Whitepaper
OCTOBER / 2020

Measuring the Indirect Effects of Transportation Infrastructure in the Amazon

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Poor transportation infrastructure is often regarded as one of the main barriers to the acceleration of economic growth in Brazil. Due to the poor condition of most of the roads and the absence of other modes of transport, freight rates are extremely high, curbing internal trade and reducing the competitiveness of the country's producers. As a response, the federal government has established a goal to implement a large portfolio of transportation infrastructure projects in the coming decade.

Nevertheless, this portfolio includes paving roads and building railroads in the Amazon, raising fears it might stimulate environmental degradation and increase deforestation in the world's largest rainforest. Identifying these impacts and proposing measures to mitigate them is, therefore, critical to enable Brazil to improve its stock of transportation infrastructure in a sustainable way. However, in the current practice, Feasibility Studies (*Estudos de Viabilidade Técnica, Econômica e Ambiental* - EVTEA) and Environmental Impact Assessment (*Estudo de Impacto Ambiental* - EIAs) – the two instruments that delimit the area of influence of the project - are not transparent as to the methodology used for delimiting the area of influence, especially when it comes to delimiting the indirect effects. This leads to the delimitation of areas that do not necessarily reflect all the effects that the project may cause.[1] A clear and substantiated identification of indirect effects, monitoring, strict enforcement of the law, among other measures, can be better targeted to mitigate these risks. This would allow the country to improve its logistics infrastructure without negatively affecting the environment.[2]

Climate Policy Initiative/Pontifical Catholic University of Rio de Janeiro (CPI/PUC-Rio) provides policymakers with a better understanding of the full impact of logistics infrastructure development. Improving transportation infrastructure has the potential to

[1] Antonaccio, Luiza; Barros, Ana Cristina; Bragança, Arthur; Chiavari, Joana; Cozendey, Gabriel. Nota Técnica. A importância em aprimorar a definição e a delimitação da Área de Influência de projetos de infraestrutura. Rio de Janeiro: Climate Policy Initiative, 2020.
[2] Araújo, Rafael; Assunção, Juliano; Bragança, Arthur (2020). "The Effects of Roads on Deforestation: A Market-Access Approach", Climate Policy Initiative.

facilitate trade and increase competitiveness of Brazil’s agriculture. However, reduced transportation costs will also affect how and where agriculture is done. These are important indirect effects when evaluating logistics projects. This Whitepaper highlights the need for the logistics projects’ EVTEA and EIAs to incorporate and correctly identify the indirect effects that result from the changes in transportation costs induced by improvements. It describes how using a combination of geoprocessing tools and statistical analysis can be used to identify these impacts and provides an example of their importance.

The Challenge

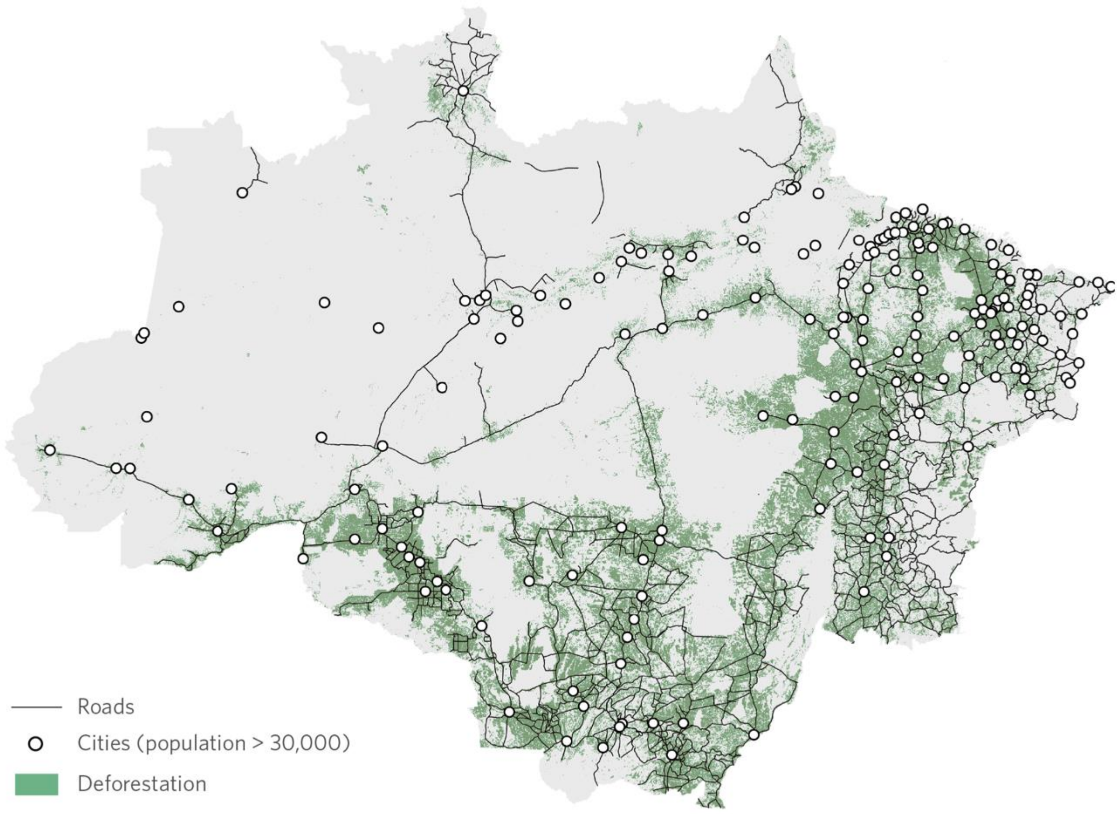
Improvements in transportation infrastructure have long been considered a pillar for promoting economic growth in developing countries for their potential for reducing both international and intranational trade costs.[3] Nonetheless, assessing the environmental cost and the economic benefits of such investments has proved difficult. Most of the literature focuses on the relationship between proximity of roads and environmental and/or economic outcomes.[4]

