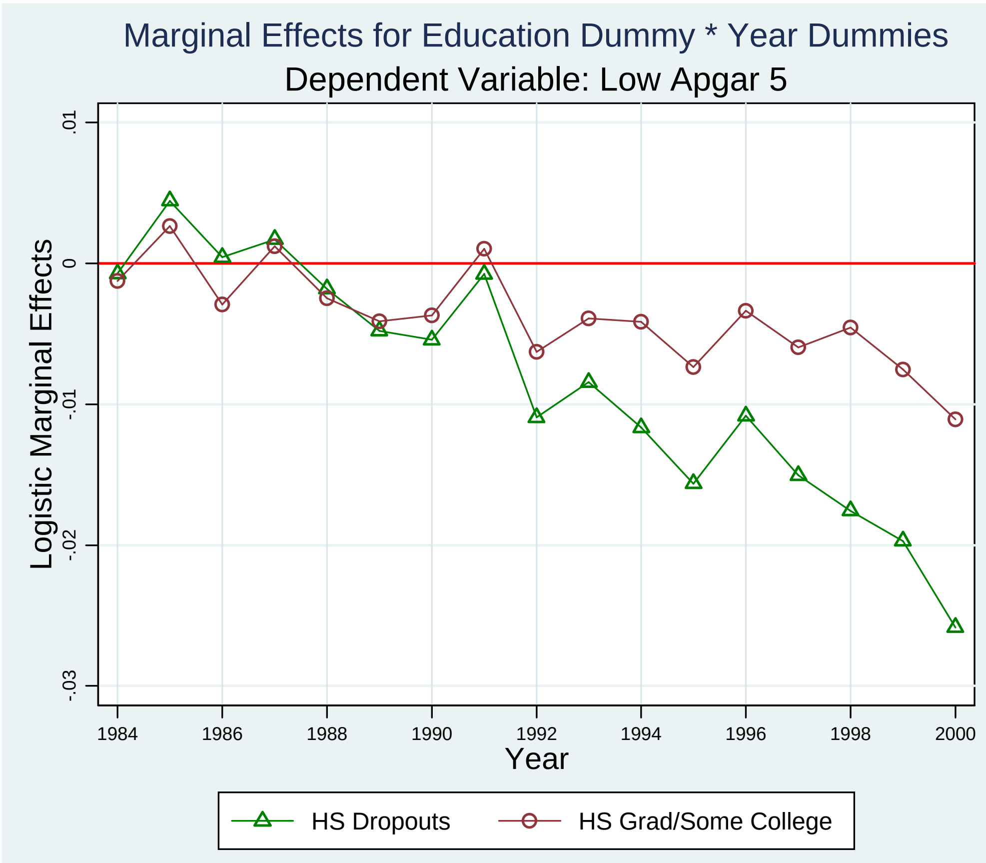
* **Response to skin stimulation to feet**

Appendix Table 2: Distribution of Apgar Scores

Apgar Score	Frequency	Percentage
0	3,016	0.07
1	8,719	0.2
2	4,276	0.1
3	4,709	0.11
4	6,817	0.16
5	12,326	0.28
6	27,749	0.64
7	70,793	1.62
8	334,017	7.66
9	3,339,701	76.64
10	545,785	12.52

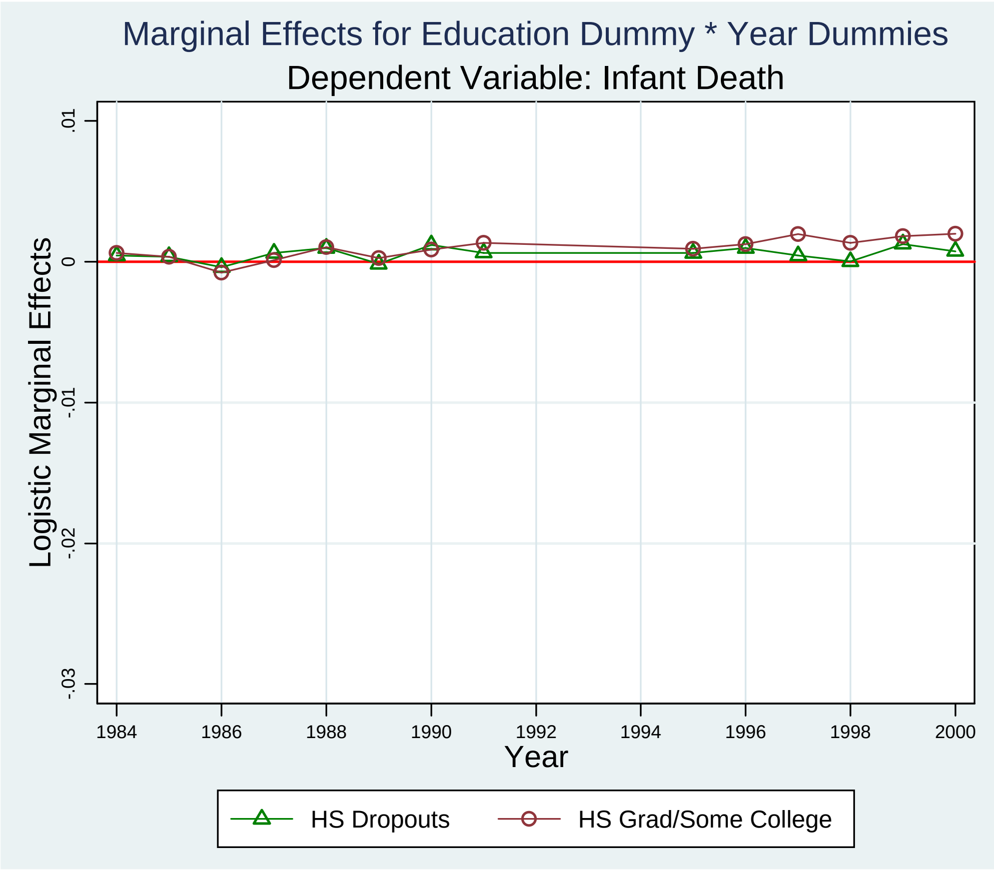
Notes: Data are from U.S. Vital Statistics, 1983 to 2000. A low Apgar score is defined as 8 or below—10% of infants have low Apgar scores.

