

A Global Perspective on Land Use Regulations and Housing Outcomes

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Abstract

This paper examines the relationship between land use regulations and housing outcomes, especially housing affordability and informality. Using a unique and important database of 191 metropolitan areas from every region of the world, it assesses whether there are consistent emergent patterns from a global perspective that may in turn be useful for informing policy on land use regulations in specific locales and contexts. The empirical results point to a number of striking conclusions. Empirical evidence from across the globe underlines the *dynamic* nature of the interaction between land use regulations and informality. In the *long run*, the evidence strongly suggests that more restrictive land use regulations lead to more rapid *growth* in informal settlements. This result conforms with prior literature that emphasizes the exclusionary effects of land use regulations. As more restrictive regulations are applied, households find themselves with fewer options outside the informal sector. This phenomenon is accentuated during periods of rapid urbanization. But from a static perspective, the situation looks quite different over the *short run*, since cities with more stringent land use regulations tend to have fewer informal settlements, and this finding is strengthened further when those land use regulations are coupled with active enforcement.

Keywords: Land Use Regulations, Informal Settlements, Inclusionary and Exclusionary Land Use Regulations, Land Use Regulations Indicators, Formal and Informal Urban Land Markets, Developed and Developing Country Cities

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1. Problem Statement and Hypotheses

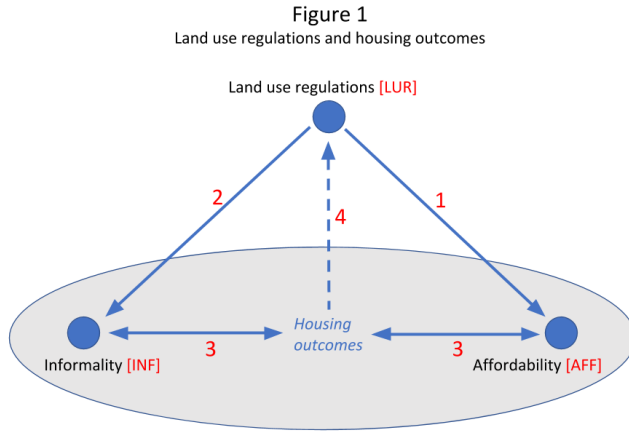
Sustainable Development Goal 11 (SDG 11) of the United Nations Sustainable Development Goals (SDGs) calls for cities, and human settlements more generally, that are inclusive, safe, resilient, and sustainable. This emphasis is reinforced by SDG 10, which seeks to reduce inequality within and between nations. As a steadily increasing majority of the world's population resides in cities, these human settlements are indeed an essential nexus for promoting sustainable development. While cities are rightly seen as potential engines of growth and upward mobility, they can also reinforce or further engender prevailing patterns of inequality and exclusion. Nowhere is this more evident than in housing outcomes, because housing is the locus of the lived experiences of daily life at a human level.

The rising proliferation of informal settlements worldwide underlines the urgency of meeting the SDG challenge. Already, by 2018, over one billion people resided in slums or informal settlements, and the UN predicts that this number will treble by 2030, as urbanization proceeds apace, especially in the global South. A crucial issue is the capacity of cities to absorb this rising population. Whether inadvertently or by design, land use regulations may often limit the capacity of the formal housing sector to accommodate its residents. Those who find themselves excluded from formal sector housing have little choice but to search for alternatives in the informal sector. Land markets may exacerbate underlying inequality dimensions, as scarce urban land is priced beyond the reach of poorer households.

Accordingly, this paper examines the relationship between land use regulations and housing outcomes, especially housing affordability and informality. This triangular relationship is fraught with mutual endogeneity, as land use regulations, informality, and affordability respond to or are shaped by each other. While we do assess the theoretical underpinnings of this mutual dependency, our primary focus here is an empirical one. Using a unique and important database of 191 metropolitan areas from every region in the world, as described below, our aim is to assess whether there are consistent emergent patterns from a global perspective that may in turn be useful for informing policy on land use regulations in specific locales and contexts.

The empirical results we derive from this research point to a number of striking conclusions. Empirical evidence from across the globe underlines the *dynamic* nature of the interaction between land use regulations and informality. In the *long run*, the evidence strongly suggests that more restrictive land use regulations lead to more rapid *growth* in informal settlements. This result conforms with prior literature, as discussed below, that emphasizes the exclusionary effects of land use regulations. As more restrictive regulations are applied, households find themselves with fewer options outside the informal sector. This phenomenon is accentuated during periods of rapid urbanization. But from a static perspective, the situation looks quite different over the *short run*, since cities with more stringent land use regulations tend to have fewer informal settlements, and this finding is strengthened further when those land use regulations are coupled with active enforcement.

2. Literature Review: Land Use Regulations and Informality



Source: Authors

The issue of affordability is elevated to a ‘global urban housing crisis’ (Wetzstein 2017; Rohe 2017; King et al. 2017) characterized by scarcity of affordable housing, unresponsive serviced land and housing supply, and the proliferation and persistence of informal settlements, in fast urbanizing low- and middle-income countries (Collier and Venables 2013). The situation entails major consequences for cities globally.

Figure 1 provides a simple schematic to help guide this discussion regarding the interplay between land use regulations [LUR] and housing outcomes—especially the presence of informal sector housing [INF] and housing

affordability [AFF]. There is a growing recognition and consensus that land use regulations can adversely impact housing affordability while also contributing to the prevalence of informal sector housing. Moreover, informality and affordability are themselves mutually dependent outcomes. Finally, land use regulations themselves may be formulated at least in part as a response to observed trends in housing outcomes. This overview begins by examining the apexes of this triangle (LUR, AFF, and INF), attending to their conceptual framing, operational definitions, and measurement issues. We then turn to the relationships between them, as indicated by the numbered arrows in Figure 1 above:

1. **LUR → AFF:** The impact of land use regulations on affordability
2. **LUR → INF:** The impact of land use regulations on the formation of informal settlements
3. **INF ↔ AFF:** The interactive relationship between informality and affordability
4. **INF + AFF → LUR:** The motivating influence of housing outcomes on land use regulations

2.1. Land Use Regulations [LUR]

Land use regulations are a logical starting point, because they are a natural locus for policy interventions; although infrastructure investments, employment/income initiatives, and fiscal policies can also be highly impactful, positively or negatively. One salient feature of land use regulations is that they are typically enacted and implemented at local levels of government, which can be useful insofar as they are more apt to reflect neighborhood conditions and aspirations. In large metropolitan areas, however—such as the Los Angeles metropolitan region, with its 191 municipalities—there is little assurance that the patchwork of local land use regulations constitutes a coherent whole. Providing some measure of regional-scale urban

planning coherence is the mission of metropolitan planning organizations (MPOs) in the United States, including the Southern California Association of Governments (SCAG), but many view the prevalence of single-family-only zoning (“R1”) restrictions as inimical to fundamental planning goals of affordability (Manville et al, 2020).

