THE BUZZ ON BABIES: THE FERTILITY-DEPRESSING EFFECT OF THE ZIKA VIRUS IN BRAZIL

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THE BUZZ ON BABIES: EL EFECTO DE LA REDUCCIÓN DE LA FERTILIDAD CAUSADA POR EL VIRUS ZIKA EN BRASIL

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Resumo: A Epidemia de Zika de 2015-2016 e o surto de recém-nascidos diagnosticados com microcefalia e outras condições de desenvolvimento chamaram a atenção dentro e fora do Brasil. Embora pesquisas envolvendo a ciência do vírus tenham explodido nos meses seguintes ao surto, o conhecimento sobre seus efeitos a jusante continuam escassos. Neste artigo, investigamos o impacto do zika vírus nas taxas de natalidade durante e após a epidemia. Especificamente, estimamos os modelos de mínimos quadrados e diferença-em-diferença para avaliar a relação entre ambos: o Zika e a exposição ao zika vírus e as taxas de natalidade no Brasil. Os resultados de nossas análises sugerem que o vírus Zika reduziu a taxa de natalidade em um período de gravidez a termo após o primeiro pico de preocupação pública com o vírus e que o resultado da epidemia deu início a um efeito de "retorno" por meio do qual a taxa de natalidade do país se recuperou. Esses achados corroboram nossa suposta lógica de que a preocupação com o vírus levou muitos a aprenderem sobre a intricada conexão entre o vírus Zika e a microcefalia e, consequentemente, agirem para retardar a gravidez até que a epidemia diminuísse. Concluímos com uma discussão sobre as implicações de nossas descobertas para políticas públicas, desenvolvimento e política e delineamos caminhos para futuras pesquisas.

Palavras-chave : Brasil, zika, saúde pública, desenvolvimento, taxa de natalidade

Abstract: The 2015-2016 Zika Epidemic and accompanying surge of newborns diagnosed with microcephaly and other developmental conditions sounded alarm bells both within and outside of Brazil. While research involving the science of the virus exploded in the months following the outbreak, knowledge on its downstream effects remains in its infancy. In this paper, we investigate the impact of the Zika virus on birth rates both during and after the epidemic. Specifically, we estimate ordinary least squares and

difference-in-difference models to assess the relationship between both the Zika virus and exposure to the Zika virus and birth rates in Brazil. The results of our analyses suggest that the Zika virus depressed the birth rate one full-term pregnancy period after the first peak in public concern with the virus and that the aftermath of the epidemic ushered in a "bouncing back" effect through which the country's birth rate rebounded. These findings corroborate our purported logic that concern with the virus led many to learn of the intricate connection between the Zika virus and microcephaly and to, consequently, act to delay pregnancies until the epidemic subsided. We conclude with a discussion on the implications of our findings for public policy, development, and politics and outline avenues for future research.

Keywords: Brazil, zika, public health, development, birth rate

Resumen: La epidemia de zika 2015-2016 y el brote de recién nacidos diagnosticados con microcefalia y otras afecciones del desarrollo llamaron la atención dentro y fuera de Brasil. Aunque la investigación sobre la ciencia del virus explotó en los meses posteriores al brote, el conocimiento sobre sus efectos posteriores sigue siendo escaso. En este artículo, investigamos el impacto del virus Zika en las tasas de natalidad durante y después de la epidemia. Específicamente, estimamos los mínimos cuadrados y los modelos de diferencia en diferencia para evaluar la relación entre la exposición al virus del Zika y el virus del Zika y las tasas de natalidad en Brasil. Los resultados de nuestros análisis sugieren que el virus del Zika redujo la tasa de natalidad en un período de embarazo a término después del primer pico de preocupación pública sobre el virus y que el resultado de la epidemia inició un efecto de "retorno" a través de que la tasa de natalidad del país se ha recuperado. Estos hallazgos corroboran nuestra supuesta lógica de que preocuparse por el virus ha llevado a muchos a aprender sobre la intrincada conexión entre el virus Zika y la microcefalia y, en consecuencia, retrasar el embarazo hasta que la epidemia desaparezca. Concluimos con una discusión sobre las implicaciones de nuestros hallazgos para las políticas públicas, el desarrollo y la política, y esbozamos caminos para futuras investigaciones.

