Marzo **2022**

WP4-2022-003

N° de serie

DOCUMENTO DE TRABAJO

Regulation and informality: effects of land plan regulations on the proliferation of informal settlements

Autores

Lina Marcela García-Tavera Héctor M. Posada

COLOMBIA CIENTÍFICA
Conocimiento Global para el Desarrollo

ALIANZAEFI
Economía Formal e Inclusiva

REGULATION AND INFORMALITY: EFFECTS OF LAND PLAN REGULATIONS ON THE PROLIFERATION OF INFORMAL SETTLEMENTS

Work in progress

Lina Marcela García-Tavera
linamarce.garcia@urosario.edu.co
[1] and Héctor M. Posada
hector.posada@udea.edu.co
[2]

[1]Faculty of Economics , Universidad del Rosario
[2]Departament of Economics, Universidad de Antioquia

March 11, 2022

Abstract

The effect of regulation on the proliferation of informal settlements is unclear. While stricter regulations can provide policy makers with tools for control them (*welfare economic approach*), they can also constitute a form of exclusion that forces many segments of the population to choose the informal market (*exclusionary purpose*). Based on an event study and a spatial regression discontinuity, we try to elucidate the effect of different types of regulation on the proliferation of informal settlements. Preliminary results show that the prevalent approach is the exclusionary one and that laxer regulations decrease the proliferation of informal settlements. The welfare effect is yet not clear. *

Keywords: Informal settlements, Regulation, GeoRDD, Informal housing
JEL Classification: R21, R28

1 Introduction

For Latin America, the United Nations (UN) estimates an increase in the population living in precarious settlements from 134 million in 2005 to 162 million by the year 2020. Colombia will have 8.7 inhabitants in such condition (Programa de las Naciones Unidas para los Asentamientos Humanos, 2010). The proliferation of informal settlements has a direct impact on the socio-economic indicators of cities. In general, people located in informal housing suffer health problems (Cattaneo et al., 2009; Hanna et al., 2016), have a lower level of education, a higher probability of being unemployed and access to lower quality jobs (CAF, 2017). The most common causes associated with this phenomenon are related to poverty and institutional problems related with lack of public investment. However, as a complex phenomenon, it's necessary to consider other possible causes.

[0]This working paper is funded by the Colombia Científica-Alianza EFI Research Program, with code 60185 and contract number FP44842-220-2018, funded by The World Bank through the call Scientific Ecosystems, managed by the Colombian Ministry of Science, Technology and Innovation.
Errors, opinions and omissions are author's responsibility and do not compromise the institutions

Following that, the focus has been places on the incidence that urban regulations may have on the proliferation of informal settlements (Biderman et al., 2008). For developing countries, the existences of a dual housing market where both formal and informal sectors converge generates special conditions where regulations can affect the incidence of informality (CAF, 2017)

The grow of urbanization has shown the need to start thinking in terms of territorial planning. The use of planning and regulatory instruments to control the growth of cities has become increasingly common. These instruments can be a way of face the problem of informal settlements, a manifestation of negative externalities of cities, as well as one of the possible causes of the proliferation of them (Biderman, 2008). This problem has been addressed through the relaxation of urban planning regulations; however, this could create an incentive for more people to migrate. If the relaxation of these regulations doesn't translate into an increase in the size of the formal sector in the same proportion as the flow of migrants, it may lead to a greater proliferation of slums. On the other hand, some policy makers have look for stricter regulations that allow them to maintain control over the growth of the city in order to mitigate the proliferation of informal settlements; the effect of these strict regulations may be the opposite. More rigid urban regulations makes more costly and complicated for residents to adapt to them, generating incentives to enter informality because of the difficulty of adaptation. There´s no consensus on the way in which the nature of these regulations affects the phenomenon, the objective is to make an approximation of the possible effect that different levels of flexibility in land-use regulations can have on the proliferation of informal settlements.

The literature on the relation between regulation and informal settlements is sparse and the findings are ambiguous. Most of the work about regulation and the housing market focuses on developed countries, particularly using data from the United States. These papers leave aside the possibility of the existence of an informal housing market, so it's not clear if the effects found are applicable to the context of developing countries where dual markets exist. In terms of causal analysis, the work done by Biderman (2008) for Brazil shows that, in developing countries, stricter urban regulation, particularly in zoning and subdivision rules, would generate higher levels of informality. In the same way, Kironde (2006) finds for Tanzania that a strict regulatory framework, in terms of the minimum size of plots, promotes informality. These results are contrary to those found by Lall et al. (2007) who find that zoning and land use planning regulations improve and stimulate housing market performance by reducing slum formation; they conclude that, in the presence of market distortions, more flexible regulations may imply an increase in informal settlements. Henderson (2009), finds that strict land-use regulations appear to be an instrument of governments to restrict population growth and exclude low-income immigrants. However, the evidence is unclear and it appears that regulation is not a significant determinant of informal settlement formation.

The effect is not clear. And this ambiguity seems to be related to the restrictive or flexible nature of the regulations. The contribution of this paper to the literature is to elucidate this ambiguous effect and to determine whether stricter regulation is one of the causes of the proliferation of informal settlements or whether, on the contrary, they are an effective way to mitigate the growth of them. For this, in a first step, we take advantage of the existence of contiguous urban settlements that, however, belong administratively to different municipalities and therefore are under different land use regimes. The decision to relax land-use planning regulations is used to analyse the existence and direction of a possible effect of these regulations on the proliferation of informal settlements. Subsequently, a spatial Regression Discontinuity (GeoRDD) is applied using the border between contiguous municipalities as an assignment threshold to decompose the effect and analyze possible mechanisms.

Preliminary results show that the relaxation of land use regulations reduces the proliferation of informal settlements. However, this decrease does not necessarily translate into an improvement in welfare, it seems to be generating a displacement effect. In the borders between municipalities, where the application of regulation seems more diffuse and institutional presence is not always clear, the effect of regulations on informal settlements disappears. These results suggest that the effect of regulation seems to be more exclusionary, which implies that it responds more to forms of

gentrification than to effective tools for the control of the negative externalities generated by the agglomeration effect of cities.

The paper is organized as follows: chapter 2 gives some context about the regulatory environment in Colombia and the reason why Medellìn and Bello were chosen as case of study; chapter 3 gives a theoretical framework about land plan regulations and it's possible implications in informal settlements; chapter 4 describes the used data; chapter 5 describes different strategies used trying to understand the phenomenon and the assumptions that had to be checked in order to implement these strategies; chapter 6 describes and analyze the results and chapter 7 concludes.

2 Context

The degree of urbanization of a country is usually correlated with the level of development. However, in developing countries this relation is weak. Today, Latin America has high levels of urbanization, comparable to richer countries, but low levels of development. This has generated that the benefits of urbanization are not fully exploited and, on the contrary, the costs associated with it are higher (CAF, 2017). Latin American countries have high levels of urbanization with informality in the housing market, which makes them a good scenario to study this phenomenon.

The institutional and social context of Colombia, a country located in the southern region of Latin America, offers advantages for analysing the relation between regulation and informal settlements. Law 388 of 1997 creates the obligation for all municipalities in Colombia to have technical and normative instruments to regulate human occupation in each territory. *"Planes de Ordenamiento Territorial (POT)"* are documents that contain the policies, strategies, programs and norms that, for a period of 12 years, will guide the physical development and land use of each administrative unit. The POT contain reserve zones for public space and urban infrastructure projects, land classification and delimitation, high-risk zones, natural resource protection and conservation areas, expansion boundaries, partial plans, areas destined for social housing development, urban development, urban construction norms (occupation and construction indexes, permitted heights, free concessions, etc.), among others. Each of these plans covers the entire territory of the municipality and its application is limited by its administrative boundaries. The POT are the land use planning regulations in the Colombian context.

The municipalities of Medellín - Bello are located in the department of Antioquia, Colombia. These municipalities share an administrative border and around this border both have contiguous urban settlements. Additionally, both are part of the "Metropolitan Area of the Aburra Valley", which is an administrative entity that brings together different municipalities in the area. This entity is in charge of the administration of the metropolitan public transport, it is also an urban environmental authority and has planning and articulation functions between the municipalities. However, despite the faculties of the Metropolitan Area, each municipality determines its own urban regulation and its application is restricted to its territorial limits.

In 2009, in compliance with the legal mandate that requires the revision of land use planning regulations every 12 years, the municipality of Bello made a change in its land use planning policy. In order to promote the development of the construction sector in the municipality, some changes were implemented in the POT that implied the flexibility of the rules. These modifications focused mainly on:

- Allow the construction of high-cost housing projects
- Create larger areas or urban grow
- Open the possibility of building in height
- Relax the requirements necessary for construction

- Have became easy to get a construction license

These changes in zoning regulations led to an increase in the supply of new housing and a consequent expansion of the formal market. Bello became a reference in terms of construction and urban renewal in the region. In the years following the reform, Bello became the city with the greatest construction dynamics in the region, even above its neighbor Medellín, which is the core municipality of the metropolitan area system to which both belong (Quintero, 2018). The graph 1 represents the dynamics of new housing construction per unit in each of the municipalities of the Aburrá Valley built from data from the Census of Buildings (CEED) conducted by the National Department of Statistics of Colombia (DANE).

