Deforestation and structural change: The case of tourism in Brazil

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Abstract

Deforestation in the tropics is a major driver of climate change. This paper studies the role of local structural change for reducing deforestation in developing countries and emerging economies. The paper focuses on tourism in Brazil as a case study. The paper combines an empirical econometric analysis with a quantitative spatial model, utilizing a granular and rich dataset that includes satellite imagery, individual-level census micro-data, establishment-level tourism data, and administrative social insurance data, among other sources. Our findings indicate that domestic and international tourism in Brazil substantially increased employment in tourism-related industries but lowered local wages, with its employment effects spilling over into other industries and nearby locations. Furthermore, simulations with our calibrated model suggest that tourism-related traded services reduced deforestation by providing local employment opportunities outside agriculture. This effect is particularly pronounced in the Amazon region.

JEL codes: Q56, R11, Q26, O13, F18

1 Introduction

Global land-use change contributes roughly one-third to anthropogenic climate change (Friedlingstein et al., 2023), with tropical forest degradation and deforestation accounting for about 10 percent of global greenhouse gas (GHG) emissions (Achard et al., 2014). Despite the importance of tropical forests for the global climate, effective policies to address the global externality of local land use changes are mostly absent. This raises an important question: how will deforestation evolve under alternative pathways of future economic development? A critical factor for this question is local structural change and specifically the extent to which local economic development is accompanied by a reallocation of labor from agriculture into other sectors. From a broader perspective, the relationship between

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structural transformation and land-use change lies at the heart of longstanding debates on economic development and environmental sustainability.

In this paper, we study how local economic development driven by an expansion of the service sector affects land use change locally and in the aggregate. We focus on tourism-related services and the geographic context is Brazil, in which tourism in 2010 accounted for about 4 percent of GDP. Tourism is a particularly interesting phenomenon for our research question because it creates external demand for services that are otherwise not traded, which can stimulate development in regions with low local demand for goods and services.[1]. Furthermore, most jobs in tourism-related industries have lower skill requirements than jobs in other traded services such as information technology and business services, making it particularly attractive for the absorption of labour from agriculture (Rodrik and Stiglitz, 2024). In an economic framework, tourism can be thought of as moving consumers across space, which means that it can have wide-ranging influence on the spatial distribution of economic activity. To study the local and aggregate effects of tourism the paper thus combines an empirical econometric analysis with a quantitative spatial economic model. Economic theory predicts that local structural change affects the spatial allocation of economic production in agriculture and other sectors through adjustments of prices in factor and goods markets. Our structural model takes these spatial and general equilibrium effects into account.

In the empirical analysis we first establish the causal effects of tourism on local economic development. We do so with an instrumental-variable strategy that leverages variation in the size of sandy beaches along the Brazilian coast as a determinant of the tourism attractiveness of a municipality. We first construct the instrumental variable from monthly Sentinel satellite images along the entire coastline and then combine it with data on the universe of tourism establishments, census micro-data on wages and sectoral employment, and municipality GDP. Our results show that tourism had economically meaningful effects on employment in tourism and tourism-related services[2]: one additional

[1]Here and in the rest of the paper we adopt the definition of tourism of the World Tourism Organisation/United Nations: "Tourism is the activity of tourists. [...] A tourist is a visitor whose trip includes an overnight stay. [...] A visitor is a traveller taking a trip to a main destination outside his/her usual environment, for less than a year, for any main purpose (business, leisure or other personal purpose) other than to be employed by a resident entity in the country or place visited." (United Nations and World Tourism Organization, 2010).

[2]Here and in the rest of the paper we follow the classification of the Brazilian government of industries as *tourism* and *tourism-related* (IBGE, 2012). This classification considers only accommodation services as *tourism*. This is generally consistent with the WTO definition of tourism as activities by travellers on trips that are associated with an overnight stay away from their place of residence. Tourism-related industries are those that provide goods and services regularly consumed by tourists, but also by local residents. Examples are food and beverages, transportation, arts and entertainment, and recreation. See also Figure 3 and the discussion in Section 2.2.

bed in touristic accommodations corresponds to about 0.4 jobs in tourism and about 3.2 jobs in tourism-related services. We use these effect sizes and calculate that about 59 percent of jobs in tourism-associated industries in Brazil can be attributed to the activities of tourists and the remainder to non-traded local services. These direct effects are accompanied by additional local jobs in other services and manufacturing. Furthermore, we find a small positive effect of tourism on GDP per capita and a small negative effect on local wages.

We next extend the empirical analysis to the rest of Brazil with a difference-in-differences research design that exploits the staggered designation of UNESCO world heritage sites. Furthermore, the difference-in-differences design allows us to also study dynamics and extend the analysis to land use changes and deforestation. For the analysis we use administrative social insurance data that includes the universe of formally employed workers in Brazil over the period 1985-2020. Our results show that the designation of a UNESCO world heritage sites generated employment in tourism and tourism-related industries. However, we find no significant effect on employment in services and manufacturing, at least over the first 10-20 years. Suggestive evidence points to an absorption of labour from other services into tourism-related activities. Furthermore, we find that the designation of a UNESCO world heritage site reduced agricultural land use and increased natural land cover relative to candidate sites.

In the second part of the paper, we develop and calibrate a structural model to translate local effects of tourism into aggregate effects on social welfare and land use change. Key features of the model are domestic and international trade in goods and tourism-related services, four sectors with input-output linkages including 10 different agricultural products, natural advantages, local amenities, and agglomeration economies. We first use data on wages and employment to calibrate the model to Brazilian data for 2010 and to back out unobserved local advantages and amenities. The calibration also uses our empirical result on the share of jobs in tourism-related services that can be attributed to tourism. In a second step we use the fully calibrated model for the simulation of counterfactual simulation in which we switch off domestic and international tourism. The results of these simulations suggest overall slightly negative effects of tourism on aggregate welfare and a slight increase in natural land cover relative to the counterfactual without any tourism. Notably, the net effects on land use mask spatial heterogeneity with tourism increasing natural land cover relative to the counterfactual scenario especially in the legal Amazon region.

Our paper makes several important contributions to the debate about economic development and the environment. Over the past decades agricultural productivity increased by on average about 2 percent per year (Agnew and Thompson, 2024). How productivity growth affects total employment in agriculture depends on the elasticity of demand for locally produced agricultural goods and whether technological change is labour saving (Bustos et al., 2016; Balboni et al., 2023). If demand for labour in agriculture decreases, workers will relocate to other sectors and potentially other regions. This relocation will however be shaped by frictions to inter-sectoral and inter-regional mobility, which are well documented in developing countries (Lagakos, 2020; Gollin and Kaboski, 2023). In this paper we model for the first time to what extent local employment opportunities in tradable services can reduce deforestation from agriculture in the presence of such spatial frictions. The tradability of local services is of particular relevance in countries in which land use change tends to occur in relatively poor regions with low local demand for goods and services. We illustrate this mechanism with our spatial economic model for the case of Brazil, for which we find that the larger the spatial dispersion forces, the larger the benefits of tourism for reducing deforestation in the Amazon region.

Land use change is of interest for environmental policy because of its environmental externalities. This is particularly the case in countries with large amounts of tropical rainforests such as Brazil due to the amount of carbon that is stored in them and that will be released in case of deforestation, contributing to the global externalities of anthropogenic climate change. Various policies have been proposed and implemented around the world to internalise the carbon externality and other externalities including market-based approaches such as carbon certificates and command-and-control regulation such as protected areas (Barrett et al., 2023). Despite this, the tropical forest in Brazil's Amazon region has been reduced by about 10 percent between 2001 and 2020. We contribute to this debate about policy instruments to reduce deforestation by quantifying the contribution that tourism-driven economic development can make in reducing land use change. Tourism is of particular policy relevance because it tends to be supported by public investments in infrastructure. Our results suggest that tourism in Brazil is associated with a trade-off: In our counterfactual simulations, tourism lowers welfare but increases natural land use, especially in the legal Amazon region. To our knowledge this is the first paper that studies the environmental consequences of tourism with a quantitative spatial economic model. The local economic costs and benefits of tourism have however already been studied empirically in many other papers, typically using panel data to compare the trajectories of countries (e.g. Lee and Chang (2008); Holzner (2011)) or within-country heterogeneity to study the development of cities or regions with different exposure to tourism (e.g. McGregor and Wills (2017); Zhang and Zhang (2023)). The results are overall mixed, with modest local economic gains from tourism reported in most papers (Gwenhure and Odhiambo, 2017; Liu et al., 2022). These empirical approaches however do not account for general and spatial equilibrium effects. Earlier work on Mexico that used a similar quantitative spatial model reported positive welfare effects of tourism (Faber and Gaubert, 2019). The literature on tourism and the environment uses a wide range of methodologies (Buckley, 2011; Sathiendrakumar, 2013; Jakobsson and Dragun, 2013), with one recent paper that studies a RCT in Colombia finding a reduction in deforestation around eco-tourism sites (Saavedra, 2022).

Finally, our work builds on earlier work that has studied the agricultural sector or land use changes in Brazil using similar quantitative spatial economic modeling frameworks. Pellegrina (2022) studies the effect of productivity and trade shocks on agricultural production in Brazil. Furthermore, Gollin and Wolfersberger (2023) and Araujo et al. (2023) assess the role of transport infrastructure for tropical deforestation. Our work is to our knowledge the first to include traded services in this type of model, and the first to relate local structural change to the environmental externality of land use change. With its focus on structural change in response to changes in demand, our work also contrasts earlier empirical work on structural change in Brazil that focused on the response to agricultural productivity shocks (Bustos et al., 2016).

2 Background and Data

2.1 Tourism in Brazil

The main touristic attraction in Brazil are the country's beaches, followed by its culture and its nature (Figure 1). A detailed analysis of the economic significance of tourism in Brazil was conducted for the year 2009 by the Instituto Brasileiro de Geografia e Estatistica (IBGE). In that year, tourism accounted for 3.9 percent of GDP and 7.3 percent of the gross value added in services. The largest share (42%) was Food Services, followed by Road Transportation (16%) and Recreational, Cultural and Sport Activities (14%). Accomodation services contributed around 6% (IBGE, 2012). Most of the consumption from tourism can be attributed to domestic tourism. Overall, it is assumed that domestic tourism is about 9-10 times more important economically than international tourism in Brazil (Rabahy, 2019).[3]

[3]International tourism grew dramatically following democratisation and opening up to globalisation in the late 1980s and early 1990s (De Araujo and Dredge, 2012; Rabahy, 2019). Within few years, the number of foreign visitors multiplied several times reaching 5 - 6 million foreign tourists per year since the early 2000s. The largest number of visitors come from Argentine, followed by the USA, other countries in the region (Chile, Uruguay, Paraguay) and some European countries (France, Germany, Italy, UK, Spain, Portugal).

