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Effects of Migration on Infant and Maternal Health in China

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Abstract

We assess the association between maternal migrant status and health outcomes in China, which has one of the world's largest migrant populations. Health records from the Shanghai First Maternity and Infant Hospital from January 1, 2013, to June 30, 2017, were used to analyze 104 681 live births for Shanghai native-born and migrant women based on *International Classification of Diseases, Tenth Revision* diagnosis codes and demographic data. Regression analysis including propensity score matching was conducted to investigate the association between maternal migrant status and adverse infant birth outcomes (fetal disease, congenital malformation, neonatal disease) and maternal health after controlling for pregnancy status and socioeconomic factors. The results demonstrate that migrant women had statistically significant increased odds (9.1%-10%, $P < .001$) of having infants with adverse health outcomes compared with their urban counterparts and that migrant mothers have less likelihood of pregnancy complications and gestational diabetes mellitus. Our results show the mixed effects of migration on infant and maternal health may be a possible outcome of China's Hukou system that often represents an important barrier in accessing prenatal health care by migrant women. Current reforms that improve access to prenatal health care services for migrant women may enhance the health outcomes of their infants.

Keywords

within-country migration, infant health, maternal health, healthy immigrant effect

What do we already know about this topic?
Despite the extensive literature on international migration among pregnant women and families with infants, there is a paucity of studies that focus on internal migration, particularly in China.
How does your research contribute to the field?
This is the first study of its kind to measure the effect of migrant status on infant birth and maternal outcomes using detailed birth records data and clinical data on women's health status drawn from 1 large obstetrics and gynecology hospital in Shanghai, East China.
What are your research's implications toward theory, practice, or policy?
Our results show the mixed effects of migration on infant and maternal health, which may be a possible outcome of China's Hukou system that often represents an important barrier in accessing prenatal health care by migrant women. Current reforms that improve access to prenatal health care services for migrant women may enhance the health outcomes of their infants.

Introduction

Infant health is a primary global health concern, given the positive association between infant health and health status in adulthood.[1] A healthy lifestyle during pregnancy increases the likelihood of a healthy infant.[2] Over the last 3 or 4 decades, there has been significant interest in assessing the association between maternal migrant status and birth outcomes.[3-7] Although much of the extensive literature has been concerned with international migrants, there are a few studies that have examined migrants who move internally within a country.[8,9] This is especially true in the case of China, where the Hukou household registration system defines (and may limit) access to public services on the basis of household registration.[10]

To control a large migrant population, the Hukou system, or the household registration system, was set up by the Chinese government in 1958. The Hukou system is an institution which controls population movement, and it confirms that a person is a resident of a district. In China, locally born urban residents have the right to benefit from a series of

national welfare programs (including housing, education, and medical care), whereas migrants to these urban areas do not have access to these programs. Such disparities lead to migrants having difficulties in accessing social and health care services compared with their urban counterparts.[11] There have, however, been recent steps to reform the Hukou system in 2014 to enable better access for migrants to welfare benefits, education, and housing.

In 2017, the National Health and Family Planning Commission noted that the migrant population of China attained 245 million or 18% of the China's population. This has caused strains on urban health care systems, and in particular on the demands for health care needs of female migrants[12,13]—especially in Shanghai, where 40.5% of the 24 million residents were migrants as of 2018 (Shanghai has the largest migrant population in china, but Shenzhen has the highest ratio according to the Chinese State Council; Yicai Global 2017. Available from: https://www.yicaiglobal.com/news/shanghai-has-largest-migrant-population-china-shenzhen-has-highest-ratio).

Existing literature regarding the association between maternal migration and infant health tends to focus on developed countries where it has been suggested that migrant mothers tend to manifest a "healthy migrant effect" with better infant health outcomes than their native-born counterparts.[14-16] Most of these studies have occurred in developed countries.[4] In addition, Bollini et al[17] found that in most European countries, immigrants have worse pregnancy outcomes than local women. Studies that focus on developing countries are limited with varied results. In Senegal, investigators found that mothers can improve their chances of survival by moving from rural to urban areas.[18] High infant mortality was found in infants of migrants from 15 developing countries compared with urban residents.[19]

In this study, we assess the effect of migrant status on birth outcomes using accurate birth records data and detailed data on women's health status drawn from the Shanghai First Maternity and Infant Hospital over the period 2013-2017. Shanghai is an ideal setting to assess the effect of migrant status on birth outcomes, owning more than 40% of migrants, as we mentioned. In addition, the Shanghai First Maternity and Infant Hospital is one of the largest obstetric hospitals in Shanghai with the greatest number of births per year (more than 30 000)—ranking it first in China.

This is the first study of its kind to measure the effect of migrant status on infant birth and maternal outcomes. Our study suggests that migrant women were at a higher risk of having infants with adverse health outcomes. However, the migrant mothers themselves had a lower rate of pregnancy complications.

