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Regional borders, commuting and transport network integration

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Regional Borders, Commuting and Transport Network Integration

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Regional Borders, Commuting and Transport Network Integration

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December 27, 2020

Abstract

I study how and why economic activity varies around regional borders. Spatial quasi-experimental variation around French departmental borders reveals discontinuous commuting and residential patterns. To tackle the endogenous border placement problem, I exploit a geometric border design proposed during the French Revolution. I then calibrate a spatial quantifiable general equilibrium framework to structurally match the quasi-experimental estimates. The commuting and residential discontinuities are well explained by a 7km bilateral distance penalty when crossing regional borders, which is the consequence of the decentralized planning and development of local transport networks. Policy simulation shows that integrating local transport networks leads to a 11.7% average growth in real per capita residential income.

Keywords: Border, Commuting, Discontinuity, Transport network, Decentralization.

JEL classification: R12, R42, O18.

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1 Introduction

With 9.7 million kilometers in length defining 49,572 jurisdictions worldwide, regional borders are one of the most common features of today's economic geography.[1] Typically operating in homogeneous socio-economic environments without border controls, these borders are barely visible to the millions of daily cross-border commuters (in the U.S., Germany and France alone, 13.5 million commuters cross regional borders).[2] Yet, regional borders delineate jurisdictions which are often sole responsible for the development of local transport networks – a setting which does not guarantee local network integration. Given the well-established role of transport networks in shaping regional economic geographies, such borders may then be less innocuous than first thought.[3] Any spatial mismatch in local networks may lead to large costs for the economy as a whole. For instance, frictions at regional borders are likely to affect the benefits of commuting openness for local labor markets (Monte, Redding, and Rossi-Hansberg, 2018), or likely to induce large opportunity costs when considering a value of time associated with commuting in the range of $20 to $40 an hour (Brownstone and Small, 2005).

Using spatial quasi-experimental variation around French departmental borders, this paper establishes robust evidence that commuting flows, labor catchment areas and local residential masses vary discontinuously at regional borders. To tackle the problem of endogenous border placement, I exploit a geometric border design proposed during the French Revolution. Then, combining a structural framework to the natural border experiment, the paper shows that the observed discontinuities at regional borders can be explained by the non-integration of local transport networks – a consequence of their decentralized planning and development. Finally, simulation results indicate that integrating such transport networks likely leads to large average real income gains.

The empirical analysis starts by using a spatial regression discontinuity (RD) estimator on municipal data to document commuting and residential location choice patterns around regional borders (see, among others, Hahn, Todd, and der Klaauw, 2001; Lee and Lemieux, 2010; Calonico, Cattaneo, and Titiunik, 2014; Ehrlich and Seidel, 2018). Comparing a municipality at a regional border to its neighbor on the other side of the border, I estimate a discontinuity in the likelihood to commute across the border of 65 percentage points (using both parametric and non-parametric

[1] In this paper, I consider as *regional*, all administrative borders *between* the national and the municipal levels (e.g, US States, European NUTS2 and NUTS3 regions, Chinese Provinces and Prefectures, etc.). *Source:* Authors' own calculation based on the 2019 Database of Global Administrative Areas (GADM). See: `https://gadm.org/`.

[2] *Source:* 5.3 millions across US State borders, Census Bureau, 2011; 3.6 million across Länder borders, Regionaldatenbank, 2018; 4.6 million across Département borders, INSEE, 2010.

[3] See, among others, Baum-Snow (2007); Duranton and Turner (2012); Faber (2014); Tombe and Zhu (2015); Fretz, Parchet, and Robert-Nicoud (2017); Caliendo, Parro, Rossi-Hansberg, and Sarte (2018).

approaches). This naturally impacts the labor catchment possibilities of jurisdictions with large labor markets. On average, the number of workers commuting to regions with large labor markets drops discontinuously by 121 at the border. I further show that residential density also jumps at regional borders. Municipalities at regional borders on the side with the larger labor market display an average excess residential mass of 79 residents (equivalent to 10.2% of the average local population).[4]

To control for endogenous border placement – an issue often over-looked in the spatial border literature – I exploit a geometric border plan proposed during the French Revolution which inspired the final design of French departmental borders. The geometric design was proposed by the Sieyès committee in 1789, and recommended to divide the country geometrically into 81 equal sized departments (squares of 18 league per side, approx. 100km). I use the distance to the regional border under the geometric delineation in an Instrumental Variable (IV) approach to predict the distance to the observed regional border. The results are qualitatively similar when using the standard and the IV spatial RD estimators.

I hypothesize that the lack of integration of local transport networks explains the commuting and residential discontinuities observed at regional borders. In France, 71% of all road kilometers are administered at the department level, and no institutional setting insures the proper integration of transport networks. To test this hypothesis, I first show – parametrically and non-parametrically – that travel distance on the road network to the centroid of a regional jurisdiction drops discontinuously at the border. Reaching the centroid of a department takes on average 7km more when starting just on the other side of the border, as opposed to just inside the jurisdiction.[5] I further test for the spatial distribution of other local public services which are departmental prerogatives (i.e., secondary schools and fire departments). I also test for variation in travel distances around local borders which are not associated with local transport network provision (i.e., Functional Urban Areas).[6] Overall, these additional analyses support the hypothesis that the decentralized provision of transport networks is, at least, a major determinant of the discontinuous commuting and residential patterns observed.

Furthermore, I test whether a 7km discontinuity alone in travel distances is sufficient to rationalize the commuting and residential discontinuities observed. To do so, I structurally estimate commuting and residential density patterns in a spatial quantifiable general equilibrium framework à la Monte et al. (2018). I use the results from the spatial regression discontinuity estimator as moments in a Generalized Method of Moments (GMM) approach. This structural approach con-

[4]The average municipality within 10km of a departmental border hosts 779 residents (see descriptive statistics in Table 7, Appendix A).

[5]Bandwidths of 500m and 1km are used.

[6]Functional Urban Areas (FUA) are the European equivalent of the US Metropolitan Statistical Areas (MSA).

firms that a 7km distance penalty when crossing regional borders best explains the discontinuities observed.

Finally, I study the cost and benefits of integrating local road networks using a spatial quantifiable general equilibrium framework à la Monte et al. (2018). As in the new economic geography literature, the framework supposes gains from agglomeration that arise from the love of varieties and increasing returns to scale. I complement the framework with two key ingredients. First, I suppose a central institution in charge of integrating local transport networks. Costs of integration are financed by a nation-wide head tax levied on all workers. Such non-distortionary tax setting allows (i) a direct exogenous matching from a tax rate to an increased local transport network integration, and (ii) the possible redistribution of the policy gains in an intuitive manner. Second, in line with the residential discontinuity estimator, I introduce a mechanism under which available residential floor space is endogenously determined by local residential income. Using precise geo-localized data on commutes, residential and workplace densities, and local transport networks, I complete the calibration of the model to match the main characteristics of the French economic geography in 2010. I then use this framework to run a cost-benefit analysis of integrating the local transport networks. Policy simulation results indicate that removing the penalty leads to a 11.7% average growth in local residential income. Especially, residential per capita real income at the wide periphery of Paris' metropolitan area, as well as local workplace income within this metropolitan area, increase.

The remainder of this paper is organized as follows. After discussing the related literature in Section 2, I present the institutional background and descriptive evidence in Sections 3 and 4, respectively. Before documenting commuting and residential location choice patterns around local borders using quasi-experimental estimators in Section 6, I detail the theoretical framework in Section 5. I study how decentralization affects cross-border travel distances in Section 7. In Section 8, I simulate the integration of regional transport networks, and analyze its consequences on the French economic geography. Finally, Section 9 concludes.

2 Literature

The study of discontinuous effects at national and regional borders is not new. A vast literature has shown that national borders act as spatial barrier to various economic outcomes.[7] The border

[7] I distinguish this literature from a second stand of the literature that has used borders as an exogenous source of policy variation in space. For instance, Dube, Lester, and Reich (2010) exploit differences in minimum wage levels across US State border to study their effects on earnings and employment. Kumar (2018) looks at Texas's interstate borders to study how limitations on home equity borrowing affect the likelihood of mortgage default. Egger and Lassmann (2015), Erhardt and Haenni (2018), and Eugster and Parchet (2019) exploit language differences at

puzzle literature in international trade highlights the presence of a border effect in trade flows at national borders (McCallum, 1995; Obstfeld and Rogoff, 2001; Anderson and van Wincoop, 2003; Evans, 2003). Ahlfeldt, Redding, Sturm, and Wolf (2015) show how the Berlin wall acted as a barrier to agglomeration and dispersion forces. Beerli, Ruffner, Siegenthaler, and Peri (2018) document the effect of opening a national border to cross-border commuting on labor market characteristics. Pinkovskiy (2017) reveals discontinuities in growth rates at national borders.

The literature has also looked at within-country border effects. Courant and Deardorff (1992) highlight the role of within country trade as a determinant of international trade patterns. Wrona (2018) reveals the presence of an intranational border effect on trade flows using regional Japanese data. Using municipal merger reforms in Germany, Egger, Koethenbuerger, and Loumeau (2017) study how the removal of local borders concentrates economic activity locally. Felbermayr and Tarasov (2015) model the spatial provision of transport infrastructure around inter- and intranational borders by non-cooperative governments, and highlight how underprovision of infrastructure may contribute to solve the trade border puzzle. Combes, Lafourcade, and Mayer (2005) emphasize the role of networks across administrative borders as determinants of trade flows.

Relative to the inter- and intranational border literature, the present paper innovates in three respects. First, it is the first to provide quasi-experimental evidence of a non-trade border effect at the intranational level (i.e., even under common language, taxes, social norms, etc). Second, the estimation of the travel distance gap at regional borders induced by the decentralized provision of transport infrastructure is novel. Third, this paper offers an Instrumental Variable (IV) strategy based on a unique historical setting to account for possible non-random border placement, an issue that has mostly been ignored in previous research.

This paper also relates to the emerging literature applying research methodologies that combine structural quantitative techniques with quasi-random policy variations. Ahlfeldt et al. (2015) exploit the construction and the fall of the Berlin Wall as a source of exogenous variation to inform a quantifiable urban general equilibrium model. Chen, Liu, Suárez Serrato, and Xu (2018) combine quasi-experimental variation around notches and structural estimation to capture the complex effects of tax cuts on R&D investments in China.

Moreover, this paper relates to the literature on endogenous transport infrastructure around borders. Felbermayr and Tarasov (2015) study under-investment in transport networks around

Swiss cantonal borders to understand the role of culture and preferences in shaping nowadays economic geography. Using the fall of the Iron Curtain, Ehrlich and Seidel (2018) analyze the persistence effects of place-based policies. Holmes (1998) and Rohlin, Rosenthal, and Ross (2014) use cross-border variations to study firm location decisions. Coomes and Hoyt (2008) focus on tax evasion and avoidance, whereas Agrawal (2015) analyze tax competition across US State borders. Agrawal and Hoyt (2018) exploit tax differentials at US State borders within metropolitan areas to analyze the effect of local taxes on commuting patterns, and ultimately on welfare.

borders as national governments do not internalize the benefits from reductions in domestic transportation costs that accrue to foreign consumers. Sippel, Nolte, Maarfield, Wolff, and Roux (2018) and Christmann, Mostert, Wilmotte, Lambotte, and Cools (2020) present case studies investigating possible missing cross-border connections between European countries.

Additionally, this paper contributes to the urban economics literature highlighting the role of commuting in determining urban equilibrium characteristics,[8] by offering a natural experiment to further understand how commuting affects the location and growth of economic activity. This paper shows that transport network decentralization leads to regional borders acting as a barrier to commuting (by increasing the distance and duration of commutes), which, in turn, affects regional workplace employment, as well as residential location choices.

Finally, this paper relates to the literature on inefficiencies arising from decentralization. Following early works by Tiebout (1956) and Oates (1969), the local public finance literature has long argued in favor of decentralization as it allows individuals to "vote with their feet" and leads to more efficient local public finances. However, more recent studies have questioned the efficiency of a decentralized organization. For instance, given mobile and heterogeneous households, Calabrese, Epple, and Romano (2012) show that inefficiencies arising from decentralization and property taxation are substantial. Beyond the public finance literature, the experimental literature (e.g., van Huyck, Battalio, and Beil, 1990, 1991) highlights the inefficiencies arising from failure to coordinate among economic agents. Applying this framework to regional jurisdictions under a decentralized organization appears natural and helps rationalize the discontinuities in travel distances at regional borders observed in this paper.

3 Three facts about French departments

The current French administrative division is composed of three layers below the national one: 13 regions, 101 departments (including overseas), and 34,968 municipalities (as of March 2019). This paper focuses on the second administrative layer in mainland France. To study the regional border effect carefully, French departments offer three key advantages. First, their design was inspired by a geometric delineation of the country into 81 equal sized squares of 100km sides. Second, in most cases, departmental borders do not follow natural features such as rivers, mountains, etc. Finally, departments have little public finance autonomy. On the revenue side, more than 80% of their income is exogenously allocated by the central government. On the expenditure side, the level of service and benefit provision is subject to extensive mandates which strongly restrict – if

[8] See, among others, Alonso (1964); Mills (1967); Muth (1969); Lucas and Rossi-Hansberg (2002); Desmet and Rossi-Hansberg (2013); Behrens, Mion, Murata, and Suedekum (2017); Monte et al. (2018).

not, eliminate – regional differences. In what follows, I explain the mentioned advantages in more detail.

3.1 Fact 1: Inspired by an historical geometric border design proposal

French departments were created during the French Revolution. Before the Revolution, the French administrative division into provinces was particularly complex. Provinces differed greatly in size, administrative borders were not all precisely defined, and did not always match with local fiscal, religious or military jurisdictions. Consequently, in 1789, the newly created National Assembly decided to reform the national administrative division. A committee, lead by the abbé Sieyès, was formed to propose a partition of France into regional units. The committee recommended to divide the country geometrically into 81 equal sized departments (squares with sides of 18 league, approximately 100km, except for those cut by national boundaries). Each department was then to be further divided into nine equal sized units, which would again be divided into nine equal sized units. Given that the French population was mostly rural at the time, these last sub-units were expected to be of similar population size. Figure 1 displays a scan of the historical map defining this geometric division.[9]

Inspired by the geometric proposal, the division finally adopted by the assembly in 1790 kept the goal of partitioning the country into equal sized units, but departed from the pure geometrical approach.[10] The final size was chosen such that one could reach the departmental capital from any point on the border within 24 hours (by horse). Except for regions impacted by the evolution of France's territory over time, the division has barely changed until today. Figure 14 (Appendix B) shows the departmental borders as they are since 1964.

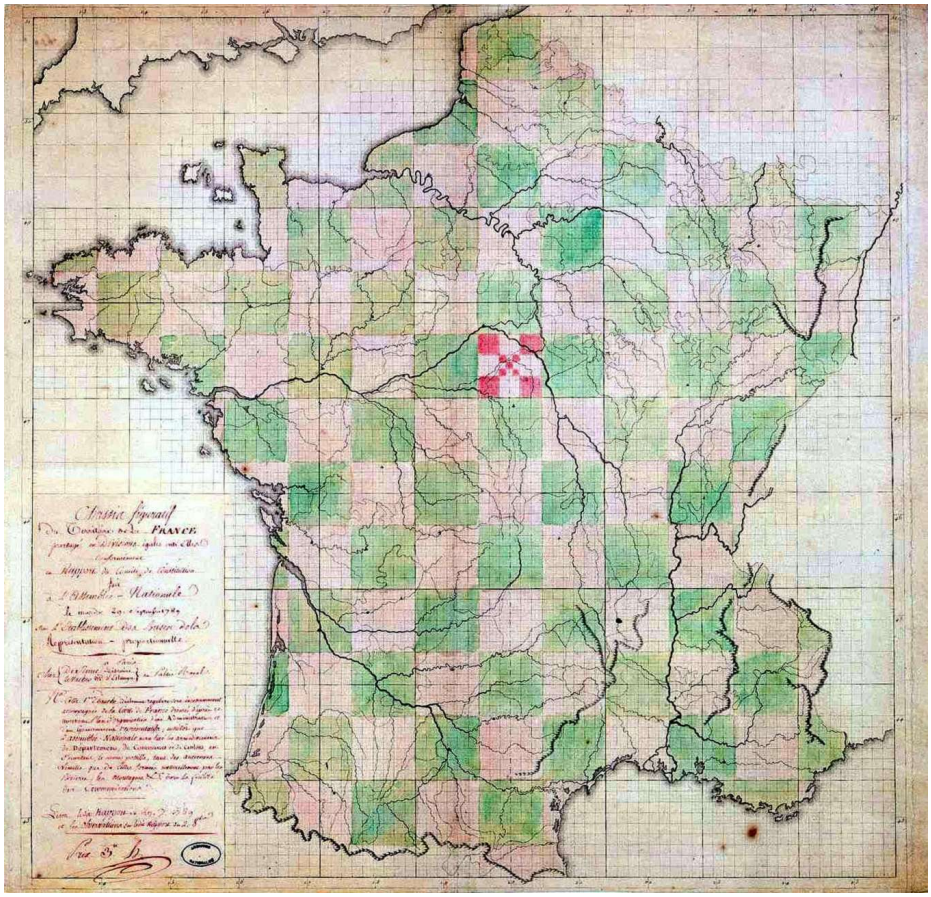
3.2 Fact 2: Limited overlap with natural features

A key concern when analyzing effects of regional borders is the possible overlap between border placement and natural features. Commuting across a border might be less likely, not because of a border per se, but because a natural feature makes it harder to cross the border. On this issue, the French case is particularly interesting to study. As mentioned above, the French National Assembly decided to design departmental jurisdictions such that they would all have a similar size and shape. This imposed strong limitations on border placement. Consequently, apart from a few exceptions (e.g., the Rhône in the South-East), departmental borders do not follow France's

[9] The absence of Corsica in the geometric division motivates the focus on mainland France in this paper.

[10] Figure 14 (Appendix B) shows the final departmental division adopted by the French National Assembly in 1790.

Figure 1: Geometric proposal by the Sieyès committee in 1789



Notes: Large green/white squares with sides of 18 league, approximately 100km, represent the proposed departmental division.

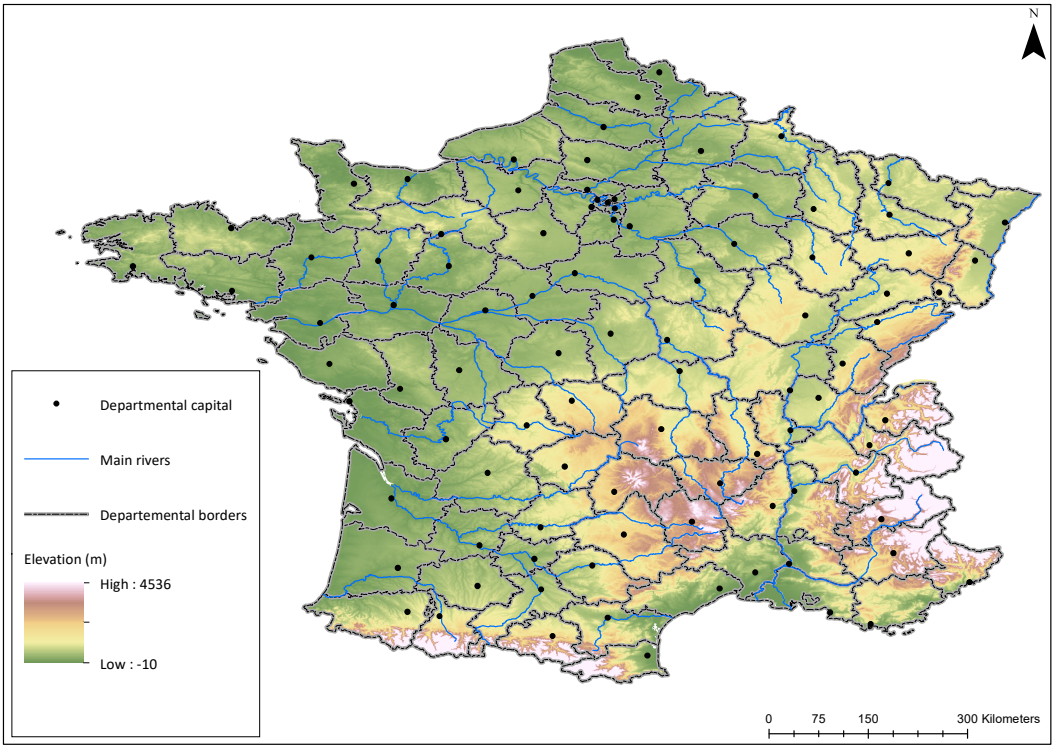
main natural features (i.e., main rivers and land elevation), as shown in Figure 2. To further control for non-endogenous border placement, I use the geometric proposal in an IV approach as detailed in Section 6. I also run robustness tests excluding all bilateral connection paths within 20km of a natural feature (i.e., river or mountain), a strategy also adopted in Black (1999) and Ehrlich and Seidel (2018). Overall, natural features appear to have little impact on the results.

