Cities Without Skylines: Worldwide Building-Height Gaps, their Determinants and their Implications

Remi Jedwab, Jason Barr and Jan Brueckner*

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Abstract

There is a large literature in the U.S. measuring the extent and stringency of land-use regulations in urban areas and how these regulations affect important outcomes such as housing prices and economic growth. This paper is the first to present an international measure of regulatory stringency by estimating what we call *building-height gaps*. Using a novel data set on the year of construction and heights of tall buildings around the world, we compare the total height of a country's actual stock of tall buildings to what the total height would have been if building-height regulations were relatively less stringent, based on parameters from a benchmark set of countries. We find that these gaps are larger for richer countries and for residential buildings rather than for commercial buildings. The gaps are driven by the central areas of larger cities. These central city gaps are not compensated by tall building construction in peripheral areas of cities or less stringent limits on outward expansion beyond the existing boundaries of the cities. We also find that countries with more urban planning and older, historic structures have more stringent height regulations. Lastly, the building-heights gaps correlate strongly with international measures of housing prices, sprawl, congestion, and pollution.

JEL Codes: R3, R5, O18, O50

Keywords: International Buildings Heights; Land Use Regulations; Building-Height Restrictions; Housing Supply; Housing Prices; Sprawl; Congestion; Pollution

*Corresponding Author: Remi Jedwab: Department of Economics, George Washington University. Email: jedwab@gwu.edu. Jan Brueckner: Department of Economics, University of California, Irvine. Email: jkbrueck@uci.edu. Jason Barr: Department of Economics, Rutgers University-Newark. Email: jmbarr@newark.rutgers.edu. We thank Juan Pablo Chauvin, Gilles Duranton, Fernando Ferreira, Edward Glaeser, Matthew Kahn, Luis Quintero, Paul Romer, Stuart Rosenthal, William Strange and seminar audiences at George Washington, the NBER Real Estate SI, the NBER Urban SI and the UEA meetings for helpful comments. Scheduled presentations at Fordham and the IGC-SAIS-Harvard urban workshop were canceled due to COVID-19. We thank Solly Angel for sharing his building regulations data sets.

Today, the majority of the world's population lives in cities, and this global urbanized population will continue to grow over the rest of the century (World Bank, 2009; UN-Habitat, 2020). Cities throughout the world must expand their stock of real estate in order to accommodate urban growth (Glaeser, 2011; Romer, 2020). But in many countries, housing prices are growing more rapidly than incomes (Knoll, Schularick and Steger, 2017), which may be partly caused by physical and regulatory barriers reducing housing supply (Glaeser and Gyourko, 2003; Glaeser, Gyourko and Saks, 2005, 2006; Saiz, 2010; Gyourko and Molloy, 2015). In particular, cities impose various land-use regulations (Helsley and Strange, 1995; Quigley and Raphael, 2005; Glaeser and Ward, 2009; Gyourko et al., 2008; Rosenthal and Ross, 2015; Gyourko et al., 2019), including restrictions on building heights and limits on developable land areas. These regulations not only have impacts today but may generate significant effects well into the future given the durable nature of real estate (Glaeser and Gyourko, 2005, 2018; Hsieh and Moretti, 2019). Higher housing prices can also lead to more exclusionary cities (Gyourko et al., 2013; Rosenthal and Ross, 2015). While the extent and impact of land-use regulations has been studied for the U.S. (Ihlanfeldt, 2007; Saks, 2008; Jackson, 2018; Brueckner and Singh, 2020), there are no such studies for the whole world. Offering such a study is the aim of this paper.

In order to study regulatory impacts, the extent of land-use regulation must first be measured. Its extent in U.S. cities has been captured through a number of different regulatory surveys, which present local government officials with a long list of different types of potential regulations, asking which ones are used in their community. While some surveys focus on specific localities or specific states (e.g., Glickfeld and Levine, 1992; Ihlanfeldt, 2007; Jackson, 2018), Gyourko et al. (2008) and Gyourko et al. (2019) carry out more ambitious national surveys. These excellent studies then use the responses from local communities to compute a regulatory index for individual cities or states.

Despite their impressive scope these surveys lack coverage of certain important regulations. For example, Gyourko et al. (2008) – on which the famous *Wharton Residential Land Use Regulation Index* is based – and Gyourko et al. (2019) do not measure building-height restrictions in the central areas of cities. Rather, they focus on frictions due to the permitting process and on other regulations that are more likely to impact low-rise dwellings in suburban parts of the city. Another issue is how to aggregate this community-level information into reliable measures for cities, states or even the country.

The survey method is also expensive and thus cannot be used to compare regulations across more than a few countries at a time. In addition, the studies mentioned above only provide a *snapshot* of regulations across the cities or states of a same country. That is also why *no* global measures of land-use regulations exist. Moreover, such measures cannot tell us if the regulations are binding given economic conditions. Finally, given migration, within a city, state or country, the aggregate impact of stringent regulations in some communities should be mitigated by other communities having less stringent regulations, hence the need for *country-level*, not city-level, analyzes of land-use regulations.

Our method of analysis is similar to that in the health sciences literature. Currently, two methods exist to measure and compare domestic and international mortality rates due to an environmental phenomenon (e.g., a pandemic). First, national agencies can compile phenomenon-related mortality information obtained from each jurisdiction, an imperfect process if jurisdictions and countries have different measurement abilities. Second, an indirect method is to perform simple regression analyzes to estimate "excess mortality rates" for all jurisdictions and countries.[1] Our method is analogous to the latter approach, except that we are measuring a shortage (rather than an excess) of tall buildings. With the survey/count method (analogous to the first health-science approach) not being feasible for the world, we thus use regression analyses to estimate country-level *building-heights gaps*, which we use as proxies for the stringency of building-height restrictions in each country. While our approach might appear simple, it has the benefit of being feasible and, as our evidence suggests, reliable.

More precisely, across countries, some cities appear more willing than others to construct tall buildings in their central cities as a way to accommodate economic and population growth. Cities in China embrace tall buildings (Barr and Luo, 2021), whereas cities in India have draconian height restrictions (Brueckner and Sridhar, 2012a). Some cities in Europe seem to represent an intermediate case, with tall buildings emerging in London (Cheshire and Dericks, 2020) and Frankfurt, although other cities, especially in southern Europe, have few tall buildings. These patterns raise three questions. First, how many tall buildings are "missing" in each country and the world overall? Second, what could be the economic and socio-cultural determinants of these building-height gaps? Third, what could be the economic and environmental consequences of these gaps?

[1]See, for example, Dushoff et al. (2005); WHO (2018); Kiang and Buckee (2020); Beaney et al. (2020).

Our approach makes use of a remarkable data set that inventories all the world's *tall buildings* (buildings above 80 meters), with information on their year of construction and height. Using a set of more laissez-faire countries as a benchmark, we ask whether the stock of tall buildings in a country outside this set is smaller than expected given the country's characteristics. More specifically, we start by running a panel regression (1950-2020) relating a measure of the tall building stocks in the set of identified benchmark countries to two variables suggested by the standard urban model (the main model used to study urban land use): income and agricultural land rent.[2] Then, for countries outside the benchmark group, we plug values for these variables into the estimated equation, yielding a predicted size for the tall building stock if the country's regulatory practices followed those in the benchmark group. The difference between the prediction and the country's actual stock is the *building-height gap*. In addition, we carry out a variety of sensitivity tests, including estimation using a state-level panel for the U.S. (1930-2020).[3]

Coming back to the three questions raised above, we first find that the world should have at least twice as many tall buildings as it does (being short about 6,000 Empire State Buildings). We then show that the gaps are relatively larger for richer countries. Poor countries have few tall buildings, but it is not because land-use regulations are binding but because their income level is low. Furthermore, knowing the main function of each building, we document that gaps are larger for residential buildings than for office buildings. Thus, cities appear more open to creating jobs than to receiving residents.

Second, regarding the determinants of the gaps, the evidence suggests that countries with more urban planning and older, historic structures have more stringent height regulations. In particular, we find that urban planners may act as defenders of cities with long histories. In contrast to the U.S. literature (see Rosenthal and Ross (2015) and Ross and Yinger (1999) for a discussion), we do not find that the restrictions are driven by the homevoter hypothesis. The hypothesis says that homeowners, worried that increases in supply reduce property values, lobby cities to impose regulations (Fischel, 2001).

[2]See Brueckner (1987), Rosenthal and Ross (2015) and Duranton and Puga (2015) for details of the model.

[3]A referee has usefully suggested that we use data on the maximum building height allowed in various cities and show in our tall building data set "bunching" just below the threshold. However, most cities' height restrictions are based on floor area ratios (FARs). As we do not have data on lot size, we cannot compute FARs. In addition, data on height restrictions does not exist beyond a few well-known cities. We use data on height restrictions but only for the peripheral areas of cities (see Section 6). Finally, many cities' implicit thresholds are clearly below 80 m (e.g., Paris), making this method inapplicable in many countries.

Third, we find that the gaps might have important global economic and environmental consequences. Consistent with theory, tall buildings are disproportionately found in the central areas of larger cities, which we confirm using city-level data for a world sample of almost 12,000 agglomerations. Logically, building-height gaps are driven by the central areas of larger cities. We then ask if central city gaps are compensated in any way by tall building construction in peripheral areas of cities or less stringent limits on outward expansion beyond the existing boundaries of the cities, reaching a negative conclusion.

Furthermore, at the world level and conditional on income, the gaps strongly correlate with measures of housing prices, sprawl, congestion, and pollution. In particular, height restrictions are associated with an increase in housing prices throughout the city and to its spatial expansion, with the land and ecological footprints growing in response to the restrictions. Overall, building-height restrictions might explain one fifth of the *global house price boom* observed since 1950 (Knoll, Schularick and Steger, 2017). Next, while total urban land area increases with the gaps, we do not find that the gaps disproportionately increase land area in larger cities (relative to smaller cities), thus suggesting that the stringency of building-height restrictions in the largest cities is compensated by sprawl in, and thus migration to, smaller cities. Finally, we do not find that countries with more stringent regulations and higher housing prices "compensate" their urban residents by subsidizing transport or providing public housing.