In the next section, we outline the conceptual framework. Data and methods are described in section "Methods." Section "Results" reports our results, and these findings are discussed in the context of the literature in section "Discussion." Section "Conclusion" offers a brief set of conclusions and policy implications.

Framework

The "healthy migrant effect" notes that although migrants tend to have lower socioeconomic status and difficulties in accessing medical services, their health status tends to be better than that of local residents. However, the health status of these migrants tends to fall over time.[8] Three factors have been identified to account for the higher initial health status of migrants. First, migration is a selective process, with healthy people having greater opportunities to move. Second, migrants are likely to underestimate the impact and consequences of potentially adverse health conditions, as they tend to have limited access to social and medical services and may fail to have periodic physical examinations.[20] Third, when migrants do fall ill, some migrants return to their birthplace.[21] Hence, the migrants who remain and settle in their host area may tend to be generally healthier than those who return home. The "healthy migrant effect" might be reflected in better reproductive outcomes for their infants than that for local urban residents.[16]

Current research findings on the health status of migrants in China are consistent with the global literature concerning the "healthy migrant effect."[22] This effect suggests that migrant health is generally better than the health status of local residents when they first move, but over time the health status of migrants converges toward (and in some cases may even fall below that of) the local population of nonmigrants.[22-24] Some Chinese studies have investigated the "healthy migrant effect."[8] Tong and Piotrowski[9] found migrants to have better health when compared with the local urban population in Beijing. However, recent research on the health status of Chinese migrants has yielded the opposite

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results.[25] They found migrants were more vulnerable to infectious and sexually transmitted diseases, occupational injuries and diseases, and had a greater likelihood of having poor reproductive health and high maternal mortality.[26] Furthermore, none of these studies have stressed the potentially important implication that access to urban public health is more difficult for migrants, which in turn might limit their access to health services.[12] Migrants further resort to paying out-of-pocket costs for urban medical services.[27] Female migrants, in particular, have limited access to medical insurance and often have lower educational status, and they often lack knowledge of antenatal care. All this taken together can result in adverse reproductive outcomes.[28]

Methods

Data Source

This study used inpatient hospitalization admission data on all women who gave birth between January 1, 2013, and June 30, 2017, at the Shanghai First Maternity and Infant Hospital. The data were used to evaluate infant birth outcomes. The data contain patient demographics and clinical details on 104 681 live births. Diagnostic information is coded using *International Classification of Diseases, Tenth Revision* (*ICD-10*).[29] Our study was approved by the Shanghai First Maternity and Infant Hospital.

Measures

Dependent variable. There are 2 kinds of health outcomes in this study: adverse infant birth outcomes and maternal health indicators. First, the adverse infant birth outcomes was measured using diagnostic information based on *International Classification of Diseases, Tenth Revision, Clinical Modification* (1CD-10-CM) (1 = if the baby was diagnosed with any disease by a pediatrician at birth; 0 = otherwise). Then, these adverse birth outcomes were further divided by a pediatrician into 4 groups: (1) fetal disease, including conditions such as embryo kidney growth abnormal, space-occupying lesions of liver, hydrops fetalis, slow fetal growth, and fetus intrauterine hypoxia; (2) neonatal malformation, including conditions such as accessory finger(s), undescended testicle, and cleft lip; (3) neonatal disease, including conditions such as macrosomia, ABO isoimmunization of newborn, low birth weight (LBW), congenital pneumonia, and neonatal jaundice; (4) other infant health condition, which refers to other similar infant health conditions. The list of these *ICD-10* codes is shown in Appendix C. A binary variable was created for each infant to signal whether the infant was healthy (ie, without any disease diagnosis).

Second are 3 variables to measure maternal health: (1) pregnancy complications (Pregnance complications *ICD-10-CM* codes O44.0 O44.1 O13.1 O13.2 O13.3 O13.9 O14.0 O48.0 O26.2 O99.3 O24.4 O26.8 O30.0 O36.0 O36.5 O36.6 O24.9; gestational diabetes mellitus ICD-10-CM codes O24.9.) (reported by *ICD-10* diagnosis codes in the medical records, as shown in Appendix C), which refer to diagnosis of medical complications during pregnancy, including placenta previa, hemorrhage, poor fetal growth, gestational hypertension, pre-eclampsia, and so on (1 = the woman has pregnancy complications; 0 = otherwise); (2) gestational diabetes mellitus (1 = the woman has gestational diabetes; 0 = otherwise); and (3) cesarean section (1 = the woman has cesarean section; 0 = the woman has natural birth).

Key independent variables. We analyzed mothers' migrant status (Hukou) as a binary variable (1 = migrants, 0 = Shanghai-born women). Sixty-five percent of the sample fell into the Shanghai native-born category (n = 68 367), and 35% were migrant women (n = 36 314) of the total sample of 104 681.