Appendix Figure 1a: Marginal Effects of Education and Year Interactions (Low Apgar score)



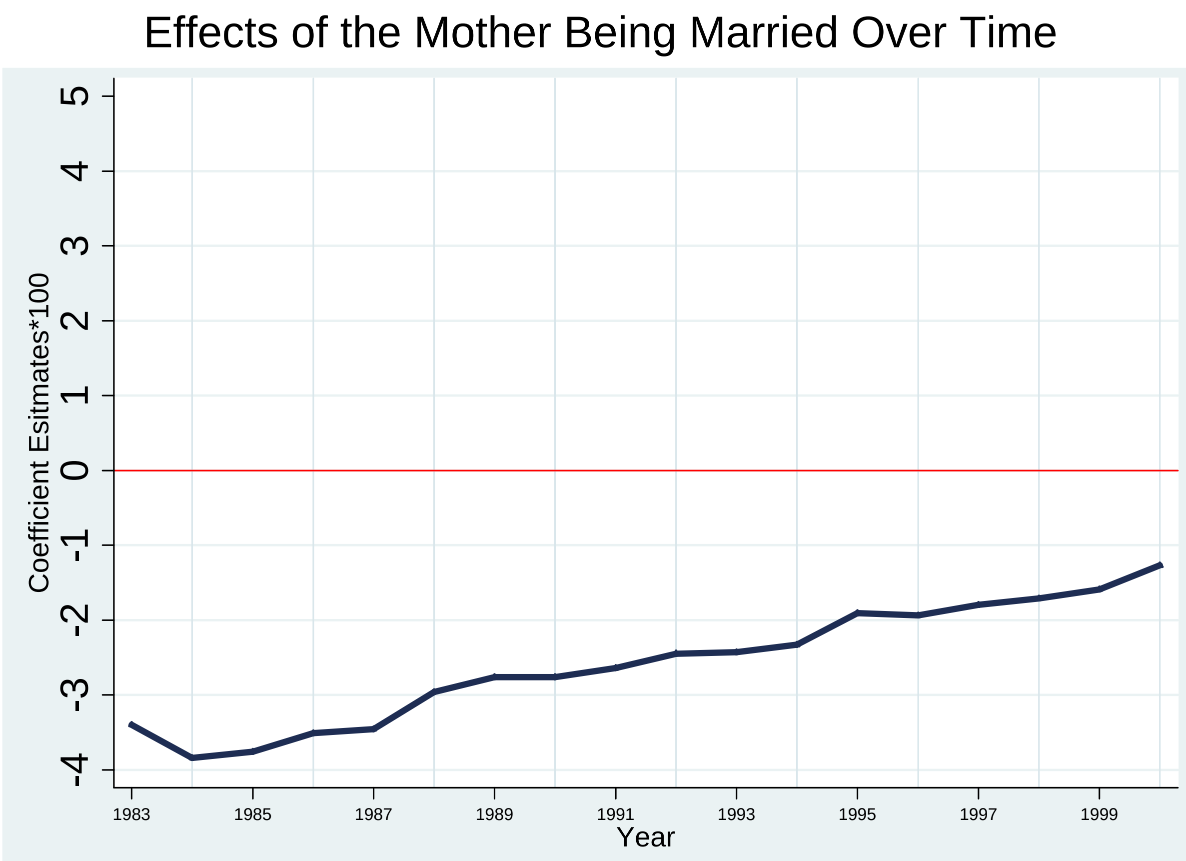
Notes: The line with triangles (circles) plots the marginal effects of low (middle) education dummy * year dummies from 1984 to 2000. The omitted year category is 1983. The red line is a horizontal line representing zero. The difference between the line with circles (triangles) and the red line measures the degree to which the gradient has converged between high and low (middle) educated women.

Appendix Figure 1b: Marginal Effects of Education and Year Interactions (Infant Death)



Notes: The line with triangles (circles) plots the marginal effects of low (middle) education dummy * year dummies from 1984 to 2000. The omitted year category is 1983. The red line is a horizontal line representing zero. The difference between the line with circles (triangles) and the red line measures the degree to which the gradient has converged between high and low (middle) educated women.

Appendix Figure 2:



Notes: The effect of being married is associated with a lower return on infant health over time. For example, being married was associated with 3% decrease in low Apgar score in 1989 (base year) but it was associated with only a 1% decrease in low Apgar score in 2000 (current year).

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Table 1: Summary Statistics by Maternal Education (Percentages Reported)

Variables	Low Education	Middle Education	High Education
Infant Outcomes			
Infant Death	1.32	0.85	0.54
Low Apgar Score	12.07	10.90	9.48
Maternal Behaviors			
Multiple Births	2.01	2.49	3.27
Mother Smokes during Pregnancy	28.33	16.46	3.05
Weight Gain less than 15 Pounds	10.02	8.04	4.30
Weight Gain greater than 60 Pounds	3.15	2.67	1.48
Teenage Mother	40.54	7.96	0.00
Maternal Age over 40	0.76	1.07	2.65
Married Mother	42.36	73.54	95.36
Demographic Variables			
Hispanic	15.79	5.35	2.79
African-American	26.84	17.99	7.08
White	53.84	73.78	85.52
Other Races	3.53	2.89	4.61
Foreign-Born Mother	15.44	7.75	10.69
Access to Medical Care			
Adequate Prenatal Care	49.47	72.22	85.42
Inadequate Prenatal Care	13.65	4.81	1.37
observations	874,774	2,632,968	904,444

Notes:

1. Low Education: less than 12 years of schooling completed; Middle Education: 12 to 15 years of schooling completed; High Education: 16 or more years of schooling completed.
2. Data are from U.S. Vital Statistics, 1983 to 2000.

Table 2: The Effects of Education on Infant Health (Logistic Marginal Effects)

	Low Apgar Score	*Infant Death*
Low Education	4.012**	0.683**
	[0.256]	[0.043]
Middle Education	2.014**	0.252**
	[0.178]	[0.028]
Time Trend * Low Education	-0.166**	0.003
	[0.012]	[0.003]
Time Trend * Middle Education	-0.068**	0.011**
	[0.008]	[0.002]
Year Trend	-0.096**	-0.031**
	[0.018]	[0.002]
Constant	-20.71**	-4.009**
	[0.229]	[0.095]
Observations	4,357,908	3,667,295

Notes:

1. The coefficients are scaled up by 100.
2. Robust standard errors in brackets.
3. Regressions do not include any controls (unconditional regressions).
4. * Significant at 5%; ** Significant at 1%
5. Data are from U.S. Vital Statistics, 1983 to 2000.