Palabras clave: Brasil, Zika, salud pública, desarrollo, tasa de natalidad

INTRODUCTION

The *Aedes aegypti* mosquito-borne Zika virus was discovered in Uganda in 1947 ("Zika virus"). For decades, the virus circulated in Africa and Asia, but the number of reported cases of the virus remained low. The Centers for Disease Control and Prevention (CDC) documents that only fourteen cases of the virus were reported as of 2007 ("Zika virus"). For this reason, the virus was largely unknown to the global public. The 2015-2016 Zika Epidemic in Brazil brought the virus into the public eye and unmasked its detrimental consequences, chiefly for infant health.

The first case of the Zika virus in Brazil and Latin America writ large was documented in May of 2015. By November of that same year, the number of reported cases of the virus increased substantially, and the Brazilian government declared a

national emergency on November 12, 2015 (Lowe et al. 2018). Three months later, the World Health Organization (WHO) followed suit (Lowe et al. 2018). The Zika outbreak continued unabated in the following year (2016), during which period more than 200,000 cases of Zika were reported (Lowe et al. 2018). It was not until the spring of 2017 that the country declared an end to the national emergency.

The Zika epidemic was especially alarming to both the Brazilian government and the public alike due to its strong link to microcephaly, a birth defect characterized by abnormalities in the size of infants' heads. As a function of this link, many Brazilians were advised to avoid pregnancy ("Unheard Voices: Women's Experiences with Zika in Brazil"). However, in a country in which abortion is illegal and in which contraception is available but challenging to access, adhering to this advice proved difficult for many of the most vulnerable Brazilian women ("Unheard Voices: Women's Experiences with Zika in Brazil"). Bahamondes et al.'s (2017) research shows that the accessibility of contraception did not improve during the height of the Zika epidemic in Brazil. This may lead some to infer that the Zika virus, in spite of the severe risks posed to newborns, had no impact on the country's birth rate. We view this jump as preemptive and frame our research around the following question: *Did the 2015-2016 Zika Epidemic in Brazil impact decisions involving family planning? Did the virus result in Brazilian women delaying their pregnancies?*

In this paper, we address these questions. Specifically, we assess whether the 2015-2016 Zika epidemic in Brazil resulted in a birth rate reduction. In doing so, we seek to advance scholars' understandings of the widespread and downstream public health and social effects of what Pereira et al. (2018) call "one of the most serious global public health emergencies since the Ebola outbreak in West Africa" (Pereira et al. 2018). Moreover, we contribute to a developed literature on fertility rates and, more specifically, on family planning in the developing world. We assess the relevance of discreet factors on family planning decisions in the developing world and weigh in on the sophistication of individuals within these contexts.

The remainder of the paper proceeds as follows: We, first, overview knowledge accumulated on fertility dynamics in the developing world and provide additional contextual information on the 2015-2016 Zika outbreak in Brazil. Then, we introduce our

data and the Ordinary Least Squares (OLS) and difference-in-difference empirical strategies that we use to estimate the effect of the Zika virus on birth rates. To preview, we find that exposure to the Zika virus in the height of the crisis resulted in a birthrate reduction. More precisely, our most temporally restricted analysis deduces that exposure to the Zika virus resulted in the reduction of 13.16 births per 100,000 people. We conclude with a summary of our findings and a discussion surrounding the implications of our work.

2. FERTILITY, DEVELOPMENT, AND THE DOWNSTREAM EFFECTS OF THE ZIKA VIRUS

Fertility and infant mortality patterns and trajectories have been the source of many scholarly contributions in disciplines including, but not limited to, public health and development. In their research, scholars frequently point to levels of development as important factors contributing to disparate cross-country infant mortality- and fertility rates. For the purpose of this paper, it is fitting to briefly introduce knowledge accumulated on birth rates and fertility patterns.

Experts calculate that the global average fertility rate has rapidly declined over the last fifty years and that it currently sits at 2.5 children per women, with the most developed countries exhibiting lower birth rates and the most underdeveloped countries exhibiting higher birth rates (Roser 2017). Accumulated knowledge suggests that the birth rate is declining in developed countries and that fertility rates, in general, tend to be higher in developing countries (Nargund 2009). Many reason that fertility rates are lower in developed countries (or areas of countries) due to distinct lifestyle choices, the economic drain imposed by children, the availability of contraception, and pregnancies delayed due to higher levels of education and demanding professional careers (Nargund 2009, Roser 2017). By contrast, conventional wisdom suggests that fertility rates are higher in developing countries due to the demands of the labor force, inaccessibility to contraceptives, and lower levels of education (especially among women) (Nargund 2009, Roser 2017). Empirical evidence stemming from subnational analyses and randomized control trials lend support to these theoretical and, perhaps, intuitive claims (For example, see Sen 1999; Duflo, Kremer, and Dupas (2015); Jensen (2012)). Recent studies have

moved beyond these compelling generalizations to study the impact of more discreet factors on fertility and family planning decisions. Brazil has served as a testing ground for some such studies.

