DOCUMENTING AND EXPLAINING BIRTHWEIGHT

TRENDS IN THE UNITED STATES, 1989-2007

by

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Documenting and Explaining Birthweight Trends in the United States, 1989-2007

Abstract: Birthweight at either the low or high end of the distribution is associated with adverse health outcomes in later life. This study uses US vital statistics data from 1989 to 2007 to document recent birthweight trends in the US and examines the possible causes behind the trends. Results are reported for all births and by maternal race/ethnicity/nativity. The trend of lower birthweight across the last 18 years is reflected in all birthweight measures: the low-birthweight rate is rising, mean birthweight is declining, and the proportion of macrosomic infants is decreasing. While this trend is most pronounced among US-born non-Hispanic whites and is least pronounced among non-Hispanic blacks, it is common to all race/ethnicity/nativity groups. Regression results suggest that much of the birthweight trend can be explained by shortened gestational age across the time period, but common maternal socio-demographic, health and behavioral, and health care and medical intervention factors cannot fully explain the birthweight trend.

INTRODUCTION

Important trends in birthweight have been observed in the United States over the last two decades. After a continuous rise in mean birthweight and a decrease in the proportion of infants born with low birthweight (<2500 grams [g]) before the late 1980s, more recently the distribution of birthweight began to shift toward the lower end. At the national level (Martin et al. 2009), the percent of singleton babies born with low birthweight was 6.49% in 2006 as compared to 5.9% in 1990. Mean birthweight was 3,298 grams in 2006, 67 grams lower than the 1990 level, The proportion of babies on the lower end of the birthweight spectrum (birthweight less than 3,500 grams) is on the rise whereas the proportion for those on the heavier end is declining.

These trends are of special concern because birthweight is considered to be a major health indicator for newborns. Studies have found that the relationship between birthweight and infant mortality follows a U-shaped pattern, with infants weighing between 3,250g to 4,000g having the lowest risk for infant mortality (Wilcox and Russell 1983; Solis et al. 2000) or perinatal mortality (Samaras et al. 2003). Thus, birthweight on either side of the spectrum is unfavorable. Infants born with low birthweight are much more likely to die before their first birthdays and are associated with adverse health outcomes in later years of life (Cramer 1987; Frisbie et al. 1996; Hack et al. 1995). Babies born with heavier birthweight, on the other hand, are at higher risk for overweight and obesity in childhood and adult life (Rogers 2003). A positive and statistically significant increased risk for adult cancer was also found with increasing birthweight

(Anderson et al. 2001). Therefore, the shift toward a lighter birthweight distribution may ease our worries about the increase of heavy birthweight babies that have occurred in other countries, while the increase in low birthweight babies, and more importantly, the decrease in the proportion of babies born with the most favorable birthweight (3,000g to 4,000g) should be monitored and the reasons behind it need to be studied.

Birthweight trends in the US are further intriguing because they have gone in a different direction in some European countries and Canada. Sweden saw an increase in mean birthweight and the proportion of babies born with birthweight over 4,500g, and the risk for large-for-gestational-age (LGA) birth increased by 23% between 1992 and 2001 (Surkan et al. 2004). In Berlin, mean birthweight remained constant between 1993 and 1999. However, the rates for birthweight over 4,000g rose from 9.1% to 10.1% (Bergmann 2003). In Norway, birthweight of term babies increased for all gestational weeks between 1967 and 1998. In Scotland, England and Wales, the percentage of babies born with heavier birthweight (>3500g) has been increasing at an annual rate of between 0.35% and 0.40% since 1983 (Power 1994).

Because of the link of low birthweight to infant mortality and unfavorable health outcomes, reducing the rate of low-birthweight infants (to 5.9% by 2010) was one of the US objectives of Healthy People 2010 (http://www.healthypeople.gov/data/midcourse/html/focusareas/FA16Objectives.htm. Accessed 18 April 2010). Recent trends in birthweight as discussed above, however, suggest that we are diverging away from that goal. Thus, a study on the causes and

implications of these trends is important and necessary in our attempt to improve maternal, infant, and child health in the United States.

Thus the aims of the study are: 1) to thoroughly describe temporal trends in birthweight in the United States between 1989 and 2007; 2) to determine whether the recent birthweight trends can be explained by changes in social and demographic, health and behavioral, and health care and medical factors; 3) to examine whether the effect of the above factors on the birthweight trends vary across race/ethnic groups.

BACKGROUND

A notable trend in recent years is a sharp increase in the rates for twins and higher-order births that began in the 1980s and has continued to date. In 2005, the rate for twin births was 32.2 per one thousand live births and the rate for triplets and higher order multiples was 161.8 per 100,000 live births, a 70% increase in all multiple births as compared to 1980 (Martin et al. 2007). Twin and other multiple births run a much higher risk of low birthweight than singleton births. In 1995-1997, 53.6% of the twin births and 93.2 of the triplets or higher order births were born under 2,500g (Blondel et al. 2002). The increase in the number of multiple births has undoubtedly contributed to the lowering birthweight trend but since multiple births account for only a very small proportion of all live births, they are unlikely to be the single cause for recent birthweight trend. Furthermore, the lowering birthweight trend is observed when only singleton births are examined. Because singleton births account for more than 96% of all births, they are the focus of the current study.

HISTORIC AND RECENT BIRTHWIGHT TRENDS AMONG SINGLETON BIRTHS

The mid and the late 20th century saw a general trend of increase in birthweight among singleton babies in the United States. Between 1960 and 1980, for example, the low birthweight rate declined from 6.82 to 5.96 percent for all singleton births. Meanwhile, those born with birthweight over 4,500g increased from 1.58 to 1.87 percent. In fact, the proportion of babies in all the categories under 2,500g decreased while those above 3,500 increased during the same period (Kessel et al. 1984; Buehler et al. 1987). As reported by the US Centers for Disease Control and Prevention (CDC) in its low birthweight trend table (www.cdc.gov/nchs/hus/updatedtables.htm. Accessed 18 April 2010), the percentage of live births under 2,500g dropped almost every year during the 1970s and 1980s, from 7.93 percent in 1970 to 6.93 in 1988. Since the end of the 1980s, however, the trend for birthweight changed direction. Most of the years in the 1990s and 2000s saw an increase in the rate of low birthweight. As a result, the percentage of low birthweight increased from 7.12 in 1991 to 7.57 in 2000 and continued to rise to 8.26 in 2006. The shift toward a lower birthweight distribution is also reflected among the normal birthweight groups. Of all babies born with birthweight greater than 2,500g, 42.9% had birthweight over 3,500g in 1991, but this number dropped to 41.8% in 2000 and even further to 37.5% in 2006 (Centers for Disease Control and Prevention http://www.cdc.gov/nchs/vitalstats.htm. Accessed 18 April 2010).

BIRTHWEIGHT PREDICTORS

To understand recent birthweight trends in the US, this study looks into the birthweight predictors identified by existing literature and examines whether their changes are the source for the lowering birthweight trends.

As a health indicator, birthweight is often seen as the outcome of a host of inter-relating social and biological factors. Over the years, researchers from different disciplines have identified many of these factors that impact birthweight (reviewed below). The trend in birthweight distribution is a function of changes in these factors and the changes in the way these factors affect birthweight over time. For the purpose of organization and discussion, this study groups the predictors into maternal socio-demographic factors, maternal behavioral and health factors, and health care and medical intervention factors. The factors reviewed here are not fully exhaustive but relevant to this study. Moreover, the categories they are divided into are "overlapping" (Frisbie 2006: 252) and could be grouped differently.

Maternal Socio-economic and Demographic Factors

Race/ethnicity (discussed in a separate section below), nativity, maternal age, education, marital status, income, and birth order are among the most common socioeconomic and demographic factors associated with birthweight (Institute of Medicine 1985; Cramer 1987).