Table 3: The Effects of Maternal Education on Infant Health (Logistic Marginal Effects) With Control Variables Reported

	1983~2000		1989~2000	
	Low Apgar Score	Infant Death	Low Apgar Score	Infant Death
Low Education	2.33**	0.26**	2.03**	0.03
	[0.22]	[0.04]	[0.29]	[0.05]
Middle Education	1.42**	0.08**	1.14**	-0.03
	[0.16]	[0.02]	[0.21]	[0.04]
Year Trend * Low Education	-0.13**	0.01**	-0.12**	0.01**
	[0.01]	[0.00]	[0.02]	[0.00]
Year Trend * Middle Education	-0.06**	0.01**	-0.05**	0.01**
	[0.01]	[0.00]	[0.01]	[0.00]
Year Trend	-0.12**	-0.03**	-0.01	-0.03**
	[0.02]	[0.00]	[0.02]	[0.00]
Adequate Prenatal Care	-1.21**	-0.28**	-0.92**	-0.19**
	[0.12]	[0.01]	[0.13]	[0.01]
Inadequate Prenatal Care	0.79**	0.15**	0.93**	0.11**
	[0.1]	[0.01]	[0.1]	[0.02]
Blacks	0.92**	0.38**	0.7*	0.31**
	[0.31]	[0.02]	[0.28]	[0.01]
Hispanics	-0.79	-0.05*	-0.85	-0.04
	[0.51]	[0.03]	[0.44]	[0.02]
Other Races	-0.44	0.09*	-0.53*	0.05
	[0.25]	[0.04]	[0.22]	[0.03]
Foreign-Born Mother	-1.4**	-0.17**	-1.19**	-0.11**
	[0.31]	[0.02]	[0.29]	[0.02]
Married Mother	-1.25**	-0.17**	-1.12**	-0.12**
	[0.07]	[0.02]	[0.08]	[0.01]
Multiple Births	11.42**	1.27**	10.96**	1.06**
	[0.28]	[0.03]	[0.27]	[0.03]
Teenage Mother	0.68**	0.03*	0.82**	0.09**
	[0.09]	[0.02]	[0.1]	[0.01]
Maternal Age over 40	1.87**	0.19**	1.61**	0.1**
	[0.16]	[0.03]	[0.17]	[0.03]

Table 3: (Continued)

Weight gain less than 15 pounds			*3.14***	*0.74***
			[0.1]	[0.02]
Weight Gain equal to or greater than 60 Pounds			0.43**	-0.32**
			[0.13]	[0.05]
Smoking			0.01	0.15**
			[0.1]	[0.01]
Constant	-18.43**	-3.22**	-19.22**	-2.72**
	[0.24]	[0.06]	[0.34]	[0.06]
Observations	4,357,908	3,667,295	2,964,046	2,246,274

Notes:

1. The coefficients are scaled up by 100.
2. Robust standard errors in brackets.
3. * Significant at 5%; ** Significant at 1%
4. Data from U.S. Vital Statistics, 1983 to 2000.

Table 4: Decomposition Results

		Changes in Characteristics		Changes in Coefficients	
	Total	Term(a)	Term(b)	Term(c)	Term(d)
Adequate Prenatal Care	37.00%	9.40%	-4.90%	14.40%	18.10%
Inadequate Prenatal Care	2.50%	4.90%	-2.90%	3.00%	-2.60%
Total Effects of Access to Medical Care	*39.50%*				
Mom Black	4.80%	4.30%	-1.00%	3.30%	-1.80%
Mom Hispanic	-5.90%	1.90%	4.40%	9.10%	-21.50%
Mom Other Races	1.00%	-1.60%	-0.10%	1.70%	0.90%
Mom Foreign-Born	12.10%	3.40%	4.20%	2.60%	1.80%
Total Effects of Demographic Changes	*12.00%*				
Mom Married	12.10%	-5.70%	4.10%	7.70%	6.00%
Multiple Births	11.10%	11.30%	-0.40%	-1.50%	1.60%
Weight Gain <=15 Pounds	9.90%	0.70%	-0.30%	3.00%	6.50%
Weight Gain >=60 Pounds	-3.10%	-0.10%	0.20%	1.00%	-4.30%
Mother Smokes During Pregnancy	3.60%	1.60%	-1.20%	-2.60%	5.90%
Mom Age >= 40	-3.40%	0.90%	0.10%	-1.20%	-3.10%
Total Effects of Behavior Changes	*30.20%*				
Constant	18.40%	0.00%	0.00%	0.00%	18.40%
Total	100.00%	31.10%	2.40%	40.60%	25.90%

Note: The first column is the sum of Term(a) through Term(d).

Table 5: 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.

	Low Apgar Score	*Infant Death*
Low Education	6.133**	0.998**
	[0.377]	[0.045]
Middle Education	2.953**	0.424**
	[0.394]	[0.031]
Year Trend * Low Education	-0.166**	0.004
	[0.026]	[0.004]
Year Trend * Middle Education	-0.083**	0.009**
	[0.03]	[0.003]
Time Trend	-0.092**	-0.032**
	[0.027]	[0.003]
Constant	-21.598**	-4.025**
	[0.331]	[0.091]
Observations	4,357,908	3,667,295

Notes:

1. The coefficients are scaled up by 100.
2. I first estimate a logistic equation predicting the probability of people going to college for 1983. Second, I take the 1983 coefficients and estimate the probability of going to 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 bottom 20% of the people as the low education group. I then estimate model (1) using these new education group variables.
3. Data are from U.S. Vital Statistics, 1983 to 2000.

