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Transport Infrastructure and the Spatial Evolution of the Productive Structure in Brazil

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Transport Infrastructure and the Spatial Evolution of the Productive Structure in Brazil

Stéphane Straub, Toulouse School of Economics

Abstract

This paper analyzes the impact of large scale investments on transport infrastructure on the spatial evolution of the productive structure in Brazil, in particular the industry/service mix. It does so using municipal-level data from the census between 1970 and 2010, a period over which the road network was dramatically expanded. It builds on previous research showing that over this period road access improvements generated a dual geographical pattern, with a growing concentration of population and economic activity in large radiuses of up to several hundred kilometers around the main urban areas in the more developed Southern part of Brazil, and an opposite movement of population and economic activity away from the main urban centers, towards secondary urban centers, around Northern State capitals. Using more disaggregated data on employment in productive sectors, it shows that improvements in long distance road access have changed the structure of the productive sector at different locations, and that the resulting patterns is consistent with previous findings, in the sense that agglomeration effects are mostly driven by increases in secondary and tertiary activities, although the exact nature of the most dynamic sectors depends on whether they are located or not close to some large urban center.

I.   Introduction

This paper analyzes the impact of large scale investments on transport infrastructure on the spatial evolution of the productive structure, in particular the agriculture / industry / service mix. It does so using municipal-level data from the Brazilian census from 1970 to 2010, a period over which the road network was dramatically expanded.

The point of departure is the paper by Bird and Straub (2014), which uses the location of the Nation federal capital city Brasília, created in 1960, as a natural experiment to solve the typical endogeneity problem arising in infrastructure empirical work because of the non-random placement of roads. This paper provided estimates of the impact of municipality-level improvements in access to the main urban centers over the period 1970-2000 on several outcomes, including population, GDP, and GDP per capita.

The main results showed consistently across specifications that road access improvements between 1970 and 2000 generated a dual geographical pattern. In the more developed Southern part of Brazil, they spurred a growing concentration of population and economic activity in large radiuses of up to several hundred kilometers around the main urban areas. The opposite process occurred around the Northern State capitals, with reductions in travel costs implying a movement of population and economic activity away from the main urban centers, towards secondary urban centers. Finally, these two effects roughly balanced, and the net effect on GDP per capita was mostly not significant.

Based on a simple theoretical framework, which alternatively predicts concentration or dispersion effect around main urban centers as a result of improvement in transportation infrastructure, the paper also shows that this dual pattern can directly related to the type of agglomeration economies observed in these urban centers, as described in the urban literature (e.g., Rosenthal and Strange, 2004, and Duranton and Puga, 2013): as predicted by the model, the improvement in road infrastructure spurs agglomeration towards urban areas that are large enough, have a high stock of human capital, a high industry to service ratio, and good amenities, and dispersion otherwise.

These results call for a better understanding of the channels involved in these spatial changes. In particular, they beg the question of how the improvements in road access over large territories have changed the structure of the productive sector at different locations. In particular, we want to illustrate how the channels for agglomeration economies found in earlier work map into the evolution of the productive structure at different locations.

At a general level, this paper relates to the literature on structural transformation, which studies the patterns of reallocation of economic activity between agriculture, manufacturing, and services, and the implications for economic growth.

While most papers to date have focused on the impact of changes in agricultural productivity, through both demand and supply channels, on industrial development, some contributions have started to shed light on how the development of transport corridors may affect patterns of structural development.

First, a number of recent studies have shown that more or better roads modify the spatial entry-exit patterns of firms, for example spurring relocation towards the main corridors. This is for example the case with the upgrade of the Golden Quadrilateral in India (Ghani, Goswami and Kerr, 2013), which spurred a 49% growth in manufacturing output in districts situated at less than 10km from the main roads, while districts farther away experienced no such improvement. In contrast, using Chinese data over the period 1986-2003, Banerjee, Duflo and Qian (2012) find a small effect on overall GDP and also conclude that the elasticities between distance from the roads (as approximated by straight lines) and both the number of firms and their profits are relatively small.

Looking at the impact of the Indian national rural road construction program that has provided paved connections to the national network to over 100,000 villages since 2000, Asher and Novosad (2016) show a significant change in the pattern of occupations. In particular, they estimate a causal reduction of 10% of the share of households and workers in agriculture, with a corresponding 10% increase in wage labor market participation. This effect concentrates on males and households with small landholdings, and is stronger for villages closer to large cities.

Agrawal (2015) estimates that this same road improvement program had a significant impact on physical and human capital accumulation, substantially increasing the adoption of agricultural technologies, and inducing teenagers to drop out of school to join the labor force. Looking in more details at occupational choices, she shows increases in employment for girls in animal-rearing, textile manufacturing and tailoring, and decrease in forestry, while for boys, there were increases in construction, animal-rearing and tailoring. In all cases, these increases seem to be associated with activities which benefited from lower transportation cost to output markets.

Using data from Indonesia, Rothenberg (2013) shows that road improvements induced a moderate dispersion of manufacturing activity, with a reduction of 20% of the spatial concentration of manufacturing employment. This effect concentrates in industries specialized in durable goods but there was no change for those producing perishable goods. Finally, this dispersion was mostly taking the form of suburbanization around existing agglomerations, rather than development of remote areas.

Also related is the spatial growth literature (Desmet and Rossi-Hansberg, 2009, 2014, forthcoming), which has shown that the evolution of the productive structure is sensitive to the interaction between technological progress and physical infrastructure. In the case of a large developed economy, Desmet and Rossi-Hansberg (2009) show that employment growth across counties exhibited very different patterns over the 1970-2000 period in manufacturing and services. While there was spatial dispersion for manufacturing (i.e.; employment growth was negatively related to initial manufacturing employment across the entire distribution of counties), there was spatial concentration for services, as employment growth in these sectors was positively related to initial service employment, at least for intermediate sized counties. The authors relate this pattern to a theory in which local sectoral growth is driven by technological diffusion across space and depends on the "age" of the sector. They consider that manufacturing is mature, as the last general purpose technology (GPT) that affected it was electricity at the beginning of the 20th century, while for services the relevant GPT was the information and communication technology revolution, which dates back approximately to the 1970s.

This paper contributes to this literature by providing two broad sets of evidence. First, it details results from Bird and Straub (2014) on the spatial pattern of concentration induced by the development of the highway system since 1970, relating them to the spatial growth literature.

Second, it presents tests of the impact of the large scale improvement of the road network on the spatial evolution of the production mix in the context of a large emerging country such as Brazil, using several proxies for activities and the identification strategy of Bird and Straub (2014) to address the endogenous placement of roads. The first proxy used is municipal GDP data for agriculture, industry, and services. The second one involves a finer disaggregation of occupations into 30 subsectors.

The paper is structured as follows. Section 2 presents the data used in the paper. Section 3 discusses the identification strategy. Section 4 presents plots of the spatial growth impact of roads over the period of interest and discusses. Section 5 introduces the main results on structural transformation and the evolution of the mix of activities, section 6 discusses the main lessons from the empirical results, and section 7 concludes.

II.   Data

The core of the dataset is taken from Bird and Straub (2014), who used a panel dataset of Brazilian municipalities covering the period 1970-2000 developed at the Institute for Applied Economic Research (IPEA) (Reis, Tafner et al., 2005, Reis, Pimentel et al., 2011) including, inter alia, geographic characteristics at a high-enough resolution level, as well as detailed socio-economic determinants derived from four successive waves of census (1970-1980-1990-2000): data on health, education and human capital, infrastructure services (water and sanitation, telecommunications, electricity), income (local GDP), poverty, population, industrial composition (% of labor force employed and GDP per sector of activity), deforestation, etc. This database was developed as part of Nemesis (Research Network of Spatial Economic Analysis of Brazil), undertaken at IPEA, Rio de Janeiro, from 1997 to 2012 with the joint support of IPEA/CNPQq and FAPERJ.

Additionally, this database is merged with the cost of access data developed at Nemesis by Castro (2002) for all the municipalities in Brazil, spanning 3 different dates: 1968, 1980 and 1995. This data provides for each municipality the real cost of access, computed as a combination of available roads and their quality, to both the State capital and to Sao Paulo (the country's economic center). Over that period, the cost of travel to Sao Paulo and the State capital fell by 44 and 33% respectively.

The database is geocoded to consider more specifically issues related to geographic dimensions, such as distance to roads, main cities, ports, etc, and to represent results in a spatial framework. Whenever the results refer to the South and North of Brazil, they correspond to the following partition: South includes the South and Southeast region, while the North corresponds to the North, Northeast and Center-west regions.

In this paper, we complement this database by considering the following disaggregated information. First, we extend the data on GDP for the primary, secondary, and tertiary sectors,

by including values from the 2010 census. Second, we track employment data by productive subsectors at the ISIC 2 level, such as fishing, commerce, education, health, food, textile or transport. This information is available between 1980 and 2000 for 30 manufacturing and service subsectors (see Appendix 1 for a list). Next section presents the empirical design used in the analysis.

III. Identification Strategy

The empirical strategy proceeds as follows. First, we superimpose onto a map of Brazil eight straight lines which connect the country's new capital to State capitals and ports chosen according to their population size and economic importance in 1956, the year of the decision to build Brasília. These lines coincide with the subsequent shape of the radial highway system.

Then, we compute for each municipality a distance index to the closest hypothetical lines. We do this by creating successive buffer zones at 10km intervals around the lines (0-10km, 10-20km, etc.), and measuring the percentage of each municipality within each zone, and take as distance index the log of weighted sum of the shares of an municipality's area lying in each successive range.

After showing in a reduced form framework that this distance index is a significant predictor of our local development outcomes, we implement a two stage strategy, which uses distance to the lines as an instrumental variable to address the potential correlation between the independent variable of interest, transport cost as proxied by the cost of access R_{is}, and the error term related to the non-random placement of roads ($Cov(R,\varepsilon)\neq 0$). Specifically, the second stage is given by:

$$Y_{is} = \beta_0 + \beta_1 R_{is} + \beta_2 (R_{is})^2 + X_{is}'\beta_3 + \theta_s + \varepsilon_{is}, \qquad (1)$$

where Y_{is} is the outcome of interest in municipality i in State s at the end the period of analysis, R_{is} is the cost of access to Sao Paulo/ the State capital, X_{is} is a vector of municipality level controls, θ_s is a state fixed effect, and we have included the quadratic cost of access term to capture potential non-linearities that arise in economic geography models.

The first stage equation is given by:

$$R_{is} = \beta_4 + \beta_5 \, Dist_{is} + X_{is}'\beta_6 + \theta_s + \varepsilon_{is}, \qquad (2)$$

where Dis is the distance between a municipality and the closest line. In this simple version, identification relies on the fact that municipalities experienced larger improvements in their road access to major economic centers over the period of interest, the closer they were to the constructed corridors. The excludability assumption is that distance to the lines affects the outcomes only through the cost of access, conditional on the controls.

Summarizing, the paper relies on a simple strategy using distance to the lines directly as an instrument for road access. Before looking at disaggregated data on employment, the next section presents results on the overall spatial pattern of growth induced by road development.

IV.   Spatial concentration

Bird and Straub (2014) established that the pattern across Brazil during the 1970-2000 period was characterized by agglomeration around the main cities that were large, had high stock of human capital, a high industry to service ratio, and good amenities as measured by the rate of access to tap water, and by dispersion otherwise.

It is interesting to relate these geographical effects to the underlying spatial pattern, in the sense of the spatial growth literature, which focuses on the relationship between the size of locations and their subsequent growth outcomes.

To do that, Figures 1 to 4 present scatter plots of the marginal effects of a fall in transport cost on population (Fig. 1 and 2) and GDP (Fig. 3 and 4) as a function of the size difference between each MCA and the size of the main city to which it is connected. The size of municipalities is measured alternatively by GDP or population at the beginning of the period, i.e. in 1970.

Take for example Figure 1. The vertical axis represent the marginal effects of transport cost on population as a function of the log difference in GDP between each municipality and its end point. The upper part displays the results for the South of Brazil. It is apparent that marginal effects are more negative on the right part of the graph, roughly where the log difference exceeds 5, which corresponds to municipalities at least 150 times smaller than the main city they are connected to (recall a negative effect means that a fall in transport cost generates more growth). This means that in the South, the larger increases in population are concentrated among smaller municipalities, so that population and GDP growth induces less spatial concentration of population and GDP.