We also adjusted for demographic and maternal clinical characteristics. These include maternal age at the child's birth; gravida—number of times a woman has been pregnant; birth parity—number of pregnancies >20 weeks; gestation weeks—measure of the age of a pregnancy which is taken from the woman's last menstrual period; ethnicity (1 = not Han Chinese; 0 = otherwise); nationality (1 = not China; 0 = otherwise); high risk of pregnancy—which means the woman or the baby is more likely to have health problems during pregnancy, and this was indicated on their medical records (1 = being at a high risk; 0 = otherwise); rescue times—which means the number of times being saved from a severe pregnancy outcome, such as postpartum hemorrhage, amniotic fluid embolism, or other outcomes; maternal near-miss (severe acute maternal morbidity)—which refers to whether the woman nearly died but survived a complication during pregnancy or at birth (1 = maternal near-miss; 0 = otherwise); and occupation (1 = employed, 0 = not employed). Cesarean section (1 = cesarean delivery, 0 = natural delivery) and pregnancy complications are mentioned previously.

Dummy variables for each study year were included in the analysis to adjust for possible changes in the social and economic environment over the study period.

Statistical Analysis

Two different estimation strategies were used. First, we begin with a series of logistic regression models predicting the competing odds of giving birth to an infant with an adverse outcome. We assessed the robustness of our results by running the analyses segmented by occupation and analyzing specific health outcomes of infants and the migrant women.

Second, we used propensity score matching (PSM) introduced by Rosenbaum and Rubin[30] to address potential self-selection issue of migrants. This method estimates the probability that a study participant was a migrant based on a series of covariates.[30] The propensity score method was

Table 1. Summary Statistics.

Variable	Shanghai locals (n =68 367)		Migrants (n = 36 314)		All (N =104 681)	
Binary variable	No.	%	No.	%	No.	%
Adverse birth outcomes	15 816	23.1	8990	24.8	24 806	23.7
Fetal diseases	2505	3.7	1187	3.3	3692	3.5
Congenital malformation	523	0.8	254	0.7	777	0.7
Neonatal disease	12 185	17.8	7366	20.3	19 551	18.7
Other infant health condition	602	0.9	183	0.5	785	0.7
Ethnicity (not Han)	556	0.8	845	2.3	1401	1.3
Nationality (not Chinese)	101	0.1	185	0.5	286	0.3
Occupation (employed)	65 924	96.4	32 202	88.7	98 126	93.7
High-risk pregnancy	33 952	49.7	19 405	53.4	53 357	51.0
Maternal near-miss	70	0.1	63	0.2	133	0.1
Cesarean delivery	28 718	14.2	13 381	12.5	42 099	40.2
Complications of pregnancy	9725	42	4536	36.8	14 261	13.6
Gestational diabetes mellitus	7345	10.7	3193	8.8	10 538	10.1
Continuous variable	Mean	SD	Mean	SD	Mean	SD
Age	30.87	3.924	30.08	4.045	30.6	3.984
Gestation weeks	39.05	2.494	39.07	4.456	39.06	3.309
Gravida	1.705	0.992	1.934	1.172	1.784	1.064
Birth parity	1.211	0.416	1.274	0.487	1.233	0.443
Rescue times	0.00294	0.0552	0.00432	0.066	0.00342	0.0592

Note. Binary variables are presented as number and percentage (%). Continuous variables including age, gestation weeks, gravida, birth parity, and rescue times are presented as mean and SD.

based on a 2-stage procedure. First, the propensity score was estimated and used to match observations in the whole dataset in such a way that individuals with similar values to the identified determining covariates were grouped together to assess the independent effect of migrant status. Then, the effect of migrant status on adverse infant outcomes was estimated using matching techniques based on propensity score estimation. In addition to using the same covariates from our logistic regression models, we added age square as matching variables in our PSM estimator.

Finally, a logistic regression approach was used to analyze the association between maternal migration status and indicators of maternal health. We estimated all results using Stata 14.

Results

Descriptive Statistics

Table 1 provides descriptive statistics for each of the variables used in the study. The average age of the sample of mothers was 30.6 years, with 35% being migrants. Almost all (94%) of the mothers were employed. Regarding nationality and ethnicity, most of the mothers were Han Chinese. Around 51% of them had a high-risk pregnancy. More than 40% of the women had a cesarean delivery, and 23.7% of infants had adverse health outcomes.