La Ferrara, Chong and Duryea (2012) explore the impact of exposure to soap operas in Brazil on fertility decisions. They show that watching soap operas in Brazil reduces fertility, especially among less educated citizens. The supposed mechanism underlying this result is that people watching soap operas want to follow the decisions made by soap operas' main characters, which they perceive to have positive and desirable life outcomes. Insofar as these characters "choose" to have less children, those watching the TV show, mimic their behavior. Similarly, Bassi and Rasul (2017) analyze fertility in the Brazilian context and show that after the Papal visit to Brazil in October 1991, Brazilians exposed to his message were more likely to refrain from using contraceptives. These contributions suggest both that more nuanced and less conventional factors can have a surprising impact on fertility in the developing and that Brazilians, specifically, are sophisticated in their family planning decisions.

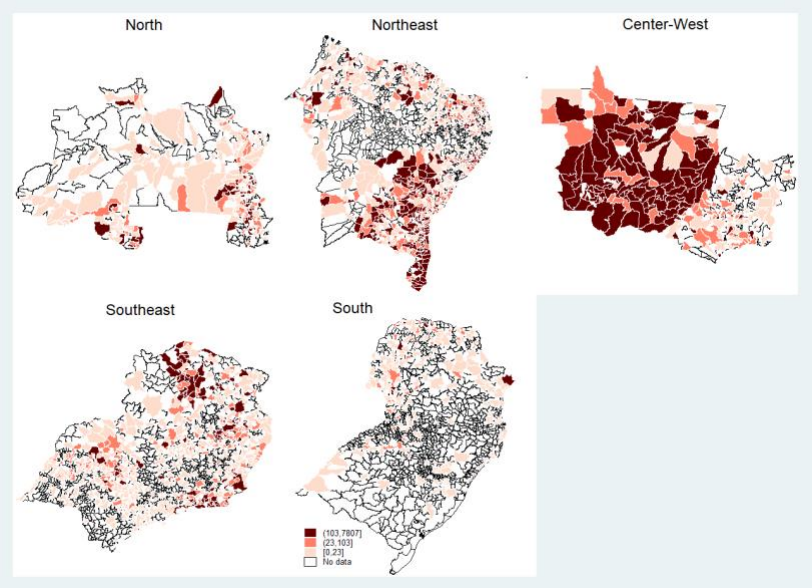
Both conventional wisdom and more recent research conducted on the prudent factors that influence fertility rates help to ground our study of the effects of the Zika virus on fertility, a largely unchartered grounds for research. Although research on the downstream, non-health-related effects of the Zika virus remains scant, several studies have emerged in recent years. In the context of Brazil, Boas and Hidalgo (2019) use an experiment to understand whether voters in Brazil who are informed about incumbent activity related to mosquito-borne viruses use that information to inform their electoral choices. Their results suggest that, at large, informing voters about government action on mosquito control does not impact voting behavior. However, they find that those personally exposed to the Zika virus are more likely to vote against the incumbent. Although our current work does not assess the political implications of the virus, it does investigate another downstream effect (fertility rates) with consequences that could have important political implications. The knowledge generated in our paper could provide an important foundation for future scholarship to take an important leap forward in assessing indirect political implications of the virus that could be used to ground Boas and Hidalgo's (2019) experimental findings in the real world.

More directly related to our research, Gamboa and Lesmes (2019) provide causal estimates of the effect of the Zika virus (and, specifically, the policy recommendation to postpone pregnancies) on birth rates and health care services in Colombia. Using difference-in-difference, matching, and synthetic control empirical techniques, they find that the revelation of the Zika virus resulted in a 10% birth rate reduction in the last two quarters of 2016. Our paper extends the knowledge accumulated on this substantive relationship to the context of Brazil – the epicenter of the 2015-2016 Latin American Zika epidemic. We also take the extra step of assessing the far-reaching fertility implications of the Zika virus by assessing what we describe in forthcoming sections as the "bouncing back effect."

The 2015-2016 Zika Epidemic in Brazil

The Zika virus emerged with force in Brazil in late-2015 and early-2016, impacting all of the country's regions. Figure 1 depicts the spatial distribution of the reported total number of cases of the Zika virus in municipalities in each of Brazil's five regions.

Figure 1 – Cases of Zika Per 100,000 People in 2016 by Brazilian Region

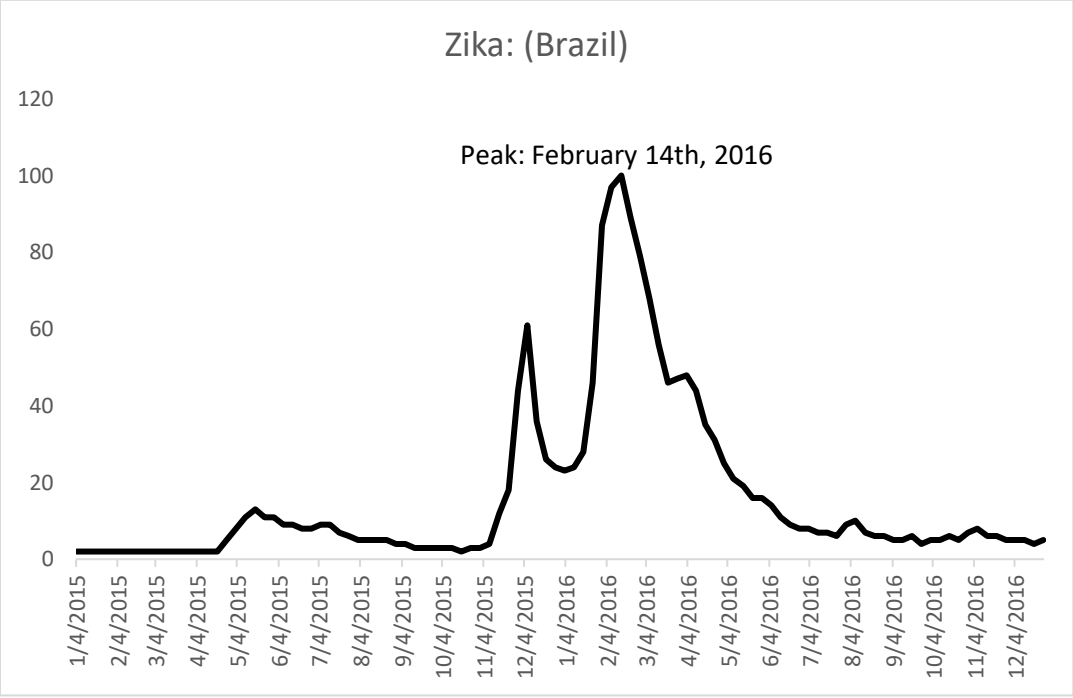


Note: The municipalities in Figure 1 are distinguished by quartiles associated with the number of reported cases of the Zika virus in 2016. Municipalities with more reported cases of the virus are depicted with darker shadings, and municipalities with less reported cases of the virus are

depicted with lighter shadings. Municipalities with no shading (i.e. municipalities left white) had no reported cases of the virus. The figure was constructed by authors with data from Brazil's Department of Informatics (DATASUS).

Though the first case of Zika was reported in May of 2015, the epidemic that came to rock Brazil did not surface until several months later. Many Brazilians first learned of and became concerned with the Zika virus in the summer of 2016. In that year, 170,535 cases were reported ("Zika virus: Brazil says emergency is over," 2017). As the number of reported cases increased and information about the detrimental effects of the virus was uncovered, Brazilians actively researched the virus. Figure 2 shows the number of Google searches for the virus. It clearly depicts that after the Brazilian government declared a national emergency on November 12, 2015, there was a sharp increase in Google searches for the Zika virus. In mid-February of 2016, the number of Google searches for Zika in Brazil reached its peak.

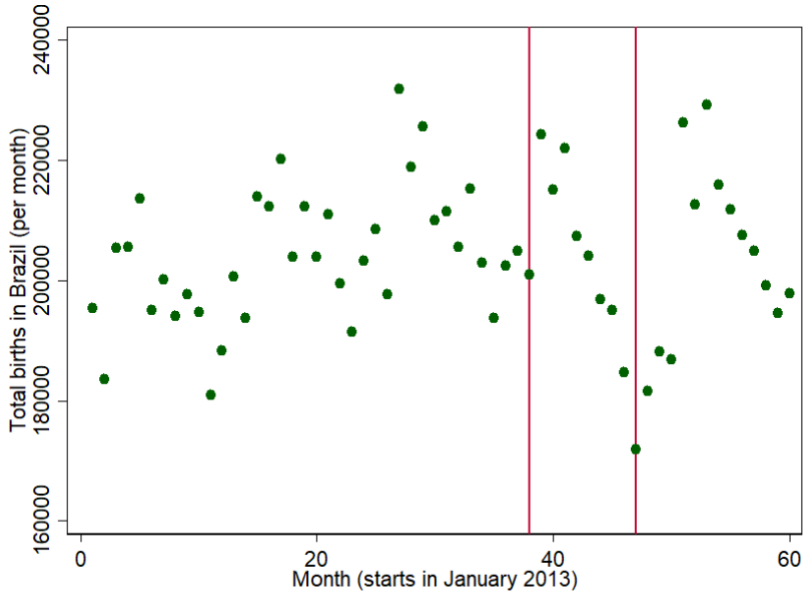
Figure 2 – Google Searches for the Zika Virus in Brazil



Note: Figure shows normalized scores of search intensity. 100 indicates peak intensity for a given search term.

In the Brazilian summer of February 2016 - one nine-month full-term pregnancy period following the peak in searches for Zika - there was a sizeable drop in the number of births in Brazil. Figure 3 illustrates this trajectory. The two vertical red lines demarcate the nine-month interval that followed the time corresponding with the peak in Google searches for the Zika virus. Figure 3 depicts a sharp drop in the number of births one full-term pregnancy period after search terms revealed skyrocketing concern with the virus. Although birth rates are seasonal, we do not suspect that Figure 3 is merely capturing a seasonality effect. Rather, we believe our illustration shows suggestive evidence of a birth control response to the Zika virus. We formally test this expectation using an econometric model that controls for seasonality.

Figure 3 – Total Number of Births in Brazil



Source: The figure was constructed by authors with data from Brazil's Department of Informatics (DATASUS).

The coincidence of public concern with Zika and the sharp decline in the birth rate in Brazil is suggestive of an intimate relationship between the virus and public health and

pregnancy decisions. It is plausible to suspect that concern with the virus led many to learn of the intricate connection between the Zika virus and microcephaly and to, consequently, act to delay pregnancies. In what follows, we introduce a series of empirical strategies to precisely estimate the possibility of a relationship between the virus and birth rates in Brazil.

DATA, RESEARCH METHODS, AND RESULTS

The Depressing Effect of the Zika Epidemic on Birth Rates

In an effort to assess the relationship between the Zika virus and birth rates in Brazil, we collected municipality-level monthly data reports of both birth rates from 2013-2017 and the Zika virus reports from 2016 from the information technology department of the Brazilian Unified Health System (DATASUS). With this data, we, first, estimate the relationship between the Zika virus and birth rates in Brazil with two simple ordinary least square models of the following form:

$$Birth\ Rate_{mt} = \alpha + \beta_1 PostOutbreak_t + \mu_t + \Lambda_m + \epsilon_{mt}, \quad (1)$$

where $Birth\ Rate_{mt}$ represents the birth rate in municipality m at time t. $PostOutbreak_t$ is a dichotomous variable equal to 1 for all observations one full-term pregnancy period (e.g. nine months) beyond the initial Google Search peak in November 2015. μ_t represents month fixed effects to control for seasonality, and Λ_m represents municipal fixed effects to control for any unobservable variable that does not vary at the monthly level. ϵ_{mt} is the error term. Our model includes robust standard errors clustered at the level of the municipality. We estimate two models of this form that differ in the sample considered – one of which considers the entire 2013-2017 period and one of which restricts the time period to the year directly prior to and the year directly succeeding the Zika epidemic (i.e. November 2014-November 2016).