Land use regulations come in many forms, most of which are quite common globally. The most prevalent are minimum lot size restrictions, floor-area ratio limitations, sectoral designations (residential, commercial, industrial, etc.) and other measures to limit or shape the density and character of urban built form. Land use regulations are felt not only through their substance but also through the often time-consuming and costly processes that developers and landowners experience in their compliance efforts (Gyourko, 2008; Monkkonen, 2020). Using cross-sectional data from U.S. municipalities, Gyourko (2008) developed an index of land use regulations intended to capture the multiplicity and diversity of land use regulations used in practice. He found the 11 components to be highly intercorrelated, suggesting that a simple sum of the standardized components could also serve as a reliable measure of land use regulation restrictiveness. The resulting Wharton Residential Land Use Regulation Index (WRLURI) has also been reformulated in other contexts outside the United States, including the CILP index developed by Goytia et al. (2015). One important aspect of land use regulations that differs between the global South and North is that of enforcement (Monkkonen, 2013; Monkkonen and Ronconi, 2013; He et al, 2017; Basile and Ehlenz, 2020). We return to this topic below.

2.2. Affordability [AFF]

Although housing affordability would seem to be a fairly straightforward concept, its operational definition and measurement can pose some challenges. It is important, therefore, to distinguish between related but distinct concepts, such as housing costs as a share of income or expenditure, housing stocks versus the flow of accommodation services derived therefrom, housing quantity versus housing expenditure, and housing affordability versus poverty. Commonly used proxies for housing affordability include housing-loan-repayment-to-income, ongoing-housing-cost-to-income, debt-to-housing price, and housing-price-to-income (Ben-Shahar and Warszawsky, 2016; Sun, 2020). Each of these, in one form or the other, pertains to the share of a household’s income or total expenditure that is allocated to housing expenditures. So, at least in part, this is an allocation decision rather than an affordability issue; although one may expect that the share of housing relative to total household expenditures will tend to vary by level of income. As Glaeser and Gyourko (2003, p. 21) point out, however, this approach tends to confuse poverty with housing prices: “... a housing affordability crisis means that housing is expensive relative to its fundamental costs of production—not that people are poor.”

A related point is that housing expenditure is the product of price and quantity. Hedonic regression analysis is a common way to disentangle this relationship (He et al., 2019; Talukdar, 2018; Gulyani et al., 2012). This approach essentially uses predicted housing expenditure as a proxy for housing quantity, similar in concept to “a dollar’s worth of peanuts”, and the effective price can then be teased out accordingly (Heikkila, 2000). Yet another related point is the distinction between the price of housing stocks or flows. This distinction becomes important when dealing with pooled samples of tenants and owner-occupiers, as there may be a wedge between the opportunity cost of capital and the value of accommodation services due to imperfections in either the rental market or the market for housing assets. Such measurement

problems are invariably compounded in informal settlements where data opacity is all too common.

2.3. Informality

Biderman and Smolka (2012, p.1) argue that “informal settlements have no common definition, let alone consistent and measurable indicators.” Indeed, a plethora of closely related terms are often used interchangeably: “informal settlement, slum, shantytown, squatter camp, favela, ghetto, bidonvilles, Katchi Abadis, and campamentos”, among others (Smit et al., 2017, p. 107). Whatever the name, the phenomenon itself is clearly of growing importance, as more than one-quarter of the world’s population now resides in informal settlements (Avis, 2016). For the purposes of this paper, however, we are specifically interested in the concept of *informal settlements* rather than slums per se, although there is evidently considerable overlap between the two concepts.

The key reason for our focus on informal settlements is that the concept reinforces our emphasis on the relationship between land use regulations and housing outcomes. Formal settlements are those largely consistent with what land use regulations prescribe, while informal settlements are not. We make this choice while recognizing and acknowledging criticisms that a formal-informal dichotomy may belie an underlying continuum or degrees of formality (Harris, 2018), or that land use regulations and associated planning practices may themselves be informal (Chiodeli and Mazzolini, 2019), or that static representations may overlook or flatten the underlying modalities of urbanization (Basile and Ehlenz, 2020; Woo and Jun, 2020).

2.4. LUR → AFF

With the three definitions now in place, we turn to an examination of the causal linkages between them, beginning with the impact of land use regulations on housing affordability. Much of the early scholarship on this topic was conducted in the United States and other countries of the global North, with Monkkonen et al. (2020) providing a useful update on the highly influential survey compiled by Quigley and Rosenthal (2005) on the topic. There is general agreement that, in the global North, more stringent land use regulations are associated with higher prices of land and housing. An unresolved issue, however, is to what extent those higher prices emanate from supply- or demand-side channels of impact (Ihlandfeldt, 2007; Monkkonen et al, 2020). Insofar as land use regulations generate localized amenities, those may be capitalized in the value of residential properties due to enhanced demand. Nonetheless, there appears to be more evidence to suggest that the supply-side effects are dominant, whereby constrained supply contributes to higher prices in the face of normal increases in demand arising from population growth and other demographic changes (Glaeser and Gyourko, 2003).

Additional complications arise in the global South. In part, there is an issue of data reliability, which makes it more difficult to ascertain empirical insights with confidence (Talukdar, 2018). This data problem is compounded by the myriad other factors that may be concomitant with informal urbanization processes in the global South (Buckley et al., 2016). Key among these other factors may be the lack of consistent enforcement of land use regulations, an issue explored by Monkkonen and Ronconi (2013), and by Monkkonen (2013), in the context of Argentina and Indonesia, respectively. They posit that more stringent land use regulations coupled with lack of enforcement can lead to more households moving into the informal sector, and this combination,

in turn, can generate negative externalities that are then reflected in lower property values in the formal sector. In a somewhat similar vein, Heikkila and Lin (2014) develop a theoretical model that comprises both formal and informal sector housing. When stringent land use regulations are imposed in that model, it has the effect of siphoning off demand pressures from the formal sector, so the externality effects in their model are pecuniary. Additional indirect evidence in this regard is provided by Gulyani and Talukdar (2008) and Talukdar (2018), in their examination of the “low-quality, high-price puzzle” in informal settlements in Nairobi.

2.5. LUR → INF

It is generally recognized that informal settlements arise where formal land use and market mechanisms are unable to respond effectively to the growing need for affordable and accessible urban housing (Avis, 2016; Buckley et al., 2016; Biderman and Smolka, 2012; Chiodelli and Mazzolini, 2019; Cities Alliance, 2018). Fewer works have sought to incorporate informal sector outcomes within formal (in the modeling sense of the term) theoretical models. Brueckner and Selod (2009) do so by building on early work by Jimenez (1985), in which a key role is played by community organizers acting on behalf of squatters framed within a game-theoretical model over formal entitlements. A different approach is taken by Heikkila and Lin (2014), whereby two income groups compete for urban land within a market context. A unique feature of their model is that an informal housing sector arises endogenously within the context of the model as a consequence of imposing land use regulations that restrict the absorptive capacity of the formal sector.

Heikkila and Harten (2020) extend this basic framework to incorporate multiple jurisdictions and an explicit urban geography. That model is in turn estimated by Goytia et al. (2020) using data for Buenos Aires, and those results are broadly consistent with the basic proposition linking formal-sector land use regulations to housing outcomes in the informal sector. Kim (2016) and Harten (2020) examine a different margin of informality in the context of Beijing and Shanghai, respectively. Their case studies explore how formal-sector dwelling units are occupied through informal quasi-market mechanisms at very high densities, contrary to what formal building codes would permit.