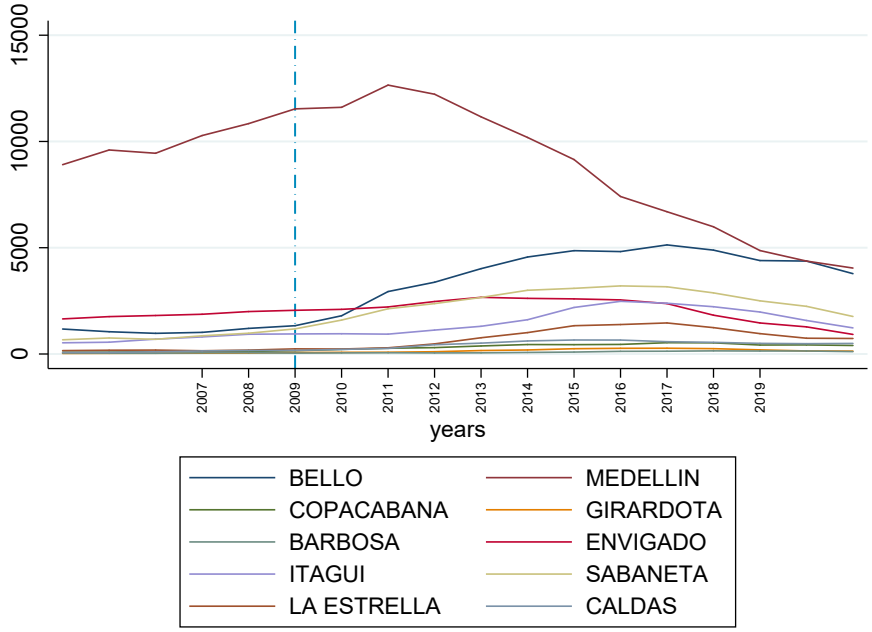


Figure 1: Supply of new housing per unit for the municipalities of Aburrá Valley

From the data it can be seen that there is a visible increase in new construction in the municipality of Bello since the change in the POT. Its neighboring municipalities to the north of the valley: Barbosa, Girardota and Copacabana, on the contrary present much lower dynamics in the construction sector. It is important to highlight the case of the municipality of Sabaneta, which, like Bello, decided to make its land-use planning regulations more flexible in 2009 in order to promote housing construction in its territory; this change also resulted in an increase in housing units. In the case of Itaguí, this flexibilization occurred in an extraordinary adjustment made in 2012 that allowed the urban expansion zone to be larger in order to encourage the construction of public housing (Gamboa Cataño and Londoño Restrepo, 2020). [1] In general, the relaxation of regulations seems to be related to an increase in the supply of housing. These results are constant through different measures of supply. To see more you can go to the Appendix III.

These increase in housing supply is consistent with the findings of Anagol et al. (2021) in their work for Brazil. They found that a flexybilization in land use regulations, specially those related with construction indexes, create an increase in the housing supply. For the municipalities that have been chosen the trends seems to be similar. However, it's necessary to find out what happens with the informal market in order to understand the effect.

[1] For the Colombian case low-cost or public interest housing is referred to as *Viviendas de Interés Prioritario (VIP)* and *Viviendas de Interés Social (VIS)*

3 Background

Several studies have shown a relationship between urban regulations and housing supply (Glaeser et al., 2005; Quigley and Raphael, 2005; Gyourko and Summers, 2006). In particular, stricter regulations seem to generate a less elastic supply of housing and increases in prices, especially for housing located in the peripheries of cities (**?**). Despite this, urban regulations remain as a way to control the growth of cities and to determine the conditions of urbanization. However, little has been said about this effect on supply and prices when we are in dual markets such as those in developing countries where there is a formal housing market which adjusts to and complies with urban regulations, and an informal market where the effect is not very clear.

Land use regulations in urban contexts are approached from different perspectives: (i) the *welfare economic approach*, points out that these regulations are constituted as a way to correct the negative externalities generated by agglomeration in cities; ii) the perspective of the *influential landowner/home-voter*, legal regulations, including those of urban planning, respond to the interest of agents who accumulate political power (political economy vision); iii) the *"exclusionary purpose"*, where regulation is used as a form of control of certain groups of potential residents (gentrification) (Goytia et al., 2015b). Starting from any of these perspectives may generate a different incentive system in the location decisions of individuals and their choice between the formal or informal housing market.

From the *welfare economic approach*, one would expect that stricter regulations would generate stronger intervention tools that allow policy makers to more effectively correct the negative externalities generated by the growth of cities. However, this perspective has a high degree of endogeneity. Cities with stricter regulations tend to be those that have experienced greater urban growth (Gyourko and Summers, 2006) and as a consequence tend to have greater problems associated with externalities. This perspective implies a trade-off between the welfare gains from controlling externalities and the costs associated with the regulations (Henderson, 2009). Additionally, to be effective, certain levels of enforcement are required to effectively apply these tools and correct the negative externalities of agglomerations. Low levels of enforcement will reduce the effect of the legal system. Thus, the expected effect of flexibilization on informal settlements would be negative and the minimum levels of enforcement required for this effect to be achieved should be determined.

In the case of the *influential landowner/home-voter*, the effect will depend on where their interests are. In general, it is expected that this influential agent will seek a regulation that ensures an increase in profits, and this increase in profits will end up being pay by consumers. However, the influential landowner may profit from the informal market and may be interested in promoting or protecting it. To that extent, the incidence of informal settlements will depend on the interest of political power holders. This perspective is inspired by *"The Homevoter Hypothesis"* of Fischel (2001), where the residents end up choosing through voting the policies that suit their interests. However, in democracies such as those of Latin American countries, where there are agents that have a high capacity to influence the administrative decisions of governments, their agendas can be imposed and legitimized through regulations. In the Colombian context, this may be particularly true given the particular conditions in which informal urbanization processes take place, where armed actors and informal developers with high levels of filtration in the State's decision-making processes may be involved. In any case, this political economy perspective requires data and elements for analysis that we do not have, so it cannot be explored in depth in this paper.

Goytia et al. (2015a) find that, for the case of Argentina, the exclusion perspective seems to predominate, where the legal norms of urban planning are constituted as instruments of control that limit the access of certain groups, especially migrants and low-income people. Under normal conditions, restrictive regulations become an effective way to control population and exclude from the city households that do not comply with the margin established by the regulation. However, this condition is not as efficient in the presence of dual housing markets. In this case, excluded households not only have the alternative of leaving the city but also have the option of moving to the informal market where they can operate outside the regulations. The existence of this duality

complicates the classical exclusion analysis (Henderson, 2009). Under this logic, in developing country markets, two possible conditions are generated:

- *Regulation effect*:Stricter regulations generate an increase in the costs of the formal market and therefore the exclusion of certain groups from it
- *Reallocation effect* The groups excluded from the formal market decide:
  - Remain in the city by entering the informal market
  - Leave the city and migrate to other places with more flexible regulations or more accessible markets

These regulations can have equilibrium effects on where people allocates. As pointed out by Henderson (2009), they can lead potential residents to move to less desirable locations, which can lead to a reduction in overall welfare. This equilibrium effect is not so clear when we are facing dual markets where the relocation effect generates two possible decision for agents. This aggregate analysis exceeds the limits of this paper, although it is expected to serve as an approximation for further work.

In order to verify these assumptions, we will take advantage of the fact that the territorial planning regulations in Colombia have a territorial limitation that is circumscribed to the municipalities and that some of these municipalities have contiguous urban settlements. Particularly, the municipalities of Bello and Medellín are taken as case studies.

4 Data

For the analysis, an indicator of informal settlements is constructed from government surveys. Although informal settlements are a complex phenomenon, they are widely identified in the literature on the basis of the criteria determined by UN-Habitat (2004):

- Difficulties in accessing domestic public services
- Housing density
- Lack of structural quality of housing
- Insecure of tenure

From this definition it is possible to construct an index of informal settlements following the Slum Severity Index (SSI), proposed by Patel et al. (2014), which measures the level of deprivation on a continuous scale according to UN-Habitat's definition of slums. The ISS at 0 indicates non-slum status, while as the value increases the more precarious the housing condition becomes suggesting higher vulnerability conditions.