Both models produce insight into the effect of the Zika virus on birth rates. However, they do not account for the most plausible mechanism connecting concern with the virus and changes in public health and pregnancy decisions. We suspect that any

such relationship between concern with the virus and birth rates is moderated by exposure to the virus. Under the assumption that concerns surrounding the virus are escalated in Zika-prone areas, we anticipate that the impact of the Zika virus on birth rates will be especially pronounced in areas of particular susceptibility to the virus. We assess this expectation with a difference-in-difference model of the following form.

$$BirthRate_{mt} = \alpha + \beta_1 PostOutbreak_t + \beta_2 PostOutbreak_t * ZikaExposure_m + \mu_t + \Lambda_m + \epsilon_{mt}, \quad (2)$$

where $Birth\ Rate_{mt}$ represents the birth rate in municipality m at time t. $PostOutbreak_t$ is a dichotomous variable equal to 1 for all observations one full-term pregnancy period (e.g. nine months) beyond the initial Google Search peak in November 2015, and $ZikaExposure_m$ is a dichotomous variable equal to 1 for all municipalities that had at least one case of the Zika virus reported during the peak of the epidemic in the summer of 2016. μ_t represents month fixed effects, and Λ_m represents municipal fixed effects. ϵ_{mt} is the error term. Our model includes robust standard errors clustered at the level of the municipality. We estimate this model with the restricted sample (November 2014-November 2016). The results of our ordinary least squares and difference-in-difference models are included below in Table 1.

Table 1: Measuring the impact of Zika virus on birth control

	(1)	(2)	(3)
VARIABLES	OLS	OLS – Restricted Sample	DID
PostOutbreak	-0.637***	-13.167***	-12.626***
	(0.172)	(0.609)	(0.654)
PostOutbreak			-1.645***
*ZikaExposure			(0.556)
Observations	334,188	66,840	66,840
R-squared	0.020	0.034	0.034

Number of code	5,570	5,570	5,570

The results from each of our models confirm the negative relationship between the Zika virus/exposure to the Zika virus and birth rates. Model 1 suggests that the materialization of the Zika virus resulted in a drop of 0.63 births per 100,000 people. Model 2 restricts the time period under consideration in an effort to better isolate the effect of the Zika virus on the birth rate. The results of this time-restricted model are suggestive of a substantial drop of 13.6 births per 100,000 people. Finally, Model 3 confirms the underlying relevance of exposure: The birth rate in municipalities with reported cases of the Zika virus was 1.64 births per 100,000 people lower than the birth rate in municipalities without reported cases of the Zika virus.

In sum, each of our models confirm a negative relationship between the Zika virus and the birth rate in Brazil. Our results are consistent with the logic that concern with the virus led many to learn of the intricate connection between the Zika virus and microcephaly and to, consequently, act to delay pregnancies. We can, however, probe this logic more pointedly by taking it one step further.

The Post-Epidemic "Bouncing Back" Effect

Although, as our evidence suggests, Brazilians acted to delay pregnancies in the height of the Zika epidemic in an effort to minimize the risk of infant exposure to microcephaly, it is unlikely that their overarching attitudes toward family planning changed dramatically during this time period. It follows that the end of the Zika epidemic and the corresponding dramatic decline in concern with the virus would coincide with a "bouncing back" effect. Figure 2 suggests that concern with Zika subsided substantially by November 2016. Thus, we would expect to observe a rebound in the birth rate nine months (one full-term pregnancy period) later.

In order to test our hypothesis of a "bouncing back" effect, we estimate supplementary variants of Equations 1 and 2 that substitute our $PostOutbreak_t$ variable with a $PostEpidemic_t$ variable. $PostEpidemic_t$ is a dichotomous variable equal to 1 for all observations one full-term pregnancy period (e.g. nine months) beyond the abatement of concern with the Zika virus as indicated by Google trends (i.e. November 2016). The

results obtained from models estimated with this substituting $PostEpidemic_t$ variable are presented below in Table 2.

Table 2: Estimating the "bouncing back" effect

	(1)	(2)	(3)
VARIABLES	OLS	OLS - Restricted Sample	DID
PostEpidemic	2.477***	3.541***	3.146***
	(0.250)	(0.608)	(0.660)
PostEpidemic			1.201**
*ZikaExposure			(0.583)
Observations	334,188	66,840	66,840
R-squared	0.020	0.043	0.043
Number of code	5,570	5,570	5,570

Robust standard errors, clustered at the municipality level, in parentheses. All regressions use municipality and month fixed effects. *** p<0.01, ** p<0.05, * p<0.1

As expected, the results from each of our supplementary models provide confirmation of a "bouncing back" effect. Put differently, they all suggest that that the birth rate increased with the termination of the Zika epidemic. Model 1 suggests that the termination of the epidemic resulted in an increase of 2.48 births per 100,000 people. The results of our time-restricted Model 2 are suggestive of an increase of 3.54 births per 100,000 people one full-term pregnancy period after the abatement of concern with the virus. Finally, Model 3 confirms that exposure matters: The post-epidemic birth rate in municipalities with reported cases of the Zika virus was 1.2 births per 100,000 people higher than the post-epidemic birth rate in municipalities without reported cases of the Zika virus.

