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Analysis

# Forest-attacking Invasive Species and Infant Health: Evidence From the Invasive Emerald Ash Borer

Benjamin A. Jones*

*University of New Mexico, Albuquerque, NM, USA*

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ABSTRACT

Trees provide many ecosystem services. Widespread tree loss, therefore, would lead to degradations in environmental quality, which might have spillover effects on human health. For the first time, the infant health externalities of tree loss caused by an invasive species are investigated. We exploit a quasi-experimental setting where millions of ash trees have been destroyed in the US due to the invasive emerald ash borer (EAB). Since EAB spread is quasi-random due to flight and weather, and since ash tree loss due to EAB is extensive, our research design can eliminate many environmental confounders of concern. We use rich, mother-level natality data covering the near-universe of US births over 1999–2015. Difference-in-differences results suggest that along the intensive margin, birth weight and gestation are lower by 12.19 g and 0.024 weeks, respectively, after EAB detection in the mother's county of residence. Along the extensive margin, the probability that a mother has a low birth weight baby increases by 0.2%, equivalent to an increase of 16.2 per 100,000 live annual births. Results are robust to using the synthetic control method and the Lasso method. An internal validity test shows that findings are not due to the changing composition of mothers after EAB.

## 1. Introduction

Forests and trees provide many beneficial ecosystem services and are important contributors to environmental quality. Trees capture air pollutants including ozone, nitrogen oxides, sulfur dioxides, carbon monoxide, and fine particulate matter (Nowak et al., 2013; Nowak et al., 2006). By creating shade, trees have tremendous cooling power and can attenuate the urban heat-island effect (McPherson, 2007). Of course, trees also have aesthetic amenity value and can make outdoor activities and recreation more enjoyable (Mullaney et al., 2015). It is now widely recognized that trees and forests are important determinants of human health. For instance, the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations have argued that the ecosystem services provided by trees have "important repercussions for human health" (Powell et al., 2013). Separately, the WHO has suggested that trees are an important "greening strategy" for improving public health and should be considered when implementing the 2016 United Nations' New Urban Agenda program (WHO, 2016).

However, forest and tree stocks are currently threatened across the globe. While there are many natural and human-caused risks to tree populations, one of the greatest threats at the moment is from invasive alien species. For example, in North America, the invasive emerald ash borer, the Asian long-horned beetle, and the Asian gypsy moth have together destroyed hundreds of millions of trees over the past decade (Herms and McCullough, 2014; Haack et al., 2010).[1] Other pests such as the polyphagous shot hole borer are currently threatening 27 million trees or 38% of the forest canopy in Southern California (Sahagun, 2017, April 19). Elsewhere, invasive forest-attacking species have destroyed millions of trees in China, Europe, and in sub-Saharan Africa (Sun et al., 2013; Haack et al., 2010).

Loss of trees due to invasive species is concerning from a public health perspective, if in fact human health and trees are causally connected. While a few studies have demonstrated links between invasive-induced tree loss and adult health (e.g., Jones and McDermott, 2017; Donovan et al., 2013), to the best of our knowledge there are no published empirical analyses of impacts to infant health. This is troubling for at least two reasons. First, economists have previously shown the existence of causally-consistent associations between infant health outcomes and changes in environmental quality (e.g., Cesur et al.,

* Department of Economics, University of New Mexico, 1 UNM Drive, MSC 05 3060, Albuquerque, NM 87131, USA.
*E-mail address:* bajones@unm.edu.

[1] In the intermountain Western US, various species of bark beetles have also ravaged spruce, lodgepole, pinyon-juniper, and ponderosa pine forests. However, bark beetles are native to the US (non-invasive).

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2017; Knittel et al., 2016; Currie and Walker, 2011; Currie and Neidell, 2005). Currie et al. (2014) argued that infants and children are particularly vulnerable to environmental exposures due to immature immune systems, among other reasons. Sharp reductions in environmental quality precipitated by invasive species-induced tree loss may therefore have consequential impacts on in utero health, with subsequent ramifications on neonatal health. However, at present, there are no credible empirical studies of this issue. Second, and perhaps more troubling, is the fact that prior research has found that infant health is connected to adult outcomes vis-à-vis educational attainment, test scores, use of disability programs, wages, and other labor market outcomes (Currie et al., 2011). As a consequence of affecting infant health, forest-attacking invasive species may therefore be generating long-term, in addition to short-term, impacts that follow individuals throughout their lives. If true, this would mean that the externalities of invasives may extend far into the future, requiring a broadening of the definition of "economic impacts of invasive species" to be more inclusive of both affected parties and potential long-term effects. Thus, there is an urgent need to better understand the relationships between infant health, tree loss, and invasive species as a way to not only advance our understanding of invasive species impacts, but also to motivate future research on the long-term economic consequences of environmental shocks to tree cover.

This research addresses the first part of this issue by using a quasi-experimental setting provided by the invasive emerald ash borer (EAB), a pernicious ash tree attacking pest, to provide causally-consistent estimates of short-term invasive species infant health externalities. Tens of millions of ash trees (*Fraxinus* spp.), one of the most common tree species in the US, have been lost to EAB within a relatively short period of time, providing an arguably exogenous shock to local environmental quality. Since EAB spread is determined in part by random weather events and insect flight, and since ash tree destruction is extensive (> 99% in many areas), our research design can mitigate many pre-treatment or pre-shock environmental confounders, such as residential sorting behavior, that are typically of concern in such investigations. Moreover, there are strong *a priori* reasons to believe that EAB may have an effect on infant health given prior work showing EAB-induced increases in air pollution through tree canopy loss (Jones and McDermott, 2017) and a separate literature on air pollution and natality outcomes (e.g., Currie and Walker, 2011). Therefore, this analysis is not only novel in that it connects invasive species to infant health for the first time, but also represents the logical progression of a nascent (but growing) literature on the health externalities of invasive-induced tree mortality.

A difference-in-differences (DID) approach is used to compare mothers in EAB detected counties to similar mothers in non-EAB detected counties. Three conclusions arise. First, mothers living in EAB infested counties experience 0.2% more low birth weights (from a base of 8.1%) relative to statistically similar mothers living in contemporaneously non-EAB detected counties. This is equivalent to an increase in low birth weights of 16.2 per 100,000 live annual births. Along the intensive margin, birth weight and gestation are lower by 12.19 g (from a base of 3291 g) and 0.024 weeks (from a base of 39 weeks), respectively, after EAB detection in the mother's county of residence. These results are robust to using both the synthetic control method and a machine learning procedure (Lasso). Second, our causal story is bolstered by the finding of 5+ year lagged impacts of EAB on infant health. This is consistent with many on-the-ground observations that it takes 5–8 years from the time of initial EAB detection until extensive ash tree dieback occurs. Hence, the timing of infant health impacts we observe overlaps with the period of time when tree destruction is greatest. Third, impacts of EAB on infant health are heterogeneous. Mothers living in higher income counties experience more low birth weights (but not prematurity) relative to mothers in lower income counties. For instance, mothers in counties at the 75th income percentile ($60,493 in our data) have 0.21% more low birth babies after EAB relative to similar mothers in counties at the 25th income percentile ($42,182). Additionally, we also find that EAB impacts are largest among white and Hispanic mothers compared to other races.

## 2. EAB and Tree Loss

EAB (*A. planipennis*) is a small, invasive borer beetle that reproduces by laying eggs inside the vascular cambium of ash trees. After hatching, the larvae disrupt the transfer of water and nutrients throughout the tree and infested adult ash typically die within 5–8 years (Herms et al., 2014). EAB is native to Asia and eastern Russia and was likely brought over to the US through infested ash and ash by-products (Herms and McCullough, 2014). Initial detection of EAB occurred in southeastern Michigan in 2002. While EAB is harmless to humans, all North American ash species are vulnerable to the invasive, including both healthy and stressed trees, and the International Union for Conservation of Nature has listed five of the six most prominent ash species in North America as "critically endangered" because of EAB. Together these endangered species comprise nearly 9 billion trees in the contiguous US.

Adult EAB and their larvae are extremely resistant to the North American climate and face few existential threats from natural predators in the areas they have infested (Herms and McCullough, 2014). Despite extensive efforts by Federal, state, and local agencies, EAB eradication is highly unlikely at this point, and even slowing its spread or directing its future travel has proved exceedingly difficult, though research is ongoing (McCullough et al., 2016). Given abundant ash stocks and few limits on growth, EAB spread has been extensive. As of June 2016, EAB has been discovered in 790 counties across 27 US states and the District of Columbia. Several newly infested counties are detected nearly every month. While many invasive species are often described as "destructive" or "harmful", such characterizations are likely understatements when it comes to EAB, which is regularly described as the most destructive forest pest ever introduced into the US (e.g., Herms and McCullough, 2014; McCullough, 2013).

The threat to environmental quality posed by EAB is a direct consequence of the fact that ash is a popular urban and street tree, often comprising 10–40% of urban forest canopies (USDA Forest Service, 2015). Since ash tree loss is nearly universal in infested areas (Herms and McCullough, 2014), EAB thus leads to sharp reductions in the ecosystem services provided by urban trees, and hence results in degradations to environmental quality. Put differently, the shock created by EAB is not simply a few dozen dead ash trees, rather, substantial tree losses in a city can occur within a few short years after EAB detection.

Why might substantive losses of trees in urban areas, but also, to a lesser degree (in terms of percentage of total forest canopy), in rural areas, matter? Because trees provide many environmental, social, and economic benefits to society. First, trees and forests act as pollutant sinks, capturing many air pollutants that are harmful to human cardio-respiratory health (Nowak et al., 2013; Nowak et al., 2006). Ash trees, in particular, are very good at capturing many common air pollutants such as ozone and particulate matter (Freer-Smith et al., 2004). Second, trees can ameliorate the urban-heat island effect through the provision of shade. It has been estimated that street trees can reduce daytime temperatures by 5°-20°C (Mullaney et al., 2015). This cooling effect may be particularly beneficial during extreme temperature events, which are known to negatively affect health (Deschenes, 2014). Third, trees and forests encourage physical activity and recreation, reduce stress, and encourage social cohesion (Mullaney et al., 2015; Van Dillen et al., 2012). For example, Ulmer et al. (2016) found that urban forest cover was related to lower obesity rates, fewer cases of Type 2 diabetes, lower blood pressure, and fewer asthma cases. Additionally, Ellaway et al. (2005) found that people living in areas with high levels of greenery, including trees, were three times more likely to be physically active. Finally, there is a growing body of evidence linking urban tree cover to lower crime rates and improved feelings of safety (Donovan and