Furthermore, the requirement that the local capital could be reached within one day by horse from any point in the department forced capitals to be centrally located within each jurisdiction, as shown in Figure 2. Hence, the special case of having capital cities located directly at regional border – which could be a source of bias when looking at economic activity close to regional borders – is a minor issue, if at all, in the present context.

3.3 Fact 3: Limited public finance autonomy

Departments are legally required to run a balanced budget, i.e., total revenues equal total spending. I retain this characteristic when modeling regional spending in Section 5. Based on the

Figure 2: Departmental borders and natural features



2016 official departmental budget data, Panel a of Table 8 (Appendix B) shows the departmental revenues, which come from mostly three sources in similar proportions: local taxes, transfers, and tax transfers. Out of the three, departments are only able to influence revenues from local taxes, mostly via the local land value tax which represent a little less than 20% of their total revenues. Overall, the rate of the local land value tax is inversely related to the tax base, i.e., the hypothetical rental value. Hence, even though local differences in the per capita amount paid do exist, these differences are minimal. To insure that local public finance differences across departments do not confound the results, I include border fixed effects in the analysis; hence, controlling for tax differentials at each border.[11] No significant changes in the results are observed.

Furthermore, French departments are locally competent on mostly four items: social programs, regional roads, secondary eduction and fire departments. The level of provision of each item is mandated by national rules. Hence, except for a more (or less) efficient administrative organization, departments have almost no leeway to influence these four items locally. Panel b of Table 8 (Appendix B) examines the total spending of the department using the 2016 official regional budget data. Social programs constitute the lion's share, i.e., 65%, of the departmental spendings. Even though spending on the remaining categories represent between 4% and 7% of the total spending, the amounts of spending on this items are far from negligible (i.e., between

[11] I also run a robustness check including the local rental value per m^2 to further account for differences in the tax base (Table 9 (Appendix B).

2.6 and 4.2 billion €). For instance, the total length of the road transport networks financed and administered by the departments constitute 71% of the sum of all road kilometers in France. Aside from regional road networks, secondary schools and fire departments are the only public service administered by the departments which may affect residential location choices and commuting flows. In the empirical exercise below, I test for a gap in fire stations, secondary schools and secondary pupil density around regional borders. Each of these outcomes appears to vary smoothly at regional borders. Moreover, note that given the use of border-specific fixed effects, any systematic difference in fire departments and secondary school characteristics is likely to be captured.

4 Descriptive evidence

After briefly describing the data used in this paper, this section provides descriptive evidence suggesting that regional borders affect surrounding economic activity.

Data

The data used in this paper come from the following sources.[12] All demographic and administrative data are provided by the National Institute of Statistics and Economic Studies (INSEE) for the year 2010. All geolocalized data (adminitrative borders and transport networks) are provided by the National Institute of Geographic and Forest Information (IGN) as of 2015, and processed using the geographic information system ArcGIS (esp., ArcGIS Network Solver). The map of the geometric border proposal by the Sieyès committee is provided by French National Archives (AN). Lastly, Chapelle and Eyméoud (2017) provide housing rents at the municipal level.

Table 7, in the Appendix A, shows simple descriptive statistics for municipalities within different bandwidths around local borders. Within 10km of a border, the average municipality hosts 779 residents and has an area of 16km^2. The average median yearly income amounts to €19,811; and housing rents are on average of €9.27 per m^2 and month. 89% of workers reside and work in the same regional jurisdiction.

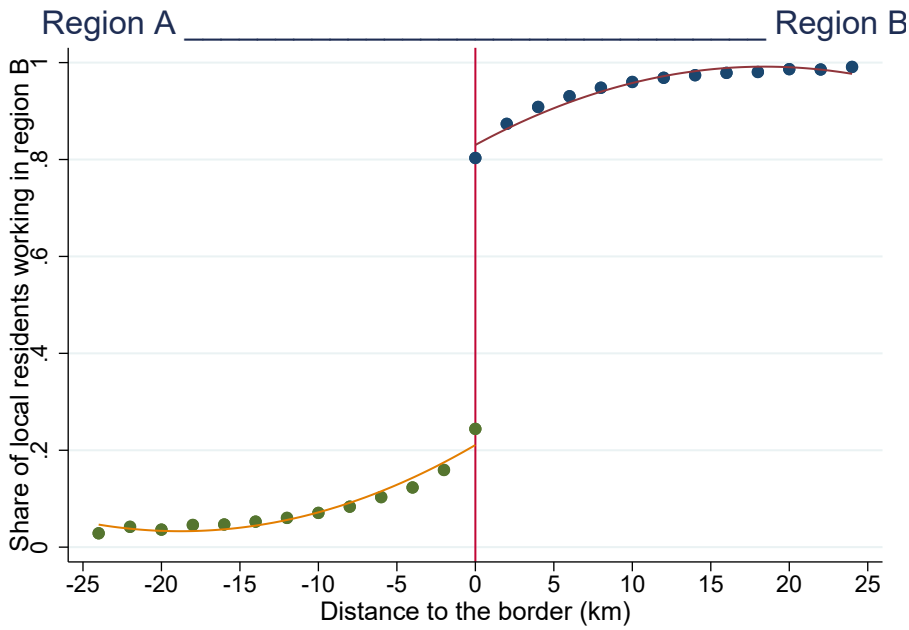
Cross-border commuting

I start by describing commuting flows around regional borders. Conditional on a destination department – which I generically label *region B* – Figure 3 shows the average share of local residents commuting to region B around the regional borders. Averages are taken over 2km bins

[12]Section A provides an in depth description of the Data.

when considering all destination departments. The figure is based on the universe of residence-to-workplace commutes in France in 2010. The horizontal axis displays the great circle distance to the border in kilometers. The orientation is defined such that, without loss of generality, the destination jurisdiction is placed on the right side with positive distances to the border. Assuming homogeneous commuters – which is mostly verified in Section 6.4 – the share of local residents should capture well how local borders affect commuting flows. Absent any border effect, one would expect the two curves in Figure 3 to *meet at the border*. Note that the precise meeting point may not be 50% as neighboring regions may be very different, e.g., in terms of labor market size. However, a discontinuity of almost 60 percentage points is present at the border. This implies that workers disproportionately refrain from crossing the regional border, even when residing at the border.

Figure 3: Share of local residents by workplace location around regional borders



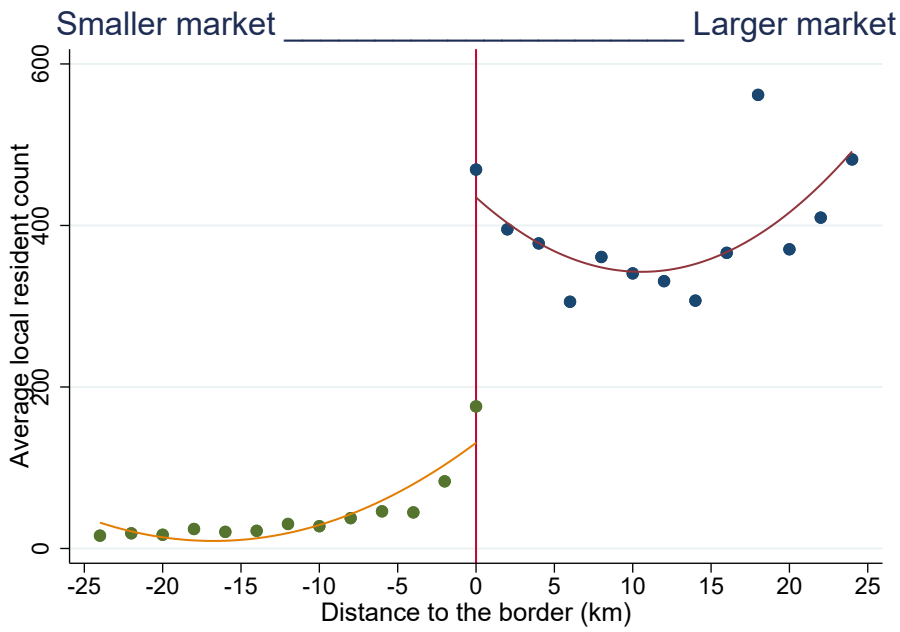
Notes: This graph is based on bilateral statistics using the universe of residence-to-workplace commutes in France in 2010. The average share of residence-to-workplace commutes by workplace location per km to the border is displayed. Scatters are obtained by taking the average share within 2km bins. Predictions from linearly regressing the average share on distance and distance squared separately below and above the border are also reported. Finally, I use a 25km bandwidth.

Labor catchment areas

The observed discontinuity in commuting flows is likely to affect the labor catchment possibilities of large labor markets. Figure 4 displays the residential location of workers working in the region with the larger labor market. The size of a region's labor market is defined as the sum of workers

working in the region. Locations within the region with the larger labor market are attributed positive distance to the border, whereas locations on the other side of the border are given negative distances. The vertical axis displays the average number of residents working in the larger labor market over 2km bins. As opposed to Figure 3, Figure 4 only considers one direction of cross-border commuting, i.e., towards the larger labor market. A sharp discontinuity appears at the border. The number of residents working in the larger labor market jumps by about 300 residents as one enters the regional with the larger labor market.[13] Hence, the border seems to cut through the larger labor market's catchment area.

Figure 4: Labor catchments around regional borders



Notes: Bilateral statistics using the universe of residence-to-workplace commutes in France in 2010. Scatters are obtained by taking the average number of residents working in region B within 2km bins. Predictions from linearly regressing the average share on distance and distance squared separately below and above the border are also reported. Finally, I use a 25km bandwidth.

Residential location choice

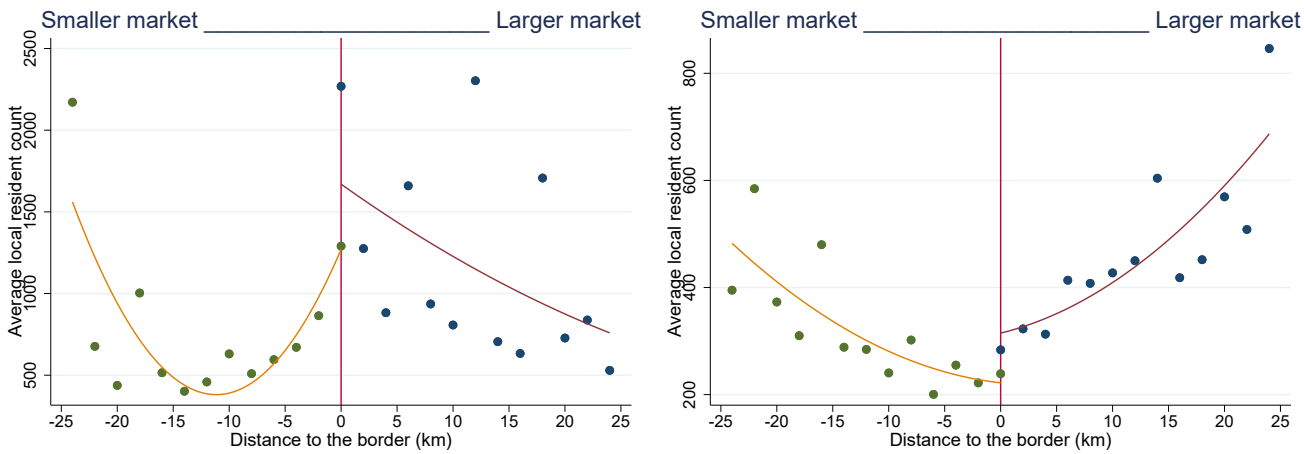
Intuitively, the discontinuity in labor catchment areas observed in Figure 4 may arise from discontinuous commuting flows, but also due to an excess residential mass at the border on the side with the larger labor market. Figure 5 studies residential count around the border for different labor market sizes: borders around which the larger labor market is greater or equal to 250,000

[13] To properly compare residential count on both sides of a regional border, it is important to exclude municipalities close to national borders. In the present case, all locations within 30km of a national borders are excluded.

workers (Panel a),[14] borders around which the larger labor market is less than 250,000 workers (Panel b). The rational for this distinction is that France's larger urban areas extend beyond their department of origin, which is not the case when one considers smaller labor markets. As in Figure 4, the horizontal axis displays the distance to the border with positive distances within the region with the larger labor market. On the vertical axis, I display the average resident count by bins of 5km. A discontinuity in average local resident count appears when looking at borders around which the larger labor market is less than 250,000 workers (Panel b). The discontinuity imprecisely observed in Panel a is driven by Paris outer districts (in French: "arrondissements"). In Panel b, a discontinuity of about 150 residents is observed.

Figure 5: Residential location choice, labor market size and regional borders

a. Larger labor market $\geq$ 250,000 workers b. Larger labor market $<$ 250,000 workers



Notes: Panel a captures France's three largest urban centers (i.e., Paris, Lyon and Marseille). Departmental labor market size and municipal resident count in France in 2010. Scatters are obtained by taking the average local municipal resident count within 5km bins. I further report predictions from linearly regressing the average count on distance and distance squared separately below and above the border.

Figures 3, 4 and 5 provide visually strong descriptive evidence that regional borders affect surrounding commuting and residential patterns. However, these graphs cannot be given a causal interpretation. This is the topic of Section 6. For that purpose, Figures 3, 4 and 5 also indicate that a spatial discontinuity estimator is likely to best represent the data and retrieve a causal relationship, as distinct, fairly flat, levels are observed on both sides of the border.

[14]This category captures France's three largest urban centers (i.e., Paris, Lyon and Marseille).

5 A spatial quantifiable equilibrium framework of commuting and residential density

I build on Monte et al. (2018)'s model of commuting openness in a spatial equilibrium. I complement the framework with two key ingredients. First, I suppose a central institution in charge of integrating local transport networks. Costs of integration are financed by a nation-wide head tax levied on all workers. Such tax setting allows a direct exogenous matching from a tax rate to a given level of increased local transport network integration. It further allows the possible redistribution of policy gains in an intuitive manner. Second, in line with the residential density results in Section 6, I introduce a mechanism under which available residential floor space is endogenously determined by residential income.

Set up

Consider a country composed of a finite number of locations $n, i \in \{1, \ldots, N\}$. Each location is located in exactly one $r \in R$ regional unit.[15] The national economy is populated by a total of L individuals who are endowed with one unit of labor each, which they supply inelastically.

Individual utility and commuting

Individuals are geographically mobile and have heterogeneous location preferences. Each individual maximizes his/her utility by choosing a pair of residential-workplace locations. Utility of individual ω residing in n and working in i, is function of final goods consumption ($C_{n\omega}$), consumption of residential space ($H_{n\omega}$), commuting costs (d_{ni}) and is affected by an idiosyncratic shock ($b_{n\omega}$),[16] according to the Cobb-Douglas form:

$$U_{ni\omega} = \frac{b_{n\omega}}{d_{ni}} \left(\frac{C_{n\omega}}{\alpha} \right)^{\alpha} \left(\frac{H_{n\omega}}{1-\alpha} \right)^{1-\alpha}, \quad 0 < \alpha < 1. \tag{1}$$

As in the new economic geography literature, the goods consumption in location n is a constant elasticity of substitution (CES) function of a continuum of tradable goods sourced from each location i:

$$C_n = \left[\sum_{i \in N} \int_0^{M_i} c_{ni}(j)^{\rho} dj \right]^{1/\rho}, \quad \sigma = \frac{1}{1-\rho} > 1. \tag{2}$$

[15] For simplicity, I suppress the regional index – except when necessary – as the index n perfectly matches the regional unit.

[16] The idiosyncratic shock ($b_{n\omega}$) describes the heterogeneity in utility that individuals derive from living in n. For each individual, this idiosyncratic component is drawn from an independent Fréchet distribution following Eaton and Kortum (2002), $G_n(b) = e^{-B_n b^{-\epsilon}}$, with $B_n > 0$ and $\epsilon > 1$.

where M_i is the total measure of produced varieties, and σ is the elasticity of substitution between varieties. Utility maximization implies that equilibrium consumption in location n of each variety sourced from location i is given by $c_{ni} = \alpha X_n P_n^{\sigma-1} p_{ni}(j)^{-\sigma}$, where X_n is the aggregate expenditure in location n; P_n is the price index dual to (2), and $p_{ni}(j)$ is the "cost inclusive of freight" price of a variety j produced in location i and consumed in location n.

I denote the after tax wages from an individual working in i by w_i, where $w_i = \tilde{w}_i - t$ with $\tilde{w}_i$ being the before tax wages and t the head tax imposed by the central government to finance regional network integration. I also denote residential rents by Q_n. Using utility maximization, the indirect utility of individual ω, residing in $i \in I$, and working in $j \in I$ is given by $U_{ni\omega} = \frac{b_{n\omega} w_i}{d_{ni} Q_n^{1-\alpha}}$. Define the attractiveness of a combination of residence and workplace, as $u_{ni} = B_n \Big[\frac{w_i}{d_{ni} Q_n^{1-\alpha}}\Big]^{\epsilon}$. Then, I can then express the probability, λ_{ni}, that an individual resides in n and works in i as:

$$\lambda_{ni} = Pr\Big[u_{ni} \geq \max\{u_{rs}\}, \forall r, s\Big] = \frac{u_{ni}}{\sum_r^N \sum_s^N u_{rs}}. \tag{3}$$

A competitive construction sector provides residential floor space, H_n, endogenously. Floor space in n is produced by combining a location's total residential income for housing purposes, $(1-\alpha)X_n = (1-\alpha)v_n R_n$, where R_n is the number of workers residing in n and v_n is their income, and a location-specific construction supply factor q_n according to the following constant return function: $H_n = \Big[(1-\alpha)X_n\Big]^{\eta} q_n^{1-\eta}, \eta \in (0,1)$. Consequently, the residential land market clearing condition implies that the demand for residential land equals the supply of land in each location; which can then be written as:[17]

$$Q_n = (1-\alpha)\frac{v_n}{H_n} R_n = \Big[(1-\alpha) q_n X_n\Big]^{1-\eta}. \tag{4}$$

Production and goods trade

Tradable varieties are produced using labor under monopolistic competition and increasing returns to scale. When producing a variety, a firm incurs a fixed cost, F, and a constant variable cost that depends on the firm's location productivity, A_i. The total amount of labor required to produce $x_i(j)$ units of variety j is $l_i(j) = F + x_i(j)/A_i$. Profit maximization implies that equilibrium prices are a constant mark-up over marginal costs: $p_{ni}(j) = \Big(\frac{\sigma}{1-\sigma}\Big)\frac{\zeta_{ni}\tilde{w}_i}{A_i}$, where ζ_{ni} are bilateral trade costs. Under profit maximization and zero profits, equilibrium output is a location-specific constant: $x_i(j) = A_i F(\sigma - 1)$. In turn, this implies that the number of varieties produced M_i is proportional to the location workforce, $M_i = \frac{L_i}{\sigma F}$. Given the CES expenditure function, the

[17] Note that under the assumption that residential land is owned by immobile landlords, who receive worker expenditure on residential land as income, and consume only goods where they live, we have: $P_n C_n = v_n R_n$.

equilibrium pricing rule, and the measure of firms, the share of location n's expenditures on goods produced in location i is:

$$\pi_{ni} = \frac{L_i(\zeta_{ni}\tilde{w}_i/A_i)^{1-\sigma}}{\sum_{k\in N} L_k(\zeta_{nk}\tilde{w}_k/A_k)^{1-\sigma}}. \tag{5}$$

Under zero profits, workplace income equals the sum of residential incomes spent on goods produced in that location, that is:

$$w_i L_i = \sum_{n\in N} \pi_{ni} v_n R_n. \tag{6}$$

Using (5), the equilibrium pricing rule and labor market clearing, the price index P_n can be expressed as follows:

$$P_n = \frac{\sigma}{\sigma-1}\left(\frac{L_m}{\sigma F \pi_{nn}}\right)^{\frac{1}{(1-\sigma)}} \frac{\zeta_{nn}\tilde{w}_n}{A_n}. \tag{7}$$

Central planner

Consider a central planner in charge of integrating regional networks. Network construction costs incurred are exactly balanced by an universal head tax (whose rate I denote by t) levied on all workers (i.e., subtracted from $\tilde{w}_i$). Denoting changes by Δ and the network construction costs per km with k, I have: $\sum_{\omega\in L} t_\omega = k\Delta\left[\sum_{n\in N}\sum_{i\in N} d_{ni}\right]$. As t_ω is the same for all individuals, I obtain:

$$tL = k\Delta\left[\sum_{n\in N}\sum_{i\in N} d_{ni}\right]. \tag{8}$$

As k, L are exogenous to the model, there is an exact mapping between t and any given reduction in the sum of bilateral travel distances, independent of the endogenous equilibrium variables.