The data on roads and deforestation in the Amazon suggest a strong correlation between these variables (see Figure 1). However, the direction of causality is not clear because deforestation might attract roads and because both deforestation and roads might be determined by other variables such as the region’s underlying economic dynamism. Researchers have tried to deal with this issue using different statistical techniques with results typically indicating that road proximity does influence deforestation.

[3] Limao, N., & Venables, A. J. (2001). “Infrastructure, geographical disadvantage, transport costs, and trade”. The world bank economic review, 15(3), 451-479; Atkin, D., & Donaldson, D. (2015). “Who's getting globalized? The size and implications of intra-national trade costs” (No. w21439). National Bureau of Economic Research; Costinot, A., & Donaldson, D. (2016). “How large are the gains from economic integration? Theory and Evidence from US agriculture, 1880-1997” (No. w22946). National Bureau of Economic Research; Donaldson, D., & Hornbeck, R. (2016). “Railroads and American economic growth: A “market access” approach”. The Quarterly Journal of Economics, 131(2), 799-858; Jedwab, R., & Storeygard, A. (2020). The average and heterogeneous effects of transportation investments: Evidence from Sub-Saharan Africa 1960-2010 (No. w27670). National Bureau of Economic Research.

[4] Chomitz, K., & Gray, D. A. (1999). Roads, lands, markets, and deforestation: a spatial model of land use in Belize. The World Bank; Pfaff, A. S. (1999). “What drives deforestation in the Brazilian Amazon? Evidence from satellite and socioeconomic data”. Journal of environmental economics and management, 37(1), 26-43; Pfaff, A., Robalino, J., Walker, R., Aldrich, S., Caldas, M., Reis, E., ... & Kirby, K. (2007). Road investments, spatial spillovers, and deforestation in the Brazilian Amazon. Journal of regional Science, 47(1), 10; Asher, S., Garg, T., & Novosad, P. (2020). The ecological impact of transportation infrastructure. The Economic Journal, 130(629), 1173-1199.

Figure 1. Roads and Deforestation



Notes: This figure presents data on state and federal roads, cities – with population greater than 30,000 – and plots of land classified as agriculture or pasture.
Source: Climate Policy Initiative with data from the Brazilian Institute of Geography and Statistics (IBGE), 2010; Ministry of Transportation, 2017; and the 4.1 Mapbiomas Project.

Nevertheless, these estimates ignore that investments in logistic infrastructure might influence economic outcomes and, consequently, environmental outcomes located far from the location of the investment itself. Indeed, these investments to improve logistic infrastructure might influence producers located in all regions who upon experiencing reduced freight costs expand their production, generating pressure to convert forests into pastures or cropland and inducing migration to these regions, both directly and indirectly, by increasing labor demand. This effectively implies that, by ignoring these indirect effects far from the projects, the EVTEA and even the EIAs of such projects will underestimate their total ecological footprint.

