Project Update

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1. NON-TECHNICAL SUMMARY

Does deforestation in the Amazon contribute to Brazil's economic development? Proponents of deforestation assert that the destruction of forests is an essential and, in their view, an inevitable component of Brazil's economic growth strategy. They argue that the economic benefits derived from agricultural expansion and increased exports, particularly in the soy and beef sectors, provide the necessary resources for Brazil to develop and prosper on the global stage. However, opponents of deforestation argue that resource exploitation in the Amazon does not necessarily translate into economic benefits. Conversely, forest conservation may even incentivize farms to intensify, rather than to expand, agricultural production by increasing investments in capital and technology, thereby leading to improvements in land productivity.

In this research, we intend to answer this question by tracing the impact of deforestation through all supplier-customer relations between the agricultural sector in the Amazon and the rest of the economy. Brazil's agricultural sector relies on a complex web of supply chains where farms depend on capital-intensive inputs from their suppliers and 80% of Brazil's beef production is consumed domestically. The structure of the network that connects farms in the Amazon to the rest of the economy is therefore key to understanding how deforestation decisions propagate through the economy and affect aggregate macroeconomic outcomes, specifically Structural Transformation. Importantly, through Fernando Chertman from the Brazilian Central Bank, we have access to confidential data on *all* inter-bank firm-level transactions in Brazil, and confidential information on the exact location and perimeter of 2/3rd of *all* Brazilian agricultural establishments. Despite a large literature on the impact of economic factors on deforestation, this is the first research on the opposite causal relationship - the macroeconomic consequence of deforestation. In a preliminary theoretical exercise on the sector-level, we show that the amount of deforestation during the presidency of Jair Bolsonaro resulted in a very modest GDP gain of less than 0.1%.

2. METHODOLOGY

To investigate whether deforestation (or conservation) in the Amazon contributes to Brazil's economic development, we merge data from different datasets that allows us to estimate the effect of farm-level deforestation on firm-level sectoral labour market outcomes. Further we construct a model of production networks based on Acemoglu et al. (2012) to estimate and decompose the macroeconomic effect of deforestation and to conduct counterfactual analysis.

Data: We have access to confidential data from the Brazilian Payments System (SPB) on *all* inter-bank transfers between 2003 and 2014, which allows us to construct yearly input-output matrices at the firm level for Brazil. We can then merge each agricultural firm with confidential data from the Environmental Rural Registry (CAR) which provides the exact location and perimeter of each rural property in Brazil. Through the Brazilian Central Bank, we have access to around 2/3rd of this dataset which are all farms that take part in Brazil's rural credit system. With the CAR at hand, we are then able to calculate deforestation rates at the farm-level (e.g., with geospatial data from MapBiomas or from Hansen et al., 2013). We show an example of the granularity of this data in the Appendix. Furthermore, we intend to use geospatial data from MapBiomas to distinguish between cattle and crop producers. Lastly, we match each firm in the network with labour market information from the Relação Anual de Informações Sociais (RAIS) dataset. This allows us to estimate the effect of deforestation on labour market outcomes such as sectoral employment movements and wages through input-output linkages.

Empirical Specification: Formally, we are interested in estimating the following regression:

$$y_{itms} = \gamma_i + \gamma_t + \gamma_{ms} + \sum_{k}^{K} \left[\sum_{j \in J: d(i,j)=k} \beta_k^{\text{down}} \times \text{Downstream}_i^{(k)} \times \Delta F_{jt} \right] + \sum_{k}^{K} \left[\sum_{j \in J: d(i,j)=k} \beta_k^{\text{up}} \times \text{Upstream}_i^{(k)} \times \Delta F_{jt} \right] + \delta X_{itms} + \epsilon_{itms}$$

where y_{itms} denotes the outcome of firm i at time t in municipality m and sector s. ΔF_{jt} denotes the change in forest cover of farm $j \in J$ at time t. k denotes the number of network links between firm i and farm j. $d(i,j)$ is a distance function that yields the minimum number of network links that connect firm i and farm j. The variables $Upstream_i^{(k)}$ and $Downstream_i^{(k)}$ are dummy variables that indicate weather firm i is a customer or supplier with distance k to farm j, respectively. We also include firm, time, and municipality-sector fixed effects γ_i, γ_t and γ_{ms} as well as a set of time-varying controls X_{itms}.

