Regulation and Informality: guidelines for more inclusive cities

by

Lina Marcela García Tavera

Supervised by
Jorge Pérez Pérez
Juan Miguel Gallego Acevedo

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"One must imagine Sisyphus happy"
"Hay que imaginar a Sísifo feliz"
Albert Camus

Yo no debería estar acá y mi único mérito es haber hecho lo que tenía que hacer. Sin embargo, heme acá, esperando dar por terminado el camino retador que ha sido transitar este doctorado, que terminé haciendo por una única razón: por chismosa (aunque suena mejor cuando lo llamo "amor al conocimiento"). Estoy aquí gracias al camino que otros ya recorrieron por mí, a las manos que me han ayudado a levantarme durante este proceso y a quienes me empujaron cuando el mundo se volvió más pesado. Estoy acá gracias a la gente que me quiere y me ha ayudado a hacer eso: simplemente lo que tenía que hacer.

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Contents

Introduction

The question that motivated this dissertation is deceptively simple: What would a lawyer who turns to economics write a doctoral thesis about? The most obvious answer is that she would write about law. This document confirms the cliché, but does so from the perspective of a market economist. Throughout these chapters, I study how legal rules shape markets. In particular, I analyze changes in urban building regulations and their consequences for the housing market in a developing country. The overarching message is that rules matter, but they matter in subtle ways that depend on the institutional environment.

Two themes thread through the thesis. The first is the role of urban regulations, especially those that determine how land can be developed and buildings built inside cities. The second is the nature of the housing market itself. In many developing countries, a dual housing market operates: a formal sector that complies with planning and building laws and an informal sector that escapes them. Informal housing is more than a collection of squatter settlements; it is a broad spectrum of dwellings and rental arrangements that do not conform to formal planning frameworks and lack legal tenure. This informality often emerges in response to rapid urbanization and the failure of formal land and housing systems to provide affordable options. Informal housing typically lacks legal documentation on the tenure of land or rental, compliance with planning regulations, and access to basic services through formal systems. At the settlement level, these groups are characterized by unregulated and unplanned development, absence of formal land tenure, inadequate infrastructure, hazardous physical conditions, and high prices for basic services. These features, together with weak enforcement, lead to precarious living conditions and persistent housing insecurity (United Nations Human Settlements Programme (UN-Habitat), 2025).

The coexistence of formal and informal sectors is not just a descriptive curiosity; it has important implications for the way regulations work. In settings with weak institutions and large income disparities, restrictive building rules increase the cost of formal housing. Households deprived of the legal market often turn to the informal sector, where they can avoid regulatory costs at the expense of unsecure tenure and poor services (United Nations Human Settlements Programme (UN-Habitat), 2025). This duality means that the effects of regulatory changes in developing countries can differ markedly from those documented in high-income contexts. Because enforcement is uneven and markets are segmented, the same legal reform can have opposite effects on formal and informal segments. Understanding these differential responses is central to this thesis. In particular, I ask how changes in urban building regulations influence informal settlements and housing supply? What mechanisms drive these effects? And how does the presence of an informal sector alter urban equilibrium outcomes?

The first article exploits an institutional discontinuity at the municipal border of Medellín and Bello, two neighboring cities in Colombia with different building codes. Using a spatial regression discontinuity design, I compare adjacent neighborhoods on either side of the border and estimate the causal effect of more flexible rules on the prevalence of informal settlements. The analysis shows that

lax regulations reduce the incidence of informal housing, but the effect is highly localized along the western edge of the border. Evidence points to a displacement mechanism: regulatory relaxation expands formal construction (greater density and verticalization), which absorbs land previously occupied by informal dwellers, pushing informality towards the urban periphery. Placebo tests using prereform data confirm the absence of pretreatment differences, and the results are robust to controlling for migration. Overall, the chapter highlights that flexibilisation can be an instrument to contain informality locally, yet it risks displacing vulnerable households unless it is accompanied by inclusionary policies.

The second article assembles a new municipal dataset on Colombian planning regulations and constructs a flexible regulation index. To identify the effect of regulatory changes on housing supply, I use a staggered difference in differences design following Sun and Abraham (2021). The results reveal that more flexible rules increase the supply of authorized units and the constructed area, but the gains accrue mainly to small satellite cities. In large metropolitan cores, the response is limited. The effects appear gradually, about five to eight years after a reform, and a component analysis indicates that the construction index is the main driver. Additional evidence on housing deficits and migration suggests a reallocation channel: satellites absorb part of the demand from cores where land is scarce and expensive. The chapter thus provides evidence that easing intensity constraints can unlock supply where absorption capacity is high, but that cores require complementary policies on land availability and permitting.

The third article turns from empirical to theoretical. Building on the urban growth model of Duranton and Puga (2019), I develop a framework in which cities in developing countries have dual housing markets. In this setting, formal housing is subject to regulation and newcomers must pay a cost to enter, while informal housing offers a cheaper alternative at the expense of insecure tenure and sanction risk. The model shows that the presence of an informal sector allows cities to accommodate more residents than conventional models predict. When the formal supply of housing is constrained by regulation, the informal sector absorbs population inflows, leading to larger cities, an 'urban surplus' consistent with the high levels of urbanization observed in low-income countries (Fay and Opal, 2000a; Roberts et al., 2017). The model also underscores the importance of enforcement: Stronger enforcement of building rules raises the cost of informality and reduces city size, while weaker enforcement has the opposite effect. This theoretical insight links the institutional environment to the observed urban outcomes and motivates the empirical analyses in the previous chapters.

Together, the three chapters illustrate how legal incentives shape housing markets in a developing country with a dual housing structure. By combining quasi-experimental evidence with theory, the thesis contributes to law and economics and urban economics in three ways. First, it documents the causal effect of building regulations on informal settlements and shows that flexibility can contain informality only when accompanied by inclusionary measures. Second, it provides new evidence on housing supply responses to regulation in developing contexts, highlighting heterogeneous effects across city sizes and metropolitan roles. Third, it offers a theoretical framework that explains why cities in developing countries often grow beyond the predictions of standard models: the coexistence of formal and informal sectors fundamentally changes the urban equilibrium. These findings have direct policy implications. They suggest that relaxing building rules is not a panacea; rather, it should be part of a broader strategy that couples regulatory reform with access to formal housing and targeted support for those at risk of displacement. In this sense, the thesis brings the tools of economics to bear on a core issue at the intersection of law and urban development, shedding light on how institutions can foster more inclusive and efficient cities.

Chapter 2

Regulation and informal housing: Effects of urban building regulations on the proliferation of informal settlements

Lina Marcela García Tavera*, Héctor M. Posada†

Abstract. *The effect of building regulations on the proliferation of informal settlements is unclear. Although stricter regulations can provide policy makers with tools to control informality, they can also generate exclusion that forces some population segments to choose informal settlements. We estimate the effect of less strict regulations on the proliferation of informal settlements by exploiting adjacent urban settlements with regulatory discontinuities in Colombia. Using a Geographic Regression Discontinuity (GeoRDD) at the Medellín–Bello border, we find that laxer regulations reduce the prevalence of informal settlements locally, with statistically significant differences concentrated at the city edge (approximately points 02–10). The evidence is consistent with a displacement mechanism through the expansion of the formal market (verticalization and higher construction intensity). Placebo tests using 2005 data show no pretreatment differences and the results are robust to controlling for migration. In general, the exclusionary purpose appears to dominate, suggesting that regulatory flexibilization alone may shift informality spatially unless complemented by inclusion instruments*.*

*Universidad del Rosario. Email: linarmarce.garcia@urosario.edu.co

†Universidad de Antioquia. Email: hector.posada@udea.edu.co

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2.1 Introduction

Since 2014, the proportion of people living in informal settlements has increased (United Nations, 2021). Twenty-four percent of the world's population lived in low-quality dwellings. For Latin America, the number of people living in informal housing has increased (Programa de las Naciones Unidas para los Asentamientos Humanos, 2010). The proliferation of informal settlements directly impacts the socioeconomic indicators of households. People 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 less access to high-quality jobs (CAF, 2017). The most common causes of this phenomenon are poverty and institutional problems related to a lack of public investment. According to United Nations (2021), the increase in informal dwellers appears to be a natural result of urbanization and population growth. However, a new focus has been placed on the incidence that urban regulations may have on the proliferation of informal settlements (Biderman et al., 2008).

For developing countries, a dual housing market in which both formal and informal sectors co-exist generates special conditions where regulations can affect the housing market differently. It implies that the effect of regulations on informal settlements is unclear: these regulatory instruments can be a way to face the problem of informal settlements, as a manifestation of negative externalities of cities, but at the same time can be one cause of their proliferation (Biderman, 2008).

Usually, policymakers addressed the problem of informal settlements by suggesting the relaxation of urban planning regulations, but, as will be discussed later, this could incentivize migration and could not be enough to improve the informal status of residents. If reducing urban regulations, especially those related to building requirements, does not 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 more significant proliferation of informality. In addition, some policymakers have sought stricter regulations that allow them to maintain control over city growth to mitigate the proliferation of informal settlements; but the effect of these strict regulations may be the opposite. More rigid urban regulations make it more expensive and complicated for residents to adapt to them, generating incentives to enter informality due to the difficulty of adaptation. There is no consensus on how the nature of these regulations affects the phenomenon of informal settlements.

The literature on the relationship between regulation and informal settlements is sparse and the findings are ambiguous. In terms of causal analysis, the work by Biderman (2008) for Brazil shows that, in developing countries, stricter urban regulation, particularly zoning and subdivision rules, would generate higher levels of informality. In the same way, Kironde (2006) finds in Tanzania that having a strict regulatory framework of the minimum size of the plots promotes informality. These results are contrary to those found by Lall et al. (2007) for Brazil, 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 can imply an increase in informal settlements. Henderson (2009) finds that strict land use regulations appear to be an instrument for governments to restrict population growth and exclude low-income immigrants. However, the evidence is unclear and regulation does not appear to be a significant determinant of informal settlement formation.

The objective is to clarify the effect that different levels of flexibility in urban building regulations can have on the proliferation of informal settlements. In this paper, we contribute to the empirical literature that studies whether stricter regulation is one cause of the proliferation of informal settlements or whether, on the contrary, they are an effective way to mitigate their growth. We exploit the existence of contiguous urban settlements that belong to different municipalities in a developing country. We used the discontinuity in urban regulations on the border between two Colombian munic-

ipalities, Medellín and Bello, to identify the causal effect of more flexible regulations on the levels of informal housing. For estimation, we use a spatial Regression Discontinuity Design [GeoRDD] using the distance to the border between contiguous municipalities as an assignment variable and the border as the threshold to decompose the effect and analyze possible transmission mechanisms.

We find that regulatory flexibilization reduces the prevalence of informal settlements, but the effect is spatially concentrated at the city edge (approximately points 02–10 along the west border). Local differences are consistent with the expansion of the formal market (higher intensity of construction and verticalization) and a reallocation mechanism. Placebo exercises using 2005 data show no pretreatment differences at the border, and the results are robust to controlling for migration.

Taken together, our findings suggest that regulatory flexibilization can be an instrument to contain informality *locally*, particularly on the urban edge, by expanding formal supply and absorbing land previously used informally; yet, on its own, it risks spatially shifting informality and displacing vulnerable households. Policy design should therefore pair flexibilization with inclusion tools that expand access to the formal market (mechanisms targeted to low-cost housing within redevelopment areas and proximity-to-jobs support), safeguards for incumbent residents at the edge (in situ upgrading and antieviction protocols) and metropolitan coordination to manage spillovers across borders.

We organize the paper as follows. Section 2 gives some background information that includes the context of a regulatory environment in Colombia and the reason why Medellín and Bello were chosen as case studies. Section 3 describes the empirical strategy and the identification assumptions. Section 4 describes and analyzes the results. Finally, Section 5 concludes.

2.2 Background

2.2.1 Literature review

The literature on the relationship between regulation and the informal housing market is sparse and the findings are ambiguous. Most of the work was done in Brazil. In terms of causal inference, using a difference-in-differences strategy, Biderman (2008) shows that stricter urban regulation, particularly zoning and subdivision rules, would generate higher levels of informality. However, urban perimeter and building rules have no significant effect. We want to test the effect in the context of Colombia of regulations associated with urban rules.

Biderman (2008) results are contrary to those found by Lall et al. (2007), also for Brazil, who find that the land use and zoning planning regulations improve and stimulate the performance of the housing market by reducing the formation of slums. They concluded that more flexible regulations may imply an increase in informal settlements in the presence of market distortions. Adopting flexible regulations implies an increase in housing stock followed by a large flow of migrants, constrains the formal market, and increases slum formation. Our results for Colombia show that even when flexibilization generates a decrease in informal settlements, this decrease is driven by migration flows that force settlers to move to the edge of the city.

Henderson (2009), using a theoretical model and data from "superstar" municipalities in Brazil, finds that strict urban regulations appear to be an instrument of governments to restrict population growth and exclude low-income immigrants. However, the evidence is unclear, and regulation may not be a significant determinant of informal settlement formation. It appears to be more related to immigration flows. Migrants are disproportionately "choosing" to build in the informal sector (with poor public services) rather than in the formal sector (which is fully served mostly). The migration

rate may exceed the formal housing supply, and there are market access restrictions for these migrants. Our results show a possible equilibrium effect related to migration as a consequence of flexibilization.

In Argentina, Goytia and Pasquini (2016), using a probit model, found that the effect depends on the type of regulation applied and is not consistent in all contexts. The mere fact that a municipality has any kind of urban regulation appears to produce growth in the informal sector. However, changes in the contents of the regulatory framework, such as building rules, minimum lot size, and restrictions on buildings, among others, do not generate any change in informality. The exception is regulations about the Zoning and Regular Projects Approval Indicator, which could be understood as an increase in developer transaction costs, which exhibit a negative effect on formality.

Outside of Latin America, Kironde (2006) finds in Tanzania that a strict regulatory framework, in terms of the minimum size of plots, promotes informality. Monkkonen (2013) describes how Indonesia has stricter urban regulation, rapid urbanization, high levels of informality, and an affordable and well-functioning market. He points out that this is because of the effect of low levels of enforcement and emphasizes the importance of considering its important role.

2.2.2 Theoretical perspectives

Theoretically, urban regulations can have three different purposes: (i) *externality correction*, regulations are designed to spatially mitigate the negative externalities generated by urban agglomeration; (ii) *profit maximization*, legal rules, including urban planning, are shaped by influential landowners/homevoters to secure economic rents; and (iii) *exclusion*, regulation is used to control access for specific groups of potential residents.[2]

Under the *externality correction* purpose, stricter regulations provide stronger instruments for policy makers to mitigate the negative externalities generated by urban growth. However, there is a concern for selection bias: Cities with stricter regulations tend to be those that have experienced greater urban growth (Gyourko and Summers, 2006) and consequently more severe externalities. This implies a trade-off between the benefits of controlling externalities and the costs associated with regulation (Henderson, 2009). An effective application also requires sufficient enforcement; low enforcement smooths the effect of the legal system. In our setting, if this purpose predominates, we would expect the effect of flexibilization on informal settlements to be negative.

Under the *profit-maximization* purpose, the expected effect of regulations on informal settlements depends on the interests of stakeholders. Influential actors may seek rules that increase their rents, with costs borne by consumers. At the same time, some may profit from the informal market and thus have incentives to promote or protect it. Hence, the incidence of informal settlements depends on the preferences of the holders of political power. This view is related to Fischel (2001), where residents vote for policies aligned with their interests. In Latin American contexts, where actors can strongly influence administrative decisions, their agendas can be imposed and legitimized through regulation. In Colombia, this may occur given the conditions under which informal urbanization processes take place, including the potential participation of armed actors and informal developers with nontrivial influence on state decision making.[3]

Evidence from Goytia et al. (2015a) for Argentina suggests that the *exclusion* purpose can predom-

[2] We follow Goytia et al. (2015b,a) for the underlying taxonomy and relabel their categories as *purposes*: externality correction (*"welfare-economics"*), profit maximization (*"homevoter/influential landowner"*), and exclusion (*"exclusionary"*). Our frame of reference emphasizes the functional role of regulation rather than a normative stance.

[3] A fuller political-economy analysis would require data we do not currently have; therefore, we do not explore it in depth in this paper.

inate, with urban planning norms acting as control instruments that limit access to specific groups, especially migrants and low-income households. Under normal conditions, restrictive regulations can effectively control the composition of the population and exclude households that do not meet regulatory thresholds. However, this mechanism may be less effective in dual housing markets, where excluded households can either exit the city or enter the informal market outside formal regulations. This duality complicates the classical exclusion analysis.

Within this exclusion logic in the markets of developing countries, two conditions can arise: (i) a *regulation effect*, where stricter rules raise formal market costs and therefore exclude certain groups; and (ii) a *reallocation effect*, where excluded groups remain in the city by moving to the informal market or relocate to places with more flexible regulations or more accessible markets. These rules can generate equilibrium effects on residential allocation; as Henderson (2009) note, they may push potential residents to less desirable locations, reducing overall welfare. In the presence of dual markets, the overall equilibrium effect is ambiguous because reallocation involves two distinct choices. If the *exclusion* purpose predominates in our case, we would expect more flexible regulations to reduce the proliferation of informal settlements.

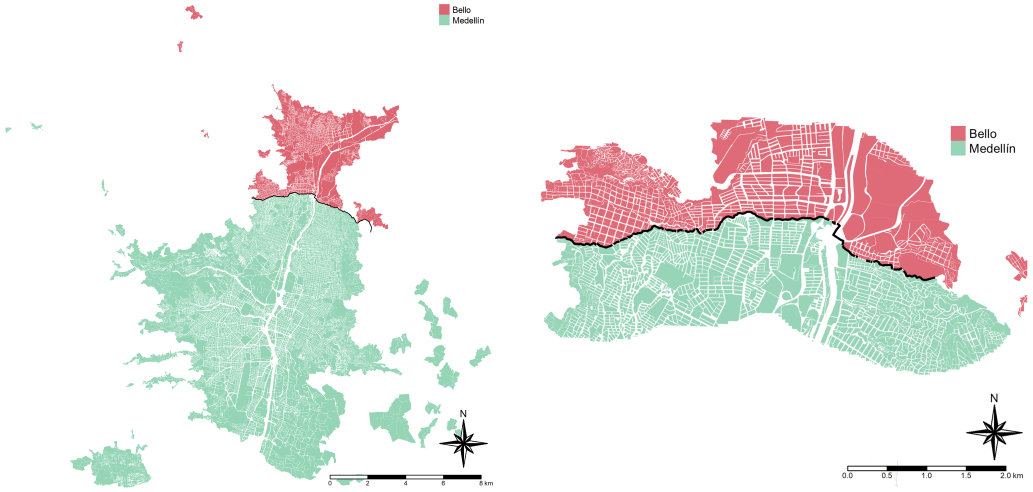
To assess which purpose dominates, we take advantage of the fact that Colombian land use regulations are created locally and attached to municipalities, some of which have contiguous urban settlements. Our main case study is the pair of Bello and Medellín.

2.3 Case study: Medellín – Bello

The institutional and social context of Colombia offers a useful setting for studying the link between urban regulation and informal settlements. Law 388 of 1997 created a nationwide mandate requiring every municipality to adopt a land-management plan (*Plan de Ordenamiento Territorial*, POT). Each POT is a 12–year technical and normative instrument that sets the policies, strategies, programs, and rules that guide physical development and land use. Delimits areas for public space and urban infrastructure, natural protection and conservation, urban expansion, social housing development, and the full regulatory framework for land use and construction standards. POTs cover the entire municipal territory and their application is confined to administrative boundaries.

Medellín and Bello are neighboring municipalities in the Department of Antioquia, Colombia. As can be seen in Figure 2.1, they share an administrative border and are part of the 'Metropolitan Area of the Aburrá Valley', which coordinates metropolitan transport, acts as an urban environmental authority and performs planning functions. Despite these metropolitan competencies, each municipality enacts and enforces its own urban regulation within its territorial limits. To better understand the location and the dinamics of our case of study municipalities, consult the Appendix A.1.

Figure 2.1: Zone of study: municipalities of Bello and Medellín



(a) Urban area (b) Urban border

Notes: In red the municipality of Bello and in green Medellín; the black line is the administrative border. Panel (a) shows the location of human settlements in the urban area of both municipalities; panel (b) shows the shared urban edge.

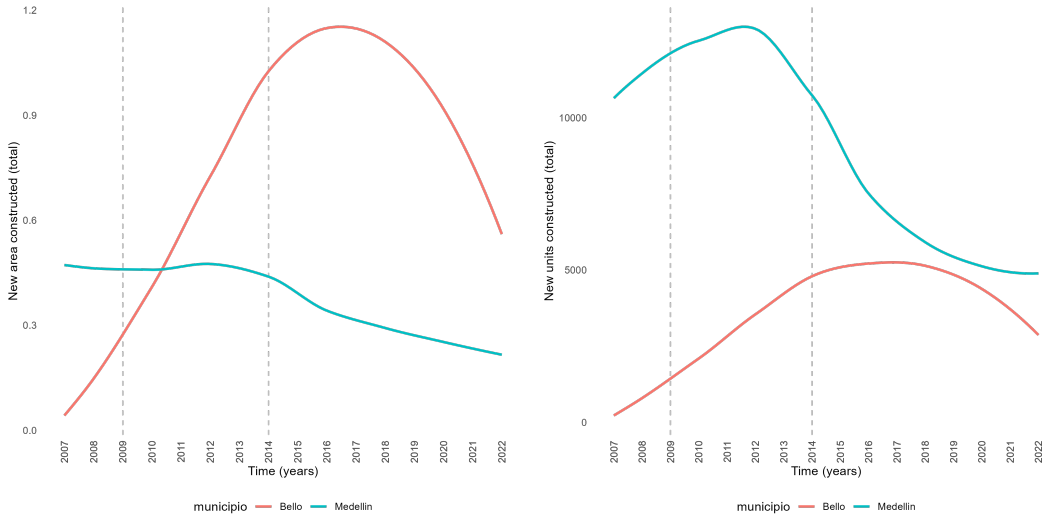
In 2009, as part of the mandatory 12-year review, Bello's municipality revised its POT with the explicit policy aim of relaxing urban rules to stimulate formal construction and reorient growth toward metropolitan centralities. The revision promoted vertical densification and the development of completed higher-quality residential projects (as opposed to incremental or unfinished units), articulating a polycentric structure anchored in designated centralities and priority development areas - particularly around the Madera, Bello and Niqua Metro stations (Concejo Municipal de Bello, 2009; Restrepo, 2012, 2007).

Substantively, the 2009 review: (i) expanded the stock of developable and redevelopment land, especially on centrally located underused and former industrial plots, opening fronts for large high–rise projects (Restrepo, 2012, 2007); (ii) relaxed key intensity and form controls by reducing effective occupancy constraints and increasing the construction index and allowable height, thereby enabling greater building densities and consolidating redevelopment corridors in well–served areas (Restrepo, 2012); and (iii) reoriented the market segment by permitting higher–cost residential projects and prioritizing finished, high–quality schemes over low–cost [4], incremental construction, while delineating 'priority development areas' around Madera, Bello, and Niquia with allowances for greater heights and densification to capitalize on these metropolitan centralities (Concejo Municipal de Bello, 2009).

As expected, these changes in regulation were followed by a surge in new housing supply and a visible expansion of the built area. Bello became a reference point for urban renewal and construction in the metropolitan region. In the years after the reform, Bello showed the strongest construction dynamics in the area, even surpassing Medellín, the core municipality of the system to which both belong (Restrepo, 2012). Figure 2.2 shows the supply side dynamics for both municipalities using the DANE Building Census (CEED).

[4] In the Colombian regulatory context, *Vivienda de Interés Social* (VIS) and *Vivienda de Interés Prioritario* (VIP) are legally defined lower–cost housing categories. When we refer to a shift towards 'higher-cost' residential projects, we mean projects above VIS / VIP thresholds

Figure 2.2: Supply of housing per municipality



(a) New area constructed

(b) New units constructed

Notes: Smooth dynamics of new housing (units and area) in Medellín and Bello. We take only new projects as a measure of new supply. Dashed lines mark the POT changes: 2009 for Bello and 2014 for Medellín.

Figure 2.2 shows a clear post–2009 increase in both the number of new constructions and the total area built in Bello, while Medellín exhibits a downward trend after its 2014 regulatory tightening [5]. At the end of our study window (2018), Bello still operated under a relatively flexible regime while Medellín was more restrictive; in the following we exploit this contrast as our treatment definition.

Within this regulatory context, land markets and development practices in Medellín and Bello have evolved in different but interconnected ways. In Bello, the availability of developable land and a more permissive regulatory environment encouraged strong participation by private developers, with licensing practices oriented toward facilitating rapid housing construction (Muñoz Quintero and Sierra Cano, 2021). In Medellín, planning control has progressively strengthened, especially in peripheral and hillside areas, reinforcing the role of the local state as a regulator of urban expansion rather than a promoter of large-scale new developments (Garcia Ferrari et al., 2018). Over time, this has produced a metropolitan pattern in which development pressures are displaced from Medellín toward neighboring municipalities such as Bello, which absorbs a significant share of both formal and informal growth (Aquilué Junyent, 2020). These dynamics show how land markets, institutional capacity, and licensing practices interact to shape urban expansion within a fragmented system of metropolitan governance.

2.3.1 Treatment definition

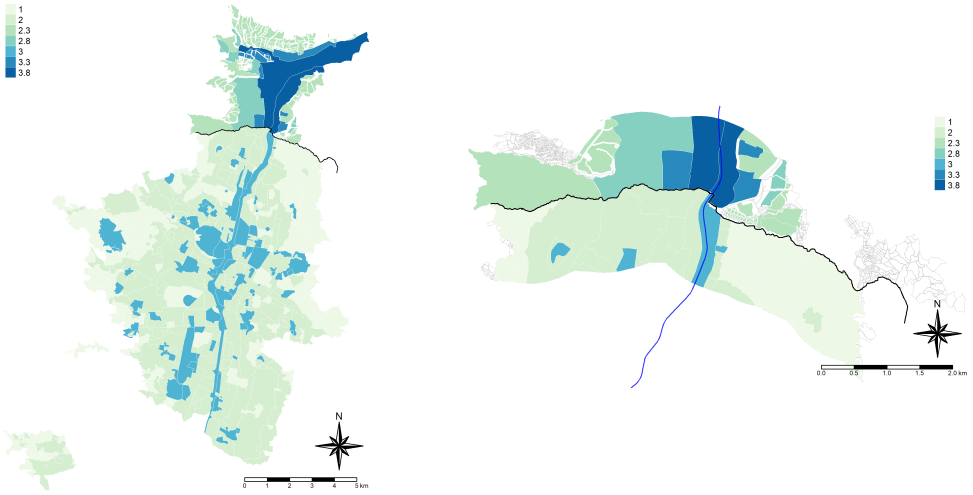
We define treatment as exposure to a more flexible urban regulatory regime in the municipality of Bello relative to Medellín. In 2009, Bello revised its *Plan de Ordenamiento Territorial* (POT) with an explicit policy to relax urban controls in order to stimulate formal construction. Review

[5] This increase in housing supply is consistent with the findings of Anagol et al. (2021) in their work for Brazil, where they found that flexibility in land use regulations, especially those related to construction indexes, increases housing supply

(i) oriented densification towards vertical building and completed higher quality residential projects [6]; (ii) broadened development and redevelopment fronts on centrally located and underused land (including former industrial plots along the Aburrá river plain); and (iii) defined priority development areas around Madera, Bello, and Niquia metro stations to capitalize on metropolitan centralities (Concejo Municipal de Bello, 2009; Restrepo, 2007, 2012). Contemporary analyzes of Bello's urban transformation document the ensuing surge in high–rise housing and redevelopment around these centralities (Restrepo, 2012; Quintero, 2018).

Operationally, we compare codified standards across jurisdictions. Higher values of the construction index (IC) [7] and more permissive form / intensity controls signal a lower regulatory stringency. Figure 2.3 maps the IC across both municipalities and at their shared border (darker colors denote higher IC). Bello systematically exhibits higher IC, particularly along the shared urban edge, implying a less restrictive regime on its side of the boundary. Medellín, by contrast, tightened its framework in 2014, resulting in a more restrictive environment during our study window.

Figure 2.3: Construction index (IC) in Medellín and Bello



(a) Municipal overview

(b) Shared urban border

Notes: Darker colors indicate higher IC (less restrictive norms). The Aburrá River crosses the valley: flatter river–plain tracts allow higher IC relative to hillside tracts.

A central component of the Bello 2009 reform was the removal of the binding height caps in most urban treatments, effectively eliminating maximum height restrictions and enabling verticalization. Appendix A.2 summarizes the average indicators by regulatory treatment: for Bello, most treatments report an average maximum height (AM) of *35*, which is the imputed value when no explicit height limit is present. In contrast, Medellín's corresponding averages remain low in all major treatments, reflecting binding caps. This gap in height permissiveness complements the greater IC in Bello and jointly characterizes a substantially more flexible regime on the Bello side of the border.

[6] In Colombia, *Vivienda de Interés Social* (VIS) and *Vivienda de Interés Prioritario* (VIP) are legally defined lower cost housing categories. When we refer to a shift towards 'higher-cost' residential projects, we mean projects above VIS / VIP thresholds Concejo Municipal de Bello (2009).

[7] This 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 larger measure of IC means a more flexible construction law

These changes manifested visibly in the built environment. After the reform, Bello experienced a marked increase in the number and height of residential towers, particularly along the central corridor and around Niquía, relative to the adjacent Medellín side of the border, where significant height and intensity restrictions remain. Published accounts describe the "verticalization" of housing as a defining feature of Bello's recent urbanization, with high–rise projects replacing low–rise stock and transforming neighborhood morphology (Restrepo, 2012, 2007; Quintero, 2018). For transparency, we also assembled a comparative database of regulatory standards (minimum lot size, (IC), occupancy rate (IO), available land for construction, and urban obligations) across Colombian cities; for Medellín–Bello, these codified indicators corroborate the qualitative assessment of relative flexibility (sample and coding rules in Appendix A.2).

Before the regulatory reforms analyzed in this chapter, Medellín and Bello exhibited distinct but interrelated urban dynamics shaped by accelerated metropolitan growth, strong pressures on land markets, and persistent informal expansion along their urban peripheries. In Bello, rapid urbanization during the 2000s was closely associated with an explicit strategy to promote real estate development as a driver of local economic growth, leading to an expansionary planning approach to activate formal housing supply and attract private investment through relatively permissive zoning and density regulations (Quintero, 2018; Muñoz Quintero and Sierra Cano, 2021). By contrast, Medellín entered the 2010s facing concerns about uncontrolled urban expansion, particularly in hillside and peripheral areas characterized by high environmental risk and the proliferation of informal settlements. The 2014 revision of Medellín's Plan de Ordenamiento Territorial (POT) marked a regulatory turn toward stronger spatial control, emphasizing risk management, landscape protection, and containment of informal growth rather than direct stimulation of real estate activity (Aquilué Junyent, 2020; Santamaría, 2018). While both reforms responded to metropolitan-scale pressures, they embodied different planning logics: Bello's 2009 POT prioritized market activation and housing production, whereas Medellín's 2014 POT focused on reasserting planning control over.

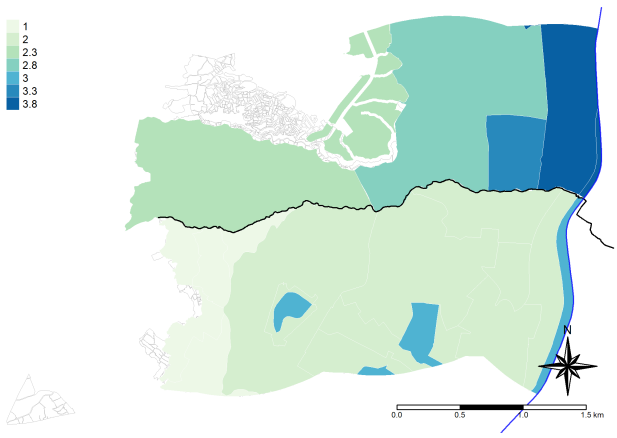
These divergent planning strategies become particularly evident in the urban interface between Medellín and Bello, where a continuous metropolitan settlement is governed by contrasting regulatory regimes. Although the two municipalities are part of the same functional urban system within the Aburrá Valley, their POTs adopt different approaches to land use, density, and development control, resulting in institutional discontinuities along their shared boundary. Bello's planning framework has historically enabled higher development intensities and greater flexibility in land-use regulation, facilitating formal real estate projects at the metropolitan fringe, while Medellín's POT imposes stricter controls on expansion areas, especially in zones of environmental sensitivity and urban–rural transition (Garcia Ferrari et al., 2018). As a result, the municipal border operates not merely as an administrative limit but as a regulatory threshold, where differences in zoning rules and development conditions shape the spatial allocation of both formal and informal urban activities (Ferrari et al., 2018; Gutiérrez, 2017). This contrast is particularly relevant at the northern edge of Medellín and the southern sector of Bello, where regulatory asymmetries contribute to the relocation of development pressures across jurisdictions rather than their resolution at the metropolitan scale.

2.3.2 Study area

We focus on the contiguous urban border between Medellín and Bello and restrict the analysis to the western segment of the shared edge, where both sides provide adequate observation support and comparable urban uses. The eastern segment is unsuitable for two reasons codified in the POT: (i) extensive tracts are classified as *Zona con Restricción por Movimiento en Masa* (ZRMM), limiting residential development due to geotechnical risk; and (ii) adjacent tracts are designated *Zona de Actividad Especializada* (ZAE), oriented to industrial/commercial uses rather than housing (Concejo

Municipal de Bello, 2009). These constraints generate asymmetric support between municipalities on the eastern edge, undermining the comparability required by the design.

Figure 2.4: Study area: western border



Notes: The panel highlights the western strip retained for the geographic RD design.

We implement a geographic regression discontinuity along this western strip using two spatial units that we justify in detail in the identification section below. First, we define *segments* as contiguous stretches of the border grouped by the distinct IC levels observed on the Bello side of the study area; these segments align the running variable with discrete shifts in regulatory intensity. Second, we define *points* as equally spaced locations on the border at 100-meter intervals (approximately the average block-to-block spacing in Colombian urban grids near our study area). The point grid anchors local neighborhoods for estimation and facilitates balance and manipulation checks.

2.4 Data

Our outcome is the severity of the informal settlement conditions at the census block level. Following UN-Habitat (2004), we focus on four canonical dimensions of slums: (i) lack of public utilities, (ii) overcrowding, (iii) poor housing quality, and (iv) insecurity of tenure. We implement a continuous *slum severity index* (SSI) in the spirit of Patel et al. (2014), where SSI= 0 indicates a non-slum status, and higher values denote greater deprivation. Conceptually, we adopt the definition of "informal settlement $\approx$ slum" reviewed by Wekesa et al. (2011), which jointly considers physical deficits and socio-economic vulnerability.

Data for the first three dimensions come from the Colombian Population and Housing Census (DANE) for 2005 and 2018, georeferenced at the block level. Specifically, we use block-level indicators of access to basic services (water, sanitation, electricity), crowding (persons per room), and

materials/structural quality of dwellings to construct the SSI components. Because the 2018 census does not allow direct identification of irregular tenure, our census-based SSI is closest to a measure of 'precarious housing' anchored in physical deprivation. The unit of analysis in all specifications is the census block (or block group, where applicable), and we compile a balanced spatial database for both municipalities (details in Appendix A.8). Throughout, we use 2018 as our main cross section and report parallel exercises for 2005 to assess stability over time.

2.5 Identification strategy

We estimate the causal effect of a more flexible land use regime on the prevalence of informal settlements by exploiting the institutional discontinuity that arises at municipal borders. In our setting, contiguous urban fabric straddles an administrative boundary across which planning rules differ. Bello (treated) adopted a more flexible POT in 2009, while Medellín (control) remained comparatively restrictive and tightened the rules in 2014. We therefore implement a geographic regression discontinuity (GeoRDD) with the municipal boundary as the cut-off, comparing units on either side of the border that are locally comparable in geography and urban form.

A key design choice in GeoRDD is whether to collapse geography to a single distance-to-border score (a univariate running variable) or to retain the two-dimensional location (latitude/longitude). As Keele and Titiunik (2015) emphasize, a distance-only specification can pair units that are equally close to the border yet poorly matched along the boundary (different terrain, accessibility, or regulatory context), violating continuity[8] We thus follow the guidance in Keele and Titiunik (2015): we account for location along the frontier and estimate effects locally rather than relying on a single scalar distance. A complete discussion, with didactic figures and alternative specifications, is provided in Appendix A.4.

When a geographic border defines the cut-off point, we find a high heterogeneity along the border (Keele and Titiunik, 2015). As a first measure to control for differences that may exist, the border is divided into different segments, taking advantage of the local variation in the zoning restrictions. Figures 2.3, panels 2.1a and 2.1b, show the municipalities with their respective zoning defining the construction index [IC]. Each segment corresponds to a variation in the IC on the Bello side.

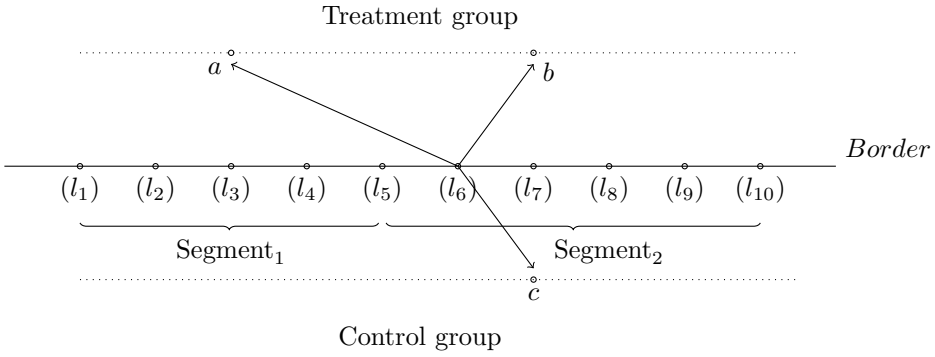
In the work by Wong et al. (2013), four different estimation strategies are compared in the scenario when there is more than one assignment variable. The *frontier* approach requires modeling the response surface of the border and then using kernel density estimates for the cutoff frontiers. As we explicitly have the cut-off, there is no need to use this approach. The *univariate* approach uses a single assignment variable and excludes all observations corresponding to the other variable. For our estimation, given that it is a very local analysis, we will not exclude observations to avoid losing statistical power. We argue that, with geographically well-defined boundaries, a reformulation of what they call the *centering* one is the best approach.

