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Fetal and infant origins of diabetes and ill health: Evidence from Puerto Rico's 1928 and 1932 hurricanes

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ABSTRACT

A natural experiment is employed to analyze the relationship between living standards, diabetes, and cardiovascular disease. Results show that shocks generated by two powerful tropical storms striking Puerto Rico during the late 1920s and early 1930s had long-term consequences consistent with the fetal origins hypothesis. Individuals in the womb or early infancy in the aftermath of the storms are more likely to report a diagnosis of hypertension, high cholesterol, diabetes, and are considerably more likely to have no formal schooling.

1. Introduction

Although some time has passed since the fetal origins hypothesis was first put forth (Barker, 1992), only recently has the field of economics contributed to the assessment of the relationship between uterine environment and later life outcomes (Almond, 2006). Adult health, disability, mortality, cognitive ability, or socio-economic status have been linked to in utero or early infancy exposure to famine, influenza, malaria, recessions, pollutants, dietary deficiencies, and Ramadan observance.[1] However, the pathways from factors affecting early life environment to outcomes in adult life are far from clear. The fetal origins hypothesis provides a potential link through biological reactions to early life deprivation that are posited to predispose individuals to diabetes, hypertension, high cholesterol, and cardiovascular disease, conditions that are leading causes of morbidity and mortality in the developed world (WHO, 2002).

Work on the biological mechanisms underpinning the predictions of the hypothesis is owed to Barker (1992). Nutrition deficiencies were posited to result in increased blood pressure required for maintaining transfer capacity across the placenta (Barker et al., 1989). High cholesterol could develop from changes in lipid metabolism in response to the same circumstances, with both conditions persisting after birth (Barker et al., 1993). Changes in fetal programming giving priority to certain organs at the expense of others like the liver were suspected to have permanent consequences on glucose and insulin metabolism (Hales et al., 1991). Research was of particular interest as it could provide an explanation for syndrome X – the association between non-insulin dependent diabetes, hypertension, and high blood cholesterol – in the form of a common origin of all three conditions. Empirical support for the proposal would also have important public health implications. Prevention of development of diabetes and cardiovascular disease would not necessarily center on moderating risk behaviors in adult life.

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[1] See Almond and Currie (2011) for a survey.

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Initial empirical findings pointed to an association between markers of early life nutrition, impaired glucose tolerance, increased serum cholesterol, and hypertension in adult life (Barker et al., 1989, 1993; Hales et al., 1991), but causal inference was questioned since results could have been generated by third factors (Rasmussen, 2001). In search of less problematic data settings, research turned to natural experiments for additional supportive evidence, with mixed results. While individuals exposed in utero to the 1944–1945 Dutch famine develop diabetes and coronary heart disease with greater frequency (Ravelli et al., 1998; Roseboom et al., 2000), survivors of the nineteenth century Finnish famine did not suffer from additional mortality risk (Kannisto et al., 1997). Moreover, a large medical study evaluating an extensive set of health outcomes did not establish long-term consequences related to the 1941–1944 Leningrad siege (Stanner et al., 1997), and systematic literature reviews were unable to establish material effects of fetal conditions on adult blood pressure or cholesterol levels (Huxley et al., 2002, 2004).

On September 13, 1928, hurricane San Felipe struck Puerto Rico bringing 10 inches of rain in the lowlands and up to 30 inches in the mountains over a period of two days. The San Juan weather station recorded an extreme wind velocity of 160 miles per hour and speeds over the island's higher elevations could have reached 200 miles per hour (Fassig, 1929). Damage to the Island's dominant agricultural sector was widespread, but the fact that it was concentrated in the 1928–1929 agricultural season provides the opportunity for defining exposed versus control groups in a natural experiment setting. Moreover, surveys providing information on a variety of health outcomes allow for direct tests of relationships between living standards, diabetes, hypertension, high cholesterol, and cardiovascular disease.

2. Survey of current research

In economics, research has produced more consistently supportive evidence of a relationship between early life conditions and a range of long-term outcomes. The 1918 Influenza Pandemic has been linked to reduced schooling, income, and increased rates of disease and disability (Almond and Mazumder, 2005; Almond, 2006). Exposure to the 1957 Asian influenza pandemic led to reduced cognitive ability and impaired growth among mothers who smoked (Kelly, 2011). The 1959–1961 Chinese famine has been tied to worsened literacy, labor market and marriage outcomes, and the nineteenth century Dutch potato famine to reduced life expectancy (Almond et al., 2007; Chen and Zhou, 2007; Lindeboom et al., 2010). Exposure to low levels of radiation from the Chernobyl reactor disaster translated to impaired neural development in Swedish children, iodine deficiency in Tanzania has led to reduced schooling, and exposure to malaria to lower income and higher poverty in the US (Almond et al., 2009; Field et al., 2009; Barreca, 2010). Even fasting during Ramadan has been related to poorer general health, disability, and symptoms indicative of diabetes and cardiovascular disease (Almond and Mazumder, 2011; van Ewijk, 2011). The latter study is a rare example of economic research addressing the direct implications of the Barker proposal.

Consequences of economic crises or income shocks have also been evaluated. Long-term health effects have not been associated with the severe drought and soil erosion striking the American Midwest during the 1930s, or with the phylloxera plague that decimated French vineyard production late in the nineteenth century (Cutler et al., 2007; Banerjee et al., 2010). However, weather shocks and recessions occurring during a person's infancy have been tied to height, health, and mortality (Block et al., 2004; del Ninno and Lundberg, 2005; van den Berg et al., 2006; Maccini and Yang, 2009; Skoufias and Vinha, 2011).

Exposure periods can be extended as in the case of studies examining later life effects of childhood asthma or the long-term consequences of the Head Start program (Currie and Thomas, 1995; Garces et al., 2002; Ludwig and Miller, 2007; Fletcher et al., 2010). Outcomes can also range from cognitive abilities, labor market outcomes, to welfare use (Currie and Hyson, 1999; Black et al., 2007; Case and Paxson, 2008a,b; Smith, 2009; Currie et al., 2010).

Even adult behaviors can be conditioned by childhood experiences such as disruptive family life (Belsky et al., 1991). In an evolutionary sense, early onset of menarche, an increased reproductive rate, and low offspring investment can obtain as adaptations to unstable or hazardous environments. Life history theory posits that when reproductive potential appears threatened, individuals may respond by adopting a fast life course emphasizing offspring quantity versus a slow one that would have emphasized quality. Empirical evidence establishes that across countries fertility is associated with indicators of mortality risk (Guégan et al., 2001), and that within societies parental investment in children is lower in more deprived neighborhoods (Nettle, 2010). Interpretation and processing of environmental cues is influenced by circumstances experienced during critical periods in childhood (Belsky, 2007). Reactions to stress and attitudes towards risk, for example, have been shown to depend on childhood rather than current socioeconomic status (Miller et al., 2009; Griskevicius et al., 2011).

3. The Puerto Rican economy and hurricane San Felipe

In the 1920s Puerto Rico was an agrarian economy based largely on sugar production. *Per capita* income was about a fifth of that of the US but higher than that of the neighboring island of Cuba, and several times that of Haiti or the Dominican Republic (Perloff, 1950:3). According to the US Census, agriculture accounted for 60% of employment in 1920, sugar cane alone accounting for 20% of all employment and 50% of crop value. Coffee was a secondary and declining economic activity relegated to the mountainous interior, unsuitable to large scale cane cultivation. Its contribution to crop value in 1920 was equivalent to that of fruits and starchy vegetables (18%).

The San Felipe hurricane caused damages equivalent to about a third of national income (Pérez, 1971). Loss of life was low but damages to agriculture were vast. The coffee