The main coefficients of interest are $\beta_k^{down}$and β_k^{up} which measure the impact of changes in farm's forest cover in the Amazon on firm outcomes with downstream and upstream network distance k to each farm. We are specifically interested in labour market outcomes such as sectoral employment and wages to understand the effect of deforestation on Structural Transformation.

Identification: If we restrict the sample to farm-firm linkages in different municipalities (e.g., deforestation in the Amazon and firms outside the Amazon), then identification holds by assuming that unobserved drivers of deforestation in the farm-municipalities are orthogonal to firm level outcomes in different municipalities. We believe this is a reasonable assumption, however we can strengthen identification by exploiting the introduction of Priority Municipalities (MPs), a conservation policy by the Ministry of Environment that blacklisted 36 municipalities in 2008. The intervention entailed a mix of policies, including increased monitoring, environmental law enforcement and fines for deforestation. We can then use the above regression within a differences-in-differences framework where we compare the network effects of deforestation between blacklisted and non-blacklisted municipalities before and after the policy intervention. The introduction of MPs has been shown to be an extremely effective policy tool to curb deforestation rates and some research indicates that farms responded by intensifying production through capital and technology investments (e.g., Assunção & Rocha 2019, Koch et al. 2019 and Moffette et al. 2021).

Another identification strategy results from the incapability of DETER to detect land cover changes in areas covered by clouds. DETER is the main tool to monitor and allocate environmental law enforcement based on satellite imagery of the Amazon Forest cover. The satellite-based technology does not identify deforestation hot spots under clouds, which generates exogenous variation in firm-level deforestation decisions. This means the average annual cloud cover percentage over farm j can be used as an instrument for issued fines for illegal deforestation (see Assunção et. al., 2013).

Production Networks Model: In the theoretical part of the research, we build on Long & Plosser (1983) and Acemoglu et al. (2012) and construct a model where goods are either consumed, exported, or used as intermediate inputs. We consider a subset of firms that are agricultural producers with an exogenously given rural property size which can either be used for forest or arable land. Properties are owned by landowners that deforest and rent out land to farms. Deforestation occurs subject to costs that are governed by law enforcement of the minimum requirement of forest on properties from the Brazilian Forest Code. Further, changes in the land use result in changes in the amount of precipitation over each farm which is a direct input into agricultural production. In a preliminary exercise, we calibrate a first version of the model at the sector-level and without a fully-fledged labour market. We show that the amount of deforestation during the presidency of Jair Bolsonaro resulted in a very modest GDP gain of less than 0.1%. We also decompose the effect at the sector level. In a counterfactual exercise with CES production, we show that firms with high labour shares can gain from forest conservation. In the next step, we intend to conduct the exercise at the firm-level and include elastic labour supply.

3. CONTRIBUTIONS TO EXPANDING THE FIELD

Despite a large literature on the impact of economic factors on deforestation (e.g., Cropper and Griffiths 1994; rural roads and accessibility of forests (Burgess et al. 2012 (administrative changes); Assunção et. al 2012 (prices and policies); Assunção et. al

2013 (rural credit); Cisneros et al. 2015, Assunção & Rocha 2019 (municípios prioritários); Da Mata and Dotta 2021 (commodity booms); Szerman et al. 2022: (agricultural productivity); Ferreira 2023 (monitoring and enforcement)), there is virtually no research on the opposite causal relationship - the macroeconomic consequence of deforestation. This research connects closest to the literature that evaluates the effectiveness of different conservation policies. Most of this literature focuses on the introduction of blacklisted municipalities (i.e., Priority Municipalities) in Brazil that went under very stringent monitoring and law enforcement to combat deforestation rates (see Assuncao & Rocha 2019, Cisneros et al. 2015, Burgess et al. 2018, Koch et al. 2019, Ferreira 2021, Moffette et al. 2021). Lastly, there is a large literature on the drivers of Structural Transformation in Brazil (see Bustos, Caprettini, Ponticelli 2016; Bustos, Caprettini, Ponticelli 2020; Albert, Bustos, Ponticelli 2023), however no research on the role of deforestation in the process of Structural Transformation.

4. LIST OF REFERENCES CITED

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5. APPENDIX

Below we show an example map of the CAR overlayed with deforestation data from Hansen et al. (2013). Rural Properties are depicted in red perimeters and pixels in green and blue depict forest losses in each time interval. Blue pixels show the amount of deforestation after the election of Jair Bolsonaro. White (blank) pixels are areas where no deforestation occurred after the year 2000. The map is a screenshot of a random location within the Legal Amazon; however, we intend to calculate property-level deforestation in all of Brazil.