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MATERNAL AND INFANT HEALTH INEQUALITY:
NEW EVIDENCE FROM LINKED ADMINISTRATIVE DATA

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ABSTRACT

We use linked administrative data that combines the universe of California birth records, hospitalizations, and death records with parental income from Internal Revenue Service tax records to provide novel evidence on economic inequality in infant and maternal health. We find that birth outcomes vary non-monotonically with parental income, and that children of parents in the top ventile of the income distribution have higher rates of low birth weight and preterm birth than those in the bottom ventile. However, unlike birth outcomes, infant mortality varies monotonically with income, and infants of parents in the top ventile of the income distribution—who have the worst birth outcomes—have a death rate that is half that of infants of parents in the bottom ventile. When studying maternal health, we find that although mothers in the top and bottom income ventiles have similar rates of severe maternal morbidity, the former group are three times less likely to die than the latter. At the same time, these disparities by parental income are small when compared to racial disparities, and we observe virtually no convergence in health outcomes across racial and ethnic groups as income rises. Indeed, infant and maternal health in Black families at the top of the income distribution is markedly worse than that of white families at the bottom of the income distribution. Lastly, we benchmark the health gradients in California to those in Sweden, finding that infant and maternal health is worse in California than in Sweden for most outcomes throughout the entire income distribution.

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1 Introduction

Despite being one of the wealthiest countries in the world, the United States fares poorly on infant and maternal health indicators compared to other nations. For example, the US infant mortality rate ranks 33rd out of the 35 countries included in the Organization for Economic Cooperation and Development (OECD) (Bronstein et al., 2018). Much of this disadvantage is driven by a greater amount of infant health *inequality* in the US than in other countries—while infants born to highly educated non-Hispanic white mothers have similar infant mortality rates as their counterparts in Canada and Europe, children of less educated and racial minority mothers in the US fare much worse (Chen et al., 2016). Yet while infant health disparities across racial and educational groups have been widely documented in an interdisciplinary literature (e.g., Lu and Halfon, 2003; Dominguez, 2008; Currie, 2009, 2011; MacDorman, 2011; MacDorman and Mathews, 2011; Aizer and Currie, 2014; Green and Hamilton, 2019), we know much less about the relationship between parental *income* and infant health. Since education is only a coarse proxy for economic well-being, and education-income associations vary substantially across different racial and ethnic groups (Braveman et al., 2001; Adler and Rehkopf, 2008), evidence on the gradient between parental income and infant health, as well as the interaction of race and income, is critical for advancing our understanding of infant health inequality.

When it comes to maternal health, the US is similarly an outlier compared to other wealthy nations: the US maternal mortality rate was 17.4 deaths per 100,000 births in 2018, which is more than double the rate of other countries such as Canada, France, and Sweden (Tikkanen et al., 2020). Moreover, the US is one of the only countries in the world that has experienced an increase in the maternal mortality rate over the last few decades (Kassebaum et al., 2016; MacDorman et al., 2016; Gemmill et al., 2022), with an additional uptick during the COVID-19 pandemic (Hoyert, 2022). And while racial disparities in maternal mortality and morbidity are widely documented—with Black women being 3.3 times more likely to die from pregnancy-related causes than their non-Hispanic white counterparts (Petersen et al., 2019)—much less is known about income gradients in maternal health, or about the interaction between race and income in maternal health. For example, we do not know whether racial disparities in maternal health become narrower as income increases.

The lack of evidence on these fundamental issues stems from a major data constraint: income is *not* reported in either birth or death records data, which contain standard measures of infant and maternal health at the population level. Thus, researchers studying health inequality in the US have had to rely on aggregate geographic measures of income—such as county- or tract-level poverty rates (see, e.g., David et al., 2010; Currie and Schwandt, 2016; Baker et al., 2019; Schwandt et al., 2021, 2022)—which may mask important within-area heterogeneity and are subject to measurement error (Bell et al., 2019). Alternatively, some studies analyze relatively small samples of survey respondents to characterize the association between family income and infant health, often with limited health measures available and insufficient statistical power to examine differences by race.[1] And while much of the research documenting the importance of infant health for predicting long-term population well-being comes from other wealthy countries—notably, Scandinavian countries, which have high quality population registers with linkages between health and tax records (e.g., Black et al., 2007; Bharadwaj et al., 2018; Maruyama and Heinesen, 2020)—evidence on income-health gradients from Scandinavia may not be easily applicable to the US setting due to differences in social insurance generosity and the degree of income inequality. An additional data-related concern is about the measurement of maternal mortality, which is typically identified using a pregnancy status checkbox in US death certificates data, and may be prone to errors or inconsistencies (Catalano et al., 2020; Hoyert et al., 2020).

This paper brings a new linked data resource to fill this knowledge gap: the universe of California birth records covering years 2007–2016, linked to inpatient data with information on infant and maternal hospitalizations and infant death certificate records from the California Department of Health Care Access and Information, and high-quality administrative data on parental income from Internal Revenue Service tax records, supplemented with the Census Household Composition Key and Numident files. This novel population-level linked dataset allows us to comprehensively analyze the association between parental income and several key measures of infant and maternal health in the most populous US state, which accounts for 11 percent of all births that occur in the US in each year and represents the fifth largest economy in the world.[2] Moreover, we study these gradients separately for different racial and ethnic groups, allowing us to examine interactions between racial and economic inequality in infant and maternal health.

Additionally, we benchmark income gradients in infant and maternal health in the US to those in Sweden, a high-income European country known for its low rates of infant and maternal mortality

[1] Nepomnyaschy (2009) and Martinson and Reichman (2016), for example, use self-reported data from the Early Childhood Longitudinal Survey: Birth Cohort (ECLS:B) to study differences in low birth weight rates across families in different quartiles or quintiles of self-reported family income. Case et al. (2002) use information on self-reported family income in the National Health Interview Survey to study health-income gradients across all ages in childhood. See further discussion in Martinson and Reichman (2016).

[2] See Osterman et al. (2023) for the number of births by state in 2022, the most recent year of data available. See https://www.forbes.com/places/ca/?sh=117754f63fef for a discussion of the size of California's economy.

(Wallace et al., 1982, 1985; MacDorman et al., 2014; Tikkanen et al., 2020), low income inequality, and a broad social safety net. Sweden's health care system, with its universal health insurance and high performance on international health rankings, is frequently used as a point of comparison to the US (e.g., Frank, 2013; Finney, 2021; Chen et al., 2022). This comparison can offer several insights, such as whether infant and maternal health outcomes are worse in the US than in Sweden only for lower-income families, or whether differences exist for higher-income families as well. Further, similar to other recent work on mortality inequality by Schwandt et al. (2021), the Sweden–US comparison provides an additional perspective on racial inequality in the US. For example, we can see whether only US Black mothers and infants fare worse than Swedish mothers and infants, or if the drivers of lower infant and maternal health outcomes in the US also affect other racial and ethnic groups.

Our analysis reveals several key findings. First, our three main birth outcomes—birth weight, an indicator for low birth weight (less than 2,500 grams, or LBW), and an indicator for preterm birth (less than 37 weeks gestation)—exhibit a strong *non-monotonic* relationship with parental income. While these outcomes improve as income increases from the bottom to the middle of the income distribution, they worsen substantially at the top of the income distribution. In fact, children of parents in the top ventile of the income distribution have *lower* average birth weight and *higher* LBW and preterm birth rates than those in the bottom ventile: 10.2 and 11.4 percent of children born to parents in the top ventile are LBW and preterm, respectively, compared to 8.2 and 9.9 percent of children born to parents in the bottom ventile. These differences are highly statistically significant ($p < 0.001$).

These patterns differ sharply from those that have been documented for other outcomes in the U.S. For instance, life expectancy at age 40 increases monotonically throughout the income distribution (Chetty et al., 2016). Similarly, in their study of intergenerational income persistence, Chetty et al. (2014) show that the conditional expectation of child income given their parents' income is linear in percentile ranks. Yet, we show that children born into the top of the income distribution—who are likely to earn the top incomes in America in adulthood (Chetty et al., 2014)—have *worse* birth outcomes than those born at the bottom of the income distribution. Notably, we demonstrate that the stark non-monotonicity in LBW and preterm birth rates is considerably muted in gradients that use county-level income measures (either median household incomes or poverty rates), underscoring the value of using individual-level parent income data.

Our second set of results sheds light on the reasons behind the non-monotonic relationship between health at birth and parental income in the raw data. Adjusting for two key factors—maternal age and an indicator for a non-singleton birth—changes this pattern, such that the relationship between parental income and favorable birth outcomes becomes increasing and concave. That is, the disproportionately adverse birth outcomes at the top of the income distribution appear to be largely explained by higher average parental age and a greater share of non-singleton births among those families. This is consistent with advanced maternal age being a well-known pregnancy risk factor (Geiger et al., 2021) and non-singleton births having lower birth weights and shorter gestation lengths than singleton births. As non-singleton births experience higher infant mortality rates than singleton births conditional on gestation length (Almond et al., 2005), we might expect that infants born to the highest income families have even worse underlying health at birth than the patterns in preterm birth or LBW suggest.[3]

This pattern is also consistent with the fact that non-singleton births are substantially more likely to occur in pregnancies conceived with assisted reproductive technologies (ART), which we show are disproportionately likely to be used by the highest-income parents. As a result, restricting our attention to only singleton births would generate a sample that is biased toward lower-income families and those with parents who are able to conceive without the help of ART. Since our goal is to characterize income and racial/ethnic inequality in infant and maternal health in the entire population, we do not make this restriction in our main analysis. That said, as we show in the Appendix, the patterns in income and racial/ethnic inequality in infant and maternal mortality are largely similar when we only use singleton births.

Our third finding is that, unlike the birth outcomes, infant mortality varies monotonically with income, with substantially higher infant death rates at the bottom than at the top of the income distribution. The infant mortality rates among children of parents in the bottom and top ventiles of the income distribution are 7.1 and 3.4 deaths per 1,000 births, respectively, reflecting more than a two-fold difference that is statistically significant ($p < 0.001$). Thus, despite having the riskiest pregnancies—in terms of both advanced maternal age and the incidence of non-singleton births—and the worst birth outcomes, women in the top ventile of the income distribution nevertheless give birth to babies who are the *least* likely to die. This finding suggests that pregnancies carried by women at the top of the income distribution are not only the riskiest, but also the most protected.[4] Moreover, this pattern re-

[3]In fact, we show that in our data, predicted infant mortality based on a regression on birth weight and gestational age is highest for the highest income families.

[4]Consistent with this conjecture, recent evidence from the U.S. documents that increasing advanced prenatal care on the margin in high-risk pregnancies reduces the likelihood of fetal death within a month before expected delivery or death within the first seven days of life (Geiger et al., 2021). Pregnancies conceived with assisted reproductive technologies also

mains after accounting for hospital-specific factors, suggesting that the relationship between infant mortality and income cannot be explained by access to quality hospital care alone. Instead, it may reflect broader resource inequalities, stemming from unequal access to high-quality childcare, paid family leave, and other supports for new families.[5]

Fourth, we find similar patterns of non-linearity in morbidity and a monotonic relationship in mortality when we examine maternal health. We find a U-shaped pattern when analyzing severe complications related to pregnancy and childbirth—women both at the bottom and the top of the income distribution have the highest rates of these complications. However, despite having similarly risky pregnancies as their lowest-income counterparts, women with incomes at the top of the income distribution are three times less likely to die (1.3 maternal deaths per 10,000 births versus 4.4 maternal deaths per 10,000 births, respectively, $p<0.001$).

Fifth, racial disparities in infant and maternal health are significantly wider than those by income, and there is essentially no convergence in outcomes across racial groups as income increases. These differences in health outcomes are especially large when it comes to the Black-white gap. Across all parental income levels, Black infants and mothers have much worse health than their non-Hispanic white counterparts. Strikingly, the LBW and preterm birth rates for infants of Black parents in the *top* of the income distribution are one and a half to two times higher than those for infants of white parents in the *bottom* of the income distribution (14.0 and 15.0 percent of Black infants in the top ventile of the income distribution are LBW and preterm, respectively, compared to 7.4 and 9.1 percent of white infants in the bottom ventile of the income distribution; all differences are statistically significant with $p < 0.001$). Infant mortality for Black infants in the top decile of the income distribution is 6.4 deaths per 1,000 births—approximately 10 percent higher than the rate of 5.8 deaths per 1,000 births among white infants in the bottom decile of the income distribution, although we do not have enough precision to reject the null hypothesis that these two mortality rates are equal ($p = 0.76$). The maternal mortality rate for Black mothers in the top quintile of the income distribution is 4.3 deaths per 10,000, about 60 percent higher than the rate among white mothers in the bottom quintile of the income distribution, which is 2.7 deaths per 10,000, although similarly we do not have enough power to detect a statistically significant difference in this outcome ($p = 0.45$).[6] Notably, while Black mothers and

tend to be highly monitored (Velez et al., 2019).

[5]We see similar downward sloping income gradients when we split the infant mortality outcome into neonatal (death before 28 days) and post-neonatal (death between 28 days and one year of age) mortality.

[6]We use quintiles to study economic inequality in maternal mortality separately by race because this is a rare outcome, and Census Bureau disclosure rules prevent us from releasing output from smaller income bins separately by race.

their infants have substantially higher rates of *all* adverse outcomes throughout the income distribution compared to the other groups, families belonging to the "Non-Hispanic Other" category—which includes those who identify as American Indian/Alaska Native, those belonging to more than one racial group, and those with missing race information—have similarly high infant mortality rates as Black families at most points in the income distribution. All together, this evidence implies that policies seeking to achieve racial health equity cannot succeed if they only target economic markers of disadvantage.

Finally, comparing the health gradients in California with those in Sweden, we find that *all* measures of infant health are worse in California than in Sweden at *all* income levels. In particular, the lowest-income infants in Sweden have higher average birth weight, lower rates of preterm birth and LBW, and lower rates of infant mortality than Californian infants at any point in the income distribution. Additionally, when we split our California and Swedish data by foreign-born status of the mother, we find that even relatively disadvantaged infants in Sweden—those born to immigrant mothers—experience lower LBW, preterm birth, and infant mortality rates throughout most of the income distribution when compared to infants of both US-born and foreign-born mothers in California. For maternal mortality, we find that overall, the rates are lower in Sweden than in California at the bottom of the income distribution, and more similar toward the middle and the top. However, non-Hispanic Black mothers in California have substantially higher mortality rates than Swedish mothers at all income levels.

Our paper contributes to an expansive and interdisciplinary literature on early-life health as a determinant of population well-being over the life cycle and across generations (for some overviews, see: Currie and Almond, 2011; Aizer and Currie, 2014; Nusslock and Miller, 2016; Almond et al., 2018). The research linking early-life health to later outcomes, combined with studies showing a positive causal impact of parental economic resources on early-life health (Lindo, 2011; Hoynes et al., 2015; Amarante et al., 2016; Wehby et al., 2020), may lead one to conclude that early-life health is an important driver of the observed intergenerational persistence of economic status. Our findings of a non-linear relationship between parental income and birth outcomes, and a strong linear income gradient in infant mortality, shed more light on the nature of this mechanism. Birth outcomes such as birth weight and gestation length may not serve as a central channel by which income persists across generations, as these outcomes are actually worse for children of parents at the very top of the income distribution who are then likely to go on to have the highest incomes themselves. However, health—

and potentially health care and other resources received—during the first year of life may be a more important mechanism, as indicated by the lowest infant mortality rate for children of parents at the top of the income distribution.[7]

Our paper also adds to the literature on maternal health inequality, which to date has been more limited in scope, especially compared to the literature on child health and overall mortality. While there is research linking maternal socioeconomic disadvantage—as measured by a low education level and unmarried status—with a variety of maternal health-related behaviors during pregnancy like smoking and weight gain, and selected conditions such as diabetes (see Aizer and Currie, 2014 for an overview), our study is, to the best of our knowledge, the first to offer direct evidence on the association between individual-level income and maternal health.[8] And while racial differences in maternal morbidity and mortality, and in particular the disproportionate burden borne by Black mothers, are widely documented and discussed,[9] our research allows one to understand interactions between race and income. The fact that Black mothers at the top of the income distribution have statistically similar (and, based on the point estimates, higher) mortality rates than white mothers at the bottom of the income distribution suggests that the widely cited racial disparity in maternal mortality is unlikely to be solely or even mostly driven by differences in average income levels across the two racial groups. Moreover, our novel linkage between birth records and maternal death records allows us to identify virtually all deaths of women in the first postpartum year without relying on the potentially poor quality pregnancy status checkbox used in prior studies (Catalano et al., 2020; Hoyert et al., 2020).