Equilibrium

The unique general equilibrium of the model can be referenced by the following seven vectors $\{w_n, v_n, Q_n, H_n, L_n, R_n, P_n\}_{n=1}^N$ and two scalars $\{\overline{U}, t\}$. I provide conditions for the existence and uniqueness of the general equilibrium in Appendix C. In doing so, I show that the system of equations can be written in the form required to apply the existence and uniqueness conditions for gravity equation models from Allen, Arkolakis, and Li (2015).

6 Natural experiments at regional borders

Descriptive statistics in Section 4 suggest that commuting, labor catchments and residential activity may be distorted by regional borders. Using a spatial discontinuity estimator relying on a minimal set of assumptions (introduced in Section 6.1), I study the presence of a discontinuity in key outcomes at regional borders in Sections 6.2. I provide Regression Discontinuity (RD) plots in Section 6.3. Structural estimation in Section 7 uses these estimators as moment conditions to recover key model parameters. Going further, I provide robustness checks (for natural features and local tax differentials) in Section 6.4 and heterogeneity analyses (by commuters' occupation and transport mode) in Section 6.5.

6.1 Spatial regression discontinuity estimator

Identification strategy

Consider the following reduced form set up. Location of municipality n is given by the coordinates of its centroid, $\boldsymbol{L}_n = (L_{nx}, L_{ny})$. Further, consider $\overline{\boldsymbol{B}}$ as the infinite set of border points constituting the local borders. Let me then define the subset $\boldsymbol{B} \in \overline{\boldsymbol{B}}$ of border points $\boldsymbol{b}_n = (b_x, b_y), \forall n$, s.t. $\boldsymbol{b}_n$ is the closest border point to municipality n. Consequently, I derive the euclidean distance to the border as $d_n = ||\boldsymbol{L}_n - \boldsymbol{b}_n||$. Additionally, it is useful to define $r_n^- \in R$ as the region in which n is located, and $r_n^+ \in R$ refers to the region closest to n, but s.t. $\boldsymbol{L}_n \notin r_n^+$. Intuitively, r_n^+ is the region "on the other side" of the closest border. Finally, for a given region r and municipality n, it is useful to define region r_{rn}^* as r_n^- if $r = r_n^-$ and as r_n^+ if $r = r_n^+$. Intuitively, r_{rn}^* is "region B" in Figure 3.

To capture the causal effect of local borders, the standard spatial RD estimator – in which a single continuous border acts as threshold and distance to it constitutes the forcing variable (e.g., Ehrlich and Seidel, 2018) – is not directly suitable. The present application requires a generalization of this approach in two dimensions: (i) the possibility to analyze jointly multiple borders, and (ii) the possibility of direction-specific border crossing (as commutes are defined by a pair of origin and destination locations). In what follows, I present a more general spatial discontinuity estimator.

Conditional on a given region r, the treatment status of municipality n can be expressed as:[18]

[18] A direct implication of (9) is that only commutes between neighboring regions are considered.

$$T_{n|r} = \begin{cases} 0 & \text{if} \quad r = r_n^- \\ 1 & \text{if} \quad r = r_n^+ \\ . & \text{otherwise} \end{cases} \tag{9}$$

To obtain the final treatment, $\boldsymbol{T}$, and outcome vectors, $\boldsymbol{Y}$, it suffice to stack all n, r specific $T_{n|r}$ and $Y_{n|r}$, as follows: $\boldsymbol{T} = \left[T_{1|1}, \ldots, T_{N|1}, T_{1|R}, \ldots, T_{N|R}\right]'$ and $\boldsymbol{Y} = \left[Y_{1|1}, \ldots, Y_{N|1}, Y_{1|R}, \ldots, Y_{N|R}\right]'$.

Define $\boldsymbol{Y}_1$ and $\boldsymbol{Y}_0$ as the outcome vectors when treated and when not, respectively. The objective is to identify the effect τ of treatment, i.e. crossing a regional border for commuting, and being located on the side with the larger labor market for residential count. As counterfactual situations for individual units are unobservable, I aim at estimating the average treatment effect $\mathbb{E}[\tau_{n|r}]$ for comparable treated and control units. To do so, I study the discontinuity in expected outcomes at the border:

$$\tau(\boldsymbol{d}) \equiv \mathbb{E}[\boldsymbol{Y}_1 - \boldsymbol{Y}_0 | d_n = 0] = \lim_{\boldsymbol{d} \to 0} [\boldsymbol{Y} | r = r_n^+] - \lim_{\boldsymbol{d} \to 0} [\boldsymbol{Y} | r = r_n^-] \tag{10}$$

I approach the spatial regression discontinuity design both parametrically and non-parametrically. In the parametric approach, I define the conditional expectations in (10) as $\mathbb{E}[\boldsymbol{Y}_0|\boldsymbol{d}] = \alpha + f(\boldsymbol{d})$ and $\mathbb{E}[\boldsymbol{Y}_1|\boldsymbol{d}] = \alpha + \tau + f(\boldsymbol{d})$, where $f(\boldsymbol{d})$ refers to flexible polynomials of shortest distance to the border. Allowing for asymmetric control distance functions insures that a kink is not misinterpreted as a discontinuity (Lee and Lemieux, 2010). The regression model is then:

$$\boldsymbol{Y} = \alpha + \boldsymbol{T}\tau + f(\boldsymbol{d}) + \boldsymbol{\epsilon} \tag{11}$$

The credibility of the model rests on the valid specification of the control functions. Therefore, I run various specifications with different order of polynomials and with different bandwidth sizes. Furthermore, as municipalities are alternatively treated and control units conditional on the commuting destination, it appears useful to cluster standard errors at the municipality level.

For the non-parametric specification, I estimate local-polynomial regression-discontinuities with robust confidence intervals and optimal bandwidth selection following Calonico et al. (2014). The performance of standard local polynomial estimators may be seriously limited by their sensitivity to the specific bandwidth employed. Whereas classical bandwidth selectors yield "large" bandwidths – leading to data-driven confidence intervals that may be biased – I employ mean squared error optimal bandwidths. These are valid given the robust approach in Calonico et al. (2014). In the present application, shortest great circle distance distance to the regional border, $\boldsymbol{d}$, works as the continuous assignment variable.

Validity of the approach

The identification strategy of a regression discontinuity design rests on two assumptions (see, Hahn et al., 2001; Lee and Lemieux, 2010). First, selective sorting of units (i.e., municipalities) at the border must be ruled out to ensure that treatment is "as good as" randomly assigned. Second, counterfactual outcomes have to be continuous at the border, that is all relevant variables besides treatment must vary smoothly. Before going further, it is useful to keep in mind that as multiple regional borders are jointly analyzed, I am able to control for border-specific effects; and therefore, capture possible confounding factors such as local tax differentials, border-specific placement strategies, etc.

The first assumption requires that municipalities cannot strategically select themselves into the treatment or control groups. In the present context, this assumption appears reasonable as departmental borders have almost not been modified since their creation in 1790 (with the observed modifications related to changes in the extent of the French territory), and they are stable since 1964 (i.e., 50 years before the analysis).

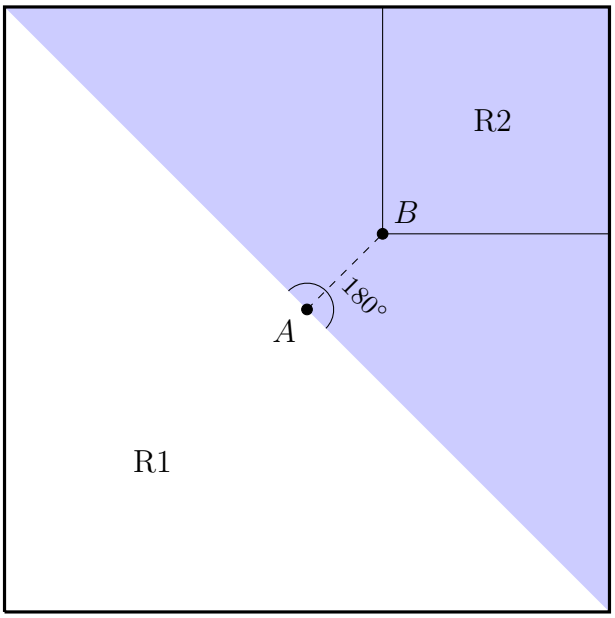
The second assumption implies random local border placement. There are, in general, several reasons to think that regional borders were strategically located, e.g., follow natural features, surround economic centers, accommodate historical road networks (which may be correlated with nowadays road networks), etc. A standard approach to assess the first assumption is to run extensive balance tests on all observed variables. Unfortunately, these tests can never be exhaustive. In this paper, I propose an alternative approach based on a novel Instrumental Variable (IV) strategy to rigorously and systematically avoid a bias associated with endogenous local border placement. I exploit the geometric delineation proposal by the Sieyès committee from 1789 displayed in Figure 1. Under this proposal, borders are straight vertical and horizontal lines dividing the country in 81 equal regions. Clearly, such delineation renders targeting precise local characteristics impossible. Given an angle at each crossing of 90° and the squares' side length, *the choice of any first border point already implies the full border map.* From now on, let me refer to the borders defined in the geometric proposal by the Sieyès committee as *Sieyès borders.*

As it constitutes its first draft, the Sieyès borders are likely to be a good predictor of the actual departmental borders. Moreover, as this proposal has been nothing more than an object of curiosity stored in the National Archives since then, it appears safe to assume that it is uncorrelated with any other economic variable.

Construction of the instrument

To construct the instrumental variable, I proceed in two steps. First, I compute the distance to the nearest Sieyès border point for each municipality. To do so, I first digitize the Sieyès border map, before computing the great-circle distance to the nearest Sieyès border point using ArcGIS.

Figure 6: Illustration of the instrument's assignment rule



Notes: Point A is the municipality of interest. It is located in region 1 (R1) next to region 2 (R2). B is the closest boundary point to A. The blue shaded area is defined by the 180° angle line crossing the segment AB in A.

Second, I assign municipalities to the treatment or control group (i.e., with positively and negatively increasing distances to the border, respectively). This second step is required as simply using the absolute distance to the nearest Sieyès border point is unlikely to have significant predictive power; and it would fail to properly account for non-random placement relative to the border. Figure 6 illustrates the assignment rule. Consider a generic municipality whose centroid is point A. It is located in region 1 (R1) next to region 2 (R2). Point B is the closest boundary point to A. Further consider the area including B and delineated by the line perpendicular to the segment AB, crossing AB at A (i.e., the blue shaded area in Figure 6). Then assignment is the same as the treatment variable if the nearest Sieyès border point is within the blue area, and reversed otherwise. This assignment rule holds no matter the orientation of segment AB.

Consequently, in the parametric approach following a Two-Stage Least Squares (2SLS) specification, I instrument the treatment status using the distance to the nearest Sieyès border point computed as defined above. As revealed in Tables 1, 2 and 3, the instrument is revealed statistically highly significant, and the Cragg-Donald F-statistic is always largely above the critical values derived by Stock and Yogo (2005). In the non-parametric approach following Calonico

et al. (2014), I replace the distance to the nearest departmental border point by the distance to the nearest Sieyès border point as the forcing variable.

6.2 Estimation results

Commuting

Table 1 studies commuting around regional borders. Panel a displays results using the spatial regression discontinuity estimator, whereas Panel b shows results that are robust to non-random border placement using the instrumentation strategy detailed above. In Panel a, columns I-IV display the estimation of (10) using the parametric approach, and Column V displays results following the non-parametric approach under optimal bandwidth selection and optimal polynomial order. Columns I-IV differ in the bandwidth size employed and the polynomial order applied to the forcing and forcing $\times$ treatment variables. As outcome, it focuses on the share of residents commuting to region r^*, also labeled "region B" in the descriptive section. Consistent with the descriptive statistics in Figure 3, I observe an highly significant discontinuity in the share of residents at the border. Results are very similar across all specifications. Based on the non-parametric specification in Column V, I observe a treatment effect of 0.65, implying that, at the border, commuters are 65 percentage points more likely to work within their department than commuting to the neighboring one.

In Panel b, accounting for non-random border placement leads to qualitatively similar results. As the treatment effect is large on the [0,1] scale, the 2SLS model using a 20km bandwidth predicts a treatment effect larger than one. Weak instrument tests are largely above the critical values derived by Stock and Yogo (2005). To account for the fact that the outcome is a share, I employ a Fractional Response Model in Columns III and IV of Panel b. Formally, I estimate fractional probit regressions adopting a control function approach, i.e., including the residual from a first stage regression of treatment on distance to the Sieyès border, to account for non-random border placement. Finally, Column V of Panel b displays result from the non-parametric approach. The difference in the point estimate comes from the significantly lower bandwidth size employed. Given the variation around borders observed in Figure 3, it is not surprising that the magnitude of the non-parametric coefficient using the Sieyès border as forcing variable is much lower than when using the actual distance to the regional border. Given that using the Sieyès border leads technically to a small shift of the border on either side, the bin average close to the border is then taken mixing locations on both sides; and therefore, we obtain a smaller point estimate.

Table 1: Commuting around regional borders

	I	II	III	IV	V
	a. Discontinuity estimator				
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.780***	0.733***	0.754***	0.713***	0.654***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.009)
Obs.	30,160	30,160	23,088	23,088	9,414
	b. Accounting for non-random border placement				
Specification	2SLS		FRM		Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	20km	20km	Opt.
Treatment	3.708***	1.348***	0.998***	1.071***	0.193***
	(0.152)	(0.025)	(0.007)	(0.011)	(0.015)
Weak instr. test	424	1,556	-	-	-
Obs.	41,641	41,641	41,641	41,641	14,829

Notes: Columns I-IV differ in the polynomial order applied to the forcing and forcing × treatment variables as well as in the bandwidth considered. Column V uses a non-parametric approach under optimal bandwidth selection à la Calonico et al. (2014). FRM stands for fractional response model. Precisely, I run fractional probit regressions. Across specifications, the instrumentation strategy is highly statistically significant and the Cragg-Donald F-statistic is always above the critical values derived by Stock and Yogo (2005), i.e., 16.38.

Labor catchment areas

I now study how the discontinuity in commuting flows observed in Table 1 impacts the labor catchment possibilities of large labor markets. Orientation relative to the border is given by the relative labor market size as in Figure 4. Akin to Panel a of Table 1, Table 2 displays the estimation of (10) using a parametric approach (Columns I-IV) and the non-parametric approach under optimal bandwidth selection (Column V). Columns I-IV differ in the polynomial order applied to the forcing and forcing × treatment variables. Confirming descriptive evidence, local workers count working in the larger labor market increases discontinuously at regional borders on the side with the larger labor market. Using the parametric approach, I obtain an highly significant treatment effect between 231 and 271 workers; and using the non-parametric discontinuity approach, the treatment effect is also significant, but of smaller magnitude, at 121 residents. Accounting for non-random border placement in Panel b leads to similar results. Across parametric specifications, the instrumentation strategy is highly statistically significant and the Cragg-Donald F-statistic is always above the critical values derived by Stock and Yogo (2005). I observe a significant positive

and large treatment effect across all parametric specifications. The non-parametric estimates in Column V, Panel b, is also positive and significant, albeit of smaller magnitude.

Table 2: Labor catchments around regional borders

	I	II	III	IV	V
	a. Discontinuity estimator				
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	271.880***	269.949***	245.785***	230.846***	121.713***
	(18.717)	(20.971)	(17.180)	(17.511)	(44.728)
Obs.	14,788	14,788	11,344	11,344	13,462
	b. Accounting for non-random border placement				
Specification	2SLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	1120.516***	906.762***	1120.516***	906.762***	47.641*
	(374.898)	(199.272)	(374.898)	(199.272)	(25.140)
Weak instr. test	79	453	79	453	-
Obs.	14,777	14,777	14,777	14,777	10,935

Notes: Columns I-IV differ in the polynomial order applied to the forcing and forcing × treatment variables as well as in the bandwidth considered. Column V uses a non-parametric approach under optimal bandwidth selection à la Calonico et al. (2014). Across specifications, the instrumentation strategy is highly statistically significant and the Cragg-Donald F-statistic is always above the critical values derived by Stock and Yogo (2005), i.e., 16.38.

Residential location choice

A likely corollary of the observed discontinuities in commuting flows and labor catchments is an excess residential mass around regional borders on the side with the larger labor market. As crossing regional borders appears to be costly, workers may favor residing in the regional jurisdiction of their workplace. To test this hypothesis using a border discontinuity approach, I estimate the effect of being on the border side with the larger labor market on residential count. As previously, I focus on municipalities close to regional borders. The results are displayed in Table 3. Panels a and b display results from the discontinuity estimator, whereas Panels c and d propose results robust to non-random border placement. Panels a and c consider regional borders in France's largest labor markets (i.e., Paris, Lyon and Marseille). Formally, these panels include all borders for which the larger labor market is above or equal to 250,000 workers. Panels b and d study all other regional borders. The rational for this distinction is that larger labor markets

are more likely to be better integrated and to span over multiple departments. Paris is a prime example of this. Its metropolitan area extends much beyond its administrative departmental borders. Consistent with this argument, the results in Panel a and c show indeed that there is no significant discontinuity in residential mass at regional borders around France's largest labor markets.

A significant jump in residential mass, however, appears when looking at all other labor markets. Municipalities on the border side with the larger labor market exhibit a significantly larger residential mass, estimated between 57 and 93 additional residents when using the discontinuity estimator (Panel b). Accounting for non-random border placement leads to significantly larger point estimates, i.e., between 163 and 211 residents. This difference is likely evidence that the departmental border design followed some locally strategic objective, i.e., targeting fundamental residential characteristics. Even though mostly drawn in 1789, some of these fundamental moments still persist today and likely explain the significant point estimate difference between Panels b and d.

6.3 Regression Discontinuity (RD) plots

For illustration, Figure 7 displays Regression Discontinuity (RD) plots that are in line with the observed effects in Tables 1, 2 and 3. Figure 7a studies at commuting patterns; Figure 7b looks at labor catchments; Figure 7c and Figure 7d investigate residential mass around borders with a larger labor market above and below 250,000 workers, respectively. In these plots, I use the distance to the actual departmental border given a 25km bandwidth. I run separate regressions on each side of the threshold. The plots represent local sample means using non-overlapping evenly spaced bins on each side of the threshold following the data-driven method for optimal choice of the number of bins described in Calonico et al. (2014). As seen above, a discontinuity at regional borders appears when looking at commuting and labor catchments, as well as when studying residential mass around small to mid-sized labor markets.