Our paper makes several contributions to the literature. To our knowledge, the above stylized facts and results have not been shown by any other study, as the profession was hitherto limited by the lack of historical international data on tall building construction. The paper also constitutes one of the first global studies on the economics of skyscrapers (see Ahlfeldt and Barr (2020) for a recent survey). Other existing studies typically focus on the U.S. only (e.g., Liu, Rosenthal and Strange, 2017, 2020, 2018; Ahlfeldt and McMillen, 2018; Rosenthal and Strange, 2008).[4] Next, there are almost no studies on how international land-use regulations, and building-height restrictions in particular, vary across countries. Contrary to common belief, we find that the U.S. is *no longer* amongst the most prolific countries in the world in terms of tall building construction. Little is also known about the determinants and effects of building-height restrictions globally.

[4]For other research on building heights, see, for example, Barr (2016), Barr and Cohen (2014), Barr (2012), Brueckner and Sridhar (2012b), Barr (2010) and Bertaud and Brueckner (2005a).

Our study is in the spirit of other studies on the global costs of various urban policies (see, for example, Davis, 2014, for fuel subsidies). Finally, our method has the advantage of being replicable for any context. So far, only a few other studies have implemented (indirect) methods to measure the stringency of regulation, defined as the degree to which regulations cause development decisions to differ from free-market outcomes.[5]

While recognizing that city-wide analysis can be important, a country-wide analysis like ours is both important and necessary. Since the main objective of this study is to obtain a measure of building-height restrictions for as many countries as possible, the analysis by construction thus has to be cross-country. Likewise, a study along the lines of Hsieh and Klenow (2009) where the extent of within-country misallocation is characterized for a few countries (relative to the U.S.) is not informative enough if one aims to quantify global gaps. In addition, the U.S. *no longer* is a benchmark country in tall building construction. Within-country analyses also miss the fact that stringent regulations in specific cities may be circumvented by migration to less stringent cities in the same country. A country-wide analysis captures any possible reallocation. Lastly, only a handful of countries have consistent city or state-level GDP and land rent data over several decades, ruling out a worldwide, within-country study.[6] Nonetheless, we run panel city-level regressions for all countries and generate results on within-country building-height misallocation for different city population size categories. We also perform our analysis for U.S. states (1930-2020) to assess the validity of the methodology. In particular, our state gaps are strongly correlated with the Wharton Index of Gyourko et al. (2008) and the housing supply elasticities of Saiz (2010). California then accounts for an astounding 48-61% of the U.S. gap. Given the data limitations, our approach is arguably the only possible way to construct cross country building height stringency measures.[7]

Lastly, our analysis is mostly a predictive exercise, which makes causality less of an issue. It is not possible to find an instrument, or more generally an identification

[5]See Bertaud and Malpezzi (2001), Glaeser et al. (2005), Turner et al. (2014), Brueckner et al. (2017), Brueckner and Singh (2018) and Albouy and Ehrlich (2018) for important works on land-use regulation.

[6]Another suggestion was that we use night lights as a proxy for city GDP. Unfortunately, night lights are only available from 1992 to 2012. The radiance calibrated version of this data, which avoids issues related to top-coding in more developed cities for which neighborhood levels of luminosity very often exceed the normal digital number upper bound of 63, is then only available for a few years between 1996 and 2011. However, we need a period long enough to estimate the gaps (preferably 1950-2020). In addition, consistent historical agricultural land rent data do not exist for the "edge" of each city of the world.

[7]Implementing Saiz's approach would require global historical housing price data, which do not exist.

strategy, that would explain income and land rent (our right-hand variables) without also directly impacting a the stock of tall buildings (whether at the country or city level). Yet, we discuss a series of robustness checks that aim to give us greater confidence in the results. Even given our relatively simple methodology, we obtain numerous results that *collectively* make sense, which we see as a possibly strong test of the analysis.

The plan of the paper is as follows. Section 2 provides the conceptual foundations for the regressions that we run. Section 3 discusses the data. Section 4 discusses the international regression results and the associated building-height gaps. Sections 5, 6 and 7 examine the nature, determinants and effects of the gaps, respectively. Sections 8 - 9 report a series of robustness checks. Section 10 concludes.

1. Conceptual Framework

1.1. The Standard Urban Model

The "standard urban model," as exposited by Brueckner (1987) and Rosenthal and Ross (2015), depicts the determination of building heights, as measured by output of floor space per acre of land. In the model, consumers value access to jobs in the city center, which leads to both higher housing prices and higher land rents near the center. Faced with expensive land, developers construct taller buildings near the center to limit use of the expensive land input. In the equilibrium of a closed city (where population is fixed), building heights depend on the city's characteristics, which include population P, per capita income y, commuting cost t per mile, and the agricultural rent r_a for the land surrounding the city. A higher population P or agricultural rent r_a raises building heights throughout the city. To accommodate the greater demand from a larger P, the city must be denser, with taller buildings. By increasing the cost of rural-to-urban land conversion and thus making the city more compact, a higher r_a also generates taller buildings.

A higher income y causes urban decentralization as residents find the cheap suburbs more attractive for the bigger dwellings they now prefer.[8] This demand shift tends to raise building heights in the suburbs while decreasing them near the city center, yielding a spatially complex income effect (a higher commuting cost t leads to the opposite impacts).

To make use of these predictions in a cross-country study, the fact that countries

[8] The locational equilibrium balances the gains from cheaper housing against the losses from higher commuting cost. If everyone now wants a bigger dwelling because of higher income, the gains from cheaper housing are now more important, creating an incentive to move farther from the CBD.

become more urbanized as they get richer can be exploited. This tendency implies that city populations in a country tend to rise with the general income level, implying that y and P tend to increase in step with one another moving across countries. Allowing these variables to change together, the result is a tendency for building heights to rise uniformly across space within cities as country income increases, simplifying the complex height effect from above. In particular, with cities tending to be bigger in high-income countries, the positive population-induced effect on building heights offsets the negative height effect in the central city due to income-induced decentralization. As a result, buildings in the high-income country's cities will tend to be taller in the center as well as the suburbs. Therefore, in a regression like ours that relates building heights to a country's income and agricultural rent, the income and agricultural rent coefficients should be positive.

1.2. Additional Elements

The standard urban model above is quite simple in that it assumes no urban amenities. But it is reasonable to assume that as cities achieve higher incomes, they add more urban amenities (cultural venues, shopping options, monuments, etc.), which tend to be downtown. By making city centers more desirable as income rises, amenities can reverse the income-driven tendency toward decentralization, strengthening the tendency of building heights to rise at all locations when income increases.

In addition, if wealthier, larger cities tend to have greater commuting costs due to traffic congestion or because the opportunity cost of commuting time increases with wages, the price premium for central locations will be higher, generating even taller buildings in the center. Combined with growing population and amenities as income rises, the tendency for building heights to rise with income is amplified.

Finally, if we add business land-use to the residential use already in the model, the association between country income and building heights is likely to be magnified. High country incomes tend to be associated with the presence of service sector firms, which may value being located in city centers in order to reduce the costs of accessing inputs (including information) and consumers. Thus, higher incomes should increase the demand for office space in city centers and cause tall building construction there.

In summary, the theories of urban spatial structure suggest an empirical specification in which a measure of the stock of tall buildings is regressed on income and agricultural rent, with the expected coefficient signs both being positive. The analysis, however, applies to a city with perfectly malleable capital, where building heights adjust immediately to reflect current conditions. In reality, tall buildings are long-lived, having been built in response to current conditions at the time of construction and lasting decades. In a model recognizing this longevity, income and agricultural rent would only determine the *increment to the tall-building stock* through an effect on new construction. The existing tall-building stock would also be a determinant of this increment, with a large stock of tall buildings potentially depressing the need for new ones.

These considerations suggest a regression with the existing tall-building stock as dependent variable and the lagged stock, income, and agricultural rent as covariates.[9]

Finally, the exact definition of the tall-building stock measure requires discussion. As mentioned above, the stock measure is a weighted one, with each tall building weighted by its height. Since the stock is measured for the entire country, not for individual cities, it is appropriate to divide the weighted stock variable by the size of the country's urban population. The dependent variable is thus the country's height-weighted stock of tall buildings *per capita*, which we call "urban height density."

2. Data and Background

To estimate our baseline model, we collected data on building heights, urban populations, urban per capita incomes, and agricultural land rents for as many countries and years as possible. Our main sample comprises 158 countries annually from 1950 to 2017.

Building Heights. The Council on Tall Buildings and Urban Habitat (CTBUH) maintains a publicly available online database of all *tall buildings* in the world.[10] For each building, we extracted information on the building's height, year of construction, usage, and several other characteristics. According to CTBUH's website, they do not use a consistent definition of tall buildings. However, as described in Appendix Section 1, the database mostly captures buildings above 80 meters. Since some countries have no such buildings, in order to avoid having their stock of heights equal to 0 when using logs, we consider for each country buildings above 80 meters as well as their 10 tallest buildings even if some

[9]Unfortunately, global historical data on commuting costs do not exist. In our baseline analysis, we will ignore the role of commuting costs. However, income may capture the effect of commuting costs if richer countries have better infrastructure and/or a higher opportunity cost of commuting time. In the robustness section, we will show that results hold when attempting to control for roads and subways.

[10]The full online database can be found here: http://www.skyscrapercenter.com/. As one example, the webpage for the Burj Khalifa is found here: http://www.skyscrapercenter.com/building/burj-khalifa

of them are below 80 meters. In the end, we use 16,369 tall buildings. Later, we will show that measurement error in building height stocks should not impact our results.[11]

Urban Population. United Nations (2018) gives the urban population of each country every 5 years from 1950 to 2020. We interpolate the data for intermediate years.

National Income. Our main source is Maddison (2008), where we obtain per capita GDP for each country annually from 1950 to 2008 (in 1990 Geary-Khamis dollars, which is equivalent to PPP and constant international 1990 $). We use per capita GDP growth rates from World Bank (2018) to reconstruct per capita GDP from 2008 to 2017.

Agricultural Land Rent. We estimate a country's agricultural land rent by dividing agricultural GDP by the total land area. We use as our main source FAO (2018), which shows the agricultural GDP shares for many countries annually from 1960 to 2017. For country-years that are still missing, we use additional sources and interpolations as needed (again Appx. Section 1). We use total land area as the divisor instead of agricultural land area because the latter area is missing for almost all countries before 1960.[12] In addition, a significant share of non-agricultural and non-urban land can potentially be used for agricultural purposes or be converted into urban land. Later, we will show that measurement error in agricultural land rent should not impact our results.

Urban Per Capita Income. Knowing for each country-year total GDP (PPP and constant international $) and the agricultural GDP share, we can reconstruct urban GDP, which we proxy by non-agricultural GDP.[13] Knowing urban GDP, we can then reconstruct urban per capita income as urban GDP divided by urban population.[14]

Urban Height Density. When logged, this is our dependent variable, equal to the sum of the heights of the country's tall buildings in a given year divided by the urban population

[11] According their website, the data have been "collected by the Council for more than 40 years [...] The Council relies on its extensive member network [of academics, land developers, architectural firms, builders, city administrations, and banks] to maintain" the database with the help of "an Editorial Board".

[12] From FAO (2018), we know total land area.

[13] The implicit assumption here is that most valuable industrial and service activities take place in urban areas, a stylized fact confirmed for a large sample of countries by Gollin et al. (2015).

[14] While urban GDP is consistently defined, urban population is not. Indeed, countries use different urban definitions. However, in our panel regressions, we will include country fixed effects, thus capturing any time-invariant factor. In addition, among the 158 countries circa 2010, 50 countries use an explicit threshold to define a locality as a city, whereas 108 countries use a more administrative definition (source: Jedwab and Vollrath (2015)). The likelihood of using a threshold-based definition does not depend on log per capita GDP (coef. = 0.03; p-value = 0.32; R2 =0.01; N = 158). The threshold also does not depend on it (coef. = 460; p-value = 0.34; R2 =0.02; N= 50). If there is measurement error, it should be classical, and lead, if anything, to downward-biased, not upward-biased, effects of urban incomes on urban height density.

for that year. We sometimes distinguish residential and commercial tall buildings.

Other Variables. We know from the World Bank the income group of each country in 2017 ("low," "lower-middle," "upper-middle" or "high income"). High income countries are viewed as developed. From The Economist (2018), we know whether each country was democratic at any point in the 2006-2017 period (data not available before). Countries are considered democratic if they are "full" or "flawed" democracies.

Descriptive Patterns. Figure 1(a) shows the evolution across time of the urban height-density measure for the U.S. along with the evolution of the same measure summed across all the world's cities. As can be seen, the U.S. contained virtually all of world's tall buildings up to 1950, with the two curves diverging thereafter. In recent years, the tall-building stock outside the U.S. has grown rapidly. Figure 1(b) shows the world evolution of the total stock of heights separately for residential buildings and commercial buildings from 1920 to 2017. As seen, most tall buildings were commercial – i.e., mostly office and retail buildings – until 2000. It is only after 2000 that tall residential buildings were built at a faster pace than commercial buildings. Circa 2017, residential buildings and commercial buildings each contribute about half of the total stock of heights in the world.

Figure 2 shows the relationship between the country-level log of urban height density in 2017 and the log of national GDP per capita for that year. As expected, the relationship is positive, with a strongly significant slope coefficient of 1.35*** and an R^2 of 0.52 (1.41*** and 0.67 if using urban population weights). Countries above (below) the dashed line have more (fewer) tall buildings than expected based on their income.

3. The Gaps

With Figure 2 showing that income matters in determining tall building stocks, we now turn to regressions using more years of data. Table 1 shows panel regressions for the years 1950, 1960, 1970, 1980, 1990, 2000, 2010, and 2017 (henceforth, "2020"). The explanatory variables are those identified by the theory, and for which panel data are available: log per capita urban GDP (LUPCGDP), the log of agricultural land rent (LAGRENT), and the lag of the dependent variable, log urban height density (LUHTDENS). We include country and year fixed effects (standard errors clustered at the country level).

Column (1) uses 158 countries. The GDP coefficient is positive and significant, as is the lagged height-density coefficient. As expected, the coefficient on this variable is less than one, indicating that an increase in the lagged tall-building stock leads to a less than one-for-one increase in the current stock, given that the increase in the prior stock depresses new construction. The agricultural-rent coefficient while positive, is not significant.

Column (2) restricts the sample to 73 countries with a positive residual in a 2017 regression that relates LUHTDENS to LUPCGDP and LAGRENT. These are countries where the tall-building stock is higher than could be expected today given the magnitudes of the covariates, a simple way to select *laissez-faire* countries. We will show later that other approaches lead to similar selections of countries. Naturally, the GDP coefficient is larger than in col. (1). The effect of agricultural rent becomes positive and significant. Logically, for 85 countries with a negative residual (col. (3)), the coefficient of GDP is almost twice smaller, and agricultural land rent has no effect.

Column (3) restricts the sample to 14 democratic upper-middle (henceforth, "UM") or high ("H") income countries whose residual is above the 75th percentile value. We restrict this benchmark sample to more-democratic and more-developed countries because market forces are less free to operate in other countries. Column (4) focuses on 8 H countries: Australia, Canada, Hong Kong, Israel, the Netherlands, Singapore, South Korea, and Uruguay. The 6 UM countries excluded are Brazil, the Dominican Republic, Macedonia, Malaysia, Panama and Thailand.[15] While the selection of these countries might seem arbitrary, we believe that this selection process is less arbitrary than us "cherry-picking" what we believe are more laissez-faire countries.

Also, based on qualitative evidence, these choices make sense. Among high-income countries, Toronto now has "the third highest number of skyscrapers in North America" (CBC News, 2020), all Australian cities, not just Melbourne and Sydney but also Adelaide, Brisbane, Gold Coast and Perth, have a significant number of tall buildings (The Conversation, 2019), Seoul and other Korean cities such as Busan and Incheon have been at the forefront of skyscraper construction and innovation for some time now (NY Times, 2011; CNN, 2017), and Tel-Aviv's skyline is "undergoing dramatic transformation" (Globes, 2017). In middle-income countries, Panama City and Sao Paulo, but also Bangkok and Kuala Lumpur, have undoubtedly some of the most impressive skylines in the world, especially given their country's middle-income status.

[15] Also considering low and lower-middle income countries adds four countries (e.g., the Philippines). As these countries were not democratic for most of the post-1950 period, it is appropriate to exclude them.

Lastly, while the U.S. is traditionally associated with skyscrapers, it has very high income and agricultural rent and a large urban population. The U.S. is strikingly close to the regression line in Figure 2, thus suggesting that the U.S. does not have disproportionate stock of tall buildings given its economic conditions. Likewise, Web Appx. Fig. A2 shows that the U.S., unlike almost all of the 14 benchmark countries described above, has experienced since 1950 a slower growth of its (logged) tall building stock (per urban capita) than of its (logged) urban per capita income. As we will show later, one reason is that California has experienced dramatic growth but still has relatively few tall buildings, thus offsetting the historical contributions of New York City and Chicago. Columns (6)-(7) then replicate columns (4)-(5), but with the height variable computed using residential buildings, while columns (8)-(9) use commercial buildings.

With the UMH sample (column (4)), the GDP coefficient is three times larger than in column (1), while the effect of agricultural rent is four times larger. With the H sample (column (5)), the GDP coefficient doubles relative to column (4). The agricultural rent coefficient is non-significant due to its strong correlation with income at the country level. The coefficient of lagged urban height density is much lower than 1, indicating little persistence in tall building heights per urban capita in that sample.[16]

Lastly, the adjusted R2 values increase from 0.79 in col. (1) when we consider all countries to 0.91 in col. (5) when we consider H countries only. This pattern shows the increasing explanatory power of income, land rent, past height density and the year fixed effects when focusing on more laissez-faire countries, thus validating our approach.[17]

To generate the gaps, we iterate each benchmark regression, respectively, to get predicted heights for 2020, and then compare those heights to the actual 2020 data. The iteration proceeds as follows. Predicted log heights for 1960 are found by evaluating

$$\text{LUH}\widehat{\text{TDEN}}\text{S}_{1960} = \alpha + \beta \text{LUPCGDP}_{1960} + \gamma \text{LAGRENT}_{1960} + \delta \text{LUHTDENS}_{1950}. \quad (1)$$

with LUHTDENS being log urban height density, LUPCGDP log per capita urban GDP and LAGRENT log agricultural land rent. (α, β, γ, δ) are obtained from Table 1.

[16] While tall buildings are durable, urban population is not. The ratio thus only remains stable if tall building construction matches urban population growth. The low persistence suggests that, in that sample, tall building construction per capita was disproportionately driven by episodes of fast income growth.

[17] We select the countries based on the dependent variable in 2020, not its evolution as a function of the main explanatory variables between 1950 and 2020. Selecting the countries based on the dependent variable also does not in itself lead to high coefficients, as shown by the negative residual specification (col. (3)).

The year fixed effects are always included. However, for simplicity, they are omitted in writing (1). By construction, we ignore the country effects to compute the gaps. Other than that, (1) is exactly the same specification as we use for Table 1. To get predicted log building heights for 1970, we rewrite (1) with 1970 values for the first two covariates and with the 1960 predicted value playing the role of LUHTDENS_{1960}:

$$\widehat{\text{LUHTDENS}}_{1970} = \alpha + \beta\text{LUPCGDP}_{1970} + \gamma\text{LAGRENT}_{1970} + \delta\widehat{\text{LUHTDENS}}_{1960}. \quad (2)$$

The procedure continues until a LUHTDENS predicted value emerges for 2020. The building-height gap measure in 2020 is then equal to

$$\text{GAP}_{2020} = \widehat{\text{LUHTDENS}}_{2020} - \text{LUHTDENS}_{2020}, \quad (3)$$

or the difference in predicted and actual log height densities.

It is helpful to derive the connection between a gap and the change in the underlying building stock required to eliminate it. Letting Δ denote change, the answer is immediate from differentiating (3):

$$\Delta\text{GAP}_{2020} \approx -\frac{\Delta\text{UHTDENS}_{2020}}{\text{UHTDENS}_{2020}}, \quad (4)$$

which is denoted the *percentage-change gap*. If GAP = 2, then the change in the log of the existing urban height density required to eliminate the gap also equals 2. With (3) then equal to 2, it follows that unlogged urban height density must increase by 200% to close the gap, with 200 then denoted the percentage-change gap.

The *per capita gap*, a different gap measure, is found by using the corrected antilog of $\widehat{\text{LUHTDENS}}_{2020}$ to obtain $\widehat{\text{UHTDENS}}_{2020}$. More precisely, we take the antilog of the predicted values and adjust them by a correction factor to get unbiased predicted heights. Indeed, when generating $exp(ln(\widehat{y}))$ we need to correct this value because of the fact that $E(exp(ln\widehat{y}))$ does not equal $E(\widehat{y})$. We follow the method suggested by Wooldridge (2016). Comparing $\widehat{\text{UHTDENS}}_{2020}$ to UHTDENS_{2020} yields the *per capita gap* (measured in km per urban inhabitant). Finally, knowing urban population, we obtain the *total gap* (km).

4. Rankings

Table 2 ranks the top 20 countries in terms of the three gap measures just discussed and using the H set as our benchmark set. Col. (1) shows the ranking based on the *percentage change gap* (the percentage change in height density required to close any gap).

However, percentage changes are mechanically larger when the denominator is small. Thus, the percentage gap is mechanically larger in fast-growing countries with still relatively small height stocks today (e.g., Mauritius).[18] If, instead, we study the ranking based on the absolute per urban capita gap (km per million of urban inhabitants) (col. (2)), we can see that the list is now dominated by developed countries, and that large-stock countries such as the U.S. and the UK are highly ranked. Finally, the total km gap (col. (3)) of a country is the product of the per urban capita gap and urban population, giving more weight to more populated countries. Then the U.S., Taiwan, Japan, the UK and Germany dominate the list. Note that the percentage gap ranking is strongly correlated with the per capita gap ranking (0.77, with urban populations as weights).[19]

Various European countries are found in the list, which concords with common beliefs that they are more stringent in regulating heights than other nations. Ireland, for example, has no buildings taller than 100 meters and only five buildings taller than 50 meters (Barr and Lyons, 2018), and this despite Dublin being one of the 10 wealthiest cities in the world and a financial hub (OECD, 2020). Paris has reluctantly embraced skyscrapers but has placed them outside of the city center in La Défense, in an attempt to keep them isolated from the old city, where skyscrapers like the Tour Montparnasse have proved controversial (Scicolone, 2012).[20] Regulations in Switzerland, for example, give strong veto power to those opposed to skyscrapers, and, as a result, there are few in that country (Vogel-Misicka, 2011). For example, there are only five tall buildings in Zurich, again one of the wealthiest cities in the world and a financial hub (OECD, 2020).[21] Many cities like London and Rome have implemented height caps so as not to block views of major monuments (Stewart, 2016). While these rules are being peeled back in some places, Europe remains slow to embrace tall buildings because of its historical traditions.

Indeed, as can be seen in Web Appx. Fig. A3, a few countries have seen their (logged) urban height density plateau out since the 1970s, for example France, Germany, Ireland, Italy, Switzerland and, to a lesser extent, the United Kingdom, despite impressive

[18]Other such countries include Equatorial Guinea, Lesotho, Sri Lanka, Trinidad, and Uzbekistan.

[19]Web Appx. Fig. A4 shows the H-based gap for each country. Web Appx. Table A9 compares the H- and UMH-based gaps and rankings. Similar countries are found in both lists.

[20]More precisely, one third of Paris' tall buildings are located outside the city, a land-use pattern that is more reminiscent of Socialist Russia (Bertaud and Renaud, 1997) than a free market economy.

[21]In our data, the other important cities of these countries also have very few, or no, tall buildings, whether Cork (3 tall buildings), Lyon (4), Marseille (4), Geneva (1), or Basel (2).

economic growth (as shown by logged urban per capita GDP). Comparing it to Web Appx. Fig. A2 that shows the same patterns for the 14 UMH countries, one can see that their growth has not been less impressive than in the UMH set but that their urban height density has not increased relatively fast enough to match their income growth. We believe that the *timing* of these results also make sense. For example, in Paris the controversial Tour Montparnasse was completed in 1973. It became one of the most hated landmarks in the world and led two years later to the ban of new buildings over seven storeys high in central Paris (NY Times, 2015), which must explain the plateau effect from 1980. Likewise, Dublin's Liberty Hall built in 1965 was immediately seen as one of Ireland's ugliest buildings (The Irish Times, 2019), which must explain the plateau effect from 1970.

In 2020, the data show 2,198 km of total height worldwide. Summing predicted values across countries, we get total predicted heights of 4,828 km, which generates a gap of 2,630 km – 6,000 Empire State Buildings (ESBs) – and a world gap factor of 2.2. However, negative gaps – i.e., an "excess" of heights given economic conditions between 1950 and 2020 – are observed in 45 countries where skyscrapers might be "white elephants" (e.g., the Gulf states, Mongolia, and North Korea, as can be seen circa 2017 in Figure 2). For 44 countries with a positive gap, the total gap is 3,143 km (7,250 ESBs). Next, if we use the UMH regression, we get a mechanically smaller predicted world total of 2,046 km. However, 31 countries still have a positive gap and their total gap is 919 km (2,100 ESBs).

While the percentage change is useful, we verify that the resulting ranking of countries is correlated with the ranking based on the absolute measure, i.e. the per capita gap in column (2) of Table 2. For the UMH and H benchmark sets, we obtain correlations of 0.65 and 0.66, respectively. However, if we weight the country gaps by the urban population of each country circa 2020, we obtain correlations of 0.77 between percentage and absolute rankings for both sets. Indeed, the weights minimize the issue coming from low-stock countries having mechanically larger percentage gaps. Next, in the rest of the analysis, we use the percentage gap as our main measure. Indeed, the issue with the absolute per urban capita gap is that it is generated by taking the antilog of the predicted values and then adjusting them by a correction factor. We follow the method of Wooldridge (2016, pp. 212–215). However, Wooldrige explains that this method is imperfect and rests on many assumptions. Notwithstanding, the high correlation between the percentage and absolute gaps suggests that the results that we establish below should not depend much on whether we use one or the other. Finally, and importantly, the ranking of countries does not depend much on whether we use UMH or H. Indeed, for a same measure, the ranking between the UMH-based ranking and the H-based ranking is 0.85-0.89.

Richer vs. Poorer Countries. Column (1) of Table 3 shows higher (H-based) gaps in historically richer countries (1950) and in countries where income increased between 1950 and 2020.[22] Fast-growing countries post-1950 apparently did not adjust their regulations in step with their fast growth. Columns (2)-(3) show that the gaps in richer countries are driven by residential buildings (col. (2)), not commercial buildings (col. (3)). We believe this to be a new finding, given that the literature has focused on the residential sector. Thus, cities are globally more open to creating jobs than receiving new residents. One possibility is that, while both businesses and residents pay local taxes, local governments may view residents as "costlier," since many services (e.g., schooling, sanitation, water, etc.) are publicly provided (the rest of Table 3 is discussed below).[23]

U.S. Case. These patterns could explain the U.S. gap. Many tall buildings were built before 1950 and subsequent U.S. construction may have failed to match income growth to the same extent as in the "best" developed countries.[24] As a result, with the gaps that we compute influenced by the experiences of such countries, it may not be surprising that the U.S. gaps are large. Lastly, to assess the validity of the methodology, we perform our panel analysis for 50 U.S. states (1930-2020; decadally) and show that the U.S. gap is driven by California. If California were like the "best" U.S. states, the U.S. would be ranked around 20th in per urban capita gap instead of 8th (see column (2) of Table 2).[25]

With the gaps now estimated, we turn to generating results on: (i) The determinants of the gaps in richer countries; (ii) Identifying the land-use regulations that the gaps capture; and (iii) The possible economic and environmental effects of the gaps. Finally, we will assess how sensitive our results are by implementing various robustness checks.

[22] In order to capture economic development, note that we use total per capitaGDP for these regressions.

[23] See Web Appx. Table A1 for the UMH-based gaps. Results are very similar.

[24] In our data, the Great Depression halted the very fast tall building construction observed in the 1920s. In particular, urban height density (km per million urban inhabitants) increased by about 1 between 1930 and 2020, roughly matching the increase between just 1900 and 1930.

[25] If we use the same specification as in Table 1 but for the U.S. only (N = 8), the coefficient of urban income is 50% smaller than for UMH (0.99*** vs. 1.54**) whereas the effect of land rent is similar (0.68* vs. 0.55**). If we study the U.S. between 1870 and 1940 (N = 7), thus dropping the World War II decade, we obtain higher effects, at 2.74** and 2.22**. This suggests that skyscrapers in the U.S. were much more responsive to economic conditions before 1950. In fact, many land use regulations were adopted in the 1960s; for example, New York City reformed its zoning ordinance in 1961, which corroborates our results.

5. Why are Gaps Larger in Richer Countries?

We have shown that richer countries have larger gaps. Why is that so? In columns (4)-(8) of Table 3, we interact the income variables with various country characteristics proxying for home ownership, urban planning, and the age and historical value of the urban system. Since we control for the independent effects of the income variables, we are studying the role of these characteristics for countries with *similar* income levels.

The so-called homevoter hypothesis says that homeowners, worried that increases in supply reduce property values, lobby local governments to impose regulations (Fischel, 2001). To explore this idea as a source of the gap/income relationship, in column (4) of Table 3 we interact 1950 income and income growth 1950-2020 with the home ownership share today (sources: Wikipedia (2020a,f); HOFINET (2020); available for 105 countries). As seen, no effect is found, consistent with Fischel's conjecture that his hypothesis mostly concerns local communities and likely does not apply to larger cities and urban systems as a whole. These non-results are important given the focus on the homevoter hypothesis in the U.S. literature on the determinants of land-use regulations (Rosenthal and Ross, 2015). While various studies have shown how land-use regulations *locally* raise property values by constraining housing supply (Ibid.), they may not be that consequential at the urban system or world level if housing demand can be reallocated spatially. Our gaps capture land-use regulations at the country level, thus across *all* communities in *all* cities, which is the right "level" when investigating the *non-local* consequences of land-use regulations.[26]

Could historical reliance on urban planning in higher-income countries be another possible channel? Urban planning became popular in the 19th century as a response to uncontrolled urbanization, with the aim of providing residents with open space and light. While some urban planners follow Le Corbusier in thinking that tall buildings are needed in order to make cities more compact, many "decentrist" urban planners follow Jane Jacobs (Jacobs, 1961) in seeing tall buildings as a threat to neighborhood quality (Glaeser, 2011). A long tradition of urban planning could thus have ambiguous effects on the gaps. We interact the income variables with the logged number of renowned urban planners per capita (Wikipedia, 2020h), finding positive and significant interaction effects (col. (5)).[27] Thus, urban planning might be contributing to stringent land-use regulations.

[26] Note that these non-results hold when excluding ex-communist countries given their high ownership share following the decollectivization of properties in the 1990s (not shown, but available upon request).

[27] The Netherlands, Denmark, Norway, France, and the United Kingdom are some of the countries with

Larger cities often have more historical buildings in their central areas, where there should be a high demand for tall buildings. We interact the income variables with the logged 1800 population of the country's largest city today (Chandler, 1987; Wikipedia, 2020g). We find a positive significant interacted effect for 1950 income (col. (6)), suggesting that historically richer countries with older (mostly pre-industrial) cities have larger gaps. In contrast, no effect is found for countries that became richer since 1950.[28]

Due to poorer construction technologies in the past, old buildings should be cheaper to replace. As such, richer countries might not adopt regulations because of old buildings *per se* but because some of these buildings are considered "valuable". We interact the income variables with the log number of cultural *World Heritage Sites* per capita (UNESCO, 2020). These include the "historic centres" of Paris, Rome, and Vienna. Much like what we found for older cities, we only find a positive significant interaction effect for 1950 income, not post-1950 growth (col. (7)). Therefore, historically richer countries with historically valuable cities have significantly larger gaps.[29] Thus, the historical patrimony effect might be due instead to richer countries valuing historical amenities for cultural reasons.

Simultaneously including all interactions (column (8)), this historical value effect is the only effect to survive. The older cities effect disappears. The urban planner effects now turns negative (however, not significantly so). This suggests that urban planners may *on net* act as defenders of historical patrimonies. Once one controls for the historical patrimony effect, they might actually encourage taller buildings.[30]

Finally, if we include continent fixed effects (Asia is the omitted category), only the Europe dummy is significant in col. (1) (not shown, but available upon request). Thus, for a given income level and a given income growth level, European countries have larger gaps (the effect is significant at 1%, suggesting a large effect). However, once we simultaneously including all interactions (col. (8)), the coefficient of the Europe dummy becomes very small and not significant and the historical value effect remains as strong as before (not shown). The R-squared also barely increases, staying around 0.7. Therefore,

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the highest number of renowned urban planners per million urban capita (value close to 1).

[28]Similar effects are found for the city's foundation year, the year it appears in the historical population database of Chandler (1987), or historical urbanization rates (not shown, but available upon request).

[29]The gaps are not positively and significantly correlated with a higher average contribution of tourism to GDP (%) in 1990-2017 (not shown; source: *World Development Indicators* database of the World Bank).

[30]On average, the positive interaction effects strongly dominate the negative effect observed for each independent variable in columns (5)-(8) (not shown, but available upon request).

the Europe effect is mostly explained by the historical value effect.

6. The Gaps and Land-Use Regulations

If the gaps are used as an international regulatory-stringency measure, it is important to examine the degree to which they correlate with other measures of land-use regulations and capture building-height restrictions in particular. However, there are almost no direct international measures of land use regulations. Nonetheless, we present regression results where we regress the gaps on several indirect land-use regulation variables.

In particular, we use a regulatory database established by Shlomo Angel. Angel's data set contains 195 global cities with at least 100,000 population in 2015. The database includes maximum Floor Area Ratio (FAR) (N = 95), maximum building height (N = 114), and the maximum number of dwellings per acre (N = 35).[31] However, one important limitation of this data set is that information is available only for the peripheral areas of cities. Therefore, to be able to use these variables, we must assume that they can serve as good proxies for the same variables in the central areas of the cities. Combining the information from these variables gives information on building-height regulations for 138 cities in 51 countries, using the maximum FAR as the main measure. For cities for which we know maximum building height but not the maximum FAR, we can predict the maximum FAR from a simple regression. We also use such a prediction based on maximum number of dwellings to gain more cities for the sample. For countries with multiple cities in the data, we average the maximum FAR values using the population of each city circa 2015, which yields country values for 49 out of our 158 countries.

As can be seen in Column (1) of Table 4, our building-height gaps show the expected negative relationship to this regulation measure, with a higher maximum FAR (indicating weaker regulation) associated with a lower building-height gap. Angel's database also provides information on other land use regulations. More precisely, we know for the cities of 47-49 countries if: (i) the city has a strong urban containment policy; (ii) there is a greenbelt or an urban growth boundary; (iii) there are strong zoning laws; (iv) if the government acquires land to plan for urban land expansion; (v) if there is a minimum allowable plot size for construction; (vi) the typical numbers of months before a permit is obtained to subdivide land and a permit is obtained to build on that land;

[31] Shlomo Angel and their co-authors obtained this data by sending various questionnaires to highly-ranked officials in the 195 cities. Their data is obviously subject to measurement error.

and (vii) if streets are delineated and infrastructure is provided by the government or a public-private partnership or whether streets and infrastructure are developed in a more haphazard fashion. As before, we obtain country values by averaging the values of these variables using the population of each city circa 2015.

Using these data, we answer two major questions. First, do the gaps capture land-use regulations other than building-height restrictions? Second, do countries with stringent height restrictions "compensate" their urban residents by having lenient regulations in other dimensions? To a large extent, the answer to both questions is "no. "

First, we show that the correlation between our gaps and maximum FAR increases when we control for other land-use policies. In cols. (2) and (3) of Table 4, we include the variables available for the 49 countries or 47 countries only, respectively (transformed so that higher values imply more stringent regulations). If we include all variables (col. (4); N = 47), the correlation between our gap measures and the maximum FAR values almost triples (coefficient of -0.32*** vs. -0.12** in col. (1)). In addition, the effects of the other variables are, for the most part, not significant, showing that the gaps are not particularly correlated with other types of land use regulations. The only other land use policy for which we find a significant effect is the number of months required to obtain a building permit. Despite their insignificance, the other coefficients have the expected signs. Measures aimed at controlling sprawl (urban containment, greenbelt, urban growth boundary) have negative coefficients, implying that the gaps are lower when cities cannot build "out" and have to build "up" (see the Conceptual Framework in section 1.). Zoning is associated with higher gaps. Lastly, a higher minimum lot size implies lower gaps since it facilitates the construction of taller structures.[32]

Second, high-gap countries could compensate their residents by having more lenient regulations in other dimensions. For example, countries that stringently restrict the height of their buildings could control sprawl less. Cities then disproportionately expand horizontally instead of vertically. If such compensation mechanisms indeed exist, we should find a strong negative correlation between our gaps and the other measures of land use regulations. However, the correlation is slightly positive in the majority of cases or weakly negative (col. (5) of Table 4). The two most negative correlations that we obtain are -0.11 and -0.14. In particular, the high-gap countries are *not less likely* to restrict sprawl

[32]Similar results are obtained if we use the UMH-based gaps (see Web Appx. Table A2).

through urban containment policies (-0.02). As such, urban areas in high-gap countries are not allowed to sprawl more, and building-height restrictions restrict supply.[33]

Next, we consider various measures taken from the *Doing Business* website that capture the "procedures, time and cost to build a warehouse," which constitute the only measures of land-use regulations that could be obtained from World Bank data (N = 155). Column (1) of Table 5 shows that the H-based gaps are higher if building regulations are of higher "quality," hence more stringent. We then find that the gaps are higher if more procedures are required to obtain approval for building a warehouse or if the cost of obtaining approval is higher (not shown, but available upon request).

Finally, in column (2) we test how the gaps correlate with a measure of the extent to which the system of landlord and tenant law and practice is pro-landlord (N = 98).[34] We classify as pro-landlord any country that is classified as either pro-landlord or strongly pro-landlord. We find reduced gaps in pro-landlord countries, possibly because the landlord-friendliness of the system captures how pro-urban-development a country's regulatory stance may be. Of course, the last two measures are imperfect and do not measure building-height restrictions. Yet, these are the only other international measures of land-use regulations that we could find, which shows the importance of our analysis.

7. The Gaps and other Urban Outcomes

Table 5 presents correlations between the H-based gaps and measures of housing prices, sprawl, congestion, and pollution (Web Appx. Table A4 shows similar results for the UMH-based gaps). Note that we always control for income. For a given income level, we thus examine how building-height restrictions might have important economic and environmental consequences. Controlling for income also ensures that we do not simply compare rich and poor countries. One caveat is that the results are not causal. Nonetheless, if we find strong correlations, this will reinforce our interpretation of the gaps as international measures of the stringency of building-height restrictions.

Housing Prices. World Bank (2019a) reports the price level of broad consumption categories in 2011 (relative to the world = 100). In column (3), we regress the price level of housing on the gaps while controlling for log nominal per capita GDP (2010) (World Bank, 2019b) and using as weights urban population (2010). We control for nominal, not

[33] We respectively obtain are -0.17, -0.28, and 0.10 for the UMH-based gaps (see Web Appx. Table A2).
[34] See https://www.globalpropertyguide.com/landlord-and-tenant.

PPP-adjusted, GDP because higher prices would be captured by PPP adjustments.[35] A unitary decrease in the gap is associated with 4% lower housing prices. The magnitude of the effect is large too: A one standard deviation increase in the gap (a value of about 2) is associated with a 0.15 standard deviation increase in the price level. Recall from above that such a unitary decrease corresponds to a 100% increase in actual height density.[36]

Countries with more stringent land use regulations could compensate their urban residents by subsidizing commuting, for example via public investments in urban transportation infrastructure. In column (4), we use the same specification but regress the price level of transportation on the gaps while also controlling for the price level of housing. While negative effects are observed, the point estimates are not significant. Thus, the higher housing prices are not compensated by cheaper transportation.

Another potentially reliable data set on global property prices is the *World's most expensive cities* list provided by GPG (2019). For the largest city in 75 countries, the list shows selling prices per sq m as well as the price-to-rent ratio (PRR). Typically, a high PRR suggests that the costs of housing will increase in the future. The two measures are available for 72 and 70 countries in our sample, respectively. The selling price ranges from 700 USD per sq m in Dar-es-Salaam to 30,000 USD per sq m in Hong Kong, while the PRR ranges from about 10 in Kingston to 50 in Vienna. In columns (5)-(6), we regress these measures on the gaps while controlling for log nominal per capita GDP (2017), log city population size (2015), and using as weights urban population (2017). The gaps strongly correlate with current and future housing prices (captured by PRR). A unitary decrease in the gap is associated with 24% lower housing prices (see col. (5)). A one standard deviation increase in the gap is then associated with a 0.56 standard deviation increase in prices. We also find strong effects for future housing prices (see col. (6)).

Knoll et al. (2017) show that housing prices have increased faster than overall prices for 14 countries post-1950. Figure 3 shows that the evolution of the total km gap of the 14 countries follows the evolution of mean real house prices in their sample. Columns (7)-(8)

[35] As discussed in Section 4., the urban population weights are important to give less weight to smaller countries as such countries might be more likely to mechanically have larger percentage gaps.

[36] The price level is for the whole housing sector. However, differences likely come from urban areas only. With rural land prices being low, rural buildings rarely exceed one story. Since we control for log per capita income, whose correlation with urbanization tends to be very high (Jedwab and Vollrath, 2015), we compare countries with similar urbanization levels. The price level effect is thus estimated controlling for the composition of the housing sector and should be interpreted as an urban price level effect.

then show using panel regressions for the 14 countries (1960-2010) the strong correlation between the gaps and real house prices (country and year fixed effects included; standard errors clustered at the country level). In column (7), we keep 1960 and 2010 to study the long-difference effect of the gaps. A unitary decrease in the gap is associated with 29% lower prices. The magnitude of the effects is large too: a one standard deviation increase in the gap is associated with a 0.60 standard deviation increase in prices. The short-difference effect, estimated using all available years, is halved, implying that gaps might have effects in the following decades. Lastly, proportionate reduction of error analysis suggests the gaps might have explained 22% of the global house price boom.

Finally, although expensive high-gap countries might exclude the urban poor unless housing is subsidized, the share of housing that is publicly provided (HOFINET, 2020) is not correlated with the gaps (column (9); using the specification of column (4)).

To summarize, high-gap countries do not appear to "compensate" their urban residents by subsidizing transportation or directly providing housing to the urban poor.

Urban Land Expansion: Country-Level Results. If cities cannot expand vertically, they may need to expand horizontally. Therefore, for a given urban population and a given per capita income level, we expect countries with larger gaps to use more urban land. However, since housing prices are overall higher, it must be that horizontal expansion is not enough to "compensate" for the lack of vertical expansion.

In column (10), we regress total urban land area (2011) (World Bank, 2019b) on the gaps. We control for log urban population (2010), log nominal per capita GDP (2010) (since higher incomes increase housing/land consumption and imply better commuting technologies), and log nominal agricultural land rent (2010) (since a higher land rent should constrain land expansion). We use urban populations (2010) as weights. Land expansion is positively correlated with the gaps. A unitary decrease in the gap is associated with urban areas consuming 19% less land. A one standard deviation increase in the gap is then associated with a 0.23 standard deviation increase in urban land area.

Moreover, we use the *Global Human Settlement* (GHS) database of European Commission (2018) to obtain for each country in 1975, in 1990, in 2000 and in 2015 the total population and total land area of all (11,719) 50K+ urban agglomerations today. In columns (11)-(12), we use as the dependent variable the log of total agglomeration area while adding country and year fixed effects and controlling for log agglomeration population, log nominal per capita GDP, and log nominal agricultural land rent, with the variable of interest being the gap. By restricting our panel analysis to the years 1975 and 2015, we capture how the gaps correlate with the long-difference change in urban land per capita. A unitary decrease in the gap is associated with urban areas consuming 5% less land. A one standard deviation in the gap is associated with a 0.07 standard deviation increase in urban land area. With the full panel, elasticities are halved (col. (12)). Using the same specifications but controlling for log built-up area, col. (13)-(14) further show that gaps correlate with sprawl (more land used conditional on built-up land area).

Theoretically, by restricting housing supply, height restrictions raise the price per unit of housing throughout the city while causing the urban footprint to expand. Residents experience a combination of higher housing prices and longer commutes. For the resident at the edge of the city, the welfare loss comes entirely from a longer commute. With utilities equalized within the city, the welfare loss for each resident equals the increase in commuting cost for the edge resident (Bertaud and Brueckner, 2005b). In Web Appx. Section B, we describe how we can use our results on urban land expansion and various assumptions to estimate this increase in commuting cost. In particular, we show that the implied costs from a one-standard-deviation increase in the gaps (≈ 2) – which corresponds to the world gap – is possibly 0.7-1.0 percent of total urban income. Crudely adding the cost of particulate matter pollution (0.4-0.8% of world GDP, see details below), we obtain 1.1-1.8% of world GDP. In comparison, Davis (2014) finds that the total annual deadweight loss from fuel subsidies is $44 billion in 2012, or about 0.06% of world GDP. Including external costs, Davis (2014) finds that the total economic cost of fuel subsidies is $76 billion annually, or 0.1% of world GDP. Both approaches differ. For example, Davis' analysis is more theory-based. However, our back-of-the-envelope calculations suggest that building-height restrictions might have major economic costs globally.[37]

Urban Land Expansion: City-Level Results. While the previous conclusions are all derived at the country level, we can combine the country-level gaps with city-level information to generate some additional insights, as follows. We take advantage of the

[37] Our crude calculations likely provide a lower bound of the real costs. Indeed, we ignore the negative environmental effects from other urban pollutants as well as sprawl (including loss of open space). In addition, Hsieh and Moretti (2019) investigate losses from land-use regulation that come from a distortion in the allocation of the workforce across cities. They show that reducing land-use regulation so as to increase housing supply elasticities in the highly productive but land-use-constrained cities of New York, San Francisco and San Jose would increase the rate of growth of output and welfare in the U.S.

fact that the GHS database reports estimates of population and land area for all 11,719 agglomerations circa 1975, 1990, 2000 and 2015. Similarly, we use our building database to obtain the total building height of each city in the same years. Focusing on the year 2015, we can regress the log of city total building heights (km) on six dummies showing if the city has 55-100K, 100-500K, 500-1,000K, 1,000-5,000K, 5,000-10,000K or 10,000K+ inhabitants (50-55K is the omitted category), while including country fixed effects, with the results illustrated diagrammatically.[38] As seen in Figure 4(a), the relationship is non-linear, with heights significantly increasing after the 100k threshold is passed. The figure also shows the same relationship for total heights in the central city (e.g., New York City for the New York-Newark-Jersey City metro area) vs. peripheral areas (e.g., Newark and Jersey City). The overall relationship is driven by central areas.

Next, we ask whether the height difference between larger and smaller cities is reduced in countries where gaps are high. Instead of six population categories, we use three dummies for whether the city has 100-500K, 500-1,000K and 1,000K+ inhabitants in 1975, respectively. We use 1975 because post-1975 changes in city populations are endogenous to post-1975 changes in the country gaps. For the years 1975 and 2015, we then run city-level panel regressions where the dependent variable is the log sum of heights and the variables of interest are the country gaps interacted with the three population category dummies. We include city and year fixed effects, country-year fixed effects, and cluster standard errors at the country level. Moreover, we control for log per capita GDP interacted with the three population dummies to capture how changes in the gaps occur in larger cities rather than the fact that gaps are becoming larger in richer countries. The effects of the country gaps are particularly visible for larger cities (col. (17)), thus suggesting that they are associated with abnormally constrained big agglomerations. If we use the full panel (1975, 1990, 2000 and 2015), thus focusing on short-term effects, the point estimates are reduced, but significant above 1,000K (col. (18)).

As such, we do not use our city-level data to estimate the country gaps themselves but, instead, to show that the country gaps are driven by the largest cities in each country (conditional on city fixed effects that absorb city-level time-invariant factors). As explained in the introduction, global historical data on city incomes and agricultural

[38] As we will show later, our tall building database is highly reliable. City-years with no tall buildings thus have no, or few, tall buildings. Since we use logs, we assign city-years with no tall buildings the minimal positive value in the data. Results hold if we use alternative methods to deal with 0s (not shown).

land rents at the edge of cities do not exist, ruling out a worldwide, within-country study.

Next, using the full panel specification, we confirm that building-height restrictions are stringent in the central areas of urban agglomerations (col. (19)). We then test if such gaps are compensated by vertical development in peripheral areas. For example, most tall buildings in the Paris and Washington DC agglomerations are located in the peripheral La Défense and Arlington areas, respectively. We re-run the same regression using the log sum of heights in peripheral areas and find, however, that the effects of the gaps interacted with the city dummies are nil or negative, not positive (col. (20)). Thus, it appears that high-gap countries abnormally constrain *all* areas of big agglomerations.

If central area gaps are not compensated by vertical development in peripheral areas, larger cities may expand beyond their initial boundaries. We test for such an effect using the city-level panel specifications except that the dependent variable is now log city area (columns (21)-(22)). No effect is found. These regressions compare relative land expansion patterns for different class sizes of cities (50-55K is the omitted category) whereas columns (11)-(12) examined the total expansion of urban areas. Since urban land expansion is correlated with the gaps (columns (11)-(12)), *all* class sizes of cities must be expanding spatially *at the same rate* due to binding gaps in the largest cities.

Finally, as cities sprawl they may become more congested, especially if workers have to rely on motorized vehicles for their commute. We test that notion now.

Congestion. Traffic congestion is available for 391 50K+ agglomerations today (TomTom, 2019). The measure indicates by how many percentage points commuting times increase during rush hours relative to non-rush hours.[39] Congestion increases with log population size (2015; with country FE; coef. = 3.7***; adj. R2 = 0.75). We then examine how this relationship is affected by the gaps. We regress congestion on the gaps again interacted with the three city-size dummies. We include country fixed effects and income interacted with the three population category dummies, and use urban populations (2020) as weights. Larger cities are disproportionately more congested than 50-100K cities in higher-gap countries (col. (23)).[40] Finally, knowing the population share of each group of cities, we compute the average effect across the three groups, equal to 1.55*. Thus, a

[39]TomTom constructs the measure using its own data on the travel patterns of 600 million drivers (accessed 02-28-2020: https://www.tomtom.com/engb/traffic-index/). The measure is available for 401 agglomerations but we could only match them with 391 agglomerations in the GHS database.

[40]Point estimates are lower in the largest cities possibly due to public transportation infrastructure.

unit increase in the gap is associated with 1.5% more congestion. The magnitude of the effects is large too: a one standard deviation in the gap raises congestion by 3%. Finally, the effect is halved and insignificant when controlling for sprawl 1975-2015 (not shown).

Pollution. With sprawl and road congestion, pollution may also increase, implying that building-height restrictions might have important environmental consequences. Air pollution in cities consists of gases – mostly carbon dioxide (CO2) and nitrogen oxides (NO_x) – and particulate matter (PM) measured by their size, such as 10 and 2.5 micrometers. CO2, NO_x and PM have health effects. C02 and NO_x also contribute to global warming. Unfortunately, ground-based measures of CO2 and NO_x are not available for enough urban areas across the world. However, there is data on PM10 and PM2.5. In columns (24)-(25), the dependent variables are the log levels of PM 10 (2010) and PM 2.5 (2017) in more populated areas, respectively (World Bank, 2019b).[41] We control for log nominal per capita GDP and log urban population (2010 or 2020), and use urban populations (2010 or 2020) as weights. A one point increase in the gap is associated with 0.05-0.07% more pollution. A one standard deviation increase in the gaps is then associated with a 0.05-0.08 standard deviation increase in PM.

Furthermore, for 1,473 GHS agglomerations we obtain from WHO (2019) the average levels of PM10 and PM2.5 in 2008-2017. Given the same specification as for congestion, gaps are associated with increased pollution in the largest cities (col. (23)-(24)). Knowing the population share of each group of cities, we can obtain the average effect across the three groups, 0.04*-0.07** for PM10 and 0.05***-0.08*** for PM2.5. Thus, a one point increase in the gap raises pollution by 4-8%. Alternatively, a one standard deviation in the gaps (= 2) raises pollution by 8-16%. Now, the cost of pollution is 4.8% of world GDP (World Bank, 2016). Thus, a world gap increase of 2 could reduce world GDP by 0.4-0.8%.

Finally, whether for the country-level (col. (15)-(16)) or city-level (col. (24)-(25)) regressions, if we control for log land area and log city population in 2015, and their squares in case congestion varies non-linearly with sprawl (area per capita), the effects of the gaps on pollution are strongly reduced and often turn insignificant (Web Appx. Table A3). This suggests that most of the pollution effects could be explained by sprawl.

[41] PM 10 is measured for urban areas above 100,000 inhabitants only. The mean level exposure of a nation's population to PM 2.5 air pollution is then computed by using the PM 2.5 level and population of different areas in each country. As such, the measure overly represents populated urban areas.

8. Robustness Checks

The gaps are over-estimated if the coefficients of income and agricultural rent in Table 1 are upward biased. A downward bias would make us under-estimate the gaps, which is less consequential. However, the bias would most likely affect the levels of the gaps, not country rankings. Despite different coefficients of income and agricultural rent, we found that the correlation between the H- and UMH-based rankings was above 0.85. The results on the determinants and effects of the gaps and which land-use regulations they capture should also be little affected. Nonetheless, to appraise the potential for bias, we gauge the extent to which our results are affected by changes in our specification or our sample by carrying out a large number of robustness checks, as follows.

Causality. Such bias would be a consequence of correlation between the two explanatory variables and the regression error term. This correlation could arise either from omitted variables or from reverse causality. In the omitted variable case, a country's commitment to free-market principles may raise both its urban income level and the height of its buildings, leading to an upward bias. Alternatively, effective transit systems may influence both incomes and building heights. While use of country fixed effects mitigates the effect of such unobservables to some extent, bias may still be a concern. Examples of reverse causality include a positive feedback effect from commercial buildings to incomes operating through agglomeration economies.[42] Alternatively, the supply-increasing effects of taller buildings may reduce housing prices enough to attract lower income consumers to cities, generating a negative feedback effect on income. Another example might be negative feedback (via reduced sprawl) from heights to agricultural land values, in which a more compact city relieves price pressure on surrounding farmland.

We do not believe that there exists an identification strategy that would fully allay these concerns; an instrument that would explain urban incomes without impacting building heights is very hard to find. We thus discuss another series of results that gives us greater confidence in the estimated coefficients. To this end, Web Appx. Table A5 presents the results of an additional eleven specifications. Col. (1) replicates the baseline results, and additional columns show that our results tend to hold if:[43]

[42]However, if human capital spillovers are as likely on campuses as in office towers, large firms that are the main contributors to economic activity may be indifferent between both (e.g., Apple, Google and Microsoft use campuses as their headquarters). In that case, this positive feedback effect might be limited.

[43]In our baseline panel specification, we include country and year fixed effects. Identification then comes

(i) We include continent (N = 5)-year fixed effects (col. (2)) or World Bank region (N = 7)-year fixed effects (col. (3)), in order to capture time-varying regional economic, institutional and cultural drivers of tall building construction that may simultaneously affect building heights, urban incomes and agricultural land rent;[44]

(ii) We include country-specific linear trends (col. (4)) or even country-specific non-linear trends (col. (5)), i.e. country dummies interacted with the year and the square of the year. In that case, identification comes from swift or very swift (and possibly exogenous) growth (or deceleration) within countries, i.e. deviations from country trends.

(iii) We capture commuting costs by controlling for whether there is a subway and the logs of the number subway lines and subway stations in the country in year t (source: Gonzalez-Navarro and Turner (2018); Gendron-Carrier et al. (2018)) as well as the percentage of country roads (including non-urban roads) that is paved during the period 1990-2017 interacted with a linear year trend (source: World Bank (2019b)).[45] As seen in column (6), the effect of income on height density increases. This change makes sense if richer countries have better transportation infrastructure, and if lower commuting costs reduce the need to build up. Then, a negative correlation between the error term and income arises, creating downward bias in the income coefficient, which is reduced by controlling for commuting infrastructure. Thus, had we better controls for commuting costs, the coefficient of income would likely increase and the gaps would too.

(iv) We add leads of the main explanatory variables to address possible reverse causality, with the variables defined as t+10 (col. (7)). The leads have no effects. Tall buildings are not built in anticipation of future income growth (at least not ten years in advance).

(v) We control for time-invariant geographical factors interacted with year fixed effects (thus allowing their effects to vary over time) in case they constrain tall building construction and affect income/land rent. These factors are the logged number of significant earthquakes ever experienced (per sq km), the logged (population-weighted) average bedrock depth and ruggedness in urban areas, and the (population-weighted) share of urban land below sea level (col. (8)-(11); see table note for details on the sources).

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from countries whose urban income and/or agricultural land rent rose faster than in the rest of the sample, i.e. country-decades with a higher than average slope in Web Appendix Figure A2.

[44]Continents: Africa, America, Asia, Europe, Oceania. Regions: East Asia & Pacific, Europe & Central Asia, Latin America, Middle East & North Africa, North America, South Asia, Sub-Saharan Africa.

[45]Unfortunately, no panel data exists on urban road stocks across countries over time.

In addition, historically important geographical constraints were, thanks to technological progress, largely overcome by 1960. During earthquakes, structural techniques allow buildings to sway without damaging the structure (Wang, 2016). While bedrock depth influences skyscraper locations very locally (Barr et al., 2011), it is unlikely to systematically impact building construction at the country level. Furthermore, piles have been used to anchor skyscrapers for one century (Bradford and Landau, 1996). While being below sea level makes foundation work costlier if soils are porous (Ibid.), this condition only concerns 0.2% of global urban land. Finally, foundation costs are low compared to construction costs and land is the most expensive factor in central city areas. Confirming these observations, the gaps (col. (1)-(2) of Table 2) are not notably high for countries with high earthquake risk (e.g., Japan, New Zealand or Turkey), a deep bedrock (the Gulf States or Central Asian countries) or ruggedness (Chile, Colombia or Lebanon).

Finally, using the 11 different regressions in Web Appx. Table A5, we can generate 11 different gap rankings for the sample countries. For $11 \times 10 \div 2 = 55$ pairs of rankings, the mean and 5th percentile correlations are 0.96, and 0.90, respectively. Rankings are thus largely insensitive to the exact magnitudes of coefficients used.[46] In addition, the coefficients are estimated using existing countries that may still not be perfectly laissez-faire. In an imaginary perfectly laissez-faire country, the effects of income and agricultural rent (and thus the gaps for real countries) might be even higher.

Sampling Checks. A Google search supports the validity of the process by which we select laissez-faire countries, as follows. For 61 UM-H countries, the correlation between the selection residuals and the number of Google search results for the country name & "cities" & "skyscrapers" is 0.61 (conditioning on the respective numbers of search results for the country name & "cities" and the country name). The correlation is 0.72 if we also control for whether English is an official language and the numbers of famous 20th and 21st century architects from the country (Wikipedia, 2020b), as some countries have renowned architects but few skyscrapers (e.g., Italy with Renzo Piano). With search results in the country's language, the correlation becomes 0.90.

Next, results also hold if we (see Web Appx. Tables A6-A7 for the H- and UMH-set regressions): Include the U.S. in the benchmark set of countries (col. (2)); give more weight to large, or small, countries (col. (3)-(4)); drop Hong Kong and Singapore (col. (5)); select

[46] We find similar results for the UMH-based regressions (Web Appx. Table A5) and similar rankings.

countries based on 1980 residuals (col. (6));[47] drop government/religious buildings (1% of the stock) (col. (7)); drop buildings among the 5 tallest buildings in the world at any point in case they reflect a government's advertising campaign (col. (8)); interact the variables with a post-1980 dummy to isolate more recent effects (col. (9)). Finally, results hold if we drop each country one by one (not shown, but available upon request).

Measurement Error in Building Heights. The dependent variable is log urban height density, which is the sum of heights (for buildings above 80 or the top 10 buildings) divided by urban population. Classical measurement error in dependent variables only affects precision. However, measurement error could be non-classical.

To compare results, we collected data from a second source, Emporis (2019), another global provider of building information.[48] Note that Emporis (2019) claims to capture all *high-rise buildings*, which they define as buildings above 35 meters (about 9 floors). They then classify as *skyscrapers* buildings above 100 meters. Finally, they use the number of floors of each 35m+ building to compute for each city a Skyline index. We do not have access to their raw data but their website reports useful information for the 100 top cities in the world.[49] For 90 of these cities also in our data, and using as weights the sum of heights in our data in order to focus on the cities with the most tall buildings, the correlation between the log of their number of skyscrapers and the log of our own number of buildings above 100 meters is 0.90. Next, the correlation between the log of their Skyline index and the log of their number of skyscrapers is 0.83. The correlation of their Skyline index with our own reconstructed index (using our data and their formula) is 0.79. Thus, our measure of urban height density is a good proxy for 35m+ buildings.

Now, is our measure also a good proxy for structures below 35m, whether low-rise (four plus one) buildings or houses? Based on Emporis, which also reports the number of low-rise buildings for seven North American cities, the (mostly 80m+) buildings in our data account for between half and two thirds of total heights including low-rises. In addition, for each building, we know the main material used. While it was steel around 1950, the use of concrete has dramatically increased over time, reaching 90% in the 2000s (see Figure 4(b)). The mean share over the period 1950-2017 is then 73%. Next,

[47]We use 1980 – the mid-point between 1950 and 2020 – because few countries had tall buildings in 1950.
[48]Their website says they rely on their extensive member network to gather information on buildings.
[49]Accessed on 12-11-2019: https://www.emporis.com/statistics/skyline-ranking.

we obtained from the *Minerals Yearbooks* of USGS and for 144 countries and each decade from 1950 the total production of cement – the main ingredient of concrete – which we use as a good proxy for cement consumption.[50] As expected, the correlation between decadal tall building construction and decadal cement use is high, at 0.77 (N = 870). Adding country and year fixed effects, we obtain a correlation of 0.80 (0.99 with urban population as weights). Therefore, tall building construction is a good proxy for overall construction.

Next, one could argue that taller skyscrapers are better measured than shorter high-rise buildings, because they stand out more. Among the buildings in our data, the height of the 25th percentile, median and mean is 100, 125 and 135 meters, respectively. Results hold if we restrict our analysis to buildings above such thresholds (see col. (10)-(12) of Web Appx. Tables A6-A7). Our results continue to hold if we drop heights that are imputed based on the number of floors (col. (13)) or add underground floors to heights (col. (14)).[51]

Specification Checks. We show results hold if we (Web Appx. Tables A6-A7): (i) Omit the lagged dependent variable (col. (15)). Indeed, with panel regressions, including a lagged dependent variable might introduce dynamic panel bias (Nickell, 1981). When doing so, the coefficient of GDP further increases for both the H and UMH sets.; (ii) Interact the lagged dependent variable with year fixed effects (col. (16)) or also include the square of it (col. (17)) in case durability/persistence varies over time or with the existing stock; (iii) Include lags of income and agricultural rent in case their effects take some time to materialize (col. (18)). The combined contemporaneous and lagged effects are similar to the contemporaneous effects; and (iv) Use 5-year (col. (19)) or 15-year (col. (20)) lags.[52]

We can also use the GHS data to re-run *at the city level* the baseline panel specifications that we used for 8 H countries (167 cities). Consistent with Table 1, we regress log city height density on log urban per capita GDP and log agricultural rent, both defined at the national level given the lack of global historical data on city incomes and agricultural

[50] Because cement is a low-value bulky item, the world trade of cement only accounts for 3% of world cement production (see, for example, https://www.worldcement.com/africa-middle-east/29042013/cement_global_trading_patterns_961/). Thus, even if we have limited data on cement imports and exports, cement production is a very good proxy for cement consumption. The *Minerals Yearbooks* can be found here: https://www.usgs.gov/centers/nmic/cement-statistics-and-information.

[51] We know the gross floor area (GFA) for one third of buildings. The correlation between log height and log GFA is 0.6, so lower than 1, due to buildings having different shapes. If we regress for the year 2017 log GFA on log height, log urban income and log agricultural rent and their interactions with log height, we find no interacted effects, thus suggesting that the GFA-height relationship does not vary with our variables of interest (not shown). Thus, not fully capturing GFAs should not dramatically affect our results.

[52] 5-year periods capture short-term effects, so the response to income is mechanically lower.

land rents at the edge of cities, as well as past log city height density. We include year and city fixed effects (standard errors clustered at the country level). In addition, we interact the variables of interest with the three dummies for whether the city has 100-500K, 500-1,000K and 1,000K+ inhabitants in 1975. As expected, we find stronger effects of urban per capita GDP for larger cities: 3.38** for 1,000K+ cities, 2.63*** for 500-1,000K cities, 0.48** for 100-500K cities and -0.27 for 50-100K cities (not shown). Given the total population shares of the different categories of cities, the average effect is 2.43***. While it is lower than in Table 1, it remains high. Indeed, large cities account for a significant share of urban populations.[53] For land rent and past height density, we obtain averages of -0.25 and 0.15. Overall, these results produce similar country rankings (not shown).[54]

Measurement error in income and land rent should lead us to under-estimate their effects and the gaps. In addition, results hold if we (Web Appx. Tables A6-A7): (i) Use log national per capita GDP instead of log urban per capita GDP (col. (21));[55] (ii) Construct land rent differently. Based on available data, urban land is 6% of total land (ca. 1990) and agricultural land is 48% (1960-2017), making non-agricultural and non-urban land 54%. Results hold if we use agricultural GDP (in t) divided by non-urban land area (1990) (col. (22)) or agricultural land area (in t; for the period 1960-2020 only) (col. (23)); and (iii) Drop countries above the mean land area across the 158 countries since land rent at the edge of urban areas is more likely to be mismeasured for them (col. (24)).

9. U.S. State Analysis and U.S. State and World Gaps

In this section we perform a similar gap analysis using U.S. state-level data, which offers another opportunity to validate our methodology. The specification that we use for this analysis differs from the one used for the international analysis. Indeed, due to interurban mobility within a country as well as agglomeration effects, population and income per capita are very strongly correlated across cities and urban areas. Therefore, on the left hand side, we do not divide the sum of heights by total urban population, and on the right hand side, we use total urban income instead of urban income per capita. However, we show below that world rankings are little affected if we use the U.S.-based coefficients.

[53] The discrepancy may also be due to the different periodicity, as the GHS data is only available for the years 1975, 1990, 2000 and 2015, whereas our main analysis focuses on the 1950-2020 period.

[54] We find similar average effects for 14 UMH countries (617 cities), at 2.48***, 0.06 and 0.28** (not shown).

[55] Since national per capita GDP is the sum of non-agricultural GDP and agricultural GDP, the correlation between income and agricultural rent is then stronger, making agricultural rent less relevant.

Data. Our sample comprises 50 states almost annually from 1929 to 2017.[56] For building heights, we use CTBUH. From Bureau of Economic Analysis (2019), we then obtain for the 1929-2017 period total income, farm income, and non-farm income, a proxy for urban income. Next, from United States Census Bureau (1975), we know state farmland area from 1929 to 1940. From United States Department of Agriculture (2017) and Wikipedia, we know agricultural land area and total land area.[57] Knowing farm income and agricultural land area, we reconstruct agricultural land rent. We use agricultural land area for the U.S. analysis – we used total land area for the international analysis – because it is well measured for the whole period.[58] From Wikipedia, we obtain the population and urbanization rate – and thus the total urban population – of each state in each year.[59]

Results. Web Appx. Table A8 shows the baseline regression in column (1), where all three coefficients are significant. Columns (2), (3) and (4) then eliminate states with residuals below 0, the 75th percentile, and the 90th percentile in a 2017 regression using GDP and agricultural rent as covariates. The GDP and agricultural-rent coefficients increase as we do. Restricting the sample to the states with residuals above the 75th or 90th percentile (columns (3)-(4)) has little effect on the GDP coefficient compared to restricting the sample to states with residuals above 0 (column (2) vs. column(1)). In order to keep more observations, we thus privilege the sample of states with residuals above 0.[60]

The other columns present robustness checks similar to those in the country-level analysis. In column (5), we include nine census region dummies $\times$ year fixed effects; adding them has little effect on the GDP coefficient. Use of state time trends yields positive, yet insignificant, coefficients (column (6)). Indeed, unlike in the international sample, no state has experienced a period of growth fast enough that the coefficients survive the inclusion of state time trends. Column (7) shows the effect of adding ten-year leads of the GDP and agricultural-rent variables, whose coefficients are insignