Love in the Time of Zika

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Abstract

We study how fertility declines shape women's labor and marriage market outcomes by exploiting exogenous variation from Brazil's Zika epidemic. Although Zika causes only mild symptoms in adults, the discovery of severe fetal risks in late 2015 led to sharp behavioral responses and a sudden, plausibly exogenous reduction in fertility. Using administrative births, labor force, and marriage records linked at fine geographic scales from 2014–2018, we compare municipalities with high versus low Zika exposure based on confirmed cases, environmental suitability for the *Aedes aegypti* mosquito, and Google search intensity. Across measures, fertility fell by 10.7 percent in the most affected areas. Beginning nine months after the health emergency declaration, women's employment rose by 2–3 percentage points, monthly earnings increased by more than 200 reais, and formal-sector participation grew by up to 3.1 percentage points—consistent with fertility-driven effects, rather than direct viral effects. Marriage-market outcomes shifted as well: divorce rates increased and peaked a year after the epidemic, while marriage rates rose with roughly a one-year lag. These patterns are consistent with improved agency and economic opportunities for women in high-exposure regions. More broadly, our findings provide causal evidence that aggregate fertility declines can meaningfully alter women's labor force attachment and family formation, with implications for countries undergoing rapid and sustained fertility transitions.

JEL: J13, J16, J21, O54

Keywords: Fertility, female labor supply, marriage and divorce, Zika virus, Brazil

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1 Introduction

Over the past half-century, fertility has fallen sharply across countries at all income levels. Brazil is emblematic of this transition: total fertility declined from more than six births per woman in the 1960s to well below replacement level today (World Bank, 2025). This dramatic shift coincides with rising female labor force participation and substantial social and economic change, but women's economic opportunities and family trajectories continue to be shaped by the timing and number of children women have. A large body of work documents that motherhood is associated with sizable and persistent earnings penalties, changes in occupations and sectors, and widening gender gaps in hours and wages (Adda et al., 2017; Kleven et al., 2019a; Sieppi and Pehkonen, 2019; Berniel et al., 2021; Cortés and Pan, 2023). As families become smaller in middle-income settings, there is an open question of how fertility declines feed back into women's labor market trajectories and marriage market outcomes. Do fewer births relax time and mobility constraints enough to raise women's earnings and formal employment? And do changes in women's economic opportunities, in turn, alter the stability and structure of marital unions?

Answering these questions is empirically challenging because fertility, labor supply, and family formation are jointly determined. Women with stronger labor market preferences may choose to delay or forgo childbearing, marry later, or select different types of partners, making it difficult to isolate the causal impact of fertility from underlying preferences or unobserved heterogeneity (Adda et al., 2017). A large literature has therefore relied on quasi-experimental variation in the number or timing of children to study labor supply responses, including twin births, sibling sex composition, and infertility shocks (Aguero and Marks, 2010; Cáceres-Delpiano, 2012; Heath, 2017). These studies provide important evidence that additional children reduce women's labor supply, shift them toward more flexible or informal occupations, and widen intra-household earnings gaps (Adda et al., 2017; Goldin and Mitchell, 2017; Bertrand et al., 2010; Angelov et al., 2016). However, most of this work focuses on the impact of having an extra child, often in high-income contexts, and says less about what happens when fertility falls in the aggregate—when many women choose not to have (or to postpone) a birth that they otherwise would have had. Yet, when considering worldwide fertility declines, the relevant variation we may need should be derived from reductions, rather than increases, in births.

In this paper, we study how fertility declines affect women's labor and marriage market outcomes by exploiting exogenous variation from Brazil's Zika epidemic. The Zika virus, which spread rapidly through Brazil in the mid-2010s, causes mild or no symptoms in most adults, but poses severe risks to fetal development when contracted during pregnancy. Clinical and epidemiological evidence links maternal Zika infection to large increases in microcephaly, brain abnormalities, and other congenital Zika syndromes (Brasil et al., 2016; Mlakar et al., 2016; Haby et al., 2018). Rates of adverse fetal outcomes are dramatically higher among Zika-exposed pregnancies (Coelho et al., 2017), and case reports documenting Zika virus in fetal brain tissue established a direct causal pathway to microcephaly (Mlakar et al., 2016). Public awareness of these fetal risks rose sharply in late 2015, following the October 2015 identification of unusual clusters of microcephaly and the November 2015 declaration of a national public health emergency, and was reinforced when the World Health Organization declared a public health emergency of international concern in February 2016.

The perceived fetal risks from Zika led to large and rapid behavioral responses in fertility. A growing literature documents that fertility fell substantially in regions with higher Zika prevalence, as women delayed or avoided pregnancies under heightened risk. Using monthly birth records and regional case counts, these studies find fertility declines on the order of seven to 10 percent in high-risk municipalities (Rangel et al., 2020; Junior and Rasul, 2020; Marteleto et al., 2020; Ryu, 2020). Survey evidence on reproductive intentions and contraceptive behavior further shows that women strategically postponed childbearing in response to perceived Zika risk, temporarily revising plans to have (additional) children

(Marteleto et al., 2017; Marteleto and Dondero, 2021; Junior and Rasul, 2020; Rangel et al., 2020). Importantly, Zika's symptoms in adults are predominantly mild and short-lived, and roughly 80 percent of infections are asymptomatic (Haby et al., 2018). Unlike pandemics such as COVID-19, Zika did not trigger broad economic shutdowns. The primary policy response focused on mosquito control and public information campaigns, rather than restrictions on work or mobility. This makes Zika an unusually clean setting in which health-related fetal risk changes women's childbearing behavior without directly disturbing aggregate labor demand or broader macroeconomic conditions.

We build on this emerging literature that uses Zika as a natural experiment to study fertility (Marteleto et al., 2017, 2020; Marteleto and Dondero, 2021; Junior and Rasul, 2020; Rangel et al., 2020; Ryu, 2020), and extend it along two key dimensions. First, we strengthen identification of fertility responses by combining administrative birth records with multiple independent measures of Zika exposure: reported case counts, environmental suitability for the *Aedes aegypti* mosquito, and municipality-level Google search intensity for "Zika." Second, and more importantly, we move beyond fertility itself to study how Zika-induced fertility declines reshape women's labor supply, earnings, and marriage outcomes in a middle-income economy with a large informal sector. In contrast to the prior Zika literature, which has focused predominantly on fertility and fertility intentions, we trace the broader consequences of fertility reductions across labor and family domains.

Our paper proceeds in three stages. First, we provide new evidence on the magnitude and timing of fertility responses to Zika using rich administrative data and improved measures of exposure. We construct a monthly municipality-level panel of births using Brazil's Live Birth Information System (SINASC), linked to three complementary measures of Zika exposure. Our preferred specification exploits the staggered geographic spread of Zika in an event-study difference-in-differences framework, comparing high- and low-exposure municipalities before and after the November 2015 emergency declaration. Across exposure measures, we find that fertility in high-Zika areas falls by 10.7 percent beginning nine months after the declaration, consistent with pregnancy avoidance rather than termination, and that births do not overshoot in later periods. This pattern indicates that many "missing births" are not simply postponed but effectively foregone, corroborating and extending existing findings (Marteleto et al., 2020; Junior and Rasul, 2020; Ryu, 2020).

Second, we estimate the causal effect of this fertility decline on women's labor market outcomes. We combine the fertility panel with quarterly microdata from the nationally representative *Pesquisa Nacional por Amostra de Domicílios Contínua* (PNAD-C), which provides detailed information on employment, formality, hours, and earnings for both formal and informal work. We link women to Zika exposure at the state–capital-region level and estimate an event-study difference-in-differences specification analogous to the fertility analysis. The timing of Zika's impact—with fertility responses beginning roughly nine months after the health emergency declaration—allows us to separate any contemporaneous, direct labor market effects of the epidemic from the lagged, fertility-mediated responses. We find that in high-Zika areas, women's employment rises by two to three percentage points and formal sector participation increases by up to 3.1 percentage points, beginning roughly nine months after the fertility shock. Monthly earnings increase by over 200 reais, or around 20 percent of pre-epidemic mean earnings for women between ages 20 and 34. Importantly, these gains persist even after fertility rates revert to trend, suggesting a structural change in women's labor market involvement. These results complement and extend prior work documenting that motherhood reduces women's labor supply and shifts them toward more flexible or lower-paying occupations (Adda et al., 2017; Goldin and Mitchell, 2017; Bertrand et al., 2010; Cortés and Pan, 2023). Here, we show the mirror image: a plausibly exogenous reduction in fertility in a middle-income setting leads to meaningful increases in women's earnings and attachment to the formal labor market.

Third, we trace out the implications of fertility declines and improved female labor outcomes for

marriage and divorce. Using annual municipality-level administrative data from the Brazilian Institute of Geography and Statistics (IBGE), we examine how marriages and divorces evolve in high- versus low-Zika areas. We document that divorces rise by about 15 percent in high-exposure municipalities, peaking roughly one to two years after the Zika shock, while marriage rates increase with a similar lag. One interpretation is that reduced fertility and stronger labor market attachment improve women's outside options and bargaining power within relationships, enabling some women to exit unsatisfactory unions and enter new ones. These patterns are consistent with broader trends of rising divorce in Brazil (Instituto Brasileiro de Geografia e Estatística, 2023; Herre et al., 2020; OECD, 2024), but our design isolates the causal role of exogenous fertility declines in accelerating these shifts. To our knowledge, this is the first paper to use the Zika epidemic to study marriage and divorce responses, and one of the few to causally link aggregate fertility shocks to changes in marriage markets in a middle-income country.

Our analysis takes place against the backdrop of long-run changes in women's economic roles and family formation in Brazil. Globally, female labor force participation has risen steadily over recent decades, but remains below male participation in virtually all countries (Goldin and Mitchell, 2017; Blau and Kahn, 2017). Brazil has followed this pattern: in the 1970s, only about 20 percent of Brazilian women were economically active, whereas in recent years female labor force participation has plateaued around 53 percent, compared to roughly 73 percent for men (World Bank, 2025). Women have attained higher levels of education than men on average, but continue to be concentrated in sectors such as education, health, hospitality, and retail, while men remain overrepresented in construction, transport, and agriculture. Gender earnings gaps, although narrowing over time, remain large and persistent, particularly in the middle of the distribution where care and time constraints are most binding (Bertrand et al., 2010; Blau and Kahn, 2017; Khanna et al., 2025). At the same time, marriage and divorce patterns in Brazil have shifted markedly. Legal reforms have simplified the process of divorce; divorce and separation have become more common; and marriages are increasingly delayed (Instituto Brasileiro de Geografia e Estatística, 2023). These trends mirror those observed across many middle- and high-income countries, where family formation has decoupled from traditional marital institutions and household structures have diversified.

A central theme of the recent literature on gender inequality is that childbearing is the main turning point at which gender earnings gaps emerge and persist. Studies using high-quality administrative data from Denmark, the United States, Finland, and other high-income countries consistently show that earnings trajectories of men and women are similar prior to the birth of the first child, but diverge sharply thereafter (Angelov et al., 2016; Chung et al., 2017; Kleven et al., 2019b; Sieppi and Pehkonen, 2019). Women's earnings and hours fall, occupational choices shift toward more flexible or family-friendly jobs, and a sizable "child penalty" emerges that persists for years or decades (Adda et al., 2017; Bertrand et al., 2010; Cortés and Pan, 2023). Evidence from developing and middle-income countries, including Latin America, suggests similar patterns, with motherhood associated with reduced labor force participation, increased informality, and larger earnings penalties where childcare systems and labor protections are weaker (Cáceres-Delpiano, 2012; Heath, 2017; Berniel et al., 2021; Aguero et al., 2020). Cross-country comparisons indicate that the magnitude of these child penalties varies systematically with institutional context and stage of development (Kleven et al., 2019a, 2021), highlighting the importance of studying fertility–labor links in settings beyond the OECD.

Taken together, our findings speak to broader debates on the interaction between demographic transitions, gender inequality, and economic development. A growing literature shows that motherhood penalties vary systematically with institutional context and stage of development (Aguero et al., 2020; Kleven et al., 2019a, 2021), and that women often sort into flexible occupations and sectors when time demands are high (Goldin and Mitchell, 2017; Bertrand et al., 2010; Adda et al., 2017; Cortés and Pan, 2023). Our results suggest that, in a middle-income country where fertility is already low, and female

labor force participation is rising, further fertility declines can amplify women's engagement in formal employment and earnings, with knock-on effects on family formation. If the mechanisms we uncover generalize, ongoing global fertility declines may reshape both labor and marriage markets in ways that narrow gender gaps, while also altering the stability and composition of households.

Unlike previous work that relies mostly on birth events for variation (and are focused on high-income countries), we study the consequences of fertility *reductions*. In many ways, reduced fertility may be the relevant variation when considering the long-term consequences of the worldwide declines in birth rates. As such, our results have important implications for how women's roles will evolve in the labor and marriage market, and within families, as the decline in fertility continues in different parts of the world. Our focus on a populous middle-income country adds substantial evidence complementing the detailed research in high-income settings.

The remainder of the paper proceeds as follows. Section 2 provides background on the Zika epidemic in Brazil and documents key trends in fertility, women's work, and marriage and divorce prior to the epidemic. Section 3 describes our administrative and survey data sources and the construction of our Zika exposure measures. Section 4 outlines our empirical strategy. Section 5 presents our main results on fertility, women's labor market outcomes, and marriage and divorce. Section 6 concludes with implications for understanding global fertility transitions and gender inequality in labor and family outcomes.