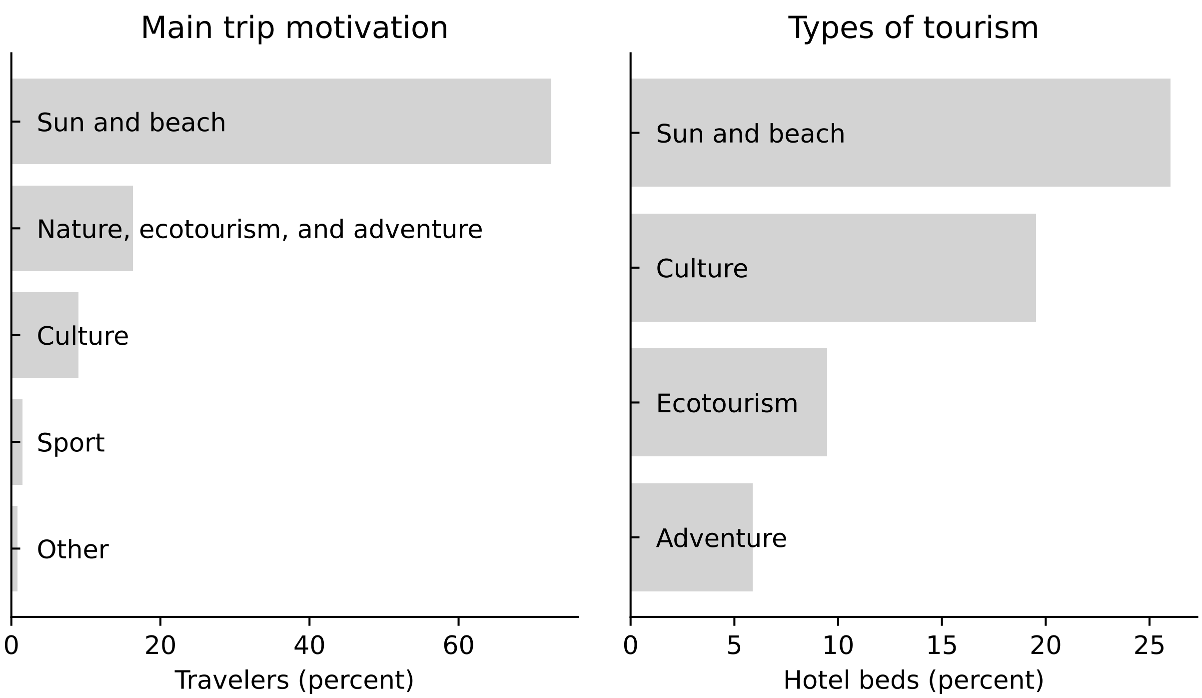

Figure 1. Main types of tourism in Brazil. Information from international travellers entering Brazil for leisure (left) and information from tourism accommodations about the main activities of their guests (right).

2.2 Economic data

Our main source of economic data is the individual-level microdata of the Census 2010, which covers a representative sample of 25 % of households. We use this dataset for information on sectoral employment, wages, and total population in each municipality. We calculate mincerized wages as residuals of a regression of the log hourly wage on quadratic polynomials of age and education. We generally distinguish five sectors throughout the paper: tourism, tourism-related industries, other services, manufacturing, agriculture, and other industries. We use granular industry codes to assign workers to these sectors. Tourism is composed only of touristic accommodations. Tourism-related industries are defined based on an economic analysis of the tourism sector published by the Brazilian government (IBGE, 2012). Manufacturing and agriculture are defined based on the first hierarchical level of the Brazilian classification of industries. Other industries include all remaining sectors.

The empirical analysis in Section 3.2 requires annual data on sectoral employment. For this analysis we use administrative individual-level data of the Social Security (Relação Anual de Informações Sociais - RAIS) that covers the universe of formally employed workers in Brazil. We prefer the Census for our analysis of 2010 because it has a higher coverage of informal employment. In some robustness checks, we however find that the empirical results are similar if we use data from RAIS for 2010. Data on the distribution of population is also obtained from the full census. Information on employment and wages is obtained from RAIS, from which we have individual-level data of the universe of formally employed workers in Brazil in 2010. We complement our data with government statistics on sectoral GDP at the level of municipalities.

Our main units of analysis are 5,572 municipalities in Brazil. We focus on the year 2010 because of the availability of a census and because it is before Brazil hosted the FIFA World Cup and the Olympic Games in 2014 and 2016, respectively, which we expect to have had a substantial impact on the tourism sector in Brazil. For the analysis of tourism, we use the official government classification of industries with "goods and services that are characteristic of tourism" to aggregate from individual workers to employment in the tourism sector (IBGE, 2012).

We complement these data with data from a government registry of all tourism accommodations in Brazil. The registry includes the precise address and capacities in terms of the number of beds of all individual establishments in Brazil, which we aggregate to the total number of beds in each municipality.

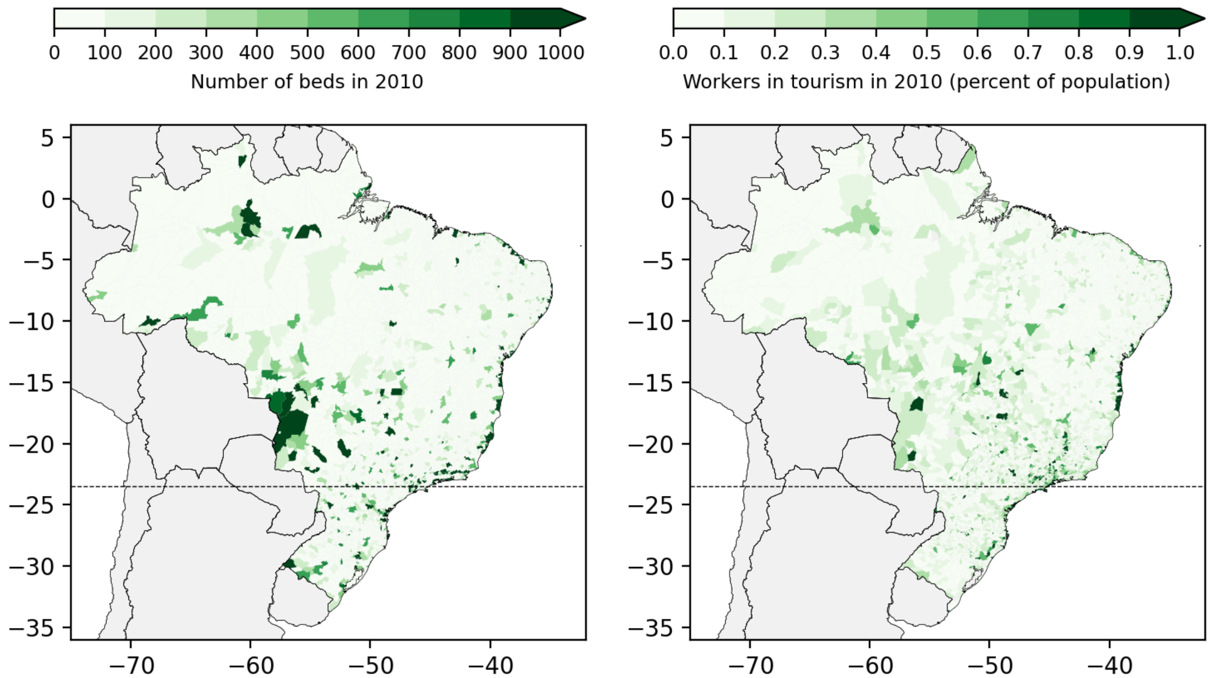

Figure 2. The distribution of tourism across municipalities in Brazil.

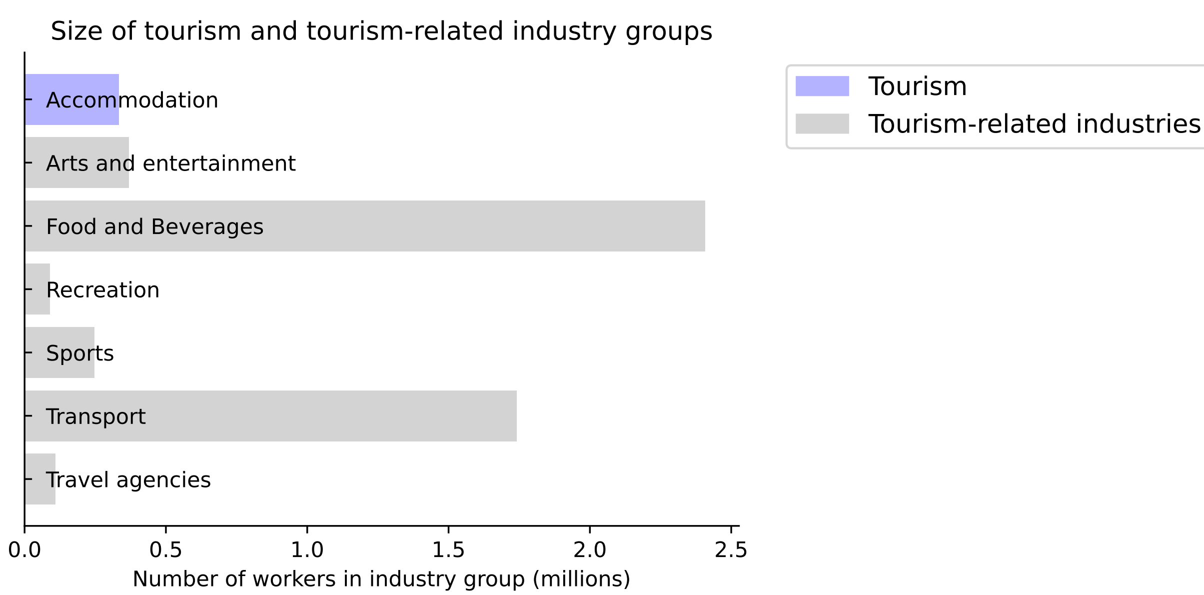

Figure 3. Tourism and tourism-related industries. The seven industry groups shown in the figure are aggregates of more granular industries for which IBGE (2012) provide a distinction between tourism, tourism-related, and other industries.

2.3 Tourism attractiveness

In the empirical analysis we exploit plausibly exogeneous variation in certain landscape features of municipalities that influence their attractiveness for tourists. For this strategy to yield valid estimates, the presence of these natural advantages must be exogeneous to economic development and they must not influence local economic development through any other channel than through tourism. We use the average width of sandy beaches along the shoreline of a municipality as a proxy of tourism attractiveness.

We quantify the area of sandy beaches using Sentinel-2 satellite images. We first partition the Brazilian coastline into 16,775 rectangular segments. For each segment, we download satellite images with a resolution of about 10 meters and identify sandy areas using six spectral bands that we aggregate to multiple indices. To address cloud cover and the seasonality of beaches, we download the 12 monthly satellite image with the lowest cloud cover, drop cloudy areas, and aggregate to annual composites. We complement the data with a satellite-derived data of build-up areas. We consider all contiguous areas classified as sand that consist of at least ten pixels within a 100 meter buffer around the shoreline as beaches. We then aggregate beach area for every municipality it divide it by the total length of its shoreline (SI Figure S1).

In the last part of the empirical analysis, we use the presence of a UNESCO world heritage site in the vicinity of a municipality as a proxy for tourism attractiveness (Figure 7). In contrast to the analysis of beaches, these sites cannot be assumed to be entirely exogeneous to economic development. We address this concern in two ways. First, we use as controls municipalities in the vicinity of UNESO world heritage candidate sites, which have gone through the same selection process at the national level and from which the designated sites have been drawn. Second, we use a difference-in-difference approach which means that we allow for heterogeneous levels in tourism between designated sites and candidate sites as long as - absence the designation - these sites have parallel trends. We test for parallel trends during the pre-treatment period and find generally reassuring results.