Infant Birth Outcome

Table 2 reports a statistically significant effect of maternal migrant status on adverse infant birth outcomes over the entire study period. After controlling for all key explanatory variables, the effect of migrant status on birth outcomes remains significant. The results demonstrate that migrant women had a statistically significant 9.3% (Model 3) to 10.0% (Model 2) increased likelihood ($P < .001$) of having infants with adverse health outcomes compared with their urban counterparts. Notably, several covariates were strongly associated with the dependent variable (Table 2). Maternal gravida and parity before pregnancy were statistically significant ($P < .001$). Similarly, high-risk pregnancy and maternal near-miss were associated with adverse infant outcomes. In the mode of delivery, natural birth was less likely to be associated with adverse infant outcomes than a cesarean delivery.

We also ran a similar analysis for each study year to investigate whether infant birth outcomes changed over time, as shown in Table 3. The results show that in 2013, migrant women had a 16% increased likelihood of having an adverse outcome, and it decreased to 12% in 2014. It further decreased by 9.8% in 2015 and by 6.9% in 2017. The results remain statistically significant. Migrant status was significant for all years except for 2017 when the sample size for that year was about half that for the other study

Table 2. Logistic Regression of the Maternal Migrant Status on Adverse Infant Birth Outcome.

	Model 1	Model 2	Model 3
Independent variable (birth outcomes)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Migrant status	1.093*** (1.061-1.126)	1.100*** (1.067-1.134)	1.091*** (1.057-1.126)
Age		1.009*** (1.005-1.012)	1.000 (0.996-1.005)
Ethnicity		0.956 (0.838-1.091)	0.905 (0.788-1.039)
Nationality		1.362** (1.038-1.788)	1.444** (1.084-1.924)
Occupation		0.996 (0.939-1.057)	1.046 (0.982-1.114)
Gravida			1.029*** (1.011-1.047)
Birth parity			0.619*** (0.593-0.646)
Gestation week			0.702*** (0.696-0.709)
High-risk pregnancy			1.535*** (1.487-1.584)
Rescue times			1.210 (0.933-1.568)
Maternal near-miss			1.966*** (1.278-3.025)
Cesarean delivery			0.926*** (0.897-0.957)
_cons	3.323*** (3.264-3.382)	4.333*** (3.829-4.904)	0.000*** (0.000-0.000)
N	104681	104681	104681

Note. 95% CI in parentheses. OR = odds ratio; CI = confidence interval.
*$P < .05$. **$P < .01$. ***$P < .001$.

Table 3. Logistic Regression of the Maternal Migrant Status on Adverse Infant Birth Outcomes by Year (2013-2017).

	2013	2014	2015	2016	2017
Independent variable	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Migrant status	1.162*** (1.061-1.274)	1.122*** (1.047-1.203)	1.098*** (1.028-1.174)	1.116*** (1.053-1.183)	1.069 (0.970-1.178)
Age	1.001 (0.992-1.010)	1.004 (0.995-1.013)	0.999 (0.990-1.008)	1.007 (0.998-1.015)	0.985** (0.972-0.999)
Ethnicity	1.209 (0.846-1.729)	0.772* (0.576-1.035)	1.059 (0.811-1.385)	0.812 (0.615-1.073)	0.725 (0.466-1.127)
Nationality	0.977 (0.546-1.747)	1.650* (0.923-2.950)	2.422*** (1.345-4.363)	1.029 (0.532-1.991)	0.623 (0.171-2.264)
Occupation	0.945 (0.791-1.129)	1.150 (0.974-1.359)	1.201** (1.034-1.395)	0.941 (0.856-1.035)	0.950 (0.784-1.150)
Gravida	1.011 (0.969-1.055)	1.035* (0.997-1.074)	1.016 (0.980-1.054)	1.027 (0.995-1.061)	1.010 (0.957-1.067)
Birth parity	0.716*** (0.636-0.806)	0.642*** (0.583-0.706)	0.615*** (0.563-0.672)	0.601*** (0.556-0.650)	0.638*** (0.561-0.726)
Gestation week	0.768*** (0.749-0.787)	0.687*** (0.673-0.701)	0.684*** (0.670-0.699)	0.692*** (0.679-0.705)	0.719*** (0.697-0.742)
High-risk pregnancy	1.634*** (1.503-1.776)	1.298*** (1.217-1.385)	1.601*** (1.495-1.714)	1.611*** (1.516-1.712)	1.945*** (1.760-2.149)
Rescue times	0.900 (0.177-4.561)	1.522 (0.522-4.438)	0.865 (0.500-1.497)	1.508* (0.998-2.280)	1.295 (0.782-2.146)
Maternal near-miss	1.037 (0.212-5.085)	1.402 (0.482-4.076)	3.430*** (1.472-7.991)	1.264 (0.564-2.835)	4.506* (0.954-21.272)
Cesarean delivery	0.847*** (0.780-0.921)	0.995 (0.931-1.062)	0.912*** (0.851-0.977)	0.905*** (0.850-0.964)	0.784*** (0.707-0.869)
_cons	0.000*** (0.000-0.000)	0.000*** (0.000-0.000)	0.000*** (0.000-0.000)	0.000*** (0.000-0.000)	0.000*** (0.000-0.000)
n	13690	24314	22669	32910	11098

Note. 95% CI in parentheses. OR = odds ratio; CI = confidence interval.
*$P < .05$. **$P < .01$. ***$P < .001$.

years. All the models were controlled for demographic and maternal health characteristics.