Age of mother at birth is one of the most important factors related to infant birthweight. Teenage mothers and mothers over 35 are more likely to give birth to infants

with low birthweight (Ventura et al. 2001; Cnattingius et al. 1992). On the other hand, mothers over 35 are also more likely to give birth to macrosomic infants (Frank et al. 2000; Boulet et al. 2003). During the last several decades, the age distribution of mothers giving births in the United States has grown older. The mean age of new mothers rose from 24.6 in 1970 to 27.2 in 2000 and the percentage of births among teenage mothers declined, whereas the percentage among mothers 35 years or older increased (Mathews and Hamilton 2002; Martin et al. 2007). Young et al. (2006) found that both the changes in mother's age distribution and in age-parity specific birthweight have contributed to the increase of low-birthweight rates from 1980 to 2000. (Young et al. 2006).

Women with low education, low income and those who are not married are far more likely to give birth to infants of low birthweight (Institute of Medicine 1985; Cramer 1995), although being married is also associated with a higher risk for macrosomic infants. In the past few decades, educational attainment has increased substantially among women who gave birth. This trend in and of itself should lead to increases, instead of decreases, in birthweight. The trend of marital status, however, has been a counter driving force for birthweight. In 1980, only 18.4% of all births occurred to unmarried women, but in 2000, this percentage more than doubled to 38.5% (Martin et al. 2009).

Maternal Behavioral and Health Factors

Maternal weight gain, maternal pre-pregnancy weight, maternal height and weight, pregnancy history, inter-pregnancy interval, maternal morbidity, cigarette smoking, and

alcohol and other drug consumption are some of the behavioral and health factors associated with birthweight. In the past few decades in the United States, the prevalence of obesity doubled among women age over 20. It rose even more for the primary fertility age groups, that is, those between 20 and 39, from 12.3% in 1976-1980 to 28.4% in 1990-2000 (Flegal 2002). Since pre-pregnancy weight is positively associated with birthweight (Frederick et al. 2008) and heavy birthweight, in turn, is a risk factor for higher BMI and obesity in later life (Rogers et al. 2003), some speculate the root for the obesity epidemic in the United States lies in the increased maternal body size and birth size (Samaras et al. 2005). However, this hypothesis does not seem to be valid, given the recent downward trend of the birthweight distribution in the United States.

Maternal weight gain is another important and closely related but independent factor that is positively associated with birthweight (Rogers et al. 2003). It also interacts with maternal pre-pregnancy weight to affect birthweight (Dietz et al. 2006). The latest guideline put forward by the Institute of Medicine (IOM) recommended different ranges of weight gain based on pre-pregnancy Body Mass Index (BMI). The range for normal weight women is between 25 to 35 pounds. It is higher for women with lower BMI and lower for women who are overweight or obese (Rasmussen and Yaktine 2009). Data from birth certificate records suggest, however, that the percentage of women with weight gain out of the recommended range on both sides has increased sharply during the past two decades (Martin et al. 2009). Other factors being equal, this would have increased both the percentage of low birthweight and macrosomic babies.

Smoking and heavy drinking during pregnancy are both risk factors for low birthweight. Women who smoke are twice as likely as non-smokers and those who drink heavily are three times as likely as those who do not drink during pregnancy to have low birthweight infants (Chomitz et al. 1995). According to a CDC report, prevalence of binge drinking among pregnant women in the US was basically unchanged from 1991 to 2005 (Denny et al. 2009). A study based on data from ten states revealed that smoking before pregnancy remain unchanged, although quitting during pregnancy rose from 37% to 46% from 1993 to 1999 (Colman and Joyce 2003). If this trend reflects the overall trend of the nation, it would have driven the birthweight distribution upward.

Health Care and Medical Factors

Improvements in health care and advances in medical technology before and during child birth have brought about positive changes in the survival of newborns (Gortmaker & Wise 1997). However, the effectiveness of prenatal care and obstetrical procedures in preventing low birthweight is not as clear (Alexander and Korenbrot 1995; Ricciotti et al. 1995).

The most noticeable trend in terms of medical intervention in the process of child birth is the sharp rise in the use of obstetric procedures to induce labor and in the rate of cesarean surgeries among all deliveries. The year 2006 saw the highest level of total cesarean delivery than any previous years in the United States. Almost one in three deliveries involved a cesarean surgery, as compared to one in four or five in the 1990s

(Martin et al. 2009). The increase in the rate of induction of labor among all births is also stunning. It has more than doubled since 1990, rising from 9.5% to 22.5% in 2006.

The increasing trends in induced labor, cesarean sections and other medical interventions have contributed to the shift toward earlier gestations, which in turn, impacted the downward trends in birthweight (Davidoff et al. 2006). In analyzing the impact of cesarean section on gestational age among singleton births, Bettegowda et al. (2008) found that singleton preterm birth rates increased from 9.7% in 1996 to 10.7% in 2004 and among preterm births, the percentage delivered vaginally decreased while the proportion delivered by cesarean increased. They thus concluded that the increase in preterm births is likely due to the increase in cesarean deliveries. They also reported that the rates of induced labor and cesarean sections increased for births at all gestational ages.

RACIAL/ETHNIC DIFFERENCES IN BIRTHWEIGHT TRENDS

Racial/ethnic differences in birthweight, especially those between black and white infants, have long been documented and have never disappeared in the United States, despite the effort made and programs designed to eliminate them (Stevens and Orleans 1999). A great amount of research has also been done in explaining racial/ethnic disparities, but no studies so far have been able to explain birthweight differences between black and white infants. However, researchers have identified a range of contributing factors and developed conceptual models to study racial/ethnic disparities in mortality and health (Mosley and Chen 1984; Hummer 1996) in general and infant mortality and health outcomes specifically (Wise 2003). These models serve as a general

framework in defining the causes behind differential birthweight trends among the major race/ethnic groups. It is beyond the scope of this paper to discuss all aspects of birthweight disparities, but a few highlights of the major predictors and their changes seen in recent years should shed light on our understanding of the differential racial/ethnic trends in birthweight.

Perhaps the most important contributors to the black-white difference are the social and economic disadvantages of the black population. These disadvantages exist at the very beginning of life. Compared to their white counterparts, black infants are more likely to be born to women between 15-19 years of age, to unmarried women and to women who do not have high school diplomas. These risk factors place blacks at higher risk for low birthweight. While these remain true, important changes in the social and demographic characteristics have taken place among white and black mothers. For example, birth rates of unmarried women age 15 to 44 dropped from 90.5 to 71.5 for blacks but rose from 24.4% to 32% for non-Hispanic whites between 1990 and 2006.

Health care and medical interventions have been viewed as intervening factors that can mediate the pathways of social influences on health outcomes. Large disparities exist in prenatal care receipt, despite improvement for all race/ethnic groups. For example, Non-Hispanic blacks are more than twice as likely as non-Hispanic white women to receive late or no care (Martin et al. 2009).

One important trend in recent years is the increasing use of medical services before, during and after child birth. And the role of medical interventions in their effect

on maternal and infant health has never been more controversial. Although utilization of these services has increased among all race/ethnic groups, white women lead in most cases. For example, the 2006 induction rate among non-Hispanic white mothers was 26.9%, compared to 19.8% among non-Hispanic black mothers (Martin et al. 2009). The role of these new trends in medical services on birthweight disparities is not clear.

The discussion on disparities, or rather, the surprising lack of disparities in birthweight between whites and Hispanics, especially foreign-born Hispanics, has revolved around the concept of "Hispanic Paradox". However, little is known about trends in birthweight among Hispanics, and particularly so for births to foreign-born Hispanic and US-born Hispanic women. This study examines the extent to which recent trends in maternal characteristics have affected birthweight among race/ethnicity/nativity groups, including among both foreign-born and U.S.-born Hispanic women.