Table 6: The Effects of Maternal Education on Infant Health by Region (South, Non-South)

	1983~2000			*1989~2000*		
	All	South	Non-South	All	South	Non-South
Low Education	3.02**	3.54**	2.88**	3.06**	3.77**	2.71**
	[0.23]	[0.22]	[0.29]	[0.23]	[0.26]	[0.24]
Middle Education	1.61**	1.95**	1.49**	1.54**	1.87**	1.41**
	[0.16]	[0.17]	[0.2]	[0.16]	[0.19]	[0.19]
Year Trend * Low Education	-0.17**	-0.20**	-0.16**	-0.18**	-0.23**	-0.14**
	[0.01]	[0.02]	[0.02]	[0.02]	[0.04]	[0.02]
Year Trend * Middle Education	-0.07**	-0.08**	-0.06**	-0.06**	-0.07**	-0.05**
	[0.01]	[0.01]	[0.01]	[0.01]	[0.03]	[0.02]
Year Trend	-0.1**	-0.05*	-0.11**	0.02	0.04	0.02
	[0.02]	[0.02]	[0.02]	[0.02]	[0.04]	[0.02]
Constant	-20.71**	-21.13**	-20.62**	-21.24**	-21.41**	-21.26**
	[0.23]	[0.44]	[0.24]	[0.34]	[0.67]	[0.37]
Observations	4,357,908	1,627,326	2,730,582	2,964,046	1,125,508	1,838,538

Notes:

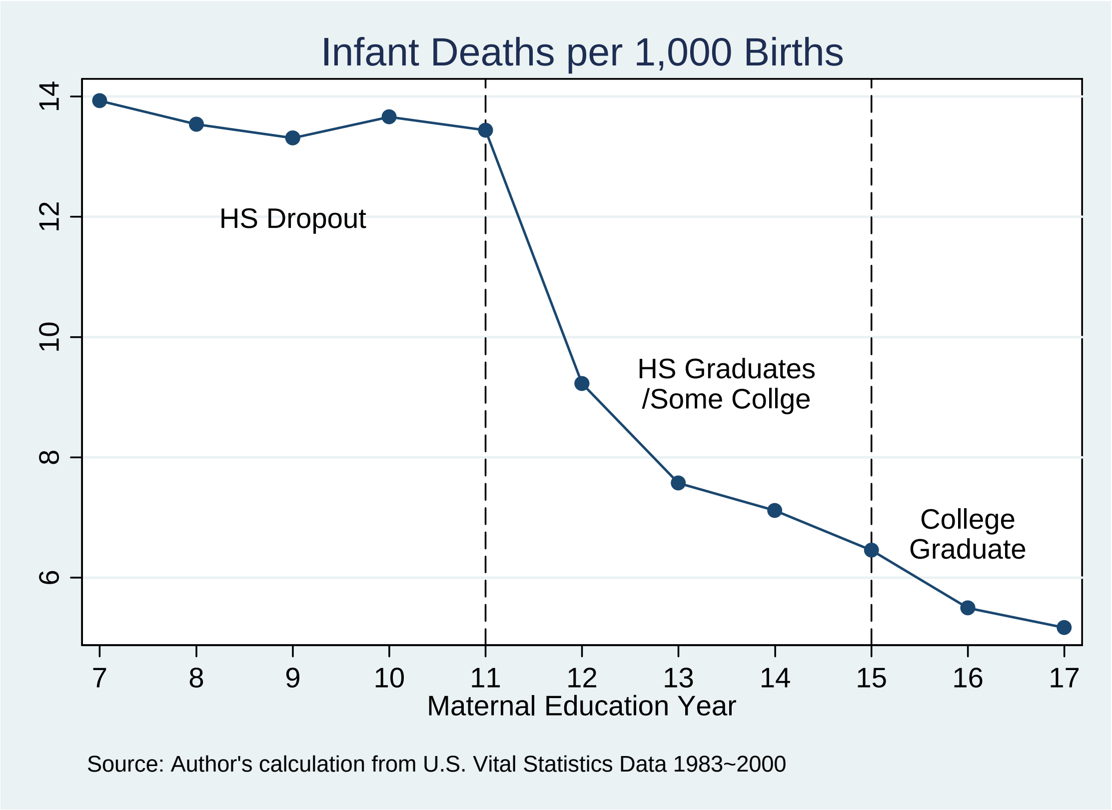
1. The dependent variable is a dummy variable for low Apgar score.
2. The coefficients are scaled up by 100.
3. Data from U.S. Vital Statistics, 1983 to 2000.
4. Robust standard errors in brackets.
5. * Significant at 5%; ** Significant at 1%.

Table 7: Decomposition Results 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%
Constant	18.4%	-46.0%	78.0%
Total	100.0%	100.0%	100.0%

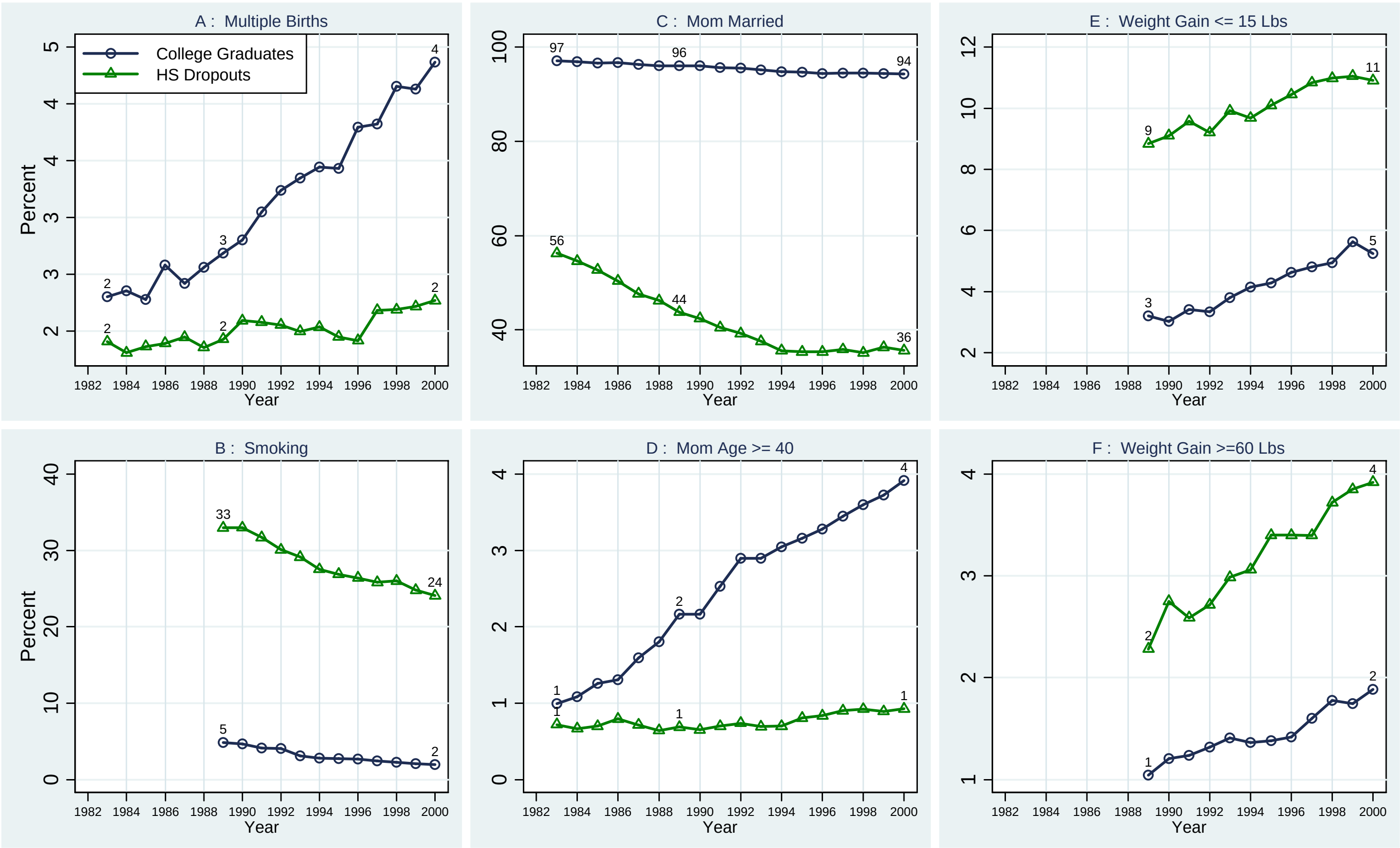
Notes: Data are from U.S. Vital Statistics, 1983 to 2000.

