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The Road to Growth: Measuring the Tradeoffs between Economic Growth and Ecological Destruction

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Summary. — Roads bring significant economic benefits that are vital for development. But they are often also the precursors to deforestation and other adverse environmental impacts. This paper examines the road-induced tradeoffs between economic growth, deforestation, and biodiversity loss in the Democratic Republic of Congo (DRC). Decades of conflict have left the DRC's transport infrastructure among the sparsest and most dilapidated in the world. Most of the provincial capitals are unconnected to the capital city, and improving road connectivity could lead to a significant boost in trade and economic growth. At the same time the DRC is also home to the second largest rainforest in the world. The iconic Congo forests are a trove of ecological value—some monetizable and most that is not. So the destruction of the DRC's forests will have significant environmental ramifications. We provide empirical estimates of the economic benefits of improving market access and reducing transportation costs. We then estimate a forest destruction function to assess the impact that new or improved roads have on forest clearing. In addition, a novel biodiversity index is developed to identify forests of high biodiversity significance. Two simulations are performed to quantitatively demonstrate the impacts of road improvement projects in terms of increased GDP, forest loss, and biodiversity that are put at risk. To our knowledge, this is the first study to jointly examine the economic benefits and ecological risks to infrastructure investments. It is envisioned that the methods employed here can be used to guide future infrastructure investments toward designs which have a large economic impact while minimizing ecological risks.

Key words — infrastructure, economic growth, forests, biodiversity

1. INTRODUCTION

Roads bring significant economic benefits that are vital for development. But they are often also the precursors to deforestation and other adverse environmental impacts. The response of conservation managers in tropical forests has typically been reactive. Attempts are made to limit damage through the demarcation and protection of areas that are deemed critical for biodiversity conservation. This strategy seeks to minimize ecological impacts by preventing or severely restricting road improvements that increase the profitability of forest clearing within protected areas. Potential conflict over the desirability of road improvements is particularly high in forested regions with significant agricultural potential. When conventional protected-area strategies confront this conflict, they may fail to protect critical ecosystems for two reasons. First, governments may seek to minimize economic opportunity costs by siting protected areas in remote regions with low agricultural potential that may not coincide with the areas of highest ecological value. Second, attempts to restrict road improvements in protected areas with strong agricultural potential may fail because economic interests overwhelm the limited resources and political support of conservation managers.

This paper presents an empirical approach that seeks to mitigate such conflicts by developing rigorous tools that can help steer infrastructure development toward sites where economic benefits can be realized, while ecological damage is avoided and minimized. We illustrate this approach by estimating the potential impacts of road upgrading in the Democratic Republic of Congo (DRC).

The DRC, with its immense forests and woeful road network, presents an apt case study for this exercise. Decades of conflict and neglect have left the DRC's transport infrastructure among the sparsest and most dilapidated in the world, even by the standards of other low-income countries (Africa Infrastructure Country Diagnostics 2008). In many parts of the country, traveling to the capital, Kinshasa, by road is impossible and most of the provincial capitals are unconnected to Kinshasa. Were economic activity evenly distributed across the country this may not matter significantly, but as Figure 1.1 illustrates, GDP in the country is highly geographically concentrated around the capital Kinshasa, with peaks in income around a few other areas such as Lubumbashi, Mbuji-Mayi, and Kivu. Connecting regions that flourish with those that lag (relatively) could provide a significant boost to economic growth. Given the vast distances and extreme variations in the spatial distribution of GDP, there are compelling reasons for improving inter-provincial as well as intra-provincial connectivity to promote trade and economic cohesion.

However, the DRC is also home to the second largest rainforest in the world. The iconic Congo forests are a trove of ecological value—some monetizable and much that is not. The DRC's forests are distinguished by the unusually high number of endemic and endangered species (UNESCO, 2010). [1] The carbon sequestered by these forests (a stock of about 30–40 gigatons) corresponds to about 3–5 years of CO_2 equivalent emitted globally (as a flow). So the destruction of the DRC's forests could have global ramifications. Roads often catalyze a process of deforestation and land conversion. In addition, they are also accompanied by a litany of other

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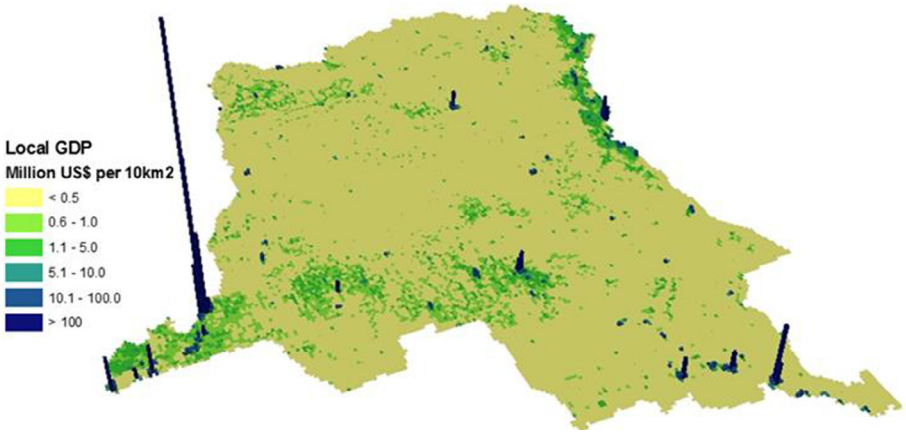

