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Diamonds are Forever
Long-Run Effects of Mining Institutions in Brazil

Os Diamantes são Eternos
Efeitos de Longo Prazo de Instituições Mineradoras no Brasil

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“ Mestre não é quem sempre ensina, mas quem de repente aprende.”

João Guimarães Rosa

Abstract

This paper uses a regression discontinuity approach to investigate whether a set of colonial policies adopted in the Diamond District have long-run impacts on development. Results show that the treatment effect is positive on household income, adult literacy and light density from satellite images. I also explore potential channels through which this historical event might be leading to these positive outcomes. I use contemporary census data to show that treated areas have higher urbanization rates. I also present evidence from 1872 and 1890 census data that areas inside the District have persistently higher human capital levels. Using a geospatial road location database and vector data constructed from historical maps, I find that observations inside the District's historical boundaries used to have less dense road networks but this is not true today. Additionally I use data from the 1830s and from the 1872 census to show that slavery was more intense in treated villages but after the decline of diamond extraction this difference vanished.

Key-words: Development, Colonial Brazil, Institutions, Channels of persistence.

Resumo

Este artigo usa a técnica de regressão descontínua para investigar se um conjunto de políticas coloniais adotado no Distrito Diamantino tem efeitos de longo prazo sobre o desenvolvimento econômico. Os resultados mostram que o tratamento tem efeito positivo sobre renda por domicílio, alfabetização de adultos e densidade de luz obtida através de imagens de satélite. Eu também exploro potenciais canais de transmissão através dos quais esse evento histórico poderia gerar esses resultados positivos. Eu uso dados do Censo de 2010 para mostrar que áreas tratadas têm taxa de urbanização mais alta. Eu também apresento evidência a partir dos Censos de 1872 e 1890 de que área dentro do Distrito tinham nível de capital humano persistentemente mais alto. Usando uma base geoespacial de localização de estradas e dados vetoriais construídos a partir de mapas históricos, eu encontro que observações dentro dos limites históricos do Distrito tinham redes viárias menos densas originalmente, mas que isso não é verdade hoje em dia. Adicionalmente, eu uso dados dos anos 1830 e do Censo de 1872 para mostrar que havia mais escravidão em paróquias tratadas, mas que com o declínio da extração dos diamantes essa diferença desapareceu.

Palavras-chaves: Desenvolvimento, Brasil Colônia, Instituições, Canais de persistência.

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1 Introduction

In this paper, I examine the long-run impacts of a set of institutions that existed for about a century in a part of colonial Brazil. When diamonds were discovered within its domains, the Portuguese Crown singled the area out, creating specific *de jure* institutions in order to extract the largest possible surplus from the mineral. The Diamond District (*Distrito Diamantino*, in Portuguese) existed for about a century from 1731 until 1832, spanned approximately 4000 km^2 ¹ and was subject to policies that differed from the rest of the colony. Although the rules specific to the diamond-mining area varied along time, they had a constant objective: maximize metropolitan control in order to avoid smuggling, extract rents and limit supply. The discrete change at the District's border suggests that a Regression Discontinuity approach might be used to evaluate its effects.

Also, this event attracted a large population and determined the initial settling of the area. The presence of this natural resource led to higher urbanization rates, which might have persisted until today. Therefore, this paper's contribution is twofold. First, I contribute to the literature that explores historical quasi-experiments to understand the role of institutions in long-run development. The effect of historical events on modern economic outcomes has generated a significant body of literature in recent years². Following the seminal contributions of [Acemoglu, Johnson e Robinson \(2001\)](#), [Acemoglu, Johnson e Robinson \(2002\)](#) and [Glaeser e Shleifer \(2002\)](#), later studies have focused on explaining the channels through which history might influence present outcomes. For example, [Dell \(2010\)](#) estimates that districts subject to forced labor in colonial Peru are relatively underdeveloped today, especially through land tenure and infrastructure provision. [Nunn \(2008\)](#) shows that African ethnicities more intensely affected by the slave trade are poorer and [Nunn e Wantchekon \(2011\)](#) find this can be explained by having developed a culture of mistrust.

I also contribute to the branch of research that investigates how initial factor endowments might affect spatial equilibria in the long-run. Theoretical research in economic geography

¹ Roughly the size of Rhode Island

² For a review of the literature, see [Nunn \(2009\)](#)

has shown that the possibility of multiple spatial equilibria arise in the presence of increasing returns to scale (KRUGMAN, 1991) or externalities (GLAESER et al., 1992). Meanwhile, empirical work has found that population and economic activity concentrations tend to persist over long periods of time. Hence, the location of economic activity might itself be a channel through which historical events are transmitted over time. For example, Davis e Weinstein (2002) find that Japanese cities reverted to prewar population trends even after being heavily bombarded in World War II. Redding, Sturm e Wolf (2011) show evidence of historical dependence in industrial location for airport hubs in reunified Germany. More significantly to our case, Bleakley e Lin (2012) show that path-dependence in the spatial distribution of economic activity can exist even if the initial locational advantage has long faded.

In Chapter 2, I provide an overview of the District's history. Chapter 3 discusses the identification strategy and presents estimated effects on contemporary development. In Chapter 4, I investigate possible channels of persistence. Chapter 5 concludes.