Figure 1: The Infant Health Gradient by Maternal Education



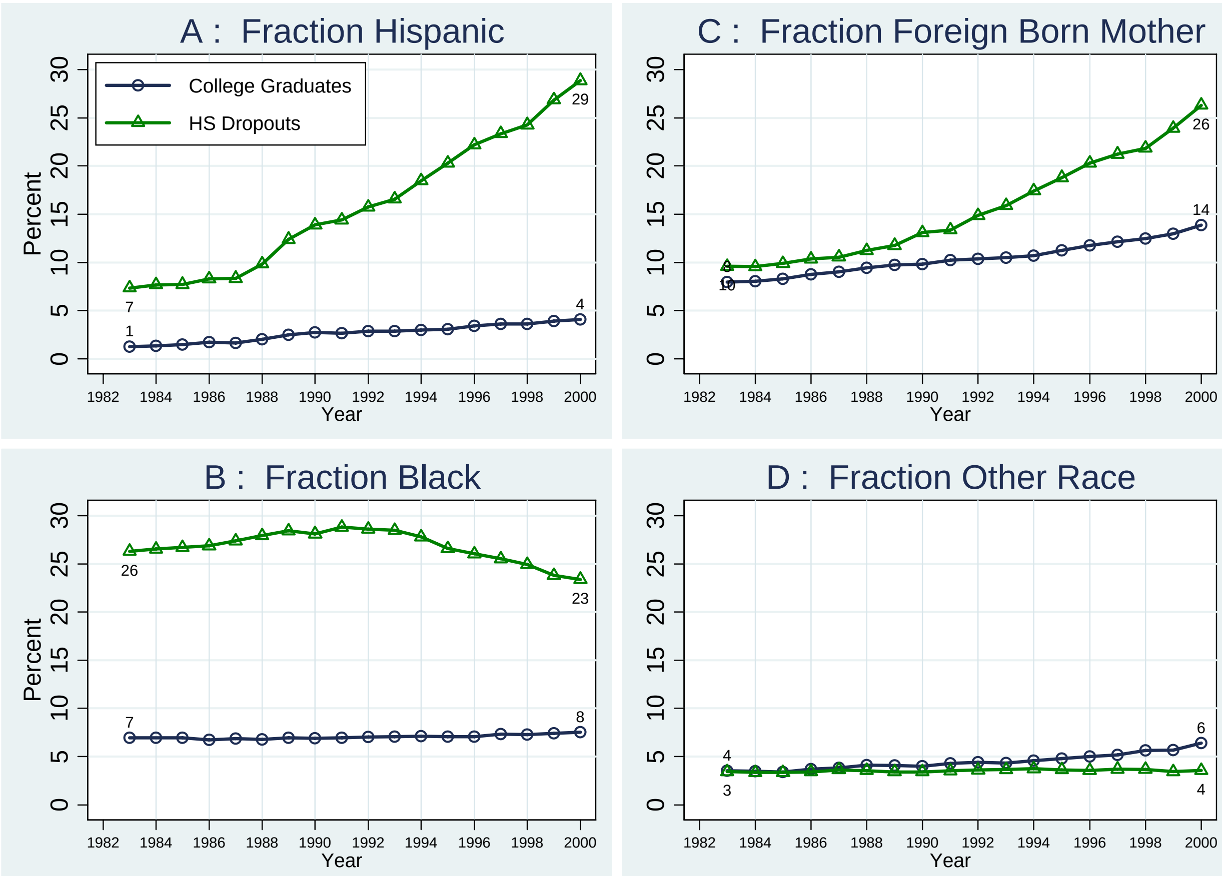
Notes: Data are from U.S. Vital Statistics, 1983 to 2000. During this period, the infant death rate is, on average, 13 per 1,000 births for women without a high school diploma while it is 5 per 1,000 births for college graduates. This figure shows that in the United States, babies born to women without a high school diploma are twice as likely to die before their first birthday as babies born to college graduates.