While minimum lot size standards could make formal housing less affordable, prompting poorer households to live in informal settlements, they may also deter potential migrants, mirroring the effect of the denial of water connections analyzed by Feler and Henderson (2011). Lall et al. (2006) find that when minimum lot size regulations are relaxed, it increases housing supply but also prompts higher population growth. This growth is in fact faster than the formal housing-supply response, leading to an increase in informal settlements formation. They indicate that such an outcome suggests that reducing barriers through land use, such as minimum-sized plots, needs to be accompanied by other steps to raise housing supply. In the absence of such measures, pro-poor land regulations may in fact exacerbate informality.

2.6. AFF ← → INF

The link between land use regulations and housing outcomes is complicated by the interplay between affordability and informality, among other factors. The emergence of informal housing is a response to a perceived lack of access to affordable housing, while it can also contribute directly to the provision of more affordable alternatives to formal sector housing. While

Kallergis et al. (2018) do find that, “The presence of informal and public housing improves the overall affordability of the housing sector”, other studies suggest that this finding is not uniformly the case. For example, Talukdar (2018) finds that the cost of typical housing in informal settlements in Nairobi is an estimated 16.4% higher than its formal-sector counterpart, even after adjusting for quality differentials.

Understanding the interplay between the formal and informal sectors is essential here. This interplay may be via physical, social, and/or environmental externalities of the type posited by Monkkonen and Ronconi (2013), and Monkkonen (2013), or pecuniary externalities of the kind that arise endogenously in the model by Heikkila and Lin (2014). Indeed, in the latter model, relative housing prices in the formal and informal sector depend on a host of parameter values pertaining to income differentials, population demographics, demand elasticities, and the like. All this suggests that there is no single, unambiguous outcome on housing prices in either the formal or informal sectors resulting from more stringent land use regulations. Additional factors arise when one considers geographic features, spatial proximity, infrastructure investments, employment effects, or institutions of metropolitan governance (Goytia et al., 2015; Buckley et al., 2016; Heikkila and Harten, 2020).

2.7. AFF + INF → LUR

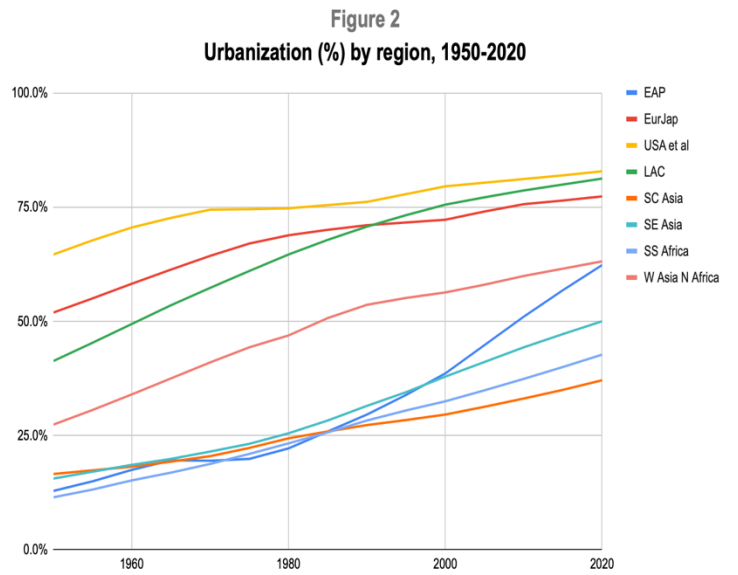
Land use regulations are not set in stone, and numerous studies have explored this endogeneity. Much of the literature on land use regulations is set in the global North, with the seminal work of Tiebout (1956) framing the issue in terms of the efficient provision of local public goods. This framework extends readily to a club theory perspective (Heikkila, 1996). Fischel’s (2001) influential homeowner hypothesis likewise features the role of local governance but with more emphasis on the underlying legal mechanisms. Hilber (2013) and McDonald and McMillan (2004) emphasize similar motivations. Gyourko (2008) finds that community wealth is strongly correlated with the stringency of land use regulations; or, as Harris (2018) puts it, “when the market value of property increases so, too, does the pressure to establish ‘hard-edged rules to manage it.’”

In a developing country context, land use entitlements in the models formulated by Jimenez (1985) and by Brueckner and Selod (2009) are allocated endogenously through bargaining processes. In Heikkila and Lin (2014), minimum lot size restrictions arise endogenously and are reflective of the interests of the class of higher-income households who are presumed to have more political influence. Monkkonen (2013, p. 257) states that “the notion of selective or flexible enforcement is one in which local officials use the threat of regulation as a means to extract resources from participants in the process, a form of rent-seeking.” Others attribute certain land use or building regulations in parts of the global South to outdated colonial legacies (Buckley et al., 2016; Basile and Ehlenz, 2020). While these and other explanations can help to endogenize land use regulations within the broader context of urbanization, they do not change the fact that such policy interventions provide a potentially important foothold for more prescriptive analyses.

3. Contextual and Historical Background

We begin this contextual analysis with an historical overview of the urbanization process in different global regions. As previewed earlier, a central finding of this paper underlines the dynamic nature of the relationship between land use regulations and housing outcomes. The ongoing process of urbanization is the context in which this dynamic relationship unfolds. As shown in Figure 2, the pace of urbanization over the past seven decades has varied widely between the eight global regions depicted here. Throughout this interval, the land-rich developed countries of the United States, Canada, and Australia [*USA et al.*] have, in the aggregate, had the highest percentage of urban population. Another region, comprising Europe and Japan [*EurJap*], has tracked that first group quite closely. Latin America and the Caribbean [*LAC*], however, outpaced *EurJap* and by 2020 had almost the same degree of urbanization as the *USA et al.* At the bottom end of the chart, four regions at the outset of 1950 had similar urban population shares, on the order of 15%. By the year 2020, South and Central Asia [*SC Asia*], Sub-Saharan Africa [*SS Africa*], and Southeast Asia [*SE Asia*] continue to have markedly lower urban population shares than other regions, while East Asia and the Pacific [*EAP*], dominated of course by China, has risen rapidly to over 60%, on par now with West Asia and North Africa [*W Asia N Africa*].

Housing outcomes around the world have evolved within the context of these regional variations. A cross-sectional view of these housing outcomes is presented in Table 1 for the year 2014. Four respective indexes are shown, pertaining to housing price, informal settlements, land use regulation, and enforcement. A detailed definition and description of those indexes is defined in the next section, but they are presented here briefly to help introduce the context for the empirical analysis that follows. Each of the four indexes is a broad measure of the variable in question and is calculated over the entire set of 190 cities, to the extent that data availability permits. A blue shading is used to highlight index values above 0.5, while a red shading indicates values below -0.5.