6.4 Robustness: Regional borders and natural features

The possible co-location of regional borders and natural features constitute a concern for identifying a regional border effect. As explained in Section 3, historical and institutional characteristics of French departments make it unlikely for this concern to explain the discontinuity in commuting and residential mass observed above. However, it may inflate the results obtained. Figure 8 offers RD plots of commuting flows, labor catchments, residential mass around regional borders *excluding all origin and destination locations in mountainous departments* (i.e., Alps, Pyrenees,

Table 3: Residential location choice around regional borders

	I	II	III	IV	V
	a. Discontinuity estimator				
	(Larger labor market $\geq$ 250,000 workers)				
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	804.025	862.142	1059.734	1027.150	-140.901
	(558.908)	(762.284)	(785.558)	(1006.907)	(582.283)
Obs.	7,643	7,643	6,836	6,836	3,845
	b. Discontinuity estimator				
	(Larger labor market < 250,000 workers)				
Specification	2SLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	93.303***	69.720***	66.346***	56.468***	78.573***
	(20.725)	(20.990)	(20.839)	(20.525)	(25.140)
Obs.	18,038	18,038	15,209	15,209	9,075
	c. Accounting for non-random border placement				
	(Larger labor market $\geq$ 250,000 workers)				
Specification	2SLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	454.900	519.918	454.900	519.918	-75.827
	(507.557)	(378.936)	(507.557)	(378.936)	(406.076)
Weak instr. test	244	1,131	244	1,131	-
Obs.	7,848	7,848	7,848	7,848	3,927
	d. Accounting for non-random border placement				
	(Larger labor market < 250,000 workers)				
Specification	2SLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	163.079	193.564**	163.079	193.564**	210.480***
	(136.412)	(87.813)	(136.412)	(87.813)	(44.160)
Weak instr. test	729	2,884	729	2,884	-
Obs.	18,991	18,991	18,991	18,991	7,335

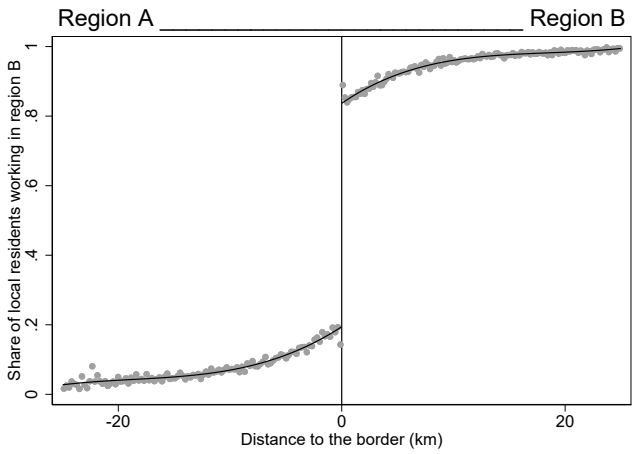
Notes: Columns I-IV differ in the polynomial order applied to the forcing and forcing $\times$ treatment variables as well as in the bandwidth considered. Column V uses a non-parametric approach under optimal bandwidth selection à la Calonico et al. (2014). Across specifications, the instrumentation strategy is highly statistically significant and the Cragg-Donald F-statistic is always above the critical values derived by Stock and Yogo (2005), i.e., 16.38.

Massif Central), *as well as within 20km of a major river.*[19] I exclude complete departments and not specific municipalities as the shortest path in mountainous areas between two valley munic-

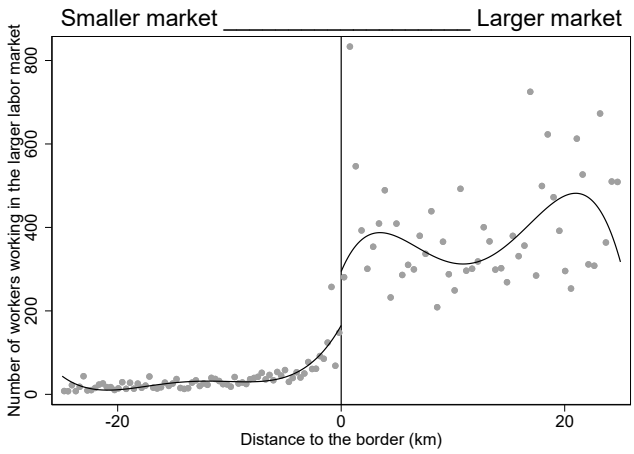
[19]When looking at residential mas around large labor markets in RD plots c and d, I only exclude mountainous departments. This choice is motivated by the fact that large labor markets are often crossed by rivers. This is the natural consequence of large cities being located on large rivers for historical accessibility and trade reasons.

Figure 7: Regression discontinuity plots

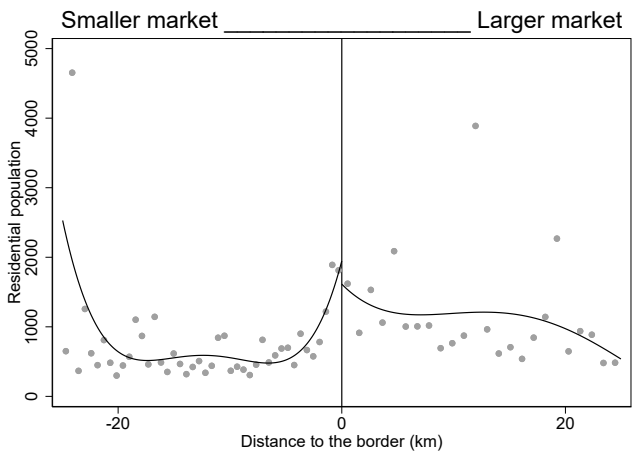
a. Commuting



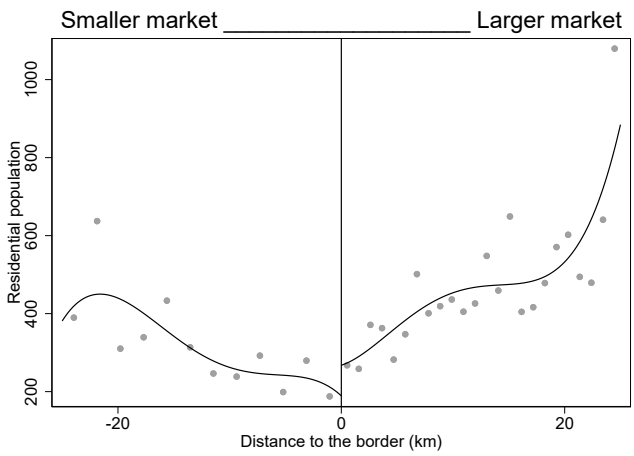
b. Labor catchments



c. Residential mass
(larger labor market $\geq$ 250,000 workers)



d. Residential mass
(larger labor market $<$ 250,000 workers)



Notes: Fourth order polynomial with 25km bandwidth used. Bin size selected using the IMSE-optimal evenly-spaced method with spacing estimators. Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France.

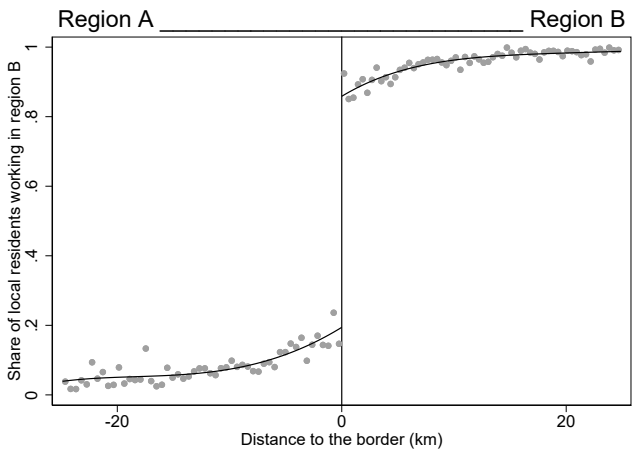
ipalities is likely to go through mountainous roads. Overall, all RD plots are similar to those including all municipalities (Figure 7).

6.5 Heterogeneity analysis: Commuters and transport modes

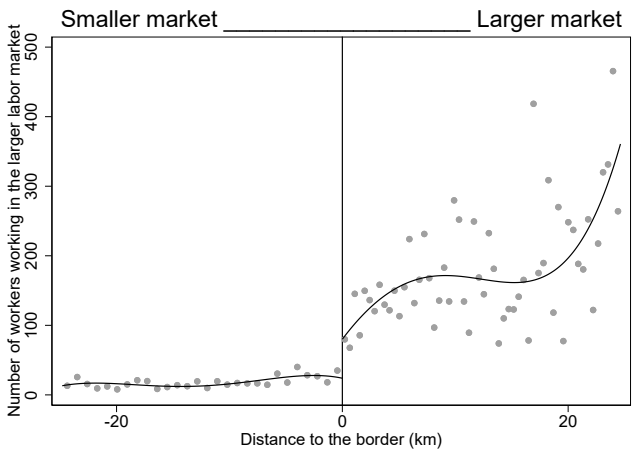
Several studies (e.g., Shoag and Muehlegger, 2015; Agrawal and Hoyt, 2018) have highlighted the presence of heterogeneity in commuting patterns with respect to individual characteristics and transport modes. Following this literature, I analyze the heterogeneity in the regional border effect on commuting along both dimensions, starting with commuter heterogeneity.

Figure 8: Regression discontinuity plots away from natural features (Excluding all origins and destinations close to natural features)

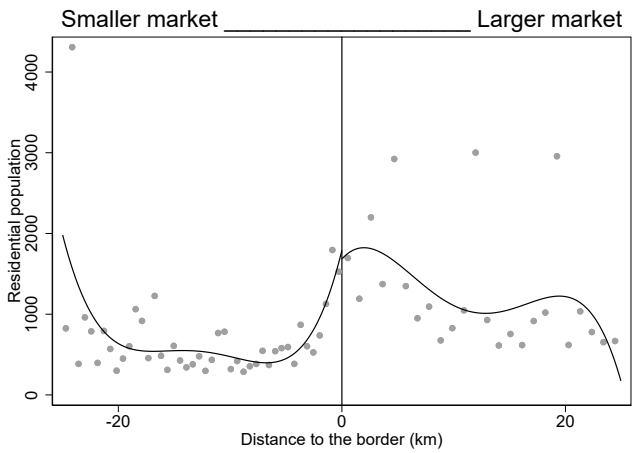
a. Commuting



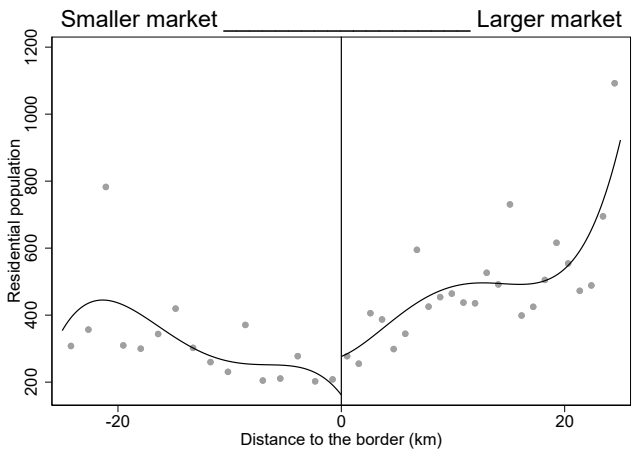
b. Labor catchments



c. Residential mass (larger labor market $\geq$ 250,000 workers)



d. Residential mass (larger labor market $<$ 250,000 workers)



Notes: Fourth order polynomial with 25km bandwidth used. Bin size selected using the IMSE-optimal evenly-spaced method with spacing estimators. Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Plots a and b exclude all origin and destination locations in mountainous departments (i.e., Alps, Pyrenees, Massif Central), as well as within 20km of a major river (based on data from the National Institute of Geographic and Forest Information). Plots c and d only exclude mountainous departments as large labor markets are often crossed by rivers, since large cities are often located on rivers for historical accessibility and trade reasons.

Heterogeneous commuters

I use the French National Statistical Office *Classification of Professions and Socioprofessional Categories* as six active categories to analyze workers heterogeneity in their commuting patterns.[20] I analyze the commuting behavior of each category separately around departmental borders. The

[20]See Classification of Professions and Socioprofessional Categories.

results are summarized in Table 10 (Appendix B). Corresponding RD plots are presented in Figure 15. Overall, regional borders affect all categories of workers. Small significant differences are nonetheless observed in the magnitude of the effect confirming previous results. That being said, the overall small magnitude of the differences across commuters supports considering homogeneous workers in Section 7.2.

Transport modes

Table 11 (Appendix B) looks at variations in commuting behavior at regional borders by transport mode. Corresponding RD plots are presented in Figure 16. Panel a focuses on commutes by private transportation (by car for the vast majority, but also by bike or foot), and Panel a looks at commutes by public transport (e.g., bus, regional train, subway, ...). A discontinuity at the border is observed for each transport mode. The magnitude is, however, significantly smaller for public transport. This result is not surprising as public transport is mostly a prerogative of the administrative unit above the departments, i.e., French Régions. Hence, on average, one would expect a smaller discontinuity when looking at public transport at the departmental borders. This is indeed what is observed.

7 Mechanism and structural estimation

This section is concerned with the question: why do commuting, labor catchment areas and residential mass vary discontinuously at regional borders? To answer it, I start from the fact that a large share of transport networks are planned and administered at the regional level. To test whether such decentralization may be responsible for the observed discontinuities, I proceed in two steps.

First, using an explorative approach, I test whether travel distances on the French road network vary discontinuously at regional borders (Section 7.1). Travel distances may be impacted by regional borders due to the decentralized planning and development of the regional road network. To discard multiple treatment concerns, I run placebo analyses and test for possible differences in the provision of other public goods. Second, using the framework developed in Section 5, I study whether a discontinuity in travel distances – of the magnitude estimated – alone can explain the commuting and residential patterns observed around regional borders (Section 7.2). In doing so, I do not specify a given discontinuity size, but instead test whether the structurally estimated one is in line with the reduced form results on travel distance, commuting and residential mass around regional borders.

7.1 Do travel distances jump at regional borders?

Decentralization and local network integration

As in many countries worldwide, the provision of a large share of the French transport network is decentralized. In particular, French departments are in charge of the planning and administration of the regional road network. Overall, this network represents 71% of the total road length in France. Each department is sole responsible for its own jurisdiction. No institutional setting fosters regional network integration beyond local own interest. This setting may lead to an inefficiently low level of transport infrastructure provision around regional borders for at least two non-exclusive reasons.

First, coordination failure-type inefficiencies may arise. Coordination failure refers to the failure to coordinate on the payoff dominant equilibrium (van Huyck et al., 1990, 1991; Brandts and Cooper, 2006).[21] In the present case, a jurisdiction is likely to finance the construction of a costly road segment towards its regional border *only if* it believes that the neighboring jurisdiction is also likely to do so – such that both segments meet at the border to the overall benefits of citizens in both jurisdictions. However, several well-documented mechanisms (e.g., uncertainty about the neighbor's real intentions, business and political cycles, unbalanced relative labor market size) are sources of frictions when local jurisdictions attempt to coordinate. In turn, one can expect that cross-border road construction projects are less likely to be undertaken than within jurisdiction projects. Sippel et al. (2018) and Christmann et al. (2020) discuss real-world case studies of an under-provision of across border infrastructure.

Second, when deciding on their transport infrastructure investments, local governments may consider only the welfare of their own constituents, and not the welfare of constituents of neighboring jurisdictions. Hence, the benefits from reducing local transportation costs that accrue to commuters from other regions are not internalized. As modeled in Felbermayr and Tarasov (2015), this situation is likely to lead to under-investment in transport infrastructure close to administrative borders.

Given under-provision of transport infrastructure close to regional borders, a travel penalty in terms of longer effective distance (i.e., along the network) when crossing regional borders is likely to appear. This is the case, even in the absence of any type of border control. Given this additional travel cost, geographically close places on both sides of a regional border are further away from each other when considering distance on the road network than similarly geographically close places away from a regional border.

[21] Devetag and Ortmann (2007) survey the coordination failure literature.

Travel distances around regional borders

To test for the presence of a distance penalty when crossing regional borders, I study the variation in effective travel distance around regional borders using the discontinuity estimator proposed in Section 6.1. As outcome, I measure the distance in km to the centroid of "region B", i.e., the destination department.[22] I use the centroid and not the capital as – in few cases – the departmental capital lies close to the border, which may lead to biased results. Treatment is defined as not having to cross a border.

The results are displayed in Table 4. Panel a considers the entire French road network,[23] whereas Panel b looks at travel distance along the regional road network only. In this analysis, it is important to remain close to the border. If we considered larger bandwidths, the great circle distance to the border would then feed into the average treatment effect leading to an overestimation of the actual effect. Column I and II adopt a parametric approach with a bandwidth of 1km and 500m, respectively. Column III and IV display the results adopting a non-parametric approach, with the distance to actual border and distance to the Sieyès border as forcing variable, respectively. Results in Column IV are expected to be free of endogeneity concerns related to non-random border placement. However, in this case, the point estimates of the actual border penalty is, in turn, expected to be slightly diluted as the border location is only imperfectly predicted. Overall, a significant distance penalty is observed across specifications and road networks, with the magnitude of the effect significantly larger than the bandwidth size. Crossing a regional border is expected to inefficiently increase travel distance by 5.48km to 10.69km (Panel a, Column II and III).

Placebo using non-transport related border

I further explore the relevance of the link between decentralization of transport planning and administration and the discontinuous commuting, labor catchments and residential mass patterns observed. To do so, I test for a discontinuity in these outcomes around a public policy border which does not separate two jurisdictions in charge of transport network planning. Namely, I look at variation at the border delineating Functional Urban Areas (FUA). Defined by Eurostat, such areas capture the actual economic and functional extent of urban centers beyond administrative borders. They are the union of a city (i.e., urban center of at least 50,000 residents) and a commuting zone (i.e., all municipalities whose share of residents commuting to the city exceeds

[22] I use distance and not duration for replicability considerations as duration is often computed using real time flow data. Note however that if we assume out congestion, duration can simply be obtained by applying the speed limit to the travel distance.

[23] Note that the analysis accounts for the fact that highways are only accessible via access ramps.

Table 4: Discontinuous travel distances at regional borders

	I	II	III	IV
	a. All road network layers			
Specification	Parametric		Non-parametric	
Bandwidth	1km	500m	Opt.[1]	Opt.
Forcing border	-	-	Actual	Sieyès
Treatment	-4.517***	-5.476*	-10.690***	-4.799***
	(1.011)	(3.303)	(4.142)	(0.722)
Obs.	1,184	124	1,905	6,003
	b. Only regional road networks			
Specification	Parametric		Non-parametric	
Bandwidth	1km	500m	Opt.[2]	Opt.
Forcing border	-	-	Actual	Sieyès
Treatment	-4.398***	-5.565	-9.396**	-4.655***
	(1.081)	(3.605)	(4.392)	(0.772)
Obs.	1,170	122	2,214	6,240

Notes: [1]: 1.183km. [2]: 1.267km. Sieyès border refers to the administrative borders as proposed by the Sieyès committee in 1789. Travel distances computed using ArcGIS Network Solver along the 2015 road network. Data is provided by the French National Institute of Geographic and Forest Information (IGN). The small difference in observations between the two Panels is due to the fact that few municipalities are only connected to the road network via national roads. Municipalities close to natural features (i.e., rivers or mountain areas) are excluded from this analysis (see Section 6.4).

15%). A wide array of public policies – e.g., social programs, land use planning, place based policies – are geographically defined based on FUA borders. If cross-border variation in any of these policies – and not decentralized transport planning – generate the commuting and residential jumps observed, one would expect similar jumps to be observed around FUA borders. Figure 9 displays RD plots, with commuting flows as outcome in Panel a and residential count in Panel b. The results indicate no discontinuity at FUA borders, neither in commuting patterns, labor catchment areas nor residential count.