Following Keele and Titiunik (2015), we capture it by setting specific coordinates for points along the border as different discontinuity points. As a result, we now have a set of assignment variables and a set of cut-off points. We place equally spaced *points* along the boundary at 100-meter intervals (approximately the average block-to-block spacing in Colombian urban grids near our area). Each point l anchors a local neighborhood on both sides of the frontier for estimation and diagnosis (balance and manipulation checks). Distances are computed as the Euclidean distance from each census block

[8] In our Figures A.3 and A.4 (in Appendix A.4), point a sits at the same perpendicular distance as points b and c, but a lies over a different along-border neighborhood (hillside vs. river plain, different accessibility and land-use mix), making b or c more credible counterfactuals than a.

to the border point l. Estimation proceeds by fitting local polynomials centered on each l to obtain a set of location-specific treatment effects β_{1l}; this produces a treatment-effect curve along the border rather than a single average (Rischard et al., 2020). Figure A.4 shows this strategy.

Figure 2.5: Propose model representation



Notes: The $(l_{\#})$ represents the dots in wich we divide the border. We measured the distances of our unit of analysis (a, b, c) to each one of the dots that will be used in the estimation.

Once we control for the location along the border, turning the variable into a single scalar will not bias the estimation and will give a better picture of the problem, allowing us to relate the estimation to specific locations. If the estimation considers possible heterogeneity along the border, the results should not differ much from those of a weighted estimator. In addition, our approach could be useful to facilitate the graphic representation and the analysis of the results.

2.5.1 Checking spatial regression discontinuity assumptions

The main identification assumption in an RDD is the continuity of $E[Y_i(0)|U_l]$ (the counterfactual result) in the assignment variable U_l, which guarantees that locally (around the cut-off or discontinuity), the treatment is assigned as good as random. To present evidence on the continuity assumption, we run a no-sorting test and an equality of means test.

2.5.1.1 No sorting assumption

The no-sorting test checks if units sort around the cut-off as evidence of self-selection. In spatial analysis, this assumption is problematic. In our case, regulation changes can generate that a specific location turns out to be more or less attractive for agents and, as a result, units sorted around municipality borders. However, the unit of analysis corresponds to housing units rather than individuals. Because houses do not move, but adjust their conditions over time, the problem of sorting on the frontier referred to housing can be partially attenuated (Rischard et al., 2020) and can even be interpreted as a general equilibrium effect. We argue that even in the presence of self-selection, there is no bias. We try to capture the adjustment that informal housing could have in response to migration caused by changes in regulation.

As was made by Dell (2010), we will not emphasize this assumption; by contrast, we will discuss this "sorting" as evidence of a possible mechanism that will explain our results. We will argue that the differences in density and migration will correspond to a general equilibrium effect. Regulation changes increase the supply of housing because developers select to construct in the Bello size, which

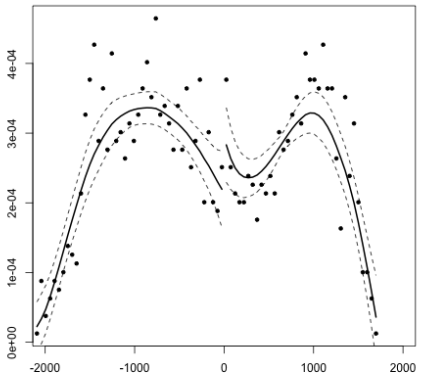
attracts more migrants and, as we will discuss later, decreases the proliferation of informal settlements via displacement.

However, given that there are geographical variations along the border (such as rivers, cliffs, hills, etc.) that can restrict the use for human settlement, we use a density test as a way to select "well-behaved" areas with enough density to run the regression.

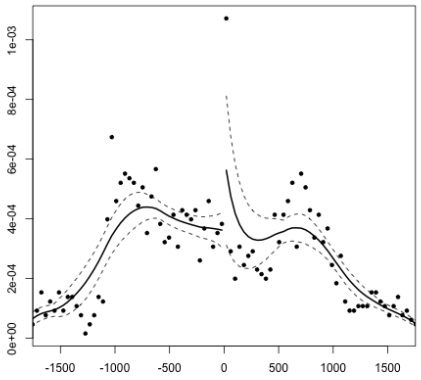
We use the test proposed by McCrary (2008) to check the sorting around borders and specific locations. The test checks if there is a discontinuity in the density function of the assignment variable around the cutoff[9]. Figure 2.6 shows the test results for the complete border and the defined segments and reveals that in segment 2, the no-sorting hypothesis is rejected. In this segment a river indicates the border between the two municipalities, it explains the shape of the density. Regarding the specific point or coordinates, we have that for 33 of 42, the no-sorting hypothesis is not rejected. The p-values for the tests are presented in Appendix A.5.

[9]The null hypothesis implies continuity so p-values < 0.05 imply sorting

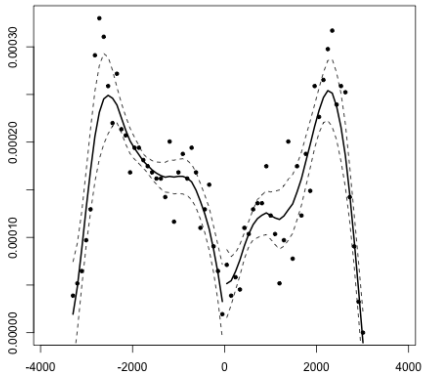
Figure 2.6: McCrary test results for all segments



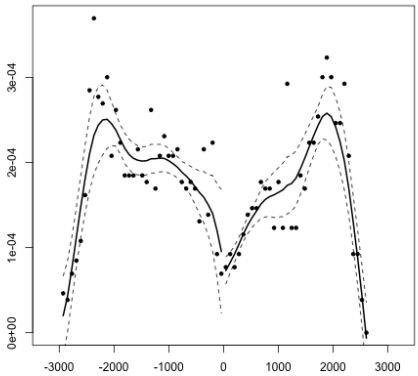
(a) Segment 1
(p-value 0.105)



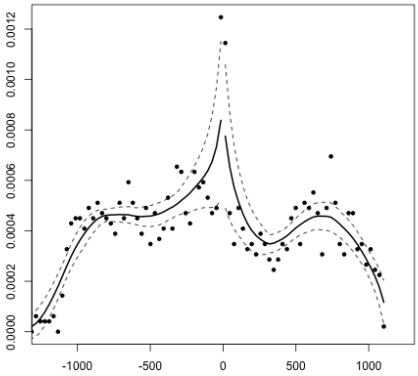
(b) Segment 2
(p-value 6.406e-06)



(c) Segment 3
(p-value 0.066)



(d) Segment 4
(p-value 0.657)



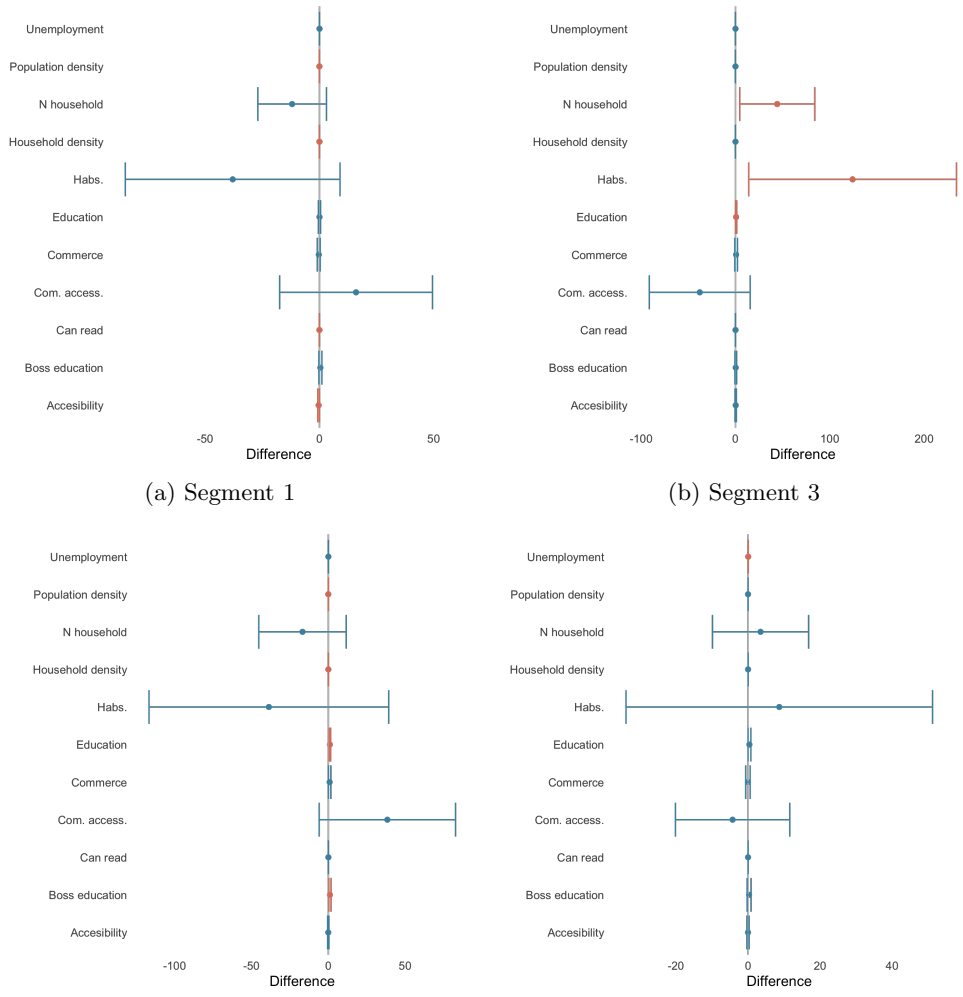
(e) Border
(p-value 0.694)

Notes: The distance is normalized. We assign negative values to locations in Medellín and positive to those located in Bello. The cero point is the border. The running variable is linear distance to the border

2.5.1.2 Balance test

We also check the continuity assumption testing to see if there are systematic differences between our treatment and control units regarding predetermined characteristics. Figure shows the results of a non-parametric RDD for the entire (west) border and segments 1, 3, and 4 (panels 2.7a, 2.7b and 2.7c), revealing that there are no systematic differences between the treated and control units.

Figure 2.7: Balance test for segments



(a) Segment 1

(b) Segment 3

(c) Segment 4

(d) Border

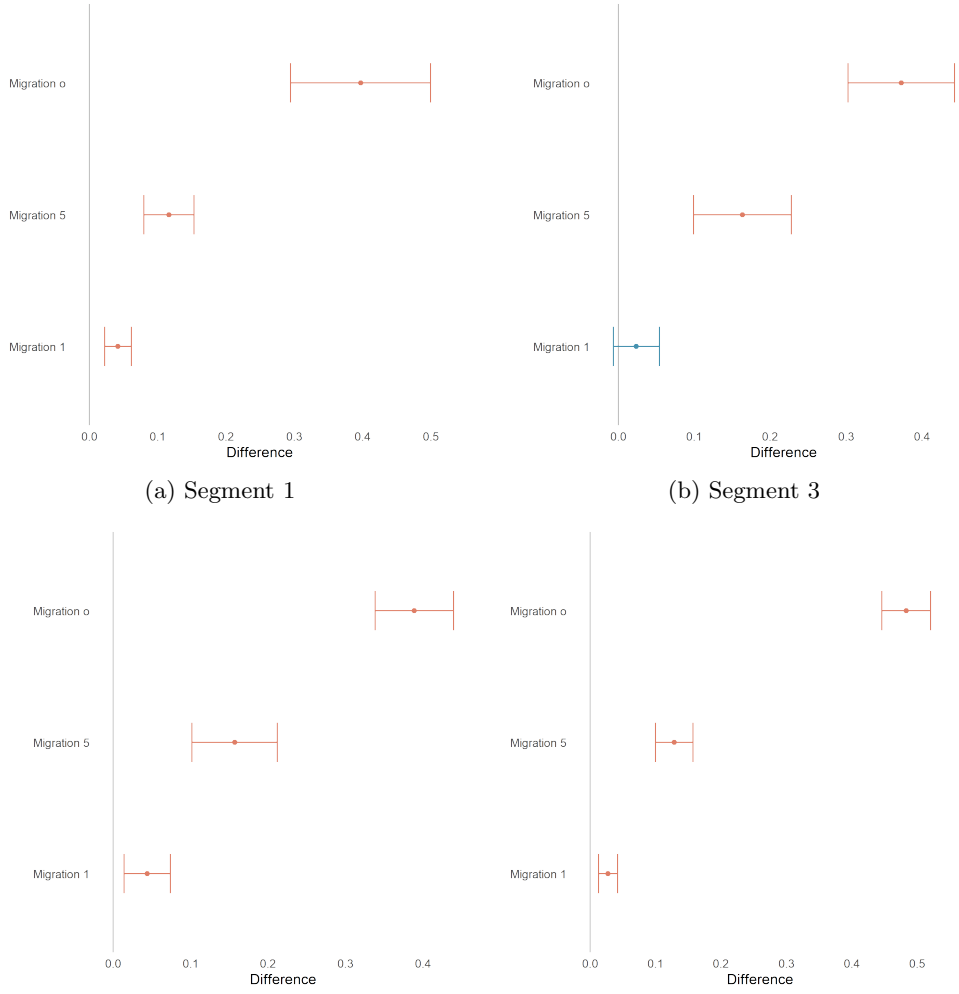
Notes: Figure represents coefficients of a simple difference test with its respective confidence interval. Blue lines imply no difference and the red ones that there are significant differences. Variables measure unemployment (*Unemployment*), population density (*Population density*), number of households per house (*N Household*), household density (Household density), means of years of education (*Education*), units of housing with commercial activities (*Commerce*), accessibility to commerce centers (*Com. access*), literacy rate (*Can read*), education of the head of the household (*Boss education*), accessibility to the nearest city core (*Accesibility*)

The estimated coefficients for segments (Tables A.3 and A.4) and the results for points (Figure

A.12) can be found in Appendix A.6. The balance tests for selected points can be found in Appendix A.5. Results will be presented for segments and points whose evidence of no sorting and no systematic difference holds.

For each segment, there are significant differences in migration rates. This difference is consistent in all points. There appears to be a constant flow of migrants arriving in Bello compared to Medellín, not necessarily related to the large migration of foreigners from Venezuela to Colombia [10]. It lets us think about a mechanism that implies reallocation of agents through the improvement of the formal housing market. We will discuss this later. Figure 2.8 shows the results for the migration rates in segments.

Figure 2.8: Differences in migration indexes



(a) Segment 1

(b) Segment 3

(c) Segment 4

(d) Border

Notes: Variables were measured using the household head. *Migran o* means that it was born in a different municipality, *migran 5* means that it migrated in the last 5 years, and *migran 1* that it arrived in the municipality in the last year.

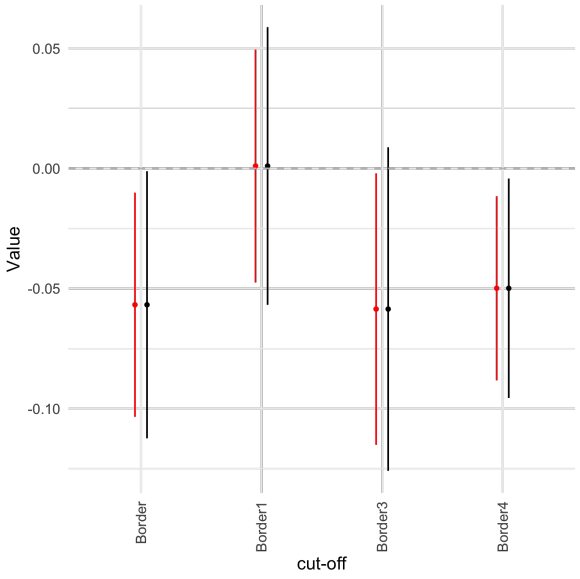
[10] Between 2015 and 2019, approximately 1.8 million Venezuelans migrated to Colombia in response to a social and economic crisis (Lebow, 2022). We checked this hypothesis and found that there are no significant differences between municipalities in foreign migrant rates

Given that migration could be an endogenous variable that could affect the output of interest, following the methodology indicated by Dell (2010), they are included as control variables to eliminate bias. We also use these consistent differences in migration as a way to explain our results.

2.6 Results

Figure 2.9 shows the results for the whole west border and for each segment that passes the validation check explained in the previous chapter. At the west border, Bello has lower levels of informal housing than its neighboring municipality Medellín [11]. It implies that less restrictive regulations could result in fewer levels of informal settlements. A disaggregated analysis shows that the effect is carried out on the west edge of both cities. Additional results and coefficients [12] can be consulted in Appendices A.8 and A.9.

Figure 2.9: Estimated effect of regulation on Informal Housing for segments



Note: The results are for the entire west border and each of the previously defined segments. The red line represents a confidence interval at 90% and the black one at the 95%.

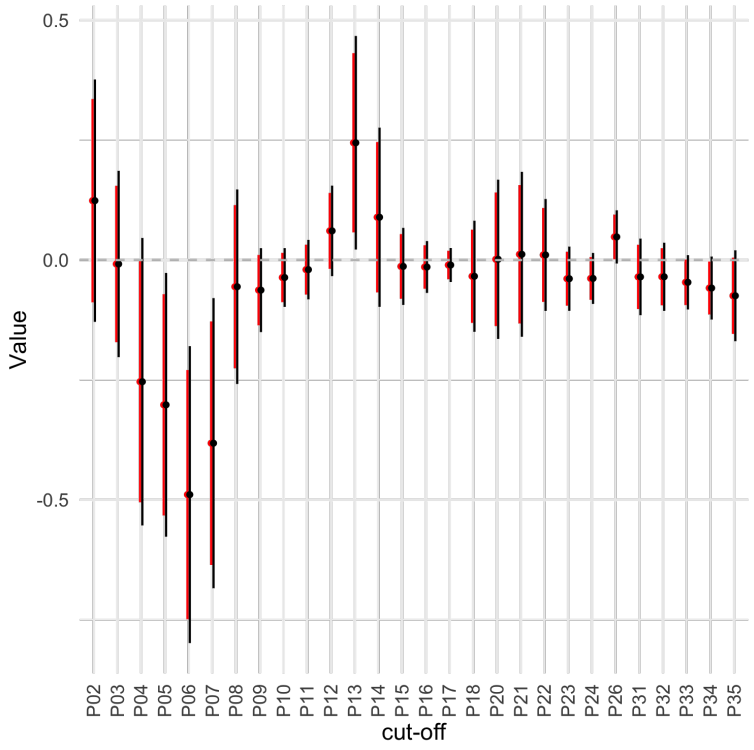
Figure 2.10 shows the results along the border using dots. Even when, on average, there are no differences along the border, some significant differences are concentrated at the edge, which is consistent with our segment results. It could imply a displacement effect. In addition, it is usual for informal settlers to allocate to the urban edge looking for land available to occupy. Because these areas are far from the city or the main business centers, access is usually difficult and the land is cheaper. In our case study, land located on the edge of municipalities in the Aburrá Valley is a high-slope area, making it more expensive for landowners or the city government to control and apply an eviction mechanism. Consistently with this pattern, statistically significant differences are concentrated at

[11] Our definition of distance implies that blocks located in Bello have positive distance and are located to the right of the threshold

[12] Interpretation of coefficients: throughout, the plotted coefficients represent local treatment effects at the cutoff (Bello minus Medellín); positive values (to the right of 0, on the Bello side) indicate a *higher* prevalence of informal settlements in Bello relative to Medellín, while negative values indicate a *lower* prevalence in Bello.

the city edge, approximately at points 02 to 10 in Figure 2.10, where the discontinuity is the most prominent and local conditions (steeper terrain, lower accessibility and effective lax enforcement) magnify the border contrast; beyond these edge points, differences along the rest of the west border are not statistically distinguishable from zero.

Figure 2.10: Estimated effect of regulation on Informal Housing for dots



Note: Represents the coefficients results for dot estimation of the GeoRDD. The dots shown on the left of the figure correspond to the ones located on the edge of both municipalities, located at the western area of the border. Going to the right figure represents dots along the entire west border

The effect is concentrated at the city's edge when analyzed locally on the shared border. By relaxing regulations, the size of the formal housing market may have increased. This affirmation is supported by the findings of the census buildings presented in Figure 2.2. Generate a reduction in cost and an increase in the demand for land in the formal housing market. This rise in formal housing supply reduces the informal market by absorbing land from it. Therefore, 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 pretreatment periods. Flexibilization reduces the size of the informal housing market, taking land from it through increased formal housing supply.

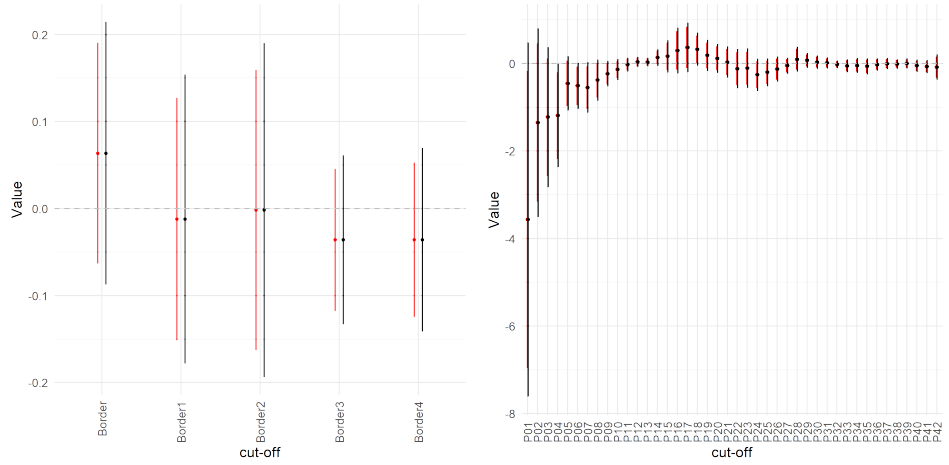
However, an increase in the land used by the formal market does not imply a reduction in the number of households in informal settlements. This flexibilization could generate a process of gentrification. The increase in the formal market and the necessary use of land and zones could cause a displacement effect. When the land is used for the formal housing market, the restrictions of the old settlers prevent them from entering and then force them to migrate to another informal settlement. According to the qualitative analysis performed by Quintero (2018), that is what happened with the flexibilization of POT in Bello. He points out that the great urban growth in the Bello municipality after the change in regulation in 2009 also implies an increase in the occupation of low-income

neighborhoods, mainly informal settlements.

An aggregate reduction in informal settlements does not imply an improvement in the status of households. Consistent differences in migration rates could support this assertion as evidence that with the increase in housing supply, there was a big movement of arriving settlers. This hypothesis is in line 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 regulations do not face access problems.

To determine the behavior of the output in the pretreatment period, the GeoRDD exercise is replicated for the year 2005. Unlike in 2018, most of the points around the border did not have the observations required for the regressions. This is because the census questions from which the informality indicators of housing are constructed are among those that were not applied to the entire population but were taken from a sample. Despite this, the exercise was carried out for those points that comply with the conditions. It can be seen that, in the periods prior to treatment, the areas analyzed did not show significant differences in the informal housing indicator. Figures 2.11, panels 2.11a and 2.11b, show that this result is consistent along the border.

Figure 2.11: Estimated effect of regulation on Informal Housing in 2005



(a) Segments (b) Dots

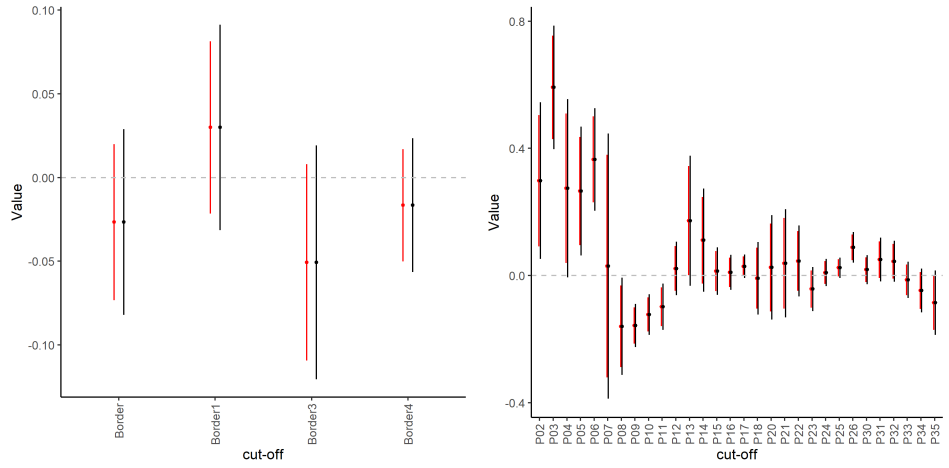
Note: On the left the results for the 2005 census at the segment level. On the right are the ones for all the west dots along the border.

This implies that, in the pretreatment periods, the levels of informality were similar at the edges for both municipalities. However, later there was an increase in the area that belonged to Medellín or a decrease in Bello. We argue that this movement is related to implementing less restrictive regulations. As was shown on the IC's map, at the border, the levels for Bello are consistently higher than those from Medellin, but the area with the higher restriction is on the edge of Medellín. These results seem to be consistent with the hypothesis of displacement generated by a growing formal housing market. Relaxation of construction regulations generated an impulse to create new housing projects in the border areas, making the land previously used by the informal market more profitable. This forced people either to enter the emerging formal market or to move to other city areas under informal conditions. The agent's decision on one option or the other will depend on whether the access conditions to this new formal housing market fit the restrictions of the families.

There are consistent differences in migration rates along the border. It implies that, compared to Medellín, Bello has more immigrants. As reported in the literature, a possible consequence of the flexibilization of regulations could be the increase in migration flows Lall et al. (2007). The growing formal market produced by flexible regulations could attract migrants. However, if the increase in migration is greater than the supply of new formal housing, the result could be an increase in the informal market.

Figure 2.12 shows the results for each segment and point controlling for migration rates. When we isolated the effect of migration, we found an increase in informal settlements on the edge of both cities. These results support the hypothesis that flexible regulations attract high-income settlers, displacing certain population groups and forcing them to occupy the edge of the cities, where the application of regulation is more diffuse, and institutional presence is not always clear. In addition, there is evidence of possible spillover effects.

Figure 2.12: Estimated effect of regulation on Informal Housing controlling for migration rates



(a) Segments (b) Dots

Although the Medellín-Bello border has been used as a study case, other borders 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 exercise demonstrates the robustness of the methodology used and the results obtained to verify some level of external validity[13]. The results show that the effect is concentrated mainly at the edge of the city. However, in the middle of the edge, there do not appear to be significant differences between adjacent municipalities with different land use regulations. It implies that there may be spillovers and general equilibrium effects in Metropolitan Areas that policymakers should consider.

2.7 Conclusions and policy recommendations

Flexible regulations seem to reduce the proliferation of informal settlements. However, the evidence indicates that these effects are largely *local* and spatially concentrated at the urban edge along the Medellín–Bello border, with no statistically significant differences observed in the central sections of

[13]Results available upon request

the border by 2018. This spatial pattern suggests that the main mechanism operates through changes in urban dynamics rather than through a uniform reduction of informality. Regulatory relaxation expands the formal construction market by allowing higher intensity and building heights, increases the profitability of redevelopment, and absorbs land previously occupied by informal settlements. As a result, informality is reshaped and displaced toward peripheral locations rather than fully eliminated.

Importantly, this mechanism unfolds within an interconnected metropolitan system. Medellín and Bello form part of a shared urban economy, characterized by integrated labor markets, commuting flows, and agglomeration forces. In this context, regulatory decisions taken in one municipality affect land prices, housing supply, and residential location choices in neighboring jurisdictions. Flexible regulation in Bello can therefore generate spillover effects that go beyond municipal boundaries, shifting both formal and informal development pressures toward adjacent areas. These dynamics imply that the effects of POT regulations cannot be fully understood within a single jurisdiction, as local planning decisions interact with metropolitan-scale forces and general equilibrium adjustments.

From the perspective of regulatory objectives, the exclusionary function of flexibilization appears to dominate. While aggregate informality declines on the treated side of the border, this does not necessarily translate into improved housing outcomes for low-income households. Instead, the expansion of the formal market may displace vulnerable groups without integrating them into the newly created housing supply. Placebo tests using 2005 data show no pretreatment differences at the urban edge, supporting the causal interpretation of the results, and the estimates remain robust when controlling for migration. Nevertheless, the observed pattern is consistent with a process of *reallocation*: households already participating in the formal market relocate toward newly developed areas, while some low-income residents are pushed toward other peripheral zones or into informal housing markets.

These findings suggest that regulatory flexibilization can be an effective tool to contain informality locally, but only under specific policy conditions. On its own, flexibilization risks shifting informality across space rather than reducing vulnerability. A more effective policy approach requires coupling flexibilization with complementary instruments that promote *absorption* rather than reallocation. These include: (i) inclusionary tools that expand access to the formal market, such as binding VIS/VIP quotas within redevelopment areas or targeted rental subsidies near employment centers; (ii) safeguards for incumbent low-income residents, including in situ upgrading strategies and clear antieviction protocols at the urban edge; and (iii) metropolitan coordination mechanisms that internalize spillovers and manage general equilibrium effects across municipal borders. Finally, the welfare incidence of these policies remains an open question. Future research should quantify household-level gains and losses to better inform the design of regulatory reforms in dual housing markets.

Flexible regulations seem to reduce the proliferation of informal settlements. However, evidence indicates that these differences are *local* and focus on the edge of the city along the Medellín-Bello border; there are no significant differences in the middle sections of the border for 2018. The mechanism appears consistent with a displacement process: regulatory relaxation expands the formal construction market (greater intensity and height), absorbs land previously occupied informally, and reshapes the spatial distribution of informality toward the urban edge.

In terms of the purposes of regulation, the exclusionary purpose seems to be predominant. The aggregate reduction in informal settlements on the treated side does not necessarily translate into improvements for households. Instead, the increase in the formal market displaces certain population groups without necessarily upgrading their housing status. Placebo tests using 2005 data show no pretreatment differences at the edge, supporting causal interpretation, and the results are robust to controlling for migration.

Regulatory flexibilization can be an instrument to contain informality locally, but on its own it

risks spatially shifting informality rather than reducing vulnerability. A more effective approach pairs flexibilization with (i) inclusion tools that expand access to the formal market (targeted VIS/VIP quotas within redevelopment areas, rental subsidies near employment centers. etc.), (ii) safeguards for incumbent low-income residents (in situ upgrading and antieviction protocols at the edge), and (iii) metropolitan coordination to manage spillovers and general equilibrium effects across borders. Finally, the welfare incidence of these policies remains an open question; future work should quantify household-level gains and losses to inform design in dual housing markets.

Chapter 3

Unlocking housing supply: The effects of building regulations in a developing economy

Lina Marcela García Tavera*

Abstract. *This paper studies how changes in local building rules affect new housing supply in the context of a developing country. I build a new municipal database for Colombia with a flexible regulation index adapted to the context. Taking advantage of changes in regulation between municipalities over time, I estimate the effect of make the building regulations more flexible on the housing supply using a staggered difference-in-differences. I find that more flexible building regulations increase the potential housing supply, but the effect is concentrated in small and satellite cities. The effects appear with a delay of about 5 to 8 years. A separate analysis of the components of the regulation index shows that the construction index (IC) is the main driver. Evidence on housing deficits (2005 vs. 2018) and migration suggests a reallocation channel: satellites receive part of the demand from cores, where land is scarce and costly*.

3.1 Introduction

There is a large literature showing that urban regulations affect housing markets (Quigley and Raphael, 2005; Gyourko and Summers, 2006; Gyourko and Molloy, 2015; Gyourko et al., 2021). Most of this evidence comes from developed countries, especially the United States (Quigley and Rosenthal, 2005; Freemark, 2020; Büchler and Lutz, 2024; Landis and Reina, 2021; Chiumenti et al., 2022; Greenaway-

*Universidad del Rosario. Email: linamarce.garcia@urosario.edu.co

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McGrevy and Phillips, 2023). In contrast, much less is known for developing countries, where institutional change, such as relaxing building rules, may have different consequences. Is relevant to study the effect of regulations on housing markets in developing settings because they often operate under weaker institutions, stronger frictions, and the presence of informal housing (United Nations Human Settlements Programme (UN-Habitat), 2016, 2020; Brueckner and Selod, 2009b)

Empirical work generally finds that tighter rules raise prices and can limit supply, with heterogeneous effects across places and regulations (Bertaud and Malpezzi, 2001; Gyourko and Summers, 2006; Whitehead et al., 2009; Freemark, 2020; Büchler and Lutz, 2024; Landis and Reina, 2021). Outside the U.S. evidence is thinner and mixed. For example, Anagol et al. (2021) show positive supply responses to more flexible rules in Brazil, while other cross-country studies point to uneven effects across metropolitan areas (Landis and Reina, 2021). Evidence from developing countries with different institutional capacity, land-market conditions, and metropolitan structures is needed to clarify the effect.

Colombia is a developing country with a legal framework that requires each municipality to update its urban plan every 12 years. The *Planes de Ordenamiento Territorial* (POT) establishes the rules for land use and building, and each municipality has the autonomy to define the content of these rules within national guidelines. In practice, both the timing and content of regulatory updates vary between municipalities, creating useful variation for empirical analysis. Colombia's urban system is also polycentric, with large cores and several satellite cities that are strongly integrated (OECD, 2022).

I gather a new municipal data set from the POT documents and adapt the index proposed by goytia2015cipuv (*CIPUV* to build a regulation flexibility index for Colombia. The index keeps only items that vary between municipalities and can be consistently measured with available information: maximum height (HB), density (DC), construction index (IC), and occupation index (IO). I also include a proxy for local enforcement (LIE). Elements that do not vary in Colombia or lack reliable data are not part of the main index.

Using this new data set, I estimate the effect of more flexible building regulations on housing supply. To do so, I use changes in rules across municipalities and over time to implement a staggered difference-in-differences event study following Sun and Abraham (2021). Outcomes come from *Censo de Edificaciones* (CEED) and are defined as the population-weighted logarithm of newly authorized units and the population-weighted logarithm of new constructed area.

I find that more flexible rules increase the potential housing supply, but the effect is concentrated in small and satellite cities. Large core cities show limited changes. The effects build slowly and become visible about five to eight years after the reform. A separate analysis of the components of the regulation index points to the construction index (IC) as the main driver. To interpret these patterns, I compare housing deficits (2005 vs. 2018) and study recent migration: major cities display large deficit reductions without a strong local construction response, while satellites expand supply and receive part of the reallocated demand from cores. These findings have clear policy implications: easing intensity rules can be effective where land is cheaper and absorption capacity is higher (satellites), whereas cores likely require complementary policies on land availability and permitting.

Contribution to the existing literature goes in two directions: creating a new set of data that converts urban regulations into a unique index and empirically checks whether regulations increase the size of housing supply in the context of developing countries. The paper proceeds as follows: Section 3.2 describes the literature framework of this work; section 3.3 describes the data and the construction of the regulation index; section 3.4 presents the empirical strategy; section 3.5 reports the main results and heterogeneity; section 3.6 studies the mechanisms using housing deficits and migration; section 3.7 discusses the implications of the policy; section 3.8 concludes.

3.2 Background

3.2.1 Literature review

Several studies show a strong relationship between urban regulations and the housing market. There is a broad consensus that zoning rules, density limits, subdivision controls, and building codes create incentives that shape the performance of the housing market. By controlling how and where housing can be developed, these rules can have significant impacts on housing supply, prices, and urban growth patterns.

However, quantifying the effects of regulation empirically has proven challenging, particularly in developing countries. As Quigley and Rosenthal (2005) notes, most studies on regulation have not performed complete cost-benefit analysis and often fail to account for the benefits of mitigating negative externalities, largely because such benefits are difficult to measure. This challenge is even greater in developing economies, where data limitations and the presence of informal housing markets complicate the assessment of regulatory impacts. Indeed, although some specific rules clearly address externalities, the general benefits of broad regulatory frameworks are notoriously difficult to quantify (Gyourko and Molloy, 2015). This paper attempts to address these issues by using a new and unique dataset on urban regulations in a developing country to better measure their effects.

Another important issue is that the regulations are not exogenous. Larger cities tend to adopt stricter rules to avoid the negative effects of congestion, preserve amenities, and control migration rates (Duranton and Puga, 2019). While stricter regulations can drive up rents and housing prices, those higher prices might in turn motivate homeowners to support even more regulation in order to protect their property values and curb congestion externalities. Therefore, the net effect of regulation on the housing market remains an open question. The fact that extensive regulations persist, despite the distortions and price increases they can cause, suggests that any reduction in welfare is not immediately apparent. This may be because many regulations are implemented to mitigate negative externalities and improve access to amenities.

Much of the empirical literature finds that stricter land-use regulations are associated with higher housing prices and less elastic housing supply. Tighter constraints on development tend to drive up costs and reduce the responsiveness of new construction to demand shocks (Glaeser et al., 2005; Quigley and Raphael, 2005; Gyourko and Summers, 2006). These outcomes imply a trade-off between the potential welfare benefits of regulation and the increased housing costs. For example, Whitehead et al. (2009) suggests that when economic conditions are strong and supply is inelastic, the benefits of regulation (such as improved amenities or reduced externalities) can be significant; however, the accompanying rise in prices means that redistributive policies may be needed to ensure that net welfare gains are positive for all groups. Empirical evidence in different contexts generally supports the idea that stricter regulations make housing supply less elastic and drive prices up, with these effects often especially pronounced in the periphery of a city (Duranton and Puga, 2019). However, the degree to which regulations constrain supply can vary. For example, Avila (2015) finds that overly rigid standards in a developing context restricted formal housing supply and forced some developers to enter the informal market to avoid high compliance costs. In contrast, Landis and Reina (2021) conclude that more restrictive regimes do not always constrain housing supply, with uneven effects across different regions. Similarly, Anagol et al. (2021) report that making regulations more flexible in Brazil led to a significant increase in the formal housing stock. These mixed findings indicate that the relationship between regulation, supply elasticity, and housing prices can differ substantially depending on local market conditions and how policies are implemented.

Bertaud and Malpezzi (2001) emphasize that land-use regulation per se is neither inherently good

or bad, what matters are the costs and benefits of specific rules under particular market conditions. In line with this, the impact of regulatory changes on housing supply can differ depending on the type of regulation and the scale of reform. In some cases, relaxing certain rules can significantly boost housing construction. For example, in the context of the city of Boston, loosing density restrictions has been identified as the most effective zoning reform to increase housing development (Chiumenti et al., 2022). By contrast, evidence from Chicago shows that upzoning policies, increasing allowed densities and reducing parking requirements, did not lead to a significant rise in new housing units over a five-year period (Freemark, 2020). Moreover, Greenaway-McGrevy and Phillips (2023) points out that only a large-scale upzoning implemented in a wide area produces noticeable increases in housing construction. Consistently, a study in Switzerland by Büchler and Lutz (2024) finds that substantial upzoning actions significantly increased the long-term supply of living space and housing units in affected zones.