Figure 1.1. *Local GDP in DRC, 2006. Source: Ghosh et al. (2010).*

forms of environmental degradation, especially in the DRC, where enforcement of regulations is immensely challenging. For instance, poaching, illegal trapping of exotic wildlife for the pet trade, fuel wood collection, and forest fires are among the plethora of problems that accompany roads in biologically sensitive forests. This suggests the need to establish procedures that preempt adverse and often irreversible consequences of road construction and yet allow for benefits of development to be realized.

The exercise outlined in this paper draws on a variety of disciplines—GIS analysis, econometrics, and conservation biology—to create an approach that could guide the location and level of investments in roads. The methodology involves four steps. First the benefits of transport infrastructure are estimated using regression analysis. We provide what we believe are the most accurate estimates of transport costs that are available for the DRC and carefully address potential sources of endogeneity bias arising from the non-random placement of roads and the spatial sorting of cities.[2] Next, a disaggregated spatial data set of forest loss is used to estimate the effects of roads on forest cover. Recognizing that not all forests are of identical ecological significance, a new composite metric of biodiversity is developed to identify forests of high (and low) biodiversity significance. In the final stage the spatial estimates are combined to simulate the effects of different policies and identify hotspots where risks are high and benefits relatively low, areas where the reverse holds, and regions where there are large trade-offs between economic and ecological goals. To our knowledge, the present paper represents the first attempt to combine these unconnected strands of research to enable better informed approaches to road infrastructure investments.

The remainder of the paper is organized as follows. Section 2 motivates the analysis with a brief review of prior empirical research on the econometric estimates of road infrastructure benefits, the economics of forest clearing, and measures of biodiversity. Section 3 describes several of the datasets employed in the analysis. Section 4 presents the results from estimating the benefits of road construction in the DRC. Section 5 presents estimates of a deforestation model that incorporates the impact of road improvement. Section 6 derives a biodiversity index of the Congo Basin that incorporates four distinct measures of biodiversity. In Section 7, we explore the implications of our results for local, regional, and national forest clearing. Section 8 concludes the paper with caveats.

2. PRIOR RESEARCH

The purpose of this section is to briefly review several hitherto distinct strands of literature: the literature on estimating the economic benefits of roads, a different body of work on the empirical drivers of deforestation, the environmental damage from development, and research on biodiversity indicators. The objective is not to provide a comprehensive assessment of these burgeoning areas of research, but merely to highlight some of the more relevant contributions.

The empirical literature on the economic benefits of roads is vast and rapidly evolving. Much of the recent analysis is concerned with identifying causal relationships between investments in roads and consequent economic impacts, with approaches that have varied considerably over time. Researchers have examined the effects of road infrastructure and investments in transport on aggregate productivity, usually measured by GDP (Aschauer, 1989; Ihori, Doi, & Kondo, 2001), with ambiguous results. To a large extent the contradictory evidence and the ensuing debates are a consequence of identification and reverse causality problems.

Recent papers have used more rigorous and compelling identification strategies to shed light on these issues (Donaldson, 2010; Datta, 2012; Faber, 2014). One solution is to use panel data methods (Khandker & Koolwal, 2011), but the approach is limited by a lack of suitable time series data, especially in developing countries. Other papers exploit natural experiments (Donaldson, 2010), comparing regions where infrastructure investments were made with regions where they were planned but never completed. However, such assessments are uncommon since the fortuitous circumstances for a natural experiment are rarely encountered. Instead, much of the literature uses a difference-in-difference (Datta, 2012), or difference-in-difference with an instrumental variable (Faber, 2014) approach, or some exogenous geographic features to exploit natural differences in a sample (Jacoby & Minten, 2009; Shrestha, 2012; Emran & Hou, 2013). The approach used in this paper is most closely related to that of Faber (2014), Damania, Berg, Russ, Federico Barra, Nash, & Ali (2017), and Russ, Berg, Damania, Barra, Ali, & Nash (2017) which rely on an instrumental variable based on exogenous variation in geography.

A distinct theoretical and empirical research on the determinants of forest clearing has provided many useful economic policy insights. The von Thunen model offers a convenient framework for understanding the process and links between

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