Our difference-in-difference estimation is particularly interesting as it results in a magnitude very similar to the difference-in-difference coefficient calculated from our primary models estimating the effect of the Zika virus on the birth rate. The only notable

difference between these coefficients is in the direction of the signs. This sign switch pattern, combined with the similar magnitude, provides us with suggestive evidence that women in municipalities exposed to the Zika virus delayed their decision to get pregnant in the height of the public health crisis. The only alternative explanation for our finding would be that a random shock made women proactively avoid pregnancy in municipalities exposed to the Zika virus and that a subsequent, post-crisis random shock reversed the family planning decisions made in response to the first random shock. This alternative explanation is far-fetched. In this light, our results give us confidence that we are capturing the effect of the Zika virus on women's' pregnancy decisions.

In sum, our findings substantiate the "bouncing back" effect and corroborate our suspicion that concern with the virus and its accompanying adverse effects for infant health led many to delay pregnancy until the epidemic had subsided. Evidently, the results our results have numerous policy and developmental implications. We turn to these in the forthcoming concluding section of our paper.

CONCLUSION

The 2015-2016 Zika Epidemic in Brazil attracted the attention of both Brazilians and international observers alike due to its association with microcephaly and other developmental disorders. While public health research relating to the virus exploded in the months following the outbreak, knowledge on its downstream effects remains limited. In this paper, we sought to address this gap in knowledge. Specifically, we empirically estimated the impact of the Zika virus on family planning decisions and delayed pregnancies. Our primary findings are twofold: First, the outbreak of the Zika virus resulted in a decline in the birth rate during the height of the epidemic. Second, the end of the epidemic led to a "bouncing back" effect in which the prior dip in the birth rate increased substantially. Thus, our substantive conclusion is that concern with and knowledge about the Zika virus and the accompanying public health emergency led Brazilians to delay pregnancies. The reality that these behavioral changes occurred even as accessibility to contraceptives remained limited (Bahamondes et al. 2017) is

suggestive of the especially meticulous and calculated efforts undertaken by Brazilians to sidestep significant challenges to infant health.

The insight accumulated in our paper provides an important foundation for the development of related public policies in Brazil. First, the post-epidemic rebounding birth rate has the potential to strain Brazil's social welfare programs, like *Bolsa Família.* The spatial overlap between high exposure to the Zika virus and low levels of development makes it appropriate to assume that the country's post-epidemic increase in the birth rate resulted in increased financial demand from programs like *Bolsa Família*. Second, the "bouncing back" effect has the potential to overextend Brazil's weak education system. Compared to other countries of similar levels of development, the quality of education in Brazil is dismal (Knobel 2014). Insofar as the post-epidemic rebounding birth rate extends enrollment rates and class sizes beyond the status quo, initiatives to respond to changing demographics and to foster classrooms conducive to learning will be required. Finally, the Zika-induced decline in the birth rate during the height of the public health crisis has the potential to further strain Brazil's overextended pension system (Darlington 2018). The reduced financial input from the cohort born during the height of the crisis may contribute to future macroeconomic duress, demanding urgent policy responses.

Movement in each of the aforementioned policy areas requires political will. *Will politicians and policymakers respond to the demographic changes and development challenges instigated by the virus? How will they do it? Which types of politicians will commit themselves to addressing the downstream fallouts of the epidemic?* Future research would be well-served to consider these questions. In doing so, there is potential not only to shed light on political developments taking shape in Brazil but also to inform responses to Zika-related exigencies in other countries more recently exposed to the epidemic (e.g. Angola) (Eisenhammer and Steenhuysen 2018).

The dire public health consequences associated with the Zika virus have rightfully demanded and generated urgent responses from public health researchers and medical professionals. However, as our research suggests, the consequences of the Zika epidemic extend beyond the narrowly-concentrated realm of public health to family planning and population health. Research has yet to comprehensively unpack the other downstream effects of the epidemic despite the notable policy implications that follow

from doing so. Only by studying the epidemic from a comprehensive perspective will we able to understand its wide substantive reach and to develop responses that protect personal liberties and economic stability.

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