Figure 2: Changes in Characteristics - Maternal Behavior



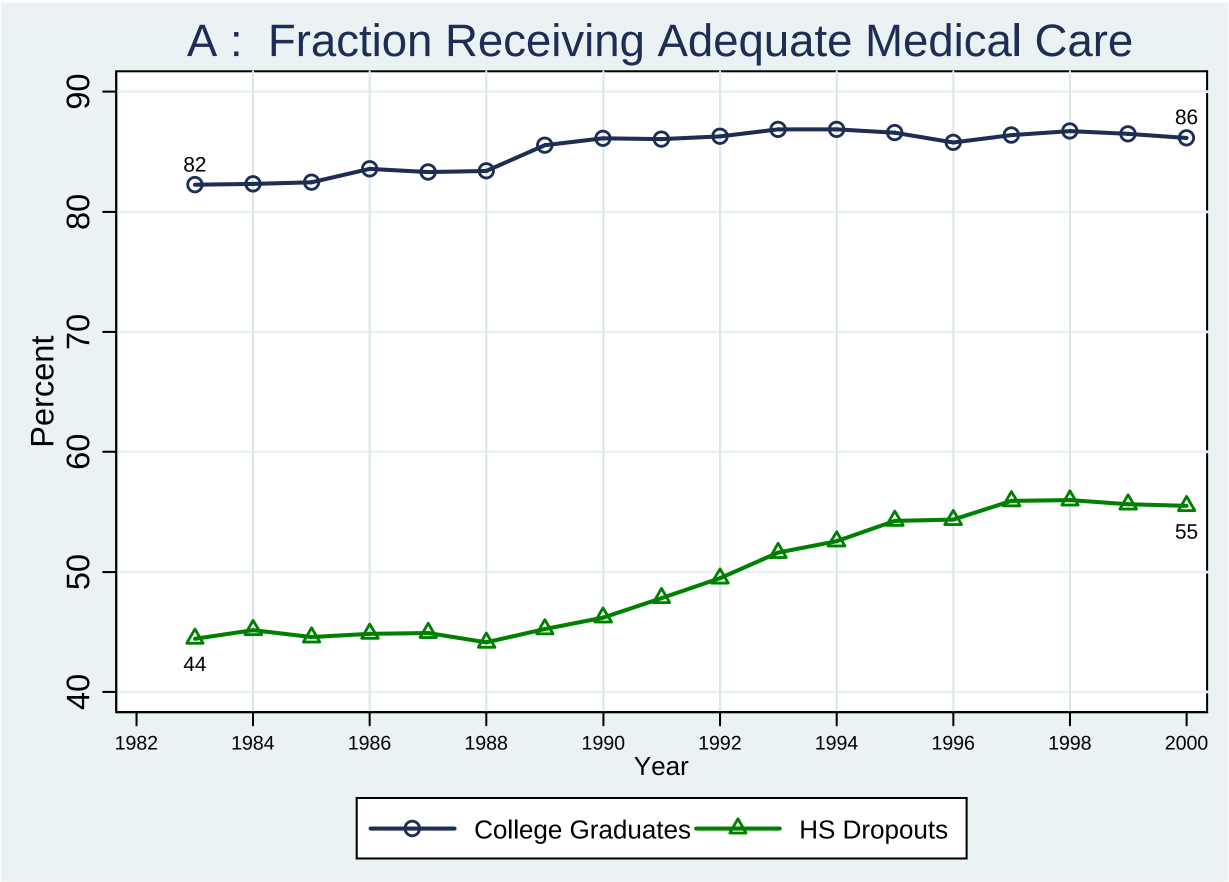
Notes: Data are from U.S. Vital Statistics, 1983 to 2000. This figure shows behavior change variables by maternal education over time.

Figure 3: Changes in Characteristics - Demographic Composition



Notes: Data are from 1983 to 2000 U.S. Vital Statistic Data. This figure shows time trends for demographic composition variables by maternal education.

Figure 4: Changes in Characteristics - Access to Medical Care



Notes: Data are from U.S. Vital Statistics, 1983 to 2000. This figure shows time trends for access to medical care by maternal education.