2 Background: Zika, fertility, marriage, and work

2.1 Zika

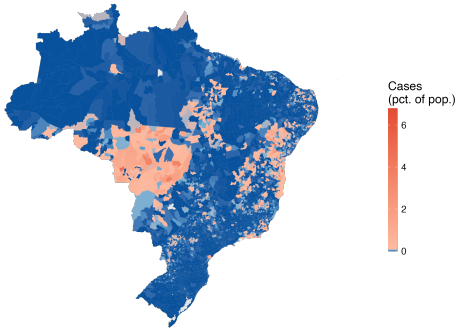
The Zika virus induces mild, short-lived symptoms in adults. Roughly 80 percent of infected people are asymptomatic; the symptomatic experience mild cold-like symptoms, and more serious complications are rare. However, when women are infected during pregnancy, the disease can be devastating to fetuses. Rates of adverse outcomes are 30 to 40 percentage points higher among fetuses, and brain abnormalities are common. In one study on Zika-affected pregnant women in Rio de Janeiro, 42 percent of live babies born to Zika-positive women had "grossly abnormal clinical and/or brain imaging," and four of those had microcephaly (Brasil et al., 2016).

The first case of Zika was confirmed via RT-PCR in May 2015, but the potential for devastating effects on fetuses was not widely known until November 2015 following the formal declaration of a public health emergency by Brazilian authorities. As symptoms were primarily observed among adults in the early stage, Zika was considered benign. In October 2015, specialists first reported a correlation between Zika and microcephaly. Brazil's Ministry of Health declared a national public health emergency in November 2015, marking the first widespread awareness of Zika's threat to the development of fetuses. As Zika spread within and beyond Brazil, the World Health Organization declared a public health emergency of international concern in February 2016.

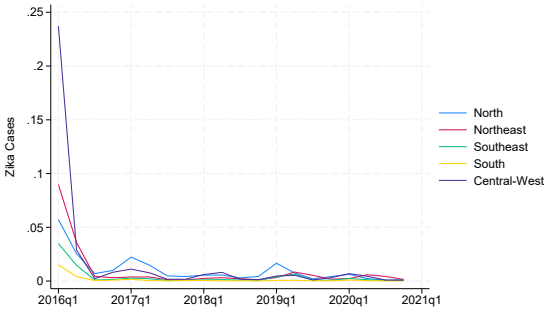
As such, a growing body of clinical and demographic evidence documents that the Zika epidemic posed severe risks to fetal health and generated large behavioral responses in fertility. Early medical studies linked maternal Zika infection to microcephaly and other serious congenital abnormalities, including evidence of Zika virus present in fetal brain tissue (Brasil et al., 2016; Mlakar et al., 2016). Subsequent research highlighted that even asymptomatic infections posed substantial threats to fetal development and contributed to fetal losses (Haby et al., 2018; Coelho et al., 2017). As information about these risks spread, fertility fell sharply in regions experiencing higher Zika transmission, with studies consistently documenting large declines in births in high-incidence municipalities (Marteleto et al., 2017, 2020; Rangel et al., 2020; Junior and Rasul, 2020; Ryu, 2020). These declines were driven not only by fetal health shocks but by households strategically delaying or avoiding pregnancy in response to perceived fetal risk

Figure 1: The Geographic and Temporal Spread of Zika Cases

(a) Map of Zika Cases



(b) Zika Cases by Region over Time



Notes: Zika case data are from the SINAN. The map in Panel 1a shows Zika case load per capita by municipality. Municipalities in blue are below the 90th percentile in case incidence, while those in red are at or above the 90th percentile. The five geographic regions shown in Panel 1b are the official regions defined by IBGE.

(Marteleto et al., 2017; Junior and Rasul, 2020; Rangel et al., 2020). For these reasons, recent research has increasingly employed Zika as a natural experiment, exploiting the geographic spread of the virus and variation in transmission risk to identify the causal impacts of fertility changes on household behavior (Marteleto et al., 2017, 2020; Marteleto and Dondero, 2021; Junior and Rasul, 2020; Rangel et al., 2020; Ryu, 2020).

Figure 1 indicates substantial variation in Zika prevalence across both time and space. The Northeastern state of Pernambuco is often considered the original epicenter of the Zika outbreak. When official case reports began in the first quarter of 2016, however, per-capita cases were the highest in the Central-West region, a landlocked agricultural area that is less densely-populated. Cases were lowest in the temperate states of the South, and in the Southeast (which includes the major population centers of Rio de Janeiro and São Paulo). Throughout the country, reported cases peaked in early 2016. With the exception of the low-population density Amazonian North that reported small outbreaks in 2017 and 2019, cases fell to near zero by early 2017, and remained there throughout the period shown.

This geographic and temporal identifying variation created by the Zika virus allows us to study the effects of fertility on labor and marriage market outcomes, as its mild symptoms in adults make it likely to affect fertility without directly affecting work behavior. Subsequent research has shown that the Zika epidemic led to a decrease in fertility in Brazil, findings that we replicate below with novel data and identification.

2.2 Fertility, Women's Work, and Family Formation

Our primary outcomes center on fertility, female employment and earnings, and marriages and divorces. We situate our analysis in a context where fertility rates worldwide have been falling steadily over the past several decades. As recently as the 1950s, the global average total fertility rate (i.e., number of children per woman over her lifetime) was roughly 4.9–5.0 children per woman, but by 2023 it had dropped to around 2.3 children per woman. This decline is also clearly visible in Brazil. In 1960, Brazil's total fertility rate was about 6.05 children per woman. Over subsequent decades, fertility fell rapidly: by 1991 it was down to around 2.9–3.0, by 2000 roughly 2.4, and by 2010 about 1.9 children per woman. In the most recent data (2023), Brazil's fertility rate stands at around 1.6 births per woman (World Bank, 2025). Thus, Brazil's trajectory mirrors the global trend: from large families once typical to well below "replacement level" in the 21st century, suggesting a dramatic demographic shift with long-term

implications.

Concurrently, across the world, female labor force participation has gradually increased over recent decades, although women continue to participate at substantially lower rates than men. According to recent estimates, around 49 percent of women globally are in the labor force, reflecting both rising educational attainment and ongoing constraints related to child care and social norms. Brazil further reflects these global patterns. In the 1970s, only about 20 percent of Brazilian women were economically active, whereas in more recent years, female labor force participation in Brazil has been around 53 percent, compared to roughly 73 percent for men (World Bank, 2025). Thus, while Brazil has experienced large gains in women's labor market involvement, persistent gender gaps remain, perhaps driven in part by unequal household responsibilities and continued barriers to formal employment (Khanna et al., 2025).

Household survey data, available in the PNAD-C, sheds light on general employment patterns for men and women in Brazil beginning in 2012. Figure A1 compares education levels of men and women both in and out of the labor force, in 2017. Women have generally attained higher levels of education, and men and women in the labor force have attained higher levels of education than those not in the labor force. This figure also compares the industry in which men and women work. Construction, transportation, and agriculture are industries primarily driven by male labor, while women tend to hold jobs in hospitality, education, and health and social services. Reflecting these education and industry trends, women are far more likely than men to work in occupations such as teaching, service, and retail.