2 Diamond District

2.1 Historical Background

Figure 1 – Timeline of the District’s History

The discovery of diamond mines in colonial Brazil was officially notified to Lisbon in 1729. The date of the actual discovery is uncertain, but believed to be around 1720. The region was located in the Province of Minas Gerais, already experiencing a gold boom since the previous century. This particular area also mined gold, but it was quite marginal in the gold-mining context. Its distance to the main gold area around the provincial capital Vila Rica was 400 km along the *Caminho dos Diamantes*¹ (Diamonds’ Path), which was only built in the 1730s. Another evidence of its limited importance before diamonds is that in 1738 the *Comarca do Serro do Frio*, which contained the District and the whole northern half of the Province, had a population of less than 10 thousand (FURTADO, 2008, p.41) (and an area comparable to the United Kingdom’s)². In spite of the area’s isolation, the presence of diamonds attracted a great deal of attention from the authorities in Lisbon. Controlling this resource was important not only for its profitability but also due to the prestige that diamonds could confer: according to Mawe (1813), “although small stones are sufficiently abundant to be within the reach of a moderate expenditure (...), those of a larger size are, and ever have been, rare; and of the most celebrated for magnitude and beauty, the whole number in Europe scarcely amounts to half a dozen, all

¹ <http://www.institutoestradaareal.com.br/caminhos/diamantes/>

² This meant that the area as a whole had 0.04 inhabitants per square kilometer, roughly the same as Greenland today.

of which are in the possession of sovereign Princes”.

Diamonds were at first extracted using simple techniques like panning (using a pan to wash away sediments from a stream bed). The institutional framework that was set up to regulate diamond mining was initially copied from the gold context: placer deposits were to be divided in lots that could be bought by anyone with the means to explore them. The government would collect, besides this initial payment, a tax on each slave used and 20% of the extracted minerals in kind (the *Quinto*, literally a fifth) (RODRIGUES, 2014). It quickly became evident that these rules were inadequate for the new product. Physical differences made it more difficult to control diamond production and avoid smuggling. Also, in the gold context the fifth was charged in foundries which made it inadequate for diamonds.

For these reasons, it was decided to set up a new system. In 1734, the District’s boundaries were first demarcated, encircling the places where diamonds were known to occur. At the same time, the Crown tried to discourage extraction by raising the *per capita* tax on slaves working in mines. This measure was motivated by international prices being greatly affected by the District’s production. Indeed, in 1751 an insider of this market observed that prices had been so low that “the public, and likewise the traders in them, were so apprehensive of the Brazil mines producing an inexhaustible store; judging from thence, the world would scarcely think Diamonds worth any consideration, especially as jewelers so undervalued them” (JEFFRIES, 1751). Until the discovery of Brazilian mines, diamonds were found exclusively in India and Borneo. Brazilian diamonds flooded the market so intensely, though, that in the early XIX century the European market was “almost wholly dependant on Brazil, for its supply of Diamonds” (MAWE, 1813). French physicist Dieulafait (1871, p. 71) reports data that illustrate the size of this effect: a one carat stone was sold for 545 francs in 1606, but only for 202 in 1750.

Since the higher tax rate on slaves was still unable to limit production, the authorities decided to halt production completely between 1734 and 1739, while also creating a new government department called Diamond Administration to run the District. It is quite clear that the Portuguese authorities were aware of the effect the Brazilian supply had

on the market: official correspondence from Lisbon that reached the colony in 1734 said that His Majesty was providing for “the means through which diamonds can recover their value, which has been so low due to their great abundance” ([Biblioteca Nacional, 1960](#)). Production restarted in 1739 under a new institutional arrangement, becoming the monopoly of a private investor or group that purchased from the Crown exclusive rights of extraction inside the District for a period of time. The king’s secretary Alexandre de Gusmão had ordered in a letter to colonial officials that “the extraction of diamonds should be done by a company, limiting the number of slaves (up to 400) and marking the right sites to be explored, which cannot be exceeded” ([CORTESÃO, 1952](#)). These regulations had the intention to limit production and to ensure the availability of stones for future contracts. The private contracts’ period lasted for 31 years, with 6 contracts being awarded during this time.

Although the institutional framework designated an official to regulate and oversee the extraction of diamonds in the name of the King, historical evidence suggests that private contractors had some ability to circumvent regulations regarding slave quotas and exploration sites, and that this was done at least in some occasions. These practical difficulties led to a progressive tightening of metropolitan policies. In 1745 it was decided to control access at the District’s boundary in order to avoid unauthorized mining, allowing entrance exclusively through the 6 guarded outposts. In 1753, diamond trade was made a monopoly by the king, which was granted to a private firm. Regarding this decision the Marquis of Pombal, secretary of State under King José I, stated that the intent was to avoid “the imminent ruin to which are exposed the contract and trade of diamonds from Brazil, not only for disorders committed in their administration and handling, with private interests superseding the public good; but also for the considerable contraband that has caused great damage” ([Arquivo Público Mineiro, 1753](#)).

This process of increasing state control reached its climax in 1771 when, allegedly to avoid frauds and smuggling, the Crown decided to extract the stones directly, creating a state-owned company called Royal Diamond Extraction, which had a legal monopoly on both mining and trading ([FURTADO, 2008](#)). At the same time, a new Regiment went

into effect inside the District subjecting its population to an even narrower control. This period, that lasted until the 1830s, has been described as the most extreme example of colonial despotism in Portuguese America, creating a *de jure* system that stood out even in comparison to the surrounding areas, subject to the already repressive gold-mining regulations (TORRES, 1980). Furthermore, Boxer (1962) describes the District in this period as “a colony within a colony, cut off from the rest of Brazil by a legal and administrative barrier” and outside observer Saint-Hilaire (1833) saw the District at the time of his visit as “almost a separate state, amidst the vast Empire of Brazil”.