2.4 Agriculture

For agriculture we further distinguish the 10 largest product groups by total production value in 2010. We implement these product groups as individual sectors in our model. The product groups are: Cattle, Soy, Sugarcane, Corn, Fruits, Coffee, Vegetables, Rice, Tobacco, and Cotton. For disaggregated data on agricultural production we combine data from the Municipal Agricultural Survey with data on cattle from Pellegrina (2022).

We them use the estimated product-specific labour intensities from Pellegrina (2022) to assign total workers in agriculture from the census for each municipality to each of the 10 agricultural subsectors according to the subsector's share of total payments to labour.

2.5 Land use and deforestation

Local economic development due to tourism is likely to affect land use changes one way or the other. For the empirical analyis we use two alternative datasets to examine the local environmental impacts of tourism. The first dataset contains annual data on the deforested area in each municipality and is provided by PRODES. The second dataset contains annual information on the representation of different land use classes in each municipality and is provided by MAPBIOMAS. We extract from this dataset information on the share of land area covered by natural forests and the share of land area used for agriculture including pasture. The two datasets are visualised in Figure 4.

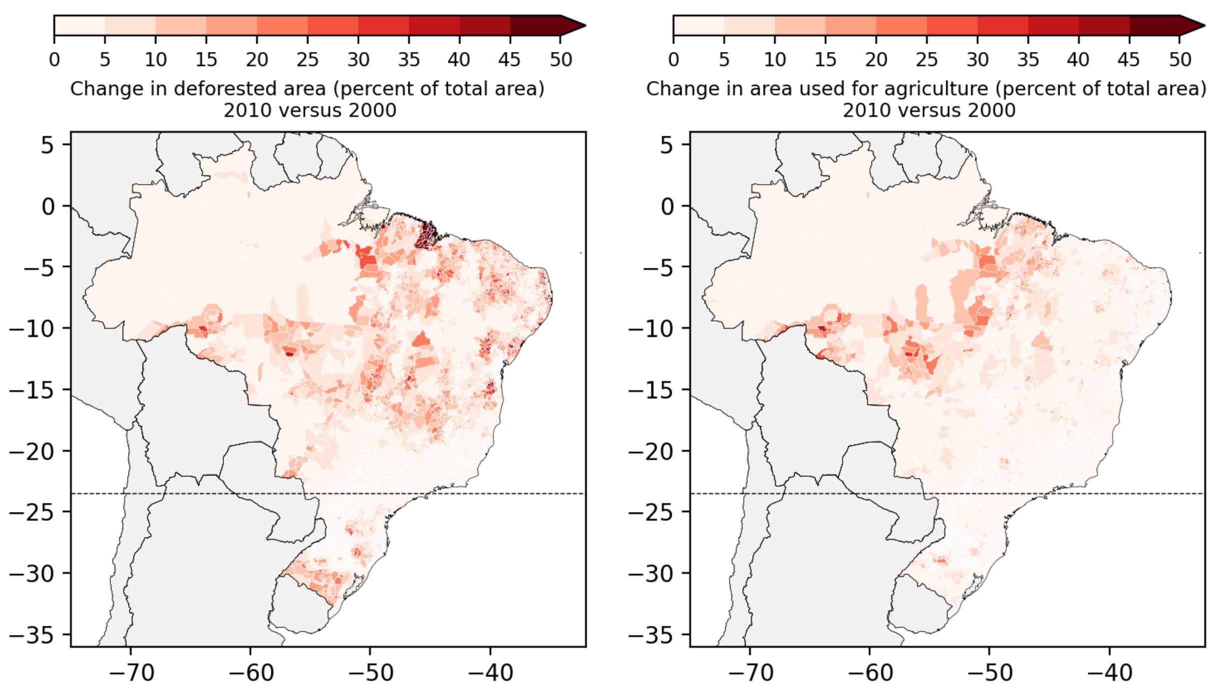

Figure 4. The distribution of deforestation (2000-2010) and changes in agricultural land use (2000-2010) across municipalities in Brazil.

2.6 Transport infrastructure

In our spatial economic model, trade in goods and services (tourism) is influenced by the physical distance between locations. We calculate distances with detailed data on the transport infrastructure in Brazil in 2010. Most of the infrastructure data were provided by Araujo et al. (2023). Our data cover four modes of transportation: roads, railways, waterways, and air transport (Figure 5). For trade in goods, we ignore air transport, because the vast majority of domestic and international trade in goods is via road, rail, or water.

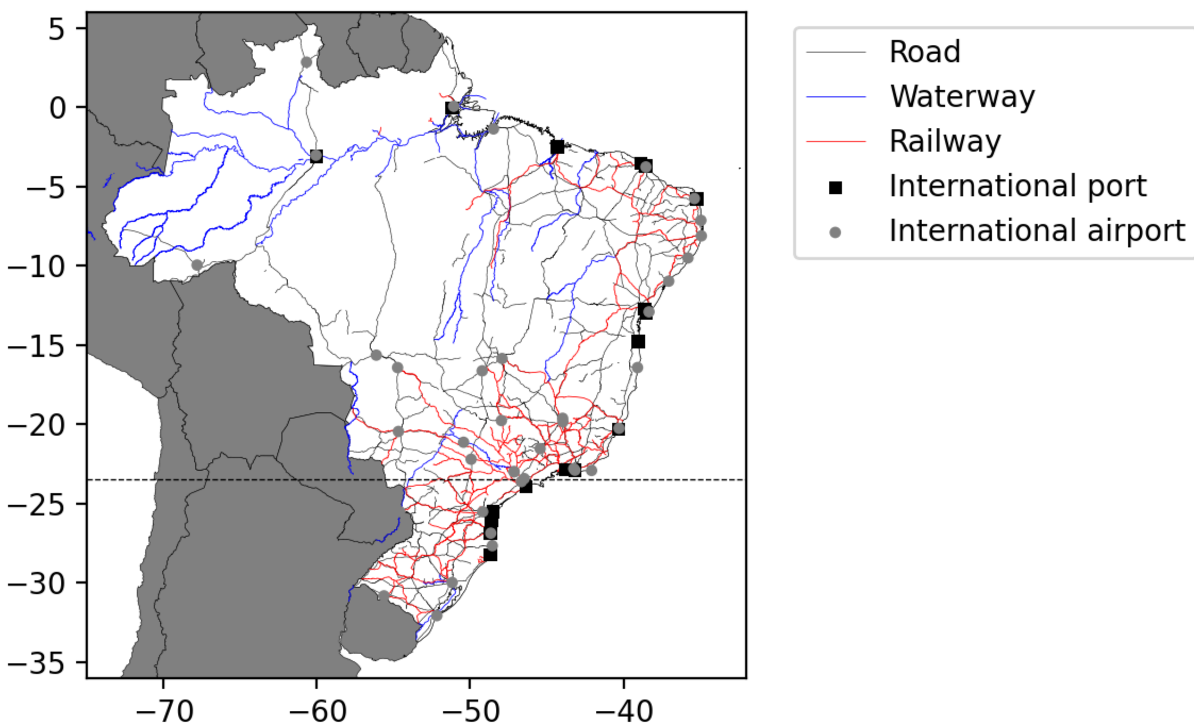

Figure 5. Transport infrastructure in Brazil. Data from Araujo et al. (2023).

We first map the transport infrastructure onto a multi-modal graph. The graph takes into account that for the transport of goods the mode can only be changed at specific locations: ports and railroad stations. We then combine the structure of the graph with information about the relative costs of travel per distance. We use relative costs from Araujo et al. (2023): waterways and railways 5, paved roads 10, unpaved roads 20, no roads 50, and flights 100. Furthermore, for the transport of goods we add fixed costs of 200 for changing mode in ports or railroad stations to incorporate terminal usage fees.

For each pair of regions we then use the Dijkstra algorithm to identify the shortest path on the graph that connects their centroids taking into account relative costs. For the distance to other countries, we use the distance to the closest international ports (for goods) and the distance to the closest international airport (for tourism).

2.7 Control Variables

We use several predermined controls that we include in our econometric analysis. The selection of controls is informed by prior work (Faber and Gaubert, 2019). The controls are annual mean temperature and annual total rainfall from ERA5 reanalysis, the land area of a municipality, the distance from the capital Brasilia, the distance from state capitals, the distance from the coast, and the distance from major ports during colonial times.

3 Empirical evidence

3.1 Beaches

In the first part of our empirical analysis we focus on the relationship between tourism and local economic development. Specifically, we are interested in how tourism affects sectoral employment, GDP per capita, population, and local wages. Tourism is measured by the total number of beds in touristic accommodations, in the following denoted as variable H. A possible concern of relating tourism to local economic development in an empirical analysis is reverse causality - tourism may influence local economic development, but the presence of hotels may also reversely be affected by the local economy. To address this concern, we instrument the number of beds in touristic accommodations with variables that characterise the tourism attractiveness of a municipality and that are themselves not affected by local economic development. In this section we use as instrument the average width of beaches along the coast, which we denote as B. The inspiration for this instrument is partly the prior work on tourism in Mexico by Faber and Gaubert (2019) as well as the fact that beach tourism is the main motivation of international tourists coming to Brazil (Figure 1).

The average width of beaches is derived from satellite images and a high-resolution dataset of the coastline of Brazil (Figure 6). The processing of the data is in more detail described in Section 2.3. In essence, the average width of beaches is calculated as the ratio of the total area of sandy pixels within a buffer of 100 meters along the coastline divided by the length of the coastline. This variable varies between 0 and around 100 meters across municipalities, with a mean value of 15 meters. Where beaches are located along the shore is primarily determined by the supply of sediments, wave dynamics, and coastal currents. The beaches of Brazil benefit particularly from the country's large rivers transporting sediment from the interior to the coast, a large continental shelf with coral reefs along some segments of the coastline that reduce erosion from waves, and ocean currents that distribute sediments along the shore.

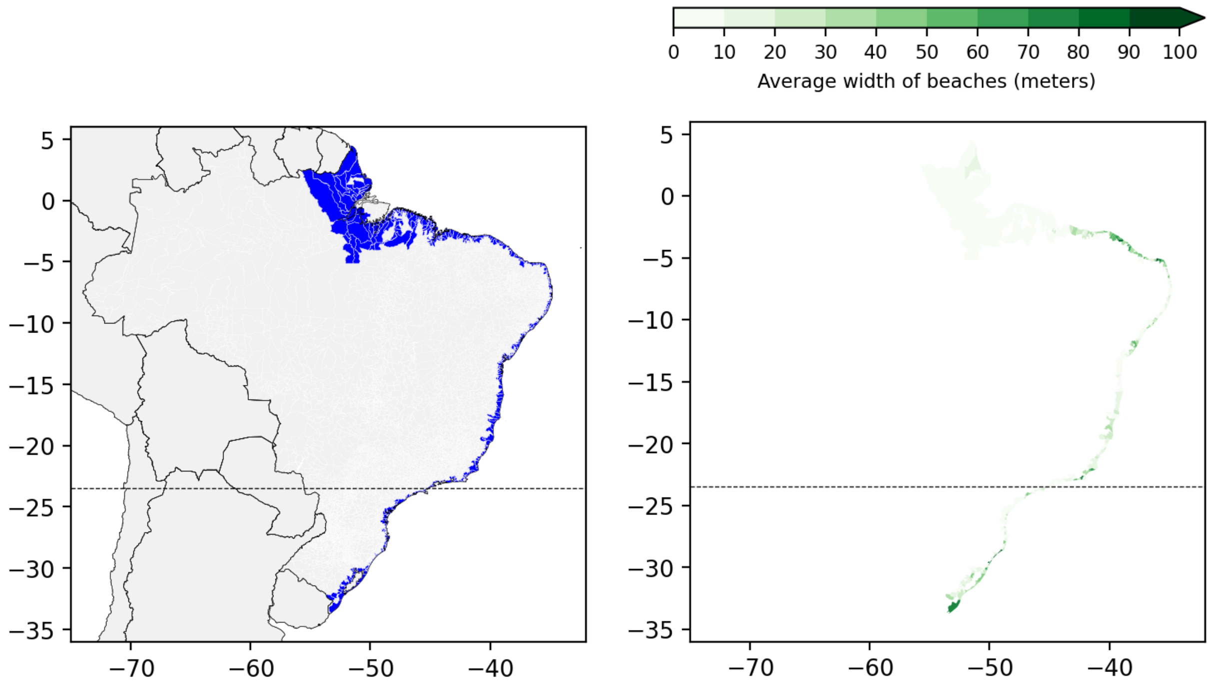

Figure 6. Municipalities with direct access to the coast and their average width of beaches.

The width of beaches is unlikely to be affected by local tourism. However, one may be concerned that there are variables that affect both the presence of beaches as well as local economic development. Given the processes behind the formation of beaches along the Brazilian coast a plausible concern is that the convergence of ocean currents benefits both the formation of beaches as well as the location of ports during colonial times. To address such concerns we include the distance to the federal capital, the distance to the state capital, and the distance to the closest colonial port as control variables in the model. For the last two variables we also include a dummy for municipalities that host the state capital and a colonial port, respectively. Furthermore, to avoid spurious correlations due to the way the width of beaches is calculated we also include as control variables the total land area of a municipality and the length of the coastline of a municipality divided by its land area. The model is estimated in two steps, with a method referred to as two-stages-least-squares (2SLS):

$$H_i = \alpha_1 + B_i\beta_1 + X_i\gamma_1 + \epsilon_i \tag{1}$$

$$\hat{H}_i = \hat{\alpha_1} + B_i\hat{\beta_1} + X_i\hat{\gamma_1} \tag{2}$$

$$y_i = \alpha_2 + \hat{H}_i\beta_2 + X_i\gamma_2 + \tilde{\epsilon}_i \tag{3}$$

for each of our economic variables of interest $y_i \in$ {Sectoral employment, GDP pc, wages}, a vector of controls X, and municipalities indexed by i. For all estimations we reduce the sample to the 424 municipalities on the Brazilian coast. Based on this sample we first estimate Equation with OLS. The estimated parameters are then used to predict B (Equation). In the last step, the outcome variables y are regressed on the predictions $\hat{B}$ and control variables X. If the exogeneity assumption of our variables for tourism attractiveness are satisfied, the estimates of β_2 will give us the causal effect of tourism on each economic outcome.

Our empirical estimates obtained with the 2SLS methodology suggest that tourism creates jobs in the core tourism sector (touristic accommodations). On average, in our sample one additional bed in a touristic accommodation is associated with an additional 0.36 jobs in tourism (Table 1). We also find that tourism creates jobs in tourism-related activities. The effect size is substantially larger: one additional bed is associated with about 3.2 additional jobs. We use these effect sizes to calibrate our spatial model further below. Furthermore, our results suggest that tourism creates additional jobs in other services and manufacturing (Table 1).

In additional to these effects of tourism in sectoral employment, we find that tourism increases local GDP per capita and lowers average wages. One additional bed in a touristic accommodation increases GDP per capita by on average R$ 25 (in 2010 values) and reduced wages by R$ 1. Consistent with its positive effect on sectoral employment, we find that tourism also increases the local population (Table 1).

The estimated coefficients shown in Table 1 can only be considered as causal if beach width affects local economic development only through tourism. As explained above, a possible concern is that beaches are correlated with the presence of colonial ports or related choices of pre-colonial and colonial settlements. We address the concern in two ways. First, the model whose results are shown in Table 1 includes several control variables related to the location of colonial ports and the distance from state capitals and the federal capital. The controls seem to make little difference, as we find essentially the same effects with models without any controls (SI Table S1). Second, we estimate the re-

Table 1. Results on beach width, tourism, and local economic development.

Dependent variable:	Sectoral employment				Other outcomes		
	Tourism	Tourism-related	Services	Manufacturing	GDP pc	Population	Wages
Column:	1	2	3	4	5	6	7
Beds in tourism accomodations	0.363***	3.205***	22.634***	3.340**	0.025**	91.292***	-0.001**
	(0.048)	(0.949)	(7.033)	(1.566)	(0.010)	(25.138)	(0.001)
Control variables	Y	Y	Y	Y	Y	Y	Y
First stage F-statistic	453	106	129	266	130	181	400
N	424	424	424	424	424	424	424

Notes: The table shows the estimated coefficients of a 2SLS regression (Equation 3). The number of beds in touristic accommodations is instrumented by the average width of beaches in a municipality. The sample includes all municipalities not further away than 200 meters from the coastline. Control variables: Land area, Length of coastline divided by land area, State capital (dummy), Distance to state capital, Colonial port (dummy), Distance to closes colonial port, Distance to Brasilia, Annual mean temperature, Annual total rainfall. Results without any controls are shown in SI Table S1. See text for interpretation of the size of the coefficients. Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

duced form model with data on the historical population from the two earliest censuses of Brazil (1872 and 1920). We find no evidence that beaches influenced the distribution of population at these times (SI Table S3).

The estimated effects reflect how beaches affect economic development in the municipality in which they are located. Given the relatively small size of many coastal municipalities, we test whether tourism in a neighbouring municipality has similar effects on local economic development. We do not find evidence for such spatial spillovers. Reassuringly, our main estimates are essentially unaffected by including the spatial lag of the instrumented number of beds in touristic accommodations (SI Table S2). Another possible concern related to the exclusion restriction is that beaches provide amenities for local residents and that these amenities are associated with economic development. To the extent that these mechanisms were already effective in earlier times, our analysis using the censuses of 1872 and 1920 address this concern. However, it seems plausible that the use of beaches by local residents for leisure is a relatively recent phenomenon. We address this concern in the next section with an alternative identification strategy. Furthermore, we regress the local amenities as calibrated with our quantitative spatial model on our instrument. Our results suggest that the average width of beaches is not a significant predictor of local amenities (SI Table S4).

3.2 UNESCO world heritage sites

The empirical analysis of beaches focuses on Brazil in the year 2010. The methodological approach with instrumental variables means that the estimated coefficients represent the long-term effect of tourism in local economic development. This long time horizon of the analysis is generally consistent with the static quantitative spatial model developed in Section 4. However, with instrumental variables the causal identification rests on assumptions that cannot be tested. Furthermore, the analysis of beach tourism is inherently limited to the coastline of Brazil, where land use change and deforestation are of less relevance than in other parts of the country.

In this section we study the employment effects of tourism with another methodological approach that leverages differences in developments over time across municipalities in Brazil. Specifically, we use a difference-in-differences approach that leverages differential trends over time between sites that were assigned UNESCO world heritage status and those that were proposed as candidates but did not succeed. The analysis has been conducted concurrently with related work on UNESCO world heritage sites in Italy (Bertacchini et al., 2024).

The UNESCO world heritage status is assigned by an international committee. The main criteria are a site's cultural and natural significance. To be considered, a site needs to be on a candidate list put together by the host country and then be nominated in the given year. By the end of 2022, Brazil hosted 23 world heritage sites and 20 additional candidate sites. Of these 43 sites, 29 are categorised as culturally significant and 21 as naturally significant (Figure 7).

For the empirical model we consider as treated municipalities all those that are within a buffer of 100 km around any designated UNESCO world heritage site. The control municipalities are those within 50 km of a candidate site. The idea behind this choice of control sites is that candidate and world heritage sites are plausibly sufficiently similar to expect parallel trends in the absence of UNESCO status designation. In robustness checks, we reduce the sample to only world heritage sites and candidate sites with only either cultural or natural significance and we change the buffer to either 50 km or 200 km. The results are qualitatively the same (SI Table S5).

Given the variation in treatment timing and possibly heterogeneous treatment effects, we estimate a difference-in-differences model using the methodology proposed by Callaway and Sant'Anna (2021). We first show the average group-time effects as event study plots and then estimate the average treatment effect of the treated (ATT) based on the 20 years around the treatment period. Confidence intervals are constructed from bootstrapped standard errors. Our main variables of interest are sectoral employment and

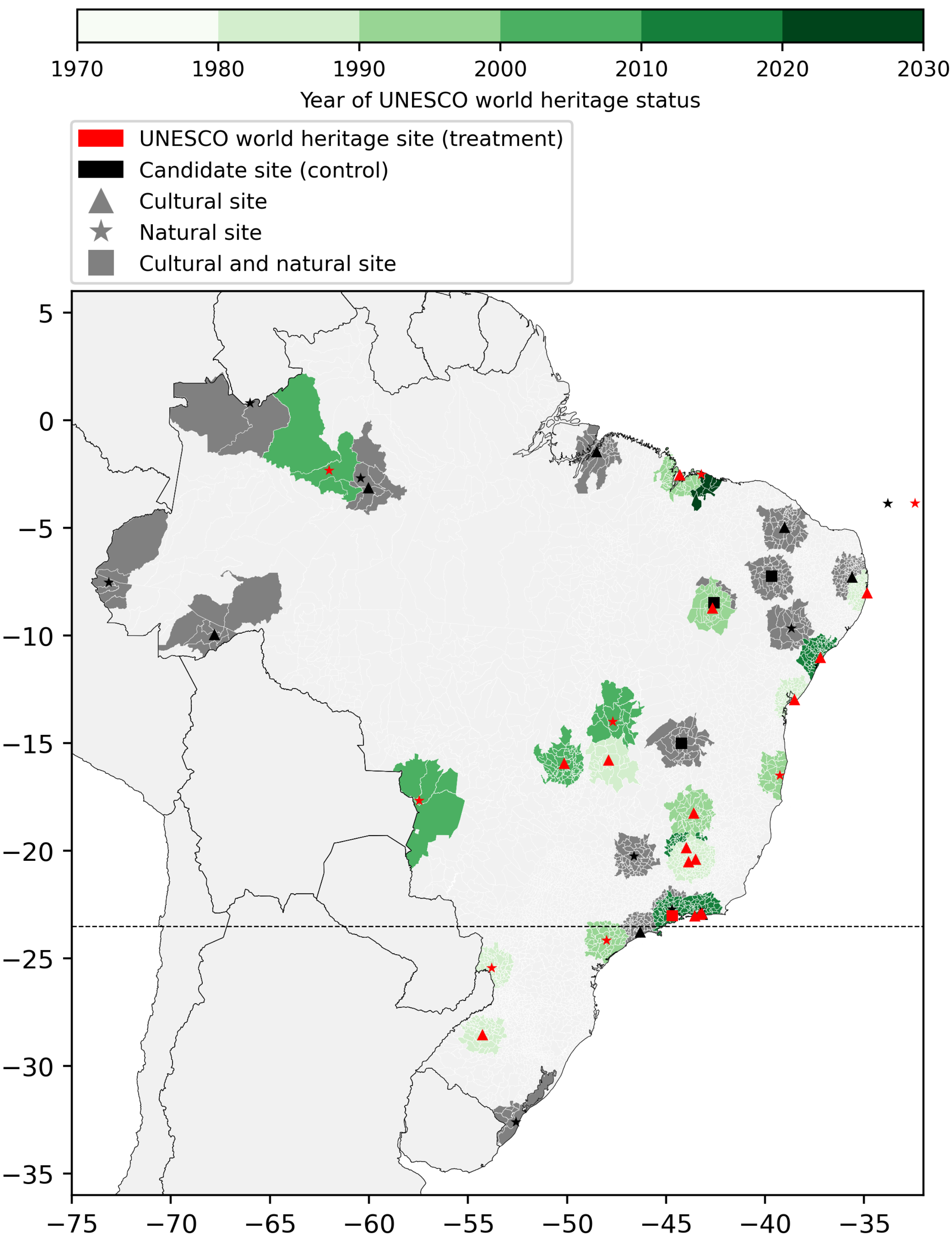

Figure 7. Location of designated and candidate sites of UNESCO world heritage status.

land cover and land use. For annual data on employment we use administrative social security data that covers the universe of registered Brazilian workers between 1985 and 2022. We standardize sectoral employment with the 2010 population of a municipality. For land cover and land use, we use data from the project Mapbiomas. The land area covered by forests and the land area used for agriculture are standardised with a municipality's total land area.