Figure A2 shows the adjustment in the distribution of earnings for men and women between 2012 and 2019. Men's earnings remained relatively steady, but female earnings increased, primarily in the middle of the distribution. As a result, the gender pay gap reduced throughout this period, though it remains high at more than 30 percentage points in the first quarter of 2019.

Marriage patterns around the world have shifted markedly in recent decades, with most countries experiencing later marriage, lower marriage rates, and rising divorce (Herre et al., 2020). While registered marriages have declined in recent years, divorces have become more common (albeit with variation across contexts), reflecting legal reforms that simplified the process and broader social changes (Herre et al., 2020; OECD, 2024). Brazil exhibits similar trends. Over the past two decades, the number of legal divorces has risen sharply, and the average duration of marriage before divorce has fallen, perhaps indicating both greater acceptance of separation and changing gender norms (Instituto Brasileiro de Geografia e Estatística, 2023). Together, these trends point toward a gradual decoupling of family formation from traditional marital institutions and a continued diversification of household structures.

Changes in fertility, women's work, and marriage are also likely to affect patterns of time use, particularly the extent to which childcare and household responsibilities constrain labor supply. Figure A3 summarizes trends in the share of individuals reporting that they were unable to work due to childcare or household duties, separately by age group and gender. Following the onset of the Zika epidemic, we observe notable declines among younger women in the share reporting that childcare or housework prevented them from working, while no comparable changes appear for older women, who had likely already completed fertility. By contrast, younger men exhibit a modest increase in reports of childcare-related work constraints, although the scale of this change is considerably smaller than that for women. These patterns are consistent with fertility declines reducing childcare-related barriers to women's labor supply, while only marginally altering men's time allocation.

3 Data Description

We combine a wealth of administrative and survey data. As exposure to the Zika virus varies by geography, we link several administrative and survey datasets at the municipal level.

3.1 Zika Exposure

Our "treatment" measure combines time-series variation in the virus' spread with cross-sectional, location-based variation in exposure to the Zika virus. For time series variation, we compare before vs. after the November, 2015 announcement of a national public health emergency by Brazil's Ministry of health.

Our preferred measure of cross-sectional variation is the precise number of Zika cases reported per capita in each municipality. Plotted in plotted in Figure 1a, these data come from Brazil's administrative health data, the *Sistema de Informação de Agravos de Notificação* (SINAN) (Ministério da Saúde, 2020). Previous literature using this measure found large declines in fertility in areas with higher case loads (Rangel et al., 2020; Codeço et al., 2017; Marteleto et al., 2017). For our estimation strategy (see Section 4), we create a geography-level indicator variable equal to one for geographies in which per-capita cases in the first quarter of 2016 lie above the 90th percentile of per-capita cases across all municipalities, and equal to zero otherwise.

One potential concern with this oft-used measure of Zika exposure is that the number of diagnosed cases may be correlated with the medical infrastructure and other local characteristics that could predict outcomes of interest. While our event study strategy would surface differential pre-trends between high and low exposure areas, we also show robustness to other measures. Our second measure addresses this concern by exploiting variation in Zika exposure across municipalities due to their environmental suitability for the *Aedes aegypti* mosquito, the primary vector for the Zika virus (Faria et al., 2017; Messina et al., 2016). We refer to this measure as "Zika suitability." For our estimation strategy (see Section 4), we create a binary indicator for each geography that assumes a value of one if suitability falls above the 90th percentile and a value of zero otherwise. Appendix Figure A4a identifies these treated regions in red.

We also consider a measure that gauges awareness and concern about the Zika epidemic. We use a municipality-level index measuring the frequency of Google searches including the word "Zika" relative to all Google searches (Google Trends, 2018).[1] For our estimation strategy (see Section 4), we create a binary indicator for each geography that assumes a value of one if any Zika-related searches are recorded in the first quarter of 2016, and a value of zero otherwise. Appendix Figure A4b identifies these treated regions in red. The treated municipalities, using this measure, are more evenly distributed throughout the country.

Comparing the three maps, we see that the various measures of Zika exposure indeed capture slightly different aspects of variation of the virus. Nonetheless, we show that these three measures are strongly correlated (results available on request). Areas with high Zika exposure show modest differences as compared to areas with low Zika exposure, e.g. slightly larger populations, especially according to the Google searches measure. For our main analysis, we include only births to women between 20 and 34 years old.

3.2 Primary Outcomes

We measure municipal-level births using administrative births data, the *Sistema de Informações Sobre Nascidos Vivos* (SINASC), which records data on every birth in Brazil, including the municipality of maternal residence and delivery (Ministério da Saúde, 2023). We collapse this data to the municipal level by mothers' municipality of residence, and merge it with the Zika exposure measures discussed above. In this way, we create a municipal-level dataset at the monthly frequency, that includes all births within a municipality and the mothers' corresponding exposure to Zika.

The employment dataset we consider, the *Pesquisa Nacional por Amostra de Domicílios- Continua* (PNAD-C), is a rotating panel household survey conducted at a quarterly frequency, which is nationally

[1] We thank Hal Varian for personally sharing the Google Search Data.

representative of Brazilians age 15 and above (Instituto Brasileiro de Geografia e Estatística, 2024). These data allow us to measure informal, as well as formal, employment and shed light on earnings and hours worked in both sectors. These data report the respondent's state of residence and whether they live in the capital municipality, resulting in 53 distinct regions that we refer to as "state-by-capital." We aggregate our measures of Zika exposure to these larger geographic regions, and link each PNAD-C respondent to the Zika exposure measure of their respective region. The result is an individual-level dataset measured at the quarterly frequency.

We obtain annual counts of marriages and divorces by municipality from *Sistema de Estatísticas Vitais* (System of Vital Statistics) maintained by the Brazilian Institute of Geography and Statistics (IBGE). These administrative records are at the municipality-year level and cover all civil marriages and legally registered divorces in Brazil and report the municipality where the marriage or divorce occurred. The System of Vital Statistics provides comprehensive national coverage, allowing us to track changes in marital formation and dissolution over time. Because the data are available only at the annual frequency, our analysis of marriage and divorce is at the municipality-year level, complementing our higher frequency fertility and labor market analysis (Instituto Brasileiro de Geografia e Estatística, 2023).

4 Estimation Strategy

Across all outcomes, we use an extended difference-in-difference specification that compares changes in high-exposure Zika areas relative to changes in low-exposure Zika areas. However, different outcomes are available at different frequencies, for different periods, and at different levels of aggregation; we accordingly adapt some details of the analysis for each group of outcomes.

We expect Zika's direct effect to be on fertility, and we estimate that relationship as follows:

$$Births_{m,t} = \gamma_m + \delta_t + \sum_{t=Jan.2015}^{Sep.2015} \left(\alpha_t \times \text{Treated}_m\right) + \sum_{t=Nov.2015}^{Dec.2018} \left(\beta_t \times \text{Treated}_m\right) + \varepsilon_{m,t}, \quad (1)$$

where m indexes municipalities and t indexes months. $Births_{m,t}$ is the count of municipal-level births to women between the ages of 20 and 25, measured at the monthly level. Treated_m is a binary measure of low or high Zika exposure in each municipality, while δ_t represents year-by-month fixed effects and γ_m represents municipality fixed effects. These fixed effects absorb variation in births over time and across municipalities, leaving variation within municipality and time-by-treatment status to identify the β coefficients of interest.