On the other hand, residents of the District still had other sources of income, even while being officially excluded from extracting diamonds. They could mine gold in the streams where diamonds were not present and could rent their slaves to the Royal Extraction, as it had already been done in the private contracts period (FURTADO, 2008). Also, it seems the Crown did not manage to extract all the surplus from the mineral: contemporary observers were surprised by how rich the District was, especially considering its isolation (SAINT-HILAIRE, 1833); and the constant change in regulations suggests that it might not have been possible to fully control the product in the first place. A report sent from the Diamond Administration in its final years supports this view by saying that “lots of mines (...) are secretly explored by gold-diggers, whose punishment is as impracticable as guarding the sealed lots.” (SANTOS, 1976, p. 425). The same document also provides evidence that diamond mines were almost exhausted at this point: “there are no streams in this demarcation that have not been already mined, and most of the current extraction is based on the residuals left by former contractors”, adding that exploring these sites required investing large sums (SANTOS, 1976, p. 427).

After Brazil became independent from Portugal in 1822, successive changes ended the system created in colonial times. In 1831 the town of Tejuco was promoted to village, which meant it now had its own municipal chamber; it would become a municipality in 1838. The Diamond Administration was extinguished in October 1832 by Imperial decree (BRASIL, 1832). The Royal Extraction was officially extinguished in 1841 (SANTOS, 1976).

2.2 The Border Assignment

The only explicit criterion for the border's demarcation was the occurrence of diamonds³. As the officials sent to demarcate the District described it, “having His Majesty the King ordered me to demarcate the mineral lands of diamonds in the *Comarca do Serro do Frio* (...), I sought to gather the appropriate information and saw the most part of the District; (...) so that it included sites where diamonds have been discovered, not extending to others” ([Biblioteca Nacional, 1960](#)). Since the presence of diamonds is probably correlated with other geographic variables, those factors might have indirectly influenced the assignment. For example, given that in this region diamonds were found mostly in streams, the authorities probably took them into account. Indeed, historical maps (see Appendix) show that some segments of the boundary encircled the headwaters of the District's rivers and since drainage basins are determined by topography, the borders are probably indirectly influenced by geography. Also, other geographical factors like vegetation might have influenced the assignment, even if historical documents do not mention them.

Another possibility is that the border's location was influenced by human factors, such as previous settlement patterns. This is will not be possible to test due to the paucity of data on human settling before the discovery of diamonds, but historical evidence suggests this is not the case. First because prior to the discovery of diamonds this was quite a marginal area in the mining context, so the region was sparsely populated (as discussed in Section 2.1). Secondly, the events that followed suggest that residents' interests would not be taken into account anyway if there was any conflict with metropolitan objectives.

[Santos \(1976, p. 34\)](#) describes in detail the process of demarcating the diamond-producing area. The first demarcation in 1734, made by royal envoy Martinho de Mendonça and Intendant Raphael Pires Pardino, was based on 6 marks, following natural landmarks to make them easily recognizable. The limits were extended in 1739, under the oversight of provincial governor Gomes Freire de Andrade to include mines that had been discovered

³ In the first years of the Districts' existence its area was expanded whenever new mines were found, remaining stable afterwards ([FURTADO, 2008](#)).

afterwards. This second demarcation, which was described verbally by the author⁴ is consistent to what can be seen in the maps used. Therefore, we can be confident that for most of the District's existence, its borders remained stable.

⁴ "From the town of São Gonçalo straight until the headwaters of the Três Barras stream, and from there to the Paraúna River; all the way downstream called Forquilha where the Pardo Pequeno River and the Pardo Grande River meet; and from the headwaters of the Pardo Grande to those of the Inhaí River, then downstream until the Jequitinhonha do Campo [River] and then until the Jequitinhonha do Mato [River], continuing through the headwaters of the Capivari River to São Gonçalo, where the demarcation begun" ([SANTOS, 1976](#), p. 55)

3 Effects on Long-Run Development

3.1 Data

Diamond District's Borders: Historical (see figures 9 and 10 maps that show the study area are available in [Costa et al. \(2002\)](#)). Using some features as control points to georeference the maps in ArcGIS it is possible to correct distortions and digitalize the boundary. I further discuss the georeferencing process in section 3.2. The maps used to draw the border, called *Mapa da Demarcação Diamantina - 1776* (Map of the Diamond Demarcation) and *Mapa da Demarcação Diamantina acrescentado até o Rio Pardo - 1784* (Map of the Diamond Demarcation including the Pardo River) were both produced during the Royal Diamond Extraction period. Since they were created for the authorities in Lisbon under royal command, it is reasonable to believe these maps were made to be as accurately as possible. Both maps display natural features like rivers and hills, towns, guard posts and roads, as well as the District border.

Contemporary Development Outcomes: Household income and adult literacy taken from the Brazilian 2010 Population Census ([IBGE, 2011](#)), at the Census tract level. Household income is measured as the average among private households within each tract. Literacy is measured as the percentage of people above 40 years of age that are able to read and write a simple note.

I will also use light density obtained from the Defense Meteorological Satellite Program's Operational Linescan System as a proxy for local economic development ([HENDERSON; STOREYGARD; WEIL, 2012](#)). In this data the unit of observation will be pixels of the satellite image. I will test effects both on the intensive and on the extensive margin (that is, the probability of a pixel being lit).

It is important to notice that most of the contemporary urban centers in this region already existed in colonial times ¹ and are shown on the historical maps, so even if there were still some uncertainty in the border's location it would not make a difference in treatment

¹ Although mostly with different names, but they have been matched by [Santos e Seabra \(2009\)](#).

status for most lit pixels and Census tracts².

Geographical Covariates: River locations obtained from [IBGE \(2010\)](#) vector files and elevation from the SRTM satellite image data ([JARVIS et al., 2008](#)). River density is measured as the total length in meters within each tract or pixel divided by its area in square kilometers. Elevation is measured in meters within pixels of 3 arc-second (approximately 90 m^2). From the raw elevation data I have also calculated terrain slope and ruggedness³ for each pixel using ArcGIS and aggregated them to the light density pixels and census tracts levels.