Although urban land use regulation has been extensively discussed, much remains to be clarified about its causes and especially its effects (Gyourko and Molloy, 2015). This is particularly true in developing countries, where formal and informal housing markets coexist. For example, Avila (2015) highlights that very strict regulations can push developers toward the informal sector. The present study specifically examines whether the easing of urban regulatory constraints can expand formal housing supply in a set of cities in Colombia, thus contributing new evidence to this field.

This paper provides new empirical evidence on the impacts of more flexible urban regulations in a developing-country context, helping to fill a notable literature gap. Using a novel data set of regulatory indicators in multiple Colombian cities, it evaluates whether the relaxation of land-use rules can promote formal housing development. This contribution is important because it extends the predominantly developed-country debate on land use regulation to a developing economy setting with dual housing markets. The findings will offer insight into the welfare implications of regulatory reform outside the contexts usually studied.

3.3 Data

I analyze 19 cities in Colombia's *Sistema de Ciudades*, as defined by the National Planning Department (DNP, by its Spanish acronym). The sample includes municipalities with complete information in the *Censo de Edificaciones* (CEED). CEED covers the universe of buildings: renovations, extensions, and new projects for sale, and I use it to track changes in housing supply over time (2002-2022). To capture developers' responses to regulation, I restrict the sample to projects for sale, which proxy new units added to the primary housing market, the estimates target the potential housing supply at the beginning of construction.[2] I focused on two outcomes: the logarithm of new housing units and the logarithm of the new constructed area standarized by cities population, measured at the project level and aggregated to the municipality–year level.

The variation in treatment is coded from a city-by-city reading of each municipality's urban land-use regulatory instruments *Planes de Ordenamiento Territorial* (POT). To my knowledge, this hand-collected regulatory data set does not exist for Colombia and constitutes one of the core contributions of the article.

[2]Projects may or may not be completed; I adopt this approximation because it captures the adjustment in developers' behavior in response to regulation changes. Estimates for effective supply are reported in Appendix B.5.

3.3.1 Regulation index: scope and construction

A widely used reference for land use regulation is the Gyourko and Summers (2006) *Wharton* index, later updated in Gyourko et al. (2021). Goytia et al. (2015b) adapt this approach to Argentina with the *CIPUV* index. In this paper, I adapt CIPUV to the Colombian institutional context.

Colombia's legal architecture and data availability imply that several CIPUV elements either (i) do not exhibit meaningful cross-municipal variability in Colombia (because they are regulated nationally with uniform application) or (ii) lack sufficiently reliable, city-comparable data. The elements of the CIPUV index that were included in this adaptation are described.

Since 1997, Colombian municipalities have been required to regulate land use through POT-type instruments. POTs [3] define, among others: land classification and delimitation; expansion boundaries; high-risk and conservation areas; partial plans; areas designated for social housing; and construction norms such as construction and occupation indices, allowed heights and density rules. POTs cover the entire municipal territory and are the primary legal source of the regulatory indicators used in the following.

3.3.1.1 Regulation index used in the analysis

I construct a regulation index based on three components that (a) are defined in POTs, (b) vary between municipalities, and (c) are observable with sufficient quality.

- **Land Plan Indicator (LPI)**: whether the municipality has an updated and valid land use plan.
- **Building Restrictions Indicator (BRI)**: intensity of rules that directly constrain or permit new residential construction.
- **Local Institutional Enforcement (LIE)**: a proxy for the municipal capacity to enforce regulations.

The resulting index is used both as a continuous measure of stringency and, for the baseline event study, as a dichotomous indicator $D_m \in \{0, 1\}$, where $D_m = 1$ denotes relatively flexible regulation (details below).

3.3.1.1.1 Land Plan Indicator (LPI)

The LPI captures whether a municipality has an updated land use plan. Law 388 of 1997 sets a 12-year validity for POTs. I code:

$$LPI_{mt} = \begin{cases} 1 & \text{POT is valid and updated} \\ 0 & \text{POT is not valid or not updated.} \end{cases}$$

[3] Depending on population size, municipalities can use *PBOT* or *EOT*, which are functional equivalents with fewer legal requirements

3.3.1.1.2 Building Restrictions Indicator (BRI)

To capture *binding* construction rules at the stage where developers decide new housing supply, I use four POT-defined instruments, aligned with Decree 1077/2015 definitions: the *construction index* (IC), *occupation index* (IO), *maximum building height* (HB), and *residential density* (DC).[4]

Higher values of IC, IO, HB, and DC imply fewer restrictions on building. I standardize each component across municipalities and define the following:

$$BRI = STD(IC) + STD(IO) + STD(HB) + STD(DC).$$

When a component is missing in a POT, I follow a conservative rule: If the POT does not impose a specific limit, I treat it as "without additional restriction" for aggregation purposes. In cases where the POT establishes that the development of a specific area is subject to a *plan parcial*[5] I impute the highest value for the corresponding instrument explicitly allowed by the POT for that treatment. This procedure reflects the fact that, under partial plan development, specific building parameters are typically defined ex post within the planning instrument rather than fixed ex ante at the zoning level. The imputation strategy adopted here is justified because partial plans are explicitly intended to accommodate higher development intensity under planning control, making the use of the maximum POT-allowed values a conservative approximation of their regulatory potential.

3.3.1.1.3 Local Institutional Enforcement (LIE)

Enforcement capacity conditions whether legal rules are de facto binding. I proxy this with municipal-level institutional indicators from DNP's *Observatorio del Sistema de Ciudades* (governance /participation /institutions), complemented with a simple interaction-based measure of administrative responsiveness during information requests (whether the municipality replied, completeness, timeliness, and baseline public availability). The composite is normalized to be comparable across cities and is interpreted as a long-term institutional capacity to enforce land use rules.

3.3.1.2 Index summary and use in the empirical strategy

Table 3.1 summarizes the resulting data set for the fifteen cities in which I was able to obtain information about their regulatory instrument[6]. These components give an idea of the nature of urban regulation and constitute a good tool for impact assessment and policy recommendations.

[4] IC: maximum built floor-area multiple per parcel; IO: share of lot area that may be occupied on ground floor; HB: maximum number of floors; DC: dwellings per hectare. In practice, POTs assign these rules by "treatments" (urbanization categories) and zones. Ideally, area-weighted aggregation would be preferable, but the lack of city-level zoning maps leads me to use means in relevant development treatments.

[5] *Planes parciales* are urban management instruments used in Colombia to guide the integrated development or redevelopment of specific areas of the city. They are designed to enable relatively intensive but organized urban development by coordinating land subdivision, infrastructure provision, public space, and building parameters within a defined area

[6] I also calculated the index for the municipalities of Armenia and Pasto. However, there was not enough information in the CEED database to do the estimation, so I excluded them from this work

Table 3.1: Regulation index (summary by municipality).

Municipality	POT year	LIE	LPI	BRI components				BRI	Treated
				HB	DC	IC	IO		
Barbosa	2015	1.67	1	0	0	0	0	0	No
Barranquilla	2014	2.59	0	1	1	1	0	3	Yes
Bello	2009	1.54	1	1	0	0	1	2	Yes
Bogota	2004	3.58	1	0	0	0	0	0	No
Bucaramanga	2014	2.54	0	1	1	0	0	2	Yes
Caldas	2010	4.62	1	1	1	0	0	2	Yes
Cali	2014	3.54	1	0	0	0	1	1	No
Copacabana	2000	1.66	1	0	0	0	1	1	No
Floridablanca	2018	0.67	0	1	0	1	0	2	Yes
Girardota	2015	2.62	0	0	0	0	0	0	No
Giron	2010	2.55	1	0	0	0	1	1	No
La Estrella	2008	3.56	1	1	0	1	0	2	Yes
Medellin	2014	2.60	0	0	0	0	1	1	No
Pereira	2016	4.61	0	1	0	1	1	3	Yes
Sabaneta	2009	4.69	0	0	0	0	0	0	No

Notes: BRI is the sum of the four components (HB, DC, IC, IO). *Treated* = Yes if BRI ≥ 2, otherwise No. *POT year* indicates the year of the POT analyze

However, the objective of this article is to figure out the effect of building regulations on housing supply in the context of a developing country, so I focused on the BRI index. For the empirical baseline application, the continuous index is transformed into a binary indicator and used as a treatment in the staggered design.

$$D_m = \begin{cases} 1 & \text{Flexible regulation (above-sample average)} \\ 0 & \text{Restrictive regulation (at-or-below average).} \end{cases}$$

This index is a pragmatic proxy focused on rules that directly shape the feasibility and intensity of residential construction and a tractable measure of local enforcement. While further refinements are possible (area-weighting components with georeferenced zoning), the present version is specifically designed to balance external validity across cities and comparability over time.

3.4 Estimation

3.4.1 Identification strategy

The objective of this chapter is to test the hypothesis that more flexible building regulations increase the supply of formal housing. To do so, I implement a staggered difference-in-differences strategy that exploits institutional variation in the timing and content of land-use regulation across Colombian municipalities. Under Colombian law, local land-use plans (*Planes de Ordenamiento Territorial - POT*) are required to be reviewed and updated every twelve years. In principle, this rule establishes a common regulatory cycle across jurisdictions. In practice, however, there are no effective enforcement mechanisms that compel municipalities to revise their POT within the legally mandated timeframe.

Updating a POT is a complex and resource-intensive process. It requires extensive technical studies, including environmental assessments, risk analysis, and infrastructure diagnostics, as well as formal coordination with environmental authorities, consultation with local communities, and final approval by the municipal council (Ministerio de Vivienda, Ciudad y Territorio, 2015). These requirements imply significant financial, technical, and political costs. As a result, many municipalities delay the revision of their land-use plans due to limited fiscal capacity, lack of technical expertise, weak political coalitions to promote a new territorial model, or the high political cost associated with adjusting existing land-use rules (Maldonado Copello, 2010; Montoya Garay, 2016). In the absence of coercive mechanisms, these constraints generate substantial heterogeneity in both the timing and the substance of regulatory updates.

This institutional setting produces three types of municipalities: those that update their POT on time, those that revise it with significant delays, and those that do not update it at all. Importantly, this variation is not random noise but reflects structural differences in local capacity and political incentives. At the same time, POT revisions differ in their regulatory content. Some municipalities adopt relatively flexible regulations, particularly by relaxing constraints related to building intensity, height, or land-use compatibility (Ministerio de Vivienda, Ciudad y Territorio, 2015). Others pursue more restrictive approaches, emphasizing control over urban expansion, environmental protection, or risk management.

The identification strategy leverages this dual source of variation. First, the staggered timing of POT revisions generates quasi-experimental variation in the introduction of new regulatory regimes across municipalities. Second, differences in the degree of regulatory flexibility introduce an intensity dimension that allows comparing municipalities that adopt more permissive building rules with those that maintain stricter standards. Together, these features enable the estimation of dynamic treatment effects under a staggered difference-in-differences framework, isolating the impact of regulatory flexibilization on housing supply while accounting for heterogeneous adoption patterns across space and time.

3.4.2 Methodology

When we have multiple periods, the usual two-way fixed-effects approximation does not recover an easy-to-interpret causal parameter when there is heterogeneity (Goodman-Bacon, 2021). According to Roth et al. (2023), this issue can be solved if there is a significant number of independent clusters for both treated and control groups, in this scenario, the ATT can be reliably estimated through a two-way fixed-effects (TWFE) regression model, while clustered standard errors ensure asymptotically valid inference. However, given that the treatment unit is at the municipal level, the cluster variation

is limited and there is a high possibility of heterogeneous effects [7].

Several recent works in the literature deal with this issue [8]. In particular, Sun and Abraham (2021) introduces an estimator designed to address the limitations of traditional regressions of two-way fixed-effects with relative time indicators. Their approach ensures consistency in estimating the average dynamic treatment effect at specific points in relative time, even under conditions of heterogeneity in the treatment response. To achieve this, their method uses untreated or late-treated units as a comparison group, providing a more flexible framework for evaluating treatment effects. This alternative estimator offers a significant improvement by mitigating the biases introduced by heterogeneity, ensuring more accurate and interpretable estimates of dynamic effects.

3.5 Results

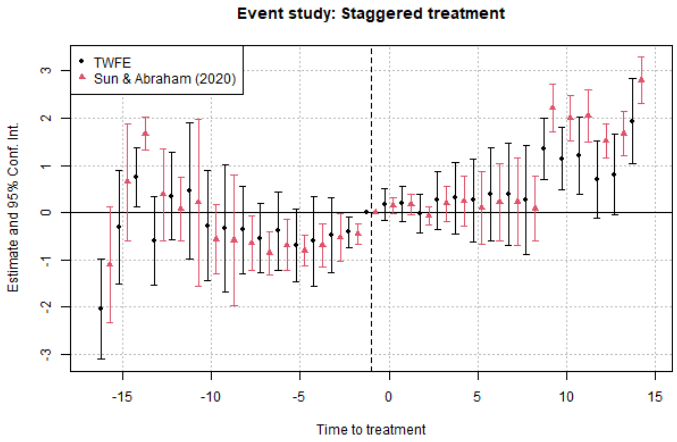
Using the method proposed by Sun and Abraham (2021), I estimate a study event for 19 municipalities in the sample: seven treated (*Barranquilla, Bello, Bucaramanga, Caldas, Floridablanca, La Estrella, Pereira*) and eleven used as control. I compare with those from the two-way fixed-effect estimation given the possibility of heterogeneity.

The results of the new units and the new areas constructed can be seen in Figure 3.1. The event study estimation shows an increase in housing supply in the long term. The effect seems to appear around the eighth period after the change in regulation was implemented. This result makes sense, considering that markets with many general equilibrium effects and any other related ones take more time to adjust to changes in the regulatory environment. In fact, these long-term effects are consistent with the findings in the literature and usually take more than 5 years for the effects to be realized (Büchler and Lutz, 2024; Freemark, 2020). This results implies an increase of around 2-3 percentage points in new units and new areas to be constructed for municipalities that make their building regulations more flexible compared to those that have more restrictive ones.

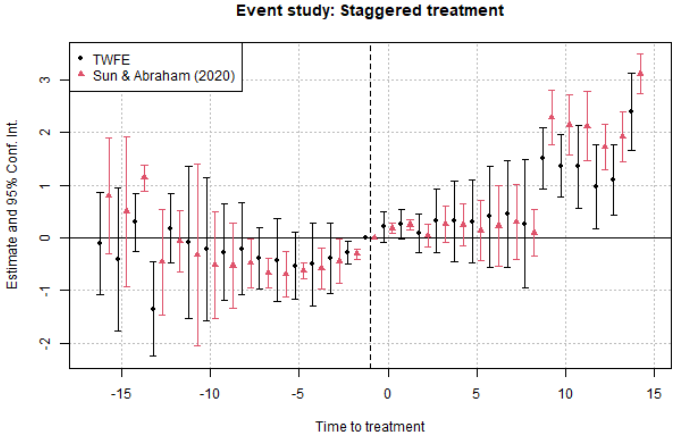
[7] Reverse causality is also a significant issue, making it challenging to analyze the problem (Gyourko and Molloy, 2015), so I try to assess this using the estimation approach proposed by Sun and Abraham (2021) that is robust to facing endogeneity problems when we have multiple treatment periods.

[8] Alternative multi-period DiD methodologies include Strezhnev (2018); Imai and Kim (2021); De Chaisemartin and d'Haultfoeuille (2020); Callaway et al. (2021); Sun and Abraham (2021); Marcus and Sant'Anna (2021); Callaway and Sant'Anna (2021).

Figure 3.1: Staggered Differences in Differences results



(a) Logarithm of new units



(b) Logarithm of new area

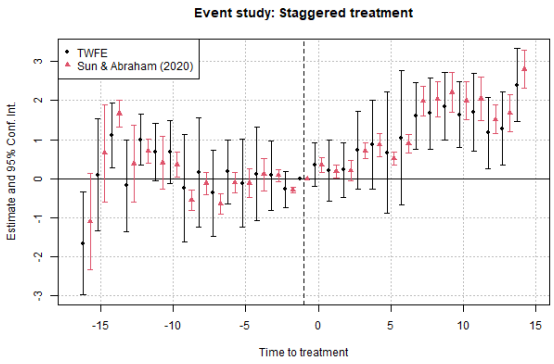
Note: Event study estimation shows the difference across time between all the treated municipalities compared with the non treated ones

However, the discontinuity around the eighth period could be caused by an imbalance in the municipalities. Some of the treated municipalities implement their policy in an earlier period, while others do so at a later stage. It implies that the *"late treated"* eventually disappear from the last periods of the event study. So, it is necessary to check whether the effect could be driven by the disproportion in the observations.

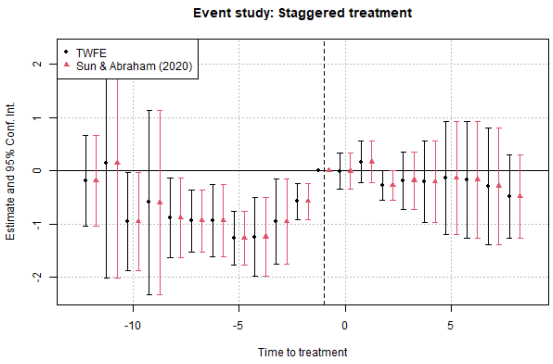
In addition, the behavior of the standard errors and the dynamics in the study event results are major signs of heterogeneity in the effects. The first hypothesis is that the rise in housing supply caused by more flexible building regulations could be effective in small cities. To verify this, I estimate the results for large and small cities. I use population from the 2018 census as selection criteria and label as big cities the ones with more than 500.000 inhabitants. Barranquilla and Bucaramanga are considered large cities, while the rest are small. Figure B.5 shows the event study for both outcomes

differentiated by city size.

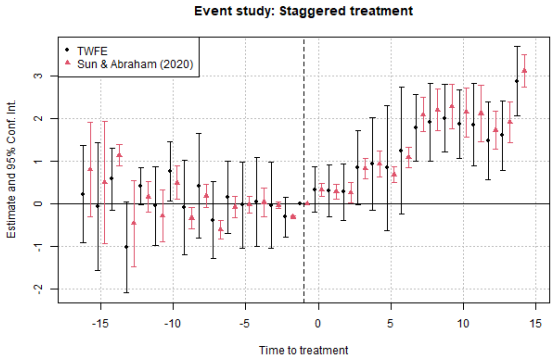
Figure 3.2: Staggered Differences in Differences results for big and small cities



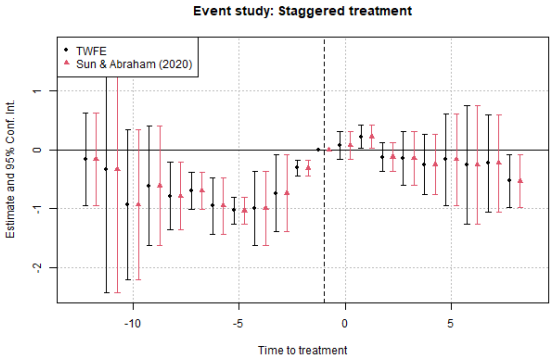
(a) Logarithm of new units in small cities



(b) Logarithm of new units in big cities



(c) Logarithm of new area in small cities



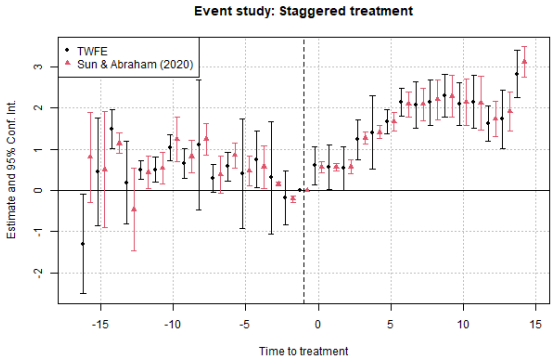
(d) Logarithm of new area in big cities

Note: On the left event study estimation for small treated cities (*Pereira, La Estrella, Floridablanca, Caldas, Bello*) compared with the non treated ones. On the right results for big treated cities (*Bucaramanga, Barranquilla*)

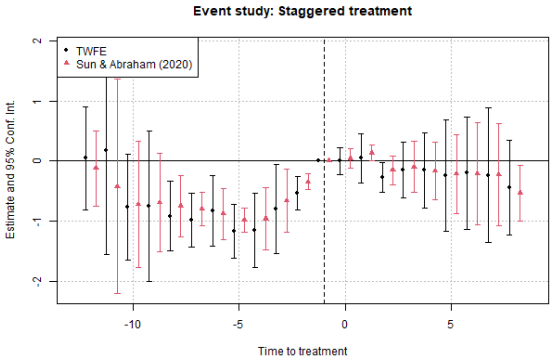
As expected, small cities experience a significant increase in the housing supply of new units and newly built areas. In contrast, large cities do not show an effect on their supply after the relaxation of building requirements. These results are very important in the sense that the effect of flexibilization of building regulations in the context of developing countries with a highly urban dynamic is concentrated in small cities and not in the big ones. An important change is that the effect in small cities appears early, around the third period after treatment, and implies an increasing trend from around 1-3 percentage points

Another possible explanation could be related not to the size but to the nature of the city. Bucaramanga, Barranquilla, and Pereira are capital cities and are also the main cities of its own Metropolitan Area. Bello, Caldas, and La Estrella are satellites of the second largest urban agglomeration in the country. Floridablanca is the satellite city of Bucaramanga. To verify this, I ran the estimate using the nature of the city. The results can be seen in Figure 3.3

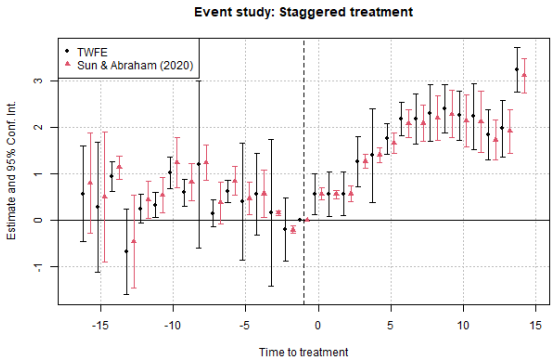
Figure 3.3: Staggered Differences in Differences results for core and satellite cities



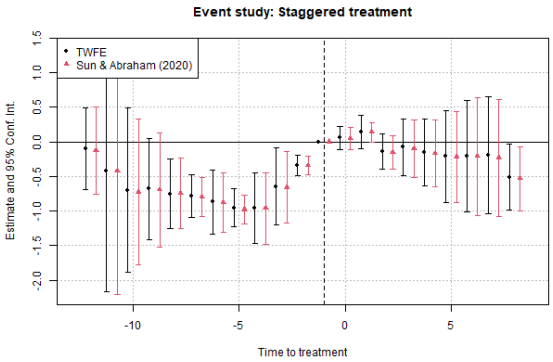
(a) Logarithm of new units in satellite cities



(b) Logarithm of new units in core cities



(c) Logarithm of new area in satellite cities



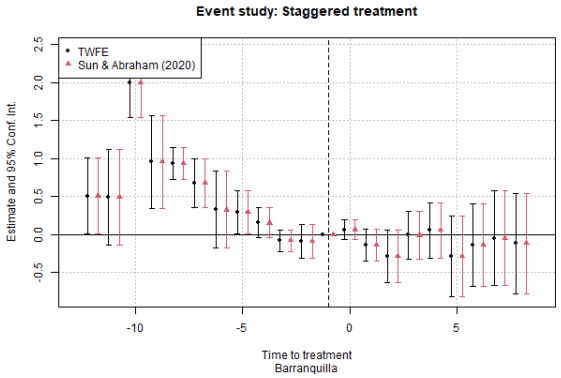
(d) Logarithm of new area in core cities

Note: On the left estimation for satellite treated cities (*La Estrella, Floridablanca, Caldas, Bello*), on the left core cities (*Pereira, Bucaramanga, Barranquilla*)

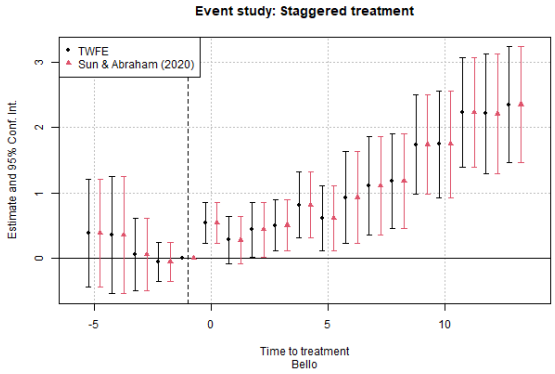
The results are consistent with the hypothesis. In fact, the effect appears early, immediately after treatment, and rapidly increases from 1 to 2 percentage points[9]. As with the aggregate, some jumps at longer horizons can be attributed to loss of observations as the risk set shrinks, reinforcing the need to inspect city-level trajectories. So, finally, to better understand the direction and nature of the effect and to address the issue that could be caused by the imbalance in the sample caused by the *early* and *late* treated cities, I calculated the event study for each municipality. The results can be seen in Figure B.6 for the new area constructed and Figure B.7 for the new units constructed.

[9]A problem is that there is not enough variability in the treated cities to differentiate the effect The only city that is small and not satellite is Pereira, which, as will be discussed, has an unusual behavior and tendency

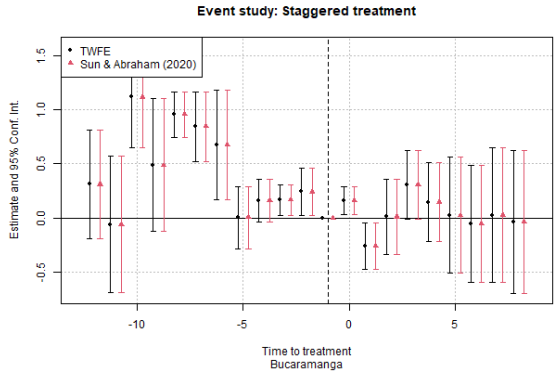
Figure 3.4: Staggered Differences in Differences for new area (logarithm) at municipality level



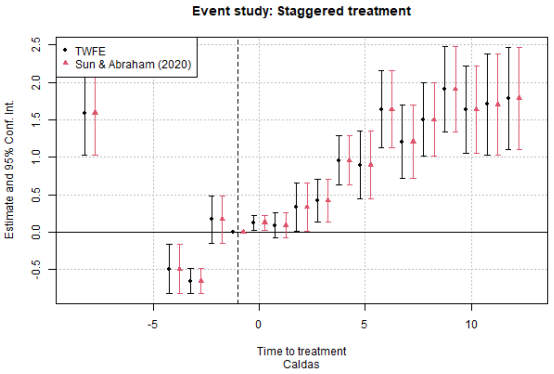
(a) Barranquilla



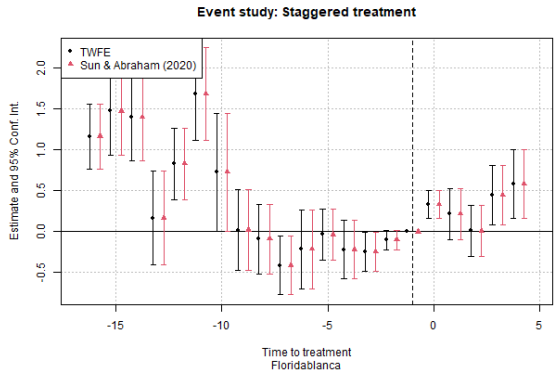
(b) Bello



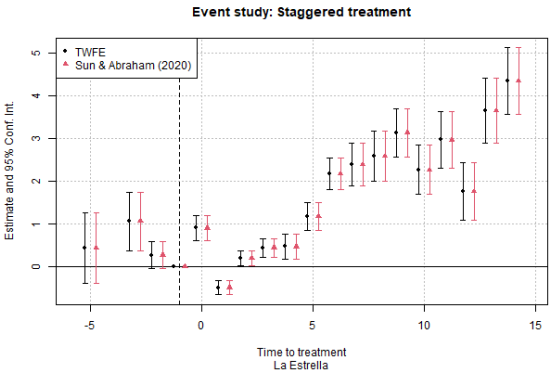
(c) Bucaramanga



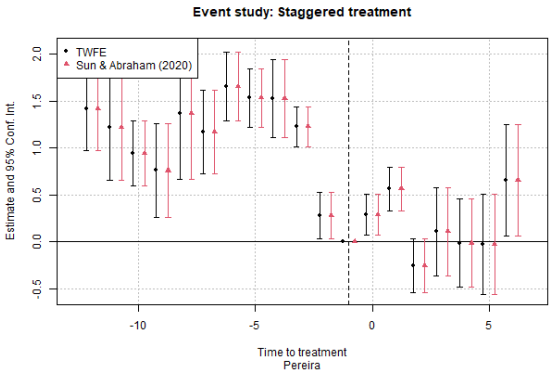
(d) Caldas



(e) Floridablanca

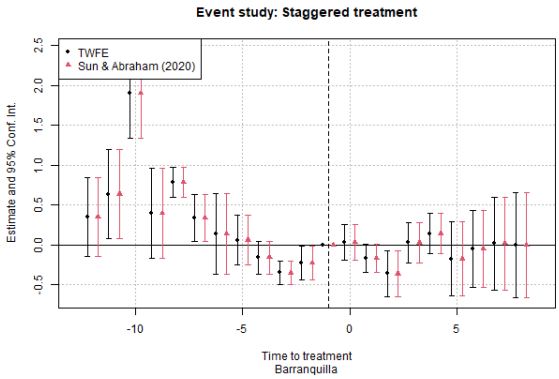


(f) La Estrella

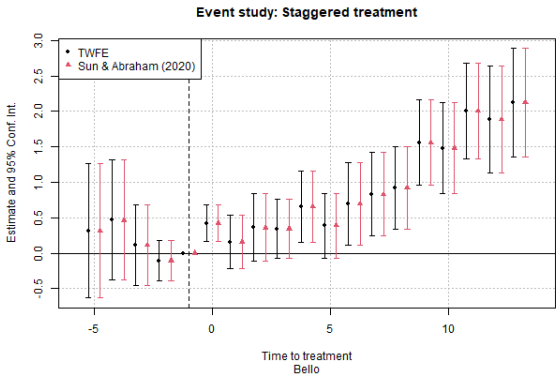


(g) Pereira

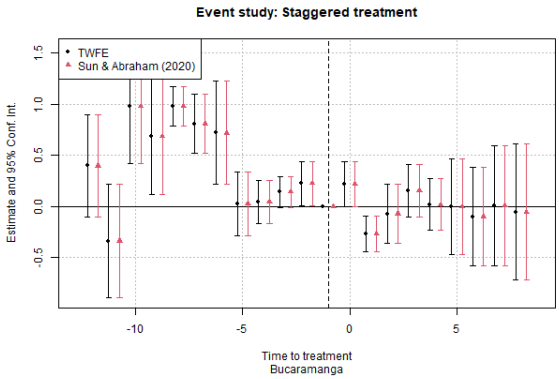
Figure 3.5: Staggered Differences in Differences Results for new units (logarithm) at municipality level



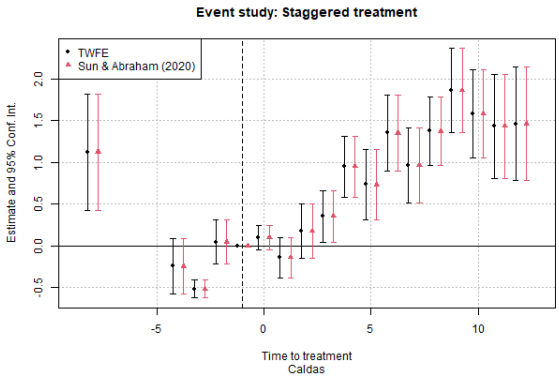
(a) Barranquilla



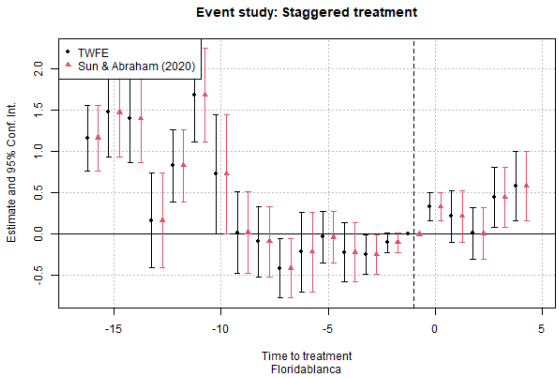
(b) Bello



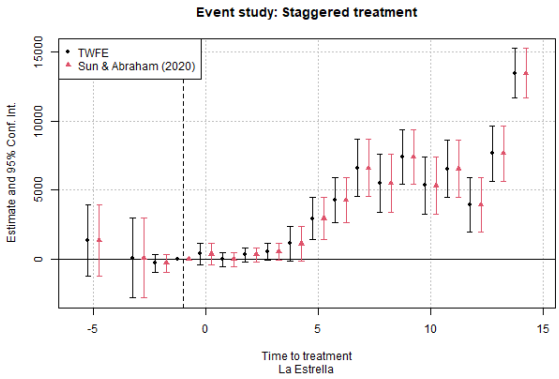
(c) Bucaramanga



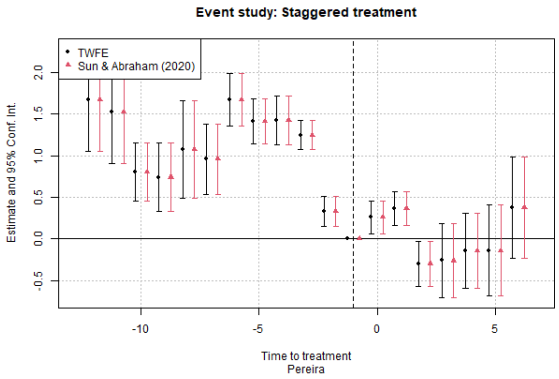
(d) Caldas



(e) Floridablanca



(f) La Estrella



(g) Pereira

The results are consistent in both outcomes: the cities of Bello, Caldas, La Estrella and Floridablanca (*early-treated* cases with observations beyond t+5) experienced an increase in housing supply monotonically rising over time. Although Barranquilla and Bucaramanga appear to be largely unaffected; in contrast, Pereira exhibits a distinct post-reform decline relative to controls. The positive effect emerges around the fifth year after treatment (+5), consistent with the idea that regulatory changes take time to translate into market responses. These city-specific patterns are informative, but they rely on a stronger identification assumption, namely parallel trends at the municipality level.

To understand these results, one must describe the nature of these municipalities. Colombia is a highly urbanized country with a relatively polycentric urban system and several major cities (OECD, 2022). Both Barranquilla and Bucaramanga are among the most populous and densely populated cities in the country. Pereira, although it is a capital, is considered an intermediate city. Bello, Caldas, La Estrella and Floridablanca are satellite cities with relatively small populations but significant urban activity due to their proximity to a city core, with which they share urban interaction dynamics.

So, the municipality results confirm the hypothesis: the effect of more flexible regulations on the housing supply seems to be driven by the small and satellite cities. These patterns are consistent with higher elasticities and lower adjustment costs in smaller markets but also with the notion that satellites can absorb spillover demand from nearby cores once regulatory frictions ease.

3.5.1 Inference validation

Because treatment varies at the municipality level, my standard errors are clustered by municipality. This allows for correlation within clusters but not between them, which is important, since ignoring the correlation within the cluster can underestimate standard errors and distort inference in DiD / event study settings (Bertrand et al., 2004; Cameron and Miller, 2015). A second concern is the small number of clusters: with 19 municipalities and an unbalanced panel, this is effectively a few-cluster application (Cameron and Miller, 2015). To address these issues, I consider (i) bias-corrected cluster robust variance, (ii) cluster bootstrap with asymptotic refinement, and (iii) improved critical values based on a distribution t.

However, applying certain robust error correction techniques, such as heteroskedasticity robust cluster bootstrap methods, can be problematic when the number of treated groups is small. Methods such as pair-bootstrap or wild-cluster bootstrap depend on having sufficient treated units to generate the necessary variation in the data. In cases with very few treated units, these techniques can fail to produce the needed variability, leading to potential problems in the robustness of the results (Ferman and Pinto, 2019).

To assess this issue, I implement the method by Ferman and Pinto (2019). They propose an inference method applicable to differences-in-differences frameworks with a small number of treated groups and many control groups, accounting for heteroskedasticity. This works well also for the case of one treated unit versus several controls.

I divided the post-treatment into three-year segments to find the p-value of each period of time compared with the pre-treatment one. Table 3.2 shows the results for the new area to be constructed.

Table 3.2: Error correction using Ferman & Pinto Methodology for new area

Municipality	Period 3	p-value	Period 6	p-value	Period 9	p-value	Period 12	p-value
Estrella	-0,713	0,354	0,234	0,790	1,614	0,000	1,051	0,341
Pereira	0,432	0,348	0,447	0,348				
Floridablanca	-0,018	0,956						
Caldas	-0,016	0,935	0,799	0,000	0,783	0,003	0,652	0,180
Bucaramanga	0,270	0,635	-0,203	0,747				
Bello	1,239	0,000	1,909	0,000	2,078	0,000	1,989	0,000
Barranquilla	0,802	0,263	0,787	0,329				

Notes: *Period 3* shows the adjusted parameter for the first tree periods after the treatment, immediately on the right its p-value. *Period 6* shows the adjusted parameter for the 3-6 period after the treatment and its p-value is on the right. It works the same for the rest of periods. Blank spaces implies that there are no enough observartions to run the test for these period.

Results show that, for small and satellite cities, the significant effect on the constructed area usually appears in the second and third time segments. The results of the Ferman and Pinto (2019) correction are consistent with the standard results of the study event. Bello is the municipality that has the biggest effect in both scenarios, the significance begins in the first period, and the parameter estimate increases the subsequent ones until it stabilizes. La Estrella does not show a significant effect until the third period, which is the moment the effect has a bigger jump, after which it oscillates and is not persistent. Floridablanca do not have a significant p-value, and only reach the sufficient observations to get the first-segment estimation; it could be explained given that the effect is only clear after four periods in the event study. The effect for Caldas is on the second and third segments and disappears in the fourth, it has a similar trend to La Estrella, so these results could also be related with the variability in the last period of analysis. In general, the correction seems to be in line with the principal results of the event-study analyzes.

Table 3.3: Error correction using Ferman & Pinto Methodology for new units

Municipality	Period 3	p-value	Period 6	p-value	Period 9	p-value	Period 12	p-value
Estrella	-0,942	0,000	0,200	0,677	1,575	0,000	1,035	0,399
Pereira	0,254	0,655	0,210	0,859				
Floridablanca	0,016	0,973						
Caldas	-0,039	0,617	0,876	0,000	0,786	0,340	0,622	0,478
Bucaramanga	0,161	0,862	-0,334	0,732				
Bello	1,097	0,000	1,714	0,000	1,823	0,000	1,705	0,000
Barranquilla	0,835	0,386	0,979	0,449				

Notes: *Period 3* shows the adjusted parameter for the first tree periods after the treatment, immediately on the right its p-value. *Period 6* shows the adjusted parameter for the 3-6 period after the treatment and its p-value is on the right. It works the same for the rest of periods. Blank spaces implies that there are no enough observartions to run the test for these period.