In sum, while improvements in educational attainment and reductions in smoking and heavy drinking will generally shift the birthweight distribution upward, increases in non-marital births, higher rates of induced labor, and higher rates of cesarean deliveries are expected to move the distribution in the opposite direction. On the other hand, the shift toward older age at childbearing and pregnancy weight gain out of the optimal range are likely to increase both the proportions of low-birthweight and macrosomic infants.

Accompanied by a decreasing trend in birthweight for all infants, there are signs that black-white differences in birthweight are decreasing in recent years. But this decreasing disparity is not due so much to the improvement of birthweight among blacks,

but rather the increase of low birthweight among whites. This is likely the results of such factors as older age of childbearing, the rise in non-marital births and increased utilization of medical services, such as induced labor and cesarean deliveries, especially among white women.

Given these trends, this study aims to both comprehensively document birthweight trends and, through careful statistical analyses, understand how changes in social and demographic, health and behavioral, and healthcare and medical factors have impacted birthweight trends as well as race/ethnic differences in those trends.

DATA AND METHODS

Public use birth micro data for the US from 1989 through 2007 from the National Center for Health Statistics at the Centers for Disease Control and Prevention are used for the analyses. The data contain all live birth records occurring in the United States to U.S. residents or non-residents; births in Puerto Rico and other US territories are excluded from current analyses. The standard U.S. birth certificate was revised in 2003 and as a result, some of the items are not comparable before and after the revision. For the purposes of this study, only items unchanged or comparable are used as variables in the analyses. About 4,000,000 births occurred each year in the US during the period from 1989 to 2007 and the full data contain 72,623,416 births.

To provide a comprehensive picture of birthweight trends in the United States between 1989 and 2007, descriptive analyses are used to document the trends in birthweight for all births and by race/ethnicity/nativity. Birthweight trends are depicted in

graphs and variable descriptions are provided in tables. Regression analyses using individual level data are conducted on various birthweight measures, more specifically, continuous birthweight in grams, low birthweight, very low birthweight, SGA and LGA, although only results on mean birthweight are reported given substantial consistency across outcomes.

Birthweight is the outcome variable in this study. The authors examined trends of multiple birthweight measures, including mean birthweight, low birthweight (BW less than 2,500g) rate, very low birthweight (BW less than 2,500 g) rate, rate of small-gestational-age babies, rate of large-for-gestational-age babies and rate of macrosomic infants (BW more than 4,500 g). In addition, proportions of babies born in the middle of the birthweight range were also calculated, including those between 2,500g and 3,499g, and those between 3,500g and 4,499g. The trends of all the measures are consistent with a lowering birthweight trend. Thus only the results of three measures are reported here, that is, mean birthweight, low birthweight rate and rate of macrosomic infants.

Three groups of predictor variables are included in the regression analyses. First, socioeconomic and demographic factors include mother's nativity, race/ethnicity, education, age, birth order, and marital status. Mother's nativity is categorized as "US-born" and "foreign-born". The mother whose origin is Hispanic is grouped into "Mexican" and "Other Hispanics". Non-Hispanic mothers are categorized into "black", "American Indians and Asian-Pacific Islander", "white" and a residual group "other". Second, maternal health and behavior factors include weight gain, tobacco use, diabetes and hypertension. Third, health care and medical intervention variables include prenatal care,

induction of labor, cesarean section, and gestational age. The Kotelchuck Index (Kotelchuck 1994) of prenatal care utilization is calculated and used to measure adequacy of prenatal care. The detailed definitions of all the variables are available upon request.

DESCRIBING BIRTHWEIGHT TRENDS IN THE U.S., 1989-2007

In this section, trends in birthweight in the US from 1989 to 2007 for all births and for major race/ethnic/nativity groups are reported. Birth records that have missing values on birthweight, gestational age, race/ethnicity/nativity are deleted. A total of 2.6 percent of all births over the years are deleted as a result.

From 1989 to 2007, the total number of births has remained relatively constant, fluctuating around 4,000,000 each year. However, the composition of mothers by nativity has changed. Births to US-born mothers have decreased steadily while births to foreign-born mothers have been on a constant rise. As a result, the number of births to foreign-born mothers climbed to 1,076,613 in 2007 and comprises 24.9% of total births in 2007, as compared to 585,855 in number and 14.5% of total births in 1989. While the biggest birth groups is the non-Hispanic whites, the biggest contributor to the increasing trend among births to foreign-born mothers is foreign-born Mexicans. With more than 450,000 births in 2007, they accounted for more than 40% of births to foreign-born mothers.

Figure 1 shows mean birthweight for singletons by race/ethnicity and nativity in the US from 1989 to 2007. A clear trend of decreasing birthweight can be observed across almost all groups. To facilitate understanding and comparison of these trends,

especially in regard to the magnitude, a linear trend equation is estimated and added alongside each of the observed birthweight trend lines in the graphs.

At an annual rate of 4.4 grams of decrease, US-born white mothers lead the trend for birthweight decline. Both US-born and foreign-born blacks, on the other hand, experienced the slowest decrease. In fact, birthweight for both groups remained pretty constant or even slightly increased until 2000, before seeing a drop in more recent years. Despite these trends, infants born to US-born blacks continue to have by far the lowest mean birthweight in 2007 (3,082g). At the same time, foreign-born and US-born white women continue to have the highest mean birthweight (3,375g and 3,355g, respectively).

Figure 1 also suggests that the decreasing birthweight trends are more pronounced among births to US-born mothers than births to foreign-born mothers. For example, mean birthweight for infants of US-born Asian and Pacific Islander (API) mothers was 3,283 grams in 1989 but dropped to 3,221 grams in 2007, an average decline of 3.5 grams per year. The decreasing rate of mean birthweight for infants of foreign-born API mothers has been much slower, at 2.5 grams per year.

Figure 2 shows trends in low birthweight rates for singletons by race/ethnicity/nativity. Consistent with the trends observed for decreasing mean birthweight, the low birthweight rate has risen among births to almost all groups of US-born and foreign-born mothers. The rising trends for the low birthweight rate are more pronounced among births to US-born mothers than births to foreign-born mothers. For example, low birthweight rates have been rising at 0.58, 0.39 and 0.33 per one thousand

on average each year for US-born APIs, US-born whites and US-born Mexicans, respectively. Increases have been slower for their foreign-born counterparts, at 0.41 per thousand for foreign-born APIs, 0.08 per thousand for foreign-born whites and 0.33 per thousand each year for foreign-born Mexicans. Despite these changes, in 2007, the highest rate of low birthweight continues to be among births to US-born black women, at 95.7 per thousand and the lowest among births to foreign-born white and foreign-born Mexican mothers, at 36.5 and 40.6 per thousand, respectively.

Contrary to the increasing trend of infants born with lower birthweight, the proportion of Infants with higher birthweight has been decreasing. Figure 3 plots the trends of change in the rates of singletons born at 4, 500 grams or higher for births to US-born mothers and to foreign-born mothers, by race/ethnicity/nativity. Almost all the race/ethnic/nativity groups have seen a drop in the proportion of heavy birthweight infants. This trend is most pronounced among singletons born to US-born white mothers; about 20 out of 1,000 singletons to US-born white mothers had birthweight of 4,500 grams or higher in 1989, but that rate dropped to 12 in 2007. The group that has the slowest decrease are infants born to US-born black mothers, although they still have the fewest births on the heaviest end in 2007 (5 per thousand). Decreases in births greater than 4,500 grams have also occurred among most groups of foreign-born mothers as well.

In sum, birthweight distribution in the US has shifted to the lower end between 1989 and 2007. This shift is reflected in all the measures examined. This decreasing trend is not shared equally between infants born to US-born and foreign-born mothers. Mostly, singletons born to US-born white mothers have been leading the trend, being the largest

group with regard to total number of births and experiencing the fastest change in birthweight and gestational age over the years. On the other hand, infants of US-born black mothers often saw the least change during this period, although they remain the group with the lowest mean birthweight and the highest low birthweight rate.