In addition, results in Bird and Straub (2014) show that the municipalities where the effects of roads are stronger are located around the main urban centers, so that road development produces a kind of home market effect. This means that the road-induced spatial dispersion process goes hand in hand with a geographical concentration process.

Looking now at results for the North in the lower panel of Figure 1, it appears that there are strong negative marginal effects (positive effect on growth of a fall in transport cost) for a group of approximately 30 relatively large municipalities with a log difference in GDP between 2 and 4, which translates into the corresponding municipalities being between 7 and 50 times smaller than the cities they are connected to in 1970.

In contrast to the pattern found in the South, the North of Brazil is characterized by of combination of spatial concentration, meaning that intermediate size cities grow more, and geographical dispersion, as these cities are mostly located at some distance from the main urban centers.

Very similar results are found in Figures 2 to 4. Figure 2 also represents the marginal effects of transport cost on population, but the size difference between each municipality and the city it is connected to is expressed in terms of population rather than GDP. Figures 3 and 4 show the marginal effects of a fall in transport cost on GDP as a function of size differences expressed again in terms of population or GDP.

V. Results

Broad sectors

Bird and Straub (2014) investigated specific areas of production, running estimations for the (log) GDP of agriculture, industry, and services. The results in that paper showed that improved access to State capitals leads to a similar dual pattern as that found for overall GDP. Industry and service GDP increase in the South around the urban centers and the effect is reversed as effective distance grows. The respective thresholds are 300km for services and 4650km for industry. In the North, a reversed pattern holds close to State capitals, where both industry and service GDP decrease, while they start growing when distance exceeds 100 and 20km respectively.

When looking at the implications for the relative importance of each sector, using sector shares in total GDP as the dependent variable, the results indicated a relative decrease of the share of industry around main urban centers in the South (up to 230km) compensated to some extent by an increase in agriculture and services.

As discussed above, more detailed insights can be added by extending the analysis to include some of the recently released 2010 census, which can be found on the Instituto Brasileiro de Geografia e Estatística (IBGE) website. This will improve the estimations by covering the recent period in which important changes occurred in the Brazilian economy.

Table 1 starts by showing new results for 2000 using as alternative dependent variable the number of workers in the primary, secondary, and tertiary sectors in 2000. In column 2 and 3, the results indicate that municipalities closer to the lines have a higher number of workers in both the secondary and the tertiary sectors. This effect is much weaker in the North and a F-test fails to reject that the combined effects are equal to zero.

Columns 4 to 6 show the instrumental estimations, where the cost of access of each municipality to the corresponding State capital is instrumented with distance to the line. Estimates include again an interaction with a North dummy, as well as a quadratic term to account for the potential non-linearities related to the fact that places at different distance from urban centers should experience different effects, as found in standard economic geography models. Columns 5 and 6 show that the number of workers in both the secondary and the tertiary sectors increases in the South around urban centers as municipalities become better connected, while the reverse holds in the North.

In Table 2, we extend these estimations by looking at GDP per sectors in 2010. The effects are even stronger. The reduced form estimations in columns 1 to 3 show that agriculture experienced

an increase in the North in places farther away from the lines, while industry and services increased close to the lines in the South, but not in the North.

The instrumental estimations are slightly weaker and suggest that the Northern part of the country experienced an increase in primary sector activity in the North around urban centers, and a decrease in services.

Overall, this suggests a pattern similar to that found in Bird and Straub (2014), with the South displaying agglomeration effects driven mostly by an increase in industrial and service activities, and the reverse pattern in the North.

Subsectors

We now examine the impact of roads at a finer level of disaggregation, namely across 30 subsectors, as listed in Appendix 1. The results from the reduced form estimations in Table 3 are striking. In the South, all subsectors have higher numbers of workers closer to the lines, except for agriculture, mining, petroleum, tobacco, and wood. In short, putting apart extractive sectors for which the location of the resource is the main issue, all sectors of activities in the secondary and tertiary sectors developed faster closer the lines following the development of the road network.

These effects appear to be much weaker in the North. In fact, the combined effects are significantly different from zero only for a few subsectors, namely chemicals, metal industries, printing, and domestic services.

Looking at the instrumental estimations in Table 4, it appears that there are significant agglomeration effects in the South for the following manufacturing subsectors: food, furniture, leather, paper, printing, construction. In addition, services are also displaying significant agglomeration effects, in particular in public administration, education, health, communication, domestic services, and finance.

On the other hand, the reverse effects tend to prevail in the North, but the combined effects are only significant for chemicals, metal, printing, wood, communication, and to a lesser extend public administration.

VI. Discussion

The results in the two previous sections conform a consistent picture of the effects of the development of the radial highway system in Brazil since the 1970s on today's spatial patterns of productive specialization.

In the South, the overall evolution can be characterized by spatial dispersion, with small municipalities growing faster, as well as agglomeration, as these small municipalities are located around the country's main urban centers. In addition, this evolution is driven by growth in industry and services, which appear to be stronger in these areas around urban centers.

Looking at the finer details of which activities are favored most reveals that for manufacturing, effects are stronger for food, furniture, leather, paper, printing, and construction. Sectors producing output that is potentially perishable or likely to be consumed locally seem to dominate and generate either suburbanization, whereby firms moves to the outskirts of big cities, or even entry of new firms in these locations. Similar agglomeration effects also hold for services, in particular in public administration, education, health, communication, domestic services, and finance.

The reversed pattern for the North found in Bird and Straub (2014) also appears to extend to the productive sector level. Overall, this part of the country displays spatial concentration, with large intermediate cities growing faster than smaller ones, and geographical dispersion, as these cities are located at some distance from the main urban centers. Again, in places with the higher growth rates induced by roads, the main drivers are industry and services. The specific activities involved are however different, as they include for manufacturing, chemicals, metal, printing, and wood, and for services, communication and public administration. The productive development of intermediate cities that have to rely at least partly on distant markets appears to be biased towards more durable products or goods for export. Services, on the other hand, appear to strive less in medium size city, with the exception of some local public administration.