3.2 Georeferencing the Border

In order to use the information that historical maps contain in a GIS, it is necessary to assign them coordinates first (ie, to georeference them). The general idea is that you have a picture file that is missing spatial reference, but as long as you can correctly identify the location of some of its points, the software is able to project that picture to the coordinate space. For example, you can match towns in the old map to their locations in the contemporary map (each one of these is called a control point). If you do this for enough control points, then the historical map is projected over the coordinate space by minimizing errors through an adjustment process of your choice. Obviously the least accurate the map, the more difficult it is to georeference it because you are not only superposing it to the “real” map, but actually correcting its imperfections (this is usually the case with old maps).

In our case, since possible control points are not evenly distributed across each map, the georeferencing alone tended to result in some uncertainty in some segments of the border. Fortunately, though, the same segments have been defined according to natural features. By exploring this, it becomes possible to greatly improve the border’s precision. When the

² For example, the historical maps show that the urban area then known as Arraial do Tejuco was inside the District. This place today is the city of Diamantina, so I know that the observations within it are treated even if there is some marginal uncertainty in the location of the border.

³ I have measured ruggedness using the Vector Ruggedness Measure introduced by [Sappington, Longshore e Thompson \(2007\)](#), because it is less correlated with slope than other measures. It is an index that varies from 0 (flat) to 100% (completely rugged).

adjustment is complete, I create a line shapefile from the reshaped border.

Since choosing a different polynomial might alter the results, I drew more than one border for each map, one for each of the nonlinear adjustment methods available in ArcGIS: 2nd and 3rd order polynomials, and spline (which matches each control point exactly, stretching everything located between them). Taking advantage of the natural landmarks used to demarcate the District, the border remains fairly stable across different adjustment methods.

3.3 Estimation Framework

Being a part of the District's historical area is a discontinuous and deterministic function of geographic location, suggesting we could estimate its effects using a spatial regression discontinuity design.

The basic regression for Census tract data is:

$$y_{tm} = \alpha + treatment_t D + X'_t \beta + f(loc_t) + \delta_s + \varepsilon_{tm} \quad (3.1)$$

where y_{tm} is the outcome variable in census tract t in municipality m ; $treatment_t$ is a dummy variable that takes on value 1 if at least 90% of the tract's area is inside the historical boundary and 0 if less than 10% of it is located within; X'_t is a vector of covariates aggregated at the tract level (terrain variables and river density); δ_s is a border segment fixed effect and $f(loc_t)$ is the RD polynomial, that controls for smooth variations along the geographic space.

Or, for the pixel-level estimations:

$$y_{pm} = \alpha + treatment_p D + X'_p \beta + f(loc_p) + \delta_s + \varepsilon_{pm} \quad (3.2)$$

with analogous definitions, except that $treatment_p$ takes value 1 if at least 95% of the pixel is inside the District's area, 0 if no more than 5% is outside.

The RD approach requires that all relevant factors other than treatment vary smoothly at the discontinuity. In other words, defining y_1 and y_0 as potential outcomes under treatment and control, $E[y_1|latitude, longitude]$ and $E[y_0|latitude, longitude]$ must be continuous

at the District's border. I examine this hypothesis in Table 1, testing for differences in terrain characteristics and river density. Since geographic data are spatially correlated, all regressions in this table, as well as in most tables in the paper, include two kinds of standard errors: clustered at the municipality-level in parentheses and with Conley (1999)'s adjustment for spatial correlation of an unknown form in brackets. The estimates show that in the narrower bands (12.5, 10 and 7.5 km), the samples are indeed balanced. Although terrain ruggedness is statistically different between subsamples in some cases, this point estimate is quite small considering that the index is measured in percentage points, so its theoretical range is from 0 to 100.

In order to adequately identify the treatment effect it is important to correctly adjust the polynomial so that nonlinear variations along the border are not mistaken for discontinuous effects. Following Dell (2010), I tested multiple specifications for the polynomial. Since the running variable is two-dimensional (latitude and longitude), I used polynomials of order up to 3 in geographical coordinates⁴. However I found that collapsing the running vector to a single dimension (ie, measuring the distance from the border)⁵ and adding fixed effects for border segments produced more stable estimates. Additionally considering that controlling for high-order polynomials might lead to poor estimates (GELMAN; IMBENS, 2014), I will in most cases use samples within 12.5, 10 and 7.5 km from the border and control for polynomials of up to 1st order.

⁴ For example, the cubic polynomial in longitude (x) and latitude (y) is: $x^3 + y^3 + x^2y + xy^2 + x^2 + y^2 + xy + x + y$.

⁵ This does not require any additional assumptions, since we are merely measuring the Euclidian distance from a point (the observation) to a line (the border). Therefore, distance is a deterministic function of the ordered pair (latitude, longitude)