Figure 5a: Low Apgar Score Fractions over Time

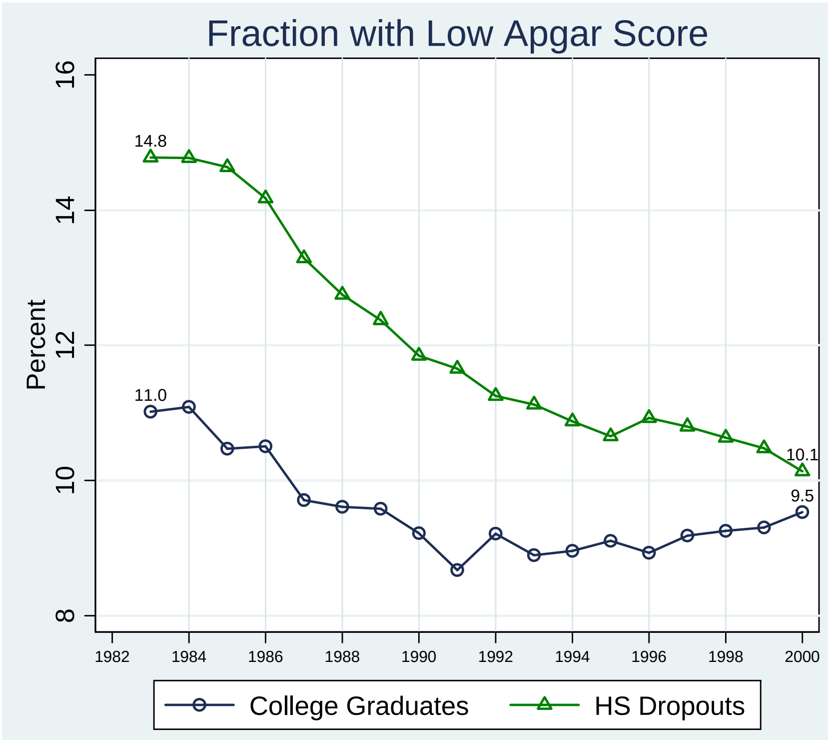
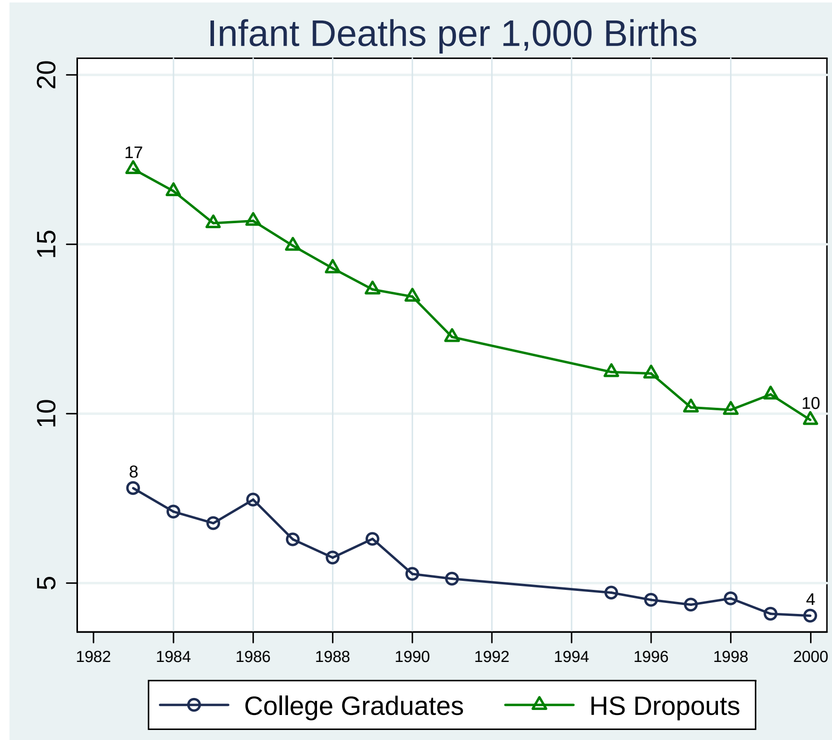
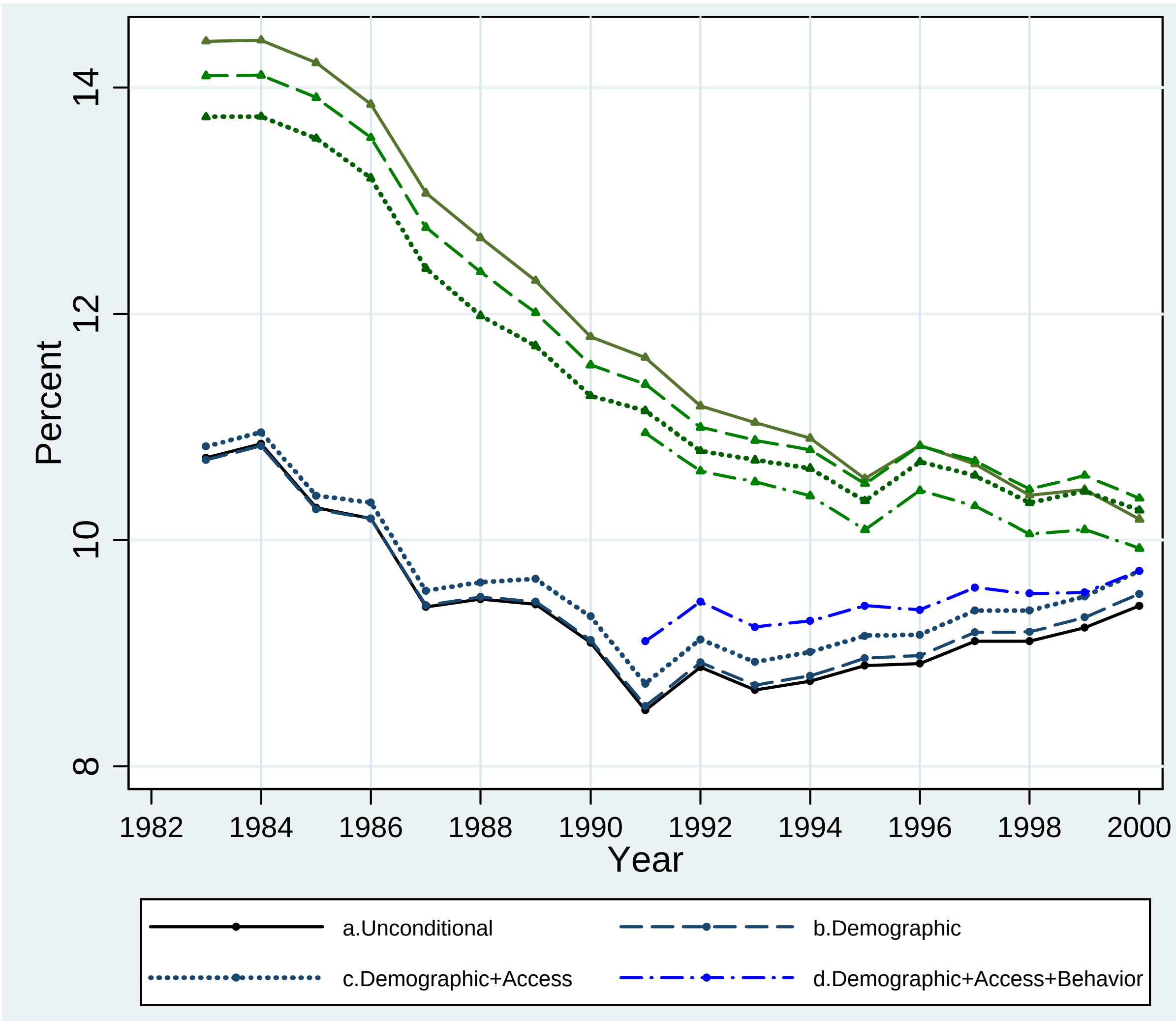


Figure 5b: Infant Death Fractions over Time



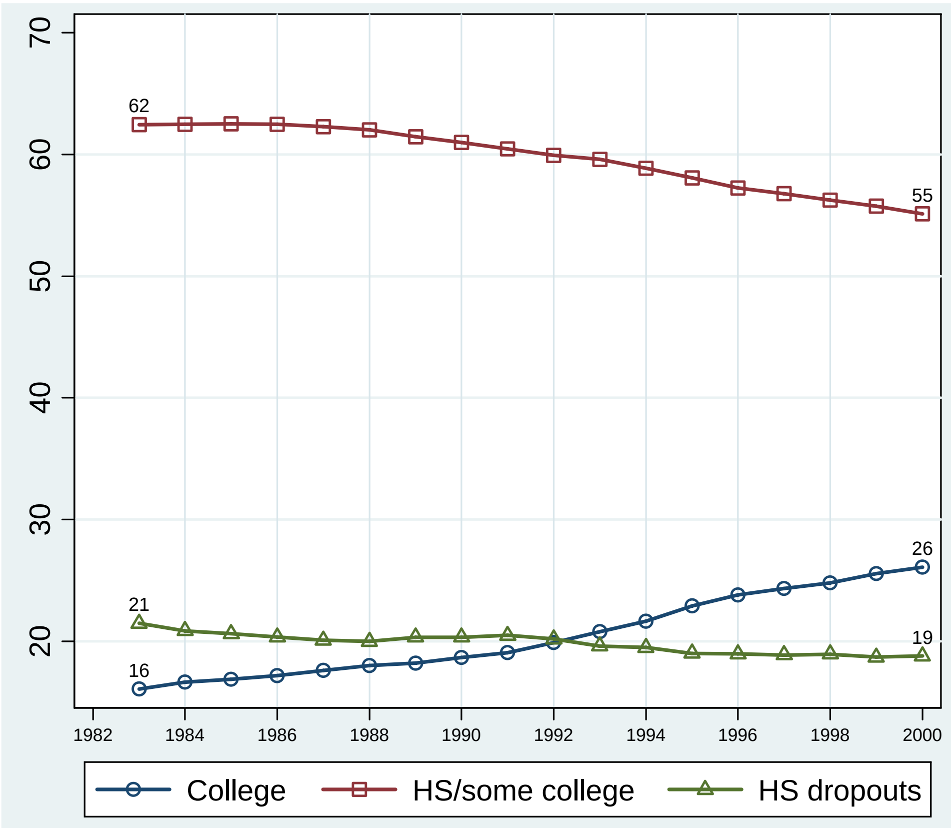
Notes: Data are from U.S. Vital Statistics, 1983 to 2000. Figures 5a and 5b plot the conditional expectation of low Apgar scores and infant death rates as a function of time by maternal education. The gradient has decreased in terms of low Apgar score and has stayed constant in terms of infant death rates.