Finally, we build on several studies that have compared health inequality in the US to those in other high-income countries (Chen et al., 2016; Baker et al., 2019; Currie et al., 2020a; Emanuel et al., 2021; Schwandt et al., 2021). Our individual-level linkages between income and health measures in California and Sweden allow us to compare these two gradients, and to shed light on potential heterogeneity in economic inequality between different sub-groups within the two countries, such as for foreign- and US-born mothers. These comparisons, in turn, provide insights into the potential mechanisms contributing to the associations that we observe.

[7]Our findings also relate to the discussions about birth weight being an imperfect proxy for prenatal and infant health, see, e.g. Conti et al. (2020).

[8]One study by Vilda et al. (2020) examines the association between state-level income inequality and pregnancy-related mortality for non-Hispanic Black and white women, finding a significant association for Black women only.

[9]For one example of the media coverage of this topic, see: https://www.pbs.org/newshour/show/why-are-black-mothers-and-infants-far-more-likely-to-die-in-u-s-from-pregnancy-related-causes.

2 Data

Our analysis links California birth records from 2007 through 2016 to several administrative data sources containing parent information, individual- and family-level income, and morbidity and mortality outcomes. To implement these linkages, we provided confidential versions of the birth records with personally identifying information (PII) for the infant, mother, and father to the Census Bureau for their Person Identification Validation System (PVS) to assign a Protected Identification Key (PIK) to each infant and each parent. The PIK is an anonymized individual identification number that allows for linkages to other Census-held data without the use of personally identifying information. The PVS assigns PIKs by comparing PII on the birth certificate input file to the characteristics in PVS reference files based on administrative records (Mulrow et al., 2011).[10] In addition, we perform some analyses using the California Department of Health Care Access and Information (CHAI)[11] maternal and infant inpatient data covering years 2007–2012, which include infant death records for births through 2011. These data were already linked to the birth certificate data by CHAI.

2.1 Births Data

The birth certificate records include all births occurring within the state of California. We restrict the analysis to births that occurred to state residents. Each record has unique child and parental identifiers, as well as detailed information on birth characteristics, including birth weight, gestation length, parity, and singleton versus multiple birth indicators. The birth records also contain parents' demographic information, including age, race, ethnicity, and whether the mother was born outside of the US. We further restrict the sample to all births to first-time mothers (i.e., births to nulliparous women), which represent 39.2 percent of all births during our analysis period. Our final sample includes approximately 2.04 million births.

In certain analyses that make comparisons to Sweden, we further restrict the sample to match that used in Chen et al. (2016) to limit any differences across countries in the reporting of births with borderline viability. This restricted sample is defined as singleton births with at least 22 weeks of gestation and 500 grams of birth weight, resulting in a sub-sample of about 1.97 million births.

[10] The information provided for the birth record linkage was full infant name, mother's first and maiden name, father's first and last name, dates of birth, and address.

[11] Formerly, the California Office of Statewide Health Planning and Development or OSHPD.

2.2 Parent Information

While the California birth records contain parent identifiers, in some cases these fields are missing or a PIK could not be assigned. In these cases, we use additional administrative records to identify parents when possible. First, we observe parent information on a composite administrative dataset called the Census Household Composition Key (CHCK) available for years 2016 to 2022. This dataset uses information from a variety of federal sources, including Social Security Number applications, the IRS Form 1040, and the Decennial Census, to identify the parents of each child (U.S. Census Bureau, 2020; Genadek et al., 2021). Second, for some children with missing parent information on the birth certificate or in the CHCK, we observe parents living with their children if they appear in the 2010 Decennial Census or the 2007 to 2021 waves of American Community Survey (ACS).[12] Finally, we fill in as parents any individuals observed filing taxes with the infant listed as their dependent for the tax year corresponding to the year of birth (more details are in Appendix B). Using all these sources, we are able to identify the mother (father) for 95.1 percent (86.7 percent) of all the births in our sample.

2.3 Income Data

Using information on the parents, we link the birth records to individual-level parental income data from the IRS available from 2005 to 2016. These data contain income information reported on the 1040 and W-2 forms, including tax filing status, wages, adjusted gross income (AGI), and taxable Social Security benefits.[13]

We use these data sources to construct a measure of family "AGI-like" income during the two years prior to the birth. To do so, we exclude taxable Social Security and disability payments from AGI to arrive at a measure of non-transfer household income. If parents file jointly both years prior to the birth, we take the average of the two pre-birth years. If parents file separately, we add the incomes of both parents in each year and take the average. If either or both parents do not file, we use their earnings as recorded in the W-2 data instead. If income is missing in one of the two pre-birth years, we use the year with the non-missing income for this measure. For infants whose fathers we are not able to identify, we use only the mother's income. Similarly, in a handful of cases where we cannot

[12]See Miller and Wherry (2022) for additional information on how parents are identified using family relationship variables in the Census surveys.

[13]We also observe quarterly data from the state unemployment insurance (UI) system through the Longitudinal Employer-Household Dynamics (LEHD) file for 12 states: Arizona, California, DC, Delaware, Kansas, Maine, Maryland, Nevada, North Dakota, Oklahoma, Tennessee, and Wisconsin. These data are available from 2005 to 2014. We use earnings information from the LEHD for only a very small number of cases—about 0.1 percent of our sample—in which earnings are missing in the W-2 filings but non-missing in the LEHD records.

identify the mother, we use only the father's income. Lastly, following Chetty et al. (2016), we do not include in our main analysis families who are unmatched to any measure of income, for whom $0 is reported on the tax return, or for whom the family "AGI-like income" is negative in either year. We report average outcomes for this group in Appendix Table B2. Further details on the family income calculation are provided in Appendix B.

Once we have calculated family income for each birth, we bin family income into percentiles based on the distribution of family income observed in each birth year. In most analyses, we present estimates in ventiles, or five percent shares of the population of births in that year. When analyzing rarer outcomes in subgroups, such as infant and maternal mortality by race/ethnicity category, we present estimates in deciles or quintiles, which represent 10 and 20 percent shares of births, respectively, in order to avoid estimates that rely on a very small number of occurrences.

Additionally, to compare our individual family income measures with those constructed with more aggregate geographic measures used in the prior literature, we also merge in data on county-level median incomes and poverty rates from the 2010 Small Area Income and Poverty Estimates (SAIPE) Program of the US Census Bureau using information on the mother's county of residence at birth. We combine the 58 California counties into 14 bins, which represent groupings of approximately 5 percent of births, with the exception of very large counties that constitute their own bins (such as Los Angeles county, which accounts for 26 percent of California births).

2.4 Morbidity and Mortality Data

To measure maternal morbidity, we use the Linked Birth File from the California Department of Health Care Access and Information (CHAI) containing inpatient visits linked to the birth records from 2007 to 2012 (Healthcare Information Resource Center, 2006). The CHAI data includes inpatient visits for the mother during the time period covering nine months before through one year following childbirth. The inpatient data include Internal Classification of Diseases ICD-9-CM diagnoses codes and ICD-9-PCS procedure codes, which allow us to identify any severe maternal morbidity (SMM) event within this window, according to the CDC definition.[14] These events capture severe and unexpected negative health consequences of labor and delivery, such as eclampsia or sepsis. Our SMM analysis sample includes about 1.26 million observations.

To calculate maternal and infant mortality—defined as a maternal and infant death occurring

[14]See: https://www.cdc.gov/reproductivehealth/maternalinfanthealth/severematernalmorbidity.html for the exact codes.

within one year of childbirth, respectively—we use information on exact date of death for deaths occurring in 2017 and earlier from the 2019 Census Numident. The Census Numident contains administrative death data for the US population collected by the Social Security Administration for individuals with a Social Security Number (SSN) or Individual Tax Identification Number (ITIN) (Mulry and Keller, 2017). Mortality records measured in the Numident have been shown to closely track adult mortality statistics as reported by the CDC (Finlay and Genadek, 2021; Miller et al., 2021); however, they are known to undercount infant deaths since many infant deaths occur before the infant has obtained an SSN and may miss deaths among adults without a SSN or ITIN (for example, undocumented individuals). Therefore, to measure infant mortality, we supplement the Numident mortality records with infant death certificates linked to birth records from CHAI available for birth years 2007 to 2011, and restrict our analysis of infant death to only those birth cohorts. Our infant mortality analysis sample consists of approximately 1.06 million observations, and the rates we calculate in our analysis sample match closely to publicly available statistics reported by CHAI and the CDC.[15] We consider both overall infant mortality rates, as well as neonatal (death within first 28 days of life) and post-neonatal (death between 28 days and 1 year) mortality rates separately.

2.5 Swedish Data

To construct analogous infant and maternal health gradients for Sweden, we link several population-wide administrative datasets. We obtain Medical Birth Records (MBR) from 2007 through 2016, as well as death records and inpatient records from 2007 through 2017, from the National Board of Health and Welfare (Socialstyrelsen, 2019). The MBR contains information on all pregnancies carried to at least 22 weeks of gestation.[16] It records the pregnancy outcome (live birth or stillbirth), birth weight, gestation length, and singleton versus multiple birth indicators. As in California, we restrict the sample from Sweden to live births of first-time mothers.[17]

The death records contain exact date of death, allowing us to construct infant and maternal mortality. Similar to the California mortality data, infant deaths that occur very early are under-counted in the administrative deaths data, as an infant may not have been issued a *Personnummer* (the Swedish equivalent of a Social Security Number) before dying. To get better coverage of the early infant deaths, we therefore also use a variable from the MBR that indicates death within one month of birth. As a

[15] More details on the infant mortality rates in our analysis data and how they compare to publicly available statistics are in Appendix B.

[16] Prior to July 1, 2008, the MBR contained all pregnancies carried 28 weeks or longer.

[17] We do not observe parity in our data from MBR in Sweden; however, we can construct parity from the family linkage data from Statistics Sweden described below.

result, we are able to closely match publicly available statistics on Swedish infant and neonatal mortality rates—i.e., we can be sure that we are not undercounting the overall Swedish infant death rate in our analysis sample.

We note that we are unable to construct an SMM indicator in the Swedish data because the hospitalizations data only contain 3-digit ICD codes, which are not specific enough to capture this outcome accurately (the CDC definition in footnote 14 relies on 5-digit codes). Thus, we omit this outcome from the Swedish comparison.

To link children to their biological parents, we use family linkage data from Statistics Sweden. We are able to identify all (100 percent of) mothers and 97.8 percent of fathers. We merge these data to Statistics Sweden's longitudinal database of individuals (LISA) from 2005 through 2016, which contains information drawn from various administrative records (Statistics Sweden, n.d.). These data allow us to observe parent demographics (age and whether the mother is foreign-born), as well as various third-party reported individual income measures. Using these income variables, we construct a measure of "AGI-like" income for each parent in each year. Then, to construct family AGI-like income, we average the sum of the parents' AGI-like income across the 2 years prior to birth.[18] As in the California data, we exclude from our main analysis sample births that have no observed measures of income, those for whom income is reported as exactly $0, and those for whom family income is negative in either year prior to birth. Appendix Table B2 presents mean infant and maternal outcomes for these observations in Sweden. More details on the Swedish parental income measure construction are provided in Appendix B.

Our final analysis sample for Swedish birth outcomes includes 482,315 observations, while the analysis sample for infant mortality, which is restricted to birth cohorts 2007–2011 as in the California data, includes 288,250 observations.

3 Results

3.1 Income Inequality in Infant and Maternal Health

Figure 1 plots average birth outcomes by family income ventile for each of the outcomes we consider using the California data. Panels (a) through (c) show a non-monotonic relationship between parental income and measures of infant health captured on the birth record. Birth outcomes appear to improve

[18] As in the US income construction, we use the available parent's income if only one parent is observed, and we use the family income from only one of the two years prior if only one year is observed.

from the lowest ventiles until the middle of the income distribution. Average birth weight is 3,219 grams for infants born to families in the lowest income ventile and peaks at 3,265 grams, 1.4 percent higher, for infants born to families in the 12th ventile. Similarly, the incidence of preterm and LBW births are 7.8 and 9.8 percent lower, respectively, for infants at the 12th ventile as compared to the poorest families in the first ventile. These differences are statistically significant ($p < 0.001$).

Slightly above the median income bin, however, this relationship reverses, with birth outcomes worsening as parental income increases, such that the worst birth outcomes in the sample are observed among infants born to the highest income families. Indeed, the incidence of preterm birth and of LBW are higher by 14 and 24 percent, respectively, when comparing infants born to families at the very top of the income distribution with those at the very bottom of the income distribution. This "J-shaped" (or "inverted J-shaped," in the case of average birth weight) pattern contrasts sharply with income-health gradients in adult population health outcomes, such as mortality and life expectancy, which have been shown to vary monotonically with income (Chetty et al., 2016). Additionally, panels (b) and (c) of Appendix Figures A1 and A2 show that the "J-shaped" patterns in preterm birth and LBW rates, respectively, are considerably muted when we instead use county-level measures of economic resources, such as median incomes or poverty rates. These comparisons highlight the unique insights about health inequality that can be discovered with individual-level administrative income data.

We find a different pattern when examining the most extreme measure of infant health—infant mortality—in panel (d) of Figure 1. In contrast to the relationship observed among the birth outcomes, the association between parental income and infant mortality is monotonic, with infants in the highest income families experiencing the lowest likelihood of death. Infants born to families in the top income ventile experience mortality rates that are less than half of those experienced by infants at the bottom ventile (3.4 deaths per 1,000 births versus 7.1 deaths per 1,000 births) and these differences are statistically significant with $p < 0.001$. Thus, despite faring the worst in terms of birth outcomes captured on the birth record, babies born into the highest income families are the most likely to survive to age one. We further emphasize this point by predicting infant mortality based on birth weight, an indicator for LBW, gestational age in weeks, and an indicator for preterm birth using a linear probability regression. As seen in Appendix Figure A3, in the highest income households, predicted infant mortality based on birth outcomes is highest, while actual true infant mortality is lowest.

Appendix Figures A1(d) and A2(d) show that similar patterns in infant mortality emerge when we use county-level median incomes or poverty rates instead of individual family incomes on the

$x-$axes. This analysis provides support for the validity of findings in prior work that has relied on aggregate economic measures to study mortality inequality at other ages (Currie and Schwandt, 2016; Baker et al., 2019; Schwandt et al., 2021, 2022).

The last two panels of Figure 1 show the measures of maternal health. We see a U-shaped pattern for severe maternal morbidity (panel (e)), in which the worst outcomes are apparent for both the lowest and highest income mothers. However, echoing our result for infant mortality, maternal mortality appears to be monotonic in income, with the highest income mothers experiencing the lowest mortality rates, despite the elevated rate of morbidity experienced by this income group. Death rates are more than three times higher for mothers in the bottom income ventile as compared to the top ventile (4.4 maternal deaths per 10,000 births versus 1.3 maternal deaths per 10,000 births; $p < 0.001$).[19]

In Figure 2, we investigate how much of these patterns can be explained by two key observable characteristics: maternal age and an indicator for non-singleton birth.[20] In contrast to the results reported in Figure 1 using raw outcome means, we find that once these two characteristics are accounted for, the patterns for LBW, preterm birth, and severe maternal morbidity become essentially monotonic in income, with the best outcomes associated with the highest family incomes. We continue to observe some reduction in average birth weight for infants born to the highest income families, but the decline in average birth weight from the 15th ventile to the 20th ventile is far less severe than in the raw data. The most extreme health outcomes, infant and maternal mortality, remain monotonic after controlling for these observable characteristics with similar relative differences in the death rates experienced by the top and bottom income ventiles, as described above.