The results for the new units are similar. La Estrella and Caldas differ for the other outcome in the sense that the first one has a negative and significant parameter in the first segment, and the second one has only significance between the four- and six-periods. Neither for area or units treated and capital municipalities show a significant increase in the supply of housing despite the flexibilization of its regulations.

3.6 Mechanisms

More flexible building regulations increase the potential supply of housing in small and satellite cities. The political decision to change regulations can therefore respond to the need to improve the housing deficit. As noted by Duranton (2009), larger cities tend to have more restrictive rules and, in our results, places with more flexible rules do not necessarily see an increase in supply if they are large centers.

The first hypothesis was that municipalities with a housing deficit changed their building rules to increase supply and close that gap. To explore this, I compare the quantitative housing deficit before and after the reforms: 2005 (before intervention) vs. 2018[10]. The pattern is clear in Table 3.4: almost all municipalities treated and controls, large and small, core and satellite, reduced their deficit between 2005 and 2018, with the exception of Barbosa. In 2005, the largest deficits were in the main cities, and these same cities show the largest reductions by 2018. Since these big cities do not display a significant increase in new supply after flexibilization, the natural interpretation is a fall in demand in place (outflows to nearby markets or slower net inflows).

Table 3.4: Quantitative housing deficit for municipalities

Municipality	% Housing Deficit 2005	% Housing Deficit 2018	Difference
Armenia	6,75	3,81	-2,94
Barbosa	1,35	1,87	0,52
Barranquilla	15,16	5,13	-10,03
Bello	5,39	4,17	-1,22
Bogotá, D.C.	14,64	3,86	-10,78
Bucaramanga	17,77	5,59	-12,18
Caldas	2,97	1,69	-1,28
Cali	12,16	1,88	-10,28
Copacabana	2,92	1,48	-1,44
Floridablanca	13,01	3,45	-9,56
Girardota	5,94	1,28	-4,66
Girón	15,76	4,76	-11
La Estrella	2,83	1,3	-1,53
Medellín	6,73	2,02	-4,71
Pasto	11,15	3,94	-7,21
Pereira	7,64	4,03	-3,61
Sabaneta	3,47	0,46	-3,01

Notes: The quantitative deficit refers to the lack of adequate housing, either due to a lack of it or because the existing ones are not suitable for improvement. The measure is percentage of population with quantitative housing deficit. The last column shows the Difference between 2018 with respect to 2005.

So, I propose two mechanisms that, combined, could produce this effect: (i) *Supply side (costs):* In the core, land is scarce and expensive. Even with more flexible rules, lower regulatory costs may not be enough to offset high land and input costs, financing constraints, or approval frictions. Developers face tighter margins and stronger competition for well-located parcels, so the supply response is limited. In contrast, small cities still have vacant or cheaper land; when rules relax, expected profits improve, and projects scale up; (ii) *Demand side (reallocation):* Satellite municipalities receive excess demand

[10]I use these years because census microdata are available for both.

from core cities with high initial deficits. Households reallocate across the metropolitan system to satellites where prices and availability are more favorable. In that setting, local supply in satellites responds to incoming demand (see migration evidence below), while cores can reduce their measured deficit without a large local construction boom.

According to the literature (See section 3.2), more flexible regulations should lower prices and increase supply. The core markets are "saturated": land competition is intense, land prices are high, and the cost savings from regulatory changes are not enough to trigger many new projects. In small cities, there is still land available and it is cheaper, so when rules are relaxed, developers start larger projects, but only if demand is expected to materialize.

To test the hypothesis of reallocation and the demand channel, I compute the share of residents who moved into each municipality in the last five years, for 2005 and 2018. I separate total migrants, internal migrants (from another Colombian municipality) and foreign migrants[11]. Table 3.5 shows the results.

Table 3.5: Migration ratio for municipalities

Municipality	Migration ratio 2005	Migration ratio 2018	Difference	Migration foreigns 2005	Migration foreigns 2018	Difference foreigns	Migration locals 2005	Migration locals 2018	Difference locals
Armenia	0.088	0.105	0.017	0.003	0.017	0.014	0.085	0.088	0.003
Barbosa	0.059	0.086	0.026	0.001	0.01	0.01	0.059	0.075	0.017
Barranquilla	0.034	0.063	0.03	0.002	0.036	0.033	0.031	0.028	-0.004
Bello	0.083	0.161	0.078	0	0.022	0.021	0.082	0.14	0.057
Bogota	0.062	0.07	0.008	0.005	0.027	0.022	0.056	0.043	-0.013
Bucaramanga	0.085	0.1	0.015	0.003	0.03	0.027	0.083	0.07	-0.012
Caldas	0.091	0.103	0.012	0.001	0.009	0.008	0.09	0.094	0.004
Cali	0.052	0.066	0.013	0.003	0.02	0.017	0.049	0.046	-0.003
Copacabana	0.086	0.152	0.066	0.002	0.012	0.009	0.084	0.14	0.056
Floridablanca	0.153	0.132	-0.02	0.002	0.021	0.019	0.151	0.112	-0.039
Girardota	0.075	0.141	0.066	0.001	0.017	0.016	0.074	0.124	0.05
Giron	0.148	0.13	-0.019	0.001	0.022	0.021	0.147	0.107	-0.04
La Estrella	0.023	0.15	0.127	0.001	0.003	0.002	0.023	0.148	0.125
Medellin	0.068	0.069	0.002	0.004	0.02	0.016	0.063	0.05	-0.014
Pasto	0.047	0.059	0.012	0.001	0.005	0.004	0.046	0.055	0.008
Pereira	0.136	0.101	-0.034	0.009	0.018	0.01	0.127	0.083	-0.044
Sabaneta	0.224	0.403	0.18	0.005	0.036	0.031	0.219	0.367	0.148

Notes: *Migration ratio* corresponds to the total amount of short term migrants (last five years). *Migration foreigns* corresponds to the ratio of short term migrants coming from a foreign country. *Migration locals* corresponds to the ratio of short term migrants coming from other municipality in Colombia.

In general, satellites display higher migrant shares and larger increases over time, especially in internal migration (*Migration locals*) for the Aburrá Valley satellites (Bello, Caldas, La Estrella) and in foreign inflows in several cities. This pattern is consistent with a reallocation of households from cores to satellites, helping cores reduce their deficit without a large local construction response, while satellites expand supply in response to incoming demand.

3.7 Policy implications

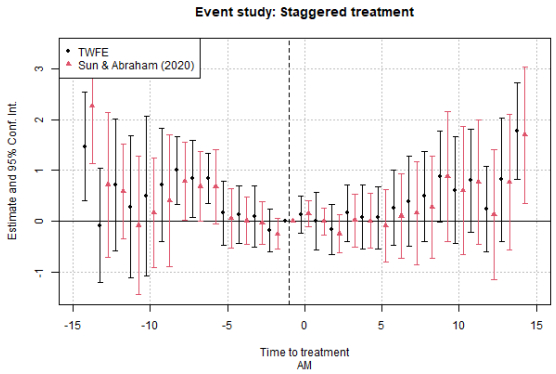
The indicator of how flexible or rigid the regulations for new housing construction are consists of four main elements: the occupancy index (IO), the construction index (IC), the housing density (DC), and the maximum height (HB). A higher value in each of these indicators implies a greater level of

[11] "Foreign" includes return migrants.

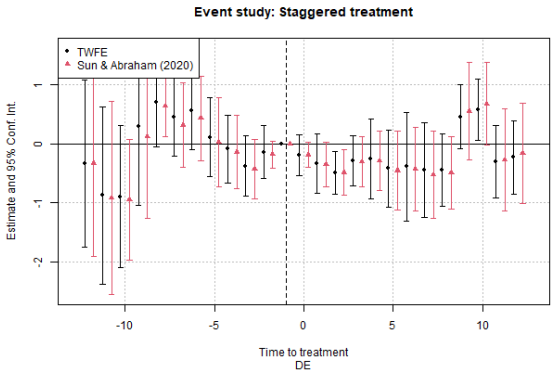
flexibility, as it allows developers to construct a larger number of units and larger housing areas. In other words, it allows for more intensive land use.

However, as noted in the literature, the effect of regulatory changes depends not only on the context in which they are applied, but also on the specific type of regulation (Bertaud and Malpezzi, 2001; Büchler and Lutz, 2024; Gyourko et al., 2021). To determine which of the BRI components drives the effect, I define a simple dummy (see Table 3.1) using municipalities with a value above the sample mean (= 1) to those above it (= 0) and conduct a separate event study using each indicator as the defined treatment. The outcomes are the population-weighted log of the new units and the population-weighted log of the new constructed area (potential supply). In short, this compares cities with high IC to those with low IC, and the same applies for IO, DC, and HB, the results can be seen in Figure 3.6.

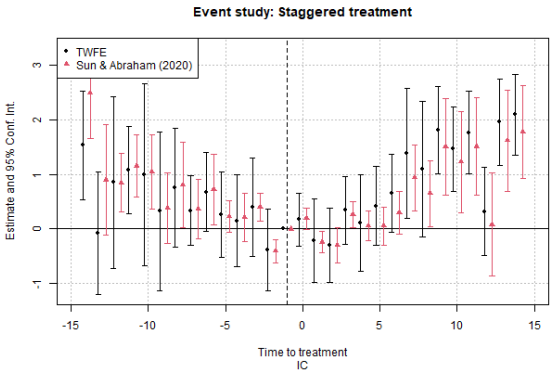
Figure 3.6: Staggered Differences in Differences results for individual indicators of regulation (new units)



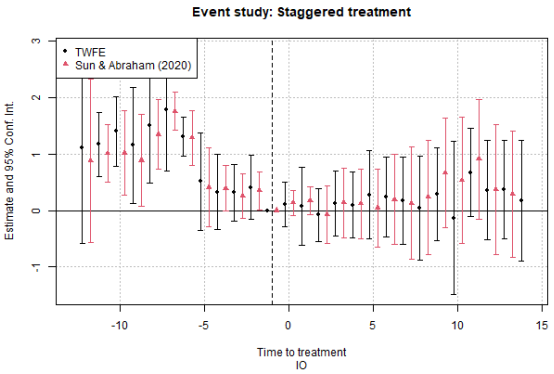
(a) Logarithm of new units constructed for maximum height indicator



(b) Logarithm of new units constructed for housing density indicator



(c) Logarithm of new units constructed for construction index



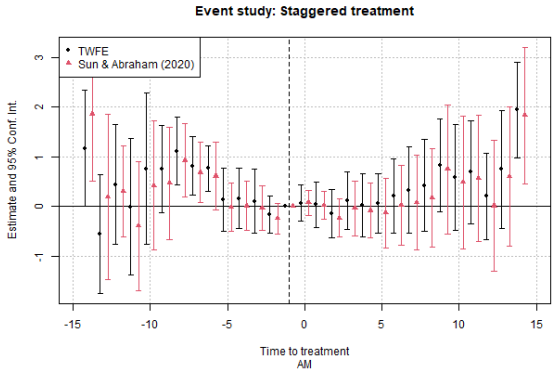
(d) Logarithm of new units constructed for occupation index

Note: Panel shows the event study results of municipalities that has each of the components of the regulation index below the mean compared with those that are not.

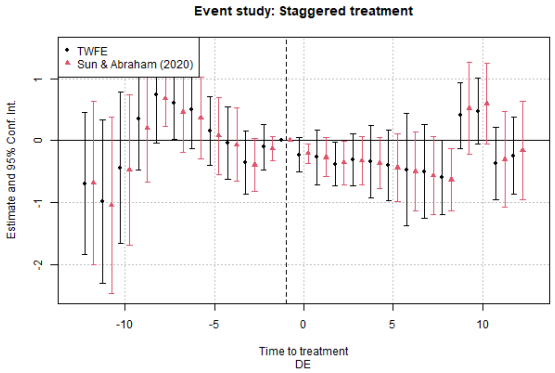
I find positive results for the construction index in terms of new units built, while the other indicators do not seem to have an effect when considered individually. In general, the combination of all indicators appears to improve housing supply; however, this effect appears to be primarily driven

by changes in the construction index. Given that this index reflects how many times a plot of land can be converted into built-up area, it makes sense that it would be the most effective way to generate higher density and, consequently, a greater housing supply. The results are also consistent for the built area, as shown in Figure 3.7.

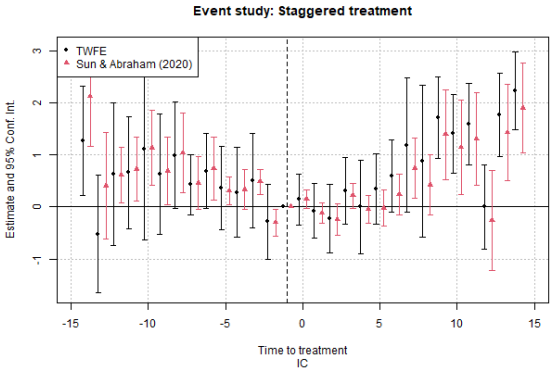
Figure 3.7: Staggered Differences in Differences results for individual indicators of regulation (new area)



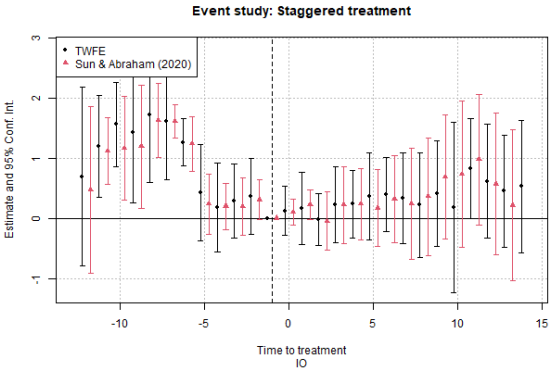
(a) Logarithm of new area for maximum height indicator



(b) Logarithm of new area for housing density indicator



(c) Logarithm of new area for construction index



(d) Logarithm of new area for occupation index

Note: Panel shows the event study results of municipalities that has each of the components of the regulation index below the mean compared with those that are not.

The most effective way to encourage the construction of new housing appears to be by increasing the building index. However, it is important to consider the complementary or restrictive nature of different types of regulations. The building index (IC), the occupation index (IO) and the housing density (DC) are complementary, which means that they do not contradict each other. In contrast, the maximum height (HB) can act as a constraint on IC. In scenarios with limited land availability, high HB is essential for IC, IO, or DC to result in a tangible increase in newly constructed housing units.

3.8 Conclusions and policy recommendations

This study contributes to understand the effects of building regulations on housing supply in the context of developing economies. The findings show that less restrictive rules significantly increase the supply of housing in small and satellite cities, while the impact in major cities is limited. This pattern is consistent with settings where frictions, high internal migration flows, and limited absorption capacity shape market outcomes and slow the passage from regulatory change to construction.

The methodological approach, staggered differences in differences following Sun and Abraham (2021), combined with a regulation flexibility index adapted to the Colombian context, addresses heterogeneity in treatment timing and helps mitigate concerns about endogeneity. By focusing on regulatory components that vary across municipalities and can be measured consistently, the index captures meaningful differences in local regulatory environments and offers a practical framework for empirical work in similar settings.

From a broader literature perspective, the paper adds evidence from a developing-country context and shows that the effects of regulatory relaxation are highly context dependent. The gains concentrate in small and satellite cities, where land availability and metropolitan reallocation of households from the core create favorable conditions for developers. The study also provides a transparent application of a regulation index tailored to Colombia, offering a tool that can be replicated in other countries facing comparable data constraints.

From a policy perspective, the results suggest that regulatory flexibilization can be an effective instrument to expand housing supply in contexts where shortages are binding, particularly in satellite cities. Relaxing urban intensity rules may help increase supply, but only if regulatory changes are aligned with incentives that effectively reduce development costs and facilitate the matching of new supply with housing demand. These incentives may include measures that lower construction and permitting costs, improve access to serviced land, or reduce financial frictions in the housing market, for example, through credit access, demand-side subsidies, or policies that ease mobility constraints associated with migration. Without such complementary measures, flexibilization alone may lead to limited supply responses or reallocation effects rather than sustained increases in housing availability.

Finally, future research should explicitly account for institutional and spatial factors that may condition the effects of regulation. In particular, heterogeneity in regulatory enforcement across cities may alter the effective impact of formal rules, while spillover effects may arise from interactions between municipalities that belong to the same urban system. Accounting for these dynamics is essential to fully understand how regulatory changes propagate across space and over time. Incorporating geospatial information, documenting enforcement capacity, and modeling inter-municipal interactions would help refine the estimated effects and improve the design of housing and land-use policies in metropolitan areas.

Chapter 4

The informal city: Urban growth and housing market duality in developing countries

Lina Marcela García Tavera*

Abstract. *Developing countries exhibit high levels of urbanization but low levels of development. This urban "surplus" may be partially explained by the structure of the housing market and the prevalence of informality. Building on the work of Duranton and Puga (2019), this study reformulates urban growth dynamics for cities in developing countries with dual housing markets. The findings reveal that the presence of an informal housing market results in larger city sizes compared to those with only formal markets. This occurs because the informal sector accommodates more residents, even when the formal market is constrained. Unlike traditional approaches that focus on productivity and transportation costs, this framework emphasizes the role of institutional factors, such as enforcement and regulation, in shaping urban expansion. The analysis provides new insights into why cities in developing countries often grow beyond the predictions of conventional theories*.*

4.1 Introduction

Urbanization in a country is usually correlated with the level of development and the size of its rural sector (Roberts et al., 2017). However, in developing countries, this relationship is weak. They have high levels of urbanization, comparable to richer countries, but low levels of development. For underdeveloped countries, the cost associated with urbanization is higher, the benefits are lower and they are not fully exploited (CAF, 2017).

*Universidad del Rosario. Email: linamarce.garcia@urosario.edu.co

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During recent decades, the literature on urbanization and development has extensively documented the phenomenon of 'urbanization without growth' or 'urban surplus' in developing countries, that is, levels of urbanization above those expected for their income or levels of industrialization. Several studies have linked this anomaly to factors such as population growth, poverty-driven rural migration, institutional weakness, failures of urban governance, and dependence on extractive rents (Fay and Opal, 2000b; Fox, 2012; Gollin et al., 2016; Sachs and Warner, 2001; Acemoglu et al., 2002). However, there is still a significant theoretical gap with respect to the specific market mechanisms that allow or exacerbate this mismatch.

In particular, while several works highlight the importance of urban informality and its expansion as a central feature of urbanization patterns in the global South (Roy, 2005; Brueckner et al., 2019b; Fay and Opal, 2000b), no theoretical model has explicitly linked the existence of informal housing markets to excessive population growth in cities, that is, as a structural cause of urban surplus. There has also been an exploration of how the coexistence of a constrained formal housing market and an expansive informal sector can alter urban equilibrium outcomes predicted by conventional models based on productivity or transport costs (Henderson, 2005; Duranton and Puga, 2019). For example, studies such as Gollin et al. (2016) and Henderson (2005) focus on the relationship between urbanization and productive structures (manufacturing vs. services), but do not directly address the housing supply as a constraint shaping urban scale. Similarly, critical work on informality (Roy, 2005) emphasizes its distributive and epistemological implications, but has not formally modeled its effects on urban equilibria.

The informal housing market provides housing units with insecure of tenure and low standards in infrastructure and services (Mutyambizi et al., 2020). A primary characteristic of the informal market is its evasion of building legislation and zoning laws (Saglamer et al., 2024). This creates a risk of sanctions or eviction, but it also offers the possibility of residing in the city at a lower cost than the formal market. For example, in South Africa, informal settlements offer a low-cost option to access urban economic opportunities, and there seems to be some advantage in living in an informal settlement compared to a rural area (Turok et al., 2017).

The particular nature of the informal housing market has significant consequences for the size of the city. Under normal conditions, a city would grow until the rent paid by a new resident equals the rent for its alternative use (Alonso, 1964). If the costs of living in the city exceed the income received by the new resident, they will leave. However, the informal housing market provides an opportunity to remain in the city at a lower cost. By avoiding urban regulations designed to limit population size, the informal market allows for additional growth by reducing housing costs, enabling more people to stay. In this sense, the central hypothesis of this paper is that cities with dual housing markets experience a 'surplus' growth due to the possibility that individuals choose the informal sector.

The objective of this paper is to identify the incidence of the informal housing market in the equilibrium of the urban system. In particular, I want to find out if part of the gap between the levels of economic development and the levels of urbanization in developing countries is related to the existence of a dual housing market and its possible mechanisms. To do this, I reformulate the urban growth model proposed by Duranton and Puga (2019) in the context of cities with dual housing markets. This model is useful because of how it shows the mechanism that controls city growth: previous residents, called incumbents, use a regulation cost to limit the number of new residents. This frame helps me capture the 'institutional approach' of informality, showing the development of housing outside the regulatory environment.

Several approaches have explored the coexistence of formal and informal housing markets in cities. One perspective focuses on eviction, where landowners decide whether or not to incur the cost of reclaiming land from informal settlers (Jimenez, 1985; Hoy and Jimenez, 1991; Turnbull, 2008). Another

looks at the supply-side dynamics, considering the risks and costs faced by developers (Kapoor and le Blanc, 2008). A spatial approach integrates these elements into a monocentric city model (Posada, 2018; Selod and Tobin, 2018). In addition, some studies propose equilibrium models in which the formal and informal sectors compete for land, with the informal market driving up prices in the formal sector (Brueckner and Selod, 2009a; Brueckner, 2013). From the perspective of consumers, heterogeneous agents weigh the choice between the formal market, with its higher costs, and the informal market, with its lower costs, but also risks such as eviction (Cavalcanti et al., 2019; Heikkila and Lin, 2014). The last approach is the one that best fits the proposed model.

This paper extends the urban growth framework of Duranton and Puga (2019) to incorporate the effects of dual housing markets in developing countries. The model assumes that cities are monocentric and their growth is driven by productivity, transportation costs, and institutional constraints. A key feature of the framework is the presence of two housing markets: a formal sector, which is subject to regulatory costs, and an informal sector, where residents face the risk of eviction or sanctions. The informal market provides a cheaper housing option, but this benefit decreases as enforcement becomes stricter. The spatial distribution of informality is determined by a cost function that decreases with distance from the city center, capturing the declining probability of sanctions as settlements expand outward. The model also includes the role of incumbents in regulating urban expansion, as they impose costs on new entrants to maintain their relative advantage in the formal market.

This study contributes to the literature by offering an alternative explanation for the persistent gap between urbanization and economic development in low-income countries. It shows how informality affects urban equilibrium, allowing cities to accommodate a larger population than conventional models predict. In particular, it suggests that weak enforcement and high regulatory costs contribute to the expansion of informal settlements, lowering housing costs, and encouraging further migration. As a result, the model proposes that the coexistence of formal and informal markets is a central mechanism that shapes urban growth in developing economies. This has direct implications for policies aimed at managing informality and urban planning.

I want to contribute to the existing literature in two directions: i) to test an alternative hypothesis for the existence of high urbanization levels in low-developed countries, and ii) to contribute to the literature that models urban system dynamics, including informality. To my knowledge, there is not yet an equilibrium analysis of urban growth that considers a dual housing market.

4.2 Background

4.2.1 Urbanization levels and economic development

The literature has emphasized the historical link between urbanization and industrialization. According to Schnore (1961), high levels of urbanization were achieved after the Industrial Revolution, which is especially driving the economic transformation of developed countries. Cross-national evidence suggests that while GDP per capita and levels of urbanization are correlated, the speed of urbanization is not necessarily associated with economic growth. Chen et al. (2014) show that this divergence is particularly strong in developing countries.

The rapid growth of urbanization levels in the last decades in developing countries does not correspond to its levels of economic development. Using the Indian case, Narayan (2014) find that the correlation between per capita income and urbanization has strengthened in recent decades, suggesting that this relationship is not static but evolves with broader structural changes. Tolley (1988) expands

on the complexity of this connection, arguing that urbanization is shaped by a mix of domestic consumption patterns, trade dynamics, and income elasticities of demand, particularly in the context of globalization.

Behind this idea is the concept of "overurbanization", which was introduced to describe urban growth that exceeds the capacity of the non-agricultural economy to absorb labor. Sovani (1964) emphasized that rural migrants are often "pushed" to cities due to rural poverty rather than "pulled" by urban job opportunities. For example, Fay and Opal (2000b) documented that between 1970 and 1995, Africa experienced urban growth despite a negative growth of GDP per capita, resulting in large urban populations living in informal settlements without access to adequate services. Fox (2012) proposed a historical explanation for the urban transition in Africa, showing that urbanization persisted due to the decline in mortality and external food supplies, even in the absence of economic growth.

This contradicts the notion that urbanization is always driven by development. This phenomenon is stronger in resource-exporting countries, where urbanization is fueled by natural resource rents rather than industrialization. These cities tend to have high levels of informality and poor performance in urban welfare outcomes (Gollin et al., 2016).

The existence of the informal housing market could work as an urban "overgrowth" mechanism. Brueckner et al. (2019b) present a theoretical model in which the existence of informal housing markets allows cities to grow larger than they would under formal market constraints. This is because the informal sector can accommodate population inflows when the formal sector is restricted. Roy (2005) argues that informality is not simply a transitional phase, but a constitutive feature of urbanization in the Global South. She positions informal settlements as the result of planning systems that systematically exclude segments of urban populations. Fay and Opal (2000b) reinforce this idea, showing that up to two-thirds of African urban dwellers live in informal areas, mainly due to the inability of formal housing markets to meet growing demand. Zoning policies and high regulatory barriers to the development of formal housing, as described by Brueckner et al. (2019b), further incentivize the growth of informal settlements by making formal housing unaffordable or inaccessible to the majority.

Although the existing literature has richly documented the phenomenon of "urbanization without growth", it tends to focus on macrolevel explanations such as resource dependence, demographic dynamics, and structural transformation (Fay and Opal, 2000b; Fox, 2012; Gollin et al., 2016). Studies of informality, on the other hand, have emphasized its causes and normative implications (Roy, 2005), but have not formally linked it to urban size equilibria or integrated it into urban growth models. What is missing is a microfounded theory of how informal housing markets allow cities to expand beyond the capacity of the formal sector, which this study calls the "urban surplus" effect of informality.

This study contributes to closing this gap by proposing a theoretical framework that explores the existence of the informal housing market as a driver of the additional growth of cities. This model goes beyond traditional models based on interactions between productivity and transport costs and instead introduces institutional variables such as enforcement, regulation and land access.

4.2.2 Regulation mechanism

Traditional urban models emphasize productivity-driven agglomeration economies. Henderson (2005) highlights how knowledge spillovers and proximity in input and output markets underpin city growth in high-income contexts. However, institutions and urban governance also play a fundamental role in shaping the size and functionality of the city. Henderson (2005) notes that property rights, land market regulations, and infrastructure investment are decisive in determining the efficiency and spatial

form of cities.

Most of the literature about the use of exclusionary regulations and their effects is concentrated on the U.S. experience. There seems to be a consensus that zoning, density, subdivision, and building regulations can generate incentives that affect market performance. For example, much of the literature on housing and regulation shows that higher restrictions can increase housing prices (Glaeser et al., 2005; Quigley and Raphael, 2005; Gyourko and Summers, 2006).

As was pointed out by Duranton and Puga (2019) without a mechanism of control, people will concentrate in more productive cities. In this scenario, the system of cities will consist of a short set of large cities and intermediate and small cities will not exist. However, in Latin American countries, for example, even when we have large cities, we also have a large set of small cities; this implies that any kind of representation of the interaction between cities needs to consider a limitation mechanism. A way that has been considered is to fix the supply of land and, therefore, the size or the possibility of expansion of cities. This limit makes sense as long as there are natural geographic barriers that can restrict the growth of cities, but it is insufficient considering that it does not necessarily capture the dynamics of growth and population (there are cities smaller than their geographic limits).

In this case, I consider a regulation mechanism to limit the growth of the city. This mechanism is used by Duranton and Puga (2019) and is well described in the work by Henderson (2009). Exclusionary regulations could be used for existing residents to regulate how many people arrive in their community. These regulations include but are not limited to building restrictions, minimum lot size zoning, requirements for more review processes or permits to proceed with new construction, and an increase in liabilities. The rationality behind the imposition of these restrictions by existing residents is related to the existence of amenities and public services, and a possible disutility for incumbents generated by congestion and free-riders.

In general, the literature considers regulations as an exogenous variable. But they are a product of a combination of interests. Agents react to changes in the conditions of the market, positive shocks leave to impose restrictive regulations that allow incumbent agents to keep the surplus generated. As was pointed out by Henderson (2009), if the unregulated supply of housing is not perfectly elastic, an increase in the demand driven by the positive shock would increase prices and incumbents would overstate this effect with regulations to limit growth.

However, this mechanism, as a way to control the expansion of cities, has not been explored in the context of developing countries where the institutional environment allows the existence of duality in the housing market. The presence of an informal market that "avoids" these regulations could generate differential effects. If regulations are too excessive, people will have incentives to locate in the informal housing market instead of the formal one (Henderson, 2009). Roy (2005) conceptualizes informality as a "state of exception" generated by planning regimes that are unable to incorporate all urban claims. Rather than being a failure, informality is produced and regulated through policy decisions. These insights challenge the relevance of standard urban equilibrium models when applied to the global South, where dual housing markets, weak enforcement, and fragmented planning regimes dominate (Roy, 2005).

The rationale for treating urban regulations as a growth-limiting mechanism in this model comes from their role in shaping informal housing dynamics. Specifically, I examine how informality emerges as an extra-legal response to regulatory constraints, exploiting institutional weaknesses prevalent in developing economies. To formalize this interaction, I adapt the framework from Duranton and Puga (2019), which incorporates regulatory barriers, and extend it to account for an alternative housing market operating outside formal legal structures. This dual-market approach captures how prospective residents can avoid regulations through informal settlements when institutional enforcement is

insufficient.

4.2.3 Informal housing market

Urban housing markets in developing countries are commonly characterized by the coexistence of formal and informal segments. A substantial share of urban households obtain housing outside formal regulatory frameworks, leading to informal settlements that operate alongside legally developed neighborhoods. This dual structure reflects persistent constraints in the formal housing market, including affordability barriers, binding land-use regulations, and limited enforcement capacity. Rather than representing a transitory phase of urbanization, informality emerges as a stable equilibrium outcome when the regulated sector fails to absorb population growth and migration pressures (Selod and Brueckner, 2009; Marx et al., 2013; Henderson et al., 2016). In this context, households rationally trade off legal security against access, location, and cost, resulting in the simultaneous operation of formal and informal housing markets within the same urban system.

A growing theoretical literature explicitly models this duality by embedding informal housing into spatial urban frameworks. Early contributions show how land-use regulation in the formal sector, combined with imperfect enforcement, can divert marginal households toward informal locations, particularly at the urban fringe (Selod and Brueckner, 2009). More recent work emphasizes institutional frictions as a central determinant of urban form, highlighting how regulation operates as a wedge that restricts access to the formal market by raising minimum housing standards (Heikkila and Harten, 2023). Within this framework, informality is not driven solely by low incomes but by the interaction between regulatory thresholds, income heterogeneity, and spatial costs. Complementary contributions stress how these frictions interact with urban dynamics and sunk investments, shaping the timing and spatial structure of city growth (Henderson et al., 2016; Duranton, 2016).

Recent empirical work provides direct evidence of these mechanisms in cities of the Global South. Using data from metropolitan Buenos Aires, Goytia et al. (2023) show that binding land-use regulations constrain formal housing supply and generate spillovers into informal settlements, consistent with a crowding-out mechanism. Complementary evidence from South Africa highlights how informal housing adapts endogenously through arrangements such as backyarding, which allow households to access urban locations while partially circumventing formal constraints (Brueckner et al., 2019a). Together, these studies indicate that informal housing markets respond systematically to regulation, enforcement, and location, and that informality often emerges at the margin where urban land competes with alternative uses.

4.3 Model description

In this section, I introduce a model of urban growth in the context of cities in developing countries with dual housing markets, inspired by the work of Duranton and Puga (2019). There is a continuum of potential sites for cities i in discrete time t. The sites differ in the underlying productivity A_{it}. The total urban population, sizes, and location of cities are endogenous and vary over time. There is a unique and tradable output across cities for consumption. The final output produced with constant returns to scale and perfect competition by combining intermediate outputs with substitution elasticity $\frac{1+\sigma}{\sigma}$. The production framework is the same as the work made by Duranton and Puga (2019). All workers are homogeneous and will have the same expected salary. For further details on the production mechanism, see the Appendix C.1.

The expected salary per worker is given by:

$$y_{it} = \rho^{\sigma} A_{it} (h_{it})^{1+\sigma} (N_{it})^{\sigma} \tag{4.1}$$

with h_{it} as the level of human capital provided by the workers, A_{it} as productivity, ρ represents the firm's agglomeration economics, and σ the elasticity of the city's population.

As an alternative to living in cities, agents can choose to reside in rural areas, and the expected individual salary would be given by:

$$y_{rt} = A_{rt} (N_{rt})^{-\lambda} \tag{4.2}$$

With λ measuring the decreasing returns to rural labor.

I consider a monocentric city with a single employment core and a continuum of residential locations indexed by distance $x \geq 0$ from the center. The production block follows the early version of Duranton and Puga (2019); the departure in this paper is on the spatial / land use side, where I introduce a dual housing market with enforcement.

The commute costs for a worker living at x distance from the downtown are given by:

$$T_{it}(x) = \tau_{it}\ x^{\gamma} \tag{4.3}$$

Whether τ_{it} cost per unit of commuting and γ elasticity of commuting cost for the distance to the center. The parameter γ allows for variation in the commuting pattern, such as a second commuting location or preferences. The cost per unit is represented as:

$$\tau_{it} = \tau_t\ (N_{it})^{\theta} \tag{4.4}$$

With θ capturing congestion and τ_t changing commuting technology over time. The cost of commuting is higher in more populated and congested cities.

4.3.1 Analysis of the formal vs. informal housing choice

Each period productivity A_{it} is updated for a shock given by $A_{it} = g_{it} A_{it-1}$. A new generation of owners replaces the old ones and occupies their place of residence in the city. New residents face regulation costs imposed on previous residents (incumbents). New potential residents decide:

- Enter the formal housing market
- Enter the informal housing market
- Or leave the city

In this model, residents choose between formal and informal housing markets based on their maximization of utility. The formal market is characterized by a fixed regulatory cost (p_{it}), while the informal market carries a risk of eviction or sanctions ($\pi(x)$).

If the household decides to enter the formal market, it has to pay a regulation cost p_{it}, and the budget constraint that it faces is given by:

$$C_{it}^{f} + z \cdot R_{it}^{f}(x) + T_{it}(x) + p_{it} = y_{it}, \tag{4.5}$$

where $R_{it}^{f}(x)$ is the rent on the formal market, z is the fixed floor space, $T_{it}(x)$ is the commuting cost in location x, C_{it}^{f} is the level of consumption for the formal market and y_{it} is the income of the resident.

The fixed cost p_{it} represents the price of accessing the formal market, which avoids the costs associated with the informal sector. Existing residents impose a regulation cost (p_{it}) that they do not pay either because they bought their house before the cost was imposed or because they live in areas exempt from the regulation (Henderson, 2009). Migrants always have to pay the extra cost if they want to enter the formal market.

All city dwellings are built on equally sized land and have identical floor space [2]. So, it is assumed that $z = 1$ and that on the city border x is equivalent to the population size $x = N_{it}$

If the household chooses the informal market, the budget constraint is as follows:

$$C_{it}^{s} + z \cdot R_{it}^{s}(x) + T_{it}(x) + \pi(x) = y_{it} \tag{4.6}$$

where $R_{it}^{s}(x)$ is the rent in the informal market and $\pi(x)$ represents the cost associated with informal housing that represents sanctions or eviction.

The risk of the informal market is represented by a cost function $\pi(x)$, which varies with the distance x from the city center. The cost function $\pi(x)$ is monotonically decreasing in x, reflecting that the risk of sanctions or eviction is highest in the city center ($x = 0$) and decreases toward the periphery.

Given these assumptions, I propose the following functional form for $\pi(x)$:

$$\pi(x) = \kappa_{it} \cdot p_{it} \cdot e^{-\alpha x} \tag{4.7}$$

where κ_{it} is the enforcement parameter, scaling the cost function, and α is a positive parameter controlling the rate at which the cost decreases with distance x. The term $e^{-\alpha x}$ ensures that $\pi(x)$ decreases smoothly and monotonically with distance from the city center. This reflects the spatial heterogeneity of enforcement, where the risk of sanctions is highest in the center and decreases toward the periphery.

The parameter α determines how quickly the cost of informality decreases as one moves away from the city center, corresponds to a spatial sensitivity factor. In other words, α reflects how the urban structure, social conditions or characteristics of the real estate market amplify or attenuate the effect of distance on the risk of sanctions or eviction. A higher α implies a steeper decline in $\pi(x)$.

The enforcement parameter κ_{it} captures the overall intensity of legal enforcement. I mantein $\kappa_{it} > 0$, so the parameter is economically meaningful. A higher κ_{it} uniformly increases the expected cost of

[2] As was made in the last version of Duranton and Puga (2019), this condition could be relaxed to represent the geographic restrictions that cities typically face. In fact, in the informal market, the size of the land used can be less than unity ($z < 1$), and could allow one to capture another source of variation in the presence of dual housing markets

informality, making the formal market more attractive at a certain locations, predominantly those close to the core of the city; a lower κ_{it} does the opposite. When institutional capacity is weak ($\kappa_{it} < 1$), the deterrence associated with sanctions and eviction is insufficient, the indifference cutoff x_* collapses toward the center (to zero after imposing the admissible domain), and the city becomes predominantly informal with no purely formal core. In contrast, sufficiently strong enforcement maintains a formal core in central areas. For the formal derivation and domain truncation, see Appendix C.3.

Figure 4.1 illustrates the proposed cost function $\pi(x)$. The curve shows the exponential decay of $\pi(x)$ with distance to the center x. It also shows how the cost function changes as the parameters increase or decrease. It also represents how the interaction between the regulation cost p_{it} and the informality cost function $\pi(x)$ could eventually determine the size of the formal and informal market, as will be explained later.