For the measurement of the first three criteria, data from the National Census in its 2005 and 2018 cuts georeferenced at the block level will be used. For the case of insecurity of tenure, it is not possible to measure it from the survey conducted by DANE in 2018. To that extent, the analysis based on census data corresponds to a measure closer to the definition of precarious housing. For more details see Appendix II. Similarly, data from the *Gran Encuesta Integrada de Hogares* (GEIH) between 2007 and 2019 are used to analyse the change in the informal housing indicator over time. The GEIH data does include a measure of irregular tenure, so this item will be evaluated.

Additionally, data from the Census of Buildings (CEED) are used to analyze changes in the supply of new housing. Colombia has weak institutional contexts that may have a high impact on the law enforcement, the index create by the Observatory of the Cities System of the National Administrative Department of Colombia (DNP) is taken as a proxy for enforcement.

5 Empirical strategy

To determine whether or not there is an effect of regulations on the proliferation of informal settlements and the possible perspective from which this effect is generated, we first use a classic model of differences in differences. Using data from the *Gran Encuesta Integrada de Hogares* (GEIH), at the housing level, we analyze the behavior of variables associated with housing informality over time. Particularly it is analyzed between the years 2007 and 2019, having as a cut-off year of treatment the year 2009 when the municipality of Bello implemented a change in its land use regulations making them more flexible with the aim of boosting the construction sector in the municipality.

The model is used to analyze the effect that this relaxation of land use regulations has had on the indicators of informal settlements. The equation to be estimated is the following:

$$Y_{it} = \beta_0 + \beta_1 D_i + \beta_2 \delta_t + \beta_3 (D_i * \delta_t) + \sigma_b + \epsilon_{it}$$

D_i: Treatment variable indicating more flexible regulation
δ_t: Variation over time
σ_b: Fixed effects at section (neighborhood) level

Although the analysis based on the GEIH can account for the impact that this change in regulation had on the proliferation of informal settlements, there are several limitations that need to be addressed with respect to this strategy. The first of these has to do with the representativeness of the data analyzed. Although the GEIH uses a probabilistic, stratified, clustered and multistage sampling system, its representative at the metropolitan area level. For this analysis, the treatment assignment units correspond to municipalities, in this case Bello and Medellín, which belong to the same metropolitan area. However, the analysis is done at the household level, which allows for an acceptable number of observations that, at least, allow us to account for the trend behavior of the dependent variable over time.

The second limitation has to do with the possibility of compose treatments. As it's already mentioned, the assignment to treatment corresponds to territorial units such as municipalities. On these administrative units converge a number of public policies and conditions that may have an impact on the analyzed variable and that are not necessarily related to changes in land use regulations. Given these conditions, it is necessary to extend the analysis to elucidate more adequately the way in which the different types of regulations affect the proliferation of informal settlements. To address these limitations, and partly as a way of clarifying the mechanisms of the effect, the methodology is extended to a more local analysis.

The existence of administrative boundaries separating contiguous urban settlements means that neighbouring territories that share cultural and community conditions are subject to different planning and land use regimes. This generates that the urban planning norms of a space can be different from those of its immediate neighbours. These borders give us the opportunity to analyze the effect that municipal land use regulations have on the proliferation of informal settlements and the possible mechanisms that are generating this effect, using a Spatial Regression Discontinuity (GeoRDD) as an identification strategy and the administrative border as a cut-off threshold. The defined treatment is maintained under the same conditions.

When we are facing RDD designs where the allocation corresponds to a geographical boundary a common approach is the one we will call as *simple model*, in which the distance to the nearest point of the boundary is calculated making it possible for the allocation function to become a scalar. This approach is useful as a first approximation and provides a relatively consistent estimate of the average effect. For some applications the simple model can work well (Zajonc, 2012). In this approach the identification strategy is equivalent to a simple RDD with the shortest distance to the border as the score.

However, when the cut-off point corresponds to geographic borders, a high level of heterogeneity can be found along the border (Keele and Titiunik, 2015). To that extent, and as a way to

face the differences that may exist, the border is divided into different segments to be analyzed. Figure 2 shows the division. This division is made using the POT from Bello. The map represents the construction index (IC) in the border of Medellin and Bello. These index is a measure of building regulations and corresponds to the maximum number of times that the surface of a piece of land can become a built-up area. It implies that a bigger measure of IC means a more flexible construction law.

The segments belong to the west side of the border because a big part of the border in the east side has the particularity of having censused human settlements only for the side corresponding to Medellín, so it would not have observations to be able to apply the empirical strategy and would be excluded. Also for the area to the right of segment 4 the area corresponding to the municipality of Bello has two conditions that limit the settlement of people for housing: a large part of the area adjacent to the border is classified as a Zone with Restriction due to Risk of Mass Movements (ZRMM), another large part is qualified as a Specialized Activity Zone (ZAE) which implies that is an area with mainly industrial and commercial potential (Municipio de Bello, 2009). These conditions mean that east zone is considered inadequate for the analysis. For the purposes of the causal analysis of the simple model, the northwestern zone of the border will be used.

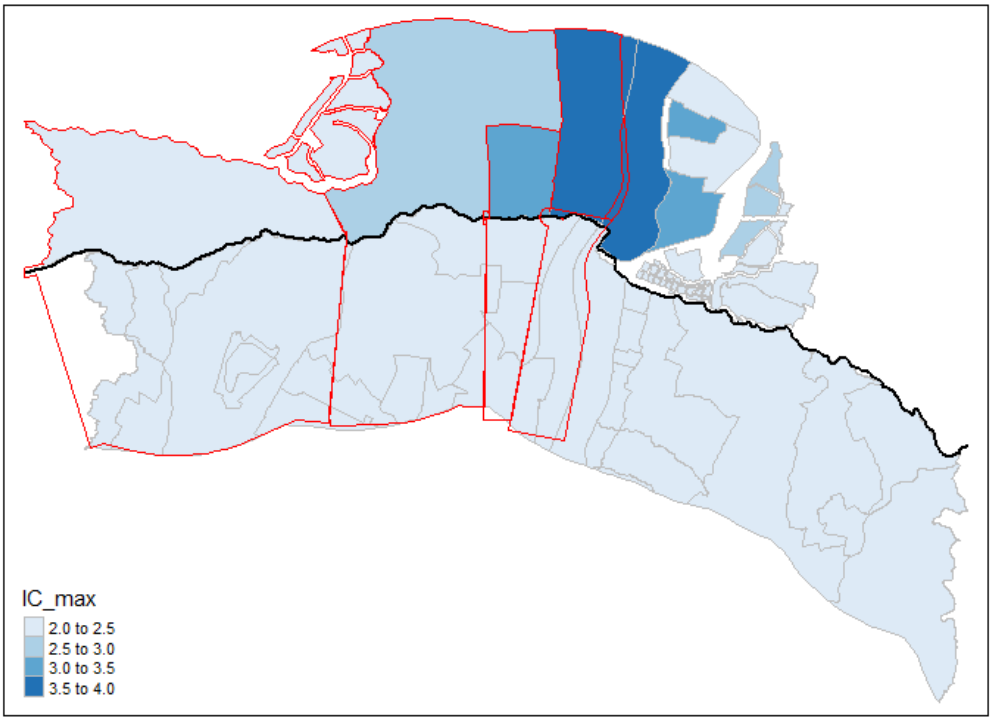


Figure 2: Segment division to the border Medellín - Bello

The spatial RDD is closer to a situation where a double allocation rule is present, so the simple model may have some limitations for its application. As pointed out by Keele and Titiunik (2015), using this type of measurement of the allocation rule can generate some methodological difficulties. In their proposal, they point out that it is necessary to treat spatial RDD as a standard model with two allocation rules. This approach provides a lot of opportunities: unlike other cases of RDD with double allocation, when we are dealing with spatial scenarios the variability of the different treatment effects found can be related to locations and segments with specific conditions that give a wider margin of interpretation. The authors draw attention to three conditions that should be kept in mind when applying a spatial RDD: i) the possibility of composite treatments, which for

the case of analysis will be addressed from the pre-treatment analysis using the 2005 Census data; ii) the sensitivity of the model to different distance measurements, and iii) the spatial variation in treatment effects. This dual assignment rule approach is the preferred specification and will be used in the analysis of the results.

One way to capture heterogeneity along the assignment frontier is point estimation along the frontier. Under this logic the estimator is a vector of results associated to specific locations (Rischard et al., 2020). . This estimation produces a continuous of treatment effects that are related with an specific location along the boundary and can be analyse as a treatment curve instead of a single coefficient (Keele and Titiunik, 2015). The estimated model is represented by the following equation:

$$Y_{il} = \beta_0 + \beta_1 D_i + X_i^{'}\beta_2 + f(U_l) + \epsilon_{il}*$$

Y_{iml}: Outcome variable for observation i for the point on boundary l
D_m: Treatment indicator. 1 if it is a municipality with flexibilization of POT and 0 otherwise
$X_{im}^{'}$: Vector of covariates
$f(U_m)$: Control function. RD polynomial, which controls the smoothing of the geographical location.
U_l: Distance to point l of the boundary

For the analysis, the border is divided into points. These points are defined with a distance between them of 100 meters, which is the average distance between blocks for Colombia. These division is trying to take into account the geographic particularities that may be there such as rivers, streams, hills, cliffs, etc. The distance measurement corresponds to the Euclidean distance from each of the observations to each of the points.