Table 1 – Balancing tests

Balancing Tests – RDD estimations with linear polynomials															
Sample within :	Sample within :														
	<25 km from Border			<15 km from Border			<12.5 km from Border			<10 km from Border			<7.5 km from Border		
	Treatment			Treatment			Treatment			Treatment			Treatment		
Panel A : Census Tracts															
Altitude (m)	-25	(69)	[51]	-21	(63)	[55]	-23	(58)	[56]	-56	(57)	[55]	-67	(55)	[60]
Slope (degrees)	-2.0	(1.0)*	[0.8]***	-1.6	(1.2)	[1.0]	-1.7	(1.6)	[1.1]	-0.8	(1.9)	[1.3]	-0.8	(2.0)	[1.5]
Ruggedness (%)	-0.19	(0.07)***	[0.05]***	-0.17	(0.08)**	[0.06]***	-0.17	(0.10)	[0.07]***	-0.08	(0.11)	[0.06]	-0.04	(0.11)	[0.07]
River density (m/km2)	6	(171)	[181]	45	(228)	[212]	2	(226)	[205]	-185	(216)	[198]	-199	(264)	[255]
Observations	250			141			118			98			79		
Panel B : Pixels (approx. 1 sq km)															
Altitude (m)	-21	(48)	[5]***	-11	(42)	[6]*	-7	(40)	[7]	-7	(37)	[7]	-1	(29)	[8]
Slope (degrees)	0.1	(0.6)	[0.1]	-0.5	(0.7)	[0.1]***	-0.8	(0.7)	[0.2]***	-1.0	(0.7)	[0.2]***	-0.9	(0.7)	[0.2]***
Ruggedness (%)	-0.02	(0.06)	[0.1]**	-0.06	(0.06)	[0.01]***	-0.08	(0.06)	[0.01]***	-0.09	(0.07)	[0.02]***	-0.07	(0.06)	[0.02]***
River density (m/km2)	-35	(30)	[22]	-27	(37)	[27]	-29	(39)	[30]	-32	(51)	[34]	12	(63)	[40]
Observations	14861			9555			8057			6529			4904		

Note: Each line reports estimates of the RD coefficients with linear polynomials. The unit of observation is the Census Tract for data in Panel A and pixels of 30 arc-second resolution (1 sq. km) in Panel B. Standard errors clustered at the municipality are in parentheses, and Conley's in brackets. The first column includes observations not more than 25 km away from the District's Border, and then the following columns do the same for 15, 12.5, 10 and 7.5 km respectively. *, ** and *** denote respectively significance at the 10%, 5% and 1% level.

Figure 2 – Household Income

3.4 Estimation Results

Table 2 reports the main results for contemporary development outcomes. The RD graphs⁶ for the same regressions are shown in Figures 2 and 3. Results indicate that the District has a strong effect of about 45-69% in Household Income. Results for Adult Literacy are quite stable, although not always significant, indicating an effect of 18-28 percentage points. Using Nighttime Lights as a proxy for local economic development (Table 3, Figures 4 and 5) also lead to positive results for the treatment, although only significant if we consider Conley's standard errors and in some of the specifications. A pixel inside the former District's area is on average 18% brighter and is 3.6% more likely to have any light in it. For robustness checks, alternative specifications are reported in the Appendix: Tables 11 and 12.

⁶ All RD graphs in the paper show the independent variable after controlling for covariates and border fixed effects.

Figure 3 – % Adult Literacy

Figure 4 – $\log(1 + \text{Luminosity})$

Table 2 – Development Outcomes - Baseline Specifications

2010 Census Data		
Dependent variable:	Linear Polynomial in Distance	
	Log(Household Income)	% Adult Literacy
Sample within:	12.5 km from Border	
Treatment	0.32 (0.18)* [0.17]*	15.0 (10.6) [10.1]
Observations	109	109
Sample within:	10 km from Border	
Treatment	0.45 (0.20)** [0.20]**	18.2 (12.2) [10.9]*
Observations	93	93
Sample within:	7.5 km from Border	
Treatment	0.69 (0.19)*** [0.23]***	28.3 (11.8)** [11.4]**
Observations	76	76
Geo. Controls	Yes	Yes
Border FE	Yes	Yes
Municipality cluster	Yes	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

All regressions include geographic controls (terrain and river density), border FE and linear polynomials in distance.

Table 3 – Development Outcomes II - Baseline Specifications

	Light Density	
	Linear Polynomial in Distance	
Dependent variable:	Log(1 + Luminosity)	Luminosity Dummy
Sample within:	12.5 km from Border	
Treatment	0.12 (0.24) [0.06]**	0.021 (0.048) [0.012]*
Observations	8057	8057
Sample within:	10 km from Border	
Treatment	0.12 (0.23) [0.06]*	0.021 (0.046) [0.013]
Observations	6529	6529
Sample within:	7.5 km from Border	
Treatment	0.13 (0.20) [0.07]*	0.020 (0.041) [0.015]
Observations	4904	4904
Geo. Controls	Yes	Yes
Border FE	Yes	Yes
Municipality cluster	Yes	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

All regressions include geographic controls (terrain and river density), border FE and linear polynomials in distance.

Figure 5 – Luminosity Dummy

4 Channels of Persistence

This chapter uses different kinds of data in order to investigate how the historical treatment might be causing the positive effects found in Chapter 3. Section 4.1 uses further Census variables to investigate whether the degree of urbanization might be generating those outcomes. Section 4.2 evaluates whether different intensities in slave labor might explain the reduced form effect. Section 4.3 evaluates through Census data from the 19th century if there have been persistent differences in human capital. Finally, Section 4.4 investigates the provision of a public good, associated with market access: road networks. To do that I combine contemporary road location data with additional historical maps to see how road provision evolved since colonial times.

4.1 Urbanization

The distribution of population and economic activity in space might be affected by locational advantages (natural resources, proximity to other markets, climates suitable to agriculture) or agglomeration effects, whether derived from increasing returns to scale as in [Krugman \(1991\)](#) or from externalities like in [Glaeser et al. \(1992\)](#). Some empirical papers provide evidence of persistence in spatial distribution even after severe population shocks ([DAVIS; WEINSTEIN, 2002](#); [MALONEY; CAICEDO, 2016](#)), showing the importance of natural endowments. Others, such as [Bleakley e Lin \(2012\)](#) and [Severnini \(2014\)](#) show that the distribution of economic activity persists even after the initial advantages have disappeared or become obsolete, rendering evidence in support of agglomeration effects. Since, as discussed in Section 2.1, diamond production has long ceased to be a major economic activity in the study area, finding evidence that urbanization is a relevant channel of persistence in this case would necessarily arise from agglomeration effects. I try to shed light on this issue by investigating whether treated areas are more urbanized today, according to data from the 2010 Census. Table 4 shows that census tracts in the former District's area are more likely to be classified as urban and are more densely

populated¹. Also, households within them have more access to several public utilities typically associated with cities, such as water supply and electricity, and waste and sewage collection. They are also more likely to be located in paved streets, with public lights and without open sewers (ie, with sanitation).