Overall, this paints a consistent dual pattern, in which the impact of large scale transport infrastructure depends strongly on initial conditions, in particular in terms of the size and nature of cities that become connected. While infrastructure public policies are often motivated by a desire to break isolation and spur the development of lagging regions by stimulating productive activities there, there is no guarantee that such an outcome will materialize. If new roads connect large and attractive urban centers, as was the case in the South of Brazil, the outcome might well be even more concentration, driven by suburbanization and the growth of industry and services around these urban centers.

VII. Conclusion

This paper has extended previous results on the impact of the development of the highway system in Brazil since the 1970s, by looking at patterns of productive development across specific activities, and by including more recent data from the 2010 census.

The overall picture completes that given in Bird and Straub (2014) and shows that the combination of spatial dispersion and geographical agglomeration found in the South of the country goes hand in hand with the development of manufacturing and services, while the opposite outcomes hold in the North. The results also show that the mix of industries driving growth is different depending on the location of the most dynamic places. In future work, we intend to extend these results, in particular by looking at firm-level data.

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Appendices

1. List of subsectors used in the estimations

Number of workers in Primary sector
Number of workers in Secondary Sector
Number of Workers in Tertiary Sector

Number of workers in agriculture and forestry
Number of Workers in Fishing
Number of workers in mining
Number of workers in manufacturing - chemical
Number of workers in manufacturing - electrical
Number of workers in manufacturing - food
Number of workers in manufacturing - furniture
Number of workers in manufacturing - leather
Number of workers in manufacturing - machinery
Number of workers in manufacturing - metal
Number of workers in manufacturing - paper
Number of workers in manufacturing - petroleum
Number of workers in manufacturing - plastic and rubber
Number of workers in manufacturing - printing
Number of workers in manufacturing - textile
Number of workers in manufacturing - tobacco
Number of workers in manufacturing - transport
Number of workers in manufacturing - wood
Number of workers in manufacturing -
Number of workers in public administration
Number of workers in education
Number of workers in health
Number of workers in transportation, warehousing and communication
Number of workers in commerce
Number of workers in construction
Number of works as domestic servants
Number of workers in Finance

2. Figures

Figure 1: Marginal effects (Population) on GDP differences (upper panel: South; lower panel: North)
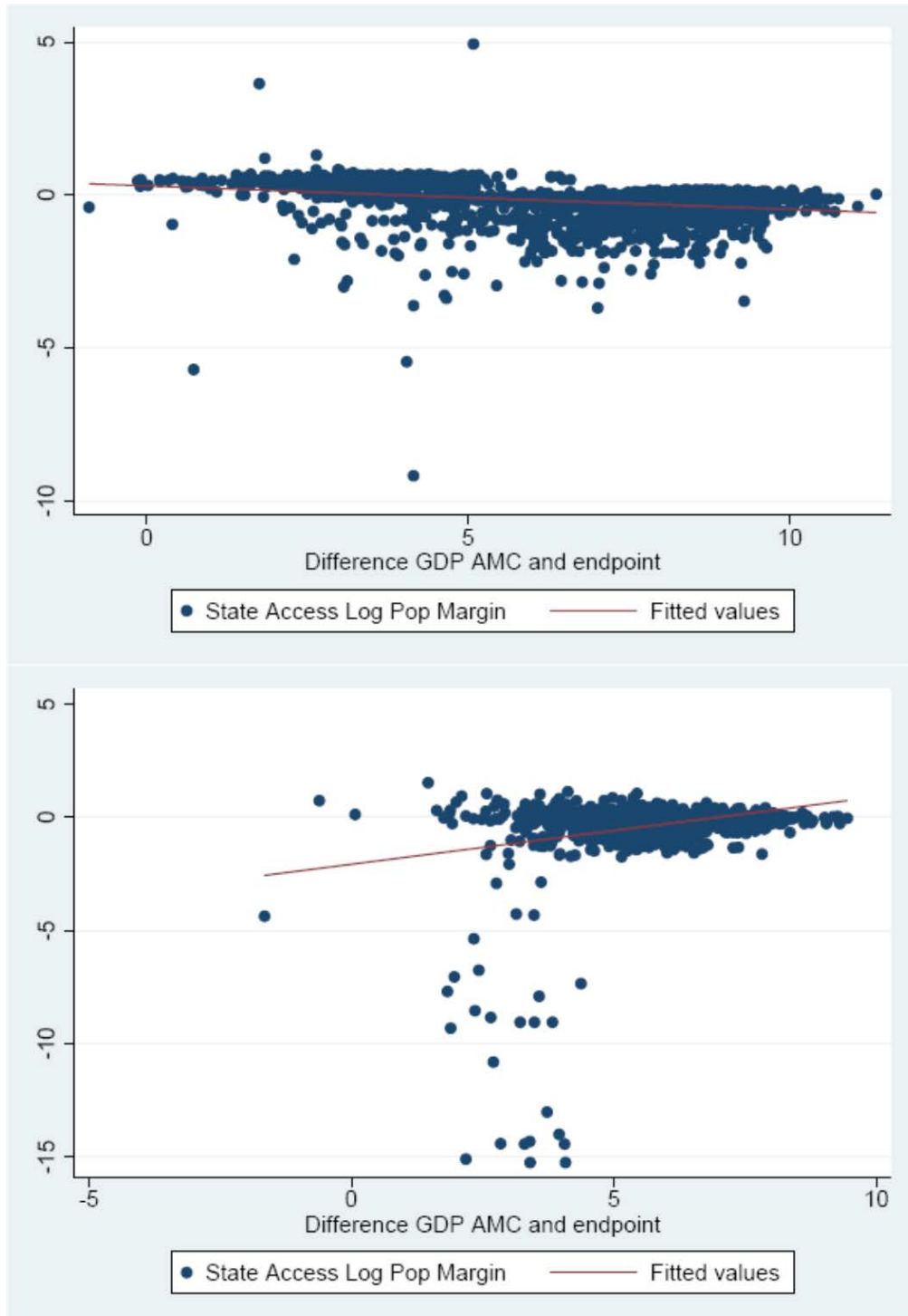
Note: Marginal effects of a change in cost of access on population levels, against the difference in GDP between MCA and endpoint. Negative values occur when a fall in costs of access results in higher population levels.