Appendix A shows the results by categories of infant health: fetal disease (column 1), neonatal malformation (column 2), neonatal disease (column 3), and other infant health condition (column 4). Although the association of fetal disease (column 1) and neonatal malformation (column 2) did not reach statistical significance, neonatal disease (column 3) remains statistically significant ($P < .001$) with an odds ratio of 1.15. And other infant health condition (column 4) also remains statistically significant ($P < .001$) with an odds ratio of 0.576. The neonatal disease group diagnoses include LBW which is one of the main factors of adverse infant outcomes.[31] Hence, this result is consistent with previous empirical findings that the migrant women are more likely to have adverse birth outcomes in the form of neonatal diseases.

Handling Potential Self-Selection Bias

There may be potential selection bias within our study context as migration is a choice, and migrants have self-selected themselves into this study group. To address this potential counterfactual problem, PSM was used.[32] The results of the average treatment effect on the treated (ATET) (see Appendix B, column 1) show the increased likelihood of migrants having infants with adverse health outcomes to be 0.017 ($P < .001$).

Table 4. Logistic Regression of the Maternal Migrant Status on Adverse Pregnancy Outcome (Pregnancy Complications and Gestational Diabetes Mellitus) and Cesarean Delivery.

	Pregnancy complications	Gestational diabetes mellitus	Cesarean delivery
Independent variable	OR (95% CI)	OR (95% CI)	OR (95% CI)
Migrant status	0.840*** (0.807-0.875)	0.785*** (0.750-0.822)	0.757*** (0.735-0.779)
Age	1.047*** (1.042-1.052)	1.065*** (1.059-1.071)	1.080*** (1.076-1.085)
Ethnicity	0.774*** (0.647-0.926)	0.724*** (0.587-0.893)	0.900* (0.795-1.019)
Nationality	0.832 (0.561-1.236)	0.983 (0.636-1.522)	0.966 (0.736-1.268)
Occupation	1.087** (1.005-1.176)	1.180*** (1.074-1.296)	0.764*** (0.723-0.808)
Gravida	1.051*** (1.030-1.072)	1.021* (0.997-1.044)	1.140*** (1.122-1.158)
Birth parity	0.841*** (0.801-0.883)	0.886*** (0.838-0.937)	0.922*** (0.889-0.957)
Gestation week	0.966*** (0.955-0.976)	0.995 (0.985-1.006)	0.808*** (0.801-0.816)
High-risk pregnancy	5.757*** (5.486-6.040)	7.875*** (7.416-8.363)	2.843*** (2.767-2.921)
Rescue times	0.664** (0.479-0.920)	0.359*** (0.220-0.586)	0.655*** (0.509-0.843)
Maternal near-miss	0.965 (0.573-1.627)	0.257** (0.079-0.841)	2.492*** (1.568-3.960)
Cesarean delivery	0.993 (0.955-1.033)	0.701*** (0.671-0.733)	—
_cons	19.500*** (12.223-31.109)	185.452*** (117.039-293.856)	0.006*** (0.004-0.008)
n	104681	104681	104681

Note. 95% CI in parentheses. OR = odds ratio; CI = confidence interval.
*$P < .05$. **$P < .01$. ***$P < .001$.

Although the likelihood has decreased, it remains statistically significant.

Test of the Healthy Migrant Effect —Maternal Health

We also investigated the healthy migrant effect by using the health status of the mother. Instead of using the self-reported health of the mother to test the healthy migrant effect, we used 2 key obstetric disease conditions—pregnancy complications and gestational diabetes—to investigate the relationship between maternal health and infant birth outcomes. These obstetric complications are better indicators as they represent key factors that might lead to adverse birth outcomes in the literature.[31-33]

In addition, we extend our test by adding the modes of delivery variable, cesarean section (cesarean delivery vs natural delivery), to estimate the relationship between whether a woman has a cesarean delivery and migration status.

Table 4 shows that migrant women are less likely to have a pregnancy complication and gestational diabetes during pregnancy than their urban counterparts. Migrant mothers have 84% (column 1, $P < .001$) less likelihood of pregnancy complications and 78.6% (column 2, $P < .001$) less likelihood of gestational diabetes mellitus. The results also show that migrant mothers are 75.7% (column 3, $P < .001$) less likely to have a cesarean delivery. These results are consistent with the previous literature; native-born mothers are relatively wealthy, and they are more able to afford the cost of cesarean delivery.[34] Furthermore, in the Chinese context, cesarean delivery has a reputation as being a safer mode of delivery relative to natural birth among both doctors and pregnant women.[35]

Discussion

Key Findings and Implications

This article presents 6 key findings.

First, the study shows the main finding of a strong and statistically significant positive relationship between mothers' migrant status and adverse infant outcomes in China. Moreover, we also found that although migrant women had a lower likelihood of pregnancy complications, they remain at higher risk of having infants with adverse birth outcomes than their Shanghai-born counterparts. In principle, a woman who has less chance of pregnancy complications might also experience less chance of adverse infant outcomes. However, the results of our study demonstrate that this is not the case; rather, our study found that migrant women experienced both a lower likelihood of complications and a higher [sic] likelihood of adverse infant outcomes than their Shanghai-born counterparts. The reasons for these findings could be due to the following.

As noted earlier, China's unique Hukou system tends to deny migrants access to urban medical care, including prenatal care. Migrants also tend to pay out-of-pocket for these costs, and that can reduce their use of prenatal checkups, which can lead to adverse infant birth outcomes. Moreover, migrants often also have lesser education and lower incomes. This lack of prenatal care awareness combined with the lower ability to afford medical expenses could result in adverse birth outcomes.

Cesarean delivery can be a lifesaving delivery for fetal survival[36] and was considered safer than natural birth.[35] Our findings are consistent with prior literature, that is, Shanghai residents are more likely to have a cesarean delivery than migrants.[37] Xiu-guo Zhang et al[38] have suggested that the major reason why migrant women have cesarean delivery is because of fetal distress. In other words, owing to the high cost of cesarean delivery, migrants generally cannot afford cesarean section in normal cases and only do it under critical health situations, such as fetal distress.

Second, although migrant women are more likely have a sick baby, the infant birth outcomes of migrants gradually reach levels closer to the birth outcomes of Shanghai-born counterparts over the time period of the study (Table 3). The migration of individuals from rural to urban centers is a major policy issue in China, especially in Shanghai, which is a major urban center. However, Hu et al[12] state that Shanghai has already begun to subsidize public hospitals for migrants so that they can avoid going to illegal private clinics. This has resulted in increasingly better health outcomes for infants over time. Also, it could be possible that the recent reforms of the Hukou system in 2014 could lead to some of this improvement, although the reforms are very recent and may not yet have a meaningful impact on infant health at this time.

Third, when the adverse infant outcomes were divided into 4 groups, we found that fetal diseases and congenital malformation have a greater chance to be related to genetic and consanguinity factors,[17] and therefore might be invariant to migrant status. This might explain why these results are not significant. However, the neonatal disease group, including the diagnosis of LBW, which is part of the neonatal disease category, is mainly dependent on socioeconomic and environmental factors.[17] This, therefore, might explain why this infant health condition was significantly related to migrant status.

Fourth, the association between maternal migrant status and adverse infant outcomes differed by maternal occupation. Employed migrant mothers were associated with a higher likelihood of adverse infant outcomes, whereas the effect on adverse infant outcomes was not pronounced for unemployed women. As noted, this was likely due to lack of power given the small proportion of the sample who are in the unemployed category.

Fifth, the results demonstrate migrant mothers have a lower risk of complications of pregnancy than their urban counterparts, which is consistent with the "healthy migrant effect." Migrant women enjoy health advantages to a certain extent because healthier people are more likely to migrate.

Sixth, Shanghai-born mothers are more likely to be diagnosed with gestational diabetes, which is one of the main factors leading to adverse outcomes.[17] The results of our study (Table 4) revealed that migrant women had a stronger likelihood of unhealthy babies, even though they are less likely to have pregnancy complications and gestational diabetes. One possible reason to explain this phenomenon could be the Hukou system. By limiting access to health services during pregnancy, this can lead to adverse birth outcomes for infants of migrant women.

Our study, therefore, lends support to the "healthy migrant effect," which suggests that migrants, including migrant mothers, are generally healthier than local residents. Existing literature has revealed that regarding infant health, the health conditions of infants born to migrants are worse than their native-born counterparts.[13] This could be due to the Hukou system, which excludes migrant workers from urban health insurance schemes. As a consequence, migrants face significant out-of-pocket costs to access health care services. Furthermore, their lower socioeconomic status can result in worse health status for migrant women, in turn resulting in poor pregnancy health outcomes.[25] In China, these factors are common for migrants, who earn lower wages, have lower levels of education, reside in poor living conditions, and tend to suffer financial difficulties. These will likely cause future physical illness and mental health concerns.[39] Consideration of improving the Hukou system to reduce health inequalities between migrants and their urban counterparts can make a substantial impact on the health of infants born to migrant women in China.