The results in this section are reinforced by historical evidence that circulation across the District's border was limited during its existence². Therefore, anyone who wanted to take advantage of the agglomeration economies and locational advantages inside the demarcation were likely to choose to live in the District.

¹ Results for demographic density are similar if the sample is restricted to urban tracts.

² In addition to the aforementioned presence of soldiers in the gates, Santos (1976, p. 187) points out that after 1782 crossing the District's border required a passport and documents proving that the person had some business or issue to attend in a specific destination. Also, an outside observer wrote in his diary that "close to the *arraial* [Paraúna] there is an outpost where a corporal controls passports. This is the beginning of the Diamond District." (SILVA et al., 1997, p. 265).

Table 4 – Urbanization and Public Services

2010 Census Data									
Dependent variable:	Urban	% Water	% Sewage Collection	% Waste Collection	% Electricity	% Street Light	% Paved Road	% No Open Sewer	Demographic Density
Sample within:	12.5 km from Border								
Treatment	19.7 (19.6) [20.9]	17.6 (19.1) [17.3]	19.5 (19.1) [19.7]	38.6 (19.3)* [18.1]**	8.4 (3.8)** [5.2]	27.2 (16.0) [20.1]	39.4 (14.8)** [18.4]**	24.3 (15.3) [20.0]	1230 (513)** [512]**
Observations	118	109	109	109	109	109	109	109	116
10 km from Border									
Treatment	35.4 (18.6)* [21.5]	25.5 (15.8) [17.0]	35.1 (20.0) [19.0]*	47.0 (18.4)** [18.2]**	11.0 (3.4)*** [6.1]*	38.1 (17.1)** [20.1]*	51.0 (14.1)*** [19.1]***	34.5 (16.8)* [19.8]*	1771 (522)*** [595]***
Observations	98	93	93	93	93	93	93	93	97
7.5 km from Border									
Treatment	68.5 (20.3)*** [20.1]***	42.7 (11.7)*** [17.1]**	53.0 (12.2)*** [18.6]***	67.0 (11.9)*** [19.7]***	12.9 (3.7)*** [6.6]*	65.8 (19.5)*** [19.0]***	78.4 (15.5)*** [18.6]***	66.3 (19.1)*** [19.2]***	1978 (568)*** [476]***
Observations	79	76	76	76	76	76	76	76	79
Geo. Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality cluster	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors in parentheses clustered at the municipality level. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. All regressions include geographic controls (terrain and river density), as well as border segment fixed effects and linear polynomials in distance. Urban is a dummy variable which takes value 1 if the census tract is classified as urban by IBGE. Demographic density is measured as the number of people per km^2 .

Each of the other variables is the proportion of households with access to that service in the census tract.

4.2 Slavery

In this section I investigate whether slave labor intensity could be related to the long-run differences in economic development found in Section 3.4. A substantial body of literature has shown that slavery and, more generally, forced labor are detrimental to development long after having been abolished ³. Since we have seen that treated observations are more developed in the long-run and that the Crown actively tried to limit diamonds extraction by controlling the number of slaves employed in it, this is potentially an important channel of transmission.

To investigate that, I use microdata from lists of the population of the Province of Minas Gerais in the 1830s (NPHEU-UFMG, 2010), right at the end of the District's existence. The data set is organized by community and household, and contain information such as status (free, slave or ex-slave), occupation, age and race. The dependent variable to be tested is a dummy that takes value 1 if the individual was a slave. Table 5 shows that a random individual was 16 to 25% more likely to be a slave if he or she lived inside the District. Therefore, despite official attempts to limit slave labor in diamond extraction, slaves were still a larger proportion of the population in treated areas. This is not surprising if we consider that the authorities could never fully extract the surplus from diamonds, and that in this context a slave was an important asset (they were, after all, employed in all kinds of manual labor, not only diamond-mining). Hence, it seems that the wealth that stayed in the diamond-producing area was at least partially invested in slaves.

I also used data from the first national Census (Diretoria Geral de Estatística – DGE, 1874?) to track how slavery intensity evolved after the District ended. These data are crucial since it was the only official census to count slaves (its successor took place in 1890, 2 years after slavery was abolished). Unfortunately, though, the most disaggregated level is the *paróquia* so I could only compare the percentage of slaves in each subsample. Table 6 reports mean tests for 4 different samples and we can see there are no statistically significant differences across subsamples.

For comparison purposes, while the proportion of slaves relative to the general population

³ e.g., Nunn (2007), Dell (2010), Acemoglu, García-Jimeno e Robinson (2012), Bruhn e Gallego (2012)

Table 5 – Slavery in 1830

Effect on Slave dummy (1830 microdata)	
Panel A: No Polynomial	
Treatment	0.16 (0.07)*
Panel B: Linear Polynomial in Distance	
Treatment	0.25 (0.003)***
Border FE	Yes
Border segments	4
Parish clusters	11
Controls	Yes
Observations	23854

Note: Controls: age, altitude, slope, ruggedness and river density. Standard errors clustered at the Parish level are in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels respectively.

was on average 16% for both 1872 subsamples, in the 1830 data the proportions for treated and untreated locations were 47% and 23% respectively. Therefore, the evidence suggests that in the 40 years following the end of the District, slave labor declined in the region as a whole but a lot more sharply in treated villages, becoming roughly equal 16 years before abolition. Therefore, it seems unlikely that slavery is driving the reduced form results. Either way, since it was more intensive in treated villages, following the literature in the long-run effects of slavery, we should expect them to be poorer today.