The study is conducted at the block level. Keeping in mind that we do not have the exact location of each household, but rather its georeferencing at the census block level, aggregate indicators have been constructed for the measurement. Although usually this type of aggregate measures are determined arbitrarily and independently of the conditions of variability within it (Keele and Titiunik, 2015), in order to obtain conclusions that are close to the level of informal settlement it is necessary to aggregate, at least, at the block level. However, we also present results at the household level using the distance to the centroid of the block as a proxy of the distance of the household. As the maximum level of georeferencing is the block, households located in the same census block will be assigned to the same distance to the border. This implies that there is a margin of error in the measurement which, however, is assumed to benefit the size and variability of the sample.

5.1 Checking spatial regression discontinuity assumptions

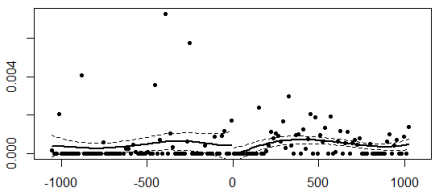
5.1.1 No sorting assumption

One of the basic assumptions for the application of RDD is no sorting, which implies that the allocation rule is an exogenous variation that eliminates the possibility of self-selection by individuals. if it is not fulfilled implies the possibility that agents violate the allocation rule and self-select for treatment or control. In spatial analysis this assumption is particularly problematic. For this case, and following Rischard et al. (2020), changes in regulation can generate that a municipality is more or less attractive for agents and to that extent that they decide to move to one or another municipality. However, the unit of analysis corresponds to the housing units rather than the agents, the houses do not move but adjust their conditions over time so the problem of sorting in the frontier referred to housing can be corrected with the use of covariates.

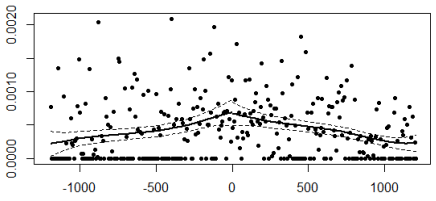
In any case, and as a form of robustness, the results of the test proposed by McCrary (2008) are presented for each segment of the border. The test performs an analysis of the discontinuity

in the cut-off of the density function of the assignment variable, the null hypothesis being that the discontinuity is zero. Under this logic, the points and segments that have a sufficient density of observations on both sides of the boundary are filtered out to proceed with the analysis.

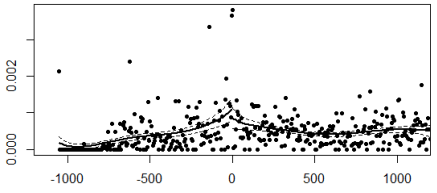
Figure 3 shows the results for each segments. The segment 3 doesn't even have enough density to run the analysis. Segment 4 also has some problems with the observations. According to the results the segment that comply with McCrary test is segment 2.



(a) Sección 1 (p-value 4.787168e-21)



(b) Sección 2 (p-value 0.3910324)



(c) Sección 4 (p-value NA)

Figure 3: Test McCrary east segments

For the *point model* the analysis will be carried out using almost all of the points, given that the results are relatively consistent along the whole border. Anyway, the results can be seen in the Appendix II where the best behaved points that comply with the test conditions are presented.

5.1.2 Balance test

We run a simple difference approach with a linear model using all the observations around the border and different measures of bandwidth. The results show that there are consistently differences between the observations around the border in almost all the covariables. It can be seen as evidence of the hypothesis that there is a big heterogeneity around the border, and shows that it's necessary to consider different strategies to take into account this heterogeneity

For each of the points along the border, the existing differences in the observable variables of the households located on both sides of the border are analyzed, based on the results of the non-parametric regression discontinuity. The variables correspond to migration conditions, education, household composition, demographics, labor conditions and commercial use. The results show an overall balance in all covariates except for the variables associated with migration.

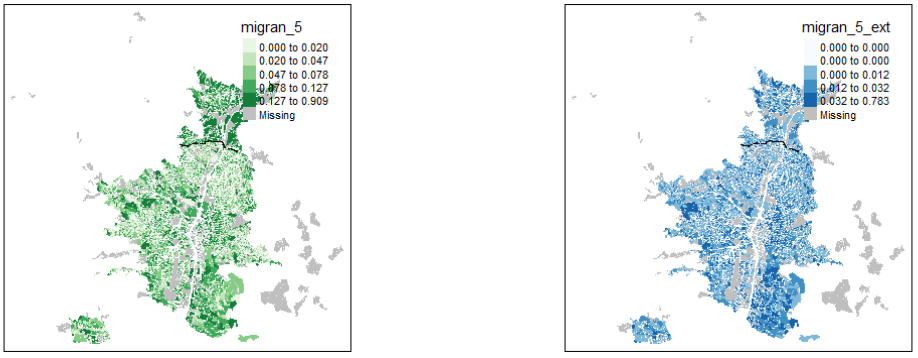
In this case, there is a difference in the border of the variable associated with the migration of persons during the 5 years prior to the survey. This migration, however, does not seem to be driven to the high flow of migrants that Colombia has had as as receiving country from neighboring Venezuela. Figure **??** shows the differences between the municipalities analyzed for the migration

DIST	Commerce	Household's size	Unemployment	Recent migration	Women	Dependency	Education
200	0.005**	-0.031	-0.0001	0.094***	-0.014	0.017	0.282***
	(0.002)	(0.024)	(0.003)	(0.004)	(0.016)	(0.012)	(0.045)
400	0.0002	-0.070***	-0.005*	0.087***	-0.034***	0.025***	0.403***
	(0.001)	(0.017)	(0.003)	(0.003)	(0.012)	(0.009)	(0.034)
600	0.0002	-0.053***	-0.005**	0.088***	-0.031***	0.019**	0.354***
	(0.001)	(0.015)	(0.002)	(0.003)	(0.011)	(0.008)	(0.031)
800	0.001	-0.068***	-0.007***	0.092***	-0.035***	0.025***	0.376***
	(0.001)	(0.014)	(0.002)	(0.002)	(0.010)	(0.007)	(0.028)
1000	0.0004	-0.085***	-0.008***	0.095***	-0.042***	0.025***	0.475***
	(0.001)	(0.013)	(0.002)	(0.002)	(0.009)	(0.007)	(0.026)

Standard errors in parentheses
Note: *p < 0.1; **p < 0.05; ***p < 0.01

Table 1: Simple differences across the border

variable in the short term (last 5 years) without differentiation for migrants on the left and for migrants of foreign origin on the right. Given that the migration variable may have a direct relationship with the proliferation of informal settlements, and following the methodology indicated by Dell (2010) to eliminate the bias generated by this variable, it is included as a covariable in the estimation.



(a) All migrants

(b) Foreign migrants

Figure 4: Migration Medellín - Bello

For the segments corresponding to the *simple model* we run a a simple mean difference using different distances to the border for each one of them. These results can be seen in the Appendix IV. Segment 2 is the only one which shows a balance in the covariables higher than 50% so it's chosen to run the analysis given that is also the unique segment that complies with McCrary test. The variables is which there are differences are used as covariables in the estimation following the approach given by Dell (2010). There are differences in recent migration, education and unemployment. These differences are expected given that all these variables can have a incidence in the decision of living in a informal housing

5.2 Checking differences in differences assumptions

5.2.1 Parallel trends assumption

One of the basic assumptions for the difference-in-differences model is parallel trends. In principle, it seeks to ensure that the effect found is due to the treatment and not to the intrinsic trend of the variable under analysis. The figure **??**, shows a change in the trend of the proliferation of informal settlements from the year 2009, which gives reasons to think about the existence of an effect between the regulations and the proliferation of informal settlements.

Beyond the graphical method, whose results are only preliminary and descriptive, there are more appropriate ways of verifying compliance with the assumption of parallel trends, such as the event study. Figure 6 shows the results obtained with the application of an event study. It is observed that there is no evidence that the assumption of parallel trends is fulfilled. As an extension, some possible strategies are being implemented at the moment when the assumption is not perfectly fulfilled, such as those proposed by Ryan et al. (2019). The use of propensity score matching algorithms as a pre-treatment prior to the application of the difference-in-differences model is a strategy to deal with differences in the pre-treatment period and to adjust for the assumption of parallel trends. However, given that we have some data access limitations these strategy can be implemented at this time.

In any case, although it is recognized that the effect found from the difference model may have some biases, it is assumed as a form of correlation from which some analysis of the phenomenon is carried out. Given that we found changes in the outcome of interest between the before and after treatment period for the two municipalities, even if the groups were different before as its seems to be, it lends to think that, in some way, the intervention could altered the trajectory of the outcome for the treated group.

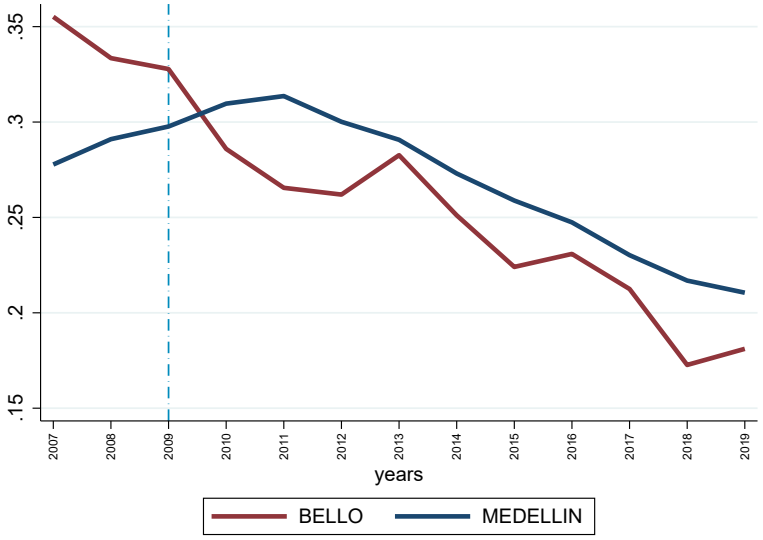


Figure 5: Informal housing Medellín - Bello

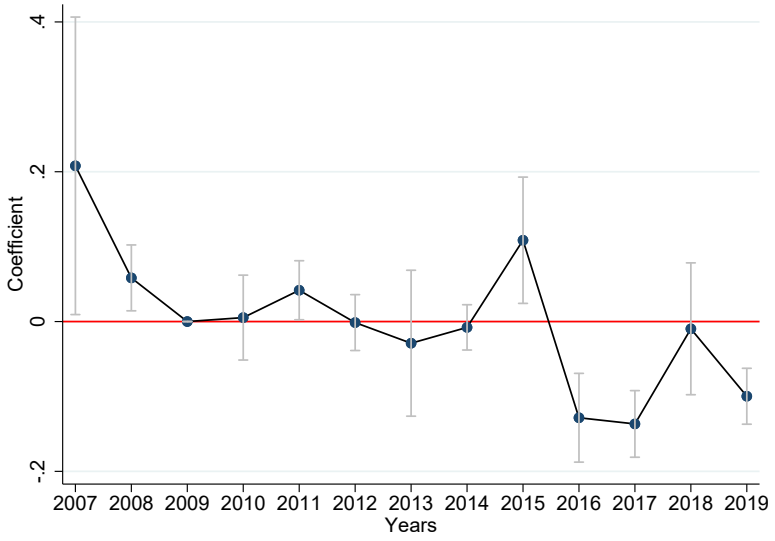


Figure 6: Event study results

6 Preliminary results

To determine whether or not the regulation produces an effect on the proliferation of informal settlements, a difference-in-difference analysis is carried out using the change in land-use regulations made by the municipality of Bello in 2009, for which the counterfactual corresponds to Medellín as a contiguous municipality where the regulation is more restrictive. The following are the results of the estimation of the SSI ("Informal") and for each of its components in a disaggregated way, carried out in a simple way and with fixed effects at section level.

	Informal	crowding	walls	floor	energy	sanitation	water	precarious	tenure
Diff	-0.0849***	0.000475	-5.65e-06	-0.0681***	0.000957	-0.0185***	-0.00297	-3.48e-05	0.00326*
	(0.0112)	(0.00123)	(0.000524)	(0.00896)	(0.000729)	(0.00365)	(0.00185)	(0.000102)	(0.00175)
R-squared	0.000	0.000	0.000	0.001	0.001	0.002	0.000	0.000	0.000
Diff FE	-0.0782***	0.000703	-0.000104	-0.0613***	0.000942	-0.0185***	-0.00327*	-5.05e-05	0.00343*
	(0.0112)	(0.00123)	(0.000525)	(0.00894)	(0.000734)	(0.00365)	(0.00186)	(0.000103)	(0.00176)
R-squared	0.007	0.001	0.000	0.013	0.001	0.004	0.002	0.001	0.003
Observations	135,217	135,217	135,217	135,217	135,217	135,217	135,217	135,217	135,217

Standard errors in parentheses
Note: *p < 0.1; **p < 0.05; ***p < 0.01

Table 2: Differences in differences regression

The results show that the municipality with more flexible regulations has a lower prevalence of informal households. It seems that the effect is given by the variables corresponding to floor quality (*"floor"*), sewerage (*"sanitation"*), aqueduct (*"water"*) and irregular tenure condition (*"tenure"*). From the results, the *"economic welfare perspective"* could be ruled out. For this case, if strict regulations gave more tools for the control of negative externalities, such as informal settlements, Medellín would be expected to have lower levels than Bello. One option could be that the effect of these regulations would be mitigated by the municipality's levels of enforcement. However, this hypothesis is discarded given that anecdotal evidence and analysis by the DNP's Cities Observatory shows that the city of Medellín has higher levels of enforcement than the city of Bello, using as a proxy of institutional capacity the index of *governance, participation and institutions* that was consistently higher for Medellín than Bello. Just for 2018, that was the year of the census,

Medellín reported an index of 59 and Bello 42.

In this case, and according to much of the literature, the *exclusionary purpose* seems to predominate. More restrictive regulations translate in a greater proliferation of informal settlements as they imply an increase in the costs of the formal market, forcing certain groups of agents to migrate or enter the informal market. This would explain the differences not only in the levels of informal settlements but also in migration. Regulations have the potential to modify the dynamics of the formal construction market influencing the associated informal housing market.

However, given that the mechanisms of this effect are not clear we use the data obtained from GeoRDD to clarify them. Using the segment 2, that complies with McCrary tests and mostly balance assumption, the figure 3 shows the results of the RDD regression for these segment. We can see that, even when the side of Bello has a flexible regulation than Medellín there are no significant differences in the indicators of informal housing.

Model	Precarious hous	Precaurious sum
Local-Linear	0.007	-0.011
	(0.01)	(0.013)
Robust	0.004	-0.016
	(0.012)	(0.015)
Bandwidth	(224.054)	(203.505)
Nobs	2925	2643
	3003	2841

Table 3: RDD results for segment 2

Figure 7 shows the results obtained for the housing informality indicator for the analyzed border. The data show that there are no also significant differences between dwellings located on both sides of the border and that the effect vanishes.

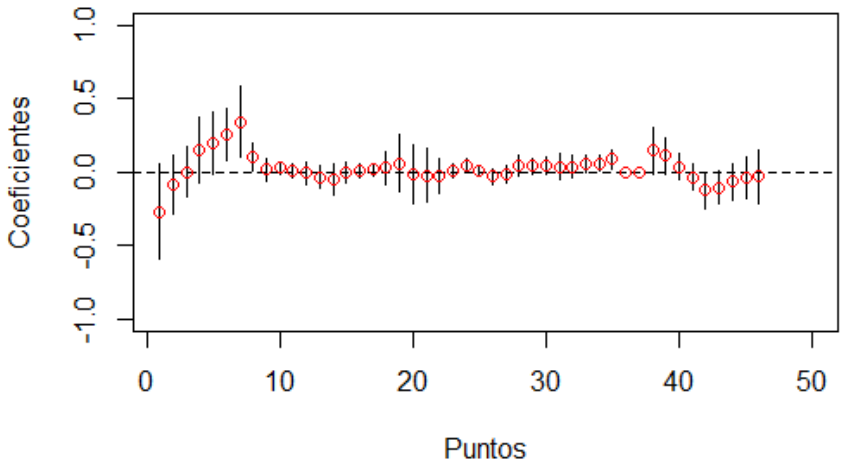
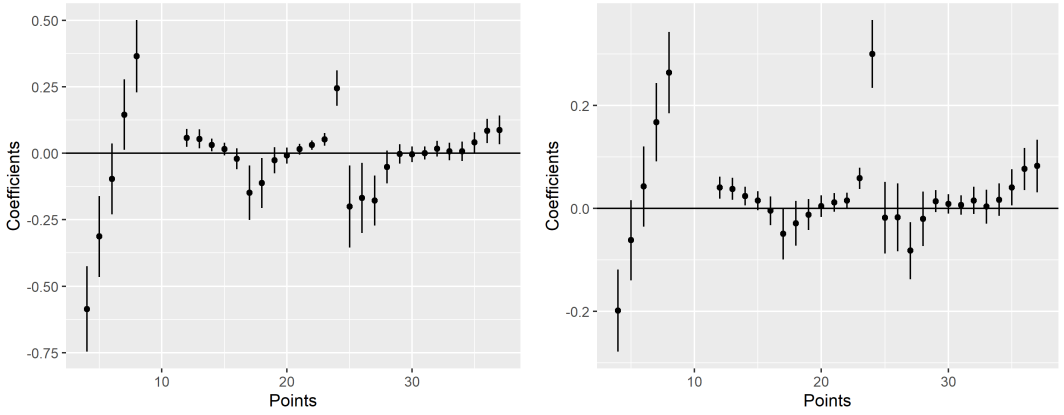


Figure 7: Estimation at the border 2018

Figure 8 indicates the results at the household level for the SSI index and for a dummy variable that indicates any presence of precarious housing indicator. It can be seen that, even when in general there are no differences around the border, there some significant differences at some points, especially there are a significant variation at the west zone. These result could be related with the fact that these points correspond with the urban edge of both municipalities. It's usual that informal settlers allocate in the urban edge looking for land available to occupy. Also because these areas are far from the downtown or business centers usually the land are cheaper and the accessibility is not easy so it could make more expensive for the city government to control. However, the results are not consistent so that indicates that probably these area has informal housing in both sides of the border.



(a) SSI index

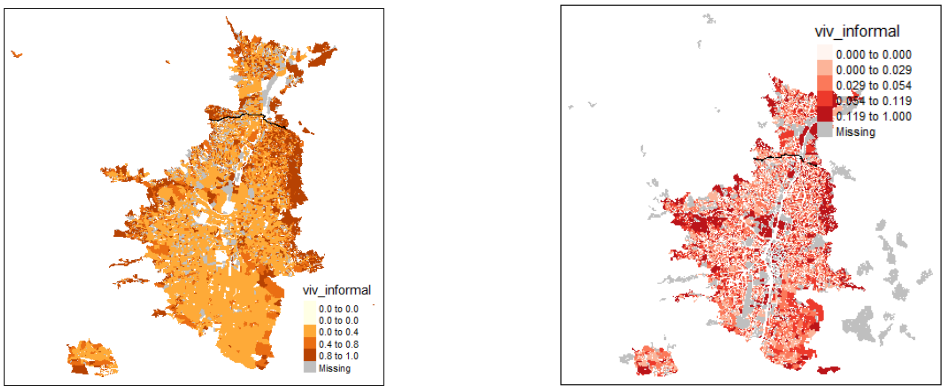
(b) Dummy index

Figure 8: Estimation at the border 2018 at the household level

There are several hypotheses to explain the disappearance of the aggregate effect when it's analyzed at the local level in the shared border. These are related to the possibility that by relaxing regulations the size of the formal housing market may have increased. This affirmation is supported by the findings from the census of buildings that were outlined in the figure 1. This increase could have generated two situations: the first is that it generated a reduction in the informal market by absorbing land and homes from it. This being the case, the levels of informality that we are seeing for 2018 in the municipality are the result of this absorption and should be lower than those in the same area in the pre-treatment periods. In other words, the flexibilization managed to equalize the levels of informality between the two municipalities in the zone with Bello being at higher levels before.

A second situation, derived from this, is that the flexibilization generated a process of gentrification. The increase of the formal market, and the use of land and zones that this required, generated the displacement of the old settlers who were forced to concentrate in the informal settlements. This implied that, although there was a densification of the area, the neighborhoods remained almost the same and therefore the levels of informality of the area at the block level. That it's the hypothesis that some qualitative analysis made of about the flexibilization of POT in Bello. Quintero (2018) points out that the big urban grown in the municipalitie of Bello after the change in regulation in 2009 means occupation also grows in low-income neighborhoods, mainly in informal settlements. Under this logic, two situations should be verified: an increase in the population density of informal settlements in the area with respect to the pre-treatment period and an increase in new constructions in the post-treatment period. This hypothesis is in accordance with what has been pointed out by Heikkila and Lin (2014), who argues that the main problem with informal settlements is related to the low absorption capacity of the formal sector, which implies that the regulations are insufficient in the face of access problems.

Using data from the 2005 Census, the configuration of the area adjacent to the border is compared for both municipalities. The maps presented in figure 9 show the behavior of the informal settlements indicator for the years 2005 and 2018. In the first instance it is shown that the conditions of occupation of the area prior to treatment differ from those analyzed for the year 2018. In the thirteen years of difference the municipality of Bello had an increase in the occupation on its eastern side. Likewise, from a preliminary analysis of the maps, there is an apparent decrease in the incidence of these settlements in the area adjacent to the border for 2018 compared to 2005.



(a) Medellín - Bello 2005

(b) Medellín - Bello 2018

Figure 9: Informal settlements Medellín - Bello

In order to determine the behaviour of the output in the pre-treatment period, the GeoRDD exercise is replicated for the year 2005. [2]. Unlike in 2018, most of the points around the border did not have the observations required for the regressions. This is partly because the census questions from which the housing informality indicators are constructed are among those that were not applied to the entire population but were taken from a sample. In spite of this, the exercise was carried out for those points that did meet the conditions to carry it out. In general, although the results are not consistent for all the points in terms of the direction of the effect, it is possible to observe that, in periods prior to the treatment, the areas analyzed presented significant differences in terms of the informal housing indicator.

These results seem consistent with the hypothesis of displacement generated by a growing formal housing market. The relaxation of construction regulations generated an impulse to the creation of new housing projects in the border areas, making use of land previously used by the informal market. This forced the inhabitants either to enter the emerging formal market or to move to other areas of the city in informal conditions. The decision of the agents between one or the other option will depend on whether the conditions of access to this new formal housing market fit the constraints of the families.

Although the Medellín - Bello border has been used as a case study, other cases with similar characteristics have been considered for evaluation. In particular, the Bogotá - Soacha and Bucaramanga - Floridablanca borders meet the conditions for replicating the analysis. This not only as an exercise of robustness of the methodology used and the results obtained, but also as a way to verify some level of external validity. Figure 10 in Appendix I shows the results for the analyzed frontiers, including the graphs of the points to which the McCrary test was applied. From these results it is possible to observe that, with the exception of the western zone of the Bogotá - Soacha border, the effect found is consistent for other cases. In general terms, there do not seem to be significant differences between adjacent municipalities with different land use regulations.

[2]The results obtained can't be shown due to data access restrictions, pending full access

7 Preliminary conclusions

Flexible regulations seem to reduce the proliferation of informal settlements. The perspective that seems predominant is the *exclusionary purpose*, where legal norms are instituted as elements for gentrification. In the shared border between Bello and Medellín, however, there are no significant differences between one or the other municipality for the year 2018. The effect of regulation seems to be generated by an increase in the dynamics of formal market construction. The mechanism of action seems to be linked to an increase in the formal market that generates an occupation of land previously dedicated to the formal market and attracts settlers in better economic conditions, displacing certain population groups and forcing them to occupied the edge of the city.

The effect of the relaxation of land-use regulations, however, does not necessarily translate into an improvement in welfare. keeping in mind that the dominant perspective seems to be the exclusionary one, the reduction of informal settlements is associated to a phenomenon of gentrification. The aggregate improvement implies a displacement of settlers in conditions of informality and not an upgrade in their status. It is essential, as a way of extending this work, to look for ways of doing welfare analysis in order to be able to construct policy recommendations more appropriate to the context of cities located in developing countries with dual housing markets. It is also necessary to get a little deeper into the aggregate dynamics in the system of cities, in order to see the effects that these types of regulations have on equilibrium conditions.

The aggregated form of the indicators at the block level makes the analysis a little closer to the definition of settlement, an analysis at the household level shed light on the phenomenon of precarious housing itself. So it is considered important not only as a way to expand the conclusions but also as a test of their robustness. In any case, the conclusions obtained at both levels constitute a complement to each other that will help to better elucidate the phenomenon under study. On the other hand, and given that it seems that the decrease in informal settlements is associated with a phenomenon of displacement from certain areas and a consequent densification of them, the analysis at a lower level shows that it's possible that the informal settlers are now occupying the edge of both cities.

References

Anagol, S., Ferreira, F. V., and Rexer, J. M. (2021). Estimating the economic value of zoning reform. Technical report, National Bureau of Economic Research.

Biderman, C. (2008). Regulation and informal settlements in brazil: a quasi-experiment approach. Technical report.

Biderman, C., Smolka, M., and Sant'Anna, A. (2008). Urban housing informality: Does building and land use regulation matter. Land lines, 20(3):14–19.

CAF (2017). RED 2017. Crecimiento urbano y acceso a oportunidades: un desafío para América Latina. CAF.

Cattaneo, M. D., Galiani, S., Gertler, P. J., Martinez, S., and Titiunik, R. (2009). Housing, health, and happiness. American Economic Journal: Economic Policy, 1(1):75–105.

Dell, M. (2010). The persistent effects of peru's mining mita. Econometrica, 78(6):1863–1903.

Fischel, W. A. (2001). The homevoter hypothesis.

Gamboa Cataño, A. M. and Londoño Restrepo, A. F. (2020). Planeación del crecimiento demográfico y urbano de Itagüí, año 2000 a 2018. PhD thesis, Bogotá: Universidad Externado de Colombia, 2020.

Glaeser, E. L., Gyourko, J., and Saks, R. (2005). Why is manhattan so expensive? regulation and the rise in housing prices. The Journal of Law and Economics, 48(2):331–369.

Goytia, C., Dorna, G., Cohen, J., and Pasquini, R. (2015a). An empirical analysis of land use regulation determinants. Lincoln Institute of Land Policy.

Goytia, C., Dorna, G., Cohen, J., and Pasquini, R. A. (2015b). The CIPUV Residential Land Use Regulatory Index: A Measure of the Local Regulatory Environment for Land and Housing Markets in Argentina's Municipalities. Lincoln Institute of Land Policy.

Gyourko, J. and Summers, A. A. (2006). The wharton survey on land use regulation: documentation and analysis of survey responses. Zell/Lurie Real Estate Center at Wharton, September (mimeograph).

Hanna, R., Duflo, E., and Greenstone, M. (2016). Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves. American Economic Journal: Economic Policy, 8(1):80–114.

Heikkila, E. J. and Lin, M. C. (2014). An integrated model of formal and informal housing sectors. The Annals of regional science, 52(1):121–140.

Henderson, J. V. (2009). The effect of residential land market regulations on urban welfare. In Urban Land Markets, pages 25–49. Springer.

Keele, L. J. and Titiunik, R. (2015). Geographic boundaries as regression discontinuities. Political Analysis, 23(1):127–155.

Kironde, J. L. (2006). The regulatory framework, unplanned development and urban poverty: Findings from dar es salaam, tanzania. Land use policy, 23(4):460–472.

Lall, S. V., Wang, H. G., Da Mata, D., et al. (2007). Do urban land regulations influence slum formation? evidence from brazilian cities. Brazilian Association of Graduate Programs in Economics.

McCrary, J. (2008). Manipulation of the running variable in the regression discontinuity design: A density test. Journal of econometrics, 142(2):698–714.

Municipio de Bello (2009). Plan de ordenamiento territorial (pot).

Patel, A., Koizumi, N., and Crooks, A. (2014). Measuring slum severity in mumbai and kolkata: A household-based approach. Habitat International, 41:300–306.

Programa de las Naciones Unidas para los Asentamientos Humanos (2010). Estado de las ciudades para américa latina y el caribe. Technical report.

Quigley, J. M. and Raphael, S. (2005). Regulation and the high cost of housing in california. American Economic Review, 95(2):323–328.

Quintero, J. D. M. (2018). Asentamientos informales y pobreza en bello, la otra cara del "progreso". aproximación crítica desde el enfoque de derechos. Revista Trabajo Social, (26-27):151–167.

Rischard, M., Branson, Z., Miratrix, L., and Bornn, L. (2020). Do school districts affect nyc house prices? identifying border differences using a bayesian nonparametric approach to geographic regression discontinuity designs. Journal of the American Statistical Association, pages 1–13.

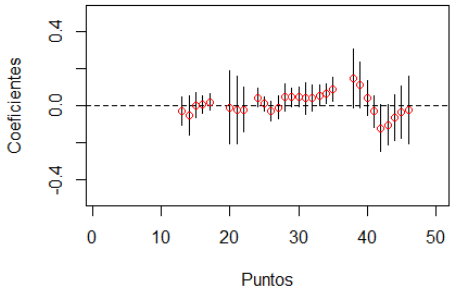
Ryan, A. M., Kontopantelis, E., Linden, A., and Burgess Jr, J. F. (2019). Now trending: Coping with non-parallel trends in difference-in-differences analysis. Statistical methods in medical research, 28(12):3697–3711.

UN-Habitat (2004). The challenge of slums: global report on human settlements 2003. Management of Environmental Quality: An International Journal, 15(3):337–338.

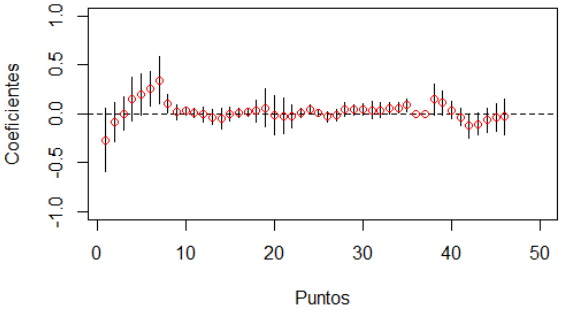
Zajonc, T. (2012). Essays on causal inference for public policy. PhD thesis.

Appendix I: Results from other colombian's borders

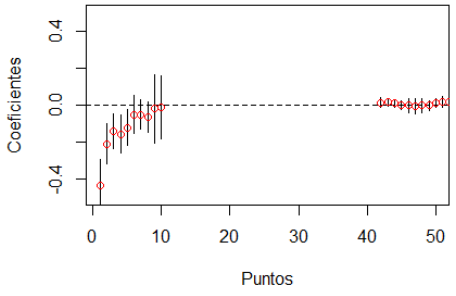
Figure 10: Estimation at different border



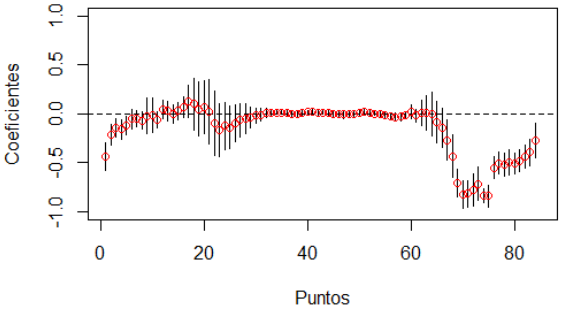
(a) Selected points Medellín - Bello



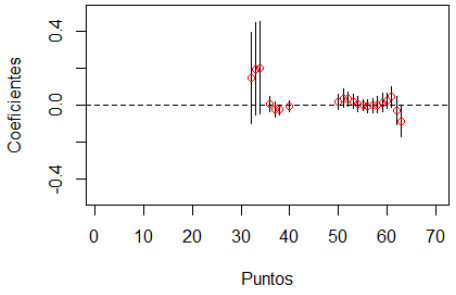
(b) Total points Medellín - Bello



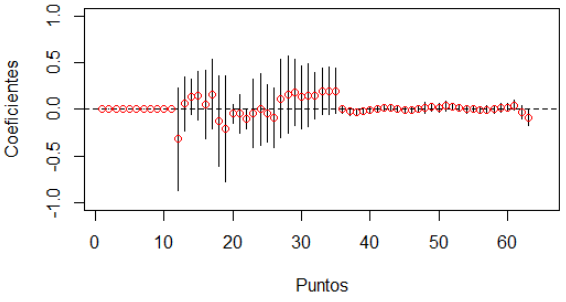
(c) Selected points Bogotá - Soacha



(d) Total points Bogotá - Soacha



(e) Selected points Bucaramanga - Floridablanca



(f) Total points Bucaramanga - Floridablanca

Appendix II: Informal settlements indicator

Difficulties of access to water and basic sanitation services.

From the data collected by the census, it is determined whether or not households have access to water, sewerage and basic sanitation services. The indicator becomes 1 if the household states that it does not have access to any of these basic services.

Housing density

For this case, the criteria established in the methodology designed by DANE (2009) to establish quantitative housing deficit are used. Two measures are identified, one corresponding to cohabitation and the other related to housing. Cohabitation is defined as those dwellings with more than one household, excluding dwellings where there is cohabitation of single-person households. In terms of overcrowding, it is defined by dividing the "number of people in the household" by the number of "rooms in which people sleep", and is considered overcrowded when there are more than three people sleeping per room. Inadequate housing density is considered to exist when there is cohabitation or overcrowding in the household.