The birthweight trends discussed here, both overall and by race/ethnicity/nativity, are complex and interesting, particularly in the context of rapid decreases in infant mortality in recent years (MacDorman and Mathews 2008). The descriptive results presented here, while important in and of themselves, set the stage and provide insights into the analyses for the next section, which explores reasons behind the recent birthweight trends in the US.

EXPLAINING TRENDS IN U.S. BIRTHWEIGHT 1989-2007

In this section, we analyze U.S. trends in birthweight in relation to trends in maternal socioeconomic and demographic factors, behavioral and health factors, and health care and medical factors. Only four major race/ethnicity/nativity groups are included, namely, US-born non-Hispanic white mothers, US-born non-Hispanic black mothers, US-born Mexican Origin mothers and foreign-born Mexican Origin mothers. Births among the four groups account for the majority (about 85%) of total births in the US during 1989-2007. The exclusion of births among the rest of the race/ethnic/nativity groups is unlikely to have a major effect on the results due to their small proportion. On the other hand, focusing on the major groups greatly simplifies the analyses and the

interpretation because of the size of the groups and the relative homogeneity among mothers within each group.

CHANGES IN PREDICTOR VARIABLES BETWEEN 1989 AND 2007

Table 1 compares the characteristics of infants/mothers in 1989 and 2007. All data, including those with missing values, are used to calculate the percentages. In general, the percentage of missing values is lower in 2007 than in 1989 and, for many variables, foreign-born Mexicans have the most missing values and US-born NH whites have the fewest among the four groups. Both the years of 1989 and 2007 have good data on mothers' socioeconomic and demographic characteristics, with relatively few missing values. Data on tobacco use and weight gain, however, are problematic, especially in 1989 and for the foreign-born Mexican mothers. About 70% of the data for foreign-born Mexicans and 27% for all mothers in 1989 on these two variables are missing. One reason for the high number of missing values is that questions on tobacco use and weight gain were not on the U.S. birth certificate in 1989 in some states, or some parts of the states, including New York, California and Texas. This is also part of the reason for relatively high missing values for maternal health factors and medical factors, although the percentage missing is at a much reduced level for maternal hypertension and diabetes, prenatal care, induction and cesarean variables in 2007 compared to 1989.

There was very little change in infants' sex and the birth order composition between 1989 and 2007. Mother's mean age at birth, on the other hand, increased from 1989 to 2007. Proportions of mothers both under 17 and between 17 and 34 years of age

have decreased, while the proportion of mothers 35 and older increased from 8% to almost 13% over the time period. To capture the interaction between mother's age and birth order, the parity variable is constructed. Third or higher order births to women under 25 years of age or fourth or higher order births to women under 30 are defined as high parity. First births to women 30 and older are put in a separate category and all the other births are defined as low parity. From 1989 to 2007, there was a slight decrease in high parity births and a relatively larger increase in women having a first birth at ages 35 and above. As a result, the percentage of low parity births decreased between 1989 and 2007.

Women's education greatly improved over the years. The percentage of mothers who have less than 12 years of schooling dropped for all race/ethnicity/nativity groups, although the overall percentage has actually increased slightly due to the rapid increase in the composition of foreign-born Mexican mothers, who have by far the highest percentage in this category (still as high as 61.8% in 2007).

In 2007, infants are more likely to be born to unmarried mothers compared to 1989. Non-marital births comprised about 40% of all births in 2007, as compared to just 26.6% in 1989. Non-marital births were also much more common among blacks (71.6%) than among whites (24.4%) in 2007, with the Mexican Origin groups falling in-between.

Three behavioral and health factors are included in the analysis: weight gain, tobacco use and a variable indicating that women suffered from either diabetes or hypertension during pregnancy. Fewer women gained 25-35 pounds during pregnancy in

2007 than in 1989; the percentage decreased from 43% to 35.1%. This is the result mainly of a rise in the percentage of women who have gained 35 pounds or more during pregnancy and to a lesser extent, an increase in women gaining less than 25 pounds. These trends, however, are less pronounced among foreign-born Mexican mothers than the other three race/ethnicity/nativity groups. Diabetes and hypertension (both gestational and chronic) are combined as one variable due to their close connection to each other. Mothers diagnosed with neither diabetes or hypertension have decreased (from 94.2 to 91.4) while those with either or both of the conditions increased between 1989 and 2007.

The prenatal care, induction, and cesarean variables constitute the health care and medical factors in the analysis. The Kotelchuck Index (Kotelchuck 1994) of prenatal care utilization is calculated and used to measure adequacy of prenatal care. While the percentage of women with inadequate and intermediate care dropped between 1989 and 2007 for all women and for each of the race/ethnicity/nativity groups, the percentage of mothers with adequate prenatal care increased for all groups except for non-Hispanic white mothers. A notable trend is that the percentage of mothers with more than adequate prenatal care increased for all groups. The induction rate more than doubled from 1989 to 2007, and now constitutes more than 20% of all deliveries for all groups except foreign-born Mexican women. Finally, the cesarean rate increased by almost 8 percentage points between 1989 and 2007. As of 2007, 30% of all deliveries were by cesarean section, with the rate highest for black women (31.8%) and the lowest rate among foreign-born Mexican women (27.7%).

REGRESSION MODELS ON CONTINUOUS BIRTHWEIGHT TRENDS FROM 1989-2007

Table 2 reports the results of the OLS regression models on continuous birthweight for all infants. Model 1 is the base model, in which the only predictors are sex of infant and the year variable depicting trends. Race variables are added in Model 2. Mothers' socioeconomic and demographic, behavioral and health, and health care and medical factors are then added in blocks in Model 3 through Model 5. Model 6 is the final model, in which gestational age is added in addition to all the variables in the previous models.

Model 1 suggests that controlling for infant's sex, birthweight dropped by an average of 3.73 grams every year from 1989 to 2007. In Model 2, race of the mother is added. It has been well documented that infants born to non-Hispanic black mothers have a much higher low-birthweight rate than non-Hispanic white mothers. Yet it is still striking that their birthweight is on average 290 grams lower than non-Hispanic whites over the past two decades. Controlling for race, however, does not change the direction or reduce the magnitude of the yearly trends. In fact, the trend variable increases slightly from 3.73 in Model 1 to 3.80 in Model 2.

In Model 3, socioeconomic and demographic variables including age, birth order, parity, education and marital status are added. The results are generally consistent with previous studies. Infants born to women age 25 to 34 have higher birthweight than those born to younger or older mothers. First-born children are lighter than second or higher order birth and high parity results in lower birthweight than low parity. Infants born to

mothers without high school degrees have the lowest birthweight and in fact, the higher the mother's education, the heavier the infant's birthweight. Births to married mothers are heavier than those to unmarried mothers. But again, controlling for these socioeconomic and demographic variables does not change the direction or reduce the magnitude of the overall birthweight trend. In fact, the trend becomes more pronounced in Model 3, with the absolute value increasing from 3.8 from the previous model to 4.22 in Model 3. This indicates that had socioeconomic and demographic variables stayed the same during the past two decades, birthweight would have been even lower in 2007 than observed.

Mothers' health and behavioral factors are added in Model 4. As expected, infants born to mothers with diabetes but not hypertension have the highest birthweight while those born to mothers with hypertension only have the lowest birthweight, about 238 grams lower than mothers who have neither diabetes nor hypertension. The higher the weight gain of mothers during pregnancy, the higher the infant's birthweight. And infants born to mothers who smoke during pregnancy weigh 217 grams less, on average, than those of mothers who do not smoke. However, the addition of the health and behavioral variables in the model still does not explain the lowering birthweight trend. Indeed, the trend becomes even more pronounced in Model 4, at -4.7 grams per year.