Source: Authors

Table 1: Index Value [P-I-R-E] by Region

Price	Informal	Regulation	Enforcement	Region
-0.22	-0.02	0.66	0.83	<- East Asia and the Pacific -
0.01	-0.55	-0.26	0.11	<- Europe and Japan -
0.02	-1.20	0.09	0.55	<- Land-Rich Developed Countries -
-0.04	-0.12	-0.02	-0.26	<- Latin America and the - Caribbean
0.18	0.69	0.15	-0.54	<- South and Central Asia -
-0.35	0.15	-0.56	-0.09	<- Southeast Asia -
0.25	1.45	-0.62	-1.18	<- Sub-Saharan Africa -
0.38	-0.14	-0.48	-0.40	<- Western Asia and North Africa -

Source: Authors

The housing **price** index has no notable outliers in this context, likely because in each city the price index is calibrated relative to local incomes. As for the index of **informality**, *Sub-Saharan Africa* is an extreme “positive” outlier, while *South and Central Asia* is somewhat less so. The *land-rich developed countries* group is a negative outlier for this informality index, while *Europe and Japan* is also a negative outlier. Regarding land use **regulation**, *East Asia and the Pacific* is a positive outlier, while *Southeast Asia* and *Sub-Saharan Africa* are negative outliers. *East Asia and the Pacific* and *Land-Rich Developed Countries* are positive outliers for **enforcement** of land use regulations, while *South and Central Asia* and *Sub-Saharan Africa* are negative outliers. Table 2 sets out the correlation coefficients for these four indexes at the regional level.

Enforcement of land use regulations is strongly correlated negatively with price and informality, while it is strongly correlated positively with land use regulations. None of the remaining correlations is notable, which suggests that enforcement may be key to understanding the role of land use regulations in shaping housing outcomes. That is why, as a novel contribution of this study, we include measures of enforcement to assess the effect of the regulatory environment on informality. This fact is quite relevant, since institutional contexts strongly differ between regions and countries.

Table 2
Correlation of P-I-R-E index values by region

Price	Informal	Regulation	Enforcement
1.000	0.259	-0.31	-0.598
	1.000	-0.313	-0.774
		1.000	0.696
			1.000

Source: Authors

In section 5, we present a full set of regression results, where the focus is on exploring the impact of land use regulations (with and without enforcement) on the prevalence of informal settlements. To set the stage for that analysis, we first present the results, here in Table 3, of an initial regression with the informal housing index regressed solely on the regional dummy variables. Several aspects of the results in Table 3 are quite striking. Notably, it shows that well over half of the total variation in the share of households in informal sector housing is explained by these regional dummy variables, where East Asia and the Pacific is used as the point of comparison.

Table 3: Regional Variations in Informal Settlements (OLS)

Dep. Variable -- Informal share	R2 -- 0.571	Adj -- 0.554
Region	Coefficient	t-statistic
sub-Saharan Africa	1.457	8.826
South and Central Asia	0.695	5.105
Southeast Asia	0.193	1.114
East Asia and the Pacific		
Western Asia and North Africa	-0.032	-0.183
Latin America and Carribbean	-0.066	-0.467
Europe and Japan	-0.489	-3.755
Land-rich Developed Countries	-1.0616	-6.571
Intercept	-0.05	-0.566

Source: Authors

An important question is whether these regional variations are rooted in the stage of urbanization or some other fixed effects, such as institutions, culture, or geographical considerations. The regions in Table 3 are set out in descending order with respect to the value of their coefficients. A positive/negative coefficient indicates that the share of informal housing is larger/smaller compared to the EAP reference region. It is remarkable that the three regions with positive coefficients correspond to the *same* three regions that have the lowest levels of urbanization: Sub-Saharan Africa, South and Central Asia and Southeast Asia. Not surprisingly, many

developing world cities appear to have a lagged, highly asynchronous relationship between investments and urbanization, indicating an inadequate supply response to urbanization in this part of the world (Dasgupta et al., 2014). Likewise, the four regions with negative coefficients (hence, lower shares of informal housing) are those with higher levels of urbanization.

An exception is Latin America, the second most urbanized region in the world. It also grew from an urbanization rate of 41% in 1950, to 80% in 2014. This suggests that informal housing is more prevalent in cities located in regions with lower overall rates of urbanization, but which are growing at a steady pace. Thus, it may not be just a question of insufficient housing options within the formal sector of a given city—it may also be that there are not enough urban options, which means lower elasticities of land with basic infrastructure services to cope with demand for urbanization. To the extent this is the case, more rapid urbanization may actually require the provision of more formal-sector land and housing options overall. For doing that, the way in which land is regulated, financed, and provided with infrastructure can be of central importance for reducing the growth of informal housing settlements (Heikkila et al, 2020). Section 5 entails a closer examination of the relationship between land use regulations and informal sector housing, but we turn next to section 4 and a detailed description of our data and methodology.

4. Methodology

4.1. Overview of data model

Our focus here is on informal sector housing as a dependent variable, with land use regulations as the explanatory variable of interest, and with regional fixed effects, institutional factors and other controls applied. The data used for this study belong to three different databases, all of them involving a stratified sample of 190 cities (Figure 1) from the universe of all 4,231 cities and metropolitan areas with more than 100,000 inhabitants. It includes cities from 75 different countries, eight geographic regions, with different population sizes and per capita incomes. The area of study for each city focused on urban metropolitan areas defined as agglomerations of contiguous built-up areas and the open spaces in and around them that may contain a large number of municipalities. This remarkably comprehensive dataset was assembled by Professor Soli Angel and his colleagues (Angel et al., 2016) at NYU.

The sample we adopted here was constructed with three strata: world regions, city population size, and number of cities in the country. Cities were selected at random from eight world regions in proportion to the urban population in each region. These regions are: East Asia and the Pacific, Southeast Asia, South and Central Asia, Western Asia and North Africa, Sub-Saharan Africa, Latin America and the Caribbean, Europe and Japan, and Land-Rich Developed Countries. This classification approximates that of UN-HABITAT, except that the developed countries are separated into two regions: land-rich developed countries, United States, Canada, and Australia and other developed countries (Japan and Europe, including the Russian Federation). The second stratum was city population size. An equal number of cities were selected at random from four city population-size ranges, each range containing one-quarter of the total population of the cities in the sample universe. The four city population size ranges were: 100,000-425,677; 425,678-1,560,000; 1,560,001-5,600,000; 5,600,001 and above.

Of principal interest for our purposes is the interplay between land use regulations, informality, and the cost of housing (or, in its inverse form, affordability). Are there any systemic aspects of this interplay evident empirically at a global scale? To explore such questions, we construct broad indexes that provide aggregate measures of these key variables. Factor analysis is a commonly used data reduction method for identifying and summarizing patterns of correlation embedded in a given data set. It is an ideal method for our purposes, because affordability, informality, and regulatory burden are important and meaningful, but they are also difficult to pin down precisely in empirical terms—especially for data compiled at a global scale. Rather than having to choose between multiple candidate variables to measure the phenomenon of interest, factor analysis takes these as its inputs and constructs composite “factors” that reflect commonalities in those underlying variables. This method, in effect, allows the data to “speak for themselves.”