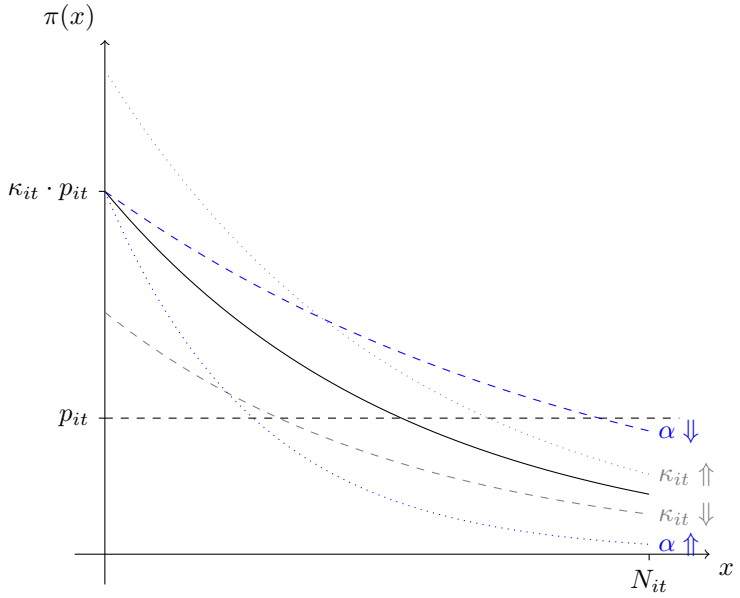


Figure 4.1: Informal cost function

In spatial equilibrium, residents must be indifferent in all locations within the city. In the city center ($x = 0$), residents do not face transportation costs ($T_{it}(0) = 0$) and the cost of informality $\pi(0) = \kappa_{it} \cdot p_{it}$ is maximized, ensuring that $\pi(0) > p_{it}$ when enforcement is sufficiently strong ($\kappa_{it} > 1$). This incentivizes residents to choose the formal market in central areas. The enforcement parameter κ plays a crucial role in shaping the urban landscape. If κ_{it} is too low, the cost of informality becomes negligible, leading to widespread informal settlements. In contrast, a high κ_{it} ensures that the enforcement remains effective, preserving the formal sector. This highlights the importance of governance and institutional capacity in the management of urban informality.

To address the concern that the condition does not hold when $\kappa < 1$, I clarify the relationship between the enforcement parameter κ_{it} and the regulatory cost p_{it} in the city center ($x = 0$). The formal housing market will only prevail in the city center if the threat of sanctions in the informal market is sufficiently credible, specifically if $\kappa_{it} > 1$. This ensures that the informal housing cost at $x = 0$ is greater than the regulatory cost.

This condition confirms that enforcement levels must be sufficiently strong for the informal housing market to be unattractive at the core. The preference for the formal sector at $x = 0$ arises when the

sum of rents and regulatory costs in the formal market is lower than the combined informal rent and sanction costs in the informal market.

$$R_{it}^{f}(0) + p_{it} < R_{it}^{s}(0) + \pi(0). \tag{4.8}$$

This explicit formulation clarifies how the enforcement parameter and regulatory costs jointly determine the viability of the formal market in the city center, ensuring that the condition is directly derived from the comparison of formal and informal options. So in a certain buffer around the center the cost of regulation is less than the cost of sanctions and eviction, so there is no informality.

$$C_{it}^{f} + R_{it}^{f}(0) + p_{it} = y_{it}, \tag{4.9}$$

As distance x increases, $\pi(x)$ decreases, reflecting weaker enforcement and a lower risk of sanctions. Beyond a critical distance x^*, $\pi(x) < p_{it}$, making the informal market more attractive. So, on the edge of the city ($x = N_{it}$), the cost of regulations is higher than the cost of regulation. In fact, if the city is too large, this cost could tend to zero ($\pi(x) \to 0$), implying that on the edge there is only informal housing:

$$C_{it}^{s} + R_{it}^{s}(N_{it}) + T_{it}(N_{it}) + \pi(N_{it}) = y_{it} \tag{4.10}$$

To simplify the model, it is assumed that in a certain location x, formal and informal housing cannot coexist at the same time, which means that it is a discrete choice that depends on the highest willingness to pay of the households for a given location. It implies the existence of a certain point ($x*$) when households are indifferent between choosing an informal or formal market and rents are equal.

$$R_{it}^{f}(x*) + p_{it} = R_{it}^{s}(x*) + \pi(x*) \tag{4.11}$$

Agents compete to choose a location in the city. A location x will be given to the agent who pays more for the spot. Locations close to the core will give the agent greater savings in transportation costs, so it is expected that they are more desirable and, as a consequence, more expensive. Agents in the formal market will pay an additional cost associated with the regulation tax that is evaded in the informal market. Given that the informal cost function decreases with the distance to the center x, the formal market is close to the core, so the existence of an informal market in a certain buffer around the center is not possible. If an agent wants to save on commute costs, it will have to pay the regulation tax. The willingness to pay in the formal market decreases with decreasing informal penalties $\pi(x)$. But there is a point where the transportation cost savings will be less than the expected disutility derived from the risk of eviction or sanctions; so the agent will choose the informal market and will not pay the regulation tax.

Using the agent's election at three different points: the center ($x = 0$), the indifference point (x^*) and the edge ($x = N_{it}$), I determine the bid rent functions R_{it}^{f} and R_{it}^{s}. To see more details, see the appendix **??**. The rent functions for formal and informal markets are the following:

$$\begin{aligned} R_{it}^{f}(x) &= T_{it}(N_{it}) + \pi(N_{it}) - T_{it}(x) - p_{it} \\ R_{it}^{s}(x) &= T_{it}(N_{it}) + \pi(N_{it}) - T_{it}(x) - \pi(x) \end{aligned} \tag{4.12}$$

The formal sector rent curve decreases with distance x, on via with the Alonso-Muth condition, the willingness to pay in the formal sector $R_{it}^{f}(x)$ is less in locations close to the edge of the city. The performance of the informal sector curve is different. Two opposite forces influence the willingness to pay in the informal sector: i) the canonical effect of transportation cost, and ii) the probability of eviction. Close to downtown, the probability of facing eviction or sanctions is too high, but transportation costs are small, so the informal bid rent curve is higher but not as much as the formal one because of the informality penalty probability. The reduction in eviction "compensates" the increase in transportation costs. So, the informal sector rent curve is flatter; for further details, see Appendix C.4.

The intersection point between the curves gives $x*$, which is the distance from the city center where households are indifferent between the formal and informal housing markets. This threshold is determined by the balance between commute costs, regulatory costs in the formal sector, and the cost function in the informal sector. The size of the formal N_{it}^{f} and informal sector N_{it}^{s} will depend on the location of the indifference point $x*$.

The city will grow until the value paid for the rent on the edge is equal to the value paid for the alternative use. Compared to a certain level of rent in the alternative rural sector R_{rt}, there is a surplus that could be generated by the presence of dual housing markets in an economy. The difference between the optimal level of N_{it} in the presence of duality and the alternative of a single housing market $(\widetilde{N_{it}})$[3] could represent the distortion in the optimal given by the existence of informality $(\widehat{N_{it}})$.

$$\widehat{N_{it}} = N_{it} - \widetilde{N_{it}} \tag{4.13}$$

Figure 4.2 represents the variation in rents throughout the city in both markets and its relation to the size of the city.

The specific level of the alternative rent R_{rt} considered in the graphical representation directly influences the optimal city size. $\widetilde{N}_{it}$ corresponds to the equilibrium without a dual housing market as proposed by Duranton and Puga. In the baseline scenario, the size of the city $\widetilde{N}_{it}$ is smaller than the size of the city with the presence of informality (N_{it}), and x^* lies to its left, reflecting the presence of informal settlements. However, if R_{rt} increases due to a stronger rural economy, $\widetilde{N}_{it}$ can shift to the right, potentially matching N_{it} and eliminating the scope of informality. In contrast, a decrease in R_{rt}, which could result from conflict, natural disasters, or declining rural productivity, would increase the size of the city predominantly through informal settlements.

It is also derived that the total rent of the city is represented by:

$$R_{it} = \int_{0}^{x*} R_{it}^{f}(x)\,\mathrm{d}x + \int_{x*}^{N_{it}} R_{it}^{s}(x)\,\mathrm{d}x \tag{4.14}$$

The total rent in the city is derived by integrating the formal and informal rent functions over their respective domains. Specifically, it is calculated as the sum of rents in the formal sector from the city center to the point of difference x^*, and in the informal sector from x^* to the city boundary N_{it}. After explicitly replacing the transport and informality cost functions, defined respectively as $T_{it}(x) = \tau_t (N_{it})^{\theta} x^{\gamma}$ and $\pi(x) = \kappa_{it} p_{it} e^{-\alpha x}$, the final expression for the total rent becomes:

[3] In the original model from Duranton and Puga (2019) this value is represented as: $\widetilde{N_{it}} = \left(\frac{\rho^{\sigma}\sigma(\gamma+1)}{\gamma+\theta}\frac{A_{it}(h_t)^{1+\sigma}}{\tau_t}\right)^{\frac{1}{\gamma+\theta-\sigma}}$

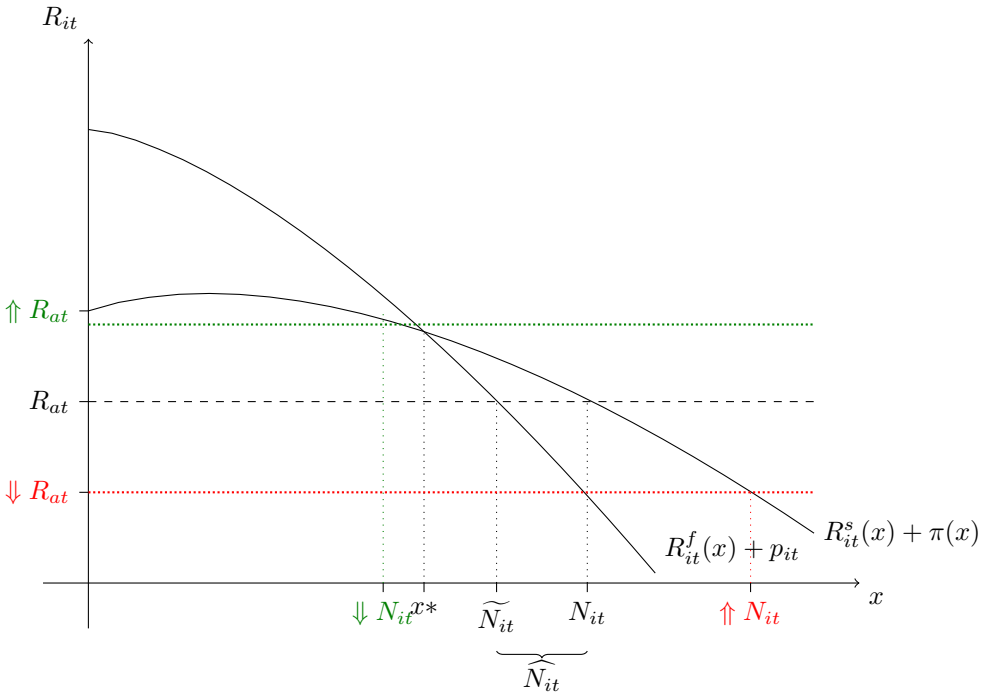


Figure 4.2: Rents variation along the city and effect of changes in the rural alternative rent R_{at} on the equilibrium city size: rural improvement ($\Downarrow$) and rural decline ($\Uparrow$). The original scenario is shown in black.

$$
\begin{aligned}
R_{it} = & \underbrace{\tau_t (N_{it})^{\theta+\gamma} N_{it} - \frac{\tau_t (N_{it})^{\theta} N_{it}^{\gamma+1}}{\gamma+1}}_{\text{Transport}} \\
& + \underbrace{\kappa_{it} p_{it} N_{it} e^{-\alpha N_{it}} + \frac{\kappa_{it} p_{it} e^{-\alpha N_{it}}}{\alpha} - \frac{\kappa_{it} p_{it} e^{-\alpha x^*}}{\alpha}}_{\text{Enforcement}} \\
& - \underbrace{(p_{it} x^*)}_{\text{Regulation}}
\end{aligned}
\tag{4.15}
$$

This formulation captures how the spatial equilibrium in the city balances the formal sector rents with the incentives for informal occupation, as transportation costs and informality costs vary with distance. It highlights how the intensity of enforcement, represented by κ_{it}, and the regulatory burden p_{it} shape the extent of informality and the final spatial configuration of the city.

This final expression for the total rent R_{it} can be separated into three distinct components that reflect the main drivers of urban land rents in the equilibrium of the dual housing market. The first group, labeled as *Transport*, includes the net rents associated with transportation costs as a function of the size of the city N_{it}, the transport cost parameter τ_t, and the elasticity parameters θ and γ. The second group, denoted as *Enforcement*, comprises the terms related to the enforcement mechanism of the informal market, shaped by the enforcement parameter κ_{it}, the regulatory burden p_{it}, and the exponential decay factor α that captures how the cost of the informal market effectively decreases with distance from the city center. The last term, *Regulation*, explicitly accounts for the direct regulatory

burden p_{it} paid by the formal housing market up to the indifference point x^*, which represents the distance from the city center at which households are indifferent between formal and informal housing options. This grouping highlights how the model captures the interaction between transportation costs, enforcement intensity, and regulatory constraints in determining the spatial equilibrium of formal and informal housing within the city.

4.3.2 Incumbents, planning, and the dual housing market

The incumbent residents decide on planning rules to control how much the city expands. They try to maximize their consumption using regulations as a way to control and fix the population (N_{it}) that give them a maximum level of consumption given by:

$$c_{it} = y_{it} - T_{it}(x) - R^i_{it}(x) + \frac{R_{it}}{N_{it}} \tag{4.16}$$

The incumbent resident does not pay the regulation cost and is located only in the formal market. So, the bid rent is only influence for the transportation cost and it is equivalent to the rent in a the model without informality:

$$R^i_{it}(x) = \tau_t \ (N_{it})^{\theta} \left[(N_{it})^{\gamma} - x^{\gamma} \right] \tag{4.17}$$

Given the city's dual housing market, there is an alternative option of choosing the informal market for new residents who cannot face the cost of regulations. This implies that the city could have a bigger size than was expected for incumbent residents. This reflection aligns with the broader interpretation of the model, where the urban rents, both formal and informal, are ultimately captured by a central planner who manages the city's land use. In this context, the regulatory parameter p_{it} serves as a policy tool that tightens the formal housing market while also increasing the enforcement costs of informality through $\pi(x) = \kappa_{it} p_{it} e^{-\alpha x}$. Consequently, the total rent R_{it} can be seen as a measure of social surplus that includes direct formal rents, indirect rents captured through informal activities, and regulatory revenues. The incumbents, as part of this system, benefit from these rents through 'amenities' or the collective value of the urban system, so the rents are weighted by the total population N_{it} in the equilibrium formulation.

Importantly, in this formulation, the total urban rent R_{it} can be interpreted as a measure of the social surplus or collective welfare generated by the city, which accrues to incumbents and the broader urban community through the 'amenities' and the cumulative benefits of the urban system. This underscores that the informal sector, while outside formal legal frameworks, still contributes to the collective value of the city. Therefore, policies aimed at balancing regulation and enforcement should consider the complex feedbacks between these elements to manage urban informality effectively and improve overall urban welfare.

In line with the dual-market setting, in what follows I assume that incumbents fully appropriate formal rents as amenities but only a fraction $\omega \in (0, 1]$ of the rents generated in the informal fringe; this keeps the structure of the objective unchanged while capturing limited appropriation from informality.

Ultimately, the effect of regulation on the spatial composition of the city depends on its interaction with enforcement (κ_{it}) and how quickly informality costs decay with distance from the center (α), highlighting the nuanced role of policy in shaping the balance between formality and informality in urban settings. Furthermore, since the cost in the informal market ($\pi(x)$) depends positively on the

level of regulation p_{it}, it could lead to levels of land regulation that are also higher than those expected for cities without informal markets.

They decided:

$$\max_{N_{it}} \; c_{it} \; = \rho^{\sigma} \, A_{it} \, h_{it}^{1+\sigma} \, N_{it}^{\sigma} \; - \; \frac{\tau_t}{1+\gamma} \, N_{it}^{\theta+\gamma} \; + \; \kappa_{it} p_{it} \, e^{-\alpha N_{it}} + \underbrace{\omega \, \kappa_{it} p_{it} \, \frac{e^{-\alpha N_{it}} - e^{-\alpha x^*}}{\alpha \, N_{it}}}_{\text{incumbents capture only a fraction of informal rents}} - \frac{p_{it} \, x^*}{N_{it}} \, . \tag{4.18}$$

The multiplicative factor $\omega \in (0, 1]$ in the informal rent term reflects that incumbents do not fully appropriate the rents generated beyond the formal limit (due to leakage, dissipation, or limited spillover of amenities), while they still capture the full formal component. This preserves the original structure of the objective and is consistent with the interpretation of rents as system-wide amenities for incumbents, but it delivers comparative statics that better match the theoretical predictions regarding regulation and enforcement.

The optimization problem for incumbent residents involves maximizing their consumption c_{it}, which depends on the population N_{it} and incorporates the effects of transportation costs, informal market risks, and enforcement. Inclusion of the informal market introduces nonlinear terms, such as the exponential decay of informal costs with distance ($e^{-\alpha x}$) and the enforcement parameter κ_{it}. These nonlinearities make it impossible to derive an exact analytical solution for N_{it}, and it is necessary to solve the optimization problem using numerical methods.

4.3.3 Population growth in presence of informal housing market

The central hypothesis of this work is that in developing countries, cities tend to be more urbanized than they should be given their levels of economic development (Schnore, 1961; Chen et al., 2014; Narayan, 2014; Tolley, 1988; Sovani, 1964; Fay and Opal, 2000b; Fox, 2012; Gollin et al., 2016) and that a key part of this "surplus" urbanization is derived from the existence of an alternative informal housing market, which functions as an adjustment mechanism that allows cities to grow beyond the absorptive capacity of their formal sectors (Brueckner et al., 2019b; Roy, 2005). In this section, the goal is to compare the outcome of the original model ($\widetilde{N_{it}}$) with the equilibrium population size (N_{it}) derived from the informal housing model.

Let $\widetilde{N_{it}}$ denote the optimal population size in the baseline model of Duranton and Puga (2019), which does not consider informality. It is given by:

$$\widetilde{N_{it}} = \left(\frac{\rho^{\sigma} \sigma(\gamma+1)}{\gamma+\theta} \frac{A_{it}(h_t)^{1+\sigma}}{\tau_t} \right)^{\frac{1}{\gamma+\theta-\sigma}} \tag{4.19}$$

The term $\widetilde{N_{it}}$ thus represents the size of the city driven solely by productivity, transportation costs, and income elasticity in a purely formal housing market. In contrast, the inclusion of informality introduces new forces that reshape the equilibrium size of the city.

The difference between the optimal population in the original model and the solution with a dual housing market can be expressed as follows:

$$\widehat{N_{it}} = N_{it} - \widetilde{N_{it}}. \tag{4.20}$$

The difference $\widehat{N_{it}}$ captures the effect of informality and enforcement on the optimal population size. This model introduces two additional forces:

- **Enforcement (κ_{it})**: Stronger enforcement discourages informal settlements, limiting the expansion of the city.
- **Regulation Costs (p_{it})**: Stricter regulations make the formal market less accessible, restricting population growth.

Regarding the spatial decay parameter α, its role is to determine how quickly informal costs decrease with distance from the city center. Although a higher α intensifies enforcement costs near the center (reducing informality locally), it also means that informal costs decrease faster in the periphery, which can either strengthen or mitigate the overall reduction in city size depending on enforcement and regulation levels.

Finally, the central hypothesis of this paper is that informality contributes to the abnormal growth of cities in developing countries. The expression $\widehat{N_{it}}$ quantifies this deviation, showing that in the absence of strong enforcement and regulation, informal markets expand the city beyond its purely formal equilibrium size.

Inclusion of informality and enforcement in the model provides a more nuanced understanding of urban growth in the context of developing countries. Although the original model predicts the size of the city based on productivity and transportation costs, this model highlights the role of institutional factors, such as enforcement and regulation, in shaping urban dynamics. The difference $\widehat{N_{it}}$ quantifies the trade-off between the formal and informal markets, providing information on the abnormal growth patterns observed in developing cities.

Given that the explicit expression form for the optimal city size N_{it} cannot be derived, I run a simulation scenario to compare the optimal population obtained with and without informality.

4.3.3.1 Simulation, numerical solution, and scenarios

The simulation uses elasticities from Duranton and Puga (2023). I set the short-term agglomeration elasticity at $\sigma \approx 0.045$ and the cost elasticities at $\gamma \approx 0.073$ and $\theta \approx 0.039$. For the remaining parameters, I follow common choices in quantitative urban work. I normalize the productivity of the total factor to $A = 1$. I also set $h = 1$ and interpret it as the level of human capital provided for workers; this fixes units and keeps comparisons transparent (Allen and Arkolakis, 2014; Duranton and Puga, 2015). Finally, I choose the transport frequency parameter τ so that the closed-form city size $\widetilde{N_{it}}$ is in a realistic range and the commuting responses are broadly consistent with empirical evidence on travel-time elasticities (Ahlfeldt et al., 2015).

For informality, I include enforcement $\kappa_{it} > 0$, a regulation cost $p_{it} > 0$, a spatial decay parameter $\alpha > 0$, and an informal capture share $\omega \in (0, 1]$ (the fraction of informal rents appropriated by incumbents). The spatial cut-off x^* is defined and operationalized in the model, and I treat it as an endogenous variable that depends on κ_{it} and α (see Appendix C.2).

Because the incumbent's objective contains exponential terms (from informal costs) and the cutoff between formal and informal use, there is no closed form for N_{it}. I solve the problem by one-dimensional global maximization over $N_{it} > 0$ (log-grid search plus golden section refinement). The baseline comparison uses $\tau = 0.30$, $\omega = 1.0$, $\alpha = 0.03$, and the Duranton and Puga (2019) elasticities above.

In the baseline, I hold ω, τ, and α fixed and let the enforcement κ_{it} and regulation p_{it} vary. I fix $\omega \in (0, 1]$ because it summarizes how much of the informal fringe rent is ultimately appropriated by incumbents through amenities; this is a structural allocation parameter and I do not want changes in appropriation to confound the comparison between N_{it} and $\widetilde{N_{it}}$. I fix τ as it captures transport technology and network frictions that move slowly with infrastructure and geography; keeping τ constant isolates institutional mechanisms from commuting technology. I also fix α, the spatial decay of informal costs, because it reflects administrative reach and urban form (how quickly informal penalties fade with distance), which are relatively persistent at the horizon I study. In contrast, I let κ_{it} (enforcement intensity) and p_{it} (regulatory cost) vary between scenarios to foreground the institutional component of urban dynamics: these are policy levers that directly shape the formal-informal margin. This design helps to understand the role of institutional parameters in the size of the city.

Given the variation of the institutional parameters, I analyze four scenarios.

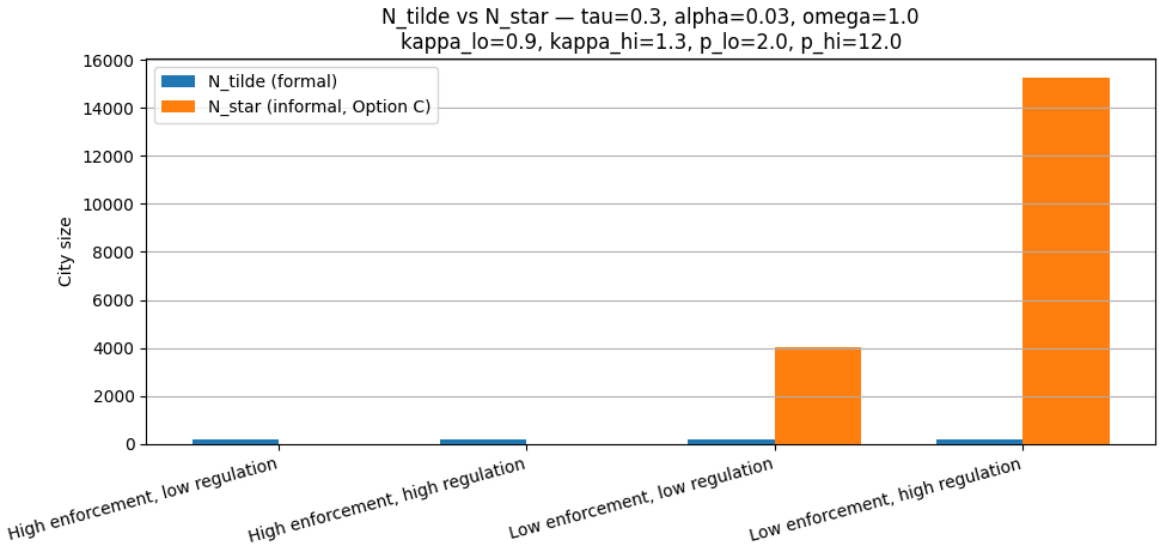
1. *High enforcement, low regulation*: κ high $\Uparrow$ - p_{it} low $\Downarrow$
2. *High enforcement, high regulation*: κ high $\Uparrow$ - p_{it} high $\Uparrow$
3. *Low enforcement, low regulation*: κ low $\Downarrow$ - p_{it} low $\Downarrow$
4. *Low enforcement, high regulation*: κ low $\Downarrow$ - p_{it} high $\Uparrow$.

I explicitly include a low-enforcement scenario ($\kappa_{it} < 1$) for reasons related to the mechanism of the model and its empirical relevance. First, institutional realism: In settings in developing countries, the enforcement is incomplete and heterogeneous (limited inspection capacity, monitoring costs, tolerance), so $\kappa_{it} < 1$ captures the gap between the rules in the books and their effective application. Second, equilibrium sensitivity: the model exhibits threshold behavior around $\kappa_{it} = 1$; small deteriorations in enforcement can trigger non-linear shifts in the indifference cutoff x^* (which collapses toward the center and tends to zero after imposing the admissible domain), expanding the informal fringe and increasing city size. Third, instrument comparison: this scenario allows us to contrast relaxing regulations (lower p_{it}) with strengthening enforcement (higher κ_{it}); the simulations show that relaxing rules without raising κ_{it} can expand informality, whereas increasing κ_{it} contracts it. Fourth, empirical calibration: $\kappa_{it} < 1$ reproduces stylized facts, wide informal belts, and asymmetric responses to reforms, facilitating the alignment of the model with the data. In the model, weak enforcement makes the informal option relatively cheaper at every location; the indifference cutoff x^* collapses toward the center, and the city becomes predominantly informal with no purely formal core (see Appendix C.3). Including $\kappa_{it} < 1$ is therefore essential both to mirror observed institutional frictions and to compare policy levers when the formal–informal margin is active.

For each scenario, I compute N_{it} and compare it with $\widetilde{N_{it}}$. Figure 4.3 shows the total population in four combinations of institutional parameters (κ, p_{it}). The results indicate that the intensity of enforcement is the key driver. When enforcement is low ($\kappa_{it} < 1$), the informal market becomes larger than the formal one, and the total size of the city exceeds the benchmark without housing duality. This effect is further amplified under high regulation (large p_{it}), which discourages the formal market

and incentivizes the informal margin, making the city substantially larger than in the other scenarios and than the formal benchmark $\widetilde{N_{it}}$ [4].

Figure 4.3: Four-scenario comparison: equilibrium city size with informality (N_{it}) versus the formal benchmark ($\widetilde{N_{it}}$) under high/low enforcement (κ_{it}) and high/low regulation (p_{it}).



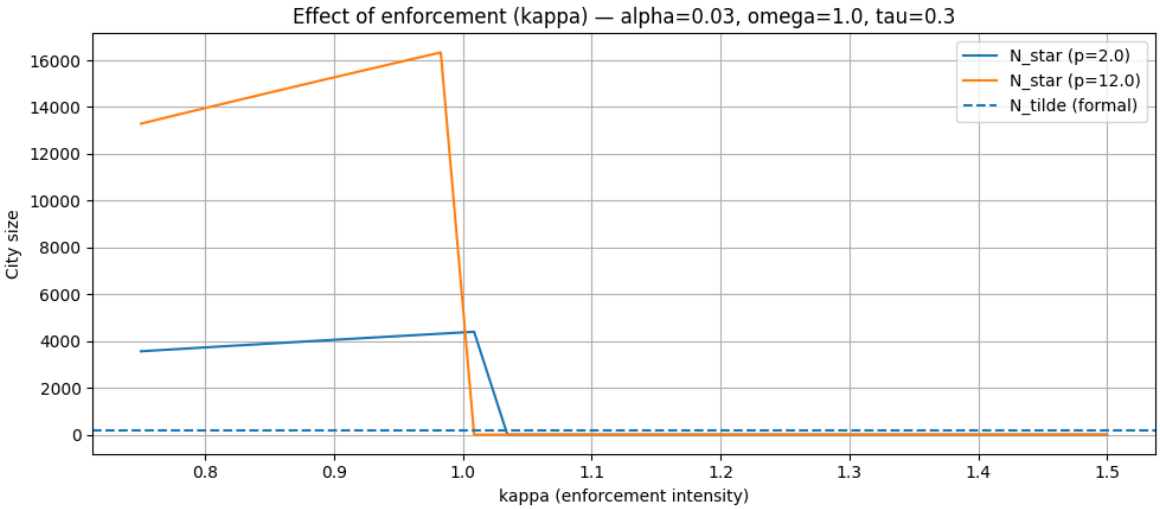
To better understand the effect of these institutional parameters, I vary them over plausible ranges and, under *ceteris paribus* assumption, how the population responds in different settings.

Fixing the baseline conditions, I then vary κ_{it} below and above one. Figure 4.4 shows that the population increases only when κ_{it} is low and that the effect is stronger under high regulation. When enforcement is sufficiently strong, so that informal entry becomes unattractive relative to regulation, the population converges to the formal benchmark in Duranton and Puga (2019). The boundary between formal and informal use also changes with regulation: Lower regulation pushes this boundary outward, requiring stronger enforcement to deliver the same outcome.

With high enforcement, $N_{it} < \widetilde{N_{it}}$ regardless of p_{it}; with low enforcement, low p_{it} may keep N_{it} near or above $\widetilde{N_{it}}$, while high p_{it} can generate a large informal fringe and $N_{it} \gg \widetilde{N_{it}}$ under the baseline calibration. This pattern is consistent with informality operating as an extensive-margin adjustment when regulation constrains the formal market.

[4] Robustness checks (varying α and ω) show that faster spatial decay (higher α) or lower appropriation from informality (lower ω) shrink the $N_{it}/\widetilde{N_{it}} > 1$ region, while the opposite expands it. The qualitative ranking of the four scenarios remains unchanged

Figure 4.4: Sensitivity of N_{it} to enforcement κ_{it} at low and high p_{it} (Horizontal line: $\widetilde{N_{it}}$).



Then I vary the regulation parameter (p_{it}). As expected, under high enforcement, the optimal population converges to the Duranton and Puga (2019) benchmark across the entire range of p_{it}. By contrast, with low enforcement the population rises as regulation costs increase. This pattern underscores the interaction of institutional levers: The "recipe" for a large city with a wide informal margin is high regulatory costs combined with weak enforcement.

At high κ_{it}, the increase p_{it} decreases N_{it} as the formal market tightens without a significant informal response. At low κ_{it}, higher p_{it} can raise N_{it} via the expansion of the informal fringe, pushing N_{it} above $\widetilde{N}$ under the baseline calibration.

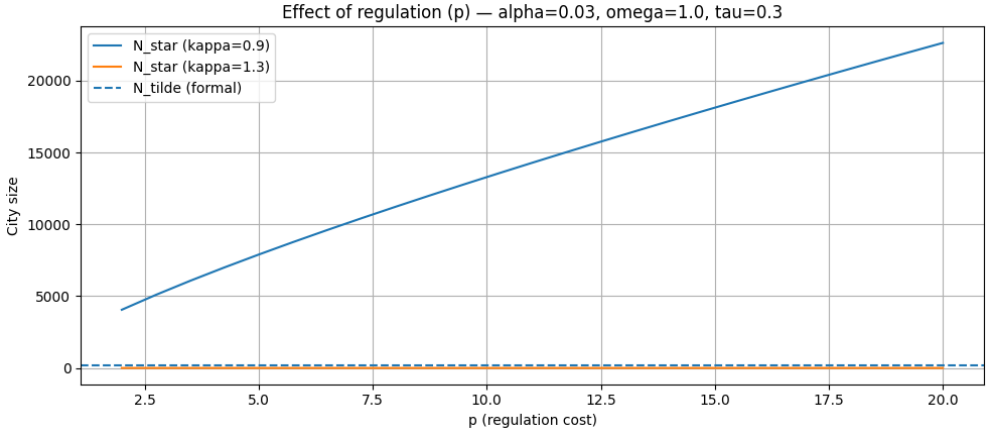


Figure 4.5: Sensitivity of N_{it} to regulation p_{it} at low and high κ_{it} (horizontal line: $\widetilde{N_{it}}$).

Under the baseline parameters, the simulations show that institutions drive the gap between the dual-market outcome and the formal benchmark. When the enforcement is high, $N_{it} \leq \widetilde{N_{it}}$ for all

p_{it}. When enforcement is low, the size of the city depends on regulation: with low p_{it}, N_{it} stays close to $\widetilde{N_{it}}$ but is still bigger; with high p_{it}, the informal fringe expands, and $N_{it} > \widetilde{N_{it}}$ significantly. The κ_{it} and p_{it} sweeps confirm this pattern. In robustness, a higher α (faster decay of informal costs) or a lower ω (less appropriation of informal rents) reduces the region where $N_{it} > \widetilde{N_{it}}$; the opposite expands it. I keep τ, ω, and α fixed and vary only κ_{it} and p_{it} to highlight the institutional channel.

4.4 Conclusions and policy implications

This paper extends the Duranton and Puga (2019) framework to a dual housing market and highlights the central role of institutions in shaping urban scale in developing countries. By introducing an informal housing segment with spatially decaying sanctions and a regulatory wedge in the formal market, the model delivers a clear mechanism: when enforcement is weak, the expected cost of informality remains low, regulation diverts marginal entrants toward informal locations, and cities expand beyond the formal benchmark. When enforcement is credible, the informal option becomes less attractive, informal entry is discouraged, and city size converges toward the outcome predicted by the formal market alone. In this setting, enforcement emerges as the main driver of urban outcomes, while regulation operates as a constraint that shapes the relative attractiveness of the formal sector.

The simulation results organize these forces into four scenarios that clarify their interaction. With high enforcement, city size remains at or below the formal benchmark ($N_{it} \leq \widetilde{N_{it}}$) across the full range of regulation costs. Under low enforcement, regulation has an asymmetric effect: when regulatory costs are low, the city remains close to the formal benchmark, but when regulation becomes more restrictive, the informal fringe expands and total city size exceeds the formal outcome. Sweeps over enforcement (κ_{it}) and regulation (p_{it}) confirm that these patterns are driven by the extensive margin of urban expansion. In the model, changes in productivity or transport technology play a secondary role compared to institutional conditions that govern the cost of informality and access to the formal market.

These results carry strong policy implications. Increasing the effective enforcement of land-use rules raises the expected cost of operating in the informal market and generates clear disincentives to informal settlement. In this sense, enforcement is not merely a complementary policy tool but a necessary condition for regulation to achieve its intended effects. At the same time, regulation matters because it defines the limits of the formal market: overly restrictive rules can constrain formal supply and push households toward informality when enforcement is weak. A third important dimension concerns the quality of the alternative use of land. In developing-country settings, this alternative is typically rural or peri-urban land use. Improving the returns and viability of alternative land uses raises the opportunity cost of informal urban occupation, reducing incentives for informal settlement at the urban fringe. In the model, this channel operates both by limiting the spatial expansion of the city and by shrinking the size of the informal market, which tends to locate precisely at the urban edge and directly competes with alternative land uses. By curbing excessive urban expansion, stronger alternatives also help mitigate the negative externalities associated with agglomeration economies, such as congestion and environmental pressure.

Finally, the model should be viewed as a flexible platform with substantial scope for extension. The current setup isolates the institutional channel by abstracting from other sources of heterogeneity, but relaxing these assumptions opens promising avenues for further research. Incorporating labor market informality would allow housing and employment decisions to be jointly determined, offering a richer account of urban inequality. Extending the framework to systems of cities or metropolitan areas would make it possible to capture spillover effects arising from inter-city interactions, which are especially relevant in developing-country contexts where municipalities are tightly interconnected. These

extensions would not only improve the realism of the model but also enhance its usefulness for evaluating integrated policies that combine land-use regulation, enforcement, and regional development strategies.

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Appendices

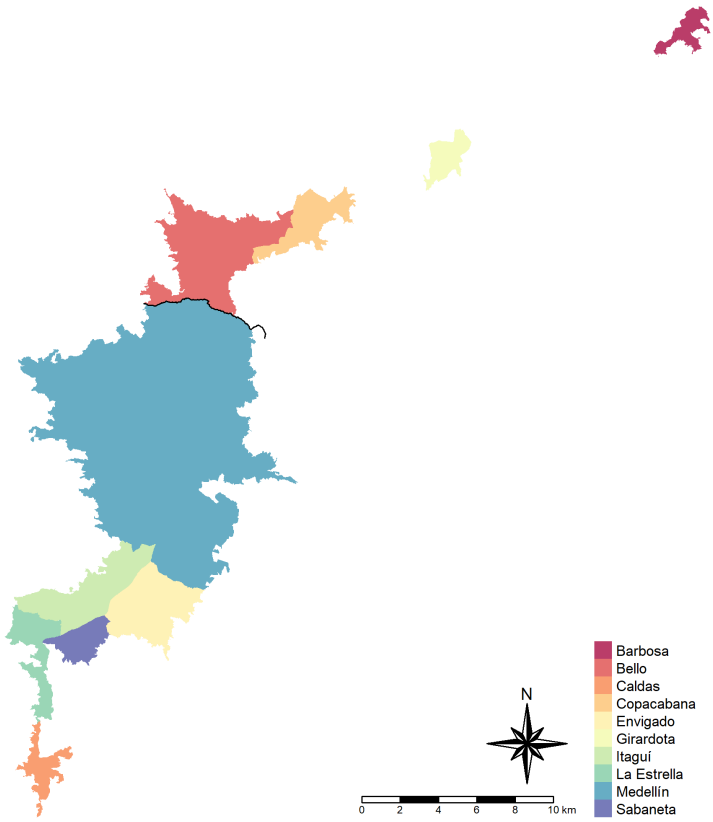
Appendix A

Appendix: Regulation and informal housing: Effects of urban building regulations on the proliferation of informal settlements

A.1 Supply-side dynamics of the housing market for Aburrá Valley municipalities

Medellín is the core municipality of the Metropolitan Area and, as can be seen in Figure A.1, it shares a border with three municipalities: Itagu, Envigado, and Bello. Despite Itagüí also having flexible regulation, we chose to work with Bello because the border with Itaguí is mostly for industrial use and this change in regulation was focused only on a certain type of low-cost public interest housing. We do not use Envigado because it also has restrictive urban regulations. So we take advantage of the normative change that was made in 2009 and the existence of continuous urban settlements between our two municipalities of study to isolate the effect of the regulation on the proliferation of informal settlements.