Thus, it appears that the "J-shaped" pattern in adverse birth outcomes and the "U-shaped" pattern in severe maternal morbidity are largely explained by the fact that mothers in the highest income families tend to be older and more likely to have non-singleton births (which, in turn, tend to have lower birth weights and shorter gestation lengths).[21] The disproportionate share of non-singleton births at the top of the income distribution is unlikely to occur by chance—as we show in Appendix Figure A4, high-income mothers are substantially more likely to use assisted reproductive technolo-

[19]The county-level maternal health gradients in Appendix Figures A1(e) and (f) and A2(e) and (f) show similar patterns, although with less precision especially for the severe maternal morbidity outcome.

[20]Specifically, we calculate residuals from a regression of each outcome on fixed effects for maternal age group bins (less than 20, 20-24, 25-34, 35+) and an indicator for a non-singleton birth. We then plot the average residuals in each income bin.

[21]The high prevalence of LBW and prematurity among non-singleton births should not be taken as an indicator that these characteristics are unimportant for these infants. Indeed, a large literature shows that, at the margin, birth weight has important short- and long-run health and economic impacts even within twin pairs; see, e.g., Black et al. (2007) and Royer (2009). Furthermore, even conditional on gestational age, non-singleton births have higher rates of infant mortality (Almond et al., 2005); we might therefore expect the underlying health of these infants to be even worse than what is indicated by rates of preterm birth alone.

gies (ART) to conceive than their lower-income counterparts (6.7 percent of births to mothers in the highest-income bin are conceived with ART, as compared to 0.2 percent of births in the lowest-income bin), and ART-conceived pregnancies are much more likely to result in non-singleton deliveries than those conceived without ART.

At the same time, the patterns for infant and maternal mortality are largely unchanged when we account for maternal age and non-singleton birth status. To better understand the income gradients in infant mortality, Appendix Figure A5 considers neonatal and post-neonatal mortality separately in panels (b) and (c), respectively, with the income gradient for overall infant mortality replicated in panel (a). We find that the downward-sloping relationship with income holds for both measures. Since hospital characteristics—including the level of the Neonatal Intensive Care Unit and the quality of pediatricians and neonatologists on staff—arguably play an important role in shaping neonatal mortality in particular, one potential explanation for the gradient is that mothers with different incomes sort into giving birth at different types of hospitals. However, when we adjust for hospital fixed effects (in addition to maternal age and a non-singleton birth indicator as in the other adjusted models) in Appendix Figure A6, the qualitative relationship between income and infant mortality is largely unchanged. Thus, it is unlikely that differential sorting into higher versus lower-quality hospitals is the primary explanation for the inequality in infant mortality that we document.

3.2 The Intersection Between Race and Income Inequality in Infant and Maternal Health

These patterns showing the relationship between parental income and infant and maternal health in the population may mask significant heterogeneity along other dimensions. We explore one source of heterogeneity—the mother's race and ethnicity—in Figure 3. This figure plots the infant and maternal health outcomes by income separately for non-Hispanic white, non-Hispanic Black, non-Hispanic Asian, Hispanic, and non-Hispanic mothers of another race (including American Indian/Alaskan Native, those belonging to multiple racial groups, and those with missing race information). These figures reveal that disparities across racial and ethnic groups are far larger than disparities across the income distribution. Panel (a) of Figure 3 shows that, on average, infants of non-Hispanic white mothers have the highest birth weights at all points in the income distribution. Indeed, at no point in the income distribution does average birth weight for any other racial or ethnic group exceed that of infants of the lowest income (first ventile) non-Hispanic white mothers. Infants born to non-Hispanic mothers of other races and Hispanic mothers have the next highest birth weights on average, and non-

Hispanic Black and non-Hispanic Asian mothers have infants with the lowest average birth weights.

Panels (b) and (c) show similarly large disparities in rates of preterm and LBW births. By these measures, infants born to non-Hispanic Black mothers have by far the worst outcomes at all points in the income distribution. Rates of preterm birth range from 11.8 percent to 15.0 percent and rates of LBW range from 11.2 percent to 14.0 percent for this group. In contrast, rates of preterm birth range from 8.1 percent to 11.4 percent and LBW rates range from 6.2 percent to 9.6 percent for infants born to non-Hispanic white mothers. Further, the gap between non-Hispanic Black and non-Hispanic white mothers does not close as we move higher up in the income distribution; rather, it remains roughly constant at all points of the income distribution. We see similar patterns for severe maternal morbidity and maternal mortality (panels (e) and (f)), with rates elevated for non-Hispanic Black mothers at all points in the income distribution. For infant mortality (panel (d)), infants of non-Hispanic Black mothers and infants of mothers belonging to the non-Hispanic other group have the highest mortality rates throughout the income distribution. In particular, for infants of Black mothers, the mortality rate ranges from 5.5 to 13.0 per 1,000 births, while for infants in the other group, it ranges from 5.1 to 11.2 per 1,000 births. Given the rare nature of these mortality events, these subgroup-specific means tend to be noisy and do not always exhibit a clear pattern in relation to family income; there does, however, still appear to be some monotonic relationship with income.

We explore the role of maternal characteristics in these cross-race/ethnicity differences by residualizing our outcomes based on maternal age and non-singleton birth status—the two key factors driving the non-linear patterns between birth outcomes and maternal morbidity and income in the overall population. Figure 4 plots the residual means by income bin and racial/ethnic group.[22] Residualizing does not appear to meaningfully close the gaps between racial and ethnic groups, although it does sometimes reduce the apparent rate of adverse health outcomes at the top of the income distribution within these groups. Even after accounting for these basic characteristics, we observe that non-Hispanic Black mothers and their infants in the *highest* income families fare worse than the *poorest* non-Hispanic white mothers and infants, and in some cases the difference in outcomes between these groups is quite large.

[22]We calculate residuals using the same coefficient estimates from the regressions of each outcome on fixed effects for maternal age group and an indicator for non-singleton births used in Figure 2.

3.3 Comparing California to Sweden

To contextualize these patterns, we compare the health gradients in California to those observed in Sweden. Figure 5 plots average outcomes by parental income ventile for Sweden (in grey) and California (in black). Infant health outcomes are dramatically better in Sweden, where we observe higher average birth weight and lower rates of preterm birth, LBW, and infant mortality (panels (a)–(d)). Appendix Figure A7 shows the raw gradients in California and Sweden separately for neonatal and post-neonatal mortality rates, in panels (a) and (b), respectively. We find that for both measures, Sweden has substantially lower rates than California at all points in the income distribution. In sum, for all measures of infant health, even the lowest income Swedish mothers have much better outcomes than the wealthiest Californians ($p < 0.001$ for LBW and preterm birth; $p = 0.06$ for infant mortality).

We examine how maternal mortality rates compare across the two countries in panel (e) of Figure 5. Since this is a substantially rarer outcome, the patterns are noisier than for the infant health outcomes just discussed. That said, it appears that maternal mortality rates are lower in Sweden than in California, at least in the bottom half of the income distribution (although the differences are not statistically significant).

Infant health comparisons across countries can be complicated by differences in terms of what is recorded as a live birth versus a stillbirth or miscarriage. In particular, some cases that are classified as (early) infant deaths in California may be classified as stillbirths in Sweden and, thus, omitted from our analysis sample that only captures live births. To account for this reporting difference, we apply the sample restrictions proposed in Chen et al. (2016) to create a sample of births that are unlikely to be categorized as stillbirths in either country: singleton births with at least 22 weeks gestation and a birth weight of at least 500 grams. Gradients based on these restricted samples are shown in Appendix Figure A8. We find that our main conclusions—that infant health is better in Sweden than in California at every point in the income distribution, and that maternal mortality is lower in Sweden than in California at many points in the income distribution—are virtually unchanged in this restricted sample.

We also compare outcomes in Sweden to those in the two racial groups in California with the worst and best infant and maternal health outcomes, respectively: non-Hispanic Blacks and non-Hispanic whites. Figure 6 shows that, at any income ventile, infants born in Sweden have better outcomes than infants in both of these groups. Further, for all birth outcomes, even the lowest income Swedish infants do better than Californian infants at any point in the income distribution in either racial group. In terms of infant mortality, only higher income non-Hispanic white families achieve rates as low as the lowest income Swedish families. When it comes to maternal health, we observe that non-Hispanic white mothers experience mortality rates similar to those of Swedish mothers. Notably, non-Hispanic Black mothers and their infants, regardless of their level of family income, experience significantly higher mortality rates than the lowest income Swedish mothers and their infants.

We examine an additional dimension of inequality within both Sweden and the US by considering the mother's place of birth. While we do not observe the race or ethnicity of the mother in our birth records data from Sweden, we are able to compare foreign-born mothers in Sweden—who may be disadvantaged on some dimensions such as less fluency in the dominant language and less familiarity with local resources—to foreign-born mothers in California, who may face similar disadvantages.[23] This comparison is presented in Figure 7. We see that both foreign-born and US-born mothers in California give birth to less healthy infants than foreign-born and Swedish-born mothers in Sweden, as measured by average birth weight and rates of preterm birth and LBW at all points of the family income distribution. Indeed, infants of foreign-born mothers in Sweden in the poorest families have better birth outcomes than infants of US-born mothers at nearly all points of the income distribution (including the highest-income households). The pattern is similar, although less precise, for infant mortality, which is a rarer outcome. We see no clear pattern in maternal mortality, although given the low rate and smaller population, the Swedish data are quite noisy.[24] Overall, it appears that even the relatively disadvantaged infants in Sweden—those born to immigrant mothers—experience better health at many points of the income distribution when compared to infants of both US-born and foreign-born mothers in California.

Finally, we note that across all of the results just discussed, we use the country-specific income distributions to compare the gradients between California and Sweden. Alternatively, we could use the California income distribution to assign family income percentiles in Sweden. Such an analysis is presented in Appendix Figures A9-A11 and the results of this exercise largely correspond to our findings when using the Swedish income distribution.

[23]We exclude from this analysis foreign-born mothers who are from Nordic countries, since they are more likely to experience similar levels of advantage as Swedish-born mothers.

[24]In our data from Sweden, the sample of foreign-born mothers is strongly concentrated within the lower deciles of the income distribution, with very few mothers in the upper deciles. Thus, the gradients in the rarer outcomes – infant and maternal mortality – are particularly noisy in the upper half of the income distribution.

4 Conclusion

In 2020, the World Index of Healthcare Innovation ranked the United States first in the world in terms of scientific advancement within healthcare (The Foundation for Research on Equal Opportunity, 2020). Indeed, Americans are among the first to gain access to new medical advances, which are often discovered at American universities and developed by American companies. The rapid pace of healthcare innovation is widely credited for the dramatic secular improvements in health that have occurred in the US over the last half century (Newhouse, 1992; Cutler, 2004; Chandra and Skinner, 2012). While innovation has influenced all domains of healthcare, a stream of new technologies targeting infant and maternal health have raised the prospects of keeping more and more infants and their mothers alive and healthy.[25]

America's superior healthcare innovation climate and world-class pediatric hospitals[26] may help explain one of our paper's key findings: Infants born into households with an abundance of resources—who may be the most likely to benefit from these effective but expensive medical interventions—are the most likely to survive to age one despite having the *lowest* birth weight and *highest* rates of prematurity. This finding suggests that it is technologically and medically feasible to counter the health disadvantages of low birth weight and prematurity by age one.

At the same time, our results underscore that these benefits do not "trickle down" to all Californians. Infants in lower income families experience higher mortality rates in the first year of life despite being observably healthier in terms of birth weight and gestation length than their highest income counterparts. Similarly, rates of maternal mortality are greatest among the lowest income mothers.

Further, these socio-economic differences are amplified by a deep racial divide. In fact, the infant and maternal health gaps between non-Hispanic white and non-Hispanic Black families—the groups that fare the best and worst, respectively—are larger than the income differences within race. The stark inequities by income and race in California are particularly striking given that the state has one of the most generous social safety net systems in the US, and is also well-known for its efforts to improve maternal and infant health outcomes and address racial disparities. For example, since the 1980s, California has operated the Comprehensive Perinatal Services Program, an enhanced prenatal

[25] Examples of such innovations in neonatal care include the development of surfactant, Continuous Positive Airway Pressure (CPAP), Extracorporeal Membrane Oxygenation (ECMO), neonatal resuscitators, and more recently neonatal kidney therapy; examples in postpartum care include medical technologies to prevent postpartum hemorrhage, and more recently new diagnostic tools in the treatment of pre-eclampsia.

[26] According to a recent ranking, more than half of the top twenty pediatric hospitals in the world are located in the United States (Newsweek, 2022).

care program for women receiving Medicaid, and the Black Infant Health Program, which provides prenatal and support services to Black mothers regardless of their income level. More recently, the California Maternal Quality Care Collaborative, a public-private partnership founded in 2006, has led clinical quality improvement initiatives throughout the state and is largely credited with helping to decrease the state's overall maternal mortality rate.[27] Despite these efforts, the disparities in maternal and infant health outcomes across racial groups are substantial and show no convergence even at higher incomes.

Additionally, we find that mothers and infants in California fare worse than their counterparts in Sweden on almost all measures of health. Remarkably, this is true even for the infants and mothers who are likely to have access to the best healthcare in California—non-Hispanic white families at the very top of the income distribution. Thus, despite the United States' leading position in healthcare innovation and pediatric care, no group of Californian babies and mothers come close to the infant and maternal health enjoyed in Sweden.

While the causal drivers of the socioeconomic, racial, and international gaps that we document are beyond the scope of this paper, we speculate that a variety of potential mechanisms may be relevant. Recent evidence suggests that differences in access to and utilization of high-quality healthcare across the income distribution may be amplified by a racial gradient. Black infants and mothers may face disproportionate supply-side barriers within the healthcare system (e.g., due to financial incentives within the Medicaid managed care reimbursement system, as in Kuziemko et al., 2018), as well as demand-side barriers rooted in a long history of racism (Green et al., 2021; Green and Darity Jr, 2010).[28] In addition, a large and persistent racial wealth gap in the US (Derenoncourt et al., 2022), policy-induced racial segregation (Collins et al., 1998; Aaronson et al., 2020, 2021), racial disparities in pollution exposure (Currie et al., 2020b), and cumulative stress due to racial discrimination (Geronimus et al., 2006; Collins et al., 2009; Love et al., 2010) are likely other important causes of poor health outcomes among Black Americans.

Finally, the more advantageous health outcomes in Sweden, as compared to the US, may emphasize the importance of equitable access to healthcare both throughout the life cycle and at the time of pregnancy and childbirth, as well as social and economic aspects of the postpartum environment such as universal access to paid family leave. Understanding the relative importance of these potential

[27]See https://www.vox.com/science-and-health/2017/6/29/15830970/women-health-care-maternal-mortality-rate for more details.

[28]See also Alsan and Wanamaker (2018) for evidence on this mechanism among older Black men.

mechanisms remains a critical area for future work.