Lack of structural quality in the dwelling

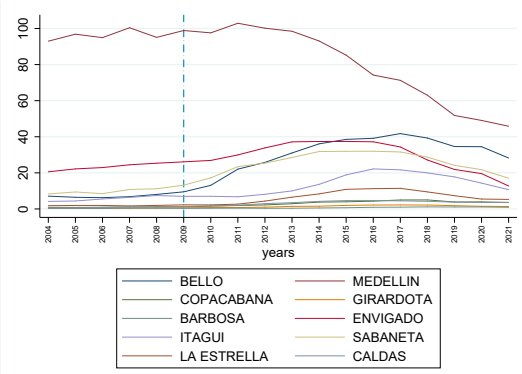
The housing unit is considered to be of low quality when its walls or floor do not correspond to minimum criteria of habitability and are built with precarious materials that put the structure of the dwelling and the well-being of its inhabitants at risk. For walls, they are considered of low quality when the houses are built with transitory or precarious materials such as cane, mats, zinc, cloth, cardboard, cans, waste, plastic, some other type of vegetable material or when there are no walls at all. For floors when the predominant material is earth or sand.

Insecurity of tenure.

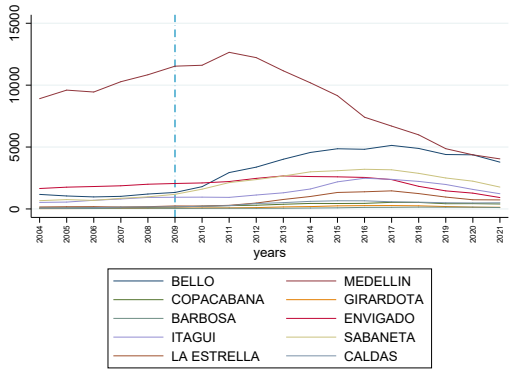
This criterion is fundamental. However, capturing the actual information is very complex. The surveys that inquire about the condition of legal ownership of housing are not sufficiently representative or are not geo-referenced. Even so, in the answers reported by the people there is a bias in the report, either by ignorance of the norm, by the legitimate confidence in social norms that generate a sense of ownership of the houses even when it is not regularized or by fear of a possible eviction. Bearing this in mind, the measure of surveys such as the GEIH is only a proxy of the condition of ownership of the dwellings.

Appendix III: Different measures of housing supply

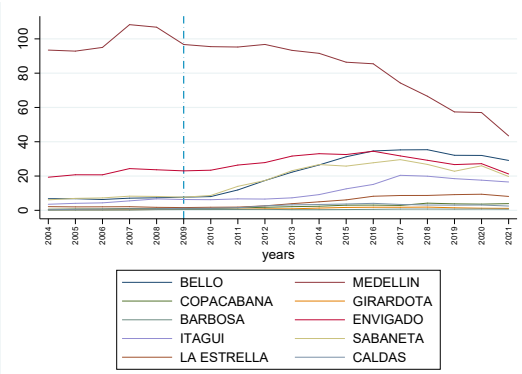
Figure 11: Measures of housing supply for Valle de Aburra Metropolitan Area



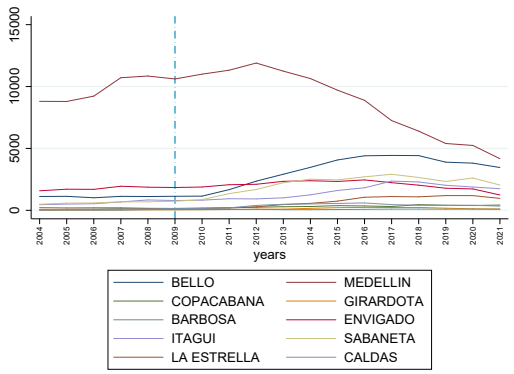
(a) Total area with new constructions in hectares



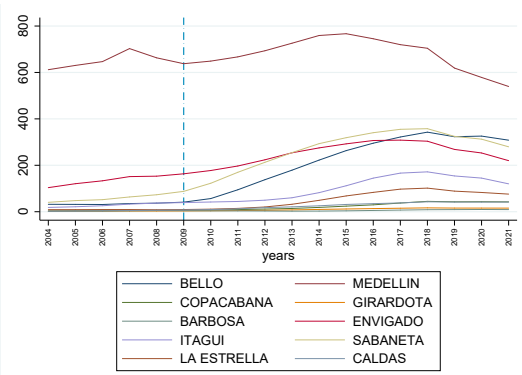
(b) Total units of new constructions



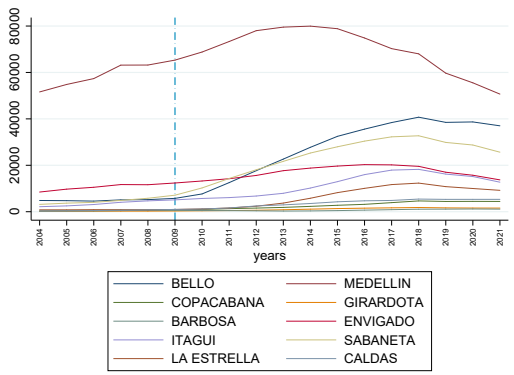
(c) Total area with finished constructions in hectares



(d) Total units of finished constructions



(e) Total area of constructions in hectares



(f) Total units of constructions

Appendix IV: Differences for segments at different bandwidths

SEGMENT - DISTANCE	Commerce	Household's size	Unemployment	Recent migration	Women	Dependency	Education
Segment 1 200	0.001	-0.077^{**}	0.005	0.078^{***}	-0.066^{***}	0.036^{**}	0.089
	(0.003)	(0.032)	(0.005)	(0.005)	(0.022)	(0.016)	(0.055)
Segment 1 400	-0.004^{*}	-0.085^{***}	0.003	0.060^{***}	-0.060^{***}	0.039^{***}	-0.059
	(0.002)	(0.025)	(0.004)	(0.004)	(0.017)	(0.012)	(0.042)
Segment 1 600	-0.004^{**}	-0.074^{***}	0.004	0.059^{***}	-0.059^{***}	0.042^{***}	-0.147^{***}
	(0.002)	(0.021)	(0.003)	(0.003)	(0.015)	(0.011)	(0.037)
Segment 1 800	-0.002	-0.090^{***}	0.0004	0.071^{***}	-0.063^{***}	0.053^{***}	-0.127^{***}
	(0.002)	(0.019)	(0.003)	(0.003)	(0.013)	(0.010)	(0.034)
Segment 1 1000	-0.002	-0.088^{***}	0.0002	0.072^{***}	-0.065^{***}	0.043^{***}	-0.173^{***}
	(0.002)	(0.018)	(0.003)	(0.003)	(0.013)	(0.009)	(0.033)
Segment 2 200	0.009^{***}	0.002	-0.007	0.108^{***}	0.040	0.022	0.693^{***}
	(0.002)	(0.039)	(0.006)	(0.007)	(0.027)	(0.020)	(0.075)
Segment 2 400	0.007^{***}	-0.032	-0.011^{**}	0.110^{***}	-0.004	0.029^{*}	0.727^{***}
	(0.002)	(0.028)	(0.004)	(0.006)	(0.020)	(0.015)	(0.057)
Segment 2 600	0.006^{***}	-0.006	-0.015^{***}	0.117^{***}	0.005	0.003	0.831^{***}
	(0.002)	(0.025)	(0.004)	(0.005)	(0.017)	(0.013)	(0.050)
Segment 2 800	0.006^{***}	-0.027	-0.016^{***}	0.113^{***}	0.0001	-0.001	0.859^{***}
	(0.001)	(0.022)	(0.003)	(0.004)	(0.015)	(0.012)	(0.043)
Segment 2 1000	0.005^{***}	-0.037^{*}	-0.016^{***}	0.112^{***}	0.0001	0.002	0.817^{***}
	(0.001)	(0.020)	(0.003)	(0.004)	(0.014)	(0.011)	(0.041)
Segment 3 200	0.011^{**}	-0.001	-0.017	0.162^{***}	0.048	-0.080^{**}	1.251^{***}
	(0.005)	(0.067)	(0.011)	(0.015)	(0.049)	(0.037)	(0.149)
Segment 3 400	0.003	-0.064	-0.023^{***}	0.138^{***}	0.024	-0.070^{***}	1.356^{***}
	(0.003)	(0.044)	(0.007)	(0.011)	(0.032)	(0.024)	(0.098)
Segment 3 600	0.003	-0.064	-0.017^{**}	0.130^{***}	0.028	-0.061^{***}	1.289^{***}
	(0.003)	(0.042)	(0.007)	(0.011)	(0.030)	(0.023)	(0.092)
Segment 3 800	0.003	-0.064	-0.017^{**}	0.130^{***}	0.028	-0.061^{***}	1.289^{***}
	(0.003)	(0.042)	(0.007)	(0.011)	(0.030)	(0.023)	(0.092)
Segment 3 1000	0.003	-0.064	-0.017^{**}	0.130^{***}	0.028	-0.061^{***}	1.289^{***}
	(0.003)	(0.042)	(0.007)	(0.011)	(0.030)	(0.023)	(0.092)

Standard errors in parentheses

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$