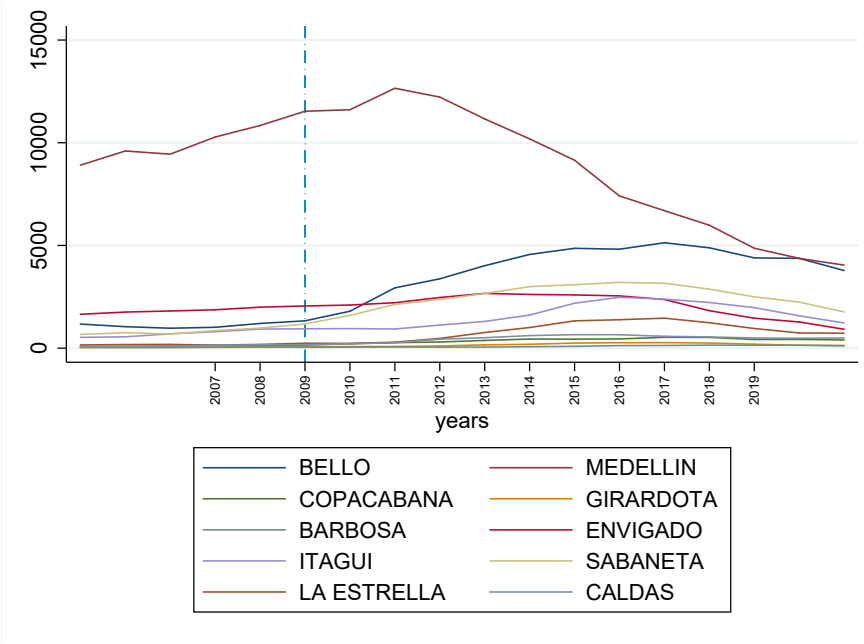
Figure A.1: Municipalities of the Aburrá Valley Metropolitan Area



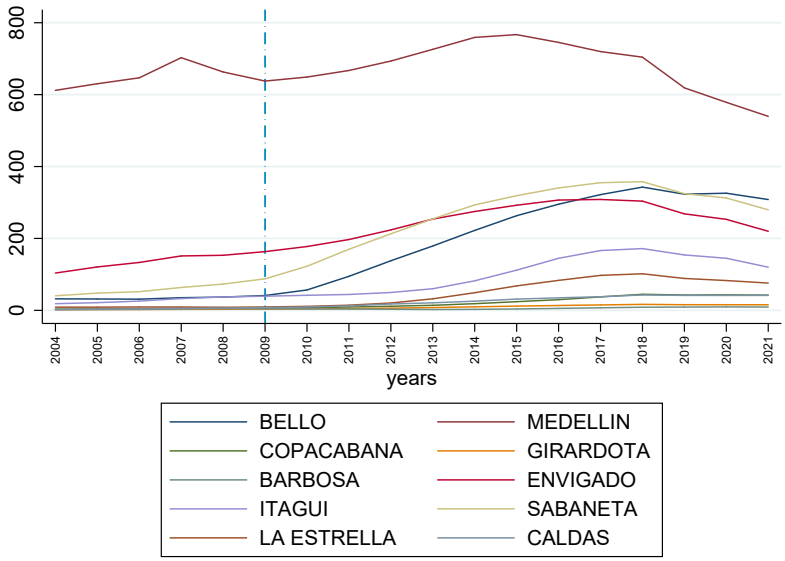
This trend is repeated in the municipalities of the Aburra Valley. Figures A.2a and A.2b show the results for all metropolitan municipalities. The neighboring municipalities of Bello in the north of the valley: Barbosa, Girardota and Copacabana have a lower construction sector dynamic, and, with the exception of Bello, the municipalities located in the North have restricted urban regulations. It is also important to highlight the case of the Sabaneta municipality, located in the south of the Valley, which, like Bello, made its land use planning regulations more flexible in 2009 to promote housing construction in its territory; this change also resulted in a significant increase in the number of housing units. In the case of Itagüí, located also in the south, this flexibilization occurred in an extraordinary change made in 2012 that allowed the urban expansion zone to be larger to encourage the construction of public housing (Gamboa Cataño and Londoño Restrepo, 2020) [1].

[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)*

Figure A.2: Supply of housing for Aburrá Valley municipalities



(a) New housing per unit



(b) New housing per area constructed

Note: The Aburrá Valley Metropolitan Area is comprised of 10 municipalities located along the valley created by the Medellín River. Medellín is the core city; Bello, Copacabana, Girardota and Barbosa, in that order, are located in the North of the city; Envigado, Itagüí, Sabaneta, La Estrella and Caldas are located in the south of the city

A.2 Regulation indicator for Medellín - Bello

Table A.1: Extract Regulation Indicator Database

	Municipality	Clasification	IC	AM
1	Bello	Conservation	1.7	4
2	Bello	Consolidation	2.5	35
4	Bello	Default	3.3	35
5	Bello	Development	2.6	39
6	Bello	Improvement	1.9	12
7	Bello	Renovation	3.2	47
8	Medellin	Conservation	NA	NA
9	Medellin	Consolidation	2.3	3
10	Medellin	Default	4.2	5
11	Medellin	Development	0.5	7
12	Medellin	Improvement	NA	2
13	Medellin	Renovation	3.2	5

Note: The classification column represents the different "treatments" the regulation defines. The IC column is the construction index and the AM column is the maximum high allowed. Both values are means of the indicator for the polygons, group by treatment

A.3 Informal settlements indicator

A.3.1 Difficulties of access to water and basic sanitation services

The data collected by the census determines whether households have access to water, sewerage, and basic sanitation services. The indicator becomes 1 if the household does not have access to any of these basic services.

A.3.2 Housing density

For this case, we use the criteria in the methodology designed by Colombia (2009) to establish quantitative housing deficits. Two measures are identified, one corresponding to cohabitation and the other 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 determined by dividing the "number of people in the household" by the number of "rooms in which people sleep" and is overcrowded when more than three people are sleeping per room. Inadequate housing density is considered when cohabitation or overcrowding exists in the household.

A.3.3 Lack of structural quality in the dwelling

The housing unit is considered low quality when its walls or floor do not correspond to the 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. Walls 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, or some other type of vegetable material or when there are no walls at all. For floors when the predominant material is earth or sand.

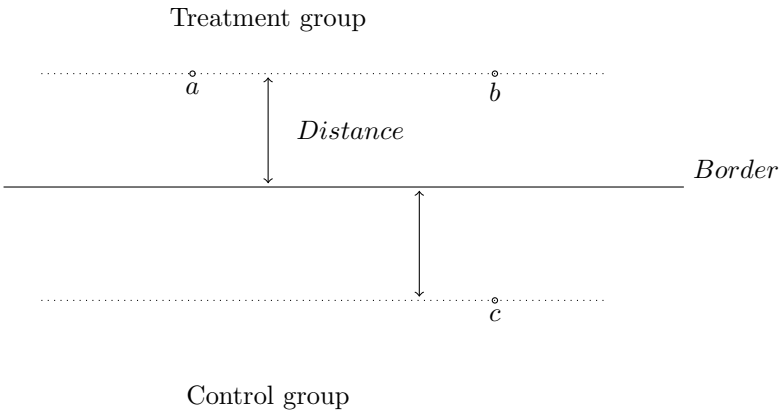
A.3.4 Insecurity of tenure.

This criterion is fundamental. However, capturing the actual information is complex. The surveys that inquire about the condition of legal ownership of housing are not sufficiently representative or are not geo-referenced. 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 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.

A.4 GeoRDD: distance-only vs. two-dimensional location

With RDD designs where the allocation corresponds to a geographical boundary, a common approach is one that we will call a *simple model*, in which the score corresponds to the distance to the nearest point on the boundary, making it possible for the allocation function to become a scalar. No matter how long the border is, units close to it are comparable. This version of the identification strategy is equivalent to a simple RDD, where the shortest distance to the border is the score or running variable. This approach is useful and provides a relatively consistent estimate of the average local effect. The simple model can work well for some applications, primarily when the interest is focused on the average effect along the boundary (Zajonc, 2012).

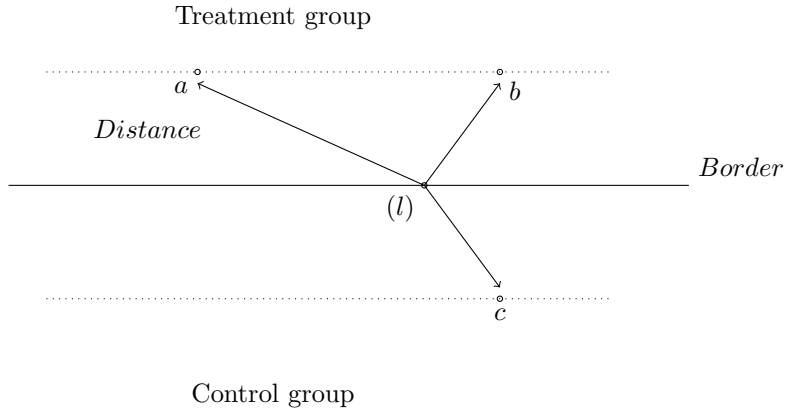
Figure A.3: Simple model representation



Notes: This graph was constructed using as reference the one contained in the work made by Keele and Titiunik (2015). The a, b, and c dots represent units of analysis. All of them are at the same distance from the nearest point of the border

Despite the advantage of the *simple model*, an estimation using this strategy could be biased. As can be seen in Figure A.3, you could end up comparing units that are not similar between them, but are located at the same distance from the border. This violated the continuity assumption of basic RDD designs and the underlying idea of making the estimation using comparable observations. Running a *simple model* could lead to understanding that unit c is as good contrafactual to unit as a, which is not.

Figure A.4: Propose model representation



Notes: The (l) represents one of the dots that will be used in the estimation

So, the spatial RDD is closer to a situation where a double allocation rule is present. As Keele and Titiunik (2015) pointed out, treating spatial RDD as a standard model with two running variables (latitude and altitude) is necessary to avoid biased estimation. This approach provides numerous opportunities: unlike other cases of RDD with double allocation, when considering 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 pretreatment analysis using the 2005 Census data; ii) the sensitivity of the model to different distance measurements, and iii) the spatial variation in treatment effects.

A.5 Assumption validation results

Table A.2: Assumptions validation results for GeoRDD

Segments	Balance proportion	McCrary pvalue	Valid
Border	0.833	0.695	Yes
Border1	0.667	0.105	Yes
Border3	0.75	0.067	Yes
Border4	0.583	0.657	Yes
P02	0.833	0.198	Yes
P03	0.833	0.077	Yes
P04	0.75	0.212	Yes
P05	0.667	0.64	Yes
P06	0.583	0.607	Yes
P07	0.667	0.612	Yes
P08	0.667	0.706	Yes
P09	0.75	0.267	Yes
P10	1	0.106	Yes
P11	1	0.112	Yes
P12	0.917	0.446	Yes
P13	0.833	0.408	Yes
P14	0.833	0.419	Yes
P15	0.833	0.317	Yes
P16	0.75	0.911	Yes
P17	0.667	0.12	Yes
P18	0.583	0.068	Yes
P20	0.917	0.093	Yes
P21	1	0.269	Yes
P22	0.917	0.791	Yes
P23	0.667	0.16	Yes
P24	0.583	0.839	Yes
P25	0.5	0.293	Yes
P26	0.75	0.118	Yes
P30	0.5	0.702	Yes
P31	0.583	0.331	Yes
P32	0.833	0.384	Yes
P33	0.917	0.807	Yes
P34	0.917	0.234	Yes
P35	0.75	0.235	Yes

Notes: The Second column indicates the proportion of co-variables that are balanced for each segment. The third one presents the p-value result for McCrary tests. Variables that are more than 50 percent balance and fulfill McCrary tests are used for the analysis

A.6 Balance test estimation

Table A.3: Balance test along the border

Variable	Treated	Control	Difference
N household	48.566	45.11	3.456
Commerce	1.028	1.073	-0.045
Habs.	152.015	143.351	8.664
Unemployment	0.14	0.106	0.035***
Education	11.319	10.947	0.371*
Boss education	11.212	10.935	0.277
Can read	0.948	0.957	-0.008
Accesibility	-10.175	-10.153	-0.021
Com. access.	-45.291	-40.987	-4.304
Population density	0.07	0.085	-0.015
Household density	0.022	0.026	-0.004

Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Table A.4: Balance test for segments

	Border 1		
Variable	Treated	Control	Difference
N household	48.518	60.47	-11.952
Commerce	0.234	0.531	-0.296
Habs.	147.65	185.592	-37.943
Unemployment	0.131	0.105	0.026
Education	12.008	11.988	0.019
Boss education	12.326	11.931	0.395
Can read	0.947	0.961	-0.014**
Accesibility	-10.068	-9.711	-0.357**
Com. access.	-68.681	-84.684	16.003
Population density	0.058	0.092	-0.034***
Household density	0.019	0.029	-0.01**

Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

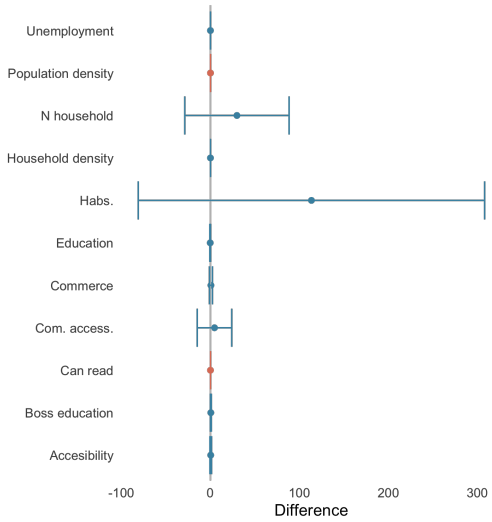
Variable	Border 3 Treated	Control	Difference
N household	87.202	43.007	44.195**
Commerce	1.087	0.452	0.635
Habs.	248.638	124.548	124.09**
Unemployment	0.075	0.087	-0.012
Education	14.127	13.485	0.642**
Boss education	14.458	14.239	0.219
Can read	0.963	0.96	0.004
Accesibility	-9.696	-9.929	0.233
Com. access.	-45.564	-7.717	-37.847
Population density	0.028	0.047	-0.02
Household density	0.01	0.019	-0.01

Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

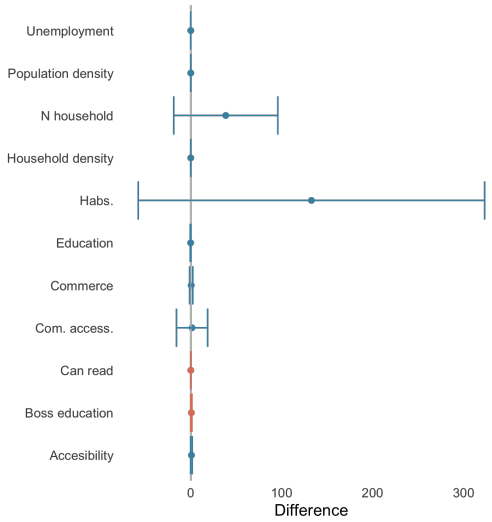
Variable	Border 4 Treated	Control	Difference
N household	50.478	67.308	-16.83
Commerce	1.037	0.233	0.805*
Habs.	152.826	191.543	-38.717
Unemployment	0.084	0.092	-0.008
Education	13.947	12.97	0.977***
Boss education	14.324	13.33	0.993***
Can read	0.963	0.964	0
Accesibility	-9.753	-9.675	-0.078
Com. access.	-49.981	-88.362	38.381*
Population density	0.032	0.084	-0.052***
Household density	0.011	0.03	-0.019***

Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Figure A.5: Balance test for dots



(a) P 02



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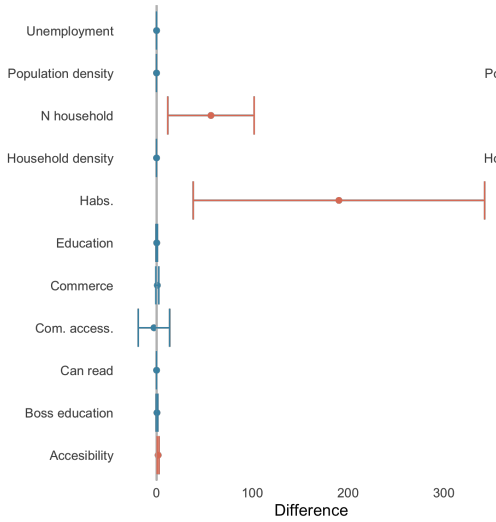
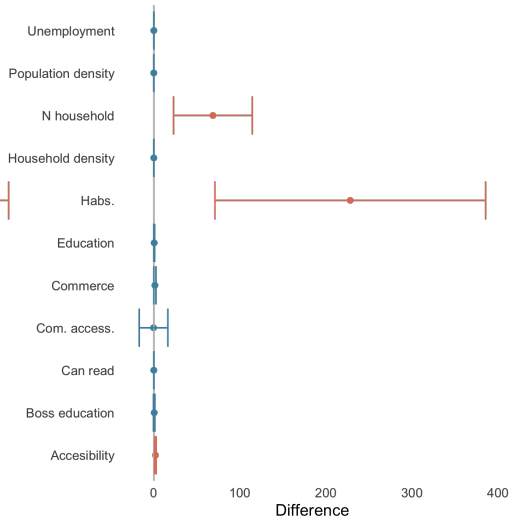
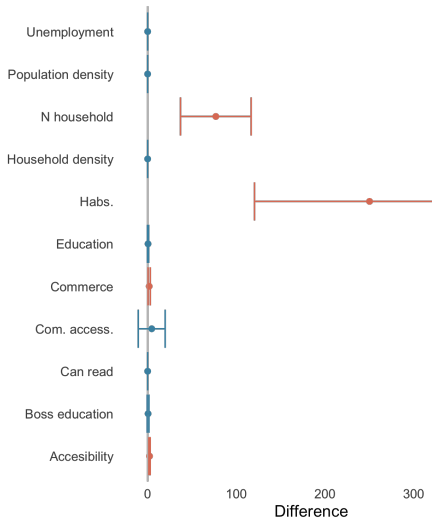


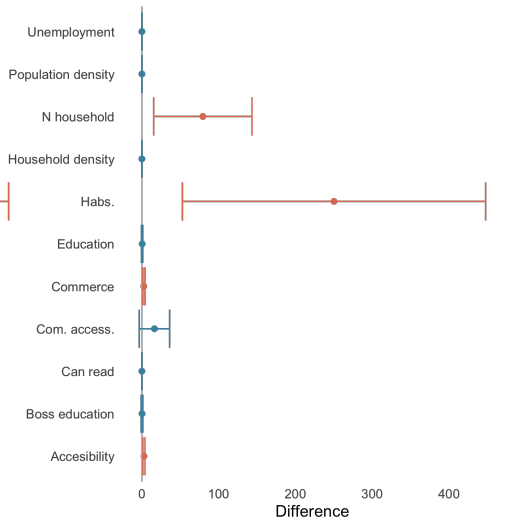
(c) P 04



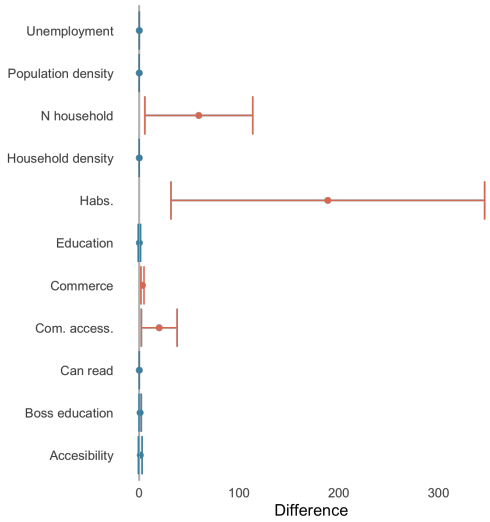
(d) P 05



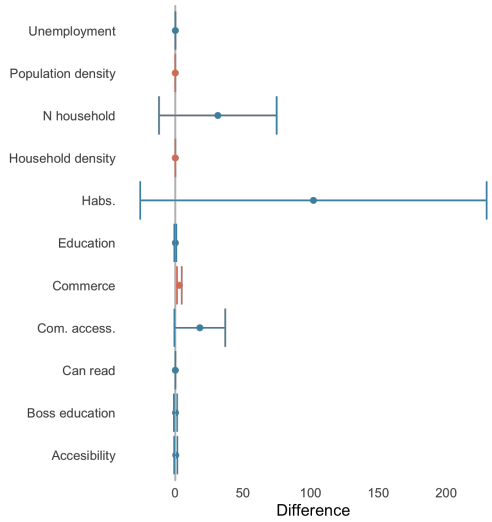
(e) P 06



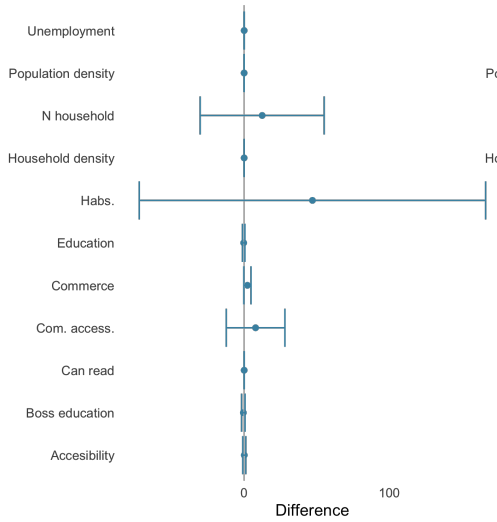
(f) P 07



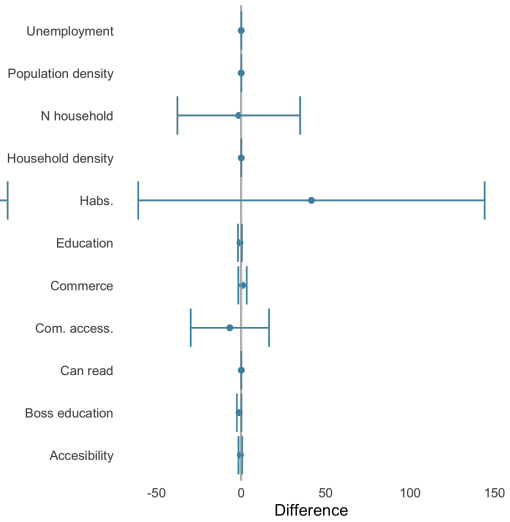
(a) P 08



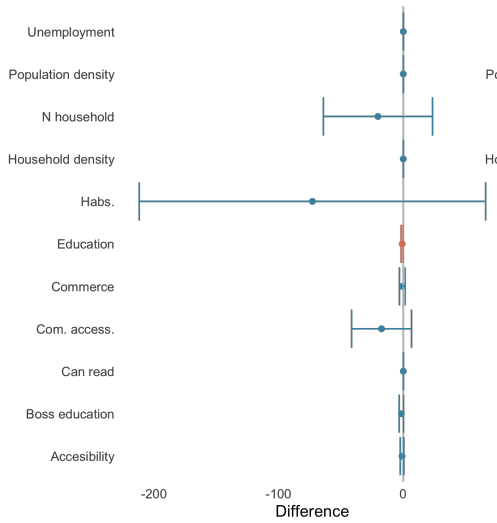
(b) P 09



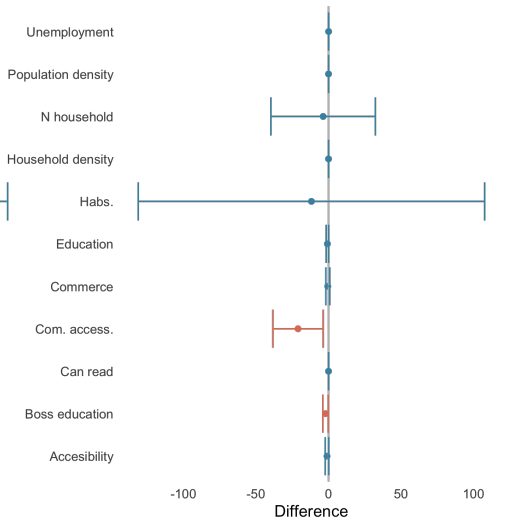
(c) P 10



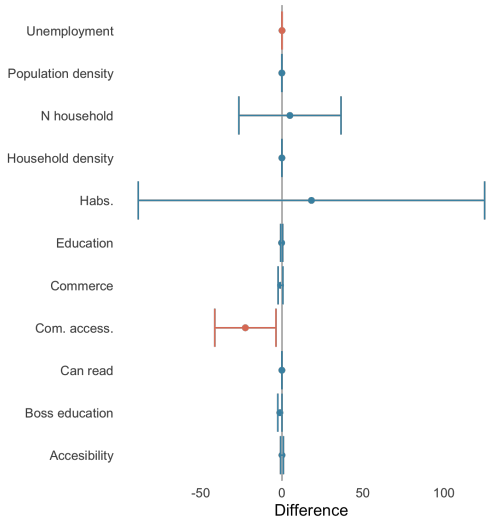
(d) P 11



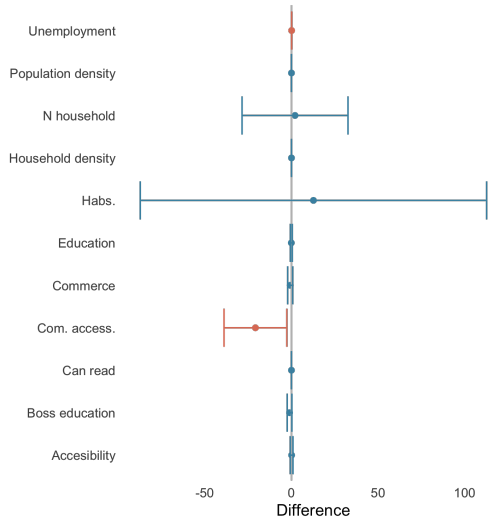
(e) P 12



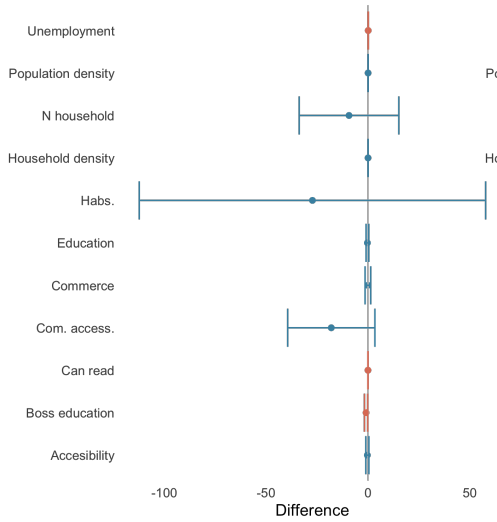
(f) P 13



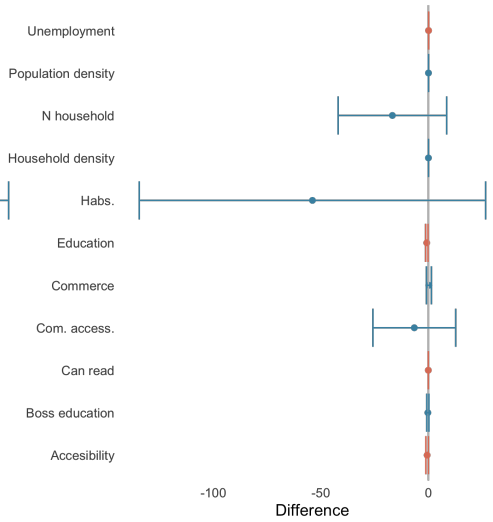
(a) P 14



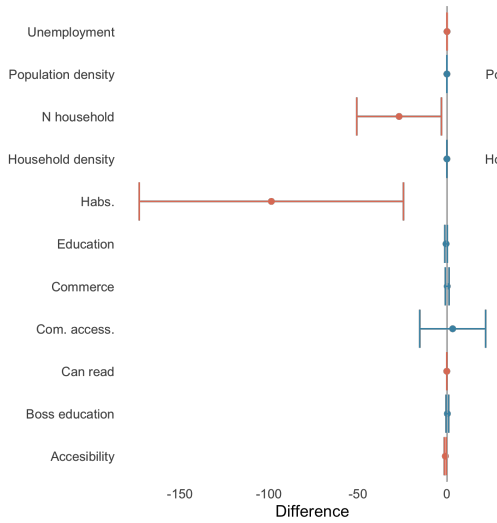
(b) P 15



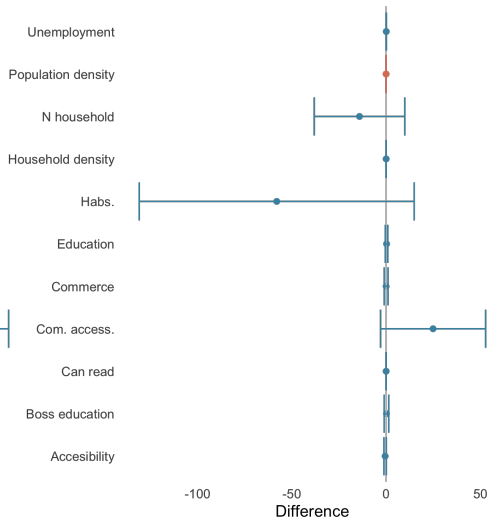
(c) P 16



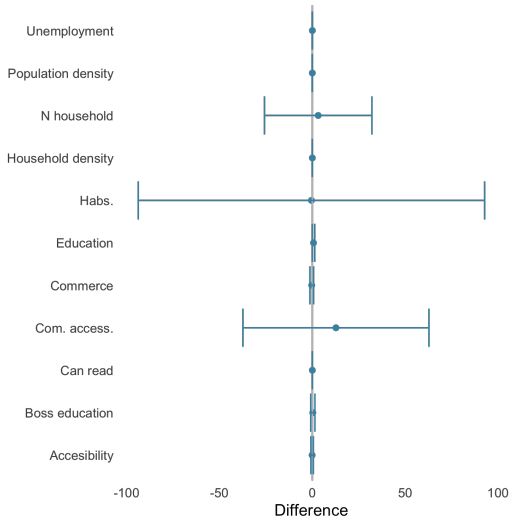
(d) P 17



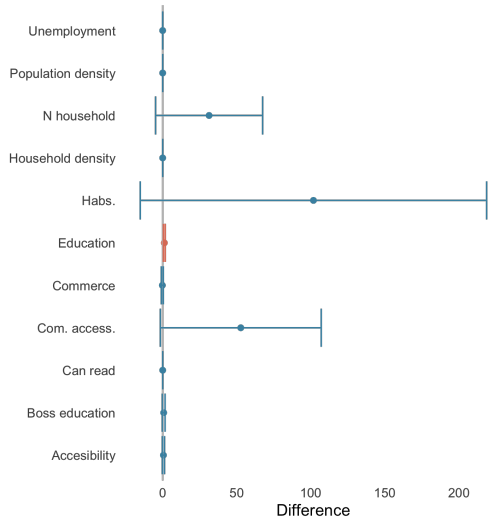
(e) P 18



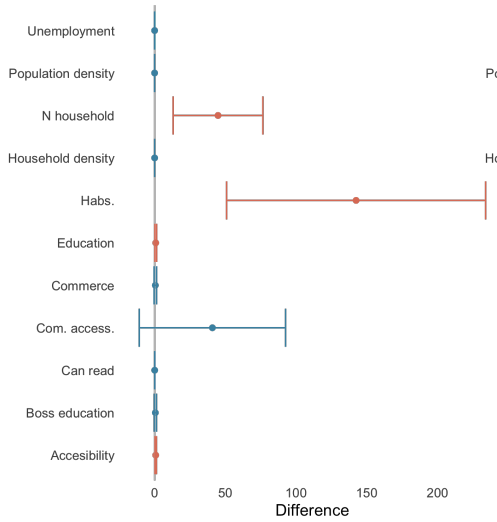
(f) P 20



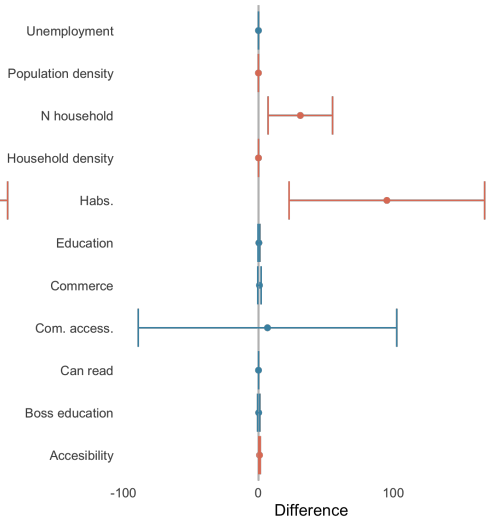
(a) P 21



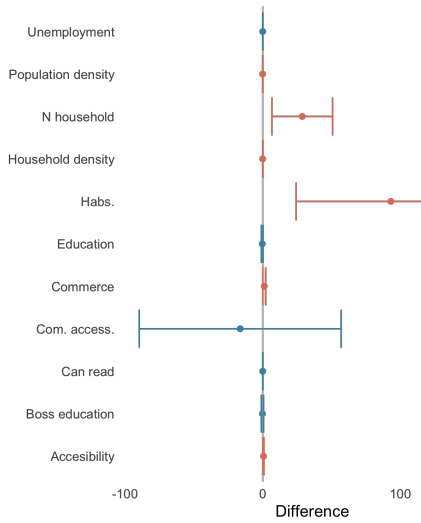
(b) P 22



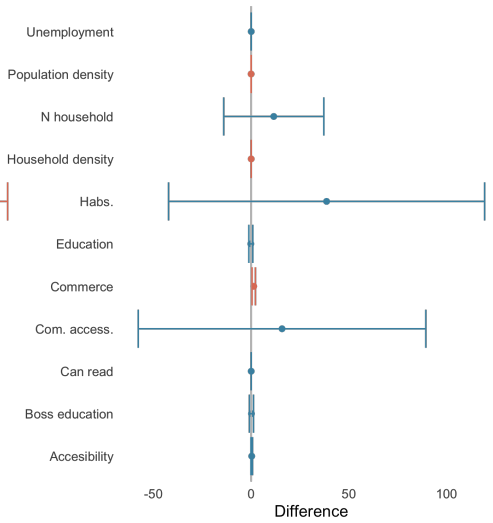
(c) P 23



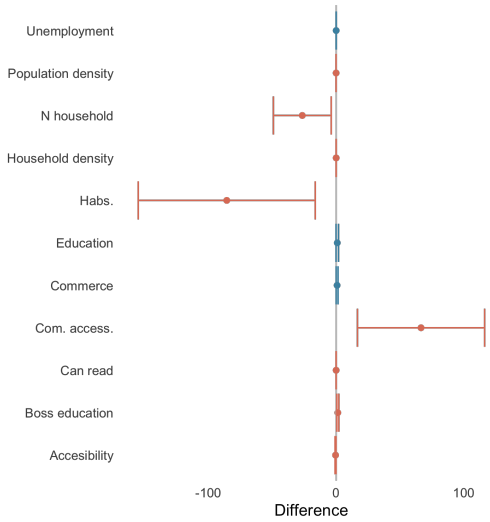
(d) P 24



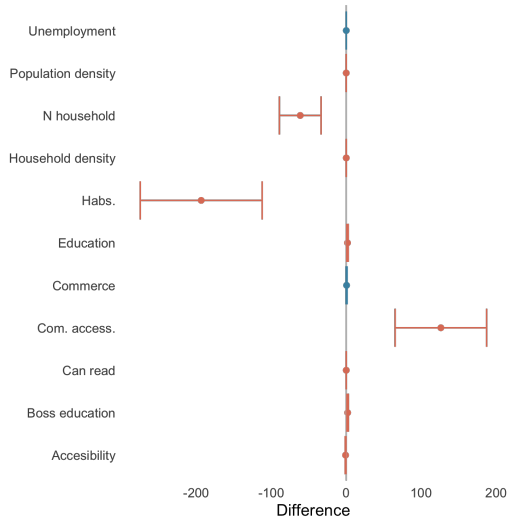
(e) P 25



(f) P 26



(a) P 27



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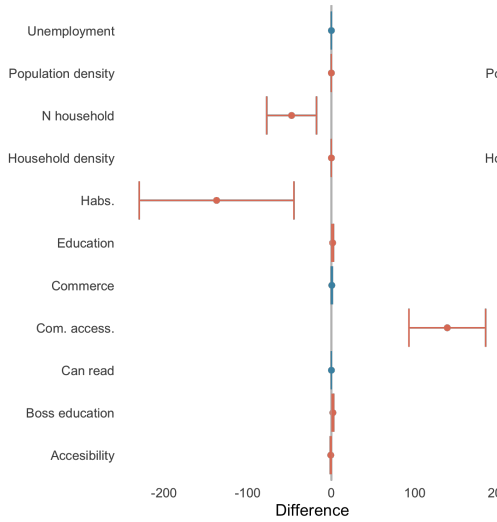
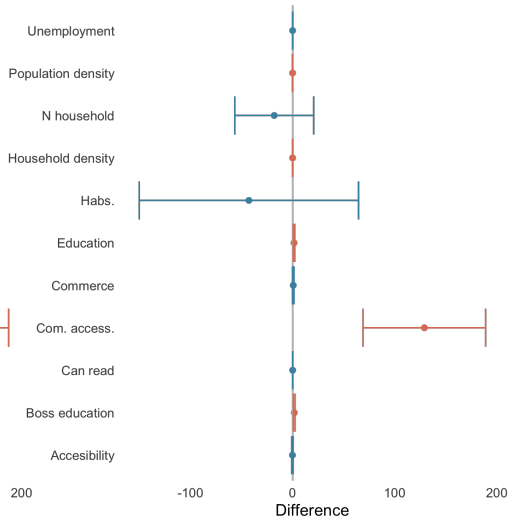
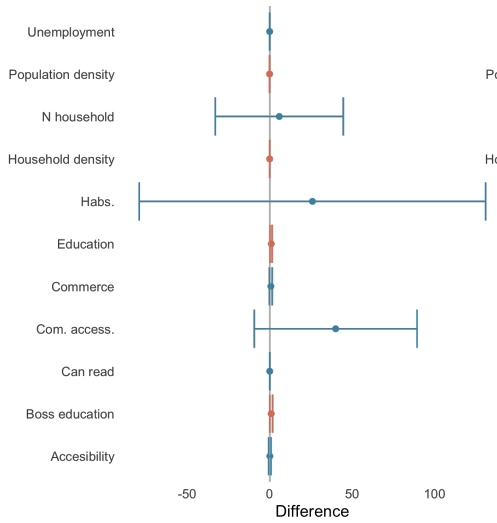


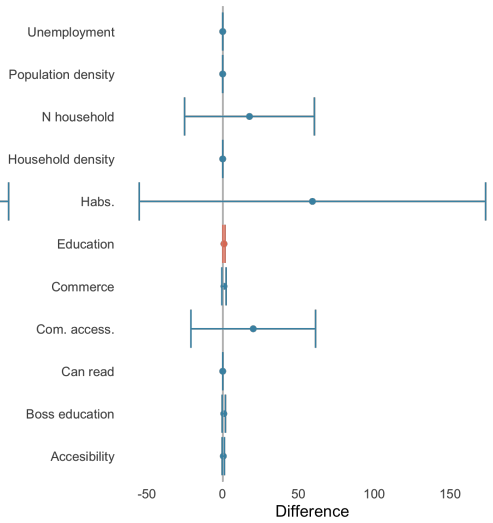
(c) P 29



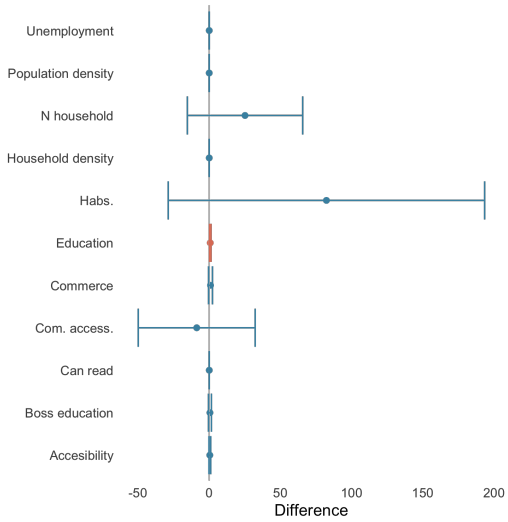
(d) P 30



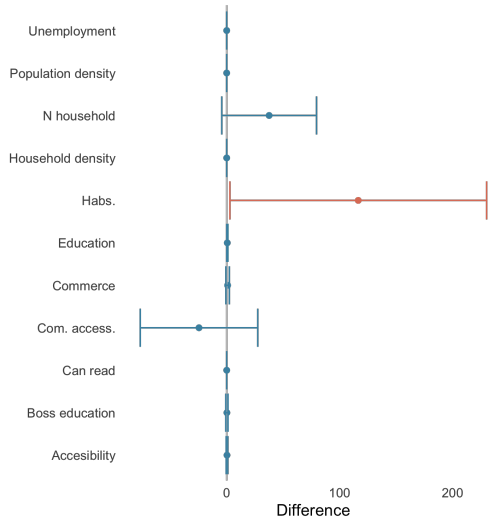
(e) P 31



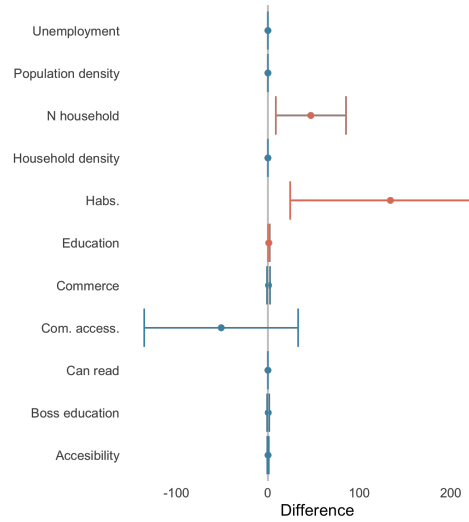
(f) P 32



(a) P 33



(b) P 34



(c) P 35

A.7 Aggregate municipality results: differences in differences estimation

We conduct a difference-in-difference analysis to see the behavior over time of the informal settlement indicator. The idea is to see if there are differences between the municipalities after and before the change in the regulation that was made for Bello [2009]. To do so we use data from Gran Encuesta Ingrada de hogares [GEIH]. Table A.5 shows results for the difference-in-difference analysis with and without fixed effects at the section level [2].