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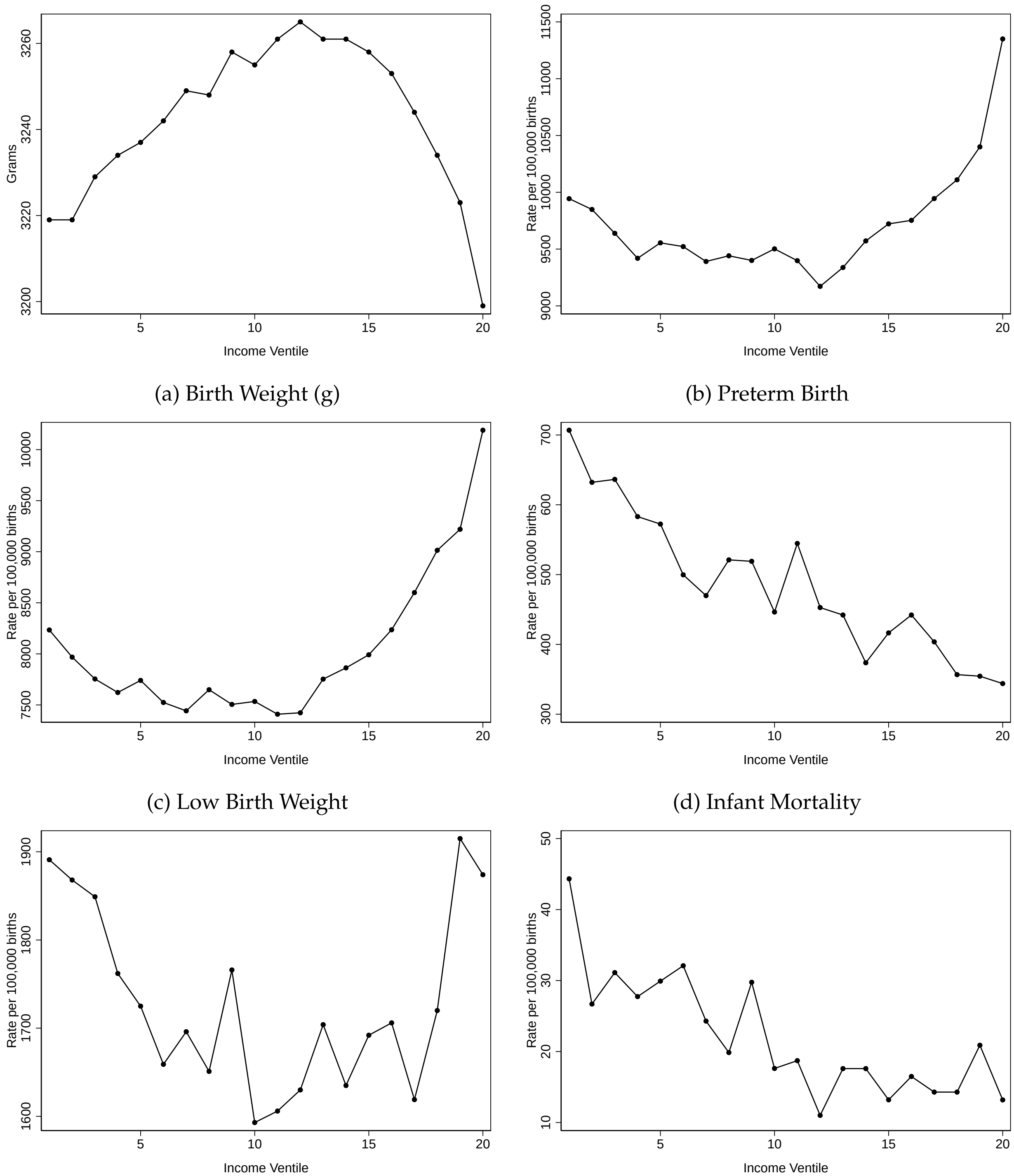
Figure 1: California Infant and Maternal Health Income Gradients



(a) Birth Weight (g)

(b) Preterm Birth

(c) Low Birth Weight

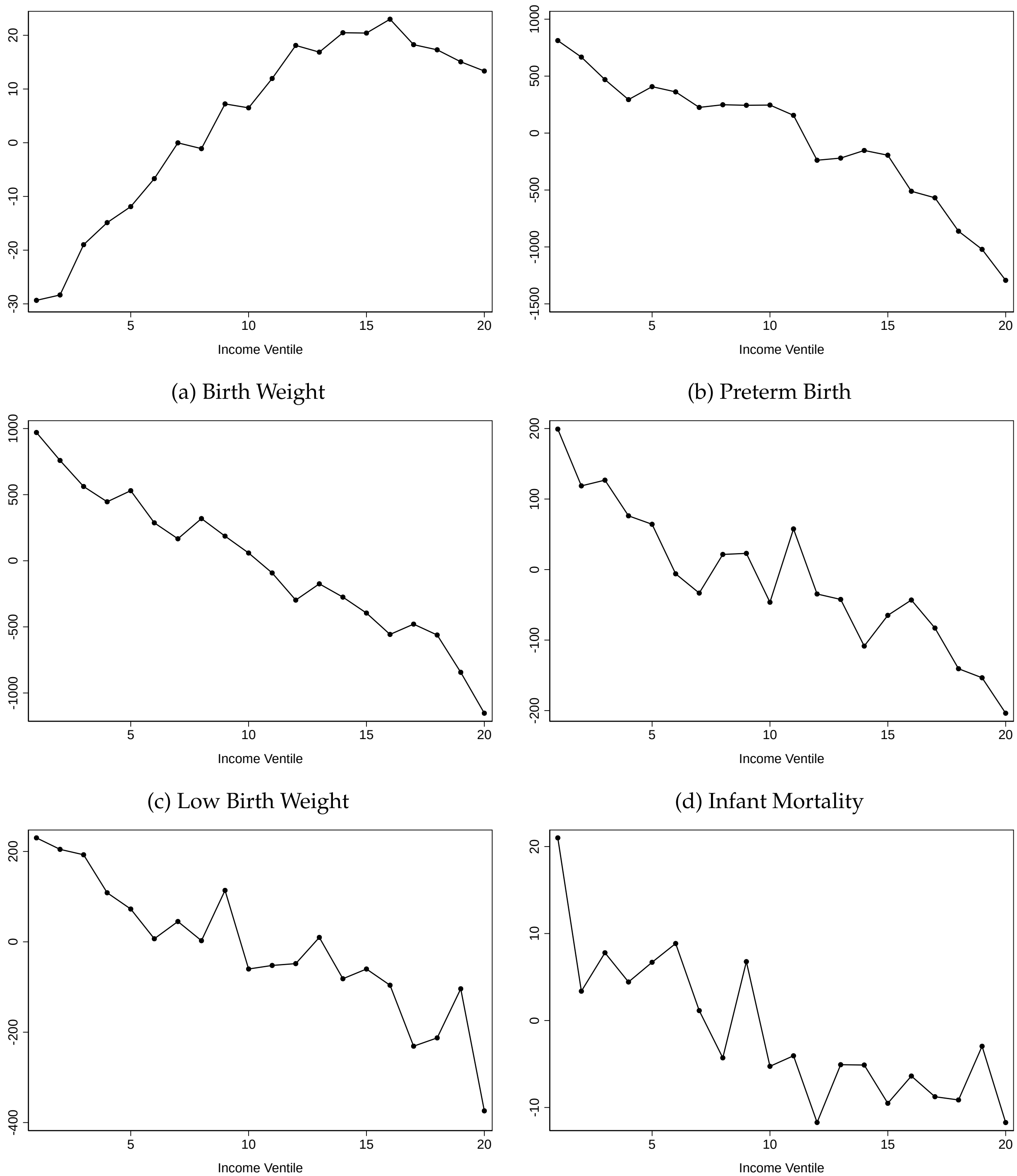
(d) Infant Mortality

(e) Severe Maternal Morbidity

(f) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on first births in California between 2007-2016 averaged within income bins corresponding to ventiles of the family income distribution in each birth year. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure 2: California Residualized Infant and Maternal Health Income Gradients



(a) Birth Weight

(b) Preterm Birth

(c) Low Birth Weight

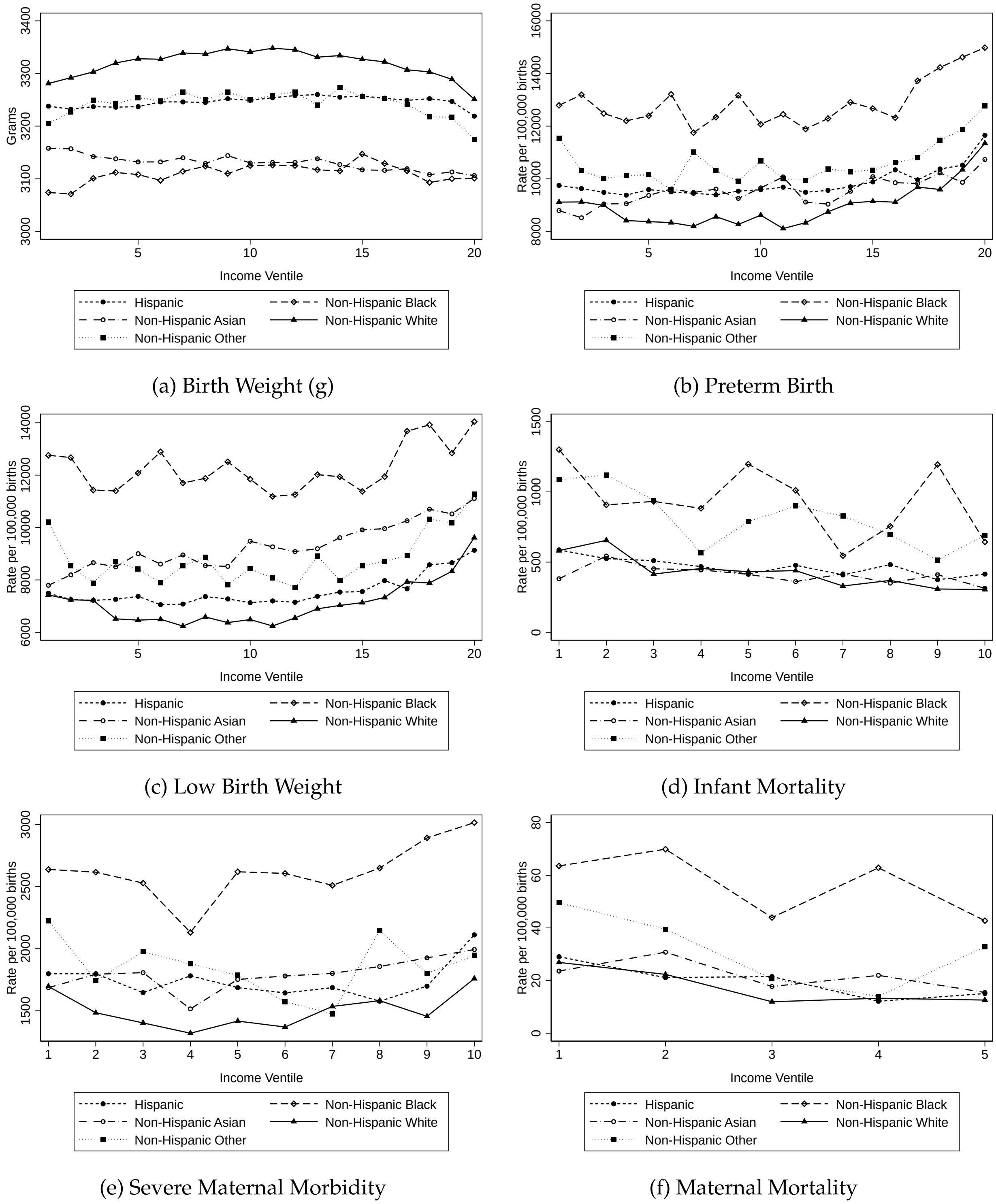
(d) Infant Mortality

(e) Severe Maternal Morbidity

(f) Maternal Mortality

Notes: Figure plots average of residuals from a regression of measures of infant and maternal health on maternal age and non-singleton birth. The analysis used data on all first births in California between 2007-2016. Binned residuals are plotted against income bins corresponding to ventiles of the family income distribution in each birth year. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure 3: California Infant and Maternal Health Income Gradients by Racial and Ethnic Groups



(a) Birth Weight (g)

(b) Preterm Birth

(c) Low Birth Weight

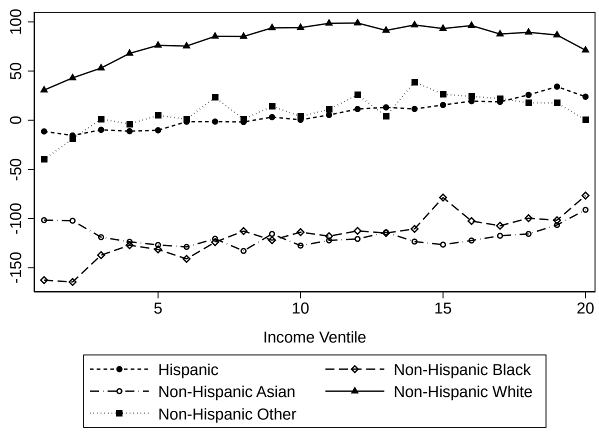
(d) Infant Mortality

(e) Severe Maternal Morbidity

(f) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on first births in California between 2007-2016 averaged within income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year. Averages are separated into subgroups based on maternal race and ethnicity. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure 4: California Residualized Infant and Maternal Health Income Gradients by Racial and Ethnic Groups



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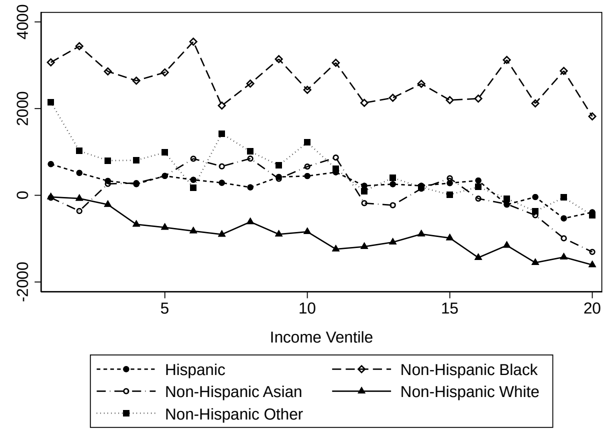
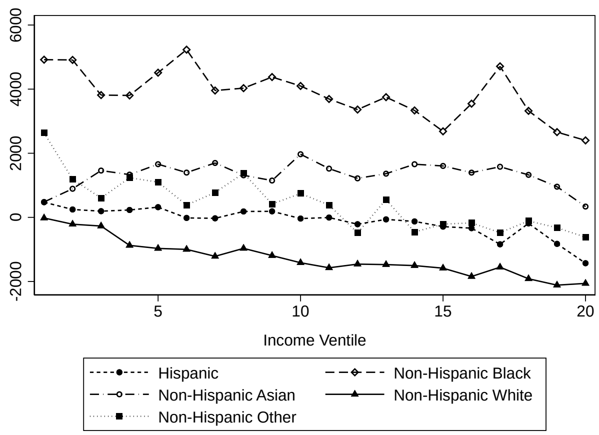
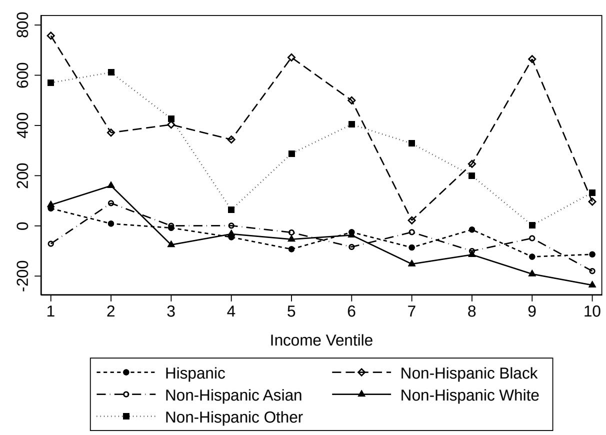