Strengths and Limitations

This is the first study to quantify the relationship between maternal migrant status on infant birth outcomes and maternal outcomes using extensive, detailed, and high-quality medical data from hospital records and using medical diagnoses instead of self-reported health. It represents an important study that sheds light on the complex relationships between migrants and infant health outcomes in China. Previous studies used national-level data that do not incorporate women's individual-level health information. This study was able to incorporate detailed patient-level health data using inpatient hospital data which include comprehensive maternal and infant medical diagnosis information as well as demographic and socioeconomic conditions.

However, there are still a range of limitations that need to be highlighted. First, the hospital for this study was based in Shanghai, and this hospital may not be representative of all hospitals in China, although the number of births in this hospital is the highest in China. Second, we recognize that there may be other mechanisms (eg, maternal psychological attributes, healthy lifestyle, and life satisfaction) that may also contribute to this association. Third, a Shanghai Hukou did not necessarily indicate that the person was born in Shanghai, which may lead to misclassification bias. However, it is unknown to what extent this could be an issue as this could represent inherent data quality issues with the Hukou coding at the registry level. Finally, our dataset did not include some

Appendix A. Logistic Regression of the Maternal Migrant Status on Adverse Infant Birth Outcome and Infant Birth Outcome by 4 Categories (Fetal Diseases, Congenital Malformation, Neonatal Disease, Other Infant Health Condition).

	Fetal diseases	Congenital malformation	Neonatal disease	Other infant health condition
Independent variable	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Migrant status	0.952 (0.886-1.023)	0.971 (0.832-1.132)	1.150*** (1.110-1.192)	0.576*** (0.486-0.683)
Age	1.016*** (1.007-1.025)	1.014 (0.996-1.033)	0.994** (0.990-0.999)	1.019** (1.001-1.036)
Ethnicity	0.610*** (0.421-0.884)	0.781 (0.379-1.611)	0.981 (0.843-1.141)	1.171 (0.612-2.240)
Nationality	2.772*** (1.599-4.804)	1.710 (0.489-5.975)	1.127 (0.813-1.561)	1.540 (0.445-5.330)
Occupation	1.224** (1.044-1.435)	1.917*** (1.291-2.848)	0.998 (0.932-1.069)	1.057 (0.761-1.468)
Gravida	0.937*** (0.898-0.978)	1.033 (0.953-1.120)	1.034*** (1.015-1.054)	1.171*** (1.085-1.264)
Birth parity	0.563*** (0.503-0.630)	0.815** (0.667-0.998)	0.649*** (0.619-0.681)	0.634*** (0.513-0.784)
Gestation week	1.024*** (1.010-1.038)	1.000 (0.980-1.021)	0.624*** (0.617-0.631)	0.945** (0.906-0.987)
High-risk pregnancy	0.780*** (0.728-0.837)	1.188** (1.022-1.382)	1.863*** (1.797-1.931)	0.428*** (0.364-0.503)
Rescue times	0.539 (0.216-1.345)	0.660 (0.140-3.123)	1.308* (0.992-1.725)	1.265 (0.433-3.699)
Maternal near-miss	0.405 (0.052-3.146)	1.216 (0.132-11.225)	1.422 (0.898-2.253)	9.624*** (3.183-29.097)
Cesarean delivery	0.924** (0.859-0.994)	1.258*** (1.082-1.462)	0.893*** (0.861-0.926)	0.763*** (0.650-0.896)
_cons	51.736*** (27.889-95.976)	381.142*** (132.285-1,098.154)	0.000*** (0.000-0.000)	11.744*** (1.941-71.053)
N	104681	104681	104681	104681

Note. 95% CI in parentheses. OR = odds ratio; CI = confidence interval.
*$P < .05$. **$P < .01$. ***$P < .001$.

Appendix B. Propensity Score Matching Results the Maternal Migrant Status on Adverse Infant Birth Outcome.

	ATET	*P* value	95% CI
Dependent variable	(1)	(2)	(3)
Birth outcomes	0.017***	<.001	(0.011-0.024)
Observations (*N*)	104,681		

Note. 95% CI in parentheses. ATET = Average Treatment Effect on the Treated; CI = confidence interval.
*$P < .05$. **$P < .01$. ***$P < .001$.

Appendix C. The *ICD-10* Code List of Infant Outcomes.