The municipality with more flexible regulations has a lower prevalence of informal settlements. The effect is given by the variables corresponding to floor quality (*floor*), sewerage (*sanitation*), aqueduct (*water*) and irregular tenure condition (*tenure*). This preliminary approach lets us think that the *economic welfare perspective* does not apply to the analyzed context. If strict regulations gave more tools for controlling negative externalities, such as informal settlements, we would expect Medellín to have lower levels than Bello. One alternative option could be that the municipality's levels of enforcement would mitigate the effect of these regulations. However, this hypothesis could not be plausible, given that Medellín has higher legal and institutional enforcement levels than Bello as we show before in Table **??**.

Table A.5: Differences in differences regression

	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

The *exclusionary purpose* seems to predominate. More restrictive regulations translate into a greater proliferation of informal settlements as they imply a constraint in the formal market and a consequent cost increase. It is 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.

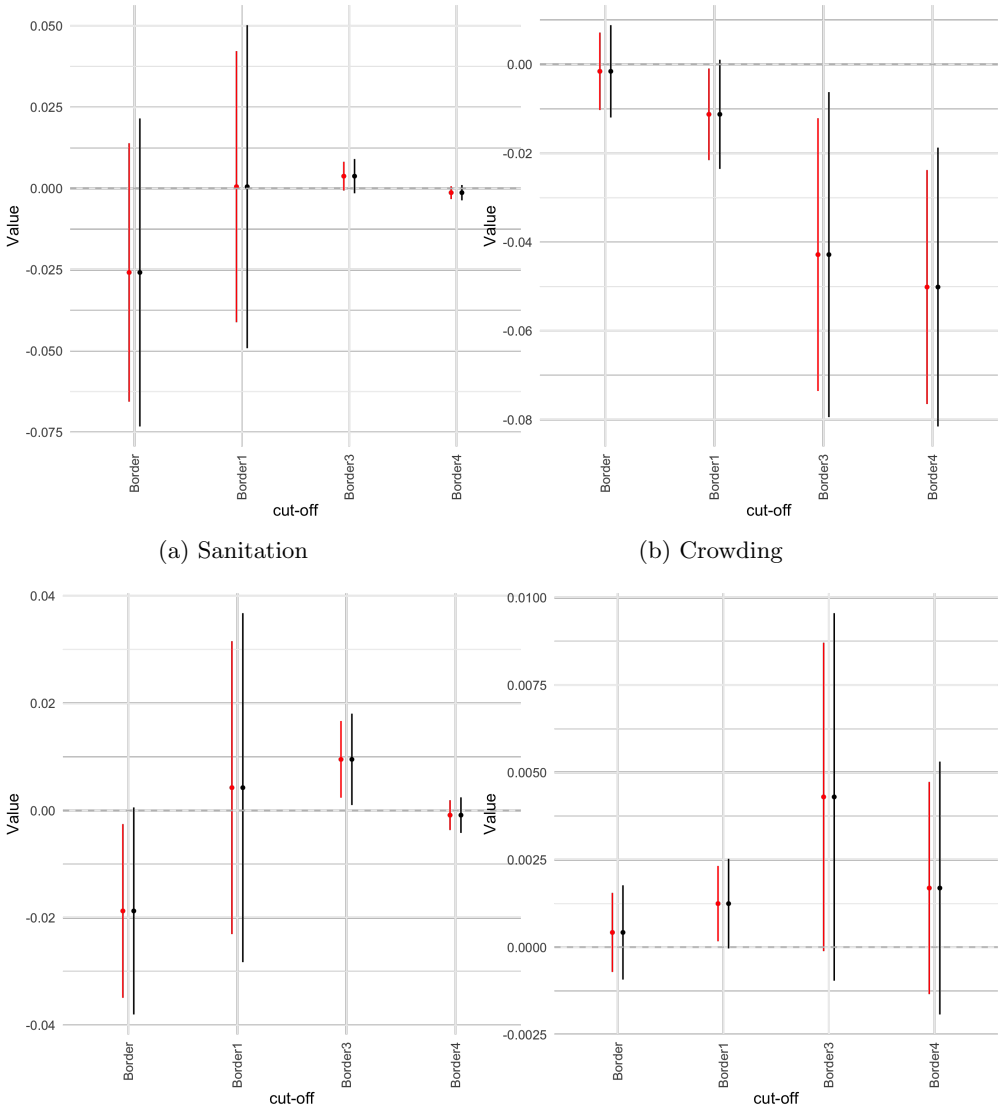
The GEIH provides us with data over time. However, we have some representativeness limitations with the data analyzed. Although the GEIH uses a probabilistic, stratified, clustered, and multistage sampling system, it's representative at the metropolitan area level. For this analysis, the treatment assignment units correspond to municipalities that belong to the same metropolitan area.

Given that the mechanism is unclear and we have limitations with the Diff-Diff approach, our preferred specification is the GeoRDDD to clarify the effect.

[2] Section is an aggrupation of blocks and its definition is close to the neighborhood concept

A.8 Estimation results for alternative measures

Figure A.11: Decompose informal housing indicator
RDD results for segments



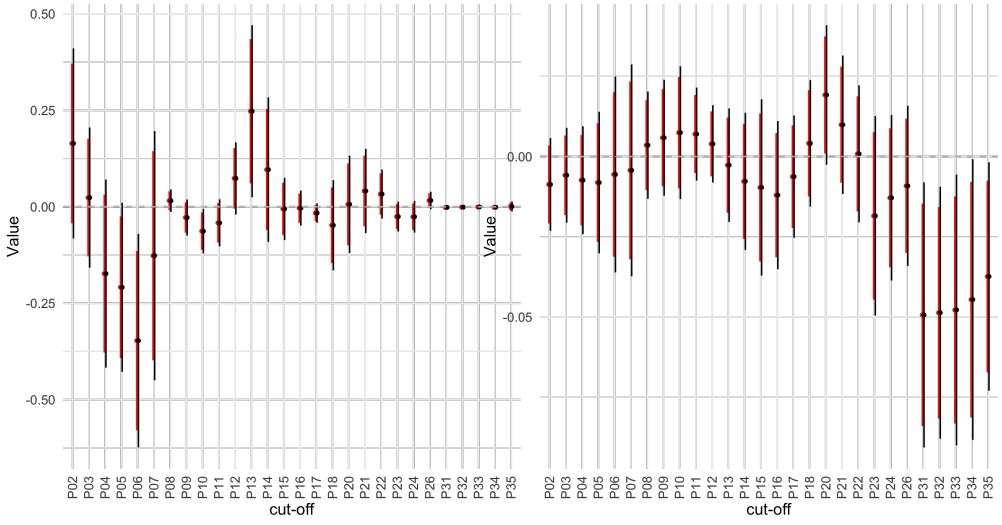
(a) Sanitation

(b) Crowding

(c) Walls

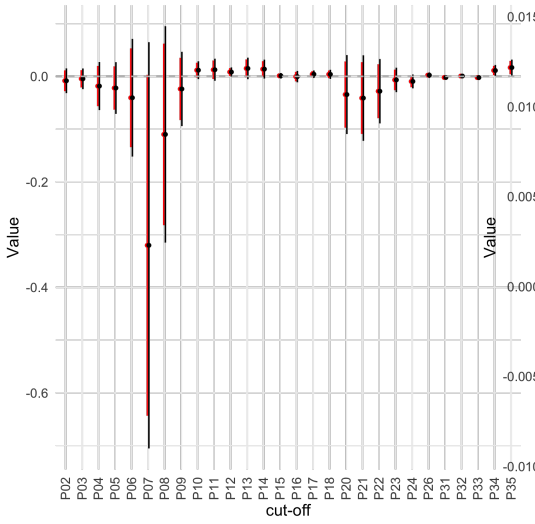
(d) Precarious house

Figure A.12: Decompose informal housing indicator
RDD results for dots

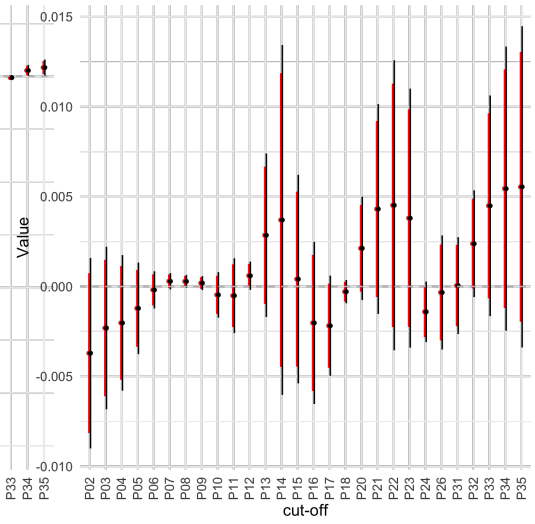


(a) Sanitation

(b) Crowding



(c) Walls



(d) Precarious house

A.9 Estimation results

Table A.6: RDD estimation results for segments

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
	Bias-Corrected	-0.057**	-0.002	-0.019**	-0.026	0
		(0.023)	(0.005)	(0.009)	(0.019)	(0.001)
Border	Conventional	-0.051**	-0.003	-0.016*	-0.022	0.001
		(0.023)	(0.005)	(0.009)	(0.019)	(0.001)
	Robust	-0.057**	-0.002	-0.019*	-0.026	0
		(0.028)	(0.005)	(0.01)	(0.024)	(0.001)
	Bias-Corrected	0.001	-0.011**	0.004	0.001	0.001
		(0.024)	(0.005)	(0.013)	(0.02)	(0.001)
Border1	Conventional	-0.004	-0.011**	0.003	0	0.001
		(0.024)	(0.005)	(0.013)	(0.02)	(0.001)
	Robust	0.001	-0.011*	0.004	0.001	0.001*
		(0.03)	(0.006)	(0.017)	(0.025)	(0.001)
	Bias-Corrected	-0.059**	-0.043***	0.01***	0.004**	0.004*
		(0.029)	(0.015)	(0.002)	(0.002)	(0.002)
Border3	Conventional	-0.062**	-0.038**	0.004**	0.002	0.003
		(0.029)	(0.015)	(0.002)	(0.002)	(0.002)
	Robust	-0.059*	-0.043**	0.01**	0.004	0.004
		(0.034)	(0.019)	(0.004)	(0.003)	(0.003)
	Bias-Corrected	-0.05**	-0.05***	-0.001	-0.001	0.002
		(0.021)	(0.014)	(0.001)	(0.001)	(0.002)
Border4	Conventional	-0.042**	-0.045***	0	0	0.001
		(0.021)	(0.014)	(0.001)	(0.001)	(0.002)
	Robust	-0.05**	-0.05***	-0.001	-0.001	0.002
		(0.023)	(0.016)	(0.002)	(0.001)	(0.002)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Table A.7: RDD estimation results for dots

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
	Bias-Corrected	0.124	-0.009	-0.008	0.164	-0.004
		(0.12)	(0.006)	(0.01)	(0.118)	(0.002)
P02	Conventional	0.1	-0.009	-0.006	0.142	-0.003
		(0.12)	(0.006)	(0.01)	(0.118)	(0.002)
	Robust	0.124	-0.009	-0.008	0.164	-0.004
		(0.129)	(0.007)	(0.012)	(0.126)	(0.003)
	Bias-Corrected	-0.008	-0.006	-0.005	0.024	-0.002
		(0.087)	(0.006)	(0.009)	(0.081)	(0.002)
P03	Conventional	-0.016	-0.007	-0.005	0.02	-0.002
		(0.087)	(0.006)	(0.009)	(0.081)	(0.002)
	Robust	-0.008	-0.006	-0.005	0.024	-0.002
		(0.099)	(0.008)	(0.01)	(0.093)	(0.002)
	Bias-Corrected	-0.254∗	-0.007	-0.018	-0.173	-0.002
		(0.136)	(0.007)	(0.02)	(0.111)	(0.002)
P04	Conventional	-0.225∗	-0.007	-0.016	-0.15	-0.002
		(0.136)	(0.007)	(0.02)	(0.111)	(0.002)
	Robust	-0.254∗	-0.007	-0.018	-0.173	-0.002
		(0.153)	(0.009)	(0.023)	(0.124)	(0.002)
	Bias-Corrected	-0.302∗∗	-0.008	-0.022	-0.209∗∗	-0.001
		(0.13)	(0.009)	(0.022)	(0.103)	(0.001)
P05	Conventional	-0.283∗∗	-0.008	-0.021	-0.195∗	-0.001
		(0.13)	(0.009)	(0.022)	(0.103)	(0.001)
	Robust	-0.302∗∗	-0.008	-0.022	-0.209∗	-0.001
		(0.14)	(0.011)	(0.025)	(0.112)	(0.001)
	Bias-Corrected	-0.489∗∗∗	-0.006	-0.041	-0.347∗∗∗	0
		(0.149)	(0.013)	(0.052)	(0.133)	(0)
P06	Conventional	-0.46∗∗∗	-0.007	-0.038	-0.325∗∗	0
		(0.149)	(0.013)	(0.052)	(0.133)	(0)
	Robust	-0.489∗∗∗	-0.006	-0.041	-0.347∗∗	0
		(0.158)	(0.016)	(0.057)	(0.141)	(0.001)
	Bias-Corrected	-0.382∗∗∗	-0.004	-0.32∗	-0.127	0∗∗∗
		(0.135)	(0.014)	(0.188)	(0.144)	(0)
P07	Conventional	-0.331∗∗	-0.003	-0.303	-0.108	0
		(0.135)	(0.014)	(0.188)	(0.144)	(0)
	Robust	-0.382∗∗	-0.004	-0.32	-0.127	0
		(0.154)	(0.017)	(0.197)	(0.165)	(0)
	Bias-Corrected	-0.056	0.004	-0.11	0.016	0∗∗∗
		(0.093)	(0.007)	(0.098)	(0.013)	(0)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
P08	Conventional	-0.069	0.002	-0.104	0.002	
		(0.093)	(0.007)	(0.098)	(0.013)	
	Robust	-0.056	0.004	-0.11	0.016	0
		(0.104)	(0.009)	(0.105)	(0.015)	(0)
	Bias-Corrected	-0.063	0.006	-0.024	-0.028	0***
		(0.041)	(0.008)	(0.031)	(0.022)	(0)
P09	Conventional	-0.069*	0.005	-0.023	-0.032	
		(0.041)	(0.008)	(0.031)	(0.022)	
	Robust	-0.063	0.006	-0.024	-0.028	0
		(0.045)	(0.009)	(0.036)	(0.024)	(0)
	Bias-Corrected	-0.036	0.007	0.012**	-0.063**	0
		(0.028)	(0.009)	(0.005)	(0.028)	(0)
P10	Conventional	-0.031	0.007	0.008	-0.057**	0
		(0.028)	(0.009)	(0.005)	(0.028)	(0)
	Robust	-0.036	0.007	0.012	-0.063**	0
		(0.031)	(0.011)	(0.009)	(0.03)	(0.001)
	Bias-Corrected	-0.02	0.007	0.013	-0.042	-0.001
		(0.025)	(0.007)	(0.008)	(0.025)	(0.001)
P11	Conventional	-0.022	0.005	0.008	-0.033	-0.001
		(0.025)	(0.007)	(0.008)	(0.025)	(0.001)
	Robust	-0.02	0.007	0.013	-0.042	-0.001
		(0.032)	(0.007)	(0.011)	(0.031)	(0.001)
	Bias-Corrected	0.061	0.004	0.008**	0.074*	0.001***
		(0.044)	(0.006)	(0.003)	(0.044)	(0)
P12	Conventional	0.049	0.002	0.005	0.067	0
		(0.044)	(0.006)	(0.003)	(0.044)	(0)
	Robust	0.061	0.004	0.008*	0.074	0.001
		(0.048)	(0.006)	(0.005)	(0.048)	(0)
	Bias-Corrected	0.245**	-0.003	0.015*	0.248**	0.003
		(0.108)	(0.007)	(0.009)	(0.107)	(0.002)
P13	Conventional	0.228**	-0.002	0.011	0.233**	0.002
		(0.108)	(0.007)	(0.009)	(0.107)	(0.002)
	Robust	0.245**	-0.003	0.015	0.248**	0.003
		(0.114)	(0.009)	(0.01)	(0.114)	(0.002)
	Bias-Corrected	0.089	-0.008	0.014*	0.096	0.004
		(0.085)	(0.009)	(0.008)	(0.084)	(0.004)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
P14	Conventional	0.076	-0.005	0.008	0.088	0.003
		(0.085)	(0.009)	(0.008)	(0.084)	(0.004)
	Robust	0.089	-0.008	0.014	0.096	0.004
		(0.095)	(0.011)	(0.009)	(0.096)	(0.005)
	Bias-Corrected	-0.013	-0.01	0.001	-0.006	0
		(0.035)	(0.012)	(0.002)	(0.035)	(0.002)
P15	Conventional	-0.017	-0.007	-0.002	0.001	0
		(0.035)	(0.012)	(0.002)	(0.035)	(0.002)
	Robust	-0.013	-0.01	0.001	-0.006	0
		(0.041)	(0.014)	(0.003)	(0.041)	(0.003)
	Bias-Corrected	-0.014	-0.012	0	-0.003	-0.002
		(0.022)	(0.01)	(0.004)	(0.018)	(0.002)
P16	Conventional	-0.017	-0.009	-0.005	-0.002	-0.002
		(0.022)	(0.01)	(0.004)	(0.018)	(0.002)
	Robust	-0.014	-0.012	0	-0.003	-0.002
		(0.028)	(0.012)	(0.006)	(0.023)	(0.002)
	Bias-Corrected	-0.01	-0.006	0.004**	-0.016	-0.002*
		(0.016)	(0.008)	(0.002)	(0.015)	(0.001)
P17	Conventional	-0.016	-0.003	-0.002	-0.018	-0.002
		(0.016)	(0.008)	(0.002)	(0.015)	(0.001)
	Robust	-0.01	-0.006	0.004	-0.016	-0.002
		(0.018)	(0.01)	(0.004)	(0.013)	(0.001)
	Bias-Corrected	-0.034	0.004	0.004	-0.048	0
		(0.048)	(0.009)	(0.004)	(0.049)	(0)
P18	Conventional	-0.035	0.006	-0.003	-0.038	0
		(0.048)	(0.009)	(0.004)	(0.049)	(0)
	Robust	-0.034	0.004	0.004	-0.048	0
		(0.059)	(0.01)	(0.004)	(0.06)	(0)
	Bias-Corrected	0.002	0.019**	-0.034	0.006	0.002
		(0.071)	(0.009)	(0.031)	(0.053)	(0.001)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
P20	Conventional	-0.009	0.017∗	-0.035	-0.001	0.002
		(0.071)	(0.009)	(0.031)	(0.053)	(0.001)
	Robust	0.002	0.019∗	-0.034	0.006	0.002
		(0.085)	(0.011)	(0.038)	(0.064)	(0.001)
	Bias-Corrected	0.012	0.01	-0.041	0.041	0.004∗
		(0.074)	(0.009)	(0.034)	(0.048)	(0.003)
P21	Conventional	0.004	0.009	-0.04	0.031	0.003
		(0.074)	(0.009)	(0.034)	(0.048)	(0.003)
	Robust	0.012	0.01	-0.041	0.041	0.004
		(0.088)	(0.011)	(0.041)	(0.056)	(0.003)
	Bias-Corrected	0.011	0.001	-0.028	0.033	0.005
		(0.05)	(0.009)	(0.026)	(0.029)	(0.003)
P22	Conventional	0.004	0.002	-0.023	0.025	0.004
		(0.05)	(0.009)	(0.026)	(0.029)	(0.003)
	Robust	0.011	0.001	-0.028	0.033	0.005
		(0.06)	(0.011)	(0.031)	(0.033)	(0.004)
	Bias-Corrected	-0.039	-0.019	-0.007	-0.025	0.004
		(0.028)	(0.014)	(0.01)	(0.016)	(0.003)
P23	Conventional	-0.033	-0.016	-0.008	-0.02	0.004
		(0.028)	(0.014)	(0.01)	(0.016)	(0.003)
	Robust	-0.039	-0.019	-0.007	-0.025	0.004
		(0.034)	(0.016)	(0.012)	(0.02)	(0.004)
	Bias-Corrected	-0.038	-0.013	-0.01∗	-0.026	-0.001∗∗∗
		(0.025)	(0.011)	(0.005)	(0.019)	(0)
P24	Conventional	-0.03	-0.011	-0.009∗	-0.021	-0.001
		(0.025)	(0.011)	(0.005)	(0.019)	(0)
	Robust	-0.038	-0.013	-0.01	-0.026	-0.001
		(0.027)	(0.013)	(0.007)	(0.021)	(0.001)
	Bias-Corrected	-0.006	-0.008	0.002	0.002	-0.001
		(0.016)	(0.01)	(0.002)	(0.004)	(0.001)
P25	Conventional	-0.008	-0.009	0.003∗	0.001	0
		(0.016)	(0.01)	(0.002)	(0.004)	(0.001)
	Robust	-0.006	-0.008	0.002	0.002	-0.001
		(0.019)	(0.012)	(0.002)	(0.004)	(0.001)
	Bias-Corrected	0.048∗	-0.009	0.002	0.016∗	0
		(0.025)	(0.011)	(0.002)	(0.009)	(0.001)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Segment	Type	Informal index	Crowding	Walls	Sanitation	Precarious
P26	Conventional	0.04	-0.011	0	0.012	0
		(0.025)	(0.011)	(0.002)	(0.009)	(0.001)
	Robust	0.048*	-0.009	0.002	0.016	0
		(0.028)	(0.013)	(0.003)	(0.012)	(0.002)
	Bias-Corrected	-0.032	-0.054***	-0.004**	-0.004***	-0.001
		(0.021)	(0.016)	(0.002)	(0.001)	(0.001)
P30	Conventional	-0.038*	-0.049***	-0.002	-0.002	-0.001
		(0.021)	(0.016)	(0.002)	(0.001)	(0.001)
	Robust	-0.032	-0.054***	-0.004*	-0.004**	-0.001
		(0.025)	(0.02)	(0.002)	(0.002)	(0.002)
	Bias-Corrected	-0.035	-0.049***	-0.002**	-0.002	0
		(0.035)	(0.018)	(0.001)	(0.001)	(0.001)
P31	Conventional	-0.03	-0.045**	-0.001	-0.001	-0.001
		(0.035)	(0.018)	(0.001)	(0.001)	(0.001)
	Robust	-0.035	-0.049**	-0.002	-0.002	0
		(0.041)	(0.021)	(0.002)	(0.001)	(0.001)
	Bias-Corrected	-0.035	-0.049***	0.001	-0.001	0.002*
		(0.032)	(0.017)	(0.001)	(0.002)	(0.001)
P32	Conventional	-0.028	-0.044**	0.001	0	0.002
		(0.032)	(0.017)	(0.001)	(0.002)	(0.001)
	Robust	-0.035	-0.049**	0.001	-0.001	0.002
		(0.036)	(0.02)	(0.002)	(0.003)	(0.002)
	Bias-Corrected	-0.046*	-0.048**	-0.002***	0	0.004
		(0.024)	(0.019)	(0.001)	(0.001)	(0.003)
P33	Conventional	-0.041*	-0.043**	-0.001	0.001	0.004
		(0.024)	(0.019)	(0.001)	(0.001)	(0.003)
	Robust	-0.046	-0.048**	-0.002	0	0.004
		(0.029)	(0.022)	(0.002)	(0.002)	(0.003)
	Bias-Corrected	-0.058**	-0.045**	0.011***	-0.001	0.005
		(0.027)	(0.019)	(0.004)	(0.002)	(0.004)
P34	Conventional	-0.057**	-0.039**	0.007	0.001	0.004
		(0.027)	(0.019)	(0.004)	(0.002)	(0.004)
	Robust	-0.058*	-0.045**	0.011**	-0.001	0.005
		(0.034)	(0.022)	(0.005)	(0.003)	(0.004)
	Bias-Corrected	-0.074*	-0.037**	0.017***	0.001	0.006
		(0.04)	(0.015)	(0.004)	(0.004)	(0.004)
P35	Conventional	-0.08**	-0.033**	0.009**	0.004	0.004
		(0.04)	(0.015)	(0.004)	(0.004)	(0.004)
	Robust	-0.074	-0.037**	0.017**	0.001	0.006
		(0.048)	(0.018)	(0.008)	(0.006)	(0.005)

Standard errors in parenthesis. Sig. Levels: *** $p < .01$ ** $p < .05$ * $p < 0.1$

Appendix B

Appendix: Unlocking Housing Supply: The Effects of Building Regulations in a Developing Economy

B.1 Access to Land Regulation Indicator (ALRI).

ALRI attempts to capture the existence of redistributive measures or measures to restrict access to land, such as forced donations of land for social services or social housing, instruments to recover the value added to land, the minimum number of construction licenses for social projects, among others.

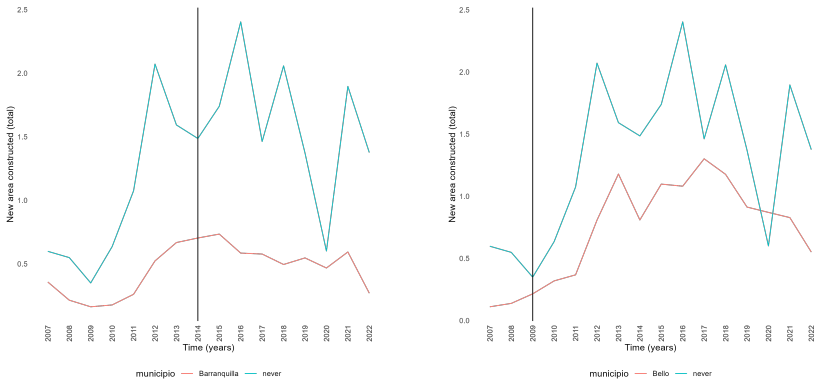
From the indicator Goytia et al. (2015b), the measures that are relevant to calculate the *ALRI* in this case are the Public Equipment Indicator PE, which captures the portion of land that the developer must give up for public equipment such as landscaping, public parks, green spaces, etc; and the Public Housing PH, which is the percentage of land that should be dedicated to low-cost or public housing projects. The original proposal also considers an indicator of regulatory instruments (RI) and one to calculate the recovery of the added value (VR), but these variables were not considered for this work since their variability is at the national level and not at the municipality level.

For the Colombian case, PE corresponds to the urban obligations of public and private green areas; that can be given as a portion of land or can be compensated with money. As for the PH, it is calculated from the areas destined to VIS and VIP [1] social housing projects. Information about urban obligations of public and private green areas was not available in the regulatory instruments for all municipalities, and the local government did not provide information about VIS and VIP. So even when this indicator applies to the Colombian case, I could not compute it due to a lack of information.

[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)*

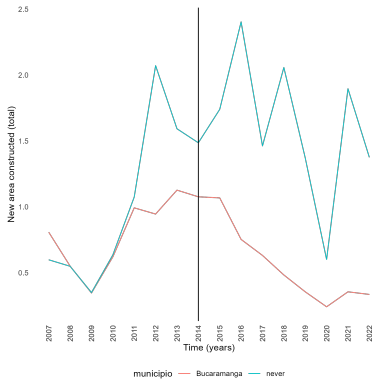
B.2 Graphs with trend for municipalities

Figure B.1: Trend for new area constructed at municipality level

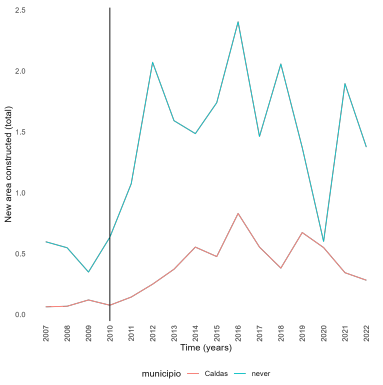


(a) Barranquilla

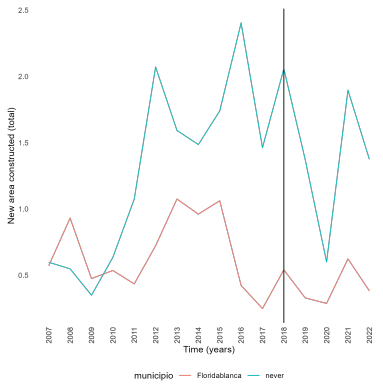
(b) Bello



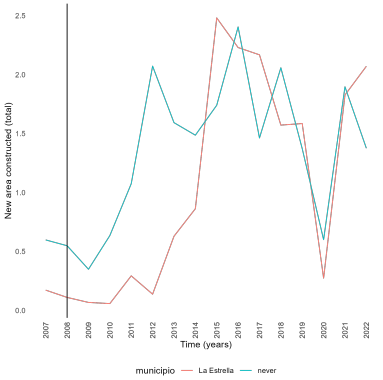
(c) Bucaramanga



(d) Caldas



(e) Floridablanca



(f) La Estrella

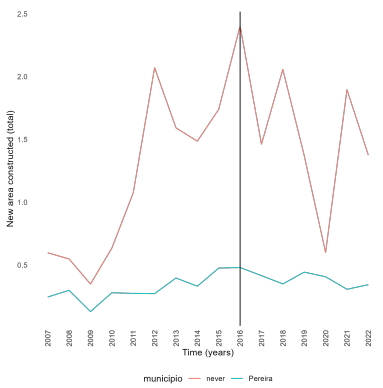
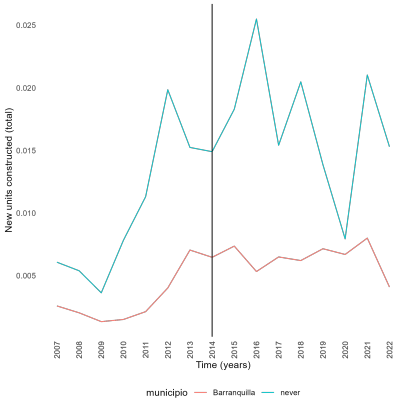
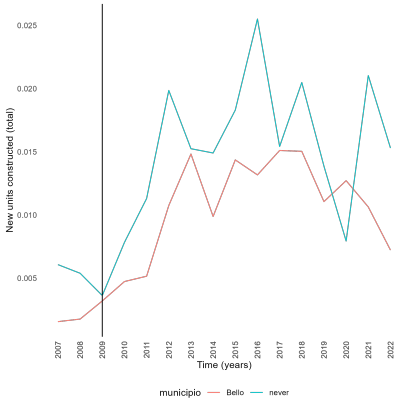


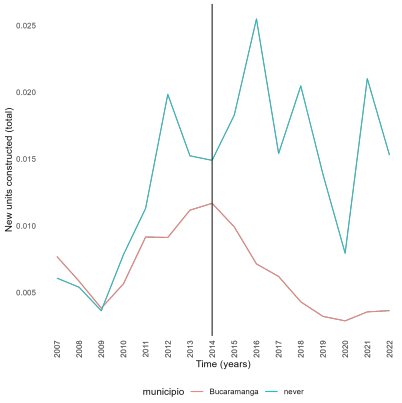
Figure B.2: Trend for new area constructed at municipality level



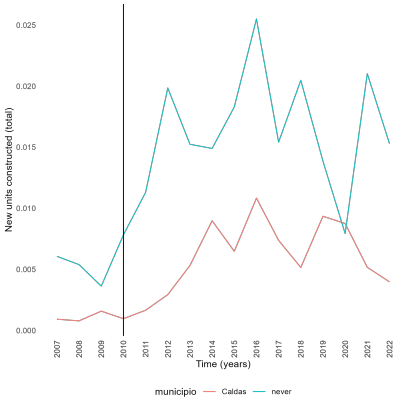
(a) Barranquilla



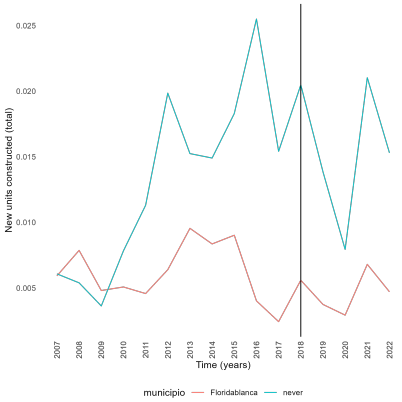
(b) Bello



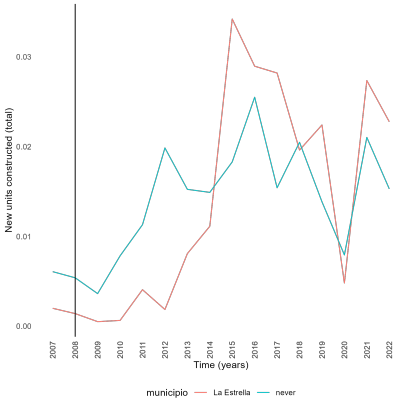
(c) Bucaramanga



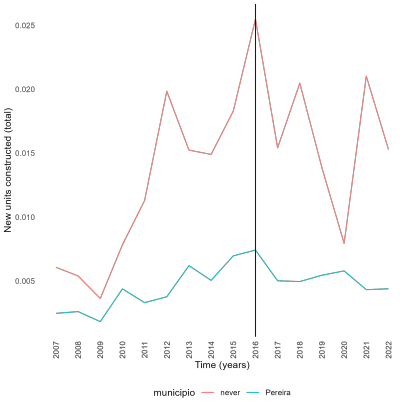
(d) Caldas



(e) Floridablanca

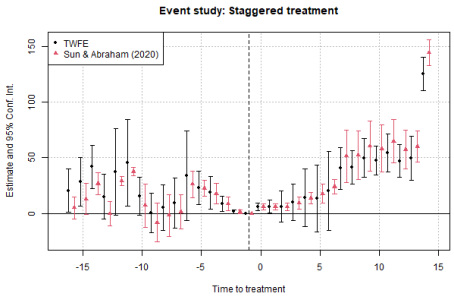


(f) La Estrella

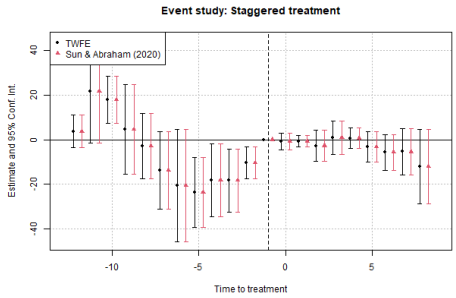


B.3 Results for ratio

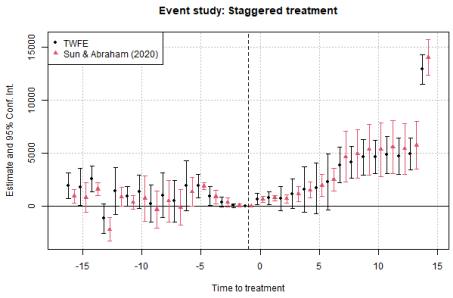
(a) Staggered Differences in Differences results for big and small cities



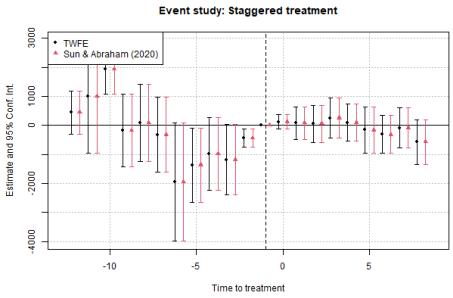
(b) Ratio of new units constructed in small cities