Figure 2: Marginal Effects (Population) on Population differences (upper panel: South; lower panel: North)
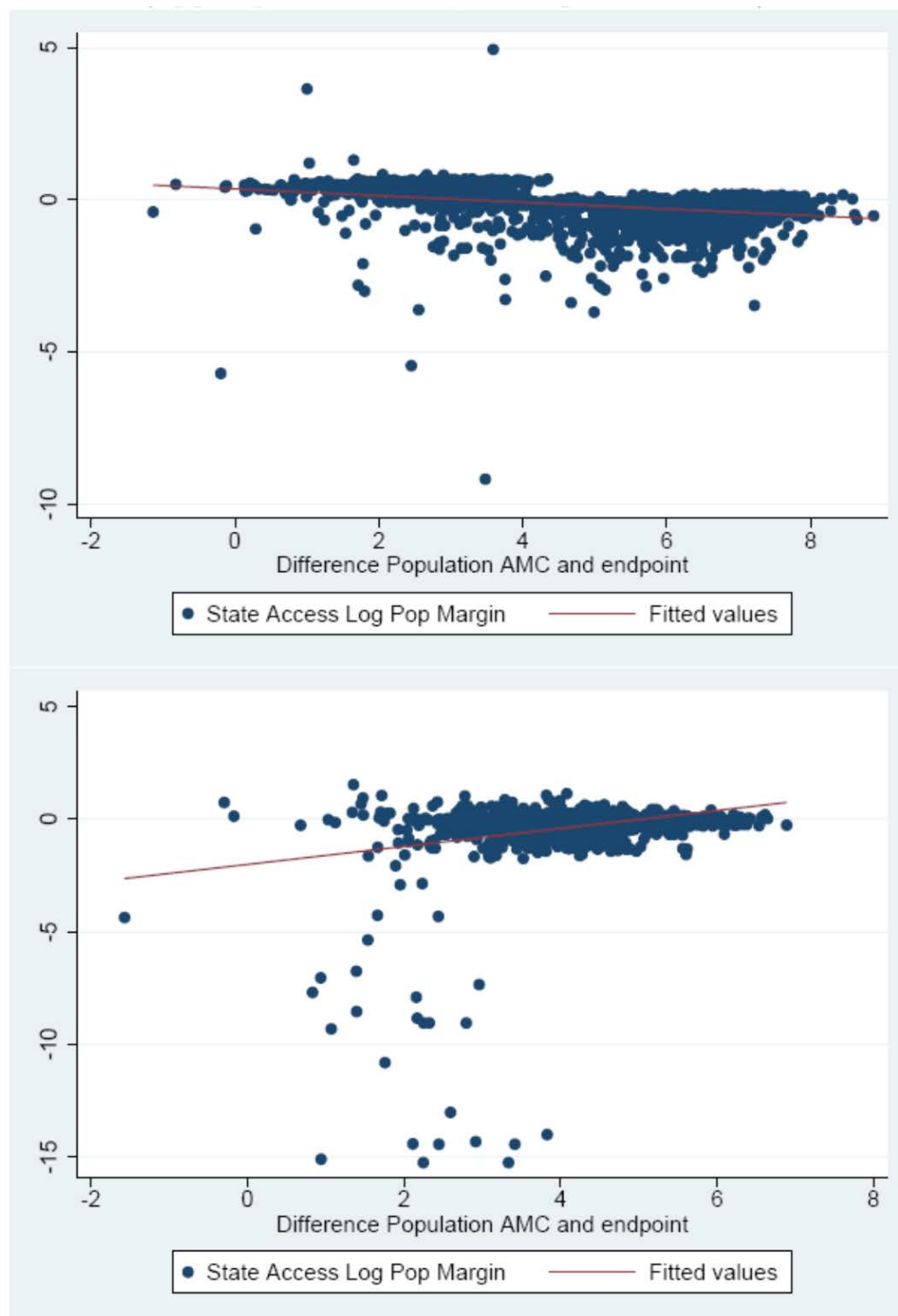
Note: Marginal effects of a change in cost of access on population levels, against the difference in population between MCA and endpoint. Negative values occur when a fall in costs of access results in higher population levels.

Figure 3: Marginal Effects (GDP) on GDP differences (South, North)

Note: Marginal effects of a change in cost of access on GDP, against the difference in GDP between AMC and endpoint. Negative values occur when a fall in costs of access results in higher population levels.