As explained in more detail in the appendix, we use **INFORMAL-T1** and **INFORMAL-T2** as the index of informality in 1990 and 2014, respectively, and **INFORMAL- Δ** as the change in the measure of informality between those two time periods. **REGULATION** is a composite measure of regulatory restrictiveness following the examples of Gyourko (2008) and Goytia et al. (2015), and **ENFORCE** couples this regulatory restrictiveness with a measure of the extent to which those regulations are vigorously enforced. **REGIONS** captures regional fixed effects, using the same dummy variables outlined earlier in section 3. **CONTROLS** comprises an additional set of land and other control variables describing the local urban context. **INSTITUTIONS** provides additional controls pertaining to the level of development for the region/nation in which each city is situated. We run this model using both ordinary least squares (OLS) and instrumental variables (IV). The definitions and data for these groups of variables are described briefly here, with additional detail presented in the appendix.

4.2. Informality

Defining and measuring informality is problematic. There is no common definition, nor are there consistent and measurable indicators for measuring informality, especially on a global scale. Challenges include information availability, the precision of measurement, and comparability across cities and countries. This means that one central issue in empirical studies related to informality is how informality is identified and measured. Moreover, scholars highlight the implications of using different definitions for the variables in different countries and cities, calling attention to the unexploited potential for international comparisons (Biderman and Smolka, 2011).

We develop three distinct variables to measure informality. We use **INFORMAL-T1** and **INFORMAL-T2** as the index of informality in 1990 and 2014, respectively, and **INFORMAL- Δ** as the change in the measure of informality between those two time periods. Given the global scope of our sample (based on Angel et al. 2016), we were able to develop a group of indicators that focuses on attributes associated with site and location, usually absent from typical household surveys. Those have always been difficult to collect, because it is not an attribute of the house or of the household but attributes of urban layouts that require a focus on high-resolution satellite imagery. Here, those measures allow us to identify informal land development and low-quality housing in a very precise way. These are areas with irregular layouts that were clearly not subdivided or laid out before residential construction took place. This category includes squatter

settlements that grew incrementally without an overall plan, homes built on irregular parcels of land, or homes built on rural plots that were not regularly subdivided before their conversion to urban use. It includes areas that have been subdivided for urban use, but that lack visible evidence of conformity to land subdivision regulations, such as regular plot dimensions, paved roads, streetlights, or sidewalks. In order to study changes over time in the attributes of urban layouts, we construct these indicators for all cities for the years 1990 and 2014, which also enables us to examine change over time.

4.3. Regulations

Land use regulation data were obtained from the *Survey of the Regulatory Regime Governing Land and Housing* (Angel et al., 2016). This survey consists of 87 questions for each of the 200 cities. Each survey was accompanied by urban extent maps that showed the study area of the survey as the extent of a city's built-up area. It involves the participation of city-based researchers who completed the survey through data collection, interviews, and contributions of other local housing experts. Their role was to compile and triangulate data to complete the survey, gathering primary and secondary sources, and interviewing local experts from their city network, about 15 interviews per city on average. Typically, these interviews included municipal agents, realtor associations, private developers, civil society organizations working on housing issues, academics, and other experts. In order to address the idiosyncratic nature of housing conditions in each of the cities, city-based researchers were encouraged to provide additional documentation and materials of interest, including land use plans, zoning and building regulatory documents, past studies on land use and housing in their city, and photographs of the different types of housing in each city. Finally, given the number of cities and of city-based researchers involved, a three-stage review ensures the comparability and robustness of the results.

The broad scope of the questionnaire allowed us to create variables capturing the land-use environment attributes in each city, following the methodology provided by previous studies (Goytia and Pasquini, 2012; Gyourko et al., 2008). We have built indicators and classified them according to their main topics: i) Land Use Plan and Regulation Indicator (LUPI); ii) Zoning and Residential Projects Approval Processes and Costs Indicator (ACI); iii) Urban Ordinance Indicator (UOI); and iv) Growth Indicator (GI). The survey also provides information related to the magnitude of informality in each city based on national statistical offices, which is another important input for our study, since it enables one of several informality indicators to be constructed.

To construct the indicators of land use regulation used in the analysis, we follow an approach similar to the one used for the CILP index for Argentina by Goytia and Pasquini (2012) and the Wharton Residential Land Use Regulation Index (WRLURI) for the United States, used by Gyourko, Saiz, and Summers (2008). In the latter case, four different indicators are constructed, which involved: i) the existence of land use plans that may act to exclude certain groups of potential residents, such as the poor or minorities; ii) building conditions and consumption standards, such as minimum lot sizes, density limits, or height restrictions that can reduce affordability by constraining the amount of housing the land can accommodate, thus restricting supply; iii) extension and growth requirement conditions, such as urban greenbelts that can raise housing prices by restricting the amount of developable land in a city, as well as the characteristics defined for infrastructure provision; and iv) project approval processes and costs.

4.4. Enforcement

Our global sample of cities includes many cities from developing countries with weak institutions, where regulatory enforcement may be weak or inconsistent (Henderson and Feler, 2011). Consequently, enforcement of land use regulations constitutes a central topic that needs to be carefully assessed in any rigorous estimation of whether formal/informal land development is driven by the regulatory context in each city of the developed and developing world (Goytia and Pasquini, 2010, Monkkonen and Ronconi, 2012). For this reason, we adapt the analytical methods of prior studies and construct new indicators that account for the level of regulation enforcement. To this end, we develop a novel second-generation set of indicators for land use regulation that introduces enforcement performance in each city's regulatory environment.

For each regulatory measure, we add an enforcement condition and use in our estimations both versions, with and without enforcement. These indicators help determine the degree of compliance by either the public and the private sector in the application of land use plans, building restrictions, and policies regulating urban extension and densification. Drawing upon these regulation sub-indexes, we construct two different versions of the aggregate regulatory factor: one with and one without enforcement performance. The development of standardized regulatory indicators facilitates comparison across cities (in this case, metropolitan areas) and also permits aggregate analysis at the regional level.

4.5. Regional groupings

Following Angel et al. (2016), and as illustrated in Figure 3, we construct regional dummy variables for eight regions:

<ul style="list-style-type: none">○ East Asia and the Pacific○ Europe and Japan○ Land-rich Developed Countries○ Latin America and the Caribbean	<ul style="list-style-type: none">○ South and Central Asia○ Southeast Asia○ Sub-Saharan Africa○ Western Asia and North Africa
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Figure 3: Map of the Sample of 200 Cities and Regions



Source: Authors, based on Angel et al., 2016.

4.6. Institutional variables and other controls

INSTITUTIONS includes several variables that depict the institutional environment. These are: GDP per capita, a widely used proxy for the level and depth of institutions (Acemoglu, 2012), the cadaster upgrading status, and the enforcement of contractual agreements. **CONTROLS** comprises a set of geographical and housing supply variables, including city size, built-up area and density, urban extent, population growth, infill, extension, leapfrog development or fragmentation, which measures the extent to which the built-up area within it is fragmented by urbanized open space. Data on affordability were obtained from the *Housing Affordability Survey* (Kallergis et al., 2018), which measures the prices as well as the key attributes of different types of residential plots, houses, and apartments available for sale or rent in the same 190-city sample and compares them with household incomes in these cities. It also provides the shares of the housing subsectors, including public housing, which totals 13% in the global sample. We also use information on the share of public housing to control for additional supply-side conditions related to affordable housing in our model.