Therefore, using ecological footprint estimates as currently defined is extremely problematic. It not only generates problems in the definition of a project's viability, but also in the definition of priority projects and in the implementation of mitigation measures. First, by ignoring the indirect environmental costs, feasibility studies based on these estimates will typically overestimate the (social) return of investments in logistic infrastructure. Second, by ignoring the heterogeneity of these indirect costs across different projects, lists of priority projects defined based on these estimates might induce the implementation of potentially harmful projects. Third, by restricting the region in which mitigation and compensation measures are implemented, the EIAs, which currently is the main environmental impact assessment instrument, will fail to present mitigation and compensation procedures for the total environmental damage that these logistics projects generate.

Recommendations for Public Policy

1. **The EVTEA of logistic projects should incorporate evaluations of the indirect environmental risks of these projects to enable the preliminary identification of its area of indirect influence and the discussions of policies to prevent these impacts from occurring.**
2. **The EIAs of logistics projects should use clear and robust methodologies to identify its area of indirect and direct influence and, as a consequence, enable mitigation and compensation measures to be proposed for the entire area in which the project's implementation will induce the changes in the economic, social, and environmental dynamics.**

Market Access Approach

The construction of roads, railroads, or waterways reduces the transportation costs for rural producers located in regions where these projects are built. This might induce rural producers to expand their production, which generates pressure for the conversion of forests into pastures or agricultural areas, drives migratory movements among workers, and increases wages.

In addition, investments in transport infrastructure might also have several indirect effects on locations beyond the reach of the lower transportation costs. First, migration and the increase in wages previously mentioned will drive up wages in regions not directly affected by the project. Second, consumers in regions not directly affected by the project benefit from the reductions in the prices of the goods produced in directly affected regions. Third, producers in regions not directly affected by the project suffer from increased competition of the producers from the directly affected regions.

The market access approach developed by researchers Dave Donaldson and Richard Hornbeck[5] allows for the ability to analyze all of these effects. They show that the various effects over producers and consumers due to transport network changes depend on a single measure of accessibility called “market access”. This measure is consistent with several interregional trade models and can be constructed from information on transport costs between a municipality and all relevant markets (hereafter, bilateral trade costs).

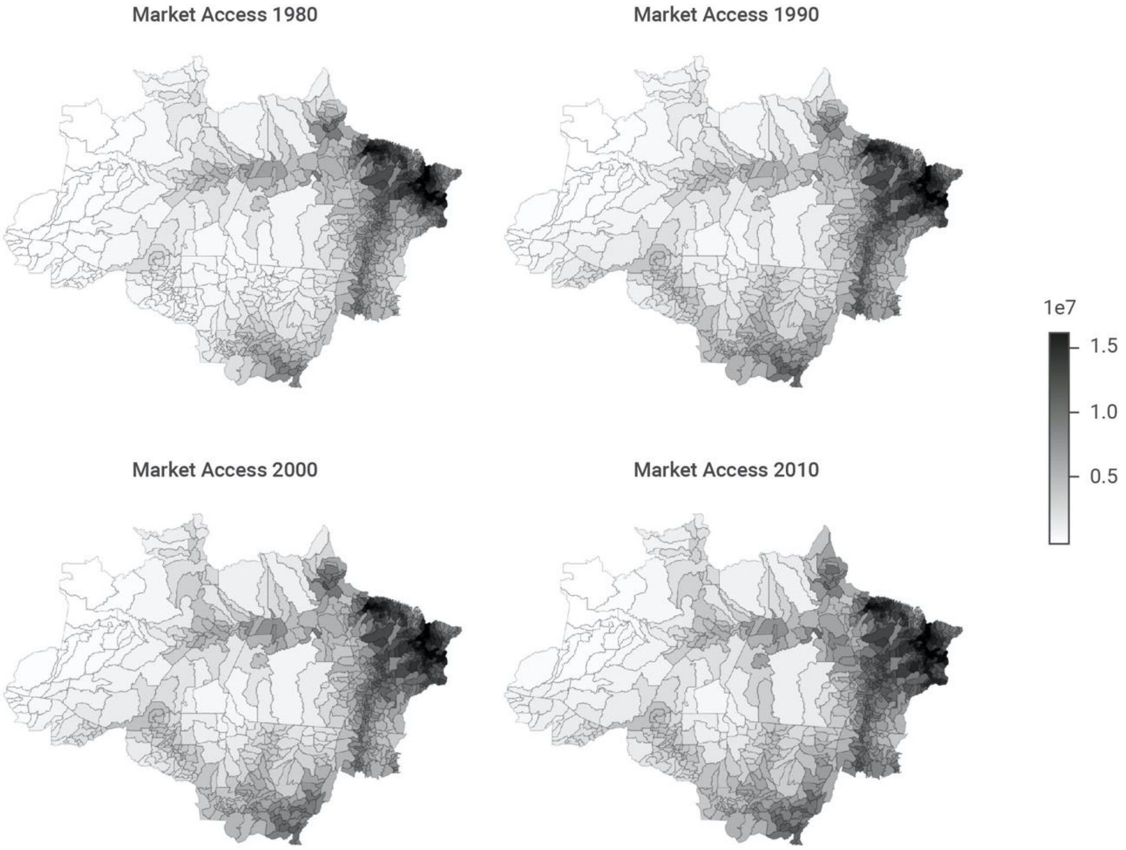
In an innovative application, researchers from CPI/PUC-Rio have adapted the market access approach to quantify the effects of the construction of a road, railroad, or waterway on the environment. The methodology uses four steps, as outlined below.