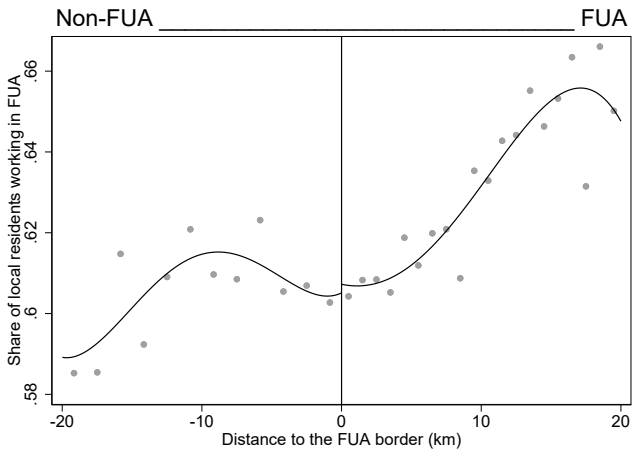
What about other public services?

Besides jumps in travel distances at regional borders, other institutional channels may contribute to the effects revealed in Section 6. Given the French departmental organization presented in Section 3, three main alternative policy variations at departmental borders may explain the commuting and residential patterns observed. These are differences in accessibility to social programs, differences in local fire departments, and differences in local secondary schools.[24] Even though

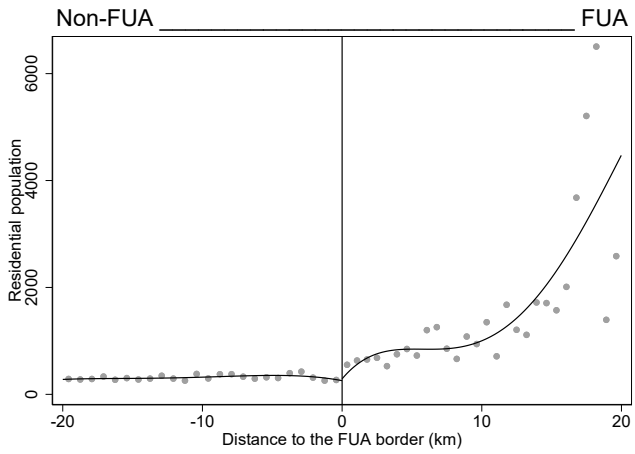
[24]Note that the robustness checks in Section 6.4 show that the observed commuting and residential patterns are not due to natural factors or local tax differentials (both in terms of tax rate and tax base).

Figure 9: Placebo analysis of Functional Urban Areas (FUA)

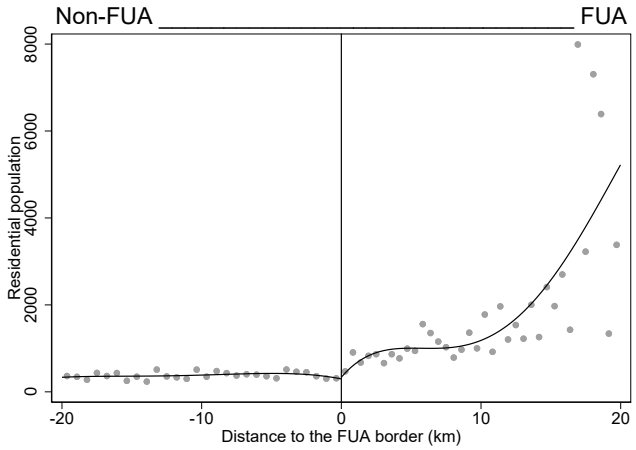
a. Commuting



b. Labor catchments



c. Residential mass



Notes: Fourth order polynomial with 20km bandwidth used. Bin size selected using the IMSE-optimal evenly-spaced method with spacing estimators. Panel a looks at the share of local share of residents working in the close-by FUA. Panel b looks at the number of local residents working in the close-by FUA. Panel c focus on the local residential count around FUA borders.

social spending represent the lion's share of French departments, they are very unlikely to generate the results obtained. The key reason being that social expenditures are centrally mandated, such that individual coverage does not differ in space (i.e., within or across departments). The provision of fire protection and secondary schooling is also strongly regulated at the national level. For instance, in the case of secondary schools, class size, teachers' education, final exams, etc, are all strictly regulated by the French Ministry of Education. Yet, different departmental location strategies may generate frictions around regional borders, as distance to these public services matters for service users.

In Figure 17 (Appendix B), I look at the distribution of fire stations, secondary schools and

secondary school pupils around regional borders (using 2km bins). For each bin, I display the count as well as the density (per km^2) of each outcome. Overall, minimal and non-systematic differences are observed for fire stations, whereas both secondary school outcomes exhibit decreasing trends as one moves away from regional borders. Overall, these observations as well as the magnitude of the differences make it unlikely for either of these outcomes to generate the large commuting and residential patterns observed above.

7.2 Can a discontinuity in travel distances explain the quasi-experimental evidence?

In the reminder of this section, I assess the capacity of the model framework to represent the real world and test the relevance of the jump in bilateral travel distances to explain the border effects observed in Section 6. Instead of attempting to list and test all possible alternative channels, this approach offers a more systematic strategy to understand the key determinant behind the quasi-experimental patterns.

To do so, I structurally estimate the framework presented in Section 5 assuming that travel distance between any two locations is a function of the great circle distance between these locations and a penalty parameter if the two locations are located in different departments. Using the discontinuity estimates above as Generalized Method of Moments (GMM) moments, I show that the framework predicts a penalty parameter in line with results in Section 7.1. Hence, the framework appears to represent the French local economic geography accurately, and decentralization alone can explain most of the commuting and residential discontinuities. I detail this strategy below.

Set of structural locations

To analyze a bilateral dataset of reasonable size, while still retaining the key insights from the reduced form analysis in Section 6, I regroup municipalities based on their geographical location. Formally, I merge municipalities (i) within the same department, (ii) with the same centroid's coordinates when rounding to the nearest 0.2° ($\approx$ 20km).[25] In total, this leads to 2,495 entities. For simplicity, I shall refer to these entities as municipalities from now on.

[25] In Figure 18 (Appendix B), I illustrate this grouping for an arbitrary French department, i.e. "Dordogne" in the South-West of France.

Functional form for mobility

As it is customary in the economic geography literature (e.g., Monte et al., 2018), I suppose a log-log gravity-type relationship between commuting probabilities and distance. To highlight the role of regional borders and guided by the insights from Section 7.1, I assume that distance between any two location pair (n, i) is a function of the great circle line between (n, i), $\overline{D}_{ni}$, and a penalty for crossing *once* a local border. Formally, consider the indicator matrix $\boldsymbol{I}_{ni}$ equal to 0 if n and i are located in the same local jurisdiction, and 1 otherwise. Then, the underlying distance function is defined as: $d_{ni} = (\overline{D}_{ni} + \nu \boldsymbol{I}_{ni})^{\kappa}$; where κ is the elasticity of distance to mobility costs and ν refers to the penalty for crossing the border measured in kilometers.

GMM estimation strategy

I use a generalized method of moments (GMM) approach to estimate the parameter vector $\Lambda = \{\kappa, \nu, \epsilon\}$. The moment conditions are based on the estimated commuting discontinuity parameter, $\hat{\tau}_{commute} = 0.65$ (Table 1), and the estimated residential discontinuity parameter, $\hat{\tau}_{residential} = 79$ (Table 3).[26]

The first moment condition defined in (12) requires that, at the local border, the difference in the likelihood of commuting within the jurisdiction and in the neighboring jurisdiction equals the commuting treatment effect estimated in Section 6.2.

$$\mathbb{E}\Big[\pi_{nr}|r^{+}\Big] - \mathbb{E}\Big[\pi_{nr}|r^{-}\Big] = \hat{\tau}_{commute}, \quad \forall r, n. \tag{12}$$

The second moment condition defined in (13) requires that, at the local border, the excess residential mass on the side with the larger labor market equals the residential treatment effect estimated in Section 6.2.

$$\mathbb{E}\Big[H_n|r^{+}\Big] - \mathbb{E}\Big[H_n|r^{-}\Big] = \hat{\tau}_{residential}, \quad \forall n. \tag{13}$$

Stacking the moment conditions, I obtain: $\mathbb{M}(\Lambda) = \frac{1}{N}\sum_{n=1}^{N} m(\boldsymbol{X}_n, \boldsymbol{\Lambda}) = 0$; where $m(\boldsymbol{X}_n, \boldsymbol{\Lambda})$ is the moment function for location n. Given the efficient weighting matrix, $\mathbb{W}$, the efficient GMM estimator solves:

$$\hat{\boldsymbol{\Lambda}}_{GMM} = \arg\min \Big(\frac{1}{N}\sum_{n=1}^{N} m(\boldsymbol{X}_n, \boldsymbol{\Lambda})'\Big)\mathbb{W}\Big(\frac{1}{N}\sum_{n=1}^{N} m(\boldsymbol{X}_n, \boldsymbol{\Lambda})\Big). \tag{14}$$

To evaluate the moment function for a given parameter vector, Λ, I proceed in two steps. First,

[26] I include these two moments, and not the estimated effect on labor catchments, as including it would be redundant given that probabilities to commute to r^* and the local residential mass are already targeted.

given the data $\{R_n, Q_n, w_i, D_{ni}, \boldsymbol{I}_{ni}\}$ and assumed starting values $\{\kappa, \nu, \epsilon\}$, I solve for locational amenities, b_n.[27] Second, I derive the commuting probabilities, λ_{ni}, and evaluate the moment conditions for the given starting parameter vector Λ. I then repeat this strategy for different values of Λ.[28]

GMM estimation results

Table 5 displays the GMM estimation results for Λ. Both, the elasticity of distance to mobility costs, $\kappa = 0.8$, and the shape parameter governing the idiosyncratic distribution of utility, $\epsilon = 2.13$, are close to standard estimates in the literature. Using a similar functional form for mobility, Monte et al. (2018) obtain a slightly larger coefficient for the former. The latter is in line with what is generally obtained in the economic geography literature (see, e.g., Desmet, Nagy, and Rossi-Hansberg, 2018; Ortega and Peri, 2016; Diamond, 2016; Fajgelbaum, Morales, Serrato, and Zidar, 2019).

The cross-border distance penalty, $\nu = 7.35$, matches surprisingly well the results in Section 7.1. I interpret this result as evidence that the framework performs well at modeling the French local economic geography, and that the decentralization induced discontinuity in travel distances at the border alone is capable of explaining most of the commuting and residential patterns documented in Section 6.

Table 5: GMM estimation results

	I Elasticity of distance to mobility costs κ	II Shape parameter of idiosyncratic utility ϵ	III Cross-border distance penalty ν
Estimate	0.80***	2.13***	7.35***
Standard errors	(0.001)	(0.004)	(0.522)

Notes: Point estimates obtained using a Generalized Method of Moments (GMM) framework with the parameters obtained using the discontinuity estimator as moment conditions. The cross-border distance penalty, ν, matches the results in Section 7.1.

[27] Existence and uniqueness proofs for the vector of local amenities given the observed data are presented in Appendix D.

[28] Matlab's *patternsearch* function is employed to find the moments solving 14. Mesh tolerance used is the default level of $1e^{-6}$. Starting values for $\Lambda = \{\kappa, \nu, \epsilon\}$ are $[0.8; 10; 4]$. An interior solution is found for all parameters using lower bounds: $[0.5; 5; 1]$, and upper bounds: $[2; 20; 15]$.

8 Counterfactual policy: Integrating local networks

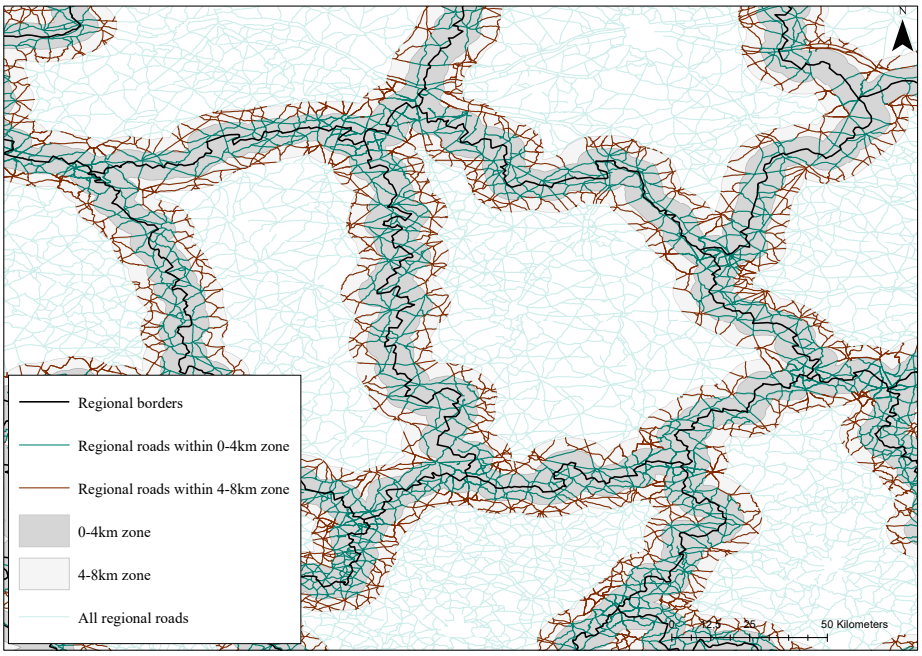
In this section, I investigate possible gains from eliminating the cross-border distance penalty, i.e., $\nu \to 0$. Following the results in the previous section, this implies leveling discontinuities in commuting, labor catchments and residency patterns around regional borders. In what follows, I first calibrate the remaining parameters, before presenting the results.

8.1 Calibrating the remaining parameters

Construction cost and head tax schedule

I model the cost of integrating regional transport networks as the investment needed to equate the road density per km^2 around regional border relative to slightly further away. I start by determining the total need of road kilometers to bridge the gap. To this end, I define the area around the border as the band within 4km of a regional border, whereas the area further away is the band within 4km to 8km of a regional border. Figure 10 shows the network density within each zones. The zone around the border contains 15 meters less departmental roads per km^2. Given the total area of this zone across the country, this implies a lack of 4,589km of regional roads needed to integrate regional networks.

Figure 10: Road density around regional borders



Notes: Zoom over the departments "Deux-Sèvres" and "Vienne". Regional roads refer to departmental roads (i.e., road network administered by the departments).

I calibrate the unit cost of building one kilometer of local road, k, using data from the Union

of French Road Industry Labor Unions annual report.[29] Based on this report, the construction of a kilometer of regional road ranges between €2-5 million. I suppose that this price includes any inefficiency or friction associated to building any large infrastructure project. The renovation of a regional road, required on average every 20 years, is expected to cost €200,000. Hence, for an arbitrary 50 years lifespan, a kilometer of regional road is calibrated to costs the community between €2.4 million and €5.4 million in total. Given the 4,589km of regional roads needed, this implies a head tax schedule ranging from €29.42 to €66.20 per capita and per year.

Floor space production

Residential floor space is produced combining total residential income and a location-specific construction supply factor. Consequently, I can retrieve the elasticity of residential floor space with respect to total residential income using the following log-log specification:

$$\ln H_n = \eta \ln X_n + \varepsilon_n \tag{15}$$

The location-specific construction supply factor is captured by the constant and the error term, ε_n. I use the sum of floor space across local primary residencies in 2016 to measure the floor space available in n. I estimate (15) using an OLS and an IV approach. The IV strategy aims at accounting for a possible reverse causality running from availability of residential floor space to local income. As instrument for total residential income, I employ the latitude of a location. Following a general European trend, important variation in income are observed on a North-South axis within France, but there is no systematic reason for why floor space production would differ on this axis except through an income channel.

Table 6 summarizes the results. Total residential income is a strong predictor of the amount of floor space. I obtain a value for η of 0.92 in the OLS specification, and a value of 0.81 using an IV strategy. In both cases, a large share of the variation is captured (adjusted R-squared of 0.96 and 0.94, respectively). As expected, the instrument performs well at predicting total residential income as the Cragg-Donald Wald F-statistic is largely above the critical value for weak instrumentation (Stock and Yogo, 2005). Hence, I take $\eta = 0.81$ as preferred estimate.

Calibrated parameters using the literature

Finally, I calibrate the remaining parameters of the model using standard sources from the literature. I assume the elasticity of substitution between varieties to be $\sigma = 4$, in line with the

[29] "Union des syndicats de l'industrie routière française" in French. Consult: https://www.routesdefrance.com/wp-content/uploads/dossier-de-presse-AG-2015-USIRF.pdf

Table 6: Elasticity of floor space production

	I	II
	OLS	IV
Total residential income (η)	0.920***	0.810***
	(0.005)	(0.026)
Adj. R^2	0.96	0.94
Obs.	2,497	2,497
Weak Instr. (F-statistic)	-	66

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Given the endogenous regressor, the instrumental variable and a maximum relative bias of 5%, the critical value for the weak instrumentation F-Statistic is 16.38 (Stock and Yogo, 2005).

estimates using price and expenditure data in Broda and Weinstein (2006). Assuming a similar functional form for trade frictions as for commuting frictions (i.e., $\zeta_{ni} = d_{ni}^{-\psi(\sigma-1)}$), I assume a trade distance elasticity of $\psi = 0.43$ (Monte et al., 2018). Finally, following Monte et al. (2018), I assume the share of goods consumption in consumer expenditure to be $\alpha = 0.6$.

8.2 Simulation

Defining the counterfactual policy

The central government invests in infrastructure to integrate regional networks such that the cross-border distance penalty is reduced to 0, i.e., $\nu \to 0$. When presenting the results, I assume a conservative value for the local road unit cost, i.e., €5.4×10^7 per km. Given the 4,589km needed, this leads to a head tax of t = €66.20. Given the functional form for mobility defined in Section 7.2, the counterfactual bilateral commuting costs, $\tilde{d}_{ni}$ simplifies to: $\tilde{d}_{ni} = \overline{D}_{ni}^{\kappa}$. Figure 19 (Appendix B) illustrates the average departmental reduction in bilateral travel distances aggregated at the departmental level.

The costs and benefits of integrating local networks

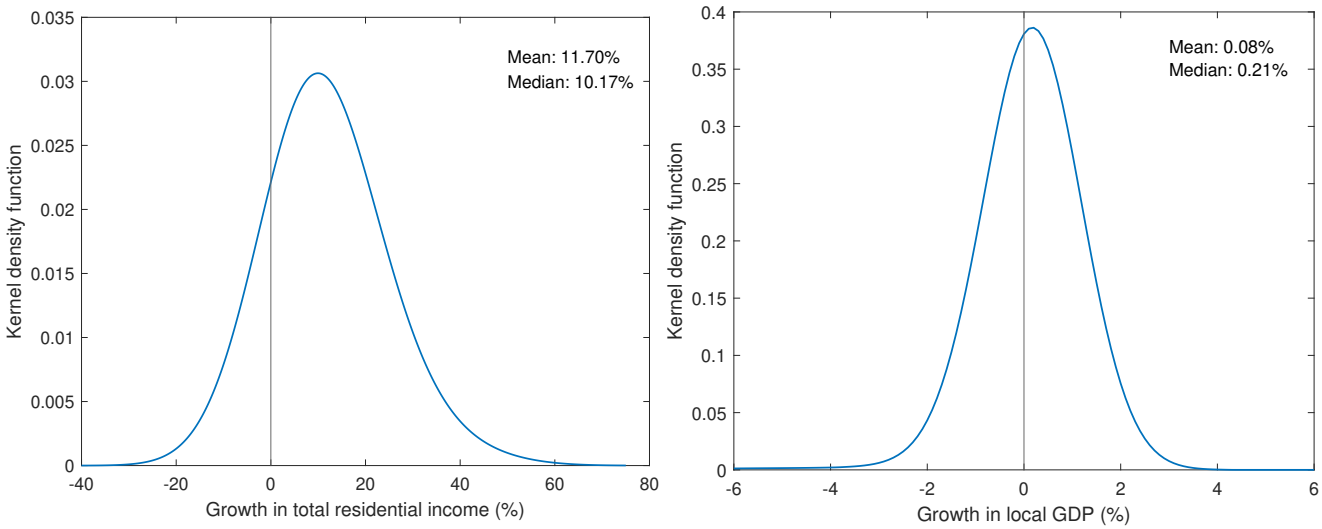
Figure 11 displays the distribution of total residential income ($Y_n = v_n \cdot R_n$) growth and the distribution of total workplace income ($Y_i = w_i \cdot L_i$) growth when $\nu \to 0$. Kernel distribution fits are displayed in Panel a and b with a bandwidth of size 10 and 1, respectively. The mean and the median of both distributions are also displayed. Eliminating the distance penalty from crossing local borders is associated to a 11.70% average growth in total residential income (Panel a) and a 0.08% growth in local workplace GDP (Panel b). Figure 13 (Panel a) geo-localizes these gains

at the departmental level. Large residential gains are observed at the periphery of large urban centers.