Model 5 adds health and medical intervention variables, including prenatal care, induction and cesarean section. Net of the socioeconomic and demographic, and health and behavioral factors included in the model, infants of mothers who receive more than adequate care have the lowest birthweight, 187 grams lower than those whose mothers receive adequate care. Infants of mothers who experience induction or Cesarean section

are on average heavier. The inclusion of medical and health care factors in Model 5 only bring down the birthweight trend by a fraction: it decreases from -4.7 in Model 4 to -4.5 in Model 5, indicating that changes in health care and medical variables do not contribute much to the lowering birthweight trend.

Finally, Model 6 includes all the variables, including gestational age. A week's increase in gestational age is associated with a 112 grams increase in birthweight. As the most proximate predictor of birthweight, the trend in shortening gestational age clearly plays an important role in explaining trends in birthweight. Controlling for gestational age, as well as the variables included in previous models, birthweight decreases at an average of 1.57 grams per year in the final model. Thus, reduced gestational age between 1989 and 2007 accounts for a large share of the overall reduction in birth weight across this time period.

Tables 3 reports the OLS regression results of birthweight for NH whites, NH blacks, US-born Mexicans and foreign-born Mexicans, respectively. In general, the associations of the mothers' various characteristics with mean birthweight are similar to the overall model, except that the magnitudes are a bit different. Therefore, only the results for the year trend variable are shown for each race/ethnicity/nativity group to examine the impact of the three groups of variables on birthweight trend.

Consistent with the descriptive analyses shown earlier, all four race groups experienced a birthweight decrease from 1989 to 2007, as suggested by the negative coefficient for the year trend variable in the base models. The trend is most pronounced

among NH whites, with an average of a 4.4 gram drop each year, and least among NH blacks, with an average 1.8 gram decline per year. There are also some differences across race groups when it comes to the role of different variables in explaining the lowering birthweight trends. Models for NH whites and US-born Mexicans are most similar to the overall model: socioeconomic and demographic, and health and behavioral factors not only fail to explain the birthweight trends but their addition make the trends more pronounced in the models. Medical and health factors also play a very limited role in explaining birthweight trends. For NH blacks, none of the three groups of mothers' characteristics explain the trends in birthweight. Had the maternal characteristics stayed the same, birthweight would have been even lower for NH blacks in 2007. Models for foreign-born Mexicans are the most different from the rest of the race/ethnic groups. While the inclusion of socioeconomic and demographic variables does increase the absolute value of the trend variable, the introduction of health and behavioral, and medical and health care variables help to explain away some of the lowering birthweight trend. After controlling for all the mothers' characteristics, the year coefficient changes from -3.26 in the base model to -2.7 in Model 4. Finally, in the models for all the race/ethnicity/nativity groups, gestational age plays the most important role. And in the final models, birthweight drops by 1.2 (US-born Mexicans) to 1.7 grams (for foreign-born Mexicans) per year after including all the variables included in the analyses.

Clearly, then, lower average gestational ages for all race/ethnic/nativity groups in 2007 compared to 1989 is the most prominent factor responsible for reductions in mean birthweight for all groups over this time period.

CONCLUSIONS

From 1989 to 2007, the birthweight distribution shifted toward the lower end of the distribution in the U.S. The proportion of low-birthweight infants (less than 2,500g) increased while the proportion of heavier-birthweight infants decreased (more than 4,500 g), and there has been a slow but steady decrease in mean birthweight. This study documents the birthweight trends for all births and by race/ethnicity/nativity. We also examine the possible reasons behind these trends. Although the increase of multiple births may have contributed to the decreasing birthweight trend, this study focuses on singleton births because they are the vast majority and account for more than 96% of all births in 2007.

The decreasing birthweight trends occurred to all race/ethnicity/nativity groups, although the extent of change varies. In general, foreign-born mothers have experienced a much lower rate of change. In fact, the lowering birthweight trends would have been more pronounced had there not been a steady increase in births to foreign-born mothers. US-born white mothers lead the decreasing birthweight trends on all measures. This deserves our special research attention not only because US-born white mothers have the most births but they have also been the group that has more favorable birthweight, especially compared to black mothers. The group with the least change between 1989 and 2007 is US-born black mothers, although they still have by far the lowest mean birthweight, the highest low-birthweight and very-low-birthweight rates.

Previous literature suggests that birthweight outcomes are affected by a set of maternal social and biological factors. This study examines three groups of determinants for birthweight, namely, maternal socio-demographic factors, maternal behavioral and health factors, and health care and medical intervention factors. Regression analyses suggest that changes in the maternal characteristics cannot fully explain the lowering birthweight trend, although part of the trend is attributable to shortened gestational age. This holds true across all race/ethnicity/nativity groups.

The results from the current analysis are different from studies in Europe and Canada, where researchers found that the increasing birthweight trends in these countries were explained by maternal factors such as the increase in mothers' weight and height, the increasing prevalence of diabetes, the increase of average mothers' age and the decrease in cigarette smoking during pregnancy (Kramer et al. 2002; Bergmann et al. 2003; Surkan et al. 2004).

The results on the birthweight trend from this study, however, are consistent with those of Donahue et al. 2010. Using US birth data from 1990 to 2005, Donahue et al. (2010) concludes that average birthweight and percent of large for gestational age births decreased for singleton term births from 1990 to 2005 and that the trends in maternal characteristics, obstetric practices and gestational age do not explain the decreasing trends in birthweight. While this paper finds results consistent Donahue et al., we expand existing literature in the following ways. First, the current study includes births at all gestational ages and does not exclude pre-term babies as have done by most previous studies. In light of the concurrent shift of birthweight and gestational age toward the

lower end, it is of special importance to include pre-term infants so as to understand the overall trends in birthweight. More importantly, in addition to overall birthweight trend, this paper expands our understanding of birthweight trends among different race/ethnicity/nativity groups. Indeed, while numerous studies have examined racial/ethnic differences in birthweight, little is known about racial/ethnic differences in recent birthweight trends. The results from the current analyses suggest that the decrease of birthweight is fastest among non-Hispanic whites and least pronounced among non-Hispanic blacks. Furthermore, maternal characteristics, health and behavioral factors and medical practices have affected birthweight trends differently across different race/ethnicity/nativity groups.

LIMITATIONS

This study is limited by the availability and quality of data. Some of the important determinants for birthweight, such as mother's weight, mother's mental health and environment and neighborhood variables are not available from the vital statistics records. Moreover, changes in the way that data are collected over the years can potentially bias the results. During the period under analyses, there have been two revisions of the standard birth certificate in the US, one in 1989 and the other one in 2003. Differences in the two revisions occur across years and between states that use different versions of the birth certificate in the same year. An examination of missing data suggests the percentage of records that have missing values on variables used in this analysis have gradually gone down from 1989 to 2007, which could also bias the results of the trend analyses. While different methods have been proposed to handle the missing data, none has stood out as a

better choice than the other (Allison 2001). This study adopts a simple and straightforward approach, that is, to include and report missing data wherever possible.

IMPLICATIONS

Results from this study suggest that the decreasing trend in birthweight in the US is due, in great part, to the shortening of gestational age between 1989 and 2007. However, there is a substantial portion of the trend that is not explained by standard determinants such as gestational age and other maternal factors. Research on the causes of the recent gestational age trend should shed light on the birthweight trend. Interestingly, this study does not find an association between the increase of induction or cesarean rates and the decrease in birthweight. However, one study on the relationship between cesarean delivery and gestational age finds that the increase in the preterm birth rate is primarily among cesarean sections (Bettegowda et al. 2008). Another study reviews the effect of Assisted Reproductive Technology (ART), which has been increasing in recent years, on birth outcomes and finds that ART is associated with elevated risk of low birthweight and preterm births. These findings suggest that recent trends in medical interventions and obstetric management both before and during pregnancy, and at delivery may have an impact on the lowering of birthweight directly or indirectly through gestational age.