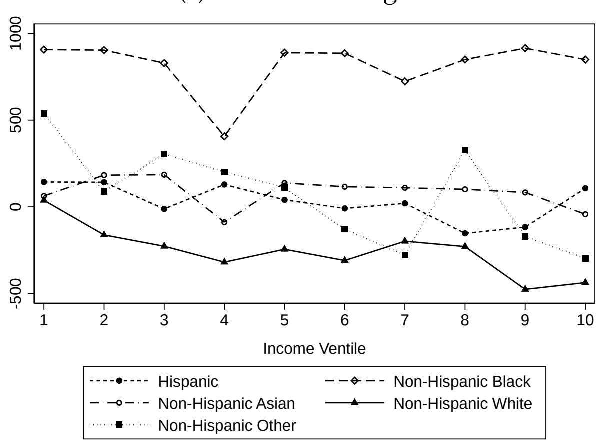
(b) Preterm Birth



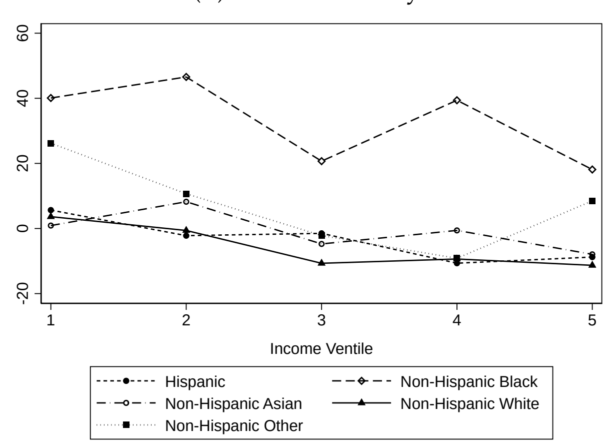
(c) Low Birth Weight



(d) Infant Mortality



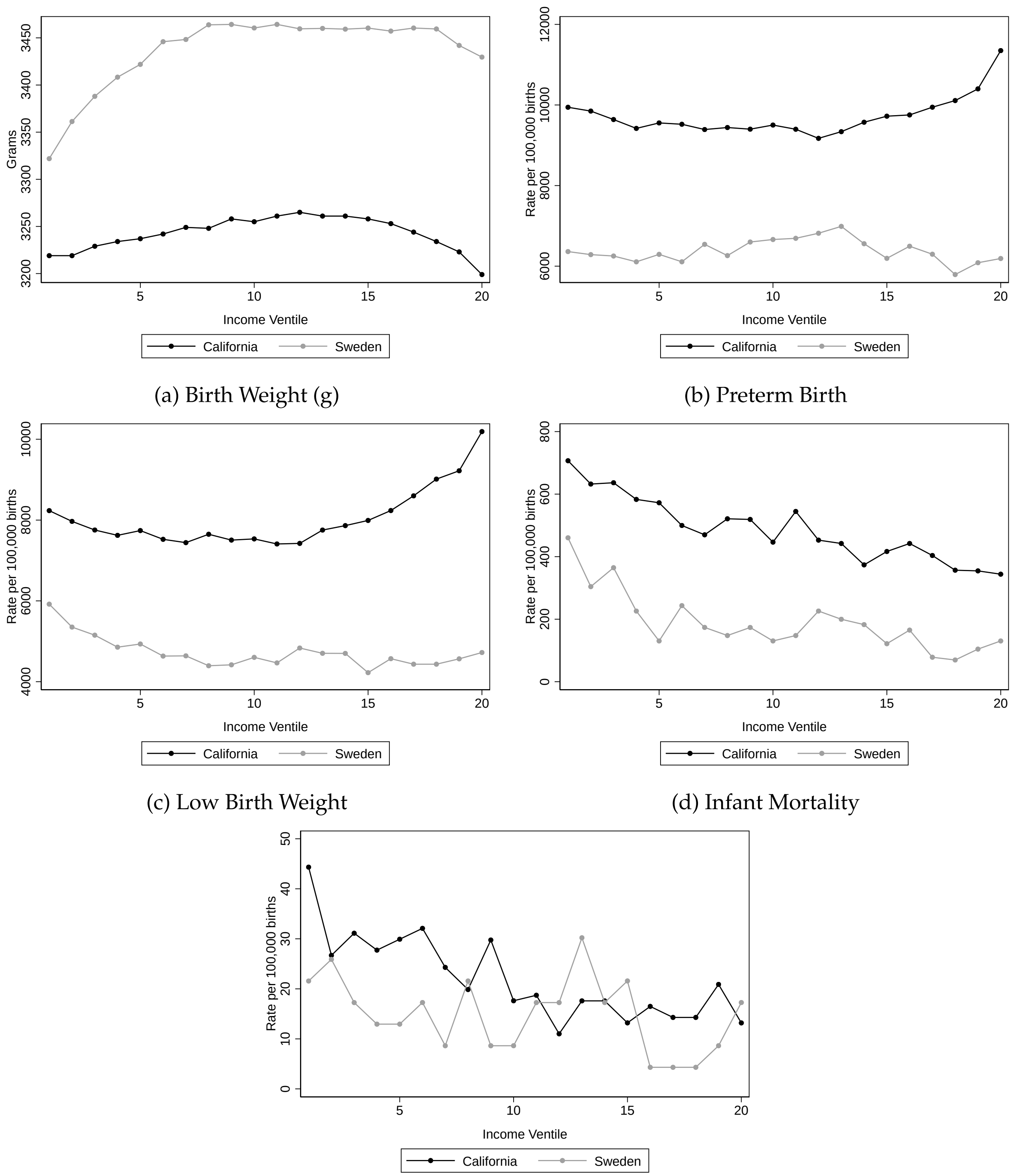
(e) Severe Maternal Morbidity



(f) Maternal Mortality

Notes: Figure plots average of residuals from a regression of measures of infant and maternal health on maternal age and non-singleton birth. The analysis used data on all first births in California between 2007-2016. Binned residuals are plotted against income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year, separated into subgroups based on maternal race and ethnicity. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure 5: Infant and Maternal Health Income Gradients, California vs. Sweden



(a) Birth Weight (g)

(b) Preterm Birth

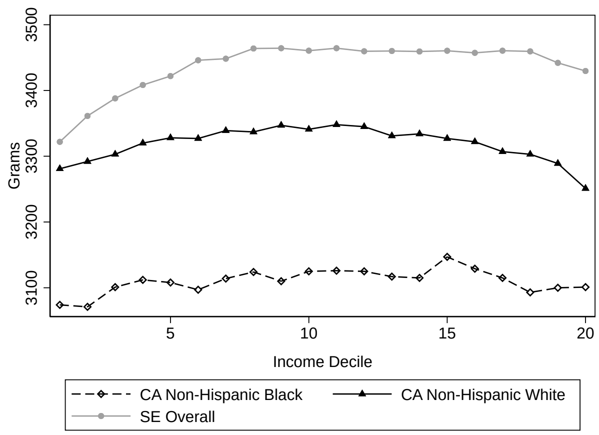
(c) Low Birth Weight

(d) Infant Mortality

(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on first births in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles of the family income distribution in each birth year. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure 6: Infant and Maternal Health Income Gradients by Racial and Ethnic Groups, California vs. Sweden



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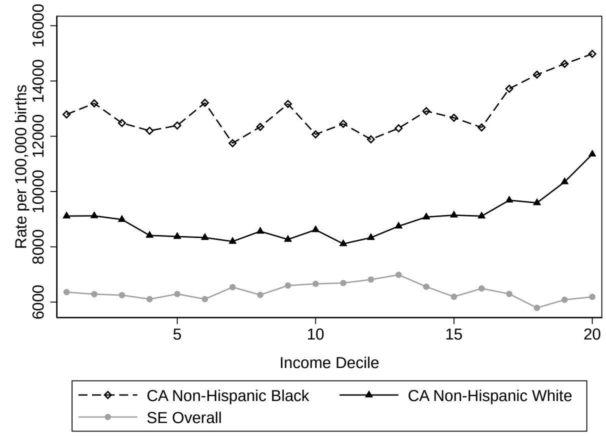
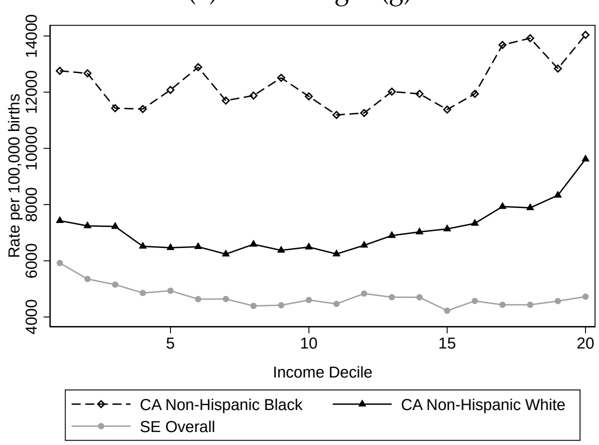
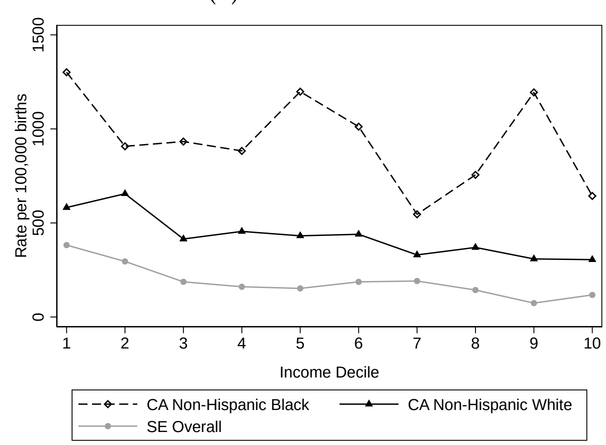


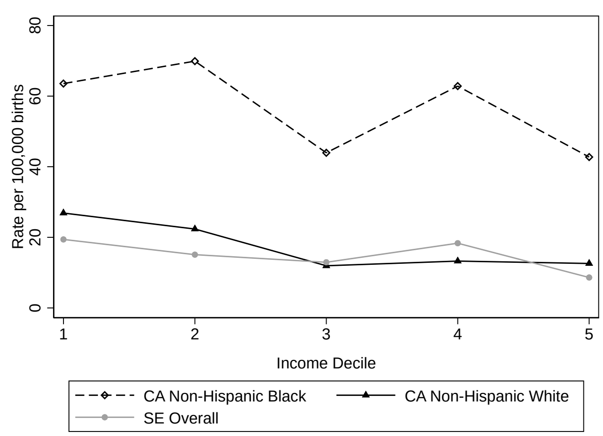
(b) Preterm Birth



(c) Low Birth Weight



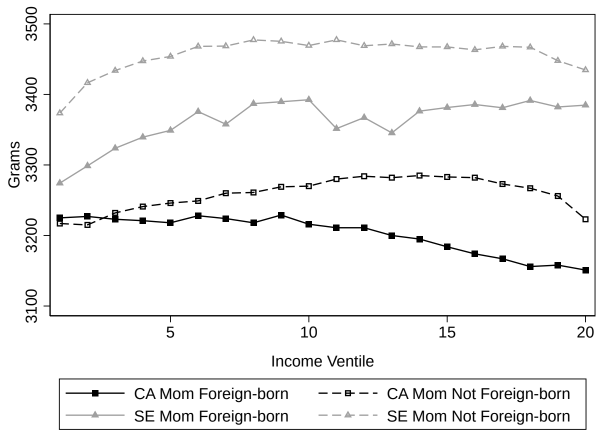
(d) Infant Mortality



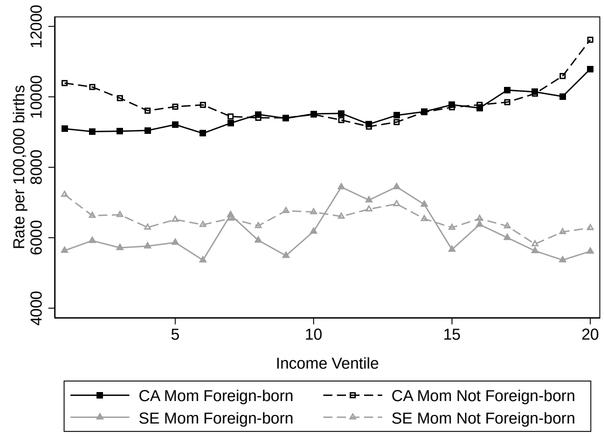
(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on first births in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year. Averages are separated into subgroups based on maternal race and ethnicity. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

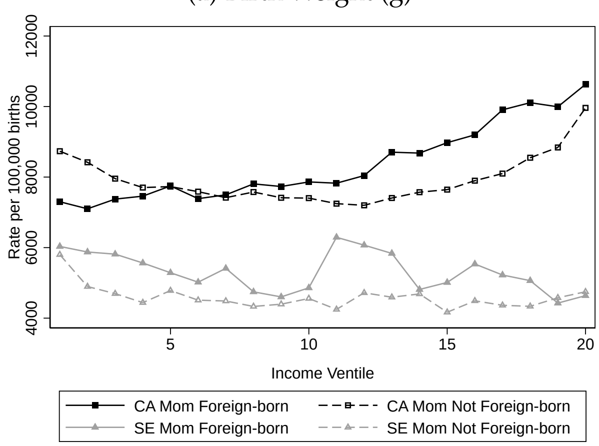
Figure 7: Infant and Maternal Health Income Gradients by Foreign-Born Status of Mother, California vs. Sweden



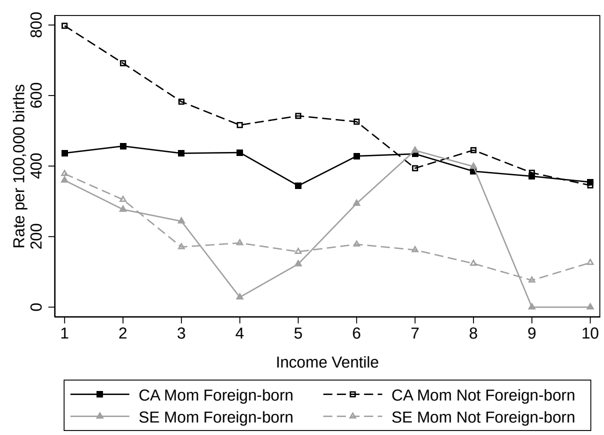
(a) Birth Weight (g)



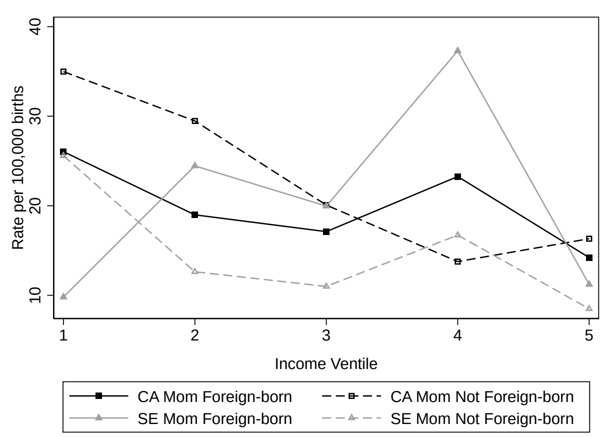
(b) Preterm Birth



(c) Low Birth Weight



(d) Infant Mortality

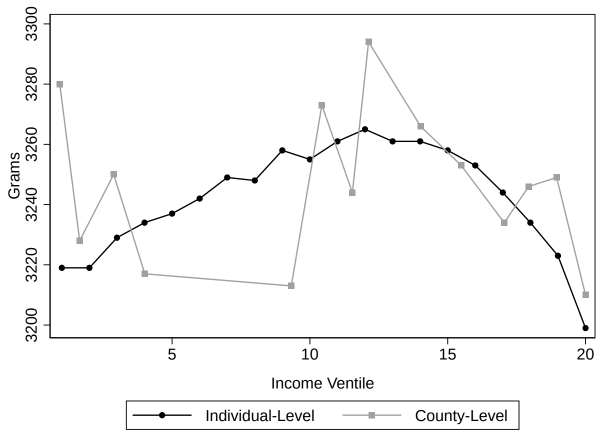


(e) Maternal Mortality

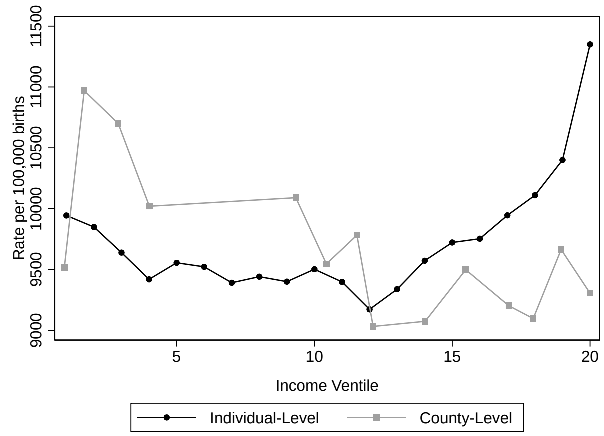
Notes: Figure plots infant and maternal health outcomes based on first births in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year. Averages are separated into subgroups based on maternal foreign born status. In these figures, the Swedish sample excludes foreign-born mothers who are from Nordic countries. See text for more details. All California results were approved for release by the by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