1. First, the analysis identifies transport infrastructure development over time to determine bilateral transportation costs. Geoprocessing tools are used to combine information on the evolution of the transport infrastructure and freight data to measure the evolution of bilateral trade costs between all Brazilian municipalities and the closest port in the period of 1980 – 2010.
2. Second, the bilateral trade costs are combined with municipal population measures to create measures of market access for each municipality. Municipalities with a higher cost of transportation have poorer market access. Figure 2 shows the evolution of the market access in the Amazon during the period 1980 – 2010. The different panels show that the construction and/or paving of roads considerably improves the market access of surrounding municipalities. However, it is possible to observe countless other municipalities that gain market access that are not directly surrounding the main transportation corridors. This reflects the capacity of the market access measure to sum up the multiple dimensions in which changes in transportation costs might affect municipalities’ market access.
3. Third, this model estimates the response, or elasticity, of agricultural expansion to the changes in market access in the Legal Amazon municipalities by combining the market access data with georeferenced information on land use during the 1985 – 2018 period. The results of this model show that an increase of 1% in market access increases the amount of deforestation by 0.2 – 0.4%.
4. Fourth, changes in the quantity of land devoted to farming activities reveal how changes in market access influenced the forest cover in Amazon municipalities. This exercise considers that areas not used in farming activities remain as

[5] Donaldson, D. and Hornbeck, R. (2016). “Railroads and American Economic Growth: A “Market Access” Approach”, *The Quarterly Journal of Economics*, vol. 131(2), pp. 799-858.

native vegetation which – in the Amazon context – means that they maintain forest cover. In total, the analysis finds that changes in accessibility were responsible for 34% of the deforestation observed from 1990 – 2017.

Figure 2. Evolution of Market Access in Legal Amazon Municipalities



Notes: Each panel reports market access in a given year with darker municipalities denoting higher market access and lighter municipalities lower market access. Market access in municipality o is measured as $\sum_{o\neq d}\tau_{odt}^{\theta}N_{dt}$, in which τ_{odt} denotes the bilateral trade cost between municipality o and destination d (another municipality or the nearest port) in year t, N_{dt} is the population of destination d (another municipality or the nearest port) in year t, and θ is the elasticity of trade volumes to trade costs ($\theta = 8$ following the literature). This measure does not have a natural scale.
Source: Climate Policy Initiative with data from the Brazilian Institute of Geography and Statistics (IBGE), 2010; Ministry of Transportation, 2017; and the 4.1 Mapbiomas Project.

How Brazil Can Resolve this Issue?

Discussion and Recommendations

1. The importance of indirect effects vis-à-vis direct effects

Incorporating indirect effects from the beginning of the project cycle and disregarding geographically exclusionary criteria may add complexities to the different phases of logistics infrastructure projects. Thus, one relevant question for discussing their incorporation in the life cycle of the logistic infrastructure projects is their importance relative to the direct effects already incorporated in this life cycle.

The example of the EF-170 (Ferrogrão) helps to illustrate the relative importance of these costs. This railroad will connect Sinop (Mato Grosso) to Itaituba (Pará). The railroad will be about 1,000 km long, running parallel to the BR163 (Santarém–Cuiabá) road. To reduce the project's environmental impact, it is designed to have just two stations, both in the mid-north of the state of Mato Grosso.

The direct carbon footprint of the project is likely to be small since the railroad will have fewer stations and will run parallel to an existing road. Indeed, because trains emit less carbon per unit of cargo than trucks, it is estimated that the project will reduce carbon emissions by 1,000,000 tCOe.

However, its indirect carbon footprint is much larger. Using the market-access approach outlined before, CPI/PUC-Rio researchers estimate that the project will increase deforestation in roughly 2,000 km^2, releasing more than 60,000,000 tCOe in the atmosphere.[6]

This large difference between direct and indirect costs highlights the importance of including indirect effects in the assessment of the environmental costs of investments in logistics. Thus, it is important for both the EVTEA as well as EIAs to include and enhance these indirect impacts in their work as proposed by recommendations (1) and (2) of this Whitepaper.

2. Promise of geoprocessing tools

Incorporating the indirect impacts coming from the changes in transportation costs induced by these investments during environmental assessments is possible due to the increasing availability of modern geoprocessing tools. These tools have created the opportunity to use detailed data on logistic infrastructure and the economic geography to map the impacts of logistic infrastructure investments.

Information technologies have been increasingly used to improve policymaking throughout the world. For instance, it has been used to encourage the delivery of

[6] Araújo, Rafael; Assunção, Juliano; Bragança, Arthur (2020). "The Environmental Impacts of the Ferrogrão Railroad: An Ex-Ante Evaluation of Deforestation Risks". *Climate Policy Initiative*.

agricultural extension,[7] and monitor deforestation.[8] The impacts of many of these initiatives is extremely large.[9] Incorporating modern technologies to the EVTEA and EIAs is another one of these opportunities.

Conclusion

Brazil currently lags in logistic infrastructure and this has deep implications for its agricultural competitivity. As Brazil ramps up efforts to increase investments in its transportation infrastructure, the environmental impact of development in the Amazon needs to be fully understood. While the economic impact of improvements is touted among investors, currently, environmental assessments do not fully account for the indirect effects of such efforts. CPI's market to access tool provides an innovative approach to measuring the broader impact of logistic infrastructure in the Amazon. Therefore, changes in delimitating indirect area of interest need to be made in order to fully avoid, mitigate, and compensate for the impacts of these projects.

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[7] Aker, Jenny C., and Mbiti, Isaac M. (2010). "Mobile phones and economic development in Africa." *Journal of Economic Perspectives*, vol. 24(3), pp. 207-232. Fabregas, Raissa, Michael Kremer, and Schilbach, Frank (2019). "Realizing the potential of digital development: The case of agricultural advice." *Science*, vol. 366.6471.

[8] Assunção, Juliano, Clarissa Gandour, and Romero Rocha (2019). "DETERring deforestation in the Brazilian Amazon: Environmental Monitoring and Law Enforcement." Climate Policy Initiative.

[9] Jensen, Robert. "The digital provide: Information (technology), market performance, and welfare in the South Indian fisheries sector." The quarterly journal of economics 122.3 (2007): 879-924.

About CPI and INPUT

With deep expertise in policy and finance, Climate Policy Initiative (CPI) works to improve the most important energy and land use practices around the world. Our mission is to help governments, businesses, and financial institutions drive growth while addressing climate risk. Our Brazil office is affiliated with the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) and has close collaborations with prominent research universities around the world.

The Land Use Initiative (INPUT) counts on a dedicated multidisciplinary team of experts who work at the forefront of how to increase environmental protection and food production. INPUT aims at analyzing and influencing the creation of a next generation of low-carbon economy policies in Brazil. CPI's work for the initiative is currently supported by Norway's International Climate and Forest Initiative (NICFI), Children's Investment Fund Foundation (CIFF) and Instituto Clima e Sociedade (iCS).

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Suggested citation: BRAGANÇA, Arthur; ARAÚJO, Rafael; ASSUNÇÃO, Juliano. Whitepaper. Building Transportation Infrastructure in the Amazon: Incorporating Indirect Effects is Essential to Understand Environmental Costs. Rio de Janeiro: Climate Policy Initiative, 2020.