4.7. Instrumental variables

Methodologically, we want to estimate the causal effect of the land regulatory framework on informality. One of the most problematic issues in this type of estimation is the issue of endogeneity, which means the regulatory framework can be affected by the level of informality in the city. To solve this, the second model we estimate is an Instrumental Variables (IV) 2SLS model. IV estimators are used to recover consistently estimated coefficients on variables of interest resolving endogeneity. In the language of linear regression, there needs to be an “instrument” which isolates this variation that is not correlated with any part of the error term in the main estimating equation. Roy (1951) model by Gronau (1974) and Heckman (1979) is informative about the more structural background of the IV estimator.

At this point, we need to acknowledge the limitations in finding reliable instruments for regulation indicators. Coming up with suitable instruments in the urban economics literature is not always straightforward, as highlighted, for example, by Inhanfelt (2007), and by Glaeser and Ward (2009). Past density, population, plans, or prior transportation infrastructure, such as railroad rights-of-way, are commonly employed [Duranton and Turner (2011, 2012); Duranton et al. (2014)]. Baum-Snow et al. (2014) use aspects of historical urban road and railroad networks as an instrument for changes in urban form. The idea of using historical infrastructure as instruments is that its rights-of-way are likely to be preserved, allowing for construction.

Residents of communities with higher informality may demand more restrictive regulations, causing some degree of reverse causation. Having this in mind, our strategy to circumvent this problem as much as we can is to use two types of instruments. One, historical population (1900 and 1930), is consistent with a dynamic interpretation of our model. The rationale for using historical population as an instrument is that it captures all the historical factors important a long time ago, which started a dynamic development process of cities. These factors may no longer be important, yet they remain relevant because of inertia, durable housing, or the generation of agglomeration forces, and are correlated with the level of land use regulation that today is implemented (Hilber and Robert-Nicoud, 2012).

The second instrument used to address endogeneity in the 2SLS model is the density (number per square kilometer of locale area) of both 3-way and 4-way intersections. Our identifying assumption for both instruments is that they do not influence the level of informality directly, but considerations may induce planning boards to regulate places endowed with different layouts that are inherent at their foundational times. To estimate the first stage, we evaluate whether the instruments are sufficiently strong predictors of our regulation indicator, using critical values for F-tests developed by Stock and Yogo (2005). By these methods we replicate the OLS analysis using instruments for the regulation regressor—using population in the year 1900, as well as additional geographical instruments.

5. Findings

The principal purpose of this paper is to gain a global perspective and empirical insights into the relationship between land use regulations and housing outcomes, especially in the informal sector. In this section, we first present a high-level overview of our principal findings. We then proceed to a re-examination of those same basic results from a regional perspective, and then an income-level (GDP) perspective.

5.1. Principal results

Table 4 presents a high-level view of our key results, while supporting detail is provided in the appendixes. This table reports the coefficient estimates for the key variables of interest, **REGULATION** and **ENFORCE**, where the dependent variable is either **INFORMAL-T1** (for 1990), **INFORMAL-T2** (for 2014), or **INFORMAL-Δ** (change from 1990-2014). The first four columns of results display the OLS estimates, beginning on the left without any additional explanatory variables. Columns 2, 3, and 4 progressively add **REGIONS**, **CONTROLS**, and **INSTITUTIONS**. The final column reports the IV estimates corresponding to the full model.

Table 4
Summary of Key Regression Results

	INFORMAL-1	INFORMAL-1	INFORMAL-1	INFORMAL-1	INFORMAL-1
REGULATION	-0.100***	-0.072***	-0.064***	-0.054**	0.040
ENFORCE	-0.148***	-0.094***	-0.090***	-0.075***	0.032
	INFORMAL-2	INFORMAL-2	INFORMAL-2	INFORMAL-2	INFORMAL-2
REGULATION	-0.090***	-0.055**	-0.061**	-0.045*	-0.083
ENFORCE	-0.144***	-0.082***	-0.091***	-0.066***	-0.014
	INFORMAL-Δ	INFORMAL-Δ	INFORMAL-Δ	INFORMAL-Δ	INFORMAL-Δ
REGULATION	0.011	0.017	0.003	0.009	-0.123
ENFORCE	0.004	0.012	-0.001	0.009	-0.046
REGION	no	yes	yes	yes	yes
CONTROLS	no	no	yes	yes	yes
INSTITUTIONS	no	no	no	yes	yes
Method	OLS	OLS	OLS	OLS	IV

* significant at 10% level, ** 5% and *** 1%, respectively. Source: Authors

The results shown in Table 4 are strikingly robust and persistent in several respects:

- For all OLS regressions, where the dependent variable is either **INFORMAL-T1** or **INFORMAL-T2**, the estimated coefficients for **REGULATION** and for **ENFORCE** are negative and significant—highly so for **ENFORCE**. This result suggests that within a static time frame, either in 1990 or in 2014, more stringent land use regulations (especially when coupled with active enforcement) do tend to reduce the extent of informality that might otherwise exist.
- For these same cases, the magnitudes of the estimated coefficients tend to diminish as regional fixed effects, additional controls, and institutional variables are applied.
- For all of the OLS estimators, the coefficients for **ENFORCE** are notably larger in magnitude than their **REGULATION** counterparts. This fact again underlines the importance of enforcement of land use regulations in determining housing outcomes.
- In *all* the OLS cases, the estimated coefficients for 1990 (**INFORMAL-T1**) are highly similar in magnitude to their 2014 (**INFORMAL-T2**) counterparts. Thus, even over a 14-year interval, the underlying relationships appear to be quite stable.
- *None* of the coefficient estimates is significant where the dependent variable is **INFORMAL-Δ**. Thus, in this case, the longer-run impacts of land use regulations on informal sector housing outcomes is unclear. In the following discussion, however, we probe this relationship from a regional and economic development lens.
- Likewise, none of the instrumental variable (IV) estimates are significant. As noted in section 2, the scholarly literature does point to various pathways for endogeneity, whereby land use regulations and enforcement are themselves influenced by the extent of informal settlements, and our results appear to confirm this fact. Moreover, as discussed in section 4, finding a suitable instrument for land use regulation is problematic.

5.2. Regional perspectives

We saw earlier that regional dummies alone explain more than half the variance in the extent of informality across our sample of 190 cities. It is instructive, therefore, to repeat the full OLS regression (as in column 4, Table 4) for the sub-sample of cities in each region. Several aspects of the results presented in Table 5 are noteworthy:

- For the static perspective, in either 1990 (**INFORMAL-T1**) or 2014 (**INFORMAL-T2**), almost all of the estimated coefficients are negative, consistent with the general expectation that land use regulation and enforcement tend to limit informal sector housing outcomes in the short run. This finding appears to be stronger and more pervasive in 2014 than in 1990.
- The results vary considerably by region. *Sub-Saharan Africa* is the only region for which the estimated coefficients of both **REGULATION** and **ENFORCE** are significant in both time periods. In contrast, in both *Europe and Japan* and *Latin America and the*

Caribbean, neither of those estimated coefficients is statistically significant for either time period.