A Appendix Figures

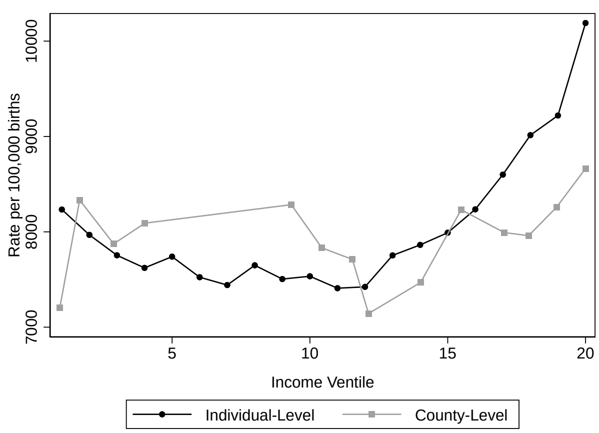
Figure A1: California Infant and Maternal Health Income Gradients, Individual Family Income vs. County-Level Median Income



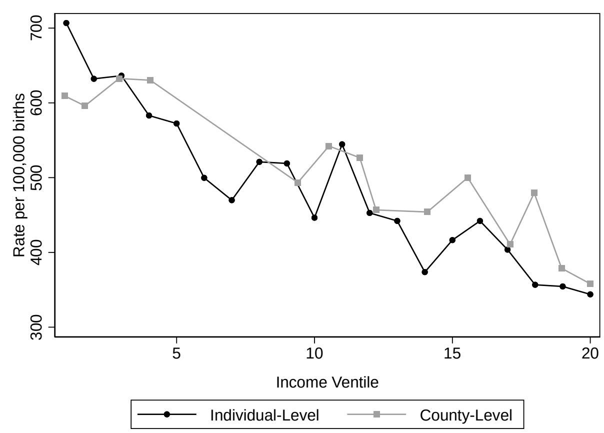
(a) Birth Weight (g)



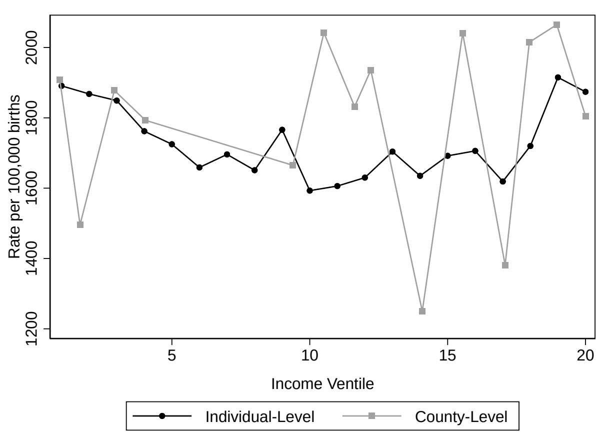
(b) Preterm Birth



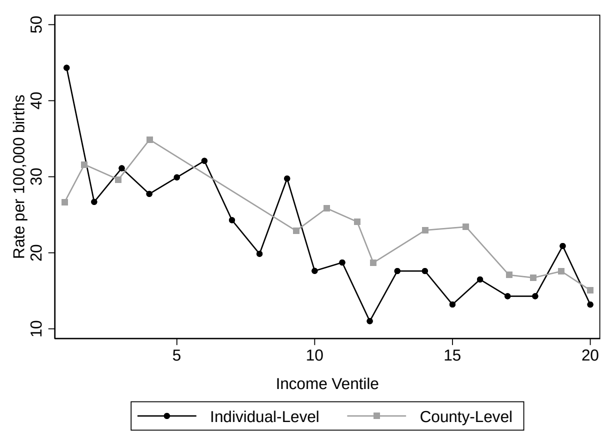
(c) Low Birth Weight



(d) Infant Mortality



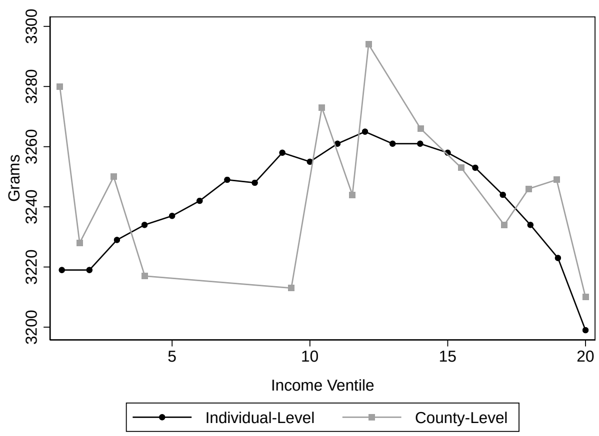
(e) Severe Maternal Morbidity



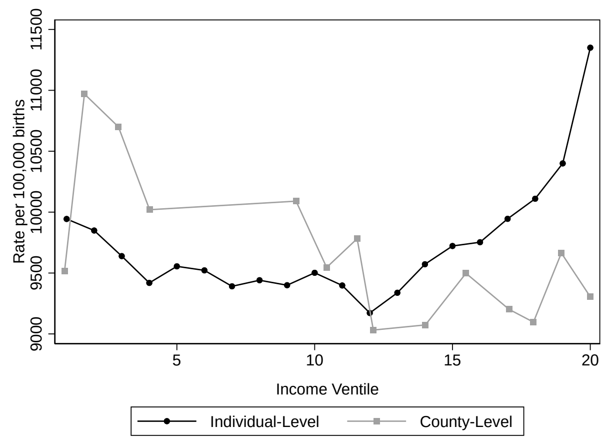
(f) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California between 2007-2016 averaged within income bins of the family income distribution, calculated either using individual family incomes (in the darker series with circles) or based on county-level median income (in the lighter series with squares). See text for more details about the family income calculation. The county groupings are formed by ranking counties by median household income measured in the 2010 Small Area Income and Poverty Estimates (SAIPE) Program of the US Census Bureau, and then combining counties into 5 percent groups as closely as possible. Larger counties (e.g., Los Angeles county, which accounts for 26 percent of births in California) are in their own bin. There are 14 county-level bins and 20 individual-level bins in total. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

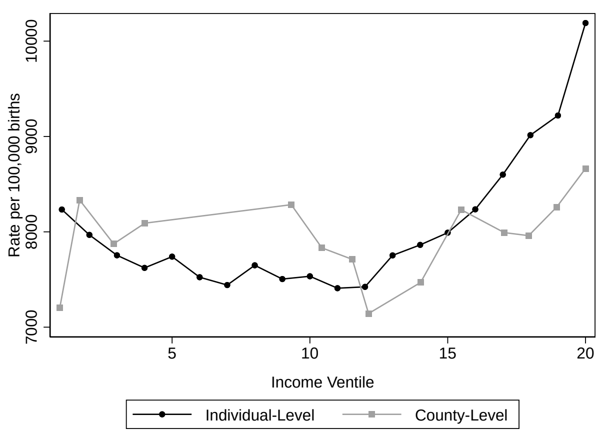
Figure A2: California Infant and Maternal Health Income Gradients, Individual Family Income vs. County-Level Poverty Rates



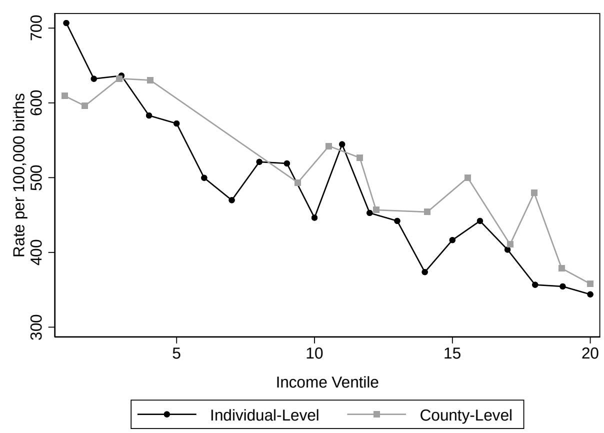
(a) Birth Weight (g)



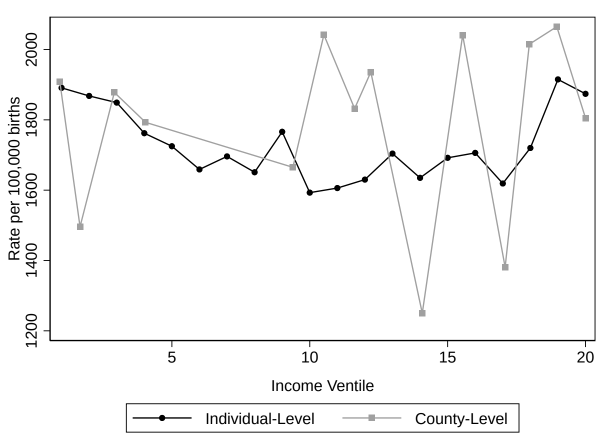
(b) Preterm Birth



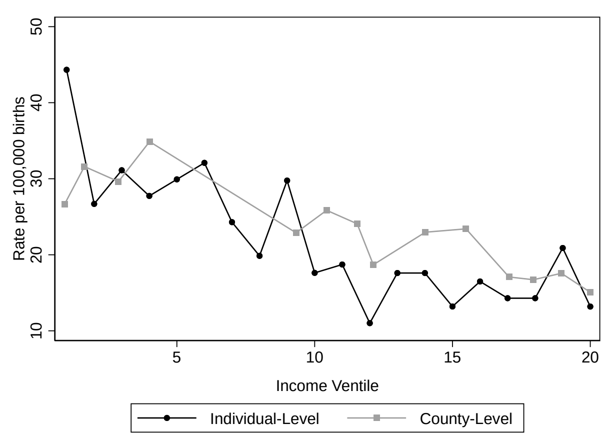
(c) Low Birth Weight



(d) Infant Mortality



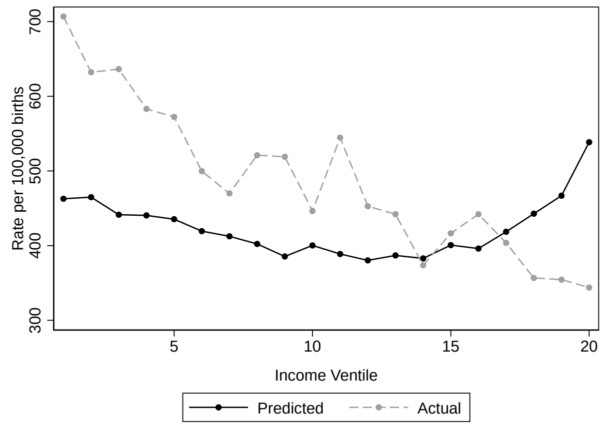
(e) Severe Maternal Morbidity



(f) Maternal Mortality

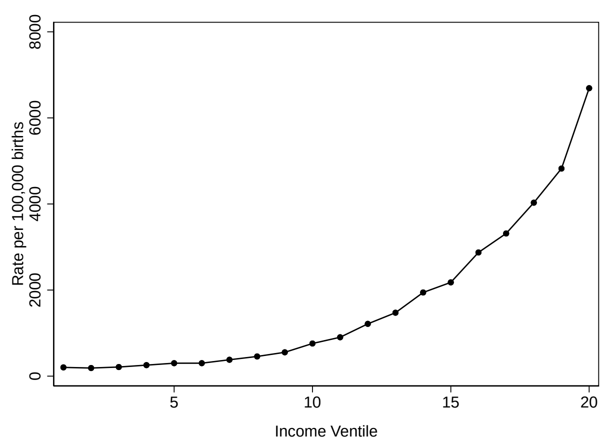
Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California between 2007-2016 averaged within income bins of the family income distribution, calculated either using individual family incomes (in the darker series with circles) or based on county-level poverty rates (in the lighter series with squares). See text for more details about the family income calculation. The county groupings are formed by ranking counties by the poverty rate measured in the 2010 Small Area Income and Poverty Estimates (SAIPE) Program of the US Census Bureau, and then combining counties into 5 percent groups as closely as possible. Larger counties (e.g., Los Angeles county, which accounts for 26 percent of births in California) are in their own bin. There are 14 county-level bins and 20 individual-level bins in total. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure A3: Predicted versus Actual Infant Mortality Income Gradients



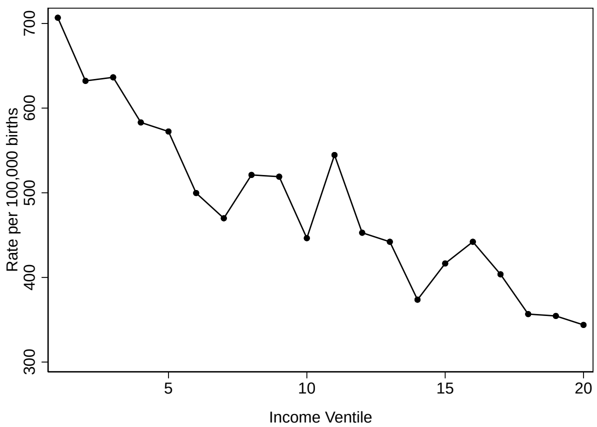
Notes: Figure plots predicted infant mortality (in black solid line) and actual infant mortality (in dashed grey line) based on births to first-time mothers in California between 2007 and 2011, averaged within income bins corresponding to ventiles of the family income distribution in each birth year. Predicted infant mortality is generated from a regression of infant mortality on birth weight, a low-birthweight indicator, gestation length, and a preterm birth indicator. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure A4: California Assisted Reproductive Technology (ART) Use Income Gradient

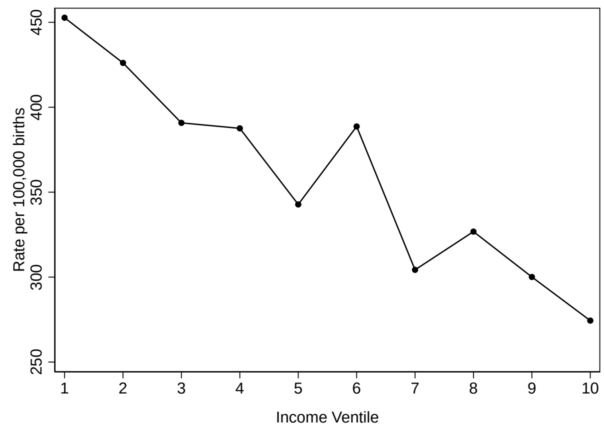


Notes: Figure plots assisted reproductive technology (ART) use rates based on births to first-time mothers in California between 2007 and 2016, averaged within income bins corresponding to ventiles of the family income distribution in each birth year. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

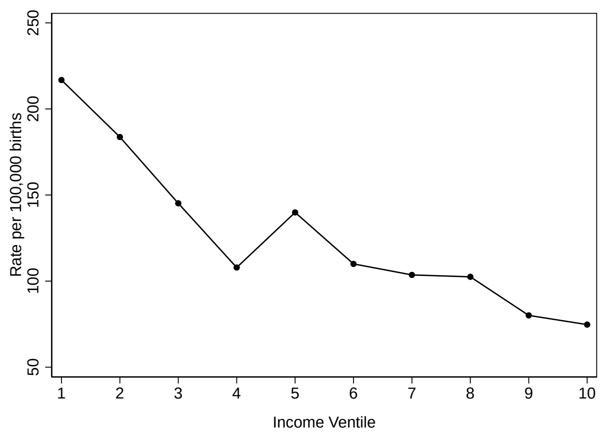
Figure A5: California Infant Mortality Income Gradients: Neonatal vs. Post-Neonatal Mortality