Table 6 – Slavery in 1872

	Sample within:											
	60 km			45 km			30 km			15 km		
	Inside	Outside	s.e.	Inside	Outside	s.e.	Inside	Outside	s.e.	Inside	Outside	s.e.
1872 Slave proportion (%)	16.0	16.0	(3.2)	16.0	16.3	(3.4)	16.0	15.4	(4.1)	16.0	14.9	(3.9)
Observations	4	16		4	11		4	6		4	4	

Note: The unit of observation is the Parish (Parochia), the level below municipalities at the 1872 census. Standard errors allowing for unequal variances across groups are in parentheses. ***, ** and * denote, respectively, significance at the 1%, 5% and 10% levels.

4.3 Human Capital

Another possible channel of transmission is human capital, since the initial presence of diamonds might have attracted a specific profile of immigrants. Also, the District was more urbanized and the Crown had to establish a substantial bureaucratic apparatus to control the resource. It is possible that this initial human capital shock was transmitted to subsequent generations and this could be partially responsible for the different contemporary outcomes.

I try to address this question by analyzing literacy rates in the 1872 and 1890 censuses ([Diretoria Geral de Estatística – DGE, 1874?](#); [Diretoria Geral de Estatística – DGE, 1898](#)). Both data are available at the *paróquia* level and in 1872 it represents the proportion of literacy among non-slaves. Mean tests are reported in [Tables 7](#) and [8](#), and the results are fairly stable across different samples and over time. These estimates suggest a treatment effect of about 10 percentage points in literacy rates, even decades after the District had ceased to exist. If we compare these results with the contemporary ones in [Tables 2](#) and [11](#), we can see that this difference is very persistent through time.

Considering the discussion in [Section 4.1](#), we can speculate that this path-dependence might be partially responsible for the externalities arising from agglomeration effects.

Table 7 – Literacy in 1872

	Sample within:											
	60 km			45 km			30 km			15 km		
	Inside	Outside	s.e.	Inside	Outside	s.e.	Inside	Outside	s.e.	Inside	Outside	s.e.
1872 Literacy rate (%)	19.5	10.9	(3.7)*	19.5	11.4	(3.9)	19.5	11.7	(4.2)	19.5	11.7	(5.0)
Observations	4	16		4	11		4	6		4	4	

Note: The unit of observation is the Parish (Parochia), the level below municipalities at the 1872 census. Standard errors allowing for unequal variances across groups are in parentheses. ***, ** and * denote, respectively, significance at the 1%, 5% and 10% levels.

Table 8 – Literacy in 1890

	Sample within:								
	40 km			30 km			10 km		
	Inside	Outside	s.e.	Inside	Outside	s.e.	Inside	Outside	s.e.
1890 Literacy rate (%)	17.8	9.6	(3.8)*	17.8	9.9	(4.0)*	20.8	11.2	(4.1)**
Observations	10	16		10	10		8	4	

Note: The unit of observation is the Parish (Parochia), the level below municipalities at the 1890 census. Standard errors allowing for unequal variances across groups are in parentheses. ***, ** and * denote, respectively, significance at the 1%, 5% and 10% levels.

4.4 Infrastructure

Another possible channel that could be driving the results is physical infrastructure. To test this hypothesis I will focus on a specific public good that might lead to different development paths through market access: road networks. In order to test whether its provision is different under treatment, I will use data from different sources which allows us to see how it evolved over time. For contemporary provision I use vector data on road locations from (IBGE, 2010). Georeferencing [Mappa... \(18--\)](#), an early-19th century⁴ map of an area that includes the District, and municipal maps from 1927⁵ available in [Minas Geraes - Serviço de Estatística Geral \(Secretaria de Agricultura\) \(1927\)](#), I was also able to generate analogous data for these other points in time. The 1800s map is shown in Figure 11 and the ones from 1927 are available online⁶. The 1927 maps include 3 kinds of road: automobile roads (*estrada de automóvel*, with only 2 short stretches in the sample), cart roads (*estrada carroçável*) and pathways (*caminhos*, the vast majority). The map from the 1800s does not explain what exactly its roads are, but judging from the early 20th century map it is reasonable to assume they are all *caminhos*. From these continuous data I measured road density per pixel in meters per km^2 , and estimated treatment effects through spatial RD.

Table 9 and Figure 6 show it is hard to say there is any effect on contemporary roads. On the other hand, estimates presented in Table 10 and Figure 7 suggest this was not the case when the District still existed. Although imprecisely estimated, the effect is consistently negative and marginally significant in the narrowest sample. Although somewhat surprising given the District's importance, this effect is not hard to explain since it is very likely that colonial authorities limited road building inside the District to avoid smuggling (as we have seen before, for most of the time crossing the border was only allowed through 6 guarded outposts). For the 1927 data in Table 10 and Figure 8, the treatment effect is more precisely estimated and even stronger.

⁴ The exact date of this map is unknown, but since it shows the District, it cannot be more recent than 1830.

⁵ Only parts of 4 1920s municipalities were located within 15 km of the District's border: Conceição, Curvello, Diamantina and Serro.

⁶ <http://www.albumchorographico1927.com.br/>

Table 9 – Contemporary Infrastructure Provision - Baseline Specifications

Road Density (m per sq. km)	
	2010 Data
Polynomial	Linear in Distance
Sample within:	12.5 km from Border
Treatment	23.4 (12.1)* [14.4]
Observations	8057
Sample within:	10 km from Border
Treatment	11.3 (18.0) [16.5]
Observations	6529
Sample within:	7.5 km from Border
Treatment	-9.7 (23.1) [19.3]
Observations	4904
Geo. Controls	Yes
Border FE	Yes
Municipality cluster	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

All regressions include geographic controls (terrain and river density), border FE and linear polynomials in distance.