Fetal diseases	Congenital malformation	Neonatal disease	Other infant health condition	Pregnancy complications
O35.0	P03.4	L02.2	P00.3	O44.0
O35.8	Q03.9	L20.8	P03.4	O44.1
O35.9	Q05.8	L85.8	P95.x	O13.1
O36.2	Q16.1	M17.1	Z04.8	O13.2
O36.3	Q16.9	M21.0	Z37.0	O13.3
P20.9	Q17.0	N13.3	Z90.7	O13.9
P05.9	Q17.2	N43.3	Z98.8	O14.0
	Q17.3	O36.1	O43.1	O48.0
	Q17.9	P03.4	O69.1	O26.2
	Q18.1	P05.0	O80.8	O99.3
	Q20.3	P05.1	N83.2	O24.4
	Q21.0	P07.0	P21.1	O26.8
	Q21.1	P07.1	P22.1	O30.0
	Q21.2	P07.2	P00.0	O36.0
	Q21.3	P07.3	P00.2	O36.5
	Q22.1	P08.0	P00.8	O36.6
	Q24.9	P08.1	P01.1	O24.9

(continued)

Appendix C. (continued)

Fetal diseases	Congenital malformation	Neonatal disease	Other infant health condition	Pregnancy complications
	Q25.0	P10.9	P01.2	
	Q25.4	P12.0	P01.5	
	Q25.6	P12.3	P01.7	
	Q26.4	P12.8	P02.0	
	Q27.8	P12.9	P02.5	
	Q30.9	P13.4	P02.6	
	Q31.5	P14.3	P03.0	
	Q33.6	P15.8	P03.1	
	Q33.9	P15.9	P03.2	
	Q35.3	P20.9	P03.4	
	Q35.9	P21.0	O33.5	
	Q36.0	P21.1	O36.5	
	Q36.9	P21.9	O36.6	
	Q37.4	P22.0	P03.5	
	Q37.5	P22.1	Z37.2	
	Q37.8	P22.8	P08.2	
	Q37.9	P22.9		
	Q38.0	P23.9		
	Q38.6	P24.0		
	Q39.2	P24.1		
	Q40.9	P24.9		
	Q41.8	P25.1		
	Q42.2	P26.9		
	Q42.3	P28.2		
	Q43.3	P28.4		
	Q43.9	P28.5		
	Q45.9	P28.8		
	Q52.2	P28.9		
	Q53.1	P29.0		
	Q53.2	P29.1		
	Q53.9	P29.3		
	Q54.9	P29.4		
	Q60.0	P36.9		
	Q60.2	P38.x		
	Q61.3	P39.1		
	Q62.0	P39.4		
	Q63.2	P39.8		
	Q63.9	P39.9		
	Q64.9	P52.9		
	Q66.0	P53.x		
	Q66.1	P54.0		
	Q66.3	P54.3		
	Q66.4	P54.9		
	Q66.6	P55.0		
	Q66.8	P55.1		
	Q68.1	P55.9		
	Q68.2	P59.0		
	Q68.8	P59.1		
	Q69.9	P59.9		
	Q70.4	P61.0		
	Q70.9	P61.1		
	Q71.3	P61.2		
	Q71.9	P61.4		

(continued)

Appendix C. (continued)

Fetal diseases	Congenital malformation	Neonatal disease	Other infant health condition	Pregnancy complications
	Q73.8	P61.6		
	Q76.4	P61.8		
	Q76.9	P70.0		
	Q79.2	P70.3		
	Q89.3	P70.4		
	Q89.7	P71.1		
	Q89.9	P71.3		
	Q97.0	P74.0		
	Q98.9	P76.9		
	Q99.8	P77.x		
	Q99.9	P78.0		
		P78.2		
		P78.8		
		P80.0		
		P81.9		
		P83.3		
		P83.5		
		P83.8		
		P83.9		
		P90.x		
		P91.6		
		P91.9		
		P92.0		
		P92.1		
		P92.5		
		P92.9		
		P96.0		
		P96.8		
		R18.x		
		R19.0		
		R21.x		
		R22.1		
		R22.2		
		R22.4		
		R33.x		
		R65.9		
		S00.0		

of the maternal social determinants such as income and education due to the unavailability of these data. This absence of information may limit our estimation of "healthy migrant effect." Further research is needed to study the full picture of maternal health and its potential interaction with adverse infant outcomes of migrants in China.

Conclusions

This study suggests that although migrant women have a lower risk of pregnancy complications than their urban counterparts, they were at a higher risk of having infants with adverse health outcomes. Overall, these results are consistent with the "healthy migrant hypothesis" and clearly highlight the mixed effects of migration in China. Current reforms to the Hukou system that improves access to prenatal health care for migrant women have the potential to enhance health outcomes for the infants of migrant women.

Author Contributions

D.T., X.G., and P.C. contributed to the design of the study. D.T. wrote the first draft, and P.C. and M.R. critically revised the paper for important intellectual content. All authors approved the final version.

Declaration of Conflicting Interests

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Ethics Committee Approval

Our study was approved by the Ethics Committee of the Shanghai First Maternity and Infant Hospital. Date of approval: June 13, 2018. Ethical acceptance number: (2018) No. (35).

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