(a) Infant Mortality



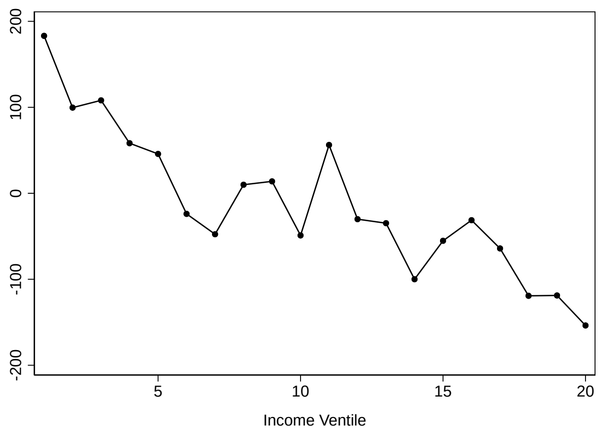
(b) Neonatal Mortality



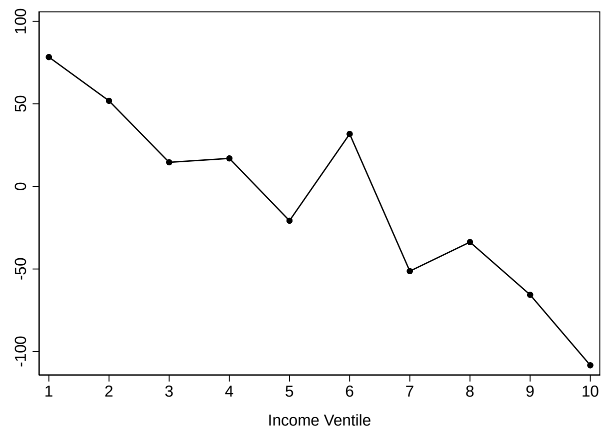
(c) Post-Neonatal Mortality

Notes: Figure plots infant mortality outcomes based on births to first-time mothers in California between 2007-2011 averaged within income bins corresponding to ventiles or deciles of the family income distribution in each birth year. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

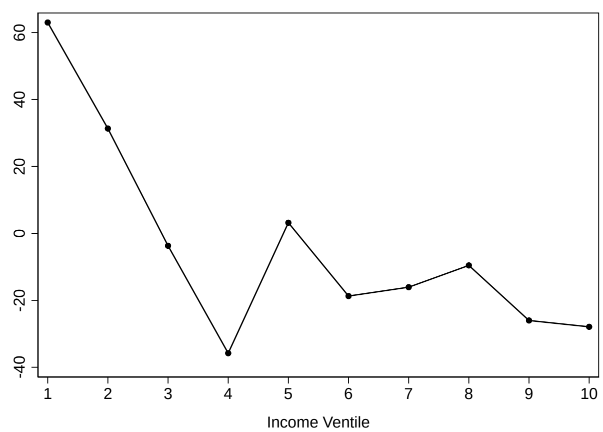
Figure A6: California Residualized Infant Mortality Income Gradients: Including Hospital Fixed Effects



(a) Infant Mortality



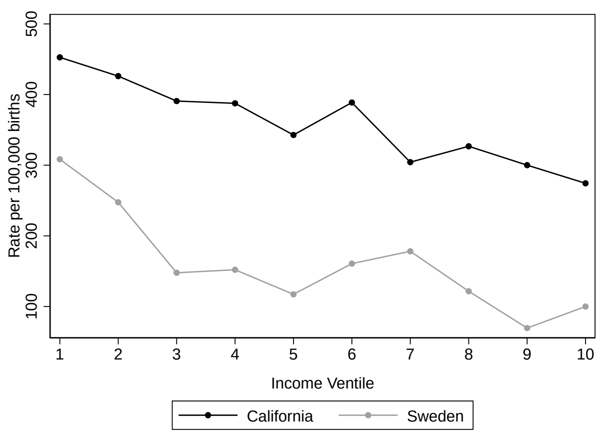
(b) Neonatal Mortality



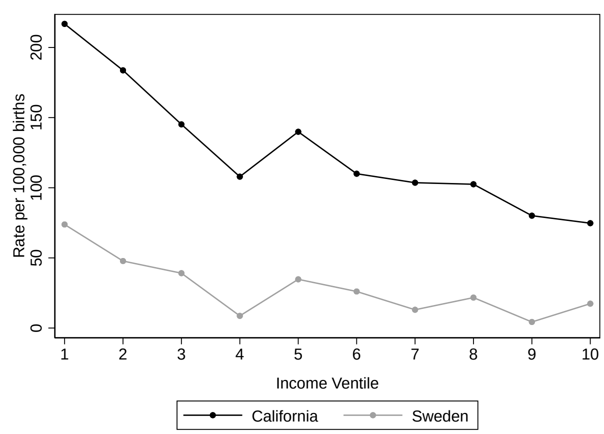
(c) Post-Neonatal Mortality

Notes: Figure plots average of residuals from a regression of measures of infant mortality outcomes on maternal age, non-singleton birth, and childbirth hospital fixed effects. The analysis used data on births to first-time mothers in California between 2007-2011. Binned residuals are plotted against income bins corresponding to ventiles or deciles of the family income distribution in each birth year. See text for more details. All results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

Figure A7: Infant Mortality Income Gradients: Neonatal vs. Post-Neonatal Mortality, California vs. Sweden



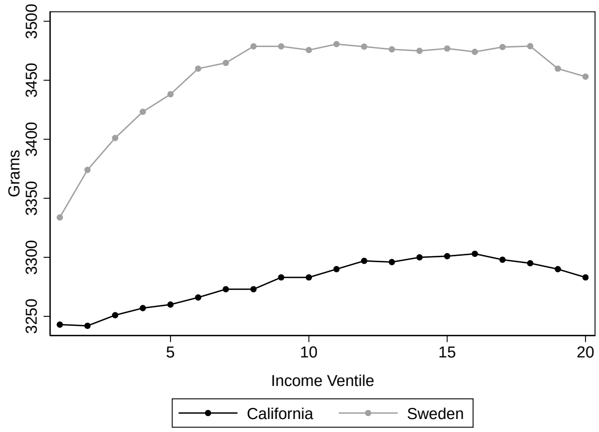
(a) Neonatal Mortality



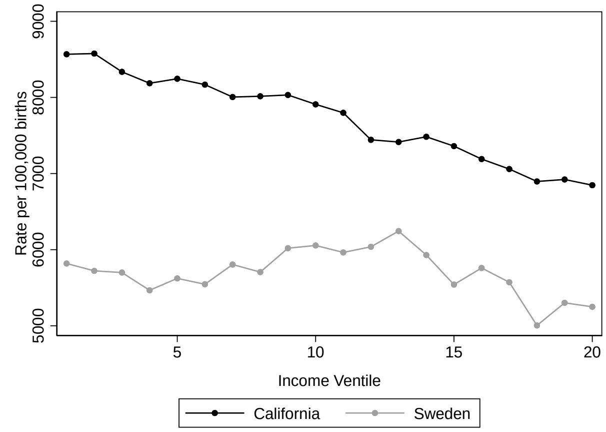
(b) Post-Neonatal Mortality

Notes: Figure plots infant mortality outcomes based on births to first-time mothers in California and Sweden between 2007-2011 averaged within income bins corresponding to deciles of the family income distribution in each birth year. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

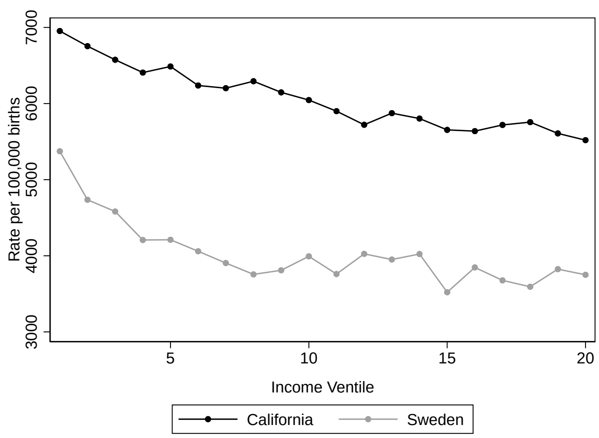
Figure A8: Infant and Maternal Health Income Gradients, California vs. Sweden using Chen, Oster & Williams (2016) Sample Restriction



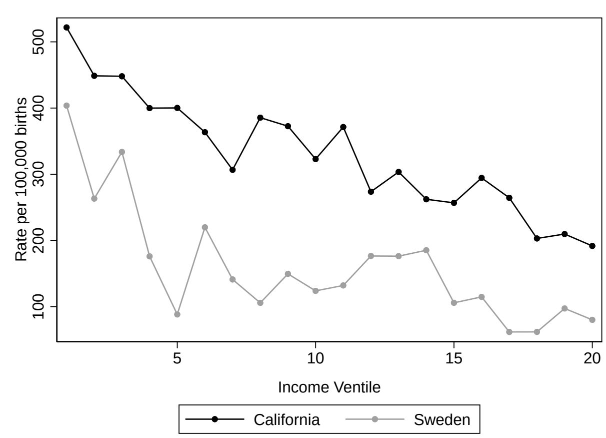
(a) Birth Weight (g)



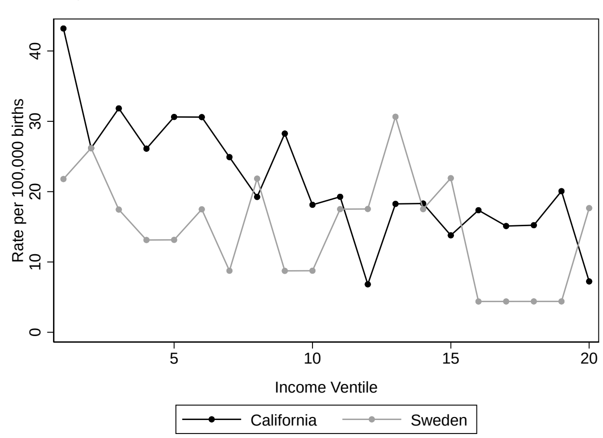
(b) Preterm Birth



(c) Low Birth Weight



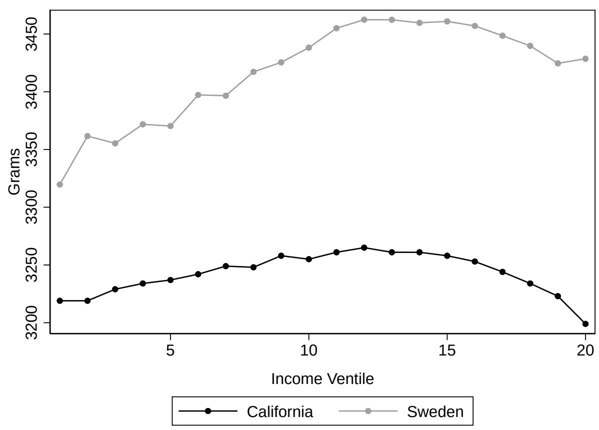
(d) Infant Mortality



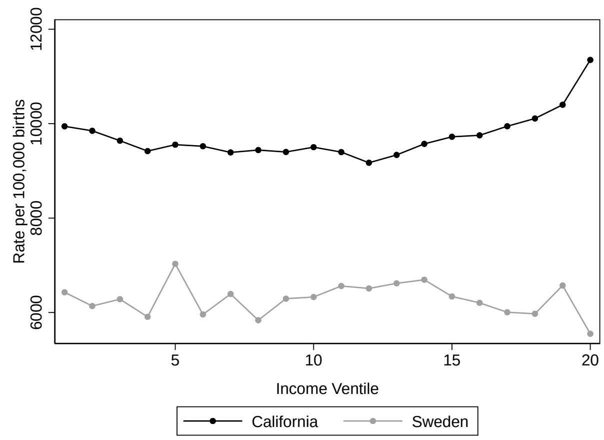
(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles of the family income distribution in each birth year. The sample here is limited to singleton births with gestation length of at least 22 weeks and birth weight of at least 500 grams, following Chen et al. (2016). All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

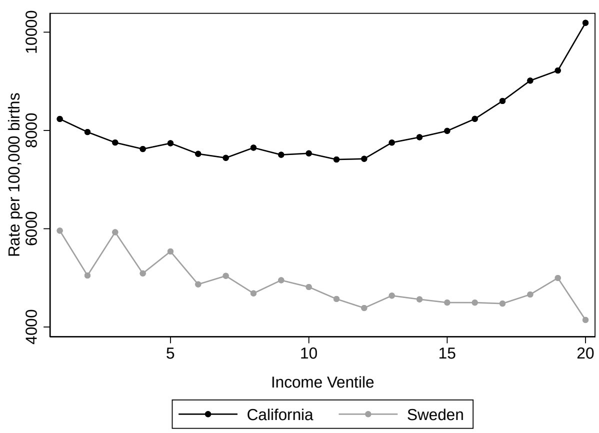
Figure A9: Infant and Maternal Health Income Gradients, Swedish Comparison using CA Percentiles



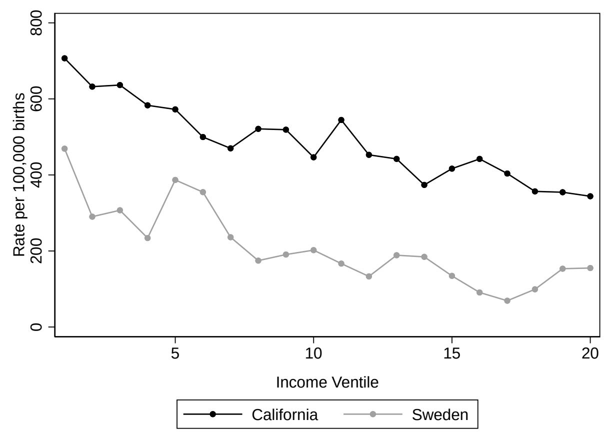
(a) Birth Weight (g)



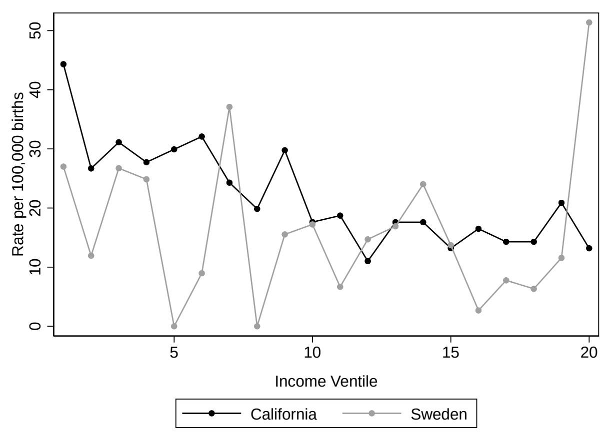
(b) Preterm Birth



(c) Low Birth Weight



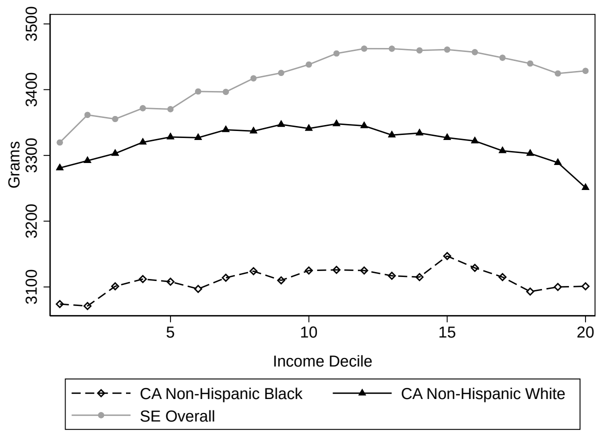
(d) Infant Mortality



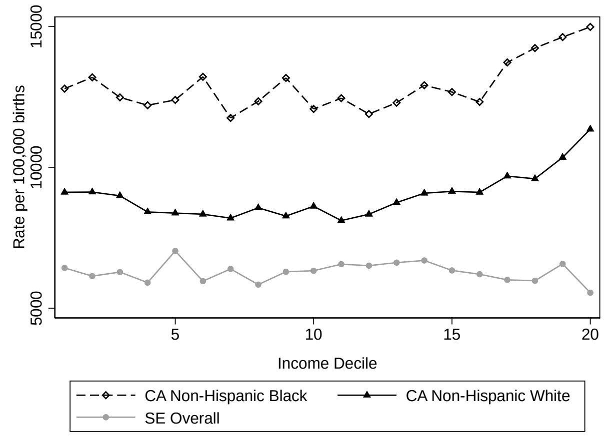
(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles of the family income distribution in each birth year. The income bins are defined using the California income percentiles by birth year. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