Put together, these estimations suggest the Portuguese underprovided transport infrastructure in the District to enhance control over diamonds, and it would take more than a century after Independence for the area to catch up to the surroundings. Over time, however, road provision inside the former District seems to be catching up, probably because there was a suppressed demand due to its higher urbanization rate. It is important to notice that Brazil's highways were built after 1927, so it is likely that 20th century policy-makers identified this suppressed demand for transport infrastructure and directed efforts to provide it.

Figure 6 – 2010 Road Density

Figure 7 – 1820 Road Density

Table 10 – Historical Infrastructure Provision

Road Density (m per sq. km) - Historical Data		
	1820 Pathways	1927 Roads
Polynomial	Linear in Distance	
Sample within:	12.5 km from Border	
Treatment	-4.8 (15.0) [12.2]	-59.1 (22.7)** [15.0]***
Observations	7511	8057
Sample within:	10 km from Border	
Treatment	-15.9 (17.1) [13.8]	-64.0 (22.1)*** [16.4]***
Observations	6137	6529
Sample within:	7.5 km from Border	
Treatment	-26.3 (27.3) [16.6]	-26.0 (26.8) [18.6]
Observations	4639	4904
Geo. Controls	Yes	Yes
Border FE	Yes	Yes
Municipality cluster	Yes	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

All regressions include geographic controls (terrain and river density), border FE and linear polynomials in distance.

Figure 8 – 1927 Road Density

5 Concluding Remarks

This paper explores a probably exogenous source of institutional variation in the Diamond District of colonial Brazil to estimate its effects on long-run development and analyze potential channels of persistence. I estimate that households inside the District's historical boundaries are at least 40% richer and that adult literacy rates are at least 15% higher. Using nighttime lights data as a proxy for local economic development, I show that 1 km^2 pixels inside the treated area are 3.6% more likely to have any light in them, and have 18% brighter lights on average. Then I investigate 4 possible channels of persistence, which allow me to test different theories of economic development: urbanization, human capital, slave labor and physical infrastructure.

I find that, even though the natural resource that made it attractive has long been exhausted, the areas inside the District are still more urbanized. This supports the idea that agglomeration economies might indeed be an important mechanism in explaining path-dependence in the spatial distribution of population and economic activity. I could not test if this could be due to increasing returns to scale, but I do present evidence that human capital is persistently higher among residents of the former District (suggesting that externalities might be playing a role).

I also document that slavery was more intense inside the District at first, which is consistent with the idea that treated areas were richer since slaves were an important asset in this society. This difference, however, had already disappeared only 4 decades after the District's end. Therefore, it does not seem that this channel is relevant in this context. If it did have any contemporary effects it would probably attenuate the reduced form estimated effect, since slavery has been shown in the literature to cause underdevelopment.

Finally, I show evidence that road provision was originally lower inside the District, and it remained so even after a hundred years. These results are not present in contemporary data, suggesting that the higher concentration of population and economic activity pressed for more provision of this public good during the 20th century.

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Appendix A

Table 11 – Development Outcomes - Alternative Specifications

2010 Census Data		
Dependent variable:	No polynomial	
	Log(Household Income)	% Adult Literacy
Sample within:	12.5 km from Border	
Treatment	0.09 (0.10) [0.08]	11.7 (7.3) [5.9]*
Observations	109	109
Sample within:	10 km from Border	
Treatment	0.15 (0.12) [0.10]	12.7 (8.1) [7.4]*
Observations	93	93
Sample within:	7.5 km from Border	
Treatment	0.15 (0.11) [0.10]	11.3 (8.9) [8.2]
Observations	76	76
Geo. Controls	Yes	Yes
Border FE	Yes	Yes
Municipality cluster	Yes	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

All regressions include geographic controls (terrain and river density) and border FE.

Table 12 – Development Outcomes II - Alternative Specifications

Light Density		
No polynomial		
Dependent variable:	Log(1 + Luminosity)	Luminosity Dummy
Sample within:	12.5 km from Border	
Treatment	0.17 (0.13) [0.03]***	0.036 (0.027) [0.005]***
Observations	8057	8057
Sample within:	10 km from Border	
Treatment	0.18 (0.14) [0.03]***	0.038 (0.027) [0.006]***
Observations	6529	6529
Sample within:	7.5 km from Border	
Treatment	0.18 (0.16) [0.03]***	0.036 (0.031) [0.007]***
Observations	4904	4904
Geo. Controls	Yes	Yes
Border FE	Yes	Yes
Municipality cluster	Yes	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. All regressions include geographic controls (terrain and river density) and border FE.

Table 13 – Contemporary Infrastructure Provision - Alternative Specifications

Road Density (m per sq. km)	
	2010 Data
Polynomial	No
Sample within:	12.5 km from Border
Treatment	63.1 (11.3)*** [7.4]***
Observations	8057
Sample within:	10 km from Border
Treatment	62.1 (10.7)*** [8.4]***
Observations	6529
Sample within:	7.5 km from Border
Treatment	57.5 (8.4)*** [9.3]***
Observations	4904
Geo. Controls	Yes
Border FE	Yes
Municipality cluster	Yes

Note: Standard errors clustered at the municipality level and according to Conley are in parentheses and brackets, respectively. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. All regressions include geographic controls (terrain and river density) and border FE.

Appendix B

Figure 9 – Mapa da Demarcação Diamantina - 1776

Figure 10 – Mapa da Demarcação Diamantina acrescentado ate o Rio Pardo - 1784

Figure 11 – Mapa da Freguesia de Vila do Príncipe - c.1820