We continue with a reduced-form regression estimating the impact of Zika on monthly, individual-level employment and wage outcomes from the PNAD-C:

$$L_{i,j,q} = \gamma_j + \delta_q + \sum_{t=2014q1}^{2015q2} \left(\alpha_q \times \text{Treated}_j\right) + \sum_{t=2015q4}^{2018q4} \left(\beta_q \times \text{Treated}_j\right) + \varepsilon_{i,j,q}, \quad (2)$$

where i indexes individuals, j indexes the 53 regions identifiable in the PNAD-C, and q indexes quarters. $L_{i,j,q}$ is an individual-level employment or earnings measured quarterly, for women between the ages of 20 and 35. Treated_j is a binary measure of low or high Zika exposure in each of the PNAD-C regions, while δ_q represents year-by-quarter fixed effects and γ_j represents regional fixed effects. As a result, the β coefficients of interest estimate changes in labor-market outcomes using within geography and time-by-treatment variation.

Our main analysis concludes with another reduced-form regression estimating the impact of Zika on family formation and dissolution. Marriage and divorce data are recorded annually, leading to the

following municipality-by-year specification:

$$M_{m,k} = \gamma_m + \delta_k + \sum_{k=2014}^{2015} \left(\alpha_k \times Treated_m\right) + \sum_{k=2017}^{2023} \left(\beta_k \times \text{Treated}_m\right) + \varepsilon_{m,k}, \tag{3}$$

where m indexes municipalities and k indexes years. $M_{m,k}$ measures municipal-level marriages and divorces at the annual level, across all age groups. Treated_m is our binary measure of low or high Zika exposure in each municipality, while δ_k represents year fixed effects and γ_m represents municipality fixed effects. These fixed effects absorb variation across years and municipalities, leaving variation within municipality and time-by-treatment status to identify the β coefficients of interest.

The coefficients of interest, β, measure whether any gap between low and high Zika exposure locations changed after Zika, specifically relative to the reference period (October 2015 for monthly specification (1), 2015 quarter 3 for quarterly specification (2), and 2016 for annual specification (3)). Three conditions must hold for these coefficients to causally estimate the impact of Zika exposure. First, in the absence of Zika, the high- and low-Zika municipalities would have had similar trends in fertility, employment, and family formation and dissolution. We estimate pre-period α coefficients that provide suggestive evidence of parallel trends before the Zika epidemic. Second, we assume SUTVA, such that there are no spillovers from high to low exposure places. This assumption would be violated if, say, the Zika epidemic led to short-term migration from high-exposure to low-exposure parts of the country. Given the immediate response in conception that we document in monthly fertility data, one may expect differential migration to be less of a concern. Third, our strategy precludes the possibility of other unrelated simultaneous changes that differentially affected high-exposure places in the corresponding months.

We require one further condition to claim that equations (2) and (3) capture the effect of fertility on employment and family formation: Zika must directly affect fertility, but only affect employment or divorces and marriages through its impact on fertility. While the effect of Zika on fertility is testable, the fact that employment and household structure are only affected via fertility responses is more challenging to test. The typical nine-month gestation period suggests that employment and marriage effects due to additional children would not appear until nine months after Brazil's declaration of a health emergency, while any impacts on employment due to pregnancy itself would likely not show up until the final trimester. This suggests that immediate direct effects on employment may be detected during the Zika pandemic, but the fertility-mediated effects would mostly appear with a six-to-nine month lag.

5 Results

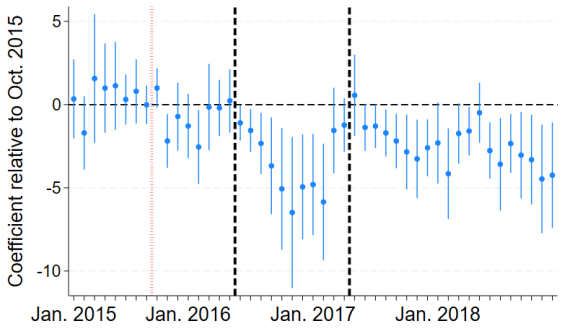
5.1 The Impact of Zika on Fertility

Figure 2 shows the impact of Zika on the total number of births within each municipality, estimated with specification 1. Each coefficient estimate measures the difference between high and low Zika exposure municipalities in the average monthly decline in births among women between the ages of 20 and 34, relative to October 2015. Thus, estimates below zero represent fewer babies in areas hardest hit by Zika.

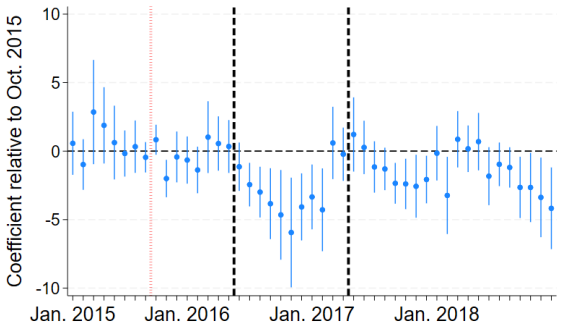
To aid interpretation, we add several vertical reference lines to the figure. The first (red) line marks our omitted month, October 2015, immediately before the declaration of the national emergency. We then plot a line nine months after the emergency was declared, corresponding to a typical gestational period when the initial shock might begin to affect births. A second line is placed nine months after cases fall back to near-zero, indicating the effective end of the epidemic. At that point as Zika became endemic at much lower rates, births may return to prior levels—or even overshoot them—as parents resume postponed childbearing.

Figure 2: Monthly Impact of Zika Virus on Births

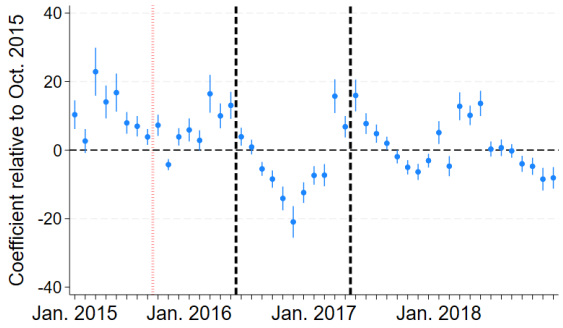
(a) Treatment is Zika Cases



(b) Treatment is Geographic Suitability



(c) Treatment is Google Searches



Notes: All specifications include year-by-month and municipality fixed effects. Standard errors are clustered at the municipality level. The sample is restricted to women ages 20-34. The outcome is births per month measured at the municipality level. The red vertical line marks the omitted period: October 2015, the last month before the declaration of the national emergency. The first black vertical line marks nine months after the declaration of the national emergency, to allow for the lagged fertility response. The second black vertical line marks nine months after the end of the epidemic. Births data are from the SINASC, 2015-2018, while case data are from the SINAN, geographic suitability data are from Messina et al. (2016), and Google search data are from Google Trends data.