The implications of shortened gestation and as a result, the lowered birthweight trend, for public health, however, are unclear. While the increases in preterm and low-birthweight infants are usually not desirable, they may reflect a "greater willingness on

the part of obstetric providers to hazard neonatal risks of prematurity rather than fetal risks in a continuing pregnancy" (Grobman 2007: 537). Indeed, according to a recent NCHS report, the US fetal mortality rate declined from 7.49 in 1990 to 6.23 in 2003 (MacDorman and Kirmeyer 2009). In every sense, causes of recent trends in birthweight and gestational age, as well as the implications of the trends, are complicated and should be closely monitored and studied.

Table 1 Mothers' characteristics by nativity/race/ethnicity, 1989 and 2007

	2007					1989				
	US NH white	US NH black	US Mex	F Mex	All	NH white	NH black	US Mex	F Mex	All
N	2,166,670	544,872	266,101	461,941	3,439,584	2,365,496	551,016	128,528	192,430	3,237,470
Infant's sex										
Female	48.7	49.2	48.9	48.9	48.8	48.6	49.3	49.0	49.0	48.8
Male	51.3	50.8	51.1	51.1	51.2	51.4	50.8	51.1	51.0	51.2
Socio-economic and demographic factors										
Age										
17 & Under	2.2	7.0	9.5	3.6	3.7	3.1	11.3	10.3	4.7	4.9
18-20	5.9	12.5	13.0	7.1	7.7	6.7	13.7	13.3	8.7	8.3
20-24	23.7	34.2	32.6	27.7	26.6	24.8	32.8	32.2	33.5	27.0
25-34	53.3	38.1	38.6	49.2	49.2	56.5	37.1	38.7	45.2	51.9
35 and older	15.0	8.2	6.3	12.3	12.9	8.8	5.1	5.5	7.9	8.0
Birth Order										
First	35.0	32.4	36.6	27.0	33.6	34.5	30.8	33.7	32.2	33.7
Second	29.2	24.7	26.4	27.8	28.1	31.0	26.9	27.6	25.9	29.9
Third+	34.9	41.7	36.7	44.7	37.5	34.0	41.7	38.6	41.7	35.9
Missing	0.8	1.3	0.4	0.5	0.8	0.5	0.6	0.2	0.3	0.5
Parity										
Low Parity	80.5	74.4	78.3	82.9	79.7	82.1	73.4	78.0	81.4	80.4
High Parity	11.2	22.9	18.7	13.8	14.0	11.7	24.5	19.9	16.3	14.5
First Birth and 35+	8.4	2.8	3.0	3.4	6.4	6.2	2.1	2.1	2.2	5.1
Education										
0-12th grade	11.2	23.4	30.2	61.3	21.5	13.9	28.7	36.9	68.3	19.6

Hi school grad or GED	26.6	37.3	35.8	24.6	28.7	36.6	41.2	35.0	16.7	36.1
Some college	22.9	24.9	20.7	6.8	20.9	20.4	18.0	12.2	5.7	19.8
Associate D or higher	38.7	13.6	12.3	5.1	28.1	19.5	6.2	4.0	2.2	15.6
Missing	0.5	0.9	1.0	2.1	0.8	9.6	5.9	11.9	7.2	8.9
Marital Status										
Married	70.9	23.8	45.5	52.5	59.0	83.7	32.2	66.3	69.6	73.4
Behavioral and health factors										
Weight Gain										
Under 25	27.0	35.6	32.1	39.8	30.5	21.7	28.4	15.9	9.7	21.9
25-35	34.4	28.4	30.8	31.8	32.8	35.1	25.9	17.4	9.3	31.3
35+	34.0	28.3	30.1	19.0	30.8	21.9	17.2	11.4	4.8	19.7
Missing	4.6	7.6	7.0	9.4	5.9	21.3	28.6	55.4	76.3	27.2
Tobacco Use										
Yes	14.4	8.5	3.4	0.4	10.7	16.7	13.8	4.8	1.0	14.8
No	79.9	83.1	93.8	95.4	83.6	59.1	63.7	47.2	30.0	57.7
Missing	5.7	8.3	2.7	4.2	5.7	24.2	22.5	48.1	69.0	27.5
Diabetes and Hypertension										
Both	0.6	0.8	0.5	0.4	0.6	0.2	0.2	0.2	0.1	0.2
Diabetes Only	3.5	2.8	3.4	4.6	3.5	1.8	1.4	1.8	1.5	1.7
Hypertension Only	4.8	5.9	3.2	2.2	4.5	3.2	3.5	2.5	1.6	3.2
Neither	90.7	89.7	92.7	92.5	90.9	89.2	88.3	80.9	90.0	88.8
Missing	0.4	0.9	0.3	0.3	0.5	5.6	6.6	14.8	6.8	6.2
Health care and medical factors										
Prenatal Care										
Inadequate	10.7	20.9	19.6	23.2	14.7	11.2	29.9	28.6	39.9	16.8

Intermediate	11.4	11.4	11.1	12.8	11.6	15.1	14.0	16.1	19.8	15.3
Adequate	41.7	30.1	33.7	33.0	38.1	47.2	27.8	31.4	23.8	41.9
Adequate plus	32.3	30.3	29.4	25.0	30.8	24.0	23.4	20.3	13.2	23.1
Missing	3.9	7.3	6.3	6.0	4.9	2.5	4.9	3.6	3.4	3.0
Induction										
Yes	28.1	20.5	19.5	13.7	4.0	10.2	6.3	6.0	3.3	9.0
No	71.5	78.7	80.0	85.9	95.6	85.0	87.7	80.3	90.5	85.6
Missing	0.4	0.8	0.5	0.5	0.5	4.8	6.0	13.8	6.1	5.4
Cesarean										
Yes	28.1	20.5	19.5	13.7	24.3	21.4	19.7	19.7	16.5	21.4
No	71.5	78.7	80.0	85.9	75.3	72.2	72.3	66.1	76.6	71.6
Missing	0.4	0.8	0.5	0.5	0.4	6.4	7.6	14.2	6.7	7.0

Table 2 OLS regression models on mean birthweight for all, from 1989 to 2007

	Model1	Model2	Model3	Model4	Model5	Model6
Year	-3.7	-3.8	-4.2	-4.7	-4.5	-1.6
Infant' Sex						
Female	REF	REF	REF	REF	REF	REF
Male	116.4	115.6	115.7	111.1	112.9	125.1
Socio-economic and demographic factors						
Race						
US NH white		REF	REF	REF	REF	REF
US NH black		-290.8	-226.7	-234.9	-219.9	-161.9
US Mexican		-84.6	-29.3	-56.0	-48.9	-35.9
FB Mexican		-32.3	35.8	0.8	4.8	8.1
Mother's Age						
Under 18			-9.7	-41.8	-37.2	-12.4
18-20			-18.1	-33.2	-31.6	-29.2
20-24			-5.7	-9.5	-9.5	-16.9
25-34			REF	REF	REF	REF
35 and older			-21.7	-16.8	-11.4	2.3
Birth Order						
First			REF	REF	REF	REF
Second			62.9	78.8	81.2	91.7
Third			88.4	108.7	110.9	126.5
Fourth and higher			86.5	113.8	117.0	143.2
Missing			28.8	43.9	66.1	81.8
Parity						
High Parity			-48.2	-41.3	-38.4	-36.1
Low Parity			REF	REF	REF	REF
1st birth and 35+			-59.6	-45.2	-41.3	-36.7
Education						
Less than High School			REF	REF	REF	REF
High School Graduate			56.0	31.0	28.9	26.0
Associate Degree			100.3	57.1	53.8	48.9
Bachelor's and higher			136.6	74.7	69.4	65.0
Missing			50.3	13.3	12.2	19.4
Married						
Yes			73.3	53.4	50.4	37.7
No			REF	REF	REF	REF