Our results suggest that assignment as a UNESCO world heritage site increases the number of workers in tourism within a few years (Figure 8). The number of workers in tourism-related activities and in manufacturing also seems to increase, albeit with a delay of about 10 years. We also observe a temporary drop of the number of workers in other services. Land covered by forests increases steeply after the assignment of world heritage status, and land used for agriculture decreases (Figure 9). The employment effects seem to be stronger for cultural sites than for natural sites, except for employment in agriculture, whereas the landcover changes seem to be stronger for natural sites than for cultural sites. We find qualitatively similar results if we use buffers of 50 km, 100 km, or 200 km around sites (SI Table S5).

4 Modelling the aggregate effects

We model the effects of tourism on the economy and the environment with a static spatial equilibrium model for the long-run steady state of the economy. The model features both domestic and international tourism. The model builds on the ideas introduced in Eaton and Kortum (2002) and follows in the footsteps of prior adaptations of these ideas, specifically the introduction of an agricultural sector (Sotelo, 2020; Pellegrina, 2022) and traded tourism-related services (Faber and Gaubert, 2019).

The key building blocks of the model are agents' preferences, production technologies and market structure, trade costs, and fundamental regional characteristics (Redding and Rossi-Hansberg, 2017). Key features of the model are the distinction of four main sectors of the economy (agriculture, manufacturing, tourism-related services, and other services), input-output linkages between sectors, and land as an additional factor of production.

4.1 Model overview

The economy is composed of regions indexed by $r \in \{1, ..., N\}$ and sectors agriculture, manufacturing, tourism-related services, and other services. For agriculture we further distinguish 10 product-specific subsectors indexed c (Section 2.4). The 13 sectors are indexed by $k \in \{A_c, M, T, S\}$, respectively. Regions differ in terms of unobserved funda-

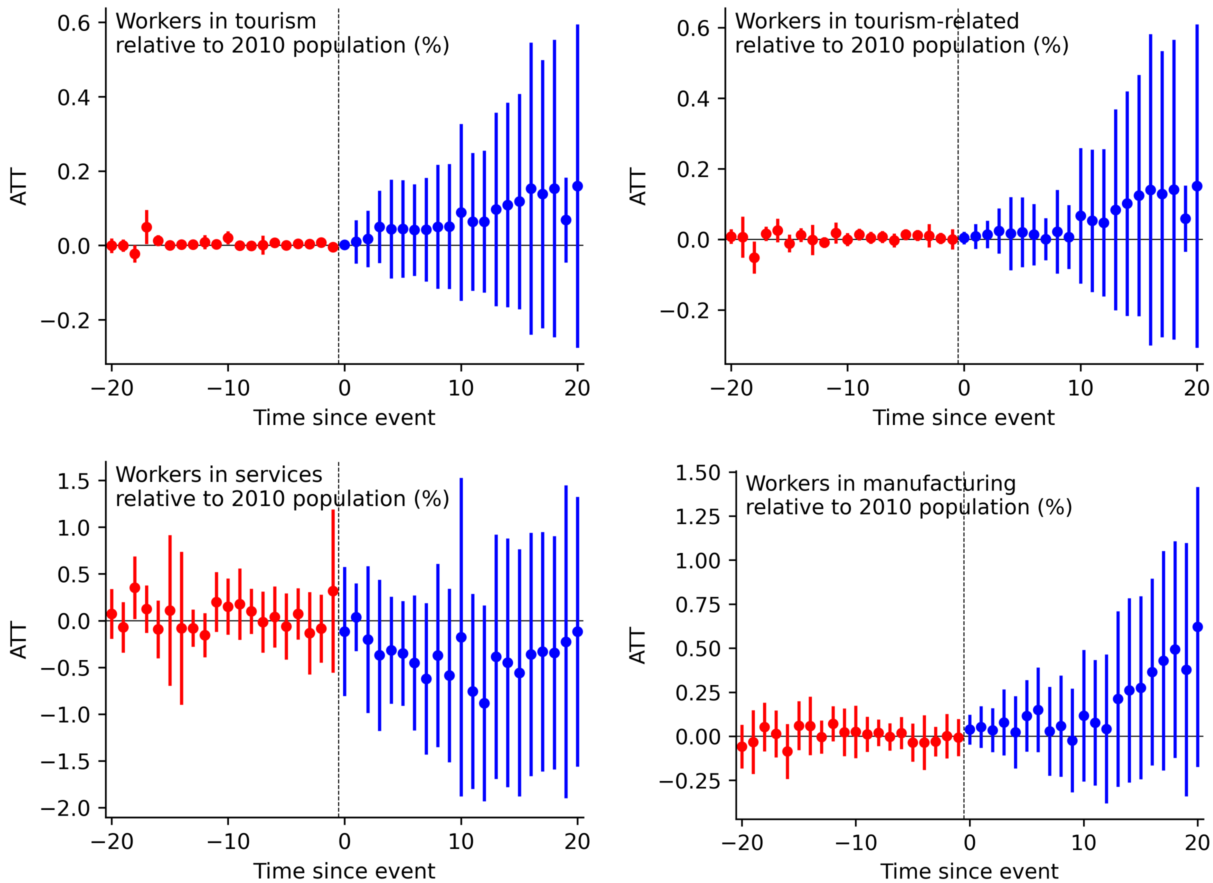

Figure 8. Estimated treatment effects of UNESCO world heritage status on sectoral employment illustrated as event study.

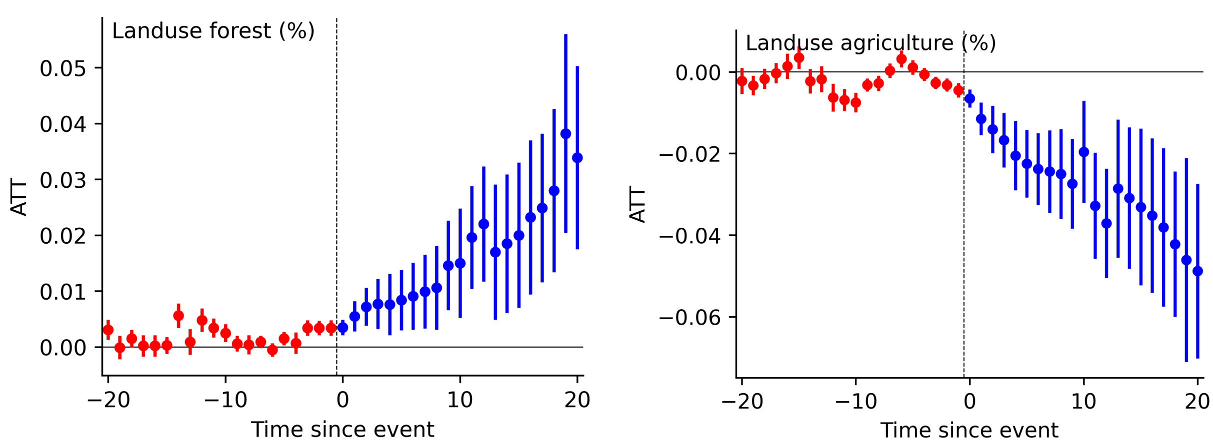

Figure 9. Estimated treatment effects of UNESCO world heritage status on land use illustrated as event study.

mentals: their level of amenities for residents B_r and their sector-specific natural advantages $Z^0_{k,r}$. Regions also differ in their total land surface H_r. Workers can freely move within Brazil resulting in an equilibrium residential population of L_r.

4.2 Consumption

The utility of worker n residing in regions r is given by

$$U_r(n) = \epsilon_r(n) C_r \tag{4}$$

with the local consumption basket C_r and an idiosyncratic preference $\epsilon_r(n)$ is for living in region r. This idiosyncratic term is drawn from a Frechet distribution with shape parameter $\kappa > 0$:

$$F_r(\epsilon) = \exp\left(-B_r \left(\frac{L_r}{H_r}\right)^{-\xi} \epsilon^{-\kappa}\right). \tag{5}$$

The scale parameter $B_r \left(\frac{L_r}{H_r}\right)^{-\xi}$ is the product of two terms. The first term B_r is a preference shifter for amenities. The second term captures utility or disutility from population density determined by the parameter ξ. The scale parameter κ in turn determines the dispersion of the distribution of idiosyncratic preferences, with a higher value implying less diverse preferences. The local consumption basket C_r is composed of agricultural goods $C_{A,r}$, manufactured goods $C_{M,r}$, tourism-related services $C_{T,r}$, and other services $C_{S,r}$ according to the following specification:

$$C_r = \prod_{k \in \{A_c, M, T, S\}} \left(\frac{1}{\alpha_{k,R(r)}} C_{k,r}\right)^{\alpha_{k,R(r)}} \tag{6}$$

where $\alpha_{A,R(r)} + \alpha_{M,R(r)} + \alpha_{T,R(r)} + \alpha_{S,R(r)} = 1$. Workers thus spend a constant share $\alpha_{k,R(r)}$ of their income on the composite product of each sector. We let these shares differ between Brazil $R(r) = \text{BRA}$ for $r \in \{1, ...N-1\}$ and the rest of the world $R(r) = \text{ROW}$ for $r = N$. The price index of the consumption basket in region r is given by:

$$P_r = \prod_{k \in \{A_c, M, T, S\}} \left(\frac{P_{k,r}}{\alpha_{k,R(r)}}\right)^{\alpha_{k,R(r)}} \tag{7}$$