- In all cases where the estimated coefficient for **REGULATION** is significant in either year, the corresponding coefficient for **ENFORCE** is also significant. There are also several cases where the coefficient for **REGULATION** is not significant, but its **ENFORCE** counterpart is significant. This fact confirms the general finding that enforcement is a crucial aspect of any land use regulation.
- From a more dynamic perspective, assessing the incremental change in informal settlements between 1990 and 2014 (**INFORMAL-Δ**), the results are mixed. For three regions (*South and Central Asia*, *Southeast Asia*, and *Sub-Saharan Africa*), land use regulations coupled with active enforcement appears to result in an increase in the proportion of informal settlements over time. This finding is consistent with a crowding-out effect, whereby restrictive land use regulations limit the ability of cities to accommodate a growing urban population. In two other regions (*East Asia and the Pacific* and *Western Asia and North Africa*), however, the estimated coefficients indicate the opposite result, suggesting that consistent enforcement of land use regulations there does diminish the extent of growth in informal settlements.

In sum, there is no “one-size-fits-all” global relationship between land use regulations and informal settlements. Instead, one must probe more closely to understand the specific context in which urbanization is unfolding. As we have seen, context varies significantly by region. And as we show next, it also varies by economic development status.

Table 5: Regression Results for Each Region

	INFORMAL-1		INFORMAL-2		INFORMAL-Δ	
	REGULATION	ENFORCE	REGULATION	ENFORCE	REGULATION	ENFORCE
East Asia and the Pacific	-0.075	-0.050	-0.122**	-0.137***	-0.047	-0.087**
Europe and Japan	-0.047	-0.002	-0.092	-0.062	-0.045	-0.060
Land-Rich Developed Countries	0.025	-0.081	0.024	-0.179**	-0.000	-0.099
Latin America and the Caribbean	-0.018	0.018	-0.003	0.025	0.015	0.006
South and Central Asia	-0.037	-0.262***	-0.031	-0.112*	0.006	0.151***
Southeast Asia	-0.150	-0.147**	0.069	-0.020	0.219**	0.127*
Sub-Saharan Africa	-0.203***	-0.233***	-0.112**	-0.142***	0.091**	0.091**
Western Asia and North Africa	-0.064	-0.073	-0.183**	-0.173***	-0.119*	-0.101**

Note:

* significant at 10% level, ** 5% and *** 1%, respectively. Source: Authors

5.3. Results stratified by GDP level

Another useful perspective from which to view the relationship between land use regulations and informal settlements is by stage of economic development. Using GDP per capita for the country in which a city is situated as a simple proxy, we sort our sample of cities into low, medium, or high levels of economic development. The results reported in Table 6 are rather striking. For those cities in high-GDP countries, none of the estimated coefficients is significant. In contrast, for those in low-GDP countries, there is clear evidence that land use regulations in both 1990

(**INFORMAL-T1**) and 2014 (**INFORMAL-T2**) were significantly associated with less extensive informal settlements. This association is even more compelling where land use regulations are more vigorously enforced. Perhaps not surprisingly, for those cities in medium-GDP countries, the results fell somewhere in the middle of their low- and high-GDP counterparts.

Table 6: Regression Results for Each GDP Level

	INFORMAL-1		INFORMAL-2		INFORMAL-A	
	REGULATION	ENFORCE	REGULATION	ENFORCE	REGULATION	ENFORCE
LOW	-0.068**	-0.158***	-0.033	-0.073**	0.035	0.085***
MEDIUM	-0.066*	-0.032	-0.076**	-0.064**	-0.011	-0.032
HIGH	0.002	-0.013	-0.004	-0.056	-0.007	-0.043

Note:

* significant at 10% level, ** 5% and *** 1%, respectively. Source: Authors

From a more dynamic perspective, with reference to the growth of informal settlements over time (**INFORMAL-Δ**), none of the estimated coefficients is statistically significant, with the *important exception* of more strictly enforced land use regulations in low-GDP countries. In this case, there is strong evidence that more vigorous enforcement of land use regulation is associated with an increase in the growth of informal settlements over time. In these cases, the short- and longer-run effects of land use restrictions work in opposing directions. From a static timeframe, increased enforcement of land use regulations reduces the prevalence of informal settlements. Over time, however, those same restrictions reduce housing options for the urban poor. This dynamic is particularly relevant for low-GDP countries, where the urbanization process is still very much underway.

6. Discussion

Quite frankly, we were not expecting to find such seemingly definitive results from this preliminary investigation. There are several reasons for our more modest initial expectations. One is that any dataset comprising a wide range of variables for 190 cities from across the globe is likely to be beset by challenges of consistency and comparability in the way variables are defined, measured, and constructed. It is a testament to the diligence and thoroughness of Professor Angel and his colleagues that such challenges appear to have been well-addressed. Beyond data considerations, one might reasonably expect the underlying phenomenon we are addressing to be “muddy”. The relationship between land use regulations, enforcement, and informal housing outcomes is fraught with potential idiosyncrasies rooted in their specific contexts. Local institutions, cultures, stages of economic development, geographical topography, political orientations, and historical legacies are all factors that could influence and shape informal housing outcomes. Competing jurisdictions within the local metropolitan region can also complicate the process by which housing outcomes are determined. Notwithstanding such considerations, the empirical results reported here underline several key messages.

6.1. Continental Divide

Our dataset comprises 190 cities in eight different regions, or roughly two dozen cities per region on average. Moreover, each region itself comprises multiple countries. With so much diversity *within* regions, it is striking that regional fixed effects would explain more than half the variance in the prevalence of informal settlements across this diverse collection of cities. This finding suggests there is indeed a “continental divide”; that Latin America and the Caribbean, Sub-Saharan Africa, Southeast Asia, and so on, are in fact meaningful lenses through which to understand urban development patterns. On the other hand, as we saw in section 3, there is also reason to believe that much of these regional effects may be linked to the degree of urbanization, as those regions whose cities had the highest shares of informal settlements were also the regions with the lowest levels of urbanization and growing recently and faster. This fact again underscores the dynamic nature of the relationships, suggesting that what on the surface appears to be a regional effect may in fact be based more fundamentally on the stage of urbanization and the way in which this urbanization is occurring.

6.2. Global Principles

Notwithstanding the pronounced regional variations, the empirical results reported in section 5 strongly suggest there are indeed global principles at work. Specifically, we find that cities with more stringent land use regulations, especially when coupled with active enforcement, are less likely to have a prevalence of informal settlements. This result holds for both time periods covered (1990 and 2014), and the corresponding parameters appear to be quite stable over time. This finding is consistent with a fairly straightforward view of land use regulations, insofar as informality, by definition, falls largely outside the scope of formal regulatory practices. Thus, where regulations are more stringent and actively enforced, one might reasonably expect there to be less scope for informality to arise. Additionally, those cities with more permissible land use regulations may in fact encourage migration into the city. If the resulting population growth outpaces additional housing supply, informal settlements may result (Lall et al., 2006 and Feler and Henderson, 2011).