The estimates show relative declines in fertility in high-exposure municipalities beginning nine months after the declaration of the national emergency. Coefficients prior to the declaration of the national emergency are not statistically different from zero, providing reassurance that the parallel trends assumption is valid. Similarly, the coefficient estimates in the nine months following the declaration of the national emergency are small and not statistically different from zero. These patterns suggest minimal termination of pregnancies that were in utero when the health emergency was declared. There is, however, a large and statistically significant decline in births beginning nine months after the declaration of the national emergency. At the nadir of the fertility decline, women are having seven fewer children per month in areas with higher Zika cases. The average monthly fall in births over the period was 10.7% (3.44 births per month over an average of 32.11 births per month before 2016). Fertility remains at this low level for about six months before recovering in April of 2017, and declining again, albeit by a smaller margin, in subsequent months. Measures of Zika cases and Zika suitability in Figures 2(a) and (b) show very similar patterns. The measure of Zika awareness in Figure 2(c) shows a consistent but more volatile pattern in fertility responses.

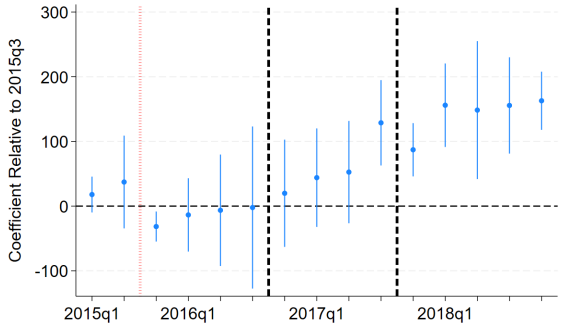
We do not detect any "rebound" or "overshooting" of births after the end of the epidemic, i.e. births

in high exposure areas remain below births in low exposure areas through this period.[2] Thus, it does not appear that women are not simply delaying fertility. The pregnancies that did not occur in the year following the declaration of the national health emergency still had not occurred prior to 2019, suggesting that there were fewer infants and toddlers in municipalities with high Zika exposure between April 2016 and the end of 2018.

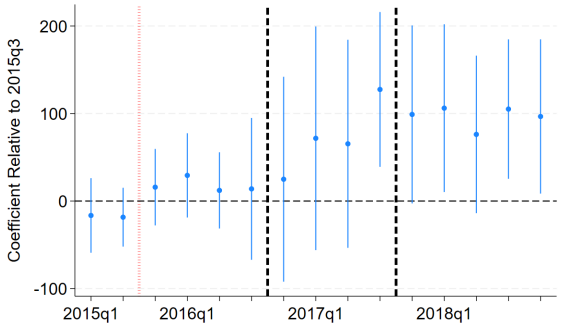
5.2 Zika's Impact on Women's Work And Family Formation

Figure 3: Quarterly impact of the Zika Virus on Monthly Earnings

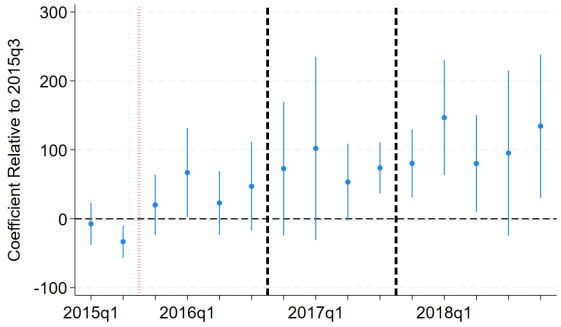
(a) Treatment is Zika Cases



(b) Treatment is Geographic Suitability



(c) Treatment is Google Searches



Notes: All specifications include year-by-month and PNAD-C region fixed effects. Standard errors are clustered at the region level. Outcomes are measured at the individual level. "Monthly Earnings" are defined as all earnings on the main, second, and other jobs in the reference month, generally the month prior. The omitted period (red dotted line) is 2015q4, the quarter of the declaration of the national health emergency. The black lines mark 2016q2 (between six and nine months following the declaration of the national health emergency) and 2017q2 (Between six and nine months following the end of the epidemic).

The previous section shows clear fertility declines in municipalities hardest hit by Zika. We now turn to the corresponding labor-market consequences for the group most exposed to the fertility declines: women aged 20-34. We use three measures of labor supply from the PNAD-C: i) monthly earnings (measured in reais), ii) a binary indicator for any employment during a reference period, and iii) a binary indicator for formal employment during a reference period. The PNAD-C is a quarterly household survey that identifies 53 regions, rather than the municipality, of residence.[3] Equation 2 represents the individual-

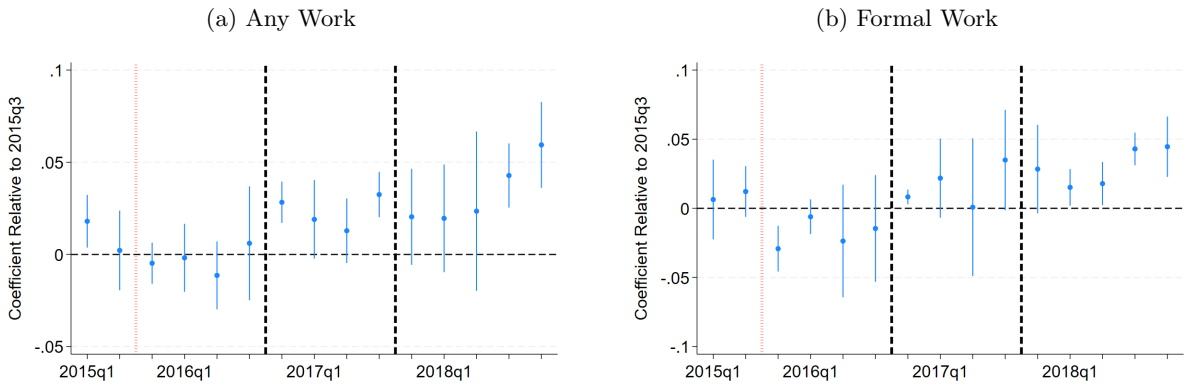
[2] Excepting a few months in 2018 when using the Google data as our measure of treatment, see Figure 2(c).

[3] PNAD-C permits identification of: i) 26 state capitals, ii) 26 states excluding their capitals, and iii) the federal district, i.e. capital of the nation. Each of the 53 regions identifiable in the PNAD-C is an aggregation of municipalities; every municipality is fully contained in a PNAD-C region.

level specification used in the estimation. As a result, each coefficient in the following graphs estimates the difference between high- and low-exposure regions in labor market indicators for women aged 20-34 relative to the third quarter of 2015.

Monthly Earnings. Figure 3 shows increases in women's earnings of around 200 reais, or about 20 percent of average earnings among women between the ages of 20 and 34 in the third quarter of 2015. The figure presents the coefficient estimates resulting from Equation 2 when the outcome variable is women's reported monthly earnings. These increases in earnings persist into 2018 and beyond. That is, even though fertility rates return to pre-epidemic levels, women's earnings persistently stay higher than before in Zika regions, perhaps as cumulative births are lower. This suggests a structural change in women's earnings capacity.

Figure 4: Quarterly impact of the Zika Virus on Employment and Formal Employment



Notes: All specifications include year-by-month and state-by-capital region fixed effects. Standard errors are clustered at the state-by-capital regional level. Outcomes are measured at the individual level. The omitted period (red dotted line) is 2015q3, the quarter before the declaration of the national health emergency. "Any work" is an indicator reporting whether the individual was working in the reference period. "Formal work" indicates whether the individual was working in a formal sector job, defined as a job upon which she contributed to social security.

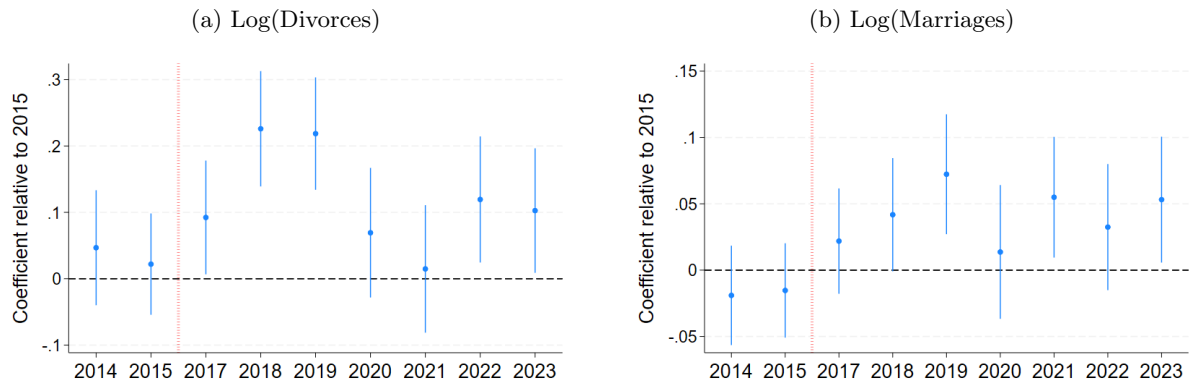
Employment. Figure 4 shows meaningful and sustained increases in female labor supply after the arrival of Zika. The figure presents the coefficient estimates resulting from Equation 2 when the outcome variables are measures of employment. The left panel is an indicator of whether a woman reports herself as working for pay in the reference period, and the right panel is work only in the formal sector. The positive and significant coefficients beginning in the fourth quarter of 2016 suggest that women's employment is around two percentage points higher during the period of fertility declines in the areas hardest hit by Zika. Formal sector work also rises by a similar magnitude.[4] These employment increases seem to maintain throughout the period, even after the end of the epidemic. Further, it is notable that the increases only begin nine months after the declaration of the national health emergency. This supports the hypothesis that the employment impacts of Zika are not direct, but are primarily a result of the corresponding fertility decline.

Marriages and Divorces. Figure 5 presents the estimated coefficients from Equation 3 when the outcomes are the log number of marriages and the log number of divorces. Figure 5a shows that divorce

[4] A decline in fertility can influence formal labor supply through two channels. First, fewer children could encourage women to begin working when they otherwise would not. Second, fewer children could encourage women to switch between the formal and informal sector.

rates begin to rise in 2017, peak in 2018 and 2019, and subsequently decline, reaching levels roughly 20 percent higher in high-exposure Zika areas relative to low-exposure Zika areas at the peak. One interpretation of these results is that reduced fertility and improved labor market opportunities enhanced women's ability to exit certain unions. Marriage rates also increase in Figure 5b, but their rise lags that of divorces by roughly one year, potentially reflecting remarriages or delayed union formation.

Figure 5: Annual Impact of the Zika Virus on Marriages and Divorces



Notes: All specifications include year and municipality fixed effects. Standard errors are clustered at the municipality level. Outcomes are annual log marriages and log divorces measured at the municipality level. The omitted period (red dotted line) is 2016, since the national emergency was declared at the end of 2015. Municipality level marriage and divorce data are from IBGE's System of Vital Statistics, 2014-2023.

6 Conclusion

Our findings demonstrate that the Zika epidemic led to a measurable fertility decline in Brazil, and this reduction was accompanied by increases in women's labor market earnings and employment, as well as notable changes in marriage and divorce patterns. Together, these results contribute to the broader literature on fertility, labor supply, and family formation by providing causal evidence that reductions in fertility influence women's employment opportunities and relationship dynamics. Unlike previous studies that focus on long-run fertility transitions or policy-driven fertility shifts, our paper leverages a sharp and plausibly exogenous public health shock to isolate the labor- and marriage-market effects of a sudden decline in childbearing, thereby offering a rare and credible estimate of the causal links between fertility and women's economic trajectories.

These findings have important implications for understanding ongoing and future demographic change. If temporary fertility declines driven by a health shock can meaningfully increase women's labor force participation and earnings, more persistent fertility declines—such as those observed across Europe, East Asia, and Latin America—may have even larger cumulative effects on women's lifetime labor supply, earnings potential, and economic independence. In many middle- and high-income countries, fertility rates have already fallen below replacement, and concerns about population aging, shrinking labor forces, and fiscal sustainability are increasingly central to policy debates. At the same time, falling fertility may enhance women's participation in paid work, accelerate the closing of gender gaps, and reshape intra-household bargaining power, with downstream effects on marriage, divorce, and household structure.

Our evidence also suggests that fertility reductions are not simply delayed births that eventually "catch up," but may translate into fewer births overall. This distinction matters for thinking about whether women's behavioral responses reflect timing (postponement) versus completed fertility reductions. If the latter, then long-run demographic change may not only shrink cohorts entering the labor

market, but may also permanently shift women's economic roles. In contexts where childcare systems remain underdeveloped, and the motherhood penalty is large, fertility declines may further amplify women's formal employment and earnings, contributing to long-run gender convergence—although potentially widening inequalities between women with children and those without.

Future research should explore whether the labor and marriage market effects we document persist over the longer term and whether similar patterns emerge in other settings where fertility rates are falling due to epidemiological shocks, economic downturns, or secular demographic transitions. Understanding how—and for whom—fertility declines translate into economic opportunities is crucial for anticipating how societies will adapt to ongoing global demographic change.