4.3 Production

Local firms in agriculture, manufacturing, and tourism produce intermediate varieties $x \in [0,1]$ according to the following production function:

$$q_{k,r}(x) = z_{k,r}(x) l_{k,r}(x)^{\nu_{k,L}} h_{k,r}(x)^{\nu_{k,H}} \prod_{i \in \{A_c,M,T,S\}} (m_{k,r,i}(x))^{\nu_{k,i}} \tag{8}$$

with inputs to production labour $l_{k,r}(x)$, land $h_{k,r}(x)$, and final composite goods of other sectors indexed by i as $m_{k,r,i}(x)$. The production function is constant returns to scale:

$$\nu_{k,L} + \nu_{k,H} + \sum_{i \in \{A_c,M,T,S\}} \nu_{k,i} = 1. \tag{9}$$

Productivity of intermediate varieties is influenced by a variety-specific local productivity $z_{k,r}(x)$ that is drawn from a Frechet distribution with shape parameter $\theta_k > 0$ and scale parameter $Z_{k,r} \geq 0$ given by $F_{k,r}(z) = \exp\left(-Z_{k,r} z^{-\theta_k}\right)$. The scale parameter $Z_{k,r}$ captures differences in productivity between regions due to sectoral natural advantages $Z^0_{k,r}$ and due to local agglomeration effects:

$$Z_{k,r} = Z^0_{k,r} \left(\frac{L_r}{H_r}\right)^{\beta}. \tag{10}$$

Given the Cobb-Douglas production function with constant returns to scale property, the unit cost function is

$$c_{k,r}(x) = \left(z_{k,r}(x) \nu_{k,L}^{\nu_{k,L}} \nu_{k,H}^{\nu_{k,H}} \prod_{i \in \{A_c,M,T,S\}} \nu_{k,i}^{\nu_{k,i}} \right)^{-1} w_r^{\nu_{k,L}} r_r^{\nu_{k,H}} \prod_{i \in \{A_c,M,T,S\}} P_{i,r}^{\nu_{k,i}} \tag{11}$$

where w_r is the unit cost of labour, r_r is the rent of land that is collected by the government, and $P_{i,r}$ is the price index of the composite good of sector i in region r. We assume perfect competition and firms therefore price at unit cost.

The transport of a good from origin region s to destination r incurs a sector-specific and distance-dependent cost $\tau_{k,r,s}$. We assume that these costs are of the iceberg type such that $\tau_{k,r,s}$ units of a good need to be purchased in s for 1 unit of the good to arrive in r:

$$\tau_{k,r,s} = \delta_k d_{k,r,s}^{D_k} + t_{R(r),R(s)} \tag{12}$$

with the sector specific distances $d_{k,r,s}$ between regions r and s, elasticities of the costs of domestic transportation to distance D_k, the costs of domestic transportation δ_k, and costs of international trade $t_{R(r),R(s)}$ for imports in region r from region s. The costs of international trade incorporate tariffs, the costs of transportation between Brazil and the rest of the world, and other frictions of international trade.

A perfectly competitive local sector aggregates intermediate varieties into a final composite good. Intermediate varieties are sourced across regions and countries and purchased from the lowest cost supplier. The price of intermediate good in region r is thus:

$$p_{k,r}(x) = \min_{s\in\{1,\dots,N\}} \{c_{k,s}(x)\tau_{k,r,s}\}. \tag{13}$$

The final composite good is a CES aggregate of intermediate varieties x:

$$Q_{k,r} = \left[\int q_{k,r}(x)^{\frac{\sigma_k-1}{\sigma_k}}\,dx\right]^{\frac{\sigma_k}{\sigma_k-1}} \tag{14}$$

The price index of the final composite good follows as:

$$P_{k,r} = \left[\int p_{k,r}(x)^{1-\sigma_k}\,dx\right]^{\frac{1}{1-\sigma_k}} \tag{15}$$

Given the Frechet distribution of natural advantages $z_{k,r}(x)$ included in the price of intermediate varieties $p_{k,r}(x)$, the price index can be rewritten as

$$P_{k,r} = \left[\Gamma_K \sum_{s\in\{1,\dots,N\}} Z_{k,s}\left(\tau_{k,r,s}c_{k,s}\right)^{-\theta_k}\right]^{-\frac{1}{\theta_k}} \tag{16}$$

where $\Gamma_K = \Gamma\left(\frac{\theta_k+1-\sigma_k}{\theta_k}\right)^{\frac{1}{1-\sigma_k}}$ is a constant. The share of sector k spending of region r on goods from region s follows as

$$\pi_{k,r,s} = \frac{Z_{k,s}\left(c_{k,s}\tau_{k,r,s}\right)^{-\theta_k}}{\sum_{t\in\{1,\dots,N\}} Z_{k,t}\left(c_{k,t}\tau_{k,r,t}\right)^{-\theta_k}}. \tag{17}$$

Other services are produced with only labour as input and with constant returns to scale:

$$Q_{S,r} = Z_{S,r}L_{S,r}. \tag{18}$$

Assuming perfect competition, the price of local services is

$$P_{S,r} = \frac{w_r}{Z_{S,r}}. \tag{19}$$

4.4 Equilibrium and welfare

Workers choose their location by maximising their utility. Income of a worker in region r is given by $v_r = w_r(1+\iota_H)$ where ι_H is a government transfer to redistribute the revenues from land rents to workers proportional to their wage. Using the properties of the Frechet distribution, the equilibrium share of workers residing in r follows as

$$\frac{L_r}{L_{R(r)}} = \frac{B_r \left(\frac{L_r}{H_r}\right)^{-\xi} \left(\frac{v_r}{P_r}\right)^{\kappa}}{\sum_{s\in R(r)} B_s \left(\frac{L_s}{H_s}\right)^{-\xi} \left(\frac{v_s}{P_s}\right)^{\kappa}} \tag{20}$$

whereby

$$L_r = \sum_{k\in\{A_c,M,T,S\}} L_{k,r} \tag{21}$$

Local sectoral labour market clearing requires:

$$w_r L_{k,r} = \nu_{k,L} \sum_{s\in\{1,\dots,N\}} \left(E_{k,s} + \sum_{o\in\{A_c,M,T,S\}} \nu_{o,k} Q_{o,s} \right) \pi_{k,s,r} \tag{22}$$

with $E_{k,s}$ the expenditure for consumption of final goods of sector k. Here, $E_{k,s} = \alpha_{R(s),k} v_s L_s$ and $\nu_{o,L} Q_{o,s} = w_s L_{o,s}$.

Furthermore, total land rents must balance total government transfers:

$$\sum_{r\in R(r)} \sum_{k\in\{A_c,M,T,S\}} r_r H_{k,r} = \sum_{r\in R(r)} \iota_H w_r L_r \tag{23}$$

As an aggregate measure of agents' individual utility, we calculate expected welfare per capita as:

$$W_{\text{BRA}} = \Gamma\left(1-\frac{1}{\kappa}\right) \left(\sum_{r\in\text{BRA}} B_r \left(\frac{L_r}{H_r}\right)^{-\xi} \left(\frac{v_r}{P_r}\right)^{\kappa} \right)^{\frac{1}{\kappa}} \tag{24}$$

5 Estimation and calibration

5.1 Overview over model quantification

We recover the unobserved local amenities and sectoral natural advantages $\{B_r, Z^0_{k,r}\}$ by calibrating our model to observed wages, sectoral employment, and sectoral land use $\{w_r, L_{k,r}, H_{k,r}\}$. For this calibration we use estimated values of the parameters $\{\nu_{k,l}, \theta_k, D_k, \delta_k, \xi, \kappa\}$

and estimate the additional parameters $\{\alpha_{k,R(r)}, t_{k,R(r),R(s)}, \iota_H\}$. We also estimate land rents to be consistent with observed land use. The calibration proceeds as described in the following.

We start by estimating the consumption shares $\alpha_{k,R(r)}$ from observed wages and sectoral employment. We do so by first using the local labour market clearing condition of the services sector to estimate $\alpha_{S,R(r)}$ (Equation 22). We then use observed sectoral import and export shares and the labour market clearing conditions to calibrate $\alpha_{A_c,R(r)}$ and $\alpha_{M,R(r)}$:

$$\alpha_{k\neq S,R(r)} = \frac{\sum_{r\in R}(1-(X_k - I_k))L_{k,r}w_r(\nu_{k,L})^{-1}) - \sum_{s\in R}\sum_l \nu_{l,k}L_{l,s}w_s(\nu_{l,L})^{-1})}{\sum_{r\in R} w_r(1+\tau)L_r} \tag{25}$$

where X_k and I_k are observed sectoral export share and import share of total domestic production, respectively. We finally calculate the consumption share of tourism as $\alpha_{T,R(r)} = 1 - \sum_c \alpha_{A_c,R(r)} - \alpha_{M,R(r)} - \alpha_{S,R(r)}$.

We estimate land rents r_r to be consistent with observed wages, employment in agriculture, and total land used for agriculture in a municipality:

$$r_r = \frac{\sum_c L_{r,A_c}w_r(\nu_{A_c,L})^{-1}\nu_{A_c,H}}{\sum_c H_{A_c,r}} \tag{26}$$

We then use the estimated rents together with land used for agriculture, wages, and total employment to estimate government transfers ι_H (Equation 23).

The sector-specific international transport costs $t_{k,R(r),R(s)}$ and sectoral productivities $Z_{k,r}$ are calibrated simultaneously with a nested algorithm. In the outer loop of this algorithm, we calibrate sectoral productivities using the sectoral labour market equilibrium conditions. In the inner loop, we calibrate tariffs by calibrating the aggregate trade shares $\pi_{k,s,r}$ to match observed sectoral import and export shares of Brazil and the Rest of the World.

In the last step, we use the recovered sectoral productivities together with the observed population and wages to calibrate the local amenities B_r (Equation 20).

5.2 Estimation of key parameters

We use the Brazilian input-output tables to estimate the sectoral factor shares $\nu_{k,i}$ with the following three exceptions. We assume that local services are produced with only labour as input and thus set $\nu_{S,i} = 0 \forall i \neq L$. Furthermore, we assume that tourism services are not used as an input of production in other sectors by setting $\nu_{k,T} = 0 \forall k$. Lastly, we also assume that only agriculture uses land as a factor of production and set $\nu_{A,H}$ to the product group specific values estimated in Pellegrina (2022). The share of labour is then calculated for each sector k as the residual $\nu_{k,L} = 1 - \sum_{i \neq L} \nu_{k,i}$.

We use the estimated parameters in the empirical analysis in Section 3.1 to define the tourism sector in the model. The empirical results suggest that each job in tourism is associated with about 8.83 jobs in tourism-related industries. If we ignore input-output leakages and productivity spillovers, which we assume to be relatively small for tourism and tourism-related industries, we calculate that about 59 percent of jobs in tourism-associated industries in Brazil can be attributed to the consumption of tourists. The remainder can be considered as non-traded local services. We thus assign 59 percent of workers in tourism-related industries to the tourism sector and the remainder to the non-traded service sector.

The parameters θ_k, D_k, ξ, and κ are obtained from the literature. We set the sectoral trade elasticities to $\theta_A = 3.9$ and $\theta_M = 6.6$ (Pellegrina, 2022), as well as $\theta_T = 2.5$ (Faber and Gaubert, 2019). The distance decay elasticity of trade in goods is set to $D_A = D_M = 0.076$ (Pellegrina, 2022). Following Faber and Gaubert (2019) we choose the elasticity for trade in tourism services slightly lower at $D_T = 0.073$. Furthermore, we set $\delta_A = 1.63$. The remaining parameters are also taken from the literature. The dispersion parameter of idiosyncratic locational preferences is set to $\xi = 0.32$ (Desmet et al., 2018) and the spatial labour supply elasticity to $\kappa = 2$, which corresponds to the lower bound of values explored in Faber and Gaubert (2019). The agglomeration parameter is set to $\beta = 0.06$ (Desmet et al., 2018). Sectoral imports and exports of the trade between Brazil and the rest of the world relative to total production in Brazil, which are used as targets in the calibration, are also obtained from the Brazilian input-output tables.