From a more dynamic perspective, however, the situation in less developed countries is starkly reversed. Growth in informal settlements between 1990 and 2014 is strongly and *positively* correlated with more stringent land use regulations and active enforcement thereof. This finding accords with the initial working hypothesis that motivated this research: restrictive land use regulations diminish the absorptive capacity of the formal sector, resulting in a crowding-out effect. It takes time, however, for this result to be achieved. In the short run, stringent land use regulations make it more difficult for informal settlements to arise. In the longer term, these same regulations restrict opportunities for households to access formal-sector housing options, and so informal settlements are the inevitable result. This phenomenon is more clearly evident in lower-income countries where urbanization is still in its earlier phases.

6.3. Implications for Planning Practitioners

Understanding the fundamental causes of informal settlements is a prerequisite for effective intervention. Land use regulations are not an end in themselves. Rather, they are the principal tools that planners have at hand for guiding the course of urban development. Planning, by its very nature, is forward-looking and anticipatory. The evidence presented here, however, suggests that land use regulations, as currently conceived, tend to be oriented more to a static perspective.

Over the longer term, especially in low-income countries, they fail to augment the absorptive capacity of formal sector housing. Simply transferring “best practices” from developed countries to other parts of the world may be misguided at best.

To address this issue more effectively, planning practice should be oriented more to three fundamental purposes. The first is to measure the absorptive capacity of formal sector housing as prescribed by existing land use regulations. The second is to assess and forecast the shortfall in formal sector housing relative to current and projected demand. Third, planning practice should entail the design and implementation of more effective interventions to enhance that absorptive capacity as needed, which is certainly based in financing infrastructure at scale to cope with the pace of urbanization in fast-growing cities. These suggestions are not new, nor should they be controversial. The empirical evidence presented in this paper, however, suggests that planning practice has not yet addressed this challenge effectively, so a more vigorous and renewed commitment is overdue.

6.4. Prioritizing Further Research

More work is needed on the research front as well. Several priorities emerge:

- **Looking inside the regional fixed-effects black box** - It is well and good to observe that regional fixed effects account for more than half the variation in the extent of informal settlements across the world’s cities, but what ARE these fixed effects and what are their pathways of influence? Well-chosen case studies of representative cities from within each region might yield important insights, especially when linked to comparative studies such as this one.
- **Measuring the absorptive capacity of formal sector land use regulations** - If we as scholars are not developing appropriate tools, we are in no position to criticize planning practitioners for failing to apply them. Heikkila and Harten (2020) does lay out a housing-land use accounting framework that has a solid theoretical foundation, but the method itself is still rather conceptual. It would be valuable to articulate it in more concrete terms and apply it to the same case studies advocated for above.
- **Urbanization: Cause or cure?** - Urbanization appears to play a dual role on informality. By definition, urbanization is the process by which cities grow through in-migration and natural population growth, and this urban population growth gives rise to the need for accommodation, which, given the nature of informal development, mainly means the affordable provision of serviced land and housing. Yet, we have evidence to suggest that cities located in *less* urbanized regions are likely to have more informal settlements. It would be useful to develop a clearer understanding of what factors are at work.
- **The role of infrastructure** - The provision of infrastructure is another complicating factor. Its importance is enhanced by the fact that it is the other key policy intervention that planning practitioners have, in addition to land use regulations, for guiding urban land use patterns. In addition to such very practical considerations, infrastructure is also important from a conceptual viewpoint. From a hedonic perspective, it may be considered part of the broad bundle of housing attributes (in addition to neighborhood amenities, accessibility, etc.) that constitute housing services. Moreover, infrastructure provision is, in part, what delineates formal sector housing.

7. Appendix: Variable Definitions

The land use plan index (LUPI)

The first component of the overall index reflects the existence of a land-use and zoning plan. Respondents were asked if there was a well-publicized and well-understood zoning and land-use plan in force, being able to answer 'Yes', 'Varies', or 'No'. These answers had a number assigned: Yes = 1, Varies = 0.5, and No = 0, which would replace the answers to create only this component. It is standardized with a mean of zero and a standard deviation of one.

The land use plan enforcement index (LUPEI)

The land use plan enforcement index is based on the answers to four survey questions, where respondents are asked whether public and private entities respect the established land use plan. Based on the answers (Always/Sometimes/Never), each response would get a score (1/0.5/0) making up to four components, from which the average would be taken, where STD refers to a standardized variable with a mean of zero and standard deviation of one.

Approval complexity index (ACI)

The survey asked respondents about four different issues related to the whole process of developing land within the city. They include: i) typical time needed to obtain all the necessary permits for a 200-unit land subdivision on land already converted to urban use; ii) the typical additional time required to get all building permits once land subdivision is approved; iii) the typical time taken to convert rural land on urban periphery to urban use for large-scale land assembly and iv) the time taken to convert rural land on urban periphery to urban use for a single plot of rural land. More specifically, respondents were asked to reply to these questions with the number of months for the review process. Answers were standardized separately, then averaged and standardized as a whole again.

Urban ordinances index (UOI)

First, this indicator includes information about the most common characteristics of building restrictions, in the form of minimum lot size requirements, maximum Floor Area Ratio (FAR) allowed, and maximum height allowed in meters. For each of them, respondents were asked whether these conditions were active or not, and, if they were active, what was their exact magnitude, in meters or square meters, etc. Other subcomponents of this indicator involve specific characteristics of single-family and multi-family units, such as single-family units can be internally subdivided into multi-family units, or if additional floors can be added over time to existing multi-family units, among other things. Magnitudes were separately segmented using quantiles to establish some order of restriction strength. For example, if a city has a minimum plot-size restriction of 610 ha, the first component of the ACI reflects a number of 5, since 610 ha is very restrictive. In the case of maximum FAR or maximum height allowed in meters, higher maximum values reflect lower restrictions; so, a component value of 1 indicates less restrictiveness, where BRI1 contemplates minimum plot restrictions, BRI2 corresponds to maximum FAR restrictions, BRI3 to maximum height restrictions, and BRI4 corresponds to single-family and multi-family restrictions.

Urban ordinances enforcement index (UOEI)

The building restriction enforcement index reflects the extent to which there is enforcement on building restrictions. Specifically, this index contemplates violations of maximum residential building size regulations and frequency of illegal subdivision of land plots. Questions responses with "Never" or "Rarely" show a higher level of restrictions enforcement.

Growth index (GI)

The containment index is based on answers to survey questions regarding urban expansion containment restrictions. The index takes the value of the number of active restrictions and adds one, if containment is an explicit goal. Containment needs to be supported by complementary physical infrastructure and social services, such as roads and transport services, drainage, street lighting, electricity, water, and sewerage, together with other equipment, like policing, schools, among other things. Services tend to involve coordination problems (i.e. network-based services cannot be provided to each household individually), an issue that a well-deserved regulatory framework sought to address in many cities.

Growth enforcement index (GEI)

The containment enforcement index simply considers a dummy variable if respondents claim that there is enforcement (1) on the attributes considered, or if there is not (0).

8. References

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