(c) Ratio of new units constructed in big cities



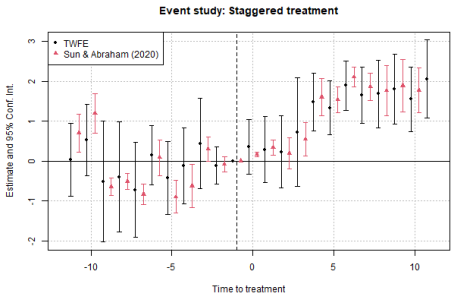
(d) Ratio of new area constructed in small cities



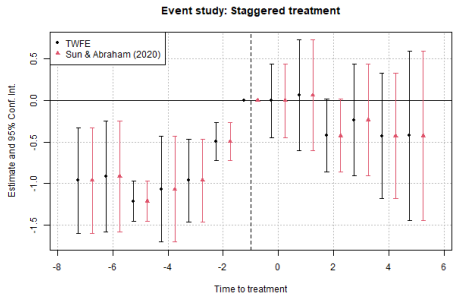
(e) Ratio of new area constructed in big cities

B.4 Results with controls

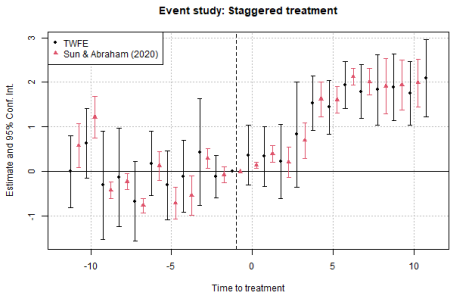
(a) Staggered Differences in Differences results for big and small cities with controls



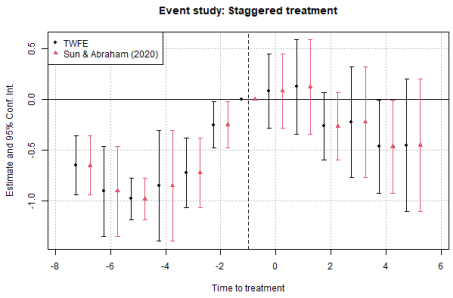
(b) Logarimth of new units constructed in small cities with controls



(c) Logarimth of new units constructed in big cities with controls



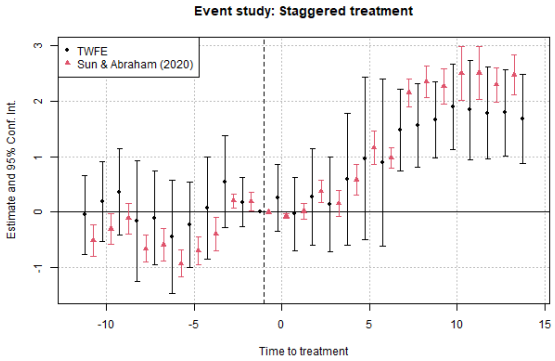
(d) Logarimth of the new area constructed in small cities with controls



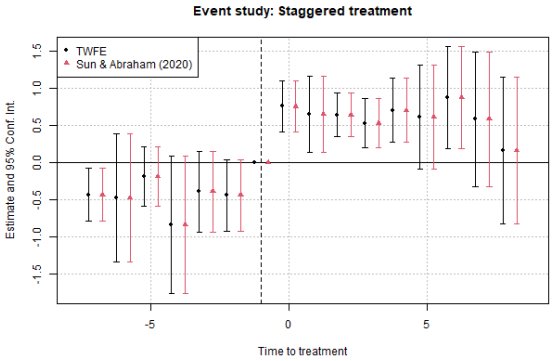
(e) Logarimth of the new area constructed in big cities with controls

B.5 Results for effective supply

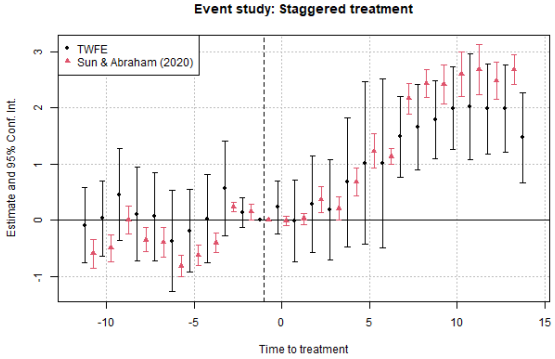
Figure B.5: Staggered Differences in Differences results for big and small cities (Effective supply)



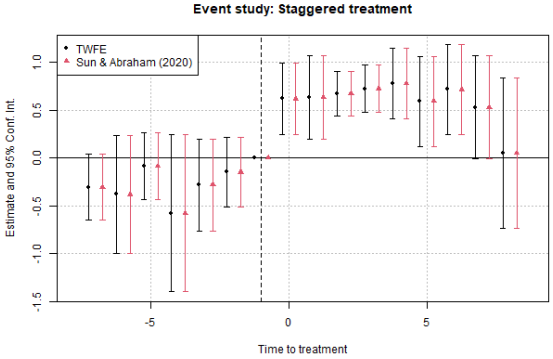
(a) Logarithm of new units in small cities



(b) Logarithm of new units in big cities

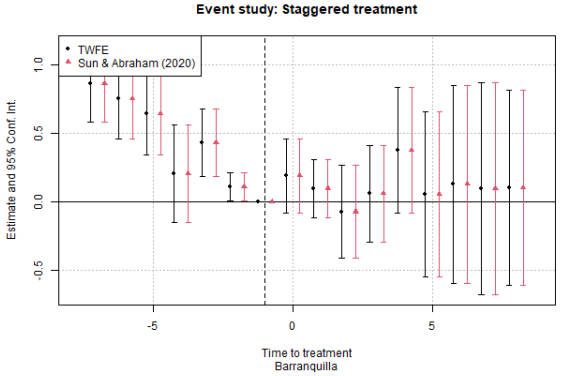


(c) Logarithm of new area in small cities

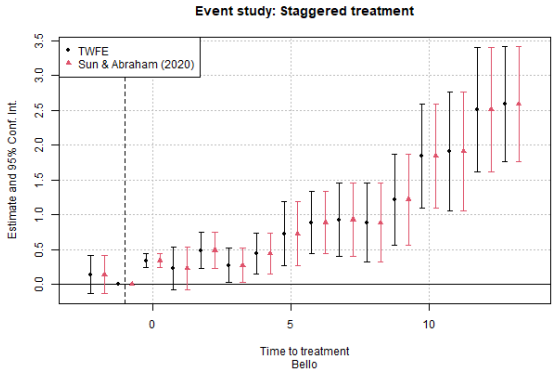


(d) Logarithm of new area in big cities

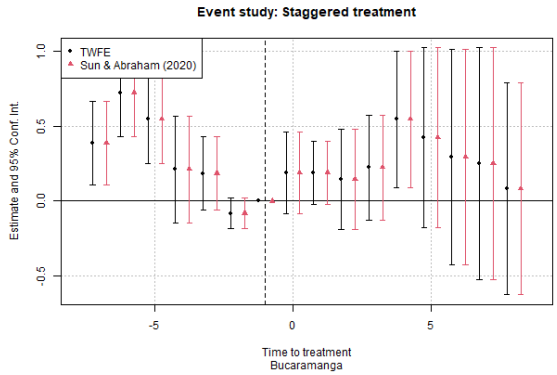
Figure B.6: Staggered Differences in Differences for new area (logarithm) at municipality level (Effective supply)



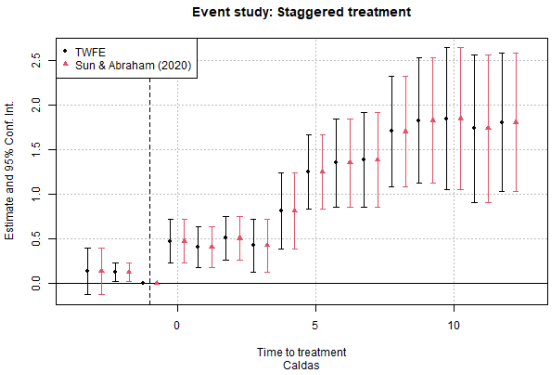
(a) Barranquilla



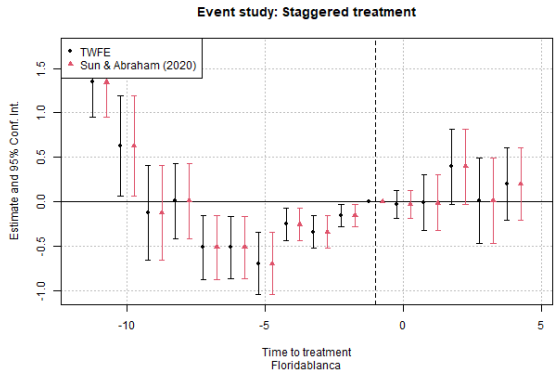
(b) Bello



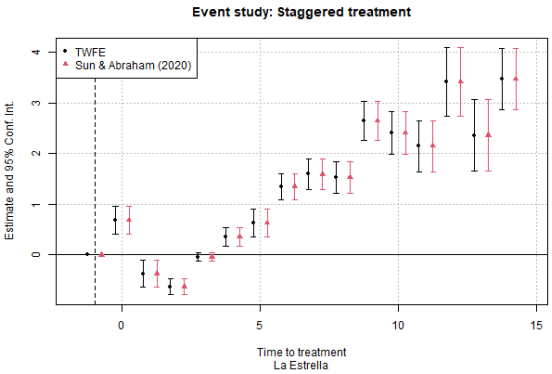
(c) Bucaramanga



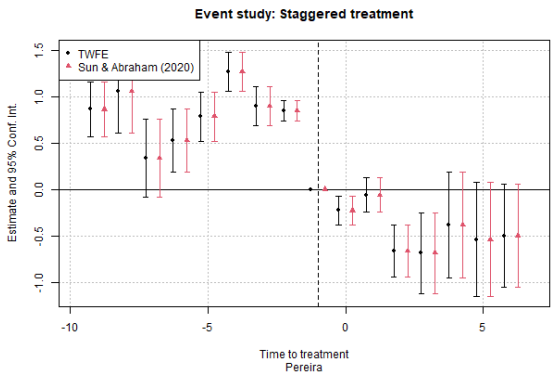
(d) Caldas



(e) Floridablanca

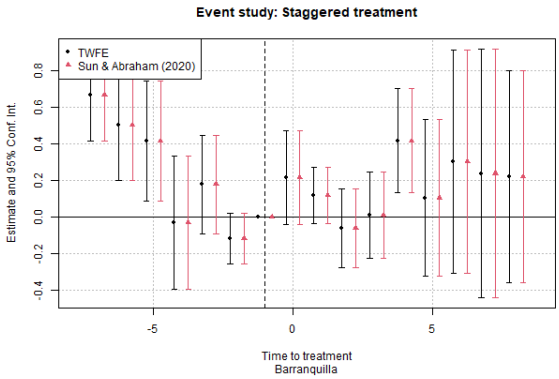


(f) La Estrella

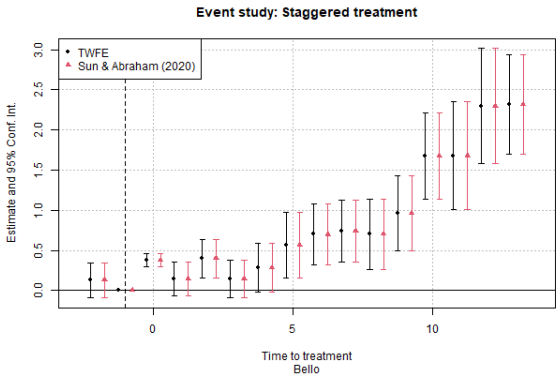


(g) Pereira

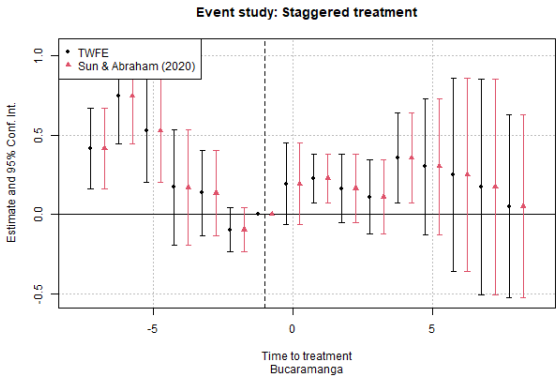
Figure B.7: Staggered Differences in Differences Results for new units (logarithm) at municipality level (Effective supply)



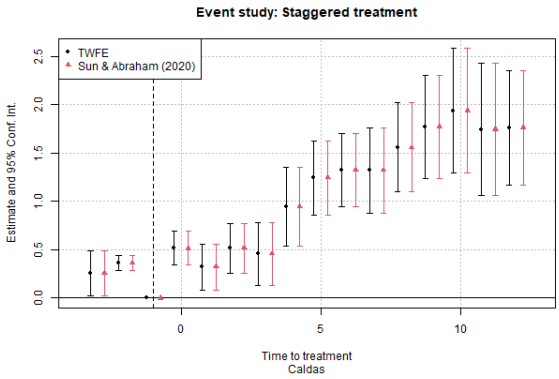
(a) Barranquilla



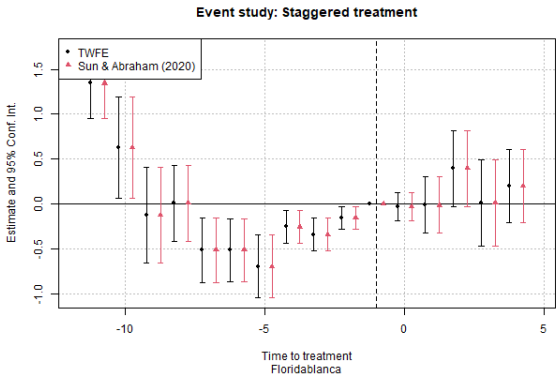
(b) Bello



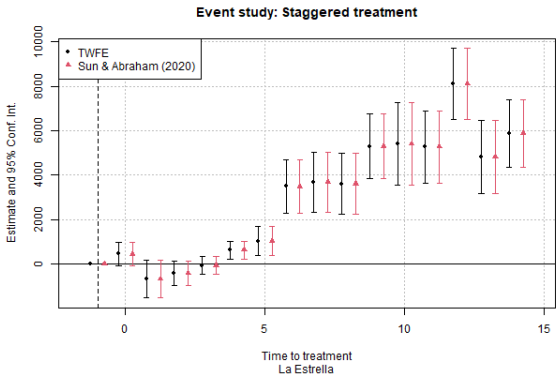
(c) Bucaramanga



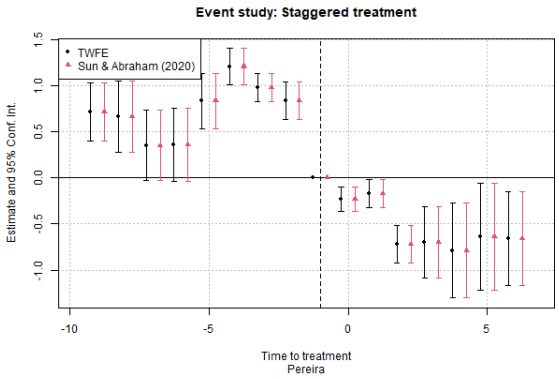
(d) Caldas



(e) Floridablanca



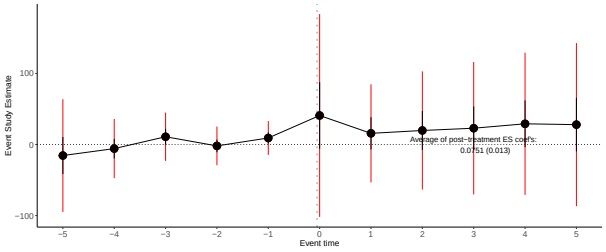
(f) La Estrella



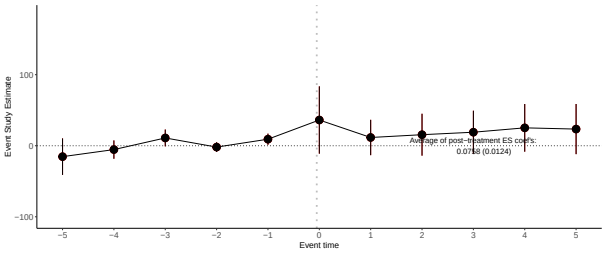
(g) Pereira

B.6 Heterogeneity results for formal and informal housing market

Figure B.8: Staggered Differences in Differences Results for new units constructed for formal market



(a) Never treat as comparison group



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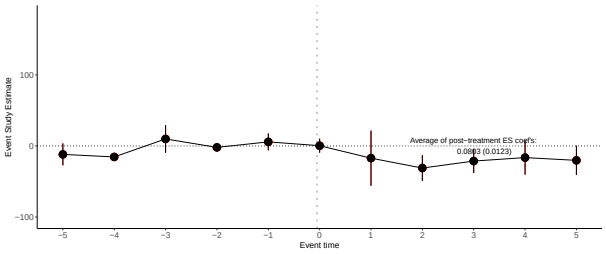
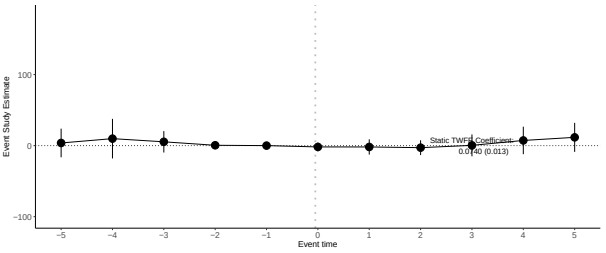
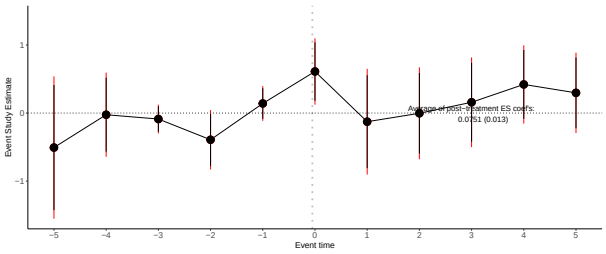


(c) Not yet treated without never treat as control group

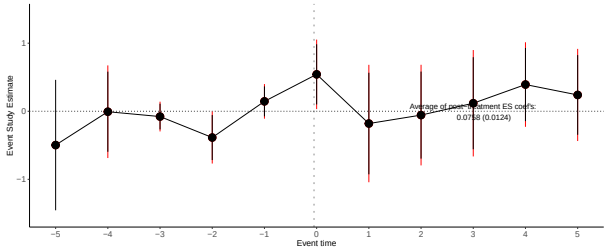


(d) Two-way fix effects

Figure B.9: Staggered Differences in Differences Results for new total area constructed for formal market



(a) Never treat as comparison group



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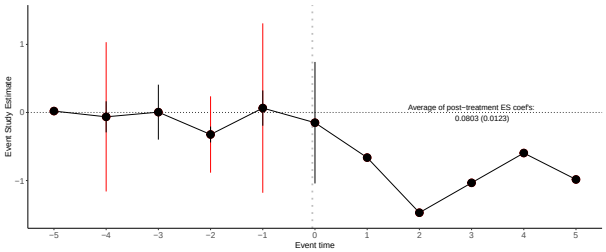

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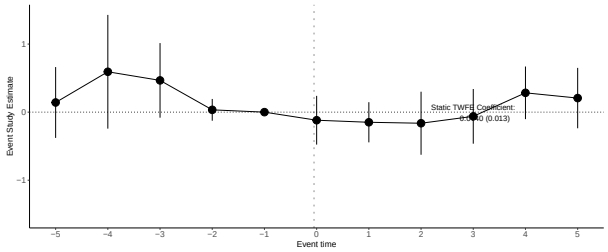
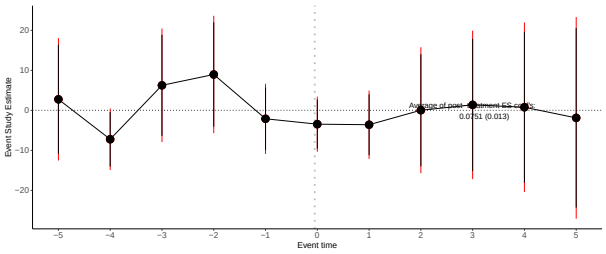


(d) Two-way fix effects

Figure B.10: Staggered Differences in Differences Results for new units constructed for informal market



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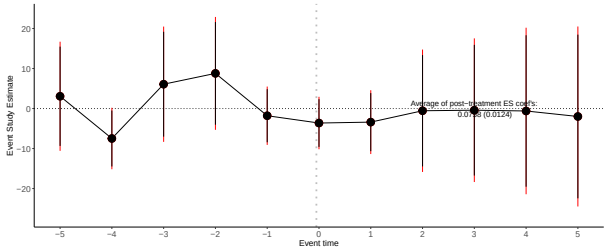

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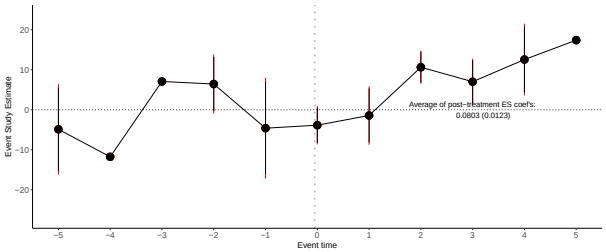

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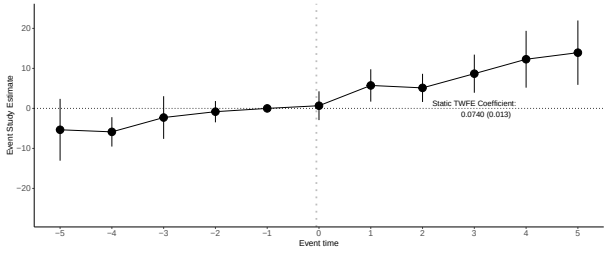
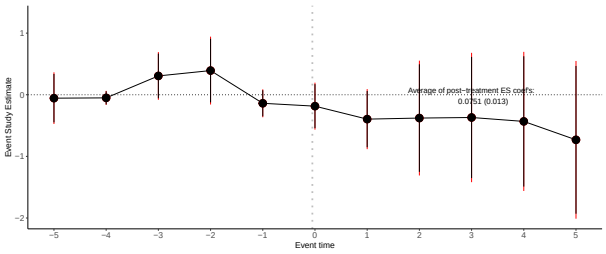
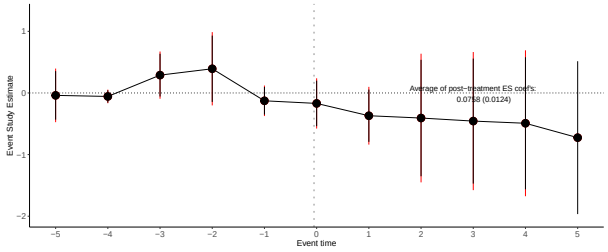


(d) Two-way fix effects

Figure B.11: Staggered Differences in Differences Results for new total area constructed for Informal market



(a) Never treat as comparison group



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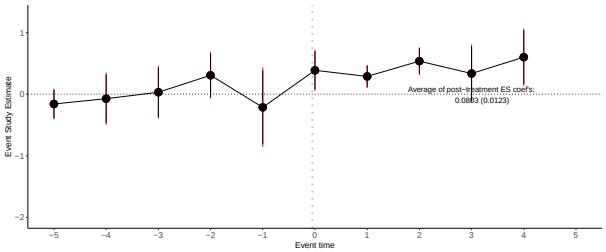

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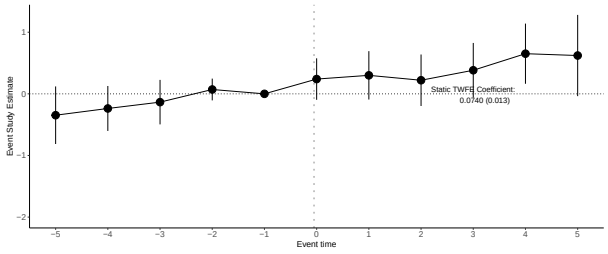
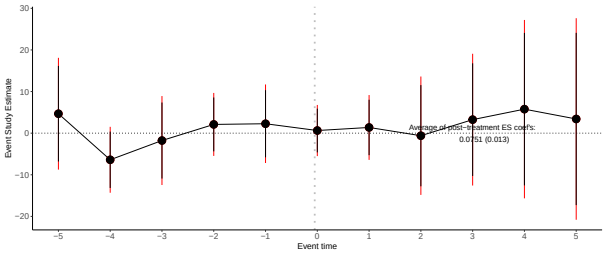
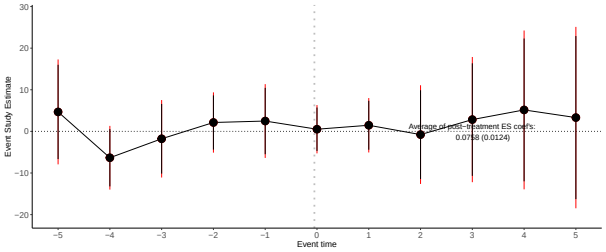


(d) Two-way fix effects

Figure B.12: Staggered Differences in Differences Results for new units constructed



(a) Never treat as comparison group



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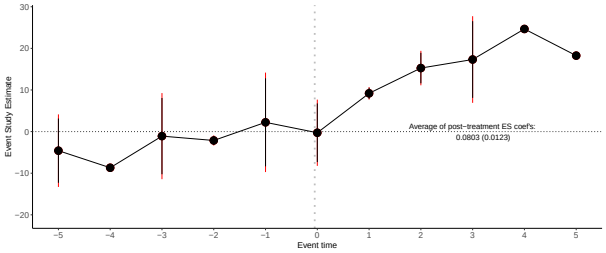

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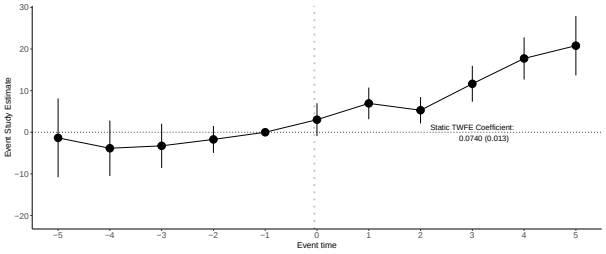
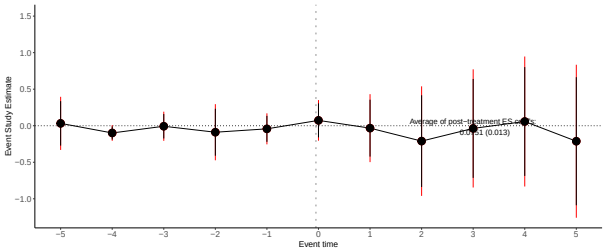


(d) Two-way fix effects

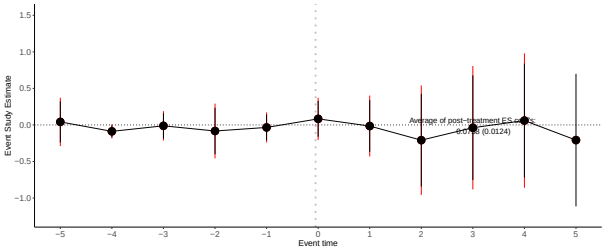
B.7 Callaway and Sannt'Anna Callaway et al. (2021) estimations

The results are consistent for the total area constructed. Figure B.13 shows the results for this outcome.

Figure B.13: Staggered Differences in Differences Results for new total area constructed



(a) Never treat as comparison group



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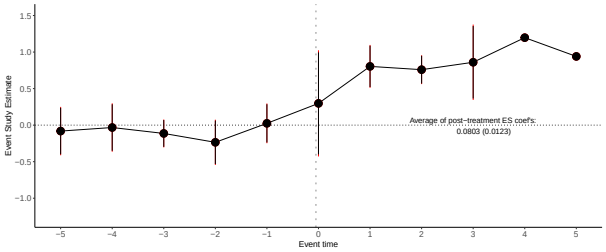
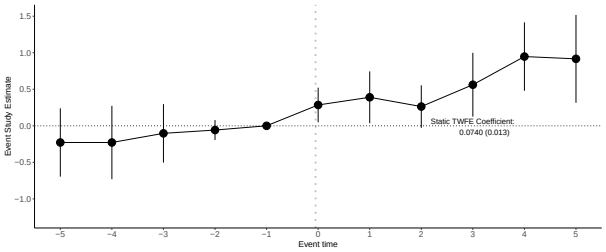


(c) Not yet treated without never treat as control group



(d) Two-way fix effects

Appendix C

Appendix: The informal city: Urban growth and housing market duality in developing countries

C.1 Production in the monocentric city

Production is given by:

$$Y_{it} = A_{it} \left\{ \int_0^{m_{it}} [q_{it}(\omega)]^{\frac{1+\sigma}{\sigma}} \, \mathrm{d}\omega \right\}^{1+\sigma} \tag{C.1}$$

With $q_{it}(\omega)$ as the number of intermediate outputs (ω) for the final production output and the mass of intermediate producers m_{it}. Production is made by using human capital, so:

$$q_{it}(\omega) = H_{it}(\omega) \tag{C.2}$$

Given that intermediate output production is symmetric, human capital is divided between producers. The total human capital to produce ω used by firms is equivalent to:

$$H_{it} = \frac{H_{it}}{m_{it}} \tag{C.3}$$

Replace in C.1 and solve

$$Y_{it} = A_{it} \, H_{it} \, m_{it}^{\sigma} \tag{C.4}$$

The final output production depends on human capital, the mass of intermediate producers, and productivity. With more human capital, entrepreneurship ideas grow. So, intermediate producers

depend on the total human capital available, and the parameter ρ represents the firm's agglomeration economics:

$$m_{it} = \rho \, H_{it}$$

Substituting

$$Y_{it} = \rho^{\sigma} A_{it} (H_{it})^{1+\sigma} \tag{C.5}$$

With ρ, entrepreneurial ideas arise in proportion to the local human capital, A_{it} level of production amenities, H_{it} total human capital, and $\frac{1+\sigma}{\sigma}$ constant substitution elasticity. A higher level of human capital in a city results in more entrepreneurial ideas and, therefore, more input-producing firms. The total local human capital can be written as

$$H_{it} = h_{it} \, N_{it}$$

with N_{it} as the population of the city and h_{it} as the level of human capital provided for workers. Replacement in C.5:

$$Y_{it} = \rho^{\sigma} A_{it} (h_{it} \, N_{it})^{1+\sigma} \tag{C.6}$$

Given that all firms are symmetric, individual income results in dividing the final city output between workers. The income per worker is:

$$y_{it} = \rho^{\sigma} A_{it} (h_{it})^{1+\sigma} (N_{it})^{\sigma} \tag{C.7}$$

Individual income increases with the elasticity of the city population σ. Equation C.7 represents the agglomeration economies in cities for workers. Bigger cities concentrate more on human capital and foster entrepreneurship (stronger agglomeration economies).

C.2 Cost Function Conditions

The proposed cost function for the informal market, $\pi(x) = \kappa \cdot p_{it} \cdot e^{-\alpha x}$, satisfies the following conditions:

1. **Initial condition**: At $x = 0$, the cost function $\pi(0) = \kappa \cdot p_{it}$ must be greater than the regulatory cost p_{it}. This condition holds if $\kappa > 1$, ensuring that $\pi(0) > p_{it}$.
2. **Decreasing behavior**: The cost function $\pi(x)$ is monotonically decreasing in x, as the exponential term $e^{-\alpha x}$ ensures a smooth and continuous decline with distance from the city center. This reflects the spatial heterogeneity of enforcement, where the risk of sanctions is highest in the center and decreases toward the periphery.

3. **Critical point**: There exists a critical distance x^* where $\pi(x^*) = p_{it}$. This point is given by:

$$x^* = \frac{\ln(\kappa)}{\alpha}$$

For distances $x < x^*$, the cost of informality exceeds the regulatory cost ($(\pi(x) > p_{it})$, making the formal market preferable. For distances $x > x^*$, the cost of informality falls below the regulatory cost ($\pi(x) < p_{it}$), incentivizing informality.

The parameter κ scales the cost function and must satisfy $\kappa > 1$ to ensure that the initial cost exceeds the regulatory cost. The parameter α controls the rate at which the cost decreases with distance, reflecting the spatial sensitivity of the enforcement. A higher α implies a steeper decline in $\pi(x)$, while a lower α results in a more gradual decrease.

C.3 Enforcement, cutoff x^*, and domain restrictions

I define the formal-informal cutoff by equating the regulation wedge in the formal market to the (distance–decaying) informal penalty, $\pi(x) = \kappa\, p_{it} e^{-\alpha x}$. The cutoff solves

$$\pi(x^*) = p_{it} \quad \Longrightarrow \quad \kappa\, e^{-\alpha x^*} = 1 \quad \Longrightarrow \quad x^* = \frac{1}{\alpha} \ln \kappa.$$

Since the spatial domain is $x \geq 0$ (and $x \leq N_{it}$), I operationalize

$$x^*_{\text{dom}} \;=\; \max\Big\{\, 0,\; \min\big\{\, N_{it},\; \tfrac{1}{\alpha} \ln \kappa \,\big\} \Big\}.$$

Thus, when $\kappa < 1$ we have $\ln \kappa < 0$ and the unconstrained solution for x^* is negative; after truncation to the admissible domain, this yields $x^*_{\text{dom}} = 0$. Economically, weak enforcement makes the informal option cheaper than the regulated formal option even in the center ($\pi(0) = \kappa p_{it} < p_{it}$), so there is no purely formal core. For completeness, the comparative statics of the cut-off point *unconstrained* are

$$\frac{\partial x^*}{\partial \kappa} = \frac{1}{\alpha\, \kappa} > 0, \qquad \frac{\partial x^*}{\partial \alpha} = -\frac{\ln \kappa}{\alpha^2},$$

so x^* increases with κ and, when $\kappa < 1$, also increases with α; after truncation at 0, these effects are locally flat at the boundary.

I keep this case in the simulations for two reasons. First, it is empirically relevant for settings in developing countries where enforcement can be weak. Second, it identifies a clear threshold behavior in the model: as κ falls below 1, the formal core collapses ($x^* \to 0$) and the allocation of rents shifts to the informal margin, which in turn drives the comparative statics of N_{it} with respect to (κ, p_{it}, α). Including the $\kappa < 1$ region is therefore essential to show when high regulation without credible enforcement expands informality and pushes the city size above the formal benchmark $\widetilde{N}_{it}$.

C.4 Analysis of the Bid Rent Slopes

Mathematically, the slopes of the bid rent functions $R_{it}^f(x)$ and $R_{it}^s(x)$ can differ. Differentiating these functions:

$$\begin{aligned} \frac{dR_{it}^f(x)}{dx} &= \gamma \tau_t x^{\gamma-1}, \\ \frac{dR_{it}^s(x)}{dx} &= \gamma \tau_t x^{\gamma-1} + \frac{d\pi(x)}{dx} \end{aligned} \tag{C.8}$$

If $\frac{d\pi(x)}{dx} \neq 0$, the slopes are different. Typically, the risk of eviction decreases with distance from the city center ($\pi(x)$ is decreasing), meaning $R_{it}^s(x)$ declines more slowly than $R_{it}^f(x)$. This implies that informal settlements extend further, contributing to urban sprawl. Furthermore, regulation costs in the formal sector create a steeper decline in formal bid rents compared to informal ones, reinforcing the hypothesis that informality contributes to larger cities.

C.5 Step-by-step calculation of the total rent integral

The total rent is computed as the sum of the integrals of the formal and informal rent functions.

$$R_{it} = \int_0^{x^*} R_{it}^f(x)\,\mathrm{d}x + \int_{x^*}^{N_{it}} R_{it}^s(x)\,\mathrm{d}x, \tag{C.9}$$

where:

$$R_{it}^f(x) = T_{it}(N_{it}) + \pi(N_{it}) - T_{it}(x) - p_{it}, \tag{C.10}$$
$$R_{it}^s(x) = T_{it}(N_{it}) + \pi(N_{it}) - T_{it}(x) - \pi(x). \tag{C.11}$$

The transport and informal cost functions are given by:

$$T_{it}(x) = \tau_t (N_{it})^\theta x^\gamma, \tag{C.12}$$
$$\pi(x) = \kappa_{it} p_{it} e^{-\alpha x}. \tag{C.13}$$

I calculate each term separately:

1. Integral of constant terms in the formal sector:

$$\int_0^{x^*} [T_{it}(N_{it}) + \pi(N_{it}) - p_{it}]\,\mathrm{d}x = [T_{it}(N_{it}) + \pi(N_{it}) - p_{it}]x^*. \tag{C.14}$$

2. Integral of transport cost throughout the city:

$$\int_0^{N_{it}} T_{it}(x)\,\mathrm{d}x = \tau_t(N_{it})^\theta \frac{N_{it}^{\gamma+1}}{\gamma+1}. \tag{C.15}$$

3. Integral of informal cost over the informal sector:

$$\int_{x^*}^{N_{it}} \pi(x)\,\mathrm{d}x = \kappa_{it} p_{it} \frac{e^{-\alpha x^*} - e^{-\alpha N_{it}}}{\alpha}. \tag{C.16}$$

4. Integrals of constant terms in the informal sector:

$$\int_{x^*}^{N_{it}} [T_{it}(N_{it}) + \pi(N_{it})]\,\mathrm{d}x = [T_{it}(N_{it}) + \pi(N_{it})](N_{it} - x^*). \tag{C.17}$$

5. Final total rent expression:

$$\begin{aligned} R_{it} = {} & [T_{it}(N_{it}) + \pi(N_{it}) - p_{it}]x^* + [T_{it}(N_{it}) + \pi(N_{it})](N_{it} - x^*) \\ & - \tau_t(N_{it})^\theta \frac{N_{it}^{\gamma+1}}{\gamma+1} - \kappa_{it} p_{it} \frac{e^{-\alpha x^*} - e^{-\alpha N_{it}}}{\alpha}. \end{aligned} \tag{C.18}$$

Substituting:

$$T_{it}(N_{it}) = \tau_t(N_{it})^{\theta+\gamma}, \tag{C.19}$$

$$\pi(N_{it}) = \kappa_{it} p_{it} e^{-\alpha N_{it}}, \tag{C.20}$$

we finally obtain:

$$\begin{aligned} R_{it} = {} & \tau_t(N_{it})^{\theta+\gamma} N_{it} + \kappa_{it} p_{it} N_{it} e^{-\alpha N_{it}} - \frac{\tau_t(N_{it})^\theta N_{it}^{\gamma+1}}{\gamma+1} \\ & - p_{it} x^* - \frac{\kappa_{it} p_{it} e^{-\alpha x^*}}{\alpha} + \frac{\kappa_{it} p_{it} e^{-\alpha N_{it}}}{\alpha}. \end{aligned} \tag{C.21}$$

This confirms the explicit dependence of total rent on enforcement intensity, regulatory burden, and spatial costs.