Figure 11: Cost-Benefit Analysis

a. Distribution of total residential income growth (%)

b. Distribution of total workplace income growth (%)



Notes: Growth is expressed in percent. Unit local road construction cost of €5.4 millions per kilometer is used. Fit of Kernel distribution are displayed in Panel a and b with a bandwidth of size 10 and 1, respectively.

The large difference in gains between total residential and total workplace income is a direct consequence of how commuting and production are modeled. Love of variety and increasing returns lead to agglomeration economies which concentrate production, but commuting costs impose a relatively smaller constraint on the concentration of residential density. Hence, removing frictions at local borders leads to stronger reactions on the residential side of the economy. This is in line with the choice of outcome variables and the reduced form results in Section 6.

How do commuting flows evolve?

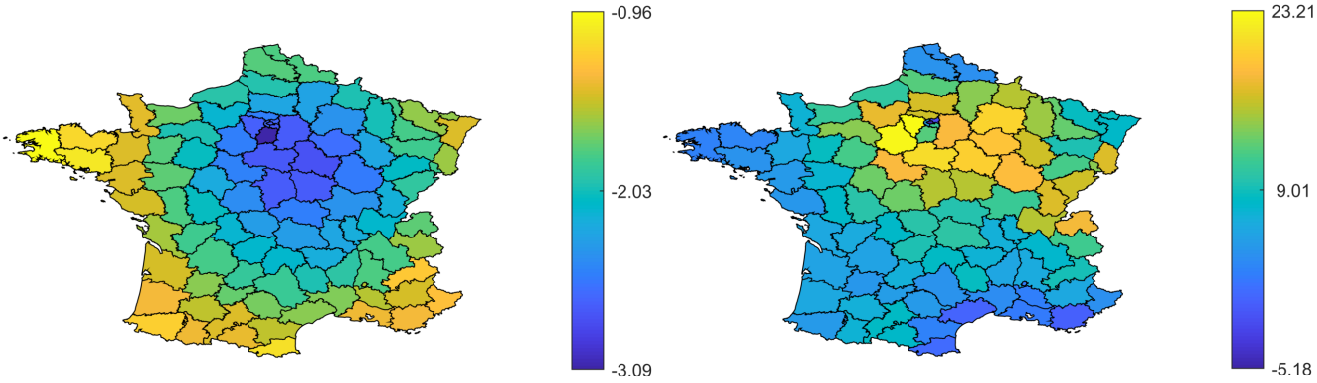
Figure 12 shows how average (Panel a) and total (Panel b) commuting distances evolve when $\nu \to 0$. Average commuting distances decrease relatively more for geographically central locations, and for those departments that have more neighbors. As the evolution is expressed in percent, this is simply reflecting the fact that eliminating the distance penalty when crossing regional borders represents relatively more for departments with smaller average distances to all other locations (e.g., Paris versus Brittany). The map of total commuting distance in Figure 12b reveals different patterns as changes in residential mass matter. Overall, locations in a large great circle around Paris appear to gain a lot in population. In the department of the Yvelines (West of Paris) the

total commuting distance (i.e., total km traveled by all residents) increases by 23.21% following an expected large movement of residential activity towards this department. Departments around the Swiss border also gain significantly, whereas departments around the Mediterranean Sea and in Brittany lose the most in terms of residents.

Figure 12: Departmental level commuting

a. Average commuting distance ($\frac{L}{R_n}\sum_i d_{ni}\lambda_{ni}$, growth in %)

b. Total commuting distance ($L\sum_i d_{ni}\lambda_{ni}$, growth in %)



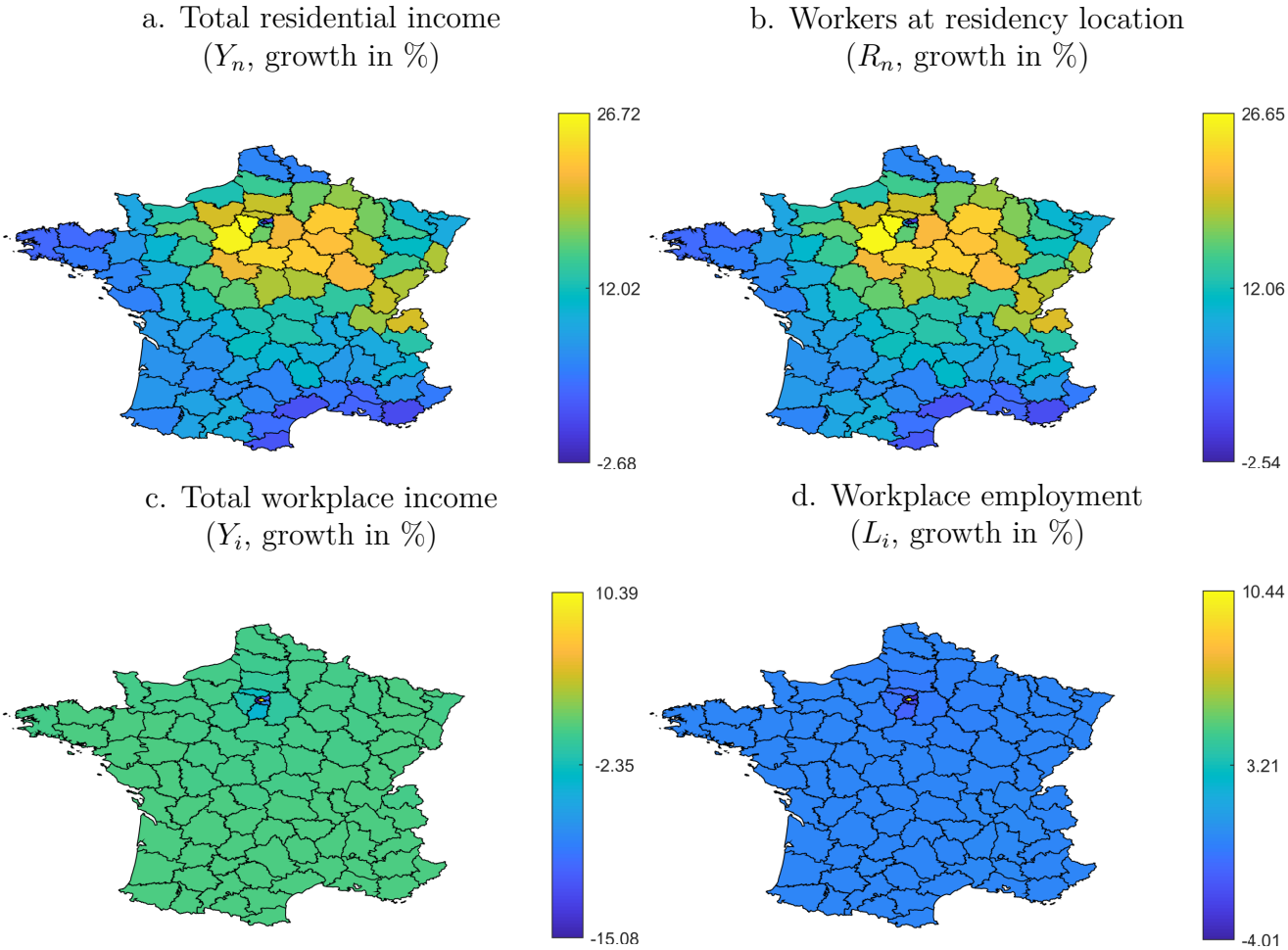
Notes: Aggregation at the department level. Growth is expressed in percent. Unit local road construction cost of €5.4 millions per kilometer is used.

How are the gains and losses spatially distributed?

Figure 13 illustrates by way of maps the growth in residential and workplace characteristics induced from removing frictions at regional borders. For each outcome, growth expressed in percent is displayed. Panel a of Figure 13 looks at total residential income growth, whereas Panel b focuses on residential population growth. Symmetrically, Panel c reports on total workplace income growth, and Panel d on workplace employment.

All departments at the periphery of the Greater Paris and towards the Champagne region (East of Paris) gain significantly in residential income and residential density in line with total commuting patterns in Figure 12. At the maximum of the effect, both population and income are predicted to increase by almost 30% in the department of the Yvelines (West of Paris). These gains occur, partly at the expense of the Paris and its close periphery ("Petite Couronne" in French), but mostly at the expense of peripheral French departments (for instance, in Brittany and along the Mediterranean coast). Taking averages at the departmental level, losses reach -2.68% in residential income and -2% in population in these regions. Consequently, the lions' share of the total residential income gains are driven by population movements. The mechanism behind this effect is intuitive. Locations at the periphery of Paris' metropolitan area are suddenly

Figure 13: Departmental level total residence and workplace income growth



Notes: Aggregation at the department level. Growth is expressed in percent. Unit local road construction cost of €5.4 millions per kilometer is used.

much closer to Paris' economic center as local border frictions decrease; and hence, relatively more attractive to workers from peripheral departments. The results then predict a significant increase in the size of Paris' metropolitan area.

Looking at workplace characteristics, minor effects are observed in the national periphery as "small" urban centers gain from increased commuting access, but regions lose overall in population. Moreover, Paris's economic center gains significantly in total workplace income and employment (about 11% growth for both).

Overall, removing the decentralization induced penalty associated to crossing regional borders acts as an *agglomeration force* for both residence and workplace characteristics. Municipalities on the side with the initial smaller labor market suddenly become more attractive for residential purposes. Around large urban centers such as Paris, the missing mass on the small side of the border appears to be only partly filled by simple local residential density smoothing. In-migration

from peripheral regions contributes greatly to fill the gap. In turn, the surrounding labor markets benefit from the arrival of workers.

9 Conclusion

In this paper, I show that commuting flows, labor catchment areas and residential masses vary discontinuously at regional borders using a quasi-experimental setting around French departmental borders. To account for possible endogeneity in the placement of borders, I propose a novel Instrumental Variable (IV) approach exploiting a geometric border design proposed during the French Revolution. This border design proposal was ultimately not adopted, but served as inspiration for the current French departmental division.

To rationalize why discontinuities appear at regional borders, I proceed in two steps. First, I estimate that crossing a regional border increases travel distances discontinuously by about 7km. This result is further supported by placebo border analyses and tests for discontinuities in the provision of other public services at regional borders. Second, I structurally estimate a quantifiable general equilibrium model of commuting openness using the commuting and residential results from the spatial regression discontinuity estimator as moments in a Generalized Method of Moments approach. In line with the empirical results, this equilibrium analysis confirms that an average 7km distance penalty best rationalizes the estimated discontinuities at regional borders. This penalty is a consequence of the decentralized planning and administration of local transport networks. Failure to coordinate by local governments leads to a lack of local network integration at regional borders.

To investigate possible gains from eliminating the distance penalty, I simulate the costs and benefits of integrating local transport networks at regional borders. The proposed analysis trades off road construction costs financed via a head tax levied on all workers and benefits from a better spatial match in residential and workplace locations. I calibrate the developed quantifiable framework to match key characteristics of the French economic geography, including realistic construction costs and endogenous residential developments. The results indicate that integrating regional networks leads to an average 11.7% real per capita income growth. Departments in a wide circle around Paris and towards the French-Swiss border particularly gain in residential density at the expense of more peripheral departments.

References

Agrawal, D. R. (2015, May). The tax gradient: Spatial aspects of fiscal competition. *American Economic Journal: Economic Policy 7*(2), 1–29.

Agrawal, D. R. and W. H. Hoyt (2018). Commuting and taxes: Theory, empirics and welfare implications. *The Economic Journal 128*(616), 2969–3007.

Ahlfeldt, G. M., S. J. Redding, D. M. Sturm, and N. Wolf (2015, November). The Economics of Density: Evidence From the Berlin Wall. *Econometrica 83*, 2127–2189.

Allen, T., C. Arkolakis, and X. Li (2015). On the existence and uniqueness of trade equilibria.

Alonso, W. (1964). *Location and Land Use.* Cambridge, MA: Harvard University Press.

Anderson, J. E. and E. van Wincoop (2003, March). Gravity with gravitas: A solution to the border puzzle. *American Economic Review 93*(1), 170–192.

Baum-Snow, N. (2007). Did highways cause suburbanization? *The Quarterly Journal of Economics 122*(2), 775–805.

Beerli, A., J. Ruffner, M. Siegenthaler, and G. Peri (2018, November). The abolition of immigration restrictions and the performance of firms and workers: Evidence from switzerland. Working Paper 25302, National Bureau of Economic Research.

Behrens, K., G. Mion, Y. Murata, and J. Suedekum (2017). Spatial frictions. *Journal of Urban Economics 97*, 40 – 70.

Black, S. E. (1999). Do better schools matter? parental valuation of elementary education. *The Quarterly Journal of Economics 114*(2), 577–599.

Brandts, J. and D. J. Cooper (2006, June). A change would do you good .... an experimental study on how to overcome coordination failure in organizations. *American Economic Review 96*(3), 669–693.

Broda, C. and D. E. Weinstein (2006, 05). Globalization and the Gains From Variety. *The Quarterly Journal of Economics 121*(2), 541–585.

Brownstone, D. and K. A. Small (2005). Valuing time and reliability: assessing the evidence from road pricing demonstrations. *Transportation Research Part A: Policy and Practice 39*(4), 279 – 293. Connection Choice: Papers from the 10th IATBR Conference.

Calabrese, S. M., D. N. Epple, and R. E. Romano (2012). Inefficiencies from metropolitan political and fiscal decentralization: Failures of tiebout competition. *The Review of Economic Studies 79*(3), 1081–1111.

Caliendo, L., F. Parro, E. Rossi-Hansberg, and P.-D. Sarte (2018). The impact of regional and sectoral productivity changes on the u.s. economy. *Review of Economic Studies 85*(4), 2042–2096.

Calonico, S., M. D. Cattaneo, and R. Titiunik (2014). Robust nonparametric confidence intervals for regression-discontinuity designs. *Econometrica 82*(6), 2295–2326.

Chapelle, G. and J.-B. Eyméoud (2017). Can big data increase our knowledge of the rental market?

Chen, Z., Z. Liu, J. C. Suárez Serrato, and Y. Xu (2018). Notching r&d investment with corporate income tax cuts in china. NBER Working Papers 24749, National Bureau of Economic Research, Inc.

Christmann, N., M. Mostert, P.-F. Wilmotte, J.-M. Lambotte, and M. Cools (2020). Opportunities for reinforcing cross-border railway connections: the case of the liège (belgium) - maastricht (the netherlands) connection. *European Planning Studies 28*(1), 105–124.

Combes, P.-P., M. Lafourcade, and T. Mayer (2005, May). The trade-creating effects of business and social networks: evidence from France. *Journal of International Economics 66*(1), 1–29.

Coomes, P. A. and W. H. Hoyt (2008). Income taxes and the destination of movers to multistate msas. *Journal of Urban Economics 63*(3), 920 – 937.

Courant, P. and A. Deardorff (1992). International trade with lumpy countries. *Journal of Political Economy 100*(1), 198–210.

Desmet, K., D. K. Nagy, and E. Rossi-Hansberg (2018). The geography of development. *Journal of Political Economy 126*(3), 903–983.

Desmet, K. and E. Rossi-Hansberg (2013, October). Urban accounting and welfare. *American Economic Review 103*(6), 2296–2327.

Devetag, G. and A. Ortmann (2007). When and why? a critical survey on coordination failure in the laboratory. *Experimental Economics 10*(3), 331–344.

Diamond, R. (2016). The determinants and welfare implications of us workers' diverging location choices by skill: 1980-2000. *American Economic Review 106*(3), 479–524.

Dube, A., T. W. Lester, and M. Reich (2010). Minimum wage effects across state borders: Estimates using contiguous counties. *The Review of Economics and Statistics 92*(4), 945–964.

Duranton, G. and M. A. Turner (2012, 03). Urban Growth and Transportation. *The Review of Economic Studies 79*(4), 1407–1440.

Eaton, J. and S. Kortum (2002). Technology, geography, and trade. *Econometrica 70*(5), 1741–1779.

Egger, P. H., M. Koethenbuerger, and G. Loumeau (2017). Local Border Reforms and Economic Activity. CESifo Working Paper Series 6738, CESifo.

Egger, P. H. and A. Lassmann (2015, 05). The Causal Impact of Common Native Language on International Trade: Evidence from a Spatial Regression Discontinuity Design. *The Economic Journal 125*(584), 699–745.

Ehrlich, M. v. and T. Seidel (2018, November). The persistent effects of place-based policy: Evidence from the west-german zonenrandgebiet. *American Economic Journal: Economic Policy 10*(4), 344–74.

Erhardt, K. and S. Haenni (2018). Born to be an entrepreneur? how cultural origin affects entrepreneurship. ECON - Working Papers 309, Department of Economics - University of Zurich.

Eugster, B. and R. Parchet (2019). Culture and taxes. *Journal of Political Economy 127*(1), 296–337.

Evans, C. L. (2003, September). The economic significance of national border effects. *American Economic Review 93*(4), 1291–1312.

Faber, B. (2014). Trade integration, market size, and industrialization: Evidence from china's national trunk highway system. *Review of Economic Studies 81*(3), 1046–1070.

Fajgelbaum, P. D., E. Morales, J. C. S. Serrato, and O. Zidar (2019). State Taxes and Spatial Misallocation. *Review of Economic Studies 86*(1), 333–376.

Felbermayr, G. and A. Tarasov (2015). Trade and the Spatial Distribution of Transport Infrastructure. CESifo Working Paper Series 5634, CESifo.

Fretz, S., R. Parchet, and F. Robert-Nicoud (2017). Highways, Market Access, and Spatial Sorting. CESifo Working Paper Series 6770, CESifo Group Munich.

Hahn, J., P. Todd, and W. V. der Klaauw (2001). Identification and estimation of treatment effects with a regression-discontinuity design. *Econometrica 69*(1), 201–209.

Holmes, T. J. (1998). The effect of state policies on the location of manufacturing: Evidence from state borders. *Journal of Political Economy 106*(4), 667–705.

Kumar, A. (2018, February). Do restrictions on home equity extraction contribute to lower mortgage defaults? evidence from a policy discontinuity at the texas border. *American Economic Journal: Economic Policy 10*(1), 268–97.

Lee, D. S. and T. Lemieux (2010). Regression discontinuity designs in economics. *Journal of Economic Literature 48*(2), 281–355.

Lucas, R. and E. Rossi-Hansberg (2002). On the internal structure of cities. *Econometrica 70*(4), 1445–1476.

McCallum, J. (1995). National borders matter: Canada-u.s. regional trade patterns. *The American Economic Review 85*(3), 615–623.

Mills, E. S. (1967). An aggregative model of resource allocation in a metropolitan area. *The American Economic Review 57*(2), 197–210.

Monte, F., S. J. Redding, and E. Rossi-Hansberg (2018, December). Commuting, migration, and local employment elasticities. *American Economic Review 108*(12), 3855–90.

Muth, R. M. (1969). *Cities and Housing*. Chicago: University of Chicago Press.

Oates, W. (1969). The effects of property taxes and local public spending on property values: An empirical study of tax capitalization and the tiebout hypothesis. *Journal of Political Economy 77*(6), 957–71.

Obstfeld, M. and K. Rogoff (2001, January). *The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?*, pp. 339–412. MIT Press.

Ortega, F. and G. Peri (2016). The effect of income and immigration policies on international migration. In *The Economics of International Migration*, Chapter 11, pp. 333–360. World Scientific Publishing Co. Pte. Ltd.