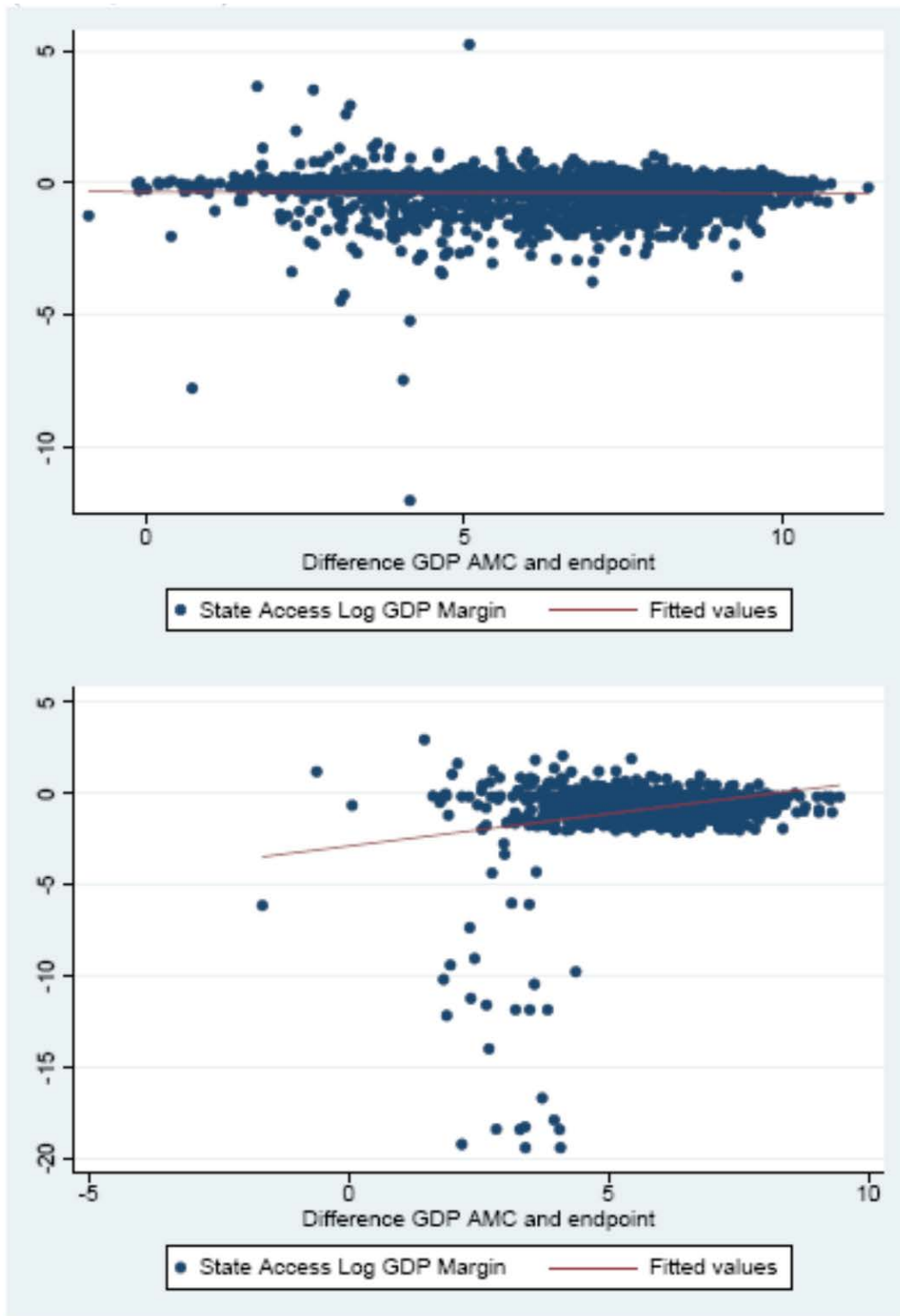**Figure 4: Marginal Effects (GDP) on Population differences**
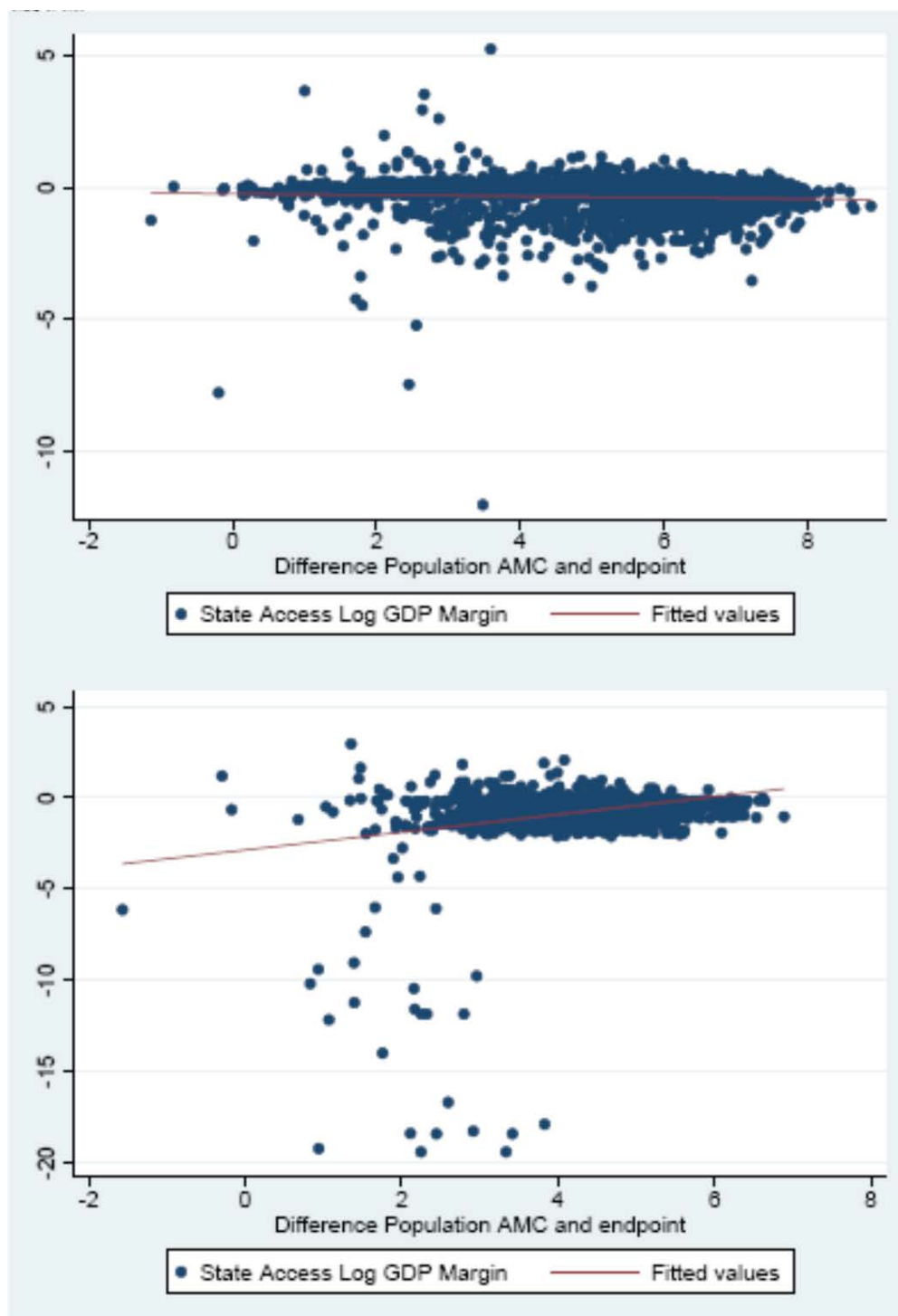

Note: Marginal effects of a change in cost of access on GDP, against the difference in population between AMC and endpoint. Negative values occur when a fall in costs of access results in higher population levels.