Behavioral and health factors			
Diabetes and Hypertension			
Both	-86.8	-54.7	20.8
Diabetes Only	106.7	123.0	128.5
Hypertension Only	-237.7	-231.4	-153.1
Neither	REF	REF	REF
Missing	-37.3	-44.4	-24.7
Weight Gain			
Under 15	-138.6	-133.8	-91.6
15-25	REF	REF	REF
25 and up	158.8	156.1	128.4
Missing	-29.5	-16.4	6.2
Smoking			
Yes	-216.7	-213.6	-202.8
No	REF	REF	REF
Missing	19.6	14.9	-6.8
Health care and medical factors			
Prenatal Care			
Inadequate		-79.9	-54.3
Intermediate		11.4	-87.0
Adequate		REF	REF
Adequate Plus		-186.8	-0.158†
Missing		-139.7	-59.4
Induction			
Yes		86.4	34.4
No		REF	REF
Missing		-0.404 †	-12.1
Cesarean section			
Yes		5.0	26.5
No		REF	REF
Missing		49.9	46.0
Gestation (wk)			110.6

†P-value greater than 0.05

Table 3 OLS Regression Models on Mean Birthweight by Race/ethnicity/nativity, from 1989 to 2007

	Model1[1]	Model3[2]	Model4[3]	Model5[4]	Model6[5]
NH White					
Year	-4.4	-4.8	-5.5	-5.3	-1.6
NH Black					
Year	-1.8	-2.1	-3.3	-3.3	-1.6
US-born Mexican					
Year	-3.5	-3.8	-3.6	-3.6	-1.3
Foreign-born Mexican					
Year	-3.3	-3.7	-3.0	-2.7	-1.7

†P-value greater than 0.05

1. Model 1 is the base model, with year and infants sex as predictor variable.
2. Model 3 adds all the socio-economic and demographic variables to the base model.
3. Model 4 adds all the socio-economic and demographic variables, and behavioral and health variables to the base model.
4. Model 5 adds all the socio-economic and demographic variables, behavioral and health variables, and health care and medical care variables to the base model.
5. Model 6 adds all the socio-economic and demographic variables, behavioral and health variables, health care and medical care variables, and gestational age variable to the base model.

Figure 1 Trends in mean birthweight for singletons born to US-born and to foreign-born mothers by race/ethnicity, United States, 1989-2007

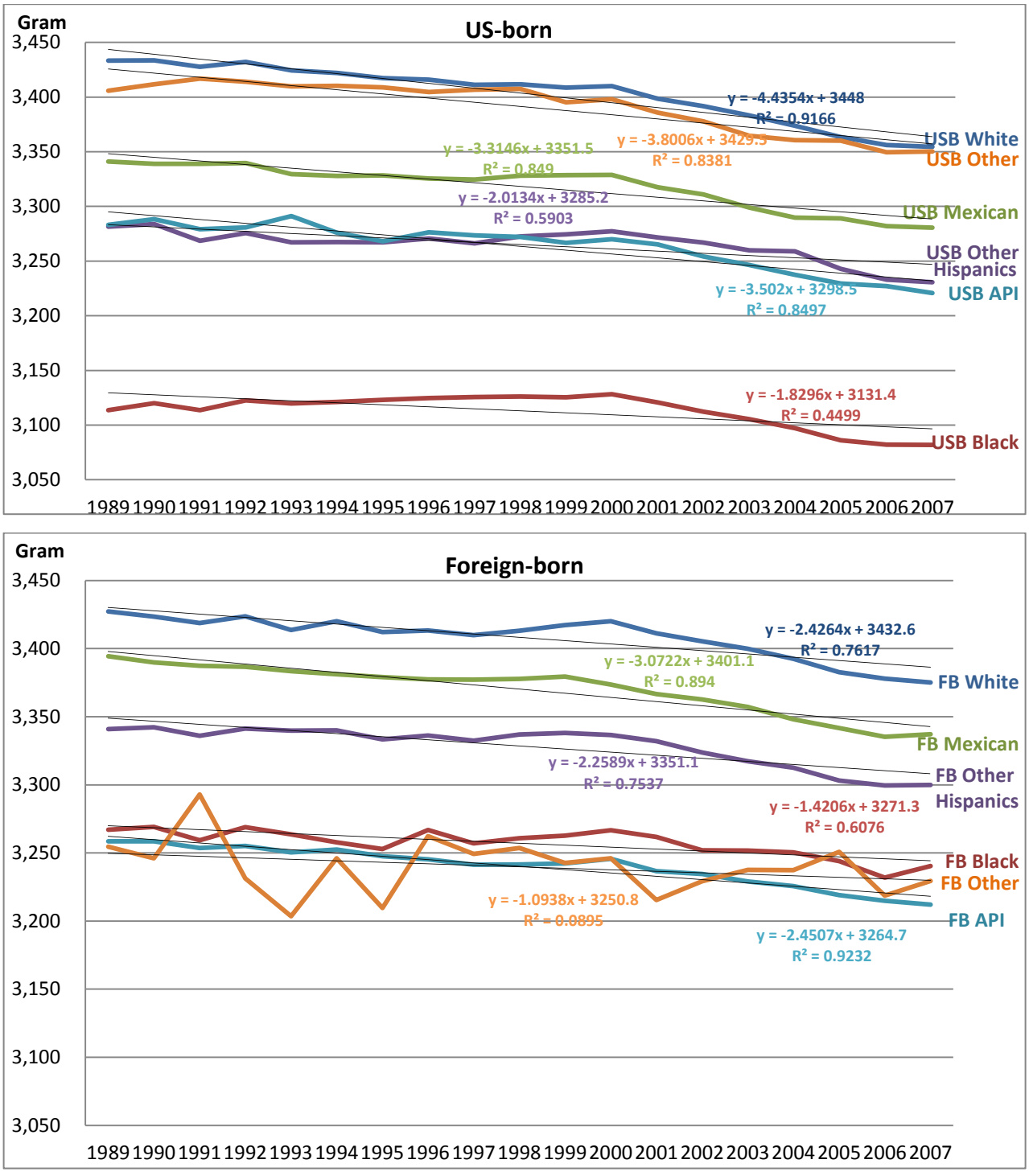


Figure 2 Trends in low birthweight rates (per thousand) for singletons born to US-born and to foreign-born mothers by race/ethnicity, United States, 1989-2007