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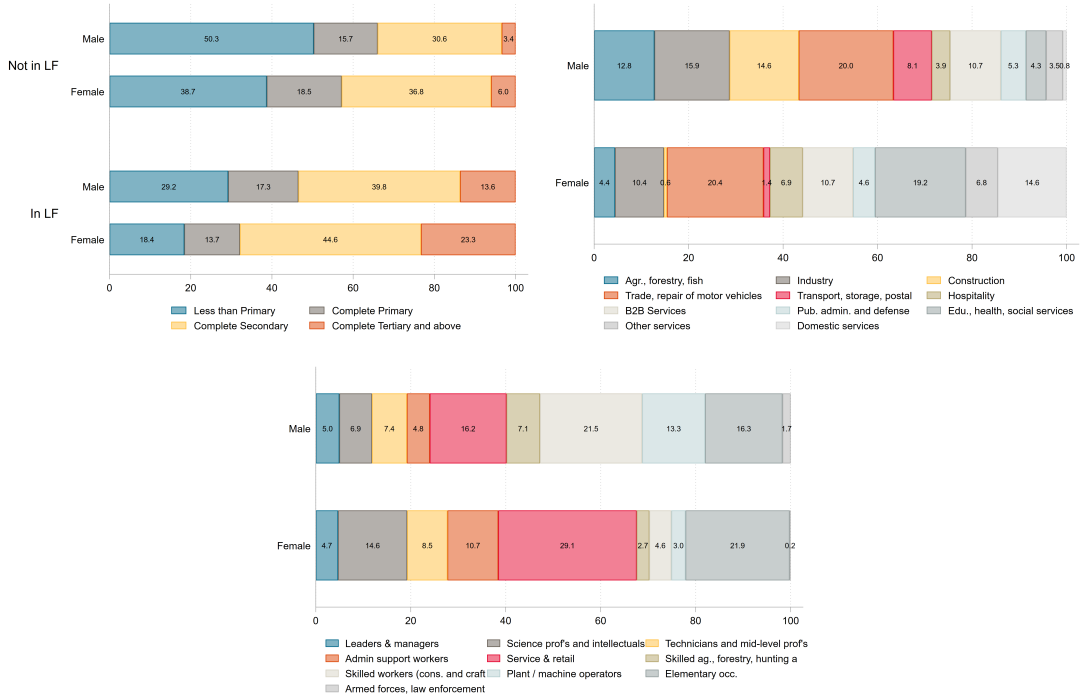
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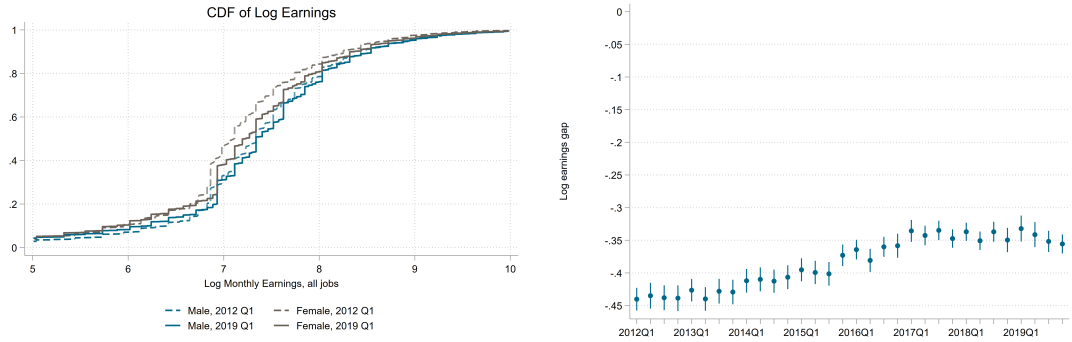
Appendix

Figure A1: Women and Men in the Workforce: Education, Industry, and Occupation



Notes: Data from PNAD-C. Includes all individuals 15-49 from pooled 2016 waves.

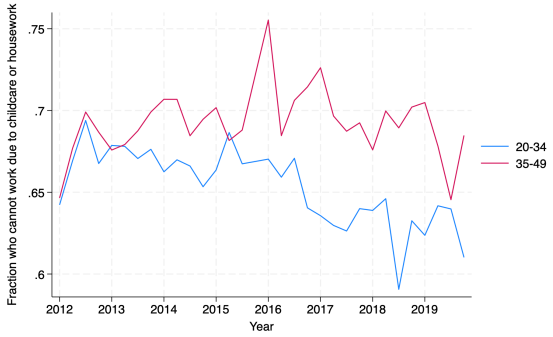
Figure A2: Women's Earnings and the Gender Pay Gap



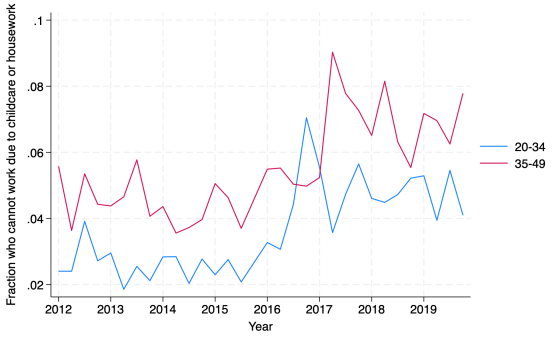
Notes: Regressed log earnings on education, age, age squared, fully interacted occupation and industry FEs, stratum FEs, and survey wave FEs. Plotted coefficients are the interaction of female and year-quarter indicators. SEs clustered by stratum and survey wave. Source: PNAD-C.

Figure A3: Fraction of People Not Working who Cannot Work due to Childcare or Housework by Age Group & Gender

(a) Women



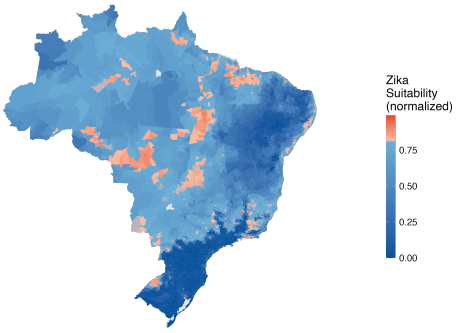
(b) Men



Notes: Sample is restricted to people ages 20-49 who are not working. Among the sample of people who are not working, we measure the share of this population who cannot work in the following week, if offered a job, due to childcare or housework obligations, PNAD-C, 2012-2019.

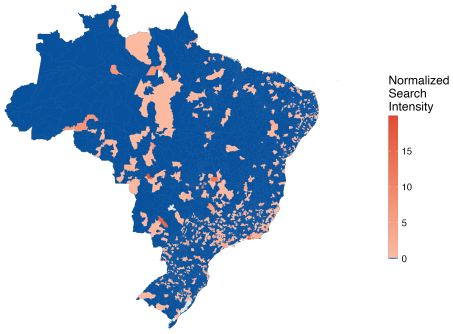
Figure A4: Alternative Treatment Measures

(a) Treatment Defined by Geographic Suitability



Notes: The map shows Aedes aegypti mosquito suitability, using data from Messina et al. (2016). Municipalities in blue are below the 90th percentile in geographic suitability, while those in red are at or above the 90th percentile.

(b) Treatment Defined by Google Searches



Notes: The map shows Zika Google search intensity using Google Trends data. Municipalities in blue have a Google search intensity index of zero, while those in red have a Google search intensity index above zero.