3. Tables

Table 1: Sector level impact in 2000.

	Log Primary workers (1)	Log Secondary workers (2)	Log Tertiary workers (3)	Log Primary workers (4)	Log Secondary workers (5)	Log Tertiary workers (6)
Log Distance from Lines	-0.0286 (0.0274)	-0.2263*** (0.0394)	-0.1765*** (0.0362)			
Northern * Distance	0.0481 (0.0399)	0.1732*** (0.0597)	0.1196** (0.0524)			
Log Cost of travel to State Capital				-2.8893 (4.1395)	-11.4668* (6.7824)	-10.7603* (6.0055)
Squared Log Cost of travel to State Capital				0.2591 (0.4018)	0.9208 (0.6531)	0.8948 (0.5802)
Northern * Log Cost of travel to State Capital				2.8651 (3.8384)	14.5431** (6.1502)	14.5013*** (5.4431)
Northern * Squared Log Cost of travel to State Cap				-0.2082 (0.3662)	-1.2750** (0.5791)	-1.2825** (0.5120)
Observations	3,644	3,644	3,644	3,638	3,638	3,638
R-squared	0.2958	0.3919	0.3710			

Note: Columns 1 to 3 reports OLS estimations of outcomes in municipality i and State s, estimated as a function of distance to the lines. Columns 4 to 6, reports the second stage of two-stage least square estimations outcomes in municipality i and State s in 1980 and 2000, estimated as a function of cost of access to the state capital and cost of access squared, using the command ivreg2 (Baum et al. 2010). The Cost of access variables are instrumented using distance to the lines. Controls include state dummies, as well as the municipalities distance to Brasília, Sao Paulo and the state capital, dummies for whether the Amazon intersects with the municipality, and whether the municipality is near the coast, and the municipalities area, and water, toilet and light access. The geographical unit used is IPEA's 1970 Minimal Comparable Areas (MCA 70-00), which covers 3,599 municipal areas, comparable at any point between 1970 and 2000. Standard errors clustered at the MCA level are in parentheses. Stars indicate statistical significance at the 1% (***), 5% (**), and 10% (*) level respectively.

Table 2: Sector level impact in 2010.

	Log GDP Primary 2010	Log GDP Secondary 2010	Log GDP Tertiary 2010	Log GDP Primary 2010	Log GDP Secondary 2010	Log GDP Tertiary 2010
	(1)	(2)	(3)	(4)	(5)	(6)
Log Distance from Lines	-0.0569 (0.0361)	-0.3007*** (0.0473)	-0.2587*** (0.0360)			
Northern * Distance	0.1490*** (0.0477)	0.2604*** (0.0688)	0.2169*** (0.0505)			
Log Cost of travel to State Capital				5.4212 (5.6692)	-5.6608 (7.2301)	-9.2011 (6.1965)
Squared Log Cost of travel to State Capital				-0.5721 (0.5450)	0.2767 (0.6982)	0.6686 (0.5957)
Northern * Log Cost of travel to State Capital				-13.2915** (5.5449)	8.0178 (6.7563)	10.5081* (5.5147)
Northern * Squared Log Cost of travel to State Cap				1.2463** (0.5264)	-0.6718 (0.6364)	-0.9165* (0.5142)
Observations	3,637	3,644	3,644	3,631	3,638	3,638
R-squared	0.3091	0.4026	0.3868			

Note: Columns 1 to 3 reports OLS estimations of outcomes in municipality i and State s, estimated as a function of distance to the lines. Columns 4 to 6, reports the second stage of two-stage least square estimations outcomes in municipality i and State s in 1980 and 2000, estimated as a function of cost of access to the state capital and cost of access squared, using the command ivreg2 (Baum et al. 2010). The Cost of access variables are instrumented using distance to the lines. Controls include state dummies, as well as the municipalities distance to Brasília, Sao Paulo and the state capital, dummies for whether the Amazon intersects with the municipality, and whether the municipality is near the coast, and the municipalities area, and water, toilet and light access. The geographical unit used is IPEA's 1970 Minimal Comparable Areas (MCA 70-00), which covers 3,599 municipal areas, comparable at any point between 1970 and 2000. Standard errors clustered at the MCA level are in parentheses. Stars indicate statistical significance at the 1% (***), 5% (**), and 10% (*) level respectively.

Table 3: Subsector level impact in 2000.

	Log Agriculture	Log Fishing	Log Mining	Log Chemical	Log Electric	Log Food	Log Furniture	Log Leather	Log Machine
Log Distance from Lines	-0.0258 (0.0281)	-0.1504*** (0.0479)	-0.0519 (0.0496)	-0.3641*** (0.0584)	-0.3117*** (0.0689)	-0.2444*** (0.0403)	-0.1722*** (0.0462)	-0.2640*** (0.0668)	-0.2730*** (0.0553)
Northern * Distance	0.0674 (0.0424)	0.0932 (0.0802)	0.0809 (0.0800)	0.2212** (0.0985)	0.2952** (0.1257)	0.1984*** (0.0676)	0.1500** (0.0701)	0.2585** (0.1047)	0.2116** (0.0944)
Observations	3,644	2,071	2,256	1,875	943	3,568	3,209	1,605	1,775
R-squared	0.2874	0.5294	0.1821	0.3047	0.3184	0.2983	0.3017	0.2465	0.3264

	Log Metal	Log Paper	Log Petroleum	Log Plastic	Log Print	Log Textile	Log Tobacco	Log Transport	Log Wood
Log Distance from Lines	-0.3030*** (0.0520)	-0.2923*** (0.0743)	0.0659 (0.0773)	-0.3212*** (0.0678)	-0.3591*** (0.0554)	-0.2532*** (0.0486)	-0.1369 (0.1572)	-0.2345*** (0.0656)	-0.0483 (0.0425)
Northern * Distance	0.1995** (0.0780)	0.2487 (0.1659)	0.0744 (0.1526)	0.2197* (0.1166)	0.2243** (0.0925)	0.2425*** (0.0742)	0.0913 (0.2598)	0.2187** (0.1063)	-0.0206 (0.0645)
Observations	3,352	926	816	1,138	1,834	3,489	282	1,426	2,868
R-squared	0.3018	0.2853	0.1847	0.3637	0.3507	0.3216	0.2122	0.3519	0.3390