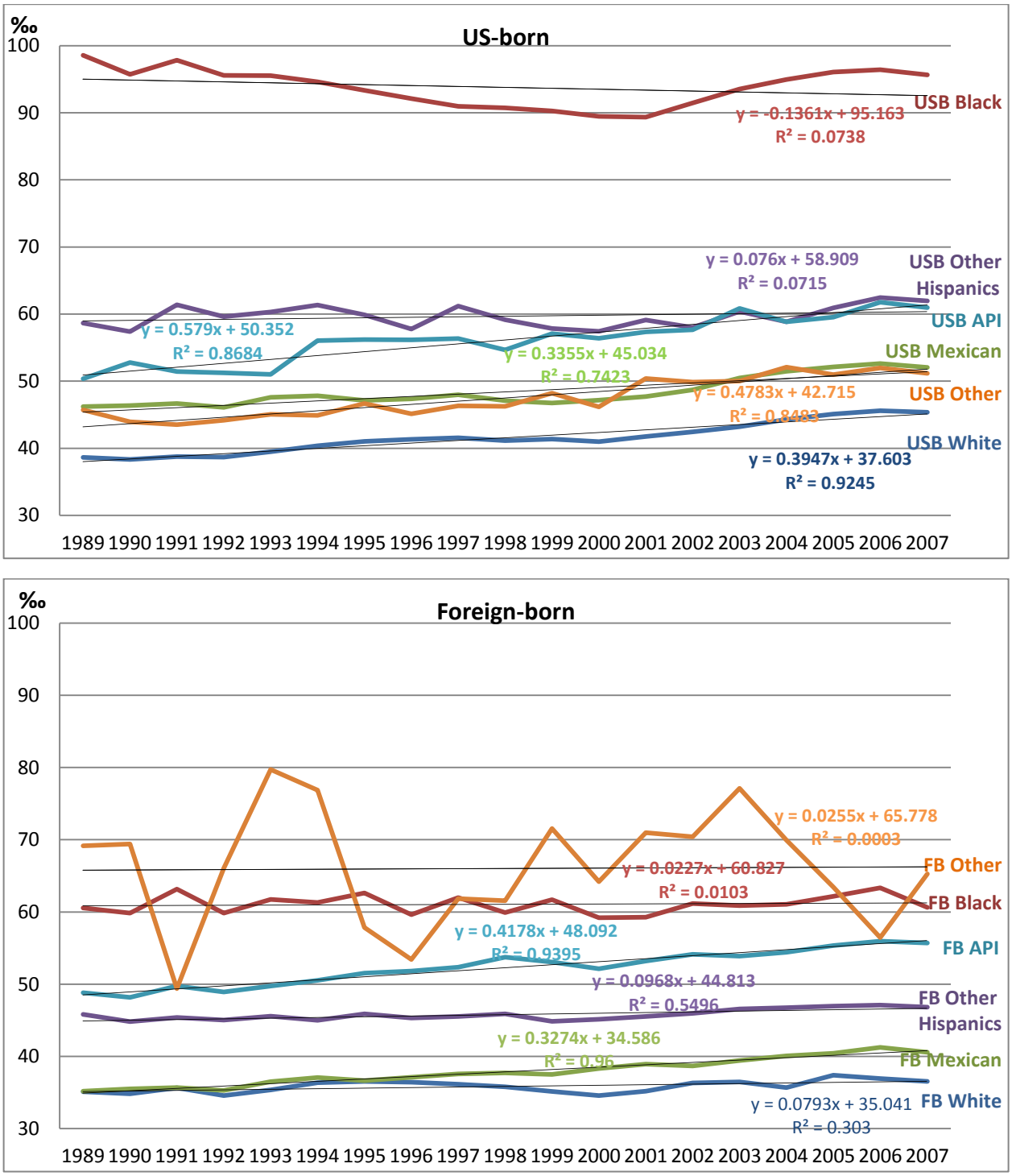
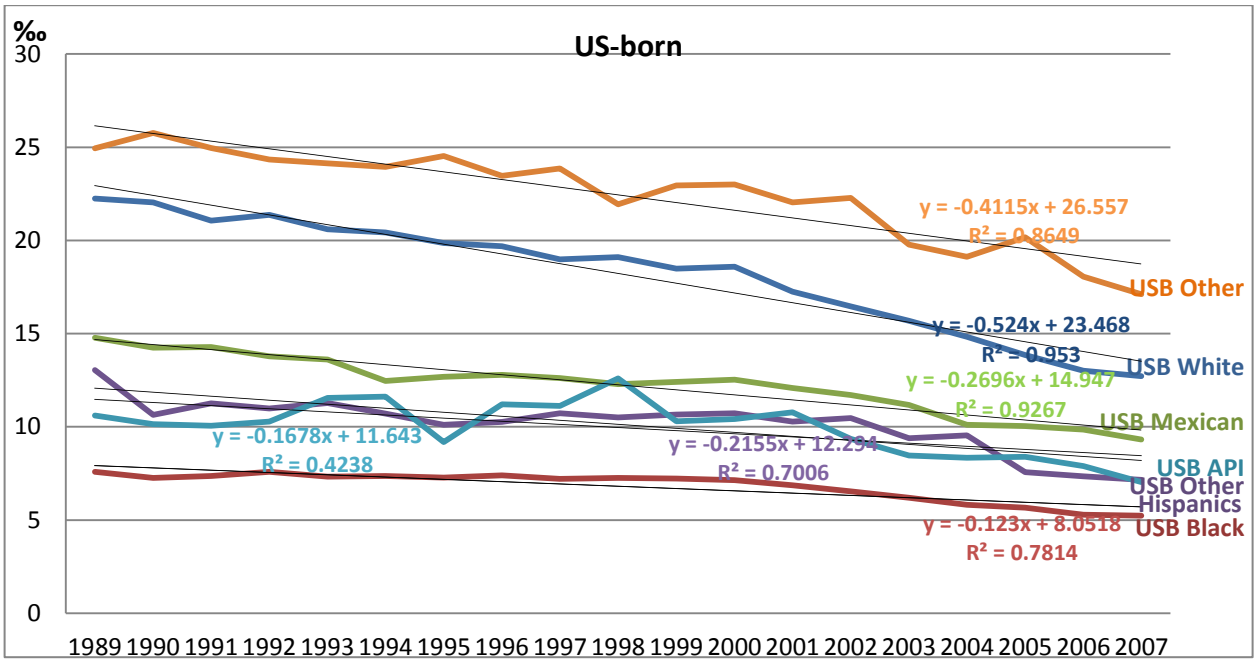
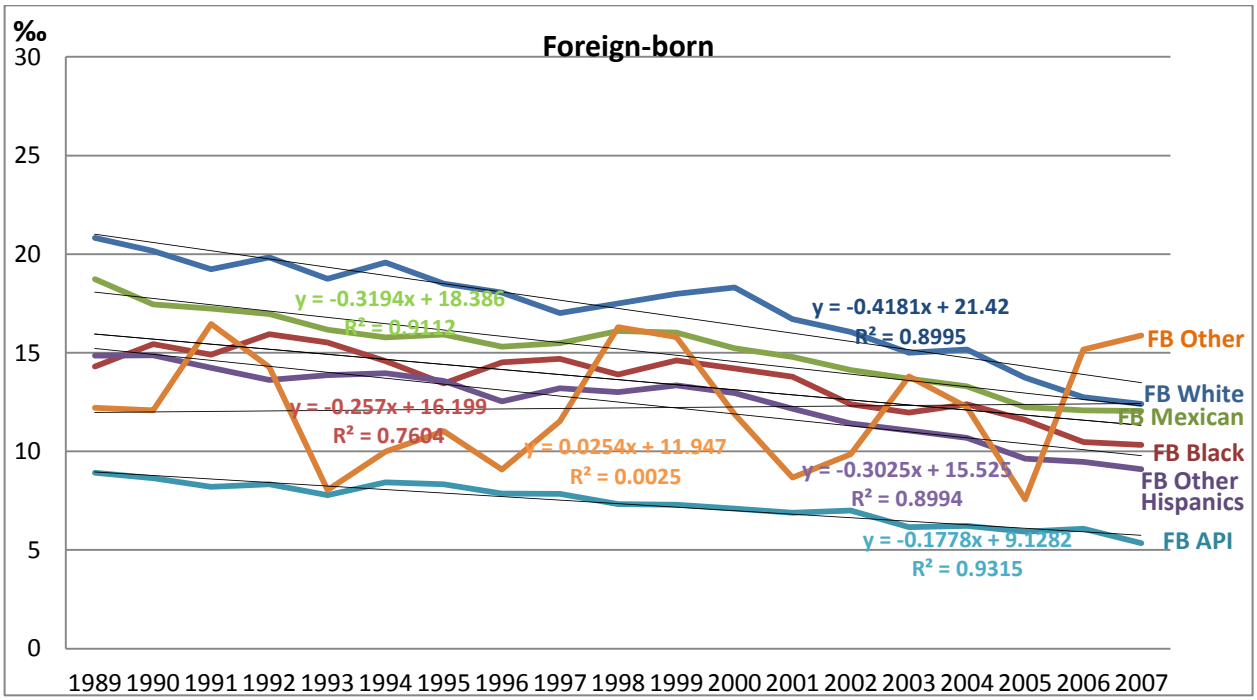


Figure 3 Trends in number (per thousand) singletons born at 4,500 grams or more to US-born and to foreign-born mothers by race/ethnicity, United States, 1989-2007





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