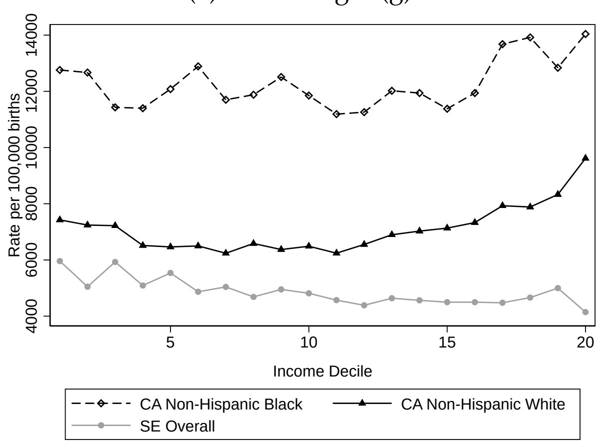
Figure A10: Infant and Maternal Health Income Gradients by Racial and Ethnic Groups, Swedish Comparison using CA Percentiles



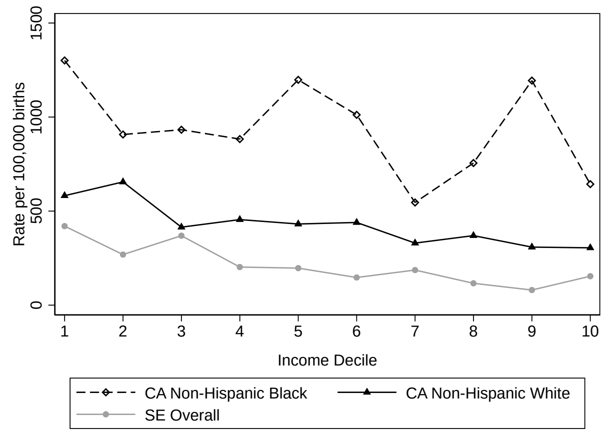
(a) Birth Weight (g)



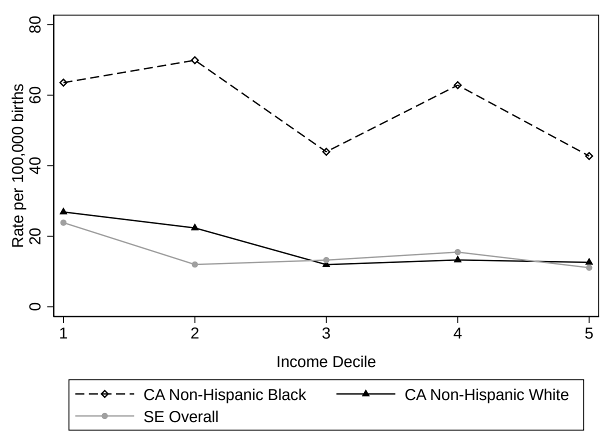
(b) Preterm Birth



(c) Low Birth Weight



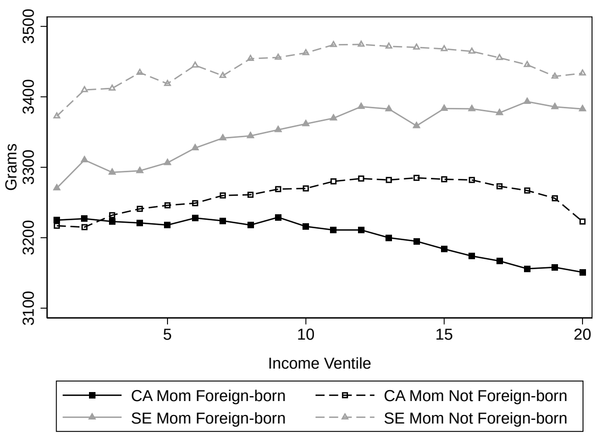
(d) Infant Mortality



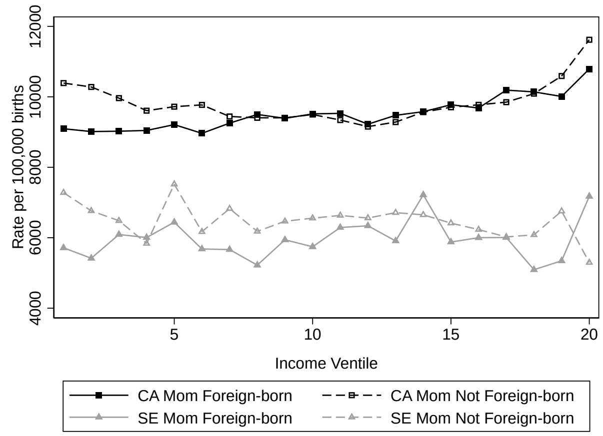
(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year. The income bins are defined using the California income percentiles by birth year. Averages are separated into subgroups based on maternal race and ethnicity. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

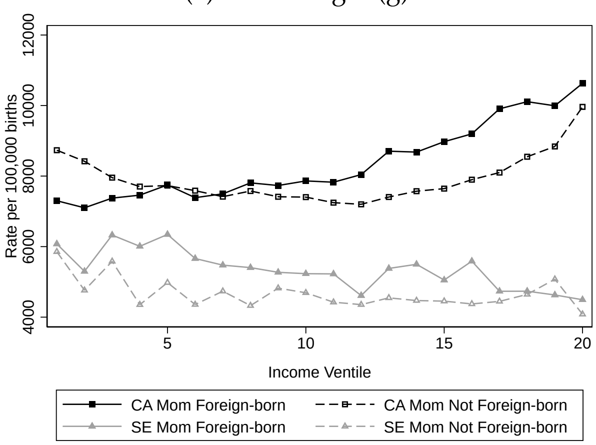
Figure A11: Infant and Maternal Health Income Gradients by Foreign-Born Status of Mother, Swedish Comparison using CA Percentiles



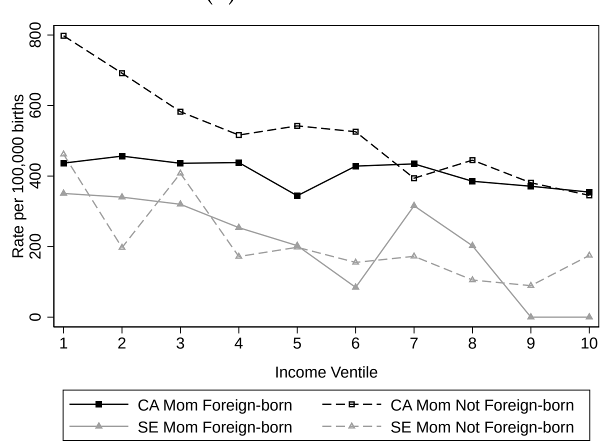
(a) Birth Weight (g)



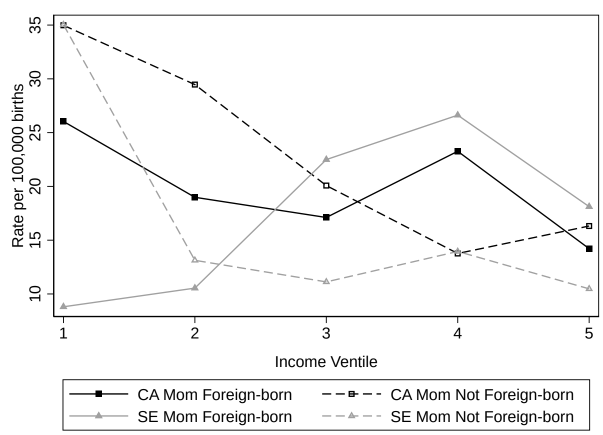
(b) Preterm Birth



(c) Low Birth Weight



(d) Infant Mortality



(e) Maternal Mortality

Notes: Figure plots infant and maternal health outcomes based on births to first-time mothers in California and Sweden between 2007-2016 averaged within income bins corresponding to ventiles, deciles, or quintiles of the family income distribution in each birth year. The income bins are defined using the California income percentiles by birth year. Averages are separated into subgroups based on maternal foreign born status. In these figures, the Swedish sample excludes foreign-born mothers who are from Nordic countries. See text for more details. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.

B Additional Details About Data, Sample, and Analyses

We provide more details on our data, sample, key variables, and analyses in this section.

Infant Mortality in the California Data: Our measure of infant mortality in California is primarily based on infant death information from the California Department of Health Care Access and Information (HCAI) Linked Birth Files, which have mortality information from the California Department of Public Health (CDPH) Birth Cohort Files. These annual files are issued by the CDPH approximately 12 months after the end of the calendar year. Our research team has linked these records to confidential versions of the 2007-2011 Static Birth Statistical Master Files (BSMF) received directly from CDPH, and which contain the identifying information for the child and parents used in our analyses. The BSMF files are generated at an earlier time point than the Birth Cohort File, at approximately ten months after the end of the calendar year, and do not include any additional records, amendments, or updates made following file generation. For this reason, there are slight differences in the infant mortality rates estimated for births in our data source (BSMF linked to the Birth Cohort File) and those published by CDPH using the Birth Cohort File alone. Additional documentation on each of these data sources and their differences may be found in the Birth Data Sources Comparison Chart on the following CDPH website: https://www.cdph.ca.gov/Programs/CHSI/Pages/Data%20Types%20and%20Limitations.aspx.

Table B1 reports the infant mortality rates for California residents by year calculated from the data used in our analyses, as described above.

Table B1: Infant Mortality Rates for California Residents by Year

Year	Total deaths	Total births	IMR per 1,000 births
2007	2,912	566,125	5.14
2008	2,804	551,557	5.08
2009	2,541	526,770	4.82
2010	2,420	509,968	4.75
2011	2,345	502,019	4.67

Notes: Table presents total infant deaths and total infant births calculated from the 2007-2011 HCAI Linked Birth Files merged to the 2007-2011 CDPH Static Birth Statistical Master Files used in our analyses. Following the methodology used for official CDPH infant mortality statistics, these numbers exclude non-California residents.

Identifying Parents in California Tax Records: For infants for whom we cannot find information on parents, either in the birth record or Census survey data, we do the following: First, if we are missing information on both parents, but we observe the infant is listed on a tax filing in the year of birth that contains information on one or two filers, then we assume the filer(s) are the missing parent(s). Second, if infants are missing information on only one parent, we look for infants listed on tax filings where the identified parent is listed as a filer and assume the second filer is the other missing parent. In cases where the gender of the parent is unknown, we exclude these observations from our analysis of maternal outcomes.

Income in the California Data: To construct "AGI-like" income, we use information on AGI and taxable Social Security benefits from the US tax records, wages from W2 forms, and, in a small number of cases, earnings from the LEHD data.

Specifically, for each parent, we use:

- If parent filed: AGI-like income = AGI−taxable Social Security benefits
- If parent did not file: AGI-like income = wage earnings

After calculating the AGI-like income for each parent that we can observe in the data, we determine the family AGI to be:

- If the mother filed jointly: Family AGI-like income = joint parent income
  - For the few cases in which the mother's AGI does not match the father's AGI (for example, sometimes one of the parent's AGI is recorded as 0 while the other is not), we use the parent with the higher AGI
- If the mother did not file jointly, we construct the family AGI as the sum of each parent's separate AGI-like income, where:
  - If we have both parents' incomes: Family AGI-like income = mother's AGI-like income + father's AGI-like income
  - If we only have one parent's income: Family AGI-like income = that parent's AGI-like income

We are unable to observe a parent's income for two reasons: (i) we cannot identify the parent for a given child, or (ii) we have the parent's identifier but their income is missing. When either case occurs, we use only the observable parent's income as the family AGI-like income.

Family income ranking at birth is assigned based on the average of family AGI-like income in the two years before the child was born relative to other families with children in the same birth cohort. For a child born in year t, the average family income is defined as:

$$AvgFamilyIncome_t = \frac{FamilyAGI_{t-1} + FamilyAGI_{t-2}}{2}$$

If the family AGI-like income is available for only one of the two years prior to the birth, we use that year's income as the $AvgFamilyIncome_t$ instead of calculating the average between years. Additionally, if family AGI is negative in either year, missing, or reported to be 0, the child is dropped from the main analysis sample and considered separately. After restricting the sample to births of first-time mothers with non-missing positive family income, we assign income ranking relative to other parents with children in the same birth cohort.

Finally, for parents who are dependents themselves, we consider the dependent's AGI and Social Security benefits to be the one reported in the federal tax records; this is likely their household income.

Income in the Swedish Data: Using administrative data from Statistics Sweden, we construct an individual-level "AGI-like" income measure for each parent. Specifically, we take the sum of income from employment and work-related benefits, positive income from active self-employment, income from passive self-employment, capital income, unemployment benefits, educational transfers, income during studies from different education support programs, income from military service, parental leave benefit income, income from benefits for taking care of a child who is sick or disabled, and income from benefits for taking care of a young child at home.

After calculating the AGI-like income for each individual, we determine the family AGI to be:

- If we have both parents' incomes: Family AGI-like income = mother's AGI-like income + father's AGI-like income
- If we only have one parent's income: Family AGI-like income = that parent's AGI-like income

Parental income ranking at birth is defined the same as in the California data.

Analysis samples: Our primary analysis sample includes all California births to first-time mothers. We construct the analogous sample in the Swedish data.

- Main birth outcomes and maternal mortality (2007–2016): We observe birth weight, gestation length, and maternal mortality for all years 2007–2016, so we use this sample for analyzing these outcomes in both California and Sweden.

- Severe maternal morbidity (2007–2012): For severe maternal morbidity, we rely on the CHAI data which covers birth cohorts 2007–2012. Thus, in the California data, we restrict the analysis sample to births within 2007–2012 which link to the CHAI data. As noted in the text, we do not analyze this outcome in the Swedish data.

- Infant mortality (2007–2011): The infant mortality indicators which we use to supplement the Numident file are only available in the CHAI data for births from 2007 to 2011. Therefore, we restrict the analysis sample for infant mortality to the subset of 2007–2011 births which link to the CHAI data. In the Swedish analysis, we restrict to the 2007–2011 birth cohorts.

Outcome Averages for Excluded Births: In our main analysis, we only include births for whom we can observe non-missing, non-zero, and non-negative family or individual income for at least one parent in at least one of the two years prior to the birth. Those with missing, negative, or zero income are likely comprised of a combination of families for whom we are unable to identify the parents, or those who have no earnings and rely exclusively on transfer payments, have only income from investments, primarily have income abroad that is not reported in the US tax data, are not successfully linked to their W2 (due to, e.g., an incorrect entry of their SSN), or have another source of support (such as living with parents or other family) that we are unable to identify. Since this is a heterogeneous group, and we are unable to identify the reason that income is missing, negative, or zero, we report outcome averages for this group separately. These averages are reported in Appendix Table B2.

Table B2: Average of Infant and Maternal Health Outcomes for Missing, Negative, or Zero Family Income Births

	California		Sweden	
	Mean	N	Mean	N
Birth Weight	3212	221000	3317	18801
Low Birth Weight	0.07821	221000	0.05750	18801
Preterm	0.0985	221000	0.06186	18834
Infant Death	0.006042	124000	0.004674	9627
Maternal Morbidity	0.01827	136000	-	-
Maternal Death	0.000336	211000	0.0002654	18843

Notes: Table presents average outcomes associated with births to mothers where family income is missing, negative, or zero for the two years prior to the birth year. All California results were approved for release by the U.S. Census Bureau, authorization number CBDRB-FY23-0405.