5.3 Counterfactual simulations

In our counterfactual analysis we compare the equilibrium of our baseline scenario with the equilibria of an alternative scenario. The alternative scenario is quantified with the calibrated model. All calibrations use the reference equilibrium as a starting point. The calibration of the alternative equilibrium then proceeds as follows. We first update the model parameters $\alpha_{i,R(r)}$ and $t_{k,R(r),R(s)}$ according to the scenario. We then use the fully calibrated model including natural advantages $Z^0_{k,r}$ and amenities B_r to recover sectoral employment $L_{k,r}$ and wages w_r.

This calibration uses again a nested algorithm. In the outer loop, we update sectoral employment using the sectoral labour market equilibrium conditions (Equation 22). In the inner loop, we update total employment and calibrate wages using the spatial equilibrium conditions that equalises expected welfare across regions (Equation 20). At every iteration we update agricultural land use $H_{k,r}$ using the estimated production function and the calibrated rents and agricultural employment. We assume that agricultural land replaces natural land.

In the counterfactual scenario we switch off international tourism by setting the costs of international trade in tourism $t_{T,R(r),R(s)}$ to a limiting high value and additionally assume that consumption of tourism services is replaced by consumption of goods from the other sectors proportionally to their existing consumption shares. We keep the total population of Brazil fixed and let the model find the new equilibrium population of each region and its sectoral composition. For the evaluation of the baseline and the counterfactual scenario we calculate the expected utility of workers in Brazil as a measure of welfare. Furthermore, we calculate how much natural land is lost to agriculture in Brazil as a whole and in the legal Amazon region.

6 Results of model simulations

6.1 Welfare and land use

We next quantify the effects of domestic and international tourism on welfare per capita (Equation 24). Because we keep population constant, the effects are equivalent to changes in total welfare. Changes in welfare arise from changes in wages, but also disutility from population density and changes to consumed local amenities from the spatial reallocation of the population. Our comparison of static equilibria does however not account for any costs of moving locations between the baseline and the counterfactual scenario. Overall the changes to welfare are small: without any tourism, welfare is about 0.06 percent lower than in the baseline scenario. This is not unexpected as our comparative static exercise allows workers to respond to lower local demand for traded tourism services by switching sector and moving location.

In the counterfactual scenario, about 8.4 percent of the workers that leave tourism enter the agricultural sector (Table 2). This increase in the agricultural workforce is associated with an increase in land used for agriculture by around 4.9 percent. Agricultural land increases disproportionately outside the Amazon region, where agricultural land increase by around 2.21 percent. Notably, the signs of the effects point to a trade-off between economic and environmental objectives: tourism is associated with lower welfare but a larger share of natural land, especially in the Amazon region.

Table 2. Results of model simulations of the effect of tourism on welfare and landuse, counterfactual scenario without tourism versus baseline scenario.

		Change rel. to baseline	
	Baseline	Counterfactual	Unit
Variable	1	2	3
Welfare		+0.06	pct
Natural land		-4.89	pct
Natural land (Amazon)		-2.12	pct
Employment in tourism		-100.00	pct
Employment in services		+12.69	pct
Employment in manufacturing		-8.88	pct
Employment in agriculture		+11.95	pct
Employment share of tourism	9.51	-9.51	ppt
Employment share of services	74.79	+9.49	ppt
Employment share of manufacturing	8.97	-0.80	ppt
Employment share of agriculture	6.73	+0.80	ppt

Notes: All variables are standardised. Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.2 Regional and sectoral heterogeneity

In the counterfactual scenario, workers not only leave the tourism sector but also the manufacturing sector. We observe this decrease in the manufacturing workforce depite a shift in demand from tourism to manufacturing relative to the baseline scenario. However, as a consequence of the spatial linkages and agglomeration benefits manufacturing production relocates to locations with higher productivity, increasing the average productivity per worker in manufacturing by around 42 percent relative to the baseline scenario. Agglomeration benefits contribute about 1 percentage point, while the rest of the effect comes from workers moving to locations with higher natural advantages.

The changes in population across regions in Brazil are highly heterogeneous. Population decreases primarily in regions with high tourism activity in the baseline scenario (Figure 10; see also Figure 2). Many of these regions are located along the coast, but they can also be found in other parts of the country. Overall, population moves into the Amazon region, whose share of the total population increases from 11.6 percent in the baseline scenario to 12.4 percent in the scenario without tourism.

6.3 Regional fundamentals and market access

To better understand the drivers of changes in land use change across regions, we distinguish between natural advantages and market access as fundamental regional characteristics. Natural advantages are recovered with our quantitative spatial model, whereas

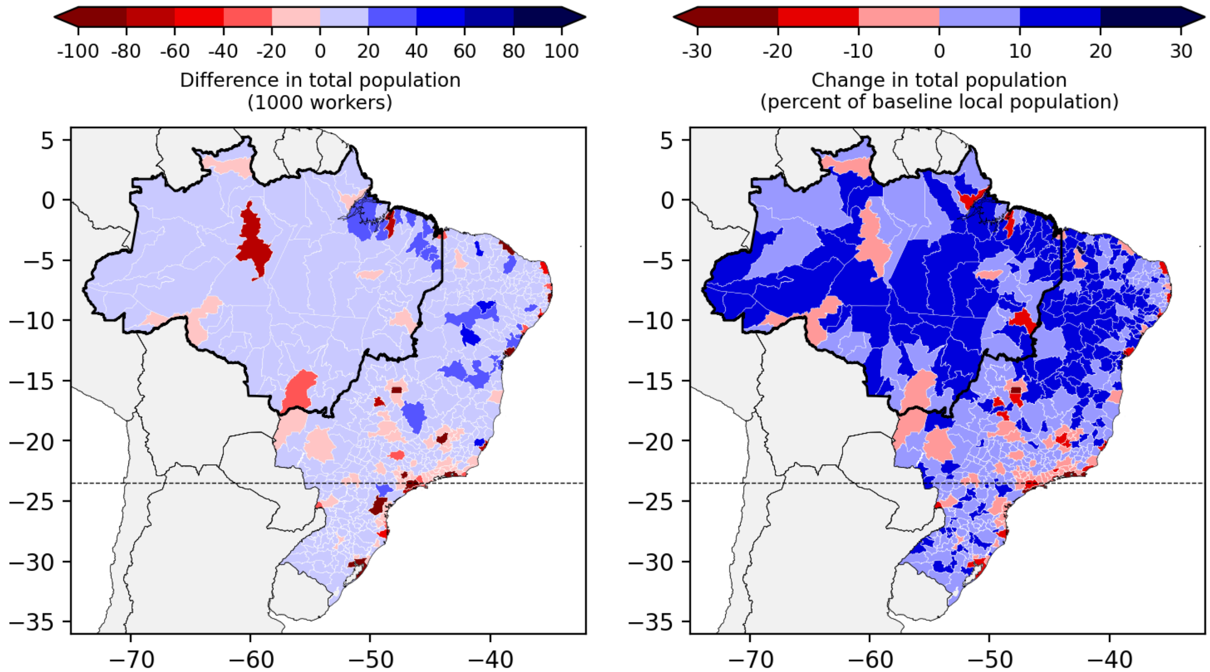

Figure 10. Changes in total population, counterfactual without tourism minus baseline. The thick black line denotes the boundary of the legal Amazon region.

market access is calculated from the existing transport infrastructure. We use the inverse cost-adjusted distance to the closests international port as our proxy for international market access and the inverse average cost-adjusted distance to other regions as proxy for domestic market access. The cost-adjusted distances are calculated in the same way as for the calibration of transport costs in the model and take into account transport on roads, railways, and waterways, with mode-specific costs per kilometer and additional costs of mode-switching (Section 2.6). We focus the analysis on the agricultural sector. For the analysis we estimate a linear regression model for which we pool the data for the 10 agricultural subsectors (products).

We find that market access is most important in explaining the increase in agricultural employment in the counterfactual scenario relative to the baseline and its variation across regions (Table 3). Domestic market access results to be most important, with the standardised coefficient being about twice as large as for international market access. Natural advantages are overall less important in explaining where labour from other sectors is absorbed into agriculture.

Table 3. Changes in agricultural employment between scenarios explained by natural advantages and market access.

Dependent variable:	Δ Workers in agric.			
Column:	1	2	3	4
Natural advantages in agriculture	0.010			0.010
	(0.008)			(0.008)
Market access (domestic)		0.139***		0.121***
		(0.014)		(0.014)
Market access (international)			0.095***	0.058***
			(0.012)	(0.012)
R2	0.00	0.02	0.01	0.02
N	5100	5100	5100	5100

Notes: n/a.

6.4 Locational preferences

An important characteristic of the tourism sector is that it can offer employment opportunities outside agriculture in locations with relatively low local demand due to its trade in services with other regions and countries. This characteristic is especially important if there are spatial frictions in the model that imply that workers do not simply move to the location with the highest real wage, but also take local amenities and idiosyncratic locational preferences into account.

In this section, we examine the important of these frictions. To do so, we use our fully calibrated model and simulate both the baseline scenario and the counterfactual scenario without tourism for alternative values of the parameter κ. This parameter determines the dispersion of idiosyncratic locational preferences (Equation 5). The larger its value, the larger is the variation in preferences and thus the spatial dispersion of the population.

We find that the negative welfare effects of tourism tend to decrease in magnitude slightly as κ increases. This is intuitive as a larger dispersion lowers agglomeration benefits and lowers the concentration of the population in places with high productivity and amenities in the baseline scenario without traded services, bringing welfare in the two scenarios closer together. Differences in total natural land between the scenarios are little affected by spatial frictions in the model. However, the positive effect of tourism on natural land in the Amazon, relative to the baseline scenario, increases relatively steeply with higher values of κ. The larger the spatial dispersion forces in the model, the more trade in tourism lowers employment in agriculture in the Amazon region.

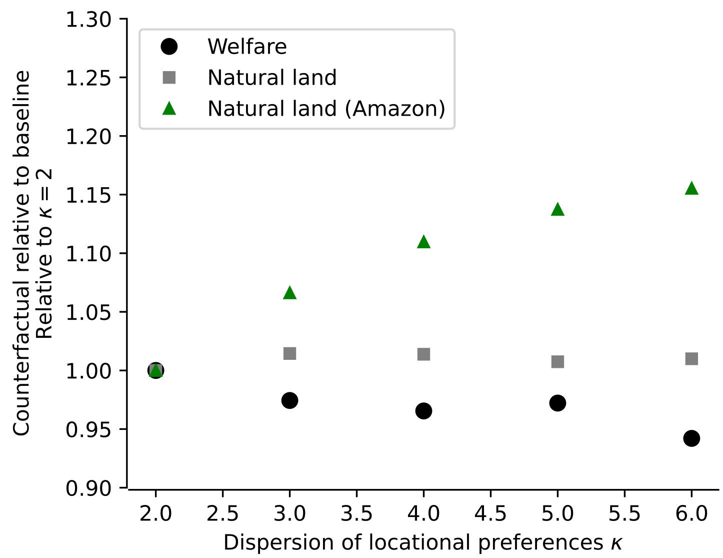

Figure 11. The effect of the dispersion of locational preferences on welfare and natural land. All results show the comparison of the counterfactual scenario and the baseline scenario, whereby the baseline and the counterfactual scenario are simulated with the same value of the parameter κ. Furthermore, all results shown are relative to the results for $\kappa = 2$, which are shown in Table 2 Column 2.