Pinkovskiy, M. L. (2017, June). Growth discontinuities at borders. *Journal of Economic Growth 22*(2), 145–192.

Rohlin, S., S. S. Rosenthal, and A. Ross (2014). Tax avoidance and business location in a state border model. *Journal of Urban Economics 83*, 34 – 49.

Shoag, D. and E. Muehlegger (2015). Commuting times and land use regulations. *Procedia Engineering 107*, 488 – 493. Humanitarian Technology: Science, Systems and Global Impact 2015, HumTech2015.

Sippel, L., J. Nolte, S. Maarfield, D. Wolff, and L. Roux (2018). Comprehensive analysis of the existing cross-border rail transport connections and missing links on the internal eu borders. Technical report, European Commission - Directorate-General for Regional and Urban Policy.

Stock, J. H. and M. Yogo (2005). *Testing for Weak Instruments in Linear IV Regression*, pp. 80–108. Cambridge University Press.

Tiebout, C. M. (1956). A pure theory of local expenditures. *Journal of Political Economy 64*.

Tombe, T. and X. Zhu (2015, June). Trade, Migration and Productivity: A Quantitative Analysis of China. Working Papers tecipa-542, University of Toronto, Department of Economics.

van Huyck, J., R. Battalio, and R. Beil (1990). Tacit coordination games, strategic uncertainty, and coordination failure. *American Economic Review 80*(1), 234–48.

van Huyck, J. B., R. C. Battalio, and R. O. Beil (1991, 08). Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games. *The Quarterly Journal of Economics 106*(3), 885–910.

Wrona, J. (2018, August). Border Effects Without Borders: What Divides Japan's Internal Trade? *International Economic Review 59*(3), 1209–1262.

APPENDIX: FOR ONLINE PUBLICATION ONLY

A Data description

The data used in this paper comes from the following sources.

1. All **demographic and administrative data** are provided by the *National Institute of Statistics and Economic Studies* (INSEE) for the year 2010. This includes:

   (a) A wide array of municipal characteristics, i.e., number of residents, number of workers, median wage (in €), sum of floor space across local primary residencies (for 2016).

   (b) The universe of municipality-to-municipality commuting flows for the entire mainland France. Commuting flows are further dissagregated by occupation (i.e., six socio-economic categories) and transport mode.

2. All **geolocalized data** are provided by the *National Institute of Geographic and Forest Information* (IGN) and processed using the geographic information system ArcGIS (esp., ArcGIS Network Solver) as of 2015. This includes:

   (a) All administrative borders, including national, departmental and municipal levels, as of January, 1st, 2015.

   (b) Road infrastructure networks, including highways, national and regional roads, as of January, 1st, 2015. The data set includes road length and speed for each segment. Highways are only accessible via access ramps. ArcGIS Network Solver is used to retrieve bilateral travel distances and times.

3. The **map of the geometric border proposal** by the Sieyès committee is provided by French *National Archives* (Centre historique des Archives nationales - Atelier de photographie).

   (a) The proposed geometric delineation is then geolocalized using ArcGIS.

4. **Housing rents** (in euro per m^2) are provided by Chapelle and Eyméoud (2017) at the municipal level. This last dataset is based on a web scrapping of France's largest online rental platforms. It is however important to note that, in some municipalities, no advertisement was posted during the surveying time. Hence, I do not observe rental prices for these municipalities. In the estimation, I treat these missing values as randomly missing. In

the structural analysis, I replace missing housing rents with the average of the neighbors' housing rents.

Below, Table 7 provides simple descriptive statistics for municipalities within different bandwidths around local borders.

Table 7: Descriptive statistics

	Bandwidth = 40km		Bandwidth = 10km		Bandwidth = 1km	
	Mean	SD	Mean	SD	Mean	SD
Residential worker count	750.36	6,111.90	774.02	7,098.56	990.91	11,079.02
Share of workers for which $i = j$	0.92	0.13	0.89	0.15	0.83	0.18
Area (km^2)	15.77	15.48	16.48	16.81	19.70	21.37
Rents (per m^2)	9.19	2.80	9.27	2.99	9.35	3.27
Wage (€)	19,917.42	2,883.98	19,810.90	2,986.88	19,554.17	3,013.37
Distance to the regional border	7.67	7.31	3.27	3.22	0.06	0.19
Obs.	29,403		19,518		7,482	

Notes: Administrative and demographic data recorded at the municipal level in 2010. Housing market data were collected between December 2015 and December 2017. *Source:* INSEE, IGN, Chapelle and Eyméoud (2017).

B Supporting material

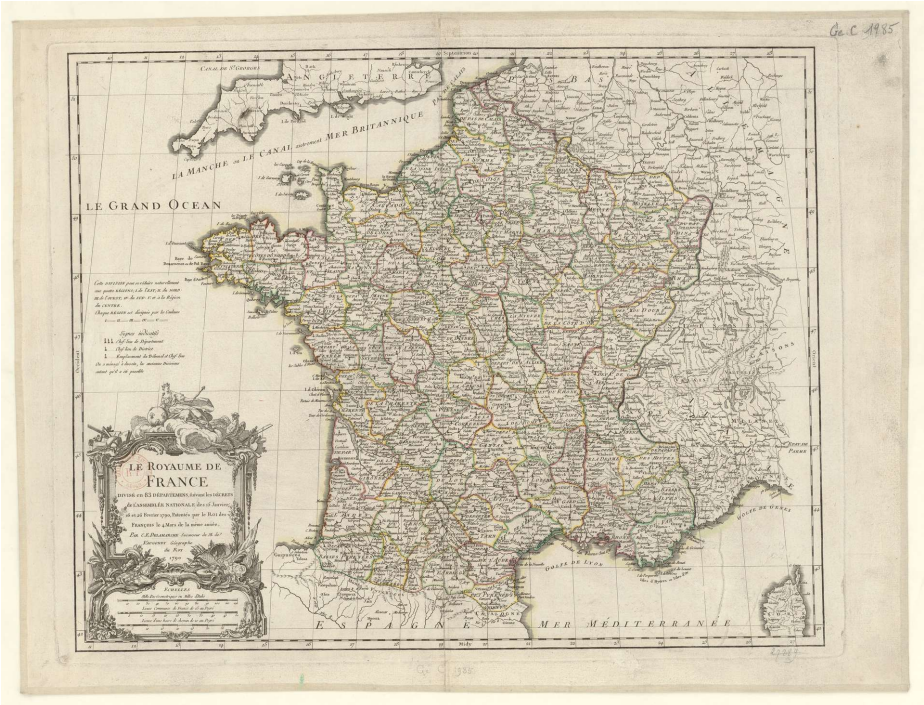
Table 8: Departmental public finances

a. Revenues	Amount (billion €)	Share of total (%)	**b. Spending**	Amount (billion €)	Share of total (%)
Local taxes	22.3	35	Social programs	38.7	65
Transfer	16.1	25	Regional roads	4.2	7
Tax transfers	22.8	36	Secondary schools	4.2	7
Other	2.7	4	Fire departments	2.6	4
			Other	14.2	17
Total	64	100	Total	64	100

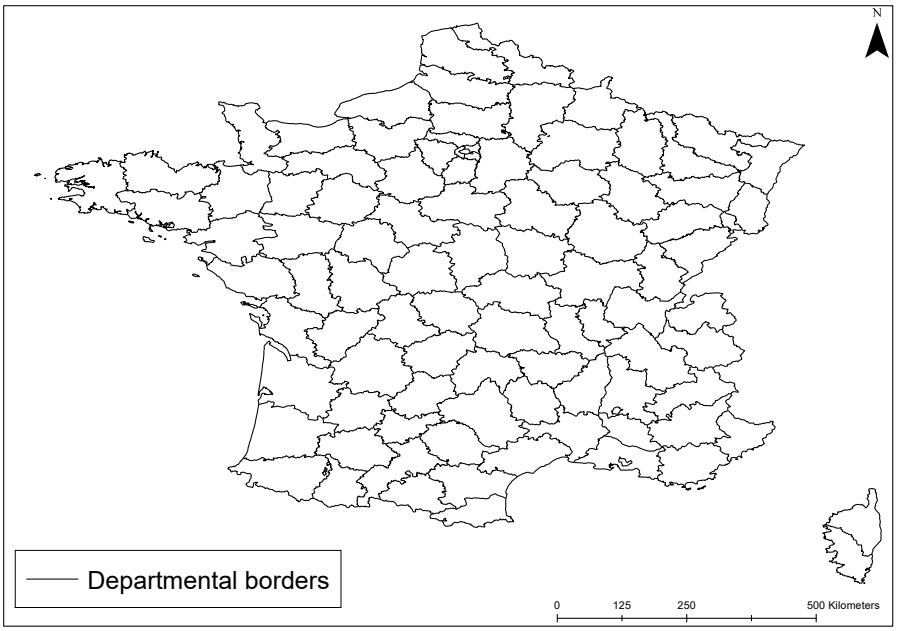
Source: Official departmental budgets, 2016.

Figure 14: Departmental borders in 1790 and today

a. Division adopted in March 1790



b. Departmental borders today



Notes: Panel a shows the final departmental division adopted by the French National Assembly in 1790. Panel b displays the departmental division since the last change in 1964. Corsica is not included in the analysis of this paper.

Table 9: Commuting analysis accounting for departmental tax base at the municipal level

	I	II	III	IV	V
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Fourth	Fifth	Opt.
Bandwidth	20	20	20	20	Opt.
Treatment	0.796***	0.750***	0.775***	0.735***	0.656***
	(0.002)	(0.003)	(0.003)	(0.004)	(0.012)
Adj. R^2	0.96	0.96	0.95	0.95	
Obs.	14,480	14,480	11,580	11,580	4,292

Notes: Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Housing rents are provided by Chapelle and Eyméoud (2017).

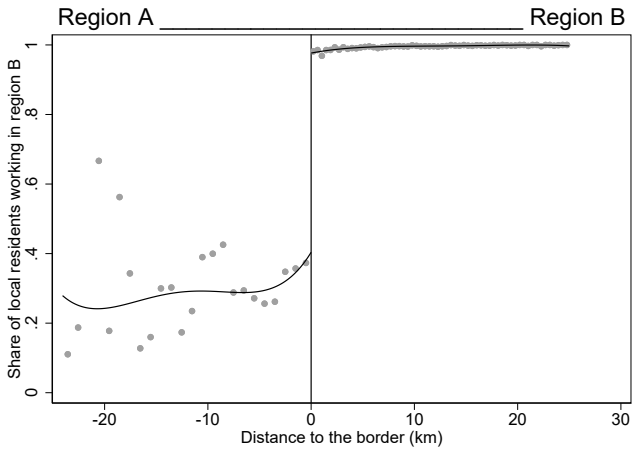
Table 10: Heterogeneous commuters

	I	II	III	IV	V
			a. Farmers		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.654***	0.645***	0.654***	0.644***	0.580***
	(0.016)	(0.020)	(0.016)	(0.018)	(0.052)
Adj. R^2	0.79	0.79	0.79	0.80	-
Obs.	14,594	14,594	9,214	9,214	3,431
			b. Craftsmen		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.717***	0.693***	0.709***	0.686***	0.625***
	(0.006)	(0.008)	(0.006)	(0.007)	(0.019)
Adj. R^2	0.84	0.84	0.84	0.84	-
Obs.	17,487	17,487	11,690	11,690	5,861
			c. White collars		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.574***	0.524***	0.561***	0.521***	0.446***
	(0.005)	(0.007)	(0.005)	(0.007)	(0.017)
Adj. R^2	0.75	0.75	0.73	0.74	-
Obs.	19,669	19,669	14,121	14,121	6,850
			d. Intermediate professions		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.654***	0.596***	0.632***	0.583***	0.520***
	(0.003)	(0.005)	(0.004)	(0.005)	(0.013)
Adj. R^2	0.84	0.84	0.82	0.83	-
Obs.	24,652	24,652	18,203	18,203	9,206
			e. Employees		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.738***	0.692***	0.720***	0.679***	0.613***
	(0.003)	(0.004)	(0.003)	(0.005)	(0.011)
Adj. R^2	0.88	0.89	0.87	0.88	-
Obs.	23,836	23,836	17,144	17,144	9,429
			f. Blue collars		
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Second	Third	Opt.
Bandwidth	20km	20km	10km	10km	Opt.
Treatment	0.702***	0.652***	0.681***	0.635***	0.557***
	(0.003)	(0.004)	(0.003)	(0.005)	(0.013)
Adj. R^2	0.87	0.88	0.86	0.86	-
Obs.	25,062	25,062	18,427	18,427	7,815

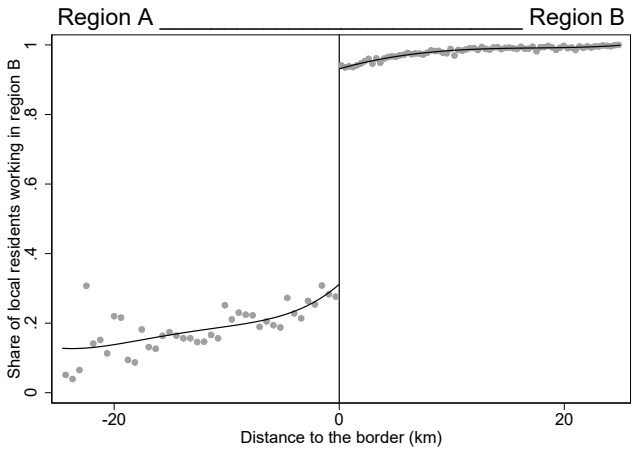
Notes: Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Categories based on the French National Statistical Office *Classification of Professions and Socioprofessional Categories.*

Figure 15: Heterogeneous commuters around regional borders

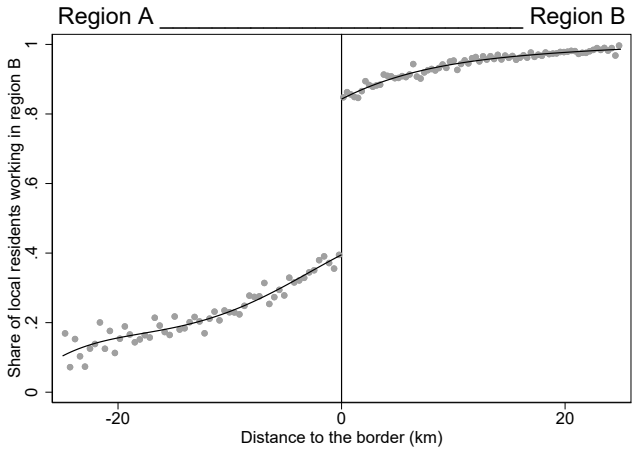
a. Farmers



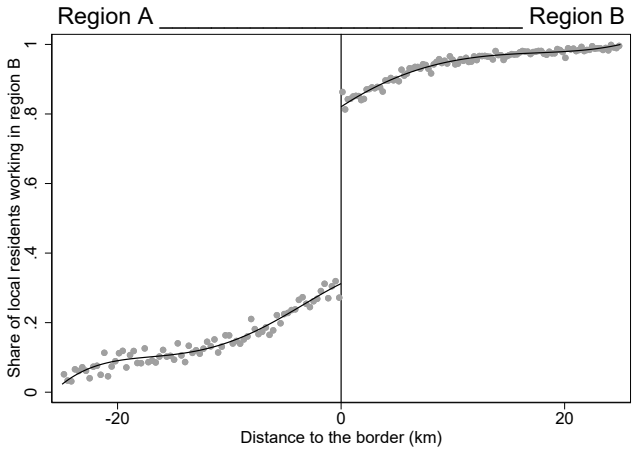
b. Craftsmen



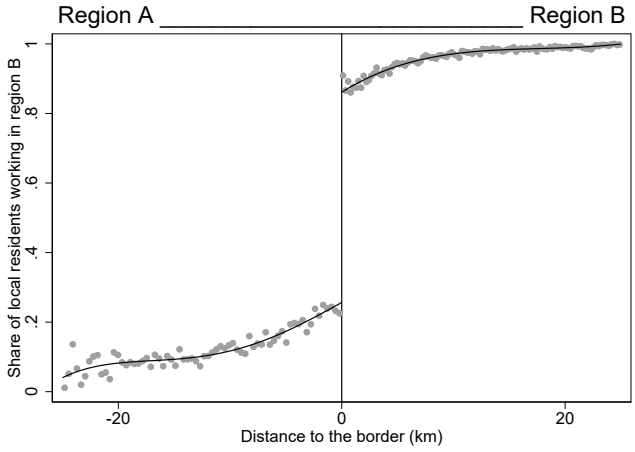
c. White collars



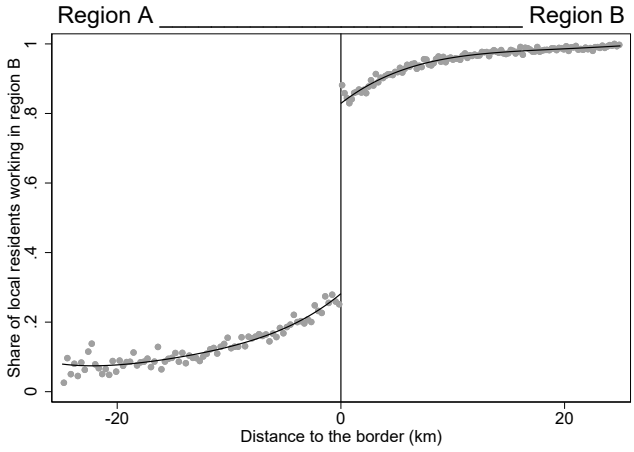
d. Intermediate professions



e. Employees



f. Blue collars



Notes: Fourth order polynomial with 25km bandwidth used. Bin size selected using the IMSE-optimal evenly-spaced method with spacing estimators. Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Categories based on the French National Statistical Office *Classification of Professions and Socioprofessional Categories*.

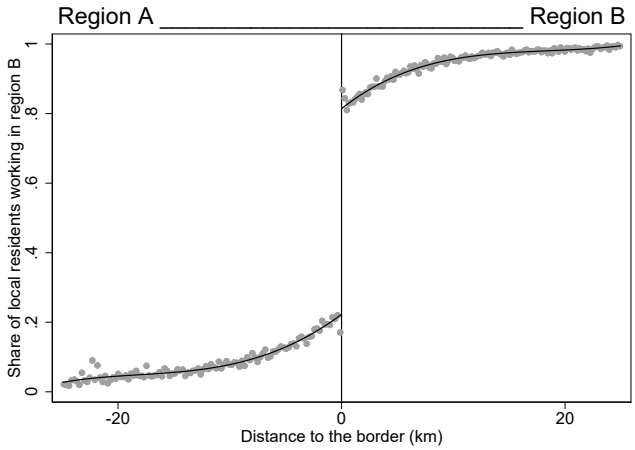
Table 11: Heterogeneous commuting by transport mode

	I	II	III	IV	V
	a. Private transport				
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Fourth	Fifth	Opt.
Bandwidth	20	20	20	20	Opt.
Treatment	0.749***	0.695***	0.725***	0.678***	0.603***
	(0.002)	(0.003)	(0.002)	(0.004)	(0.010)
Adj. R^2	0.93	0.93	0.92	0.92	
Obs.	29,951	29,951	23,390	23,390	9,120
	b. Public transport				
Specification	OLS				Non-parametric
Polynomial order	Second	Third	Fourth	Fifth	Opt.
Bandwidth	20	20	20	20	Opt.
Treatment	0.473***	0.452***	0.463***	0.442***	0.398***
	(0.010)	(0.012)	(0.010)	(0.012)	(0.040)
Adj. R^2	0.56	0.56	0.57	0.57	-
Obs.	8,986	8,986	6,299	6,299	2,187

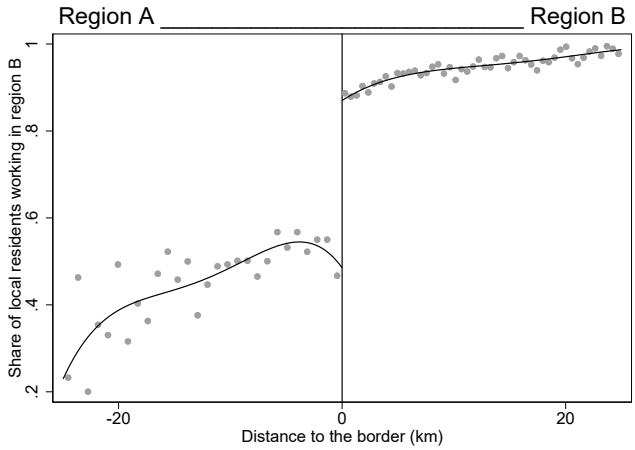
Notes: Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Private transport includes commuting by car, bike or walk. Public transport includes commuting by bus, regional train, subway, etc.

Figure 16: Heterogeneous commuters around regional borders

a. Private transport



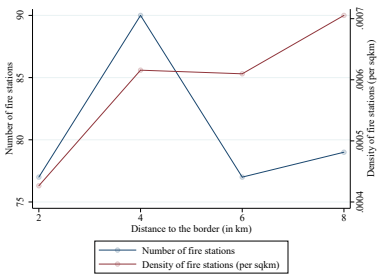
b. Public transport



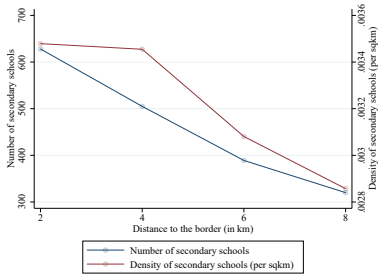
Notes: Fourth order polynomial with 25km bandwidth used. Bin size selected using the IMSE-optimal evenly-spaced method with spacing estimators. Commuting flows based on the universe of residence-to-workplace commuting flows in 2010 in France. Private transport includes commuting by car, bike or walk. Public transport includes commuting by bus, regional train, subway, etc.

Figure 17: Fire stations and secondary schools around regional borders

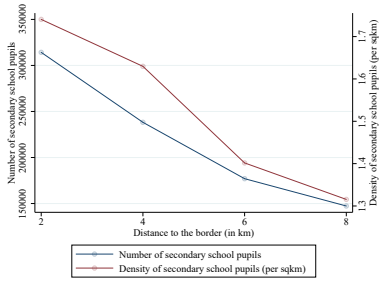
a. Fire stations



b. Secondary schools



b. Secondary school pupils

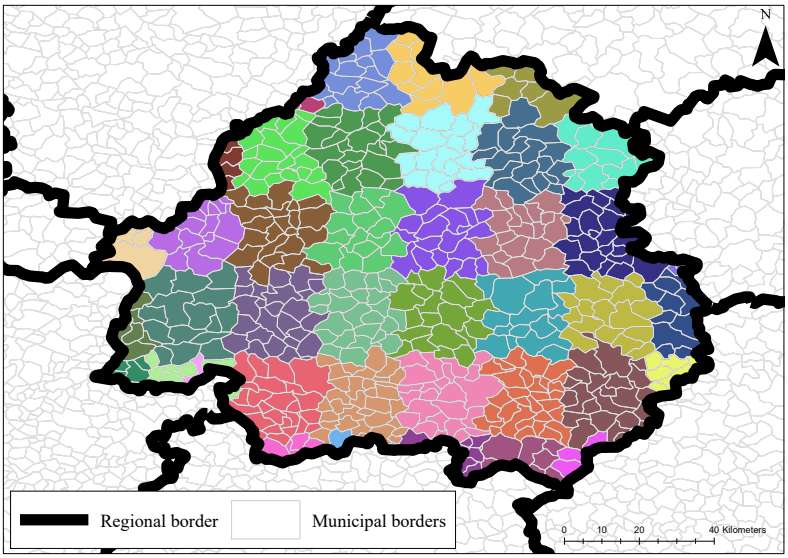


Notes: The location of fire stations is provided by Open Street Map (OSM), accessed on Nov 4th, 2020. Data on secondary schools' location and attendance is provided by the French Ministry of Education for the year 2015. Area within 2km, 4km, 6km, and 8km of a regional border is produced using ArcGIS based on the official French departmental borders shapefile.

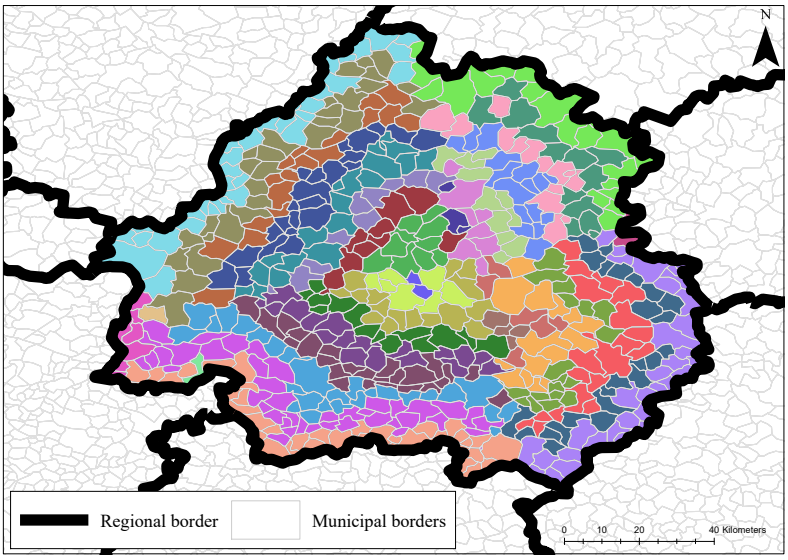
Figure 18 displays an example of the set of structural locations (Panel a), as well as an alternative definition (Panel b), using a zoom of the department of Dordogne (NUTS3 code: 24). The sum of distances between the centroid of the areas and each individual municipalities is smaller under the adopted definition.

Figure 18: Set of locations considered in the analysis

(a) Squares of 0.2° (≈ 20km)
(adopted definition)

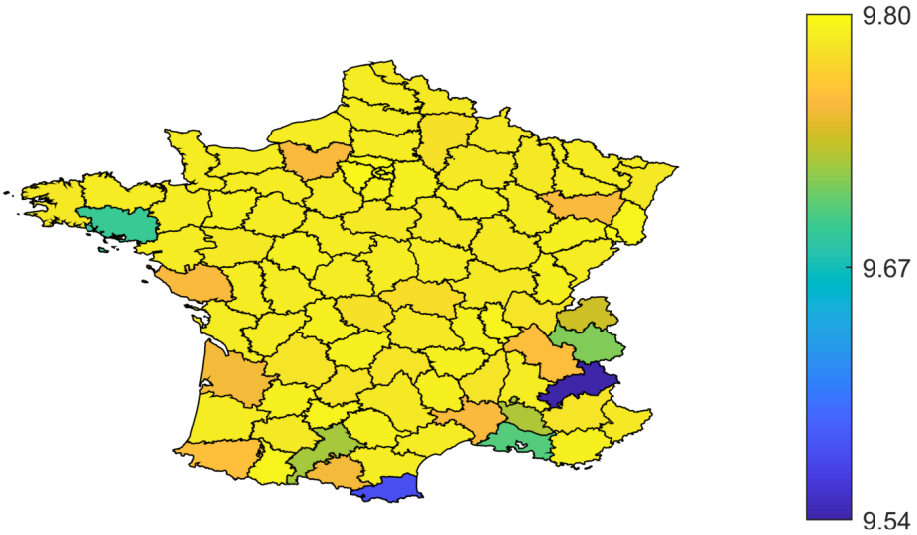


(a) 5km band of the regional borders
(alternative definition)



Notes: Zoom over the department "Dordogne" (NUTS3 code: 24).

Figure 19: Reduction in aggregated bilateral travel distances



Notes: Average reduction in aggregated bilateral travel distances, in km, when $\nu \to 0$. Aggregation at the department level.

C Existence and uniqueness of equilibrium

I present conditions for the existence and uniqueness of a general equilibrium of the modeled economy. The proof follows closely Monte et al. (2018). First, I reformulate key equations of the model. Using land market clearing (4), denoting the utility level in the country with $\overline{U}$, I can express the total workplace income, Y_i, as:

$$Y_i = \left(\frac{\overline{U}}{\delta}\right)^{-\epsilon} \overline{L}(1-\alpha)^{-(1-\alpha)(1-\eta)\epsilon} q_n^{-(1-\alpha)(1-\eta)\epsilon} w_i^{1+\epsilon} \sum_{n\in N} B_n \kappa_{ni}^{\epsilon} P_n^{-\alpha\epsilon} X_n^{-(1-\alpha)(1-\eta)\epsilon}. \tag{16}$$

Similarly, I can express total residential income, Y_n, as:

$$Y_n = \left(\frac{\overline{U}}{\delta}\right)^{-\epsilon} \overline{L}(1-\alpha)^{-(1-\alpha)(1-\eta)\epsilon} q_n^{-(1-\alpha)(1-\eta)\epsilon} P_n^{-\alpha\epsilon} X_n^{-(1-\alpha)(1-\eta)\epsilon} B_n \sum_{i\in N} \kappa_{ni}^{\epsilon} w_i^{1+\epsilon}. \tag{17}$$

Given $Y_i = w_i L_i$, the price index in n, P_n can be expressed as:

$$P_n^{1-\sigma} = \left(\frac{\sigma}{1-\sigma}\right)^{1-\sigma} \frac{1}{\sigma F} \left[\sum_{i\in N} Y_i \left(\frac{\zeta_{ni}}{A_i}\right)^{1-\sigma} w_i^{-\sigma}\right]. \tag{18}$$

Finally, the goods market clearing condition can be simplified to:

$$w_i^{\sigma} = \left(\frac{\sigma}{1-\sigma}\right)^{1-\sigma} \frac{1}{\sigma F} \sum_{n\in N} \left(\frac{\zeta_{ni}}{A_i}\right)^{1-\sigma} P_n^{\sigma-1} X_n. \tag{19}$$

Given symmetric commuting ($\kappa_{ni} = \kappa_{in}$) and trade costs $\zeta_{ni} = \zeta_{in}$, and combining the four above equations (16), (17), (18), and (19), I obtain the following system of equations:

$$P_n^{1-\sigma} = \xi^P \sum_{i\in N} \mathfrak{K}_{ni}^P Y_i w_i^{-\sigma}, \tag{20}$$

$$w_n^{\sigma} = \xi^w \sum_{i\in N} \mathfrak{K}_{ni}^w P_i^{\sigma-1} X_i, \tag{21}$$

$$Y_n w_n^{-(1+\epsilon)} = \xi^Y \sum_{i\in N} \mathfrak{K}_{ni}^Y P_i^{-\alpha\epsilon} X_i^{-(1-\alpha)(1-\eta)\epsilon}, \tag{22}$$

$$X_n^{1+\epsilon(1-\alpha)(1-\eta)} P_n^{\alpha\epsilon} = \xi^X \sum_{i\in N} \mathfrak{K}_{ni}^X w_i^{1+\epsilon}; \tag{23}$$

where I have the following scalars:

$$\xi^P \equiv \left(\frac{\sigma}{1-\sigma}\right)^{1-\sigma} \frac{1}{\sigma F}, \tag{24}$$

$$\xi^w \equiv \left(\frac{\sigma}{1-\sigma}\right)^{1-\sigma} \frac{1}{\sigma F}, \tag{25}$$

$$\xi^Y \equiv \left(\frac{\overline{U}}{\delta}\right)^{-\epsilon} \overline{L}(1-\alpha)^{-(1-\alpha)\epsilon}, \tag{26}$$

$$\xi^X \equiv \left(\frac{\overline{U}}{\delta}\right)^{-\epsilon} \overline{L}(1-\alpha)^{-(1-\alpha)\epsilon}; \tag{27}$$

and the following kernels:

$$\mathfrak{K}^Y_{ni} \equiv \left(\frac{\zeta_{ni}}{A_i}\right)^{1-\sigma}, \tag{28}$$

$$\mathfrak{K}^Y_{ni} \equiv \left(\frac{\zeta_{ni}}{A_i}\right)^{1-\sigma}, \tag{29}$$

$$\mathfrak{K}^Y_{ni} \equiv B_n \kappa_{ni}^{-\epsilon} q_n^{-(1-\alpha)(1-\eta)\epsilon}, \tag{30}$$

$$\mathfrak{K}^Y_{ni} \equiv B_n \kappa_{ni}^{-\epsilon} q_n^{-(1-\alpha)(1-\eta)\epsilon}. \tag{31}$$

Denote by x_i^h the value of the endogenous variable $h \in [1, ..., H]$ for location $i = [1, ..., I]$. Using this notation, and further denoting the corresponding sets of endogenous variables and locations, Ω^H and Ω^N, respectively, the system of equations (20)-(23) can be rewritten as:

$$\prod_{h=1}^{H} (x_i^h)^{\beta_{kh}} = \xi_k \sum_{n=1}^{N} \mathfrak{K}^k_{ni} \left[\prod_{h=1}^{H} (x_n^h)^{\gamma_{kh}} \right], \quad i \in \Omega^N, \quad k, h \in \Omega^H. \tag{32}$$

I then denote B and Γ as the $H \times H$ matrices, whose elements $(B)_{kh} = \beta_{kh}$ and $(\Gamma)_{kh} = \gamma_{kh}$ are the parameters from the left and right-hand sides of these equations, respectively. From equations (20)-(23), we have:

$$B = \begin{bmatrix} 1-\sigma & 0 & 0 & 0 \\ 0 & \sigma & 0 & 0 \\ 0 & -(1+\epsilon) & 1 & 0 \\ \alpha\epsilon & 0 & 0 & 1+(1-\alpha)(1-\eta)\epsilon \end{bmatrix} \tag{33}$$

$$\Gamma = \begin{bmatrix} 0 & -\sigma & 1 & 0 \\ \sigma - 1 & 0 & 0 & 1 \\ -\alpha\epsilon & 0 & 0 & -(1-\alpha)(1-\eta)\epsilon \\ 0 & 1+\epsilon & 0 & 0 \end{bmatrix} \tag{34}$$

Note that both B and Γ are invertible. Consider the composite matrix $A = \Gamma B^{-1}$, and denote by A^p the matrix whose elements equal the absolute value of the elements of A, such that $(A^p)_{kh} = |(A)_{kh}|$, and define by $\rho(A^p)$ as the largest eigenvalue of A^p. Applying Theorem 3 of Allen et al. (2015), a sufficient condition for the equilibrium of the economy to be unique is $\rho(A^p) \leq 1$. All other endogenous variables follow.

D Calibration: Residential amenities and locational productivity

Calibrating locational productivity — The goods market clearing condition (6) can be written as the following system of N equations for the N unknown locational productivity $\overline{A}_i = A_i^{\sigma-1}$ as follows:

$$D_i(\overline{\boldsymbol{A}}) = w_i L_i - \sum_{n \in N} \frac{\overline{A}_i L_i (\zeta_{ni} \tilde{w}_i)^{1-\sigma}}{\sum_{k \in N} \overline{A}_k L_k (\zeta_{nk} \tilde{w}_k)^{1-\sigma}} v_n R_n = 0. \tag{35}$$

Given known parameters and observables, the system in (35) exhibits the following properties:

Property 1: $D(\overline{\boldsymbol{A}})$ is continuous.

Property 2: $D(\overline{\boldsymbol{A}})$ is homogeneous of degree zero.

Property 3: $\sum_{i=1}^{N} D_i(\overline{\boldsymbol{A}}) = 0$.

Property 4: $D(\overline{\boldsymbol{A}})$ exhibits gross substitution:

$$\frac{\partial D_i(\overline{\boldsymbol{A}})}{\partial \overline{A}_r} > 0, \quad \forall \text{ i, r} \neq \text{i} \tag{36}$$

$$\frac{\partial D_i(\overline{\boldsymbol{A}})}{\partial \overline{A}_i} < 0, \quad \forall \text{ i} \tag{37}$$

Properties 1 and 2 of Lemma 3 follow directly from an inspection of (35). Property 3 is satisfied by noting:

$$\sum_{i=1}^{N} D_i(\overline{\boldsymbol{A}}) = \sum_{i=1}^{N} w_i L_i - \sum_{n=1}^{N} v_n R_n = 0 \tag{38}$$

Property 4 can be established by noting:

$$\frac{\partial D_i(\overline{\boldsymbol{A}})}{\partial \overline{A}_r} = \sum_{n=1}^{N} \frac{L_r (d_{nr} w_r)^{1-\sigma} \overline{A}_i L_i (d_{ni} w_i)^{1-\sigma}}{\left[\sum_{k=1}^{N} \overline{A}_k L_k (d_{nk} w_k)^{1-\sigma}\right]^2} v_n R_n > 0. \tag{39}$$

Using property 2, which implies $\nabla D_i(\overline{\boldsymbol{A}})\overline{\boldsymbol{A}} = 0$, it follows that:

$$\frac{\partial D_i(\overline{\boldsymbol{A}})}{\partial \overline{A}_i} < 0, \quad \forall \text{ i}. \tag{40}$$

Thus, gross substitution is established. Gross substitution requires that $D(\overline{\boldsymbol{A}}) = D(\overline{\boldsymbol{A}}')$ cannot occur if B and B' non-collinear vectors. By homogeneity of degree zero, I can assume that $\overline{\boldsymbol{A}}' \geq \overline{\boldsymbol{A}}$

and $\overline{A}_i = \overline{A}_i'$ for some i. Now suppose that I lower (or keep constant) $\overline{\boldsymbol{A}}'$ in all locations except in i one at a time. By gross substitution, $\overline{A}_i$ will increase in at least one step. Hence, $D(\overline{\boldsymbol{A}}) > D(\overline{\boldsymbol{A}}')$ which is a contradiction.

By homogeneity of degree zero, the search for an equilibrium amenity vector can be restricted to the unit simplex $\Delta = \{\sum_{i=1}^{N} \overline{A}_i = 1\}$. Define on Δ the function $D^+(\cdot)$ by $D_i^+(\overline{\boldsymbol{A}}) = \max\{D_i(\overline{\boldsymbol{A}}), 0\}$. $D^+(\cdot)$ is continuous. Denote $\alpha(\overline{\boldsymbol{A}}) = \sum_{i=1}^{N}[\overline{A}_i + D_i^+(\overline{\boldsymbol{A}})]$ with $\alpha(\overline{\boldsymbol{A}}) \geq 1, \forall \overline{\boldsymbol{A}}$. Then define the function $f(\cdot)$ from the closed convex set Δ into itself as:

$$f(\overline{\boldsymbol{A}}) = [1/\alpha(\overline{\boldsymbol{A}})][\overline{\boldsymbol{A}} + D^+(\overline{\boldsymbol{A}})]. \tag{41}$$

By Brouwer's Fixed Point Theorem, there exist a $\overline{\boldsymbol{A}}^* \in \Delta$ such that $\overline{\boldsymbol{A}}^* = f(\overline{\boldsymbol{A}}^*)$. Since $\sum_{i=1}^{N} D_i(\overline{\boldsymbol{A}}) = 0$, it follows that at the fixed point for amenity, $\overline{\boldsymbol{A}}^* = f(\overline{\boldsymbol{A}}^*)$ and $D_i(\overline{\boldsymbol{A}}) = 0$ for all i. It follows that there exists a unique vector of unobserved productivities $(\overline{\boldsymbol{A}})$ that solves the system (35).

Q.E.D.

Calibrating residential amenities — Given the commuting probability (3), mobility clearing can be written as the following system of N equations for the N unknown:

$$D_n(\overline{\boldsymbol{B}}) = L_n - L\frac{\sum_{i\in N} B_n w_i^{\epsilon}(\kappa_{ni} Q_n^{1-\alpha})^{-\epsilon}}{\sum_{r\in N}\sum_{s\in N} B_r w_s^{\epsilon}(\kappa_{rs} Q_r^{1-\alpha})^{-\epsilon}} = 0. \tag{42}$$

The system (42) exhibits the same properties in $\overline{\boldsymbol{B}}$ than the system (35) does in $\overline{\boldsymbol{A}}$. It follows that there exists a unique vector of unobserved residential amenities $(\overline{\boldsymbol{B}})$ that solves the system (42).