Figure 6: Predicted Low Apgar Score with Different Sets of Control Variables



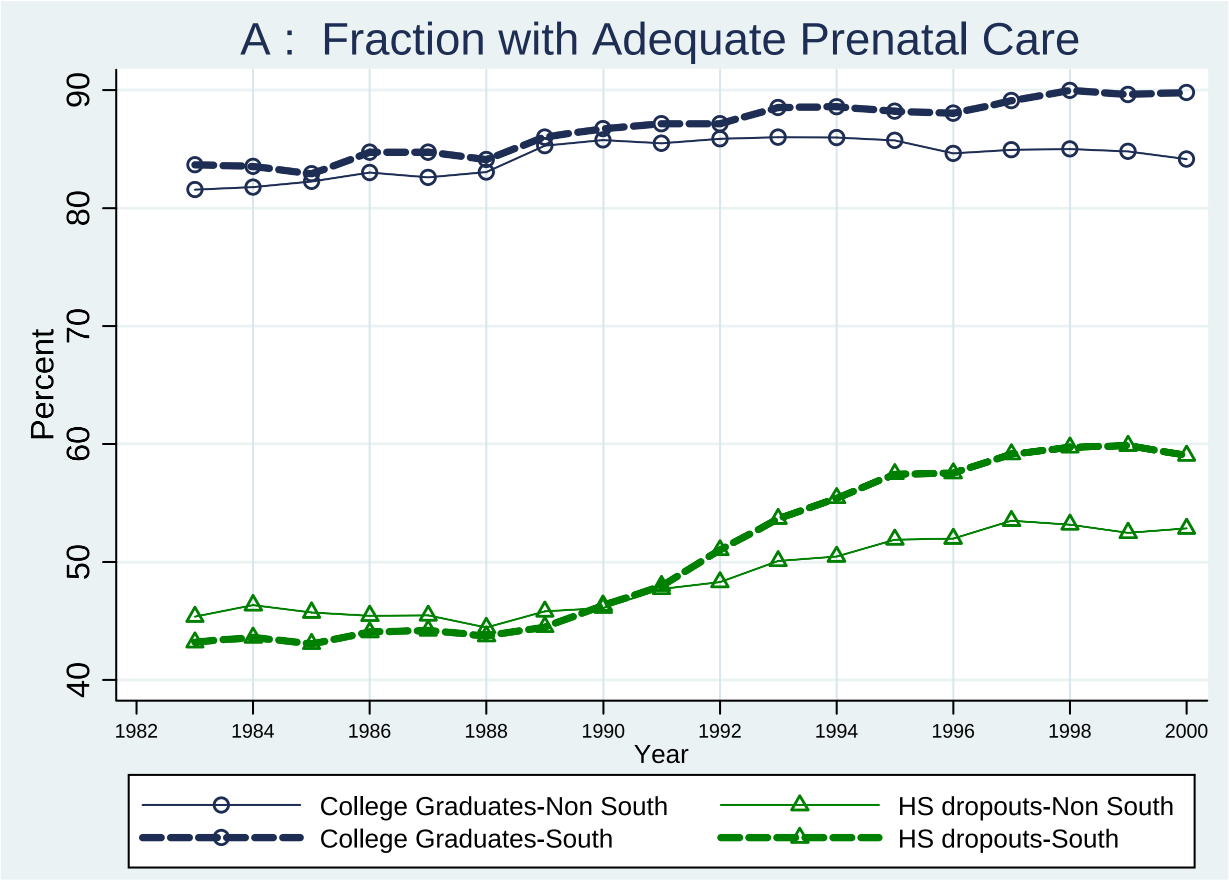
Notes: Data are from U.S. Vital Statistics, 1983 to 2000. This graph shows that when each additional set of control variable is added in the gap decreases. It plots the conditional expectation of low Apgar score for high and low education groups controlling for different sets of covariates according to the hypotheses discussed in the text. The top four lines are for high education groups while the bottom four lines are for low education groups. The solid line is the unconditional expectation, which for comparison, is the same as in Figure 5a. The dashed line is the conditional expectation controlling for demographic variables. The dotted line is the conditional expectation when I control for both demographic variables and access to medical care. The dotted-dashed line is the conditional expectation controlling for all three sets of variables.

Figure 7: Fraction of Infants Born to Mothers of Different Education Groups over Time



Notes: Data are from U.S. Vital Statistics, 1983 to 2000. The line with circles represents the fraction of infants born to college graduate mothers. The line with triangles represents the fraction of infants born to mothers who have high school diplomas or some college. The line with squares represents the fraction of mothers who are high school dropouts. This graph illustrates that due to the general increase in education level over time, the fraction of babies born to the high education group has been increasing while the fraction of babies born to low education group has been decreasing.

Figure 8: Access to Medical Care by Maternal Education and <u>by Region</u>



Notes: Data are from U.S. Vital Statistics, 1983 to 2000. This graph shows that after 1990, the low education group in the South had more adequate prenatal care than their non-South counterpart. The timing of the increase of prenatal care coincides with the rapid Medicaid expansion in the late 80s and early 90s.