	Log Manufactu	Log Public Admin	Log Education	Log Health	Log Communicat°	Log Commerce	Log Construct°	Log Domes services	Log Finance
Log Distance from Lines	-0.2822*** (0.0425)	-0.0933*** (0.0300)	-0.1333*** (0.0351)	-0.2075*** (0.0422)	-0.2550*** (0.0406)	-0.2170*** (0.0410)	-0.1685*** (0.0380)	-0.1487*** (0.0362)	-0.2482*** (0.0488)
Northern * Distance	0.2507*** (0.0653)	0.0503 (0.0457)	0.0942* (0.0487)	0.1408** (0.0634)	0.1792*** (0.0623)	0.1712*** (0.0608)	0.1048* (0.0579)	0.0772 (0.0536)	0.1774** (0.0764)
Observations	3,641	3,644	3,644	3,531	3,637	3,644	3,643	3,643	2,658
R-squared	0.4017	0.3531	0.3148	0.3592	0.3434	0.3729	0.3442	0.3531	0.3600

Note: See Table 1 for details.

Table 4: Subsector level impact in 2000.

	Log Agriculture	Log Fishing	Log Mining	Log Chemical	Log Electric	Log Food	Log Furniture
Log Cost of travel to State Capital	-3.6698	9.4340**	-1.6391	-8.5777	-6.5185	-16.1358*	-14.1175*
	(4.4994)	(4.6341)	(5.4743)	(9.3783)	(7.3288)	(8.3118)	(7.3253)
Squared Log Cost of travel to State Capital	0.3407	-1.0633**	0.1141	0.5347	0.4552	1.3772*	1.2522*
	(0.4368)	(0.4663)	(0.5721)	(0.9305)	(0.7450)	(0.8022)	(0.7125)
Northern * Log Cost of travel to State Capital	2.7110	-5.3665	5.3767	14.4560*	6.2627	15.1060**	14.8345**
	(4.3272)	(4.4930)	(4.7994)	(8.2239)	(6.3544)	(7.3899)	(6.6123)
Northern * Squared Log Cost of travel to State Capital	-0.1664	0.5976	-0.3998	-1.2882*	-0.5016	-1.3567*	-1.2958**
	(0.4152)	(0.4393)	(0.4754)	(0.7758)	(0.6307)	(0.6937)	(0.6319)
Observations	3,638	2,065	2,25	1,869	937	3,562	3,203

	Log Leather	Log Machine	Log Metal	Log Paper	Log Petroleum	Log Plastic	Log Print
Log Cost of travel to State Capital	-22.0048*	-11.1678	-9.0937	-11.0766*	-3.6945	-11.4967	-19.8465*
	(12.3842)	(7.0660)	(7.5712)	(5.9196)	(8.6030)	(7.2284)	(10.6797)
Squared Log Cost of travel to State Capital	2.0366	0.9112	0.6200	0.9289	0.5555	0.9189	1.7085
	(1.2574)	(0.7058)	(0.7338)	(0.6013)	(1.0426)	(0.7340)	(1.0694)
Northern * Log Cost of travel to State Capital	17.8528*	12.4452**	16.7888**	7.6546	-18.2166	15.3139**	22.6787**
	(10.2551)	(5.8404)	(7.4471)	(5.9788)	(47.6131)	(6.4731)	(9.0267)
Northern * Squared Log Cost of travel to State Capital	-1.6039	-1.1340**	-1.4805**	-0.7077	1.7626	-1.3730**	-2.0457**
	(1.0052)	(0.5577)	(0.7093)	(0.5887)	(4.5881)	(0.6380)	(0.8580)
Observations	1,599	1,769	3,346	921	811	1,132	1,828

Table 4 (continued)

	Log Textile	Log Tobacco	Log Transport	Log Wood	Log Manu	Log Public Admin	Log Education
Log Cost of travel to State Capital	-5.1899 (6.2556)	-14.9269 (19.1977)	-5.8057 (5.8589)	-9.2889 (6.0171)	-12.5026* (7.5692)	-7.4646* (4.2991)	-10.2314* (5.6789)
Squared Log Cost of travel to State Capital	0.2774 (0.6078)	1.6363 (2.1281)	0.3762 (0.5715)	0.8802 (0.5938)	0.9749 (0.7285)	0.6457 (0.4185)	0.8826 (0.5492)
Northern * Log Cost of travel to State Capital	8.6028 (6.0854)	36.3025 (36.0393)	7.9711 (5.2781)	12.6902** (5.5573)	14.0803** (6.7359)	10.6047*** (4.0911)	13.5310*** (5.0636)
Northern * Squared Log Cost of travel to State Capital	-0.6723 (0.5869)	-3.6836 (3.6548)	-0.6529 (0.4977)	-1.1836** (0.5264)	-1.1982* (0.6327)	-0.9447** (0.3935)	-1.1814** (0.4762)
Observations	3,483	277	1,42	2,862	3,635	3,638	3,638

	Log Health	Log Communication	Log Commerce	Log Construction	Log Domestic Services	Log Finance
Log Cost of travel to State Capital	-14.1807** (7.0193)	-13.2291* (7.1689)	-10.7856 (6.6614)	-12.4810* (6.7207)	-11.9025* (6.4363)	-20.2505** (10.1611)
Squared Log Cost of travel to State Capital	1.2104* (0.6766)	1.0658 (0.6912)	0.8593 (0.6436)	1.0736* (0.6483)	1.0376* (0.6215)	1.7929* (0.9967)
Northern * Log Cost of travel to State Capital	16.8881*** (6.2632)	18.2337*** (6.6329)	14.6622** (6.0458)	16.4940*** (6.1075)	14.4555** (5.7856)	25.0365*** (8.2785)
Northern * Squared Log Cost of travel to State Capital	-1.5196*** (0.5889)	-1.6084** (0.6259)	-1.2640** (0.5706)	-1.4679** (0.5760)	-1.3279** (0.5428)	-2.2332*** (0.7729)
Observations	3,525	3,631	3,638	3,637	3,637	2,652

Note: See Table 2 for details