7 Conclusion

In this paper, we study how tourism-related traded services affect economic development and land use change in Brazil. Brazil provides an ideal setting for this analysis, given the importance of domestic and international tourism in terms of its GDP, its status as an emerging economy with large tropical forests, and its diversity in touristic activities. Our paper combines an empirical analysis with an economic model that allows us to simulate counterfactual scenarios of spatial and inter-sectoral equilibria with and without tourism.

In the empirical analysis we estimate the causal effect of tourism on economic development and land use changes with two alternative identification strategies, an instrumental variable and a difference-in-differences approach. We use these approaches to quantify the economic importance of tourism, including the share of tourism-related activities that can be attributed to tourism. In the second part, we calibrate and estimate our quantitative spatial model. The results of counterfactual simulations with the fully calibrated model suggest a trade-off between average income and environmental sustainability. In our counterfactual simulations, tourism lowers welfare but increases natural land use, especially in the legal Amazon region. Furthermore, our results illustrate how the benefits of tourism can be related to spatial dispersion forces in the model and the tradability of tourism services.

Because of limitations to what one single paper can achieve, some questions must remain for future research. A major limitation of our analysis is that we do not account for natural land as a form of capital that can be exploited for touristic purposes. Ecotourism is an important motivation especially among international travelers coming to Brazil, and future work may want to include this mechanism in the model. Some effects of this mechanism may be captured by our empirical analysis that leverages UNESCO world heritage sites to study land use changes following an official designation. However, the similarity of the results for sites recognised for the cultural value and those recognised for their natural value suggests that these mechanisms may not be of first order in that analysis. Another limitation is that we do not account for public infrastructure beyond the effect of the existing transport infrastructure on market access. Tourism is regularly supported by public investments, with benefits potentially spilling over to other sectors. We also do not account for dynamic effects and our comparative static simulations do not account for any individual-level costs of switching sector or moving location. This limitation is associated with the very nature of our analysis, but limits the extent to which the results are indicate of the consequences of gradual future transitions away from the current equilibrium. Similarly, we do not account for any consequences of future climate change on agriculture and other sectors in Brazil, which may affect local structural change too (Brunel and Liu, 2020; Oliveira and Pereda, 2020; Christoph Albert et al., 2023).

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Supplementary Information (SI)

A Empirical results

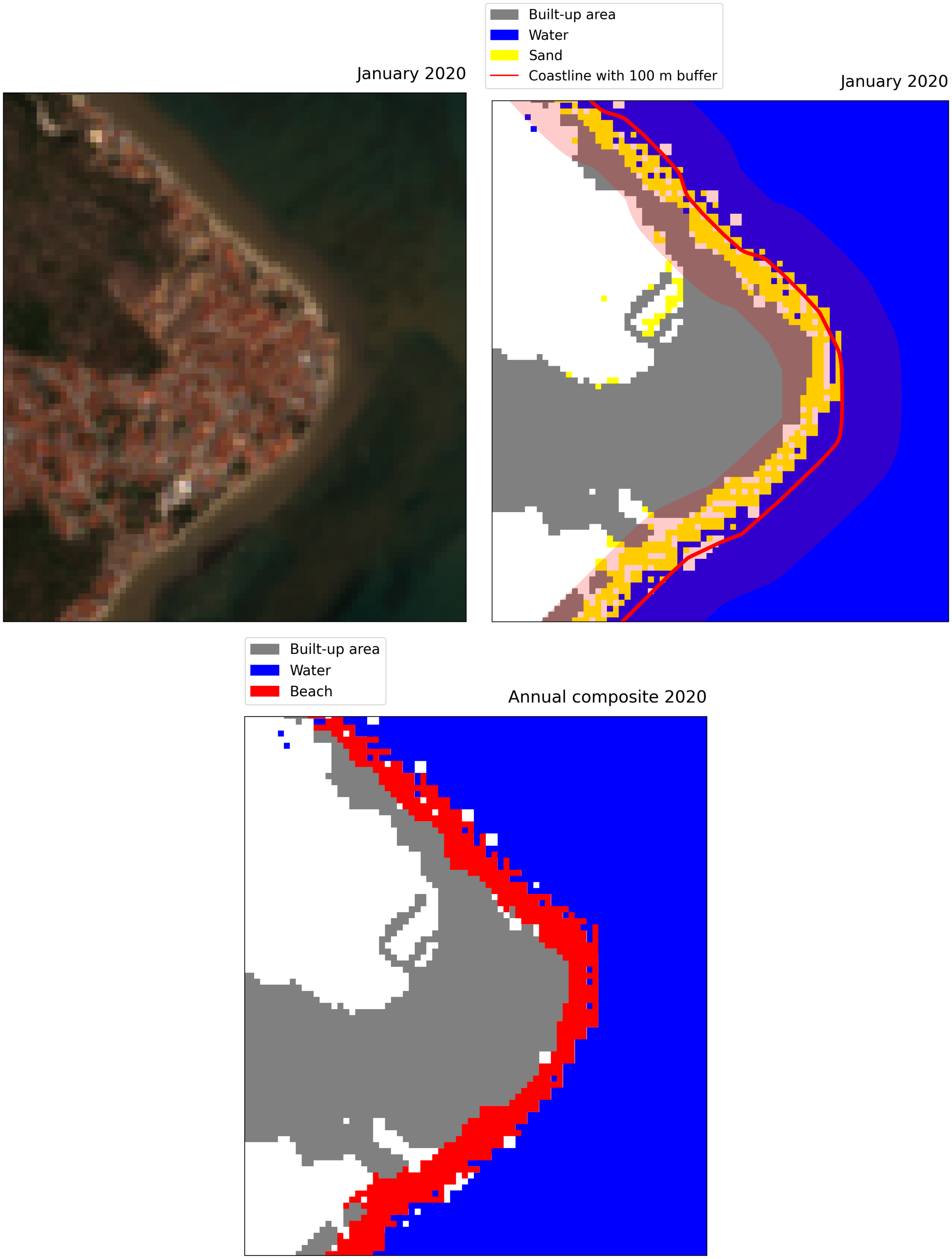

Figure S1. Illustrations of the construction of the dataset on the average size of beaches along the coast of Brazil from satellite imagery.

Table S1. Robustness exercise to test for the influence of covariates in the model. The table shows results without any covariates, which closely resemble the main results with covariates shown in Table 1.

Dependent variable:	Sectoral employment				Other outcomes		
	Tourism	Tourism-related	Services	Manufacturing	GDP pc	Population	Wages
Column:	1	2	3	4	5	6	7
Beds in tourism accomodations	0.392***	4.273***	33.255***	4.988***	0.024***	132.429***	-0.003***
	(0.030)	(0.599)	(4.425)	(0.944)	(0.006)	(15.091)	(0.001)
Control variables	N	N	N	N	N	N	N
First stage F-statistic	170	51	56	28	17	77	14
N	424	424	424	424	424	424	424

Notes: Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table S2. Robustness exercise to test for possible violations of the SUTVA assumption. The results suggest that the estimated effects of tourism on other outcomes are robust to accounting for spatial spillovers.

Dependent variable:	Sectoral employment				Other outcomes		
	Tourism	Tourism-related	Services	Manufacturing	GDP pc	Population	Wages
Column:	1	2	3	4	5	6	7
Beds in tourism accomodations	0.339***	3.532**	24.629**	3.595*	0.021*	97.376***	-0.001**
	(0.057)	(1.413)	(10.030)	(2.084)	(0.011)	(35.400)	(0.001)
Beds in tourism accomodations (neighbour)	55.871	-765.358	-4666.566	-596.952	8.969	-14236.135	-0.025
	(51.492)	(1860.361)	(12881.156)	(1970.258)	(8.886)	(45221.673)	(0.603)
Control variables	Y	Y	Y	Y	Y	Y	Y
First stage F-statistic	611	96	123	362	111	179	399
N	424	424	424	424	424	424	424

Notes: Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table S3. Estimation results to study the validity of the instrument. The results suggest no significant effect of the average width of beaches on population density for historical periods that predate modern forms of tourism.

Population data:	1872	1920
Column:	1	2
Average width of beaches	0.020	0.002
	(0.048)	(0.036)
Control variables	Y	Y
R2	0.51	0.50
N	130	178

Notes: For better comparison across columns, all variables have been transformed to z-scores. Note that the data is here aggregated to the historical census districts of the given census year. Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table S4. Estimation results to study the validity of the instrument. The results suggest no significant effect of the average width of beaches on the amenities that we recovered from the calibrated quantitative spatial model.

Dependent variable:	Amenities	
Column:	1	2
Average width of beaches	0.055	0.099
	(0.097)	(0.132)
Control variables	N	Y
R2	0.00	0.48
N	81	81

Notes: For better comparison across columns, all variables have been transformed to z-scores. Note that the variables are here aggregated to intermediate regions, which is the level of aggregation used for the quantitative spatial model. Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table S5. Aggregated treatment effects from the difference-in-differences estimation.

Significance:	Either			Only natural			Only cultural		
Buffer:	50 km	100 km	200 km	50 km	100 km	200 km	50 km	100 km	200 km
Employment in agriculture	**0.078	***0.261	***0.168	**0.078	***0.320	***0.368	0.065	***0.181	***0.103
	(0.080)	(0.058)	(0.061)	(0.067)	(0.060)	(0.054)	(0.146)	(0.117)	(0.079)
Employment in manufacturing	***0.245	***0.156	***0.358	***0.277	***0.197	-0.039	***0.256	***0.260	***0.611
	(0.147)	(0.102)	(0.080)	(0.168)	(0.113)	(0.081)	(0.213)	(0.130)	(0.121)
Employment in other services	**-0.651	***-0.368	***0.520	0.017	***-0.337	-0.057	**-1.496	0.008	***0.959
	(0.593)	(0.266)	(0.162)	(0.239)	(0.224)	(0.149)	(1.449)	(0.631)	(0.245)
Employment in tourism	**0.188	**0.070	***0.048	***0.021	0.001	0.004	**0.451	**0.194	***0.090
	(0.181)	(0.074)	(0.030)	(0.013)	(0.018)	(0.006)	(0.456)	(0.190)	(0.052)
Employment in tourism-related industries	**0.139	*0.052	***0.081	0.007	***-0.020	-0.000	**0.353	***0.191	***0.139
	(0.151)	(0.065)	(0.025)	(0.019)	(0.014)	(0.011)	(0.376)	(0.160)	(0.045)
Land cover (agriculture)	***-0.038	***-0.026	***-0.015	***-0.045	***-0.034	***-0.007	-0.001	***-0.006	***-0.012
	(0.006)	(0.004)	(0.002)	(0.005)	(0.003)	(0.002)	(0.005)	(0.005)	(0.003)
Land cover (forest)	***0.015	***0.014	***0.004	***0.015	***0.015	0.001	**0.005	***0.009	*0.001
	(0.004)	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.005)	(0.004)	(0.002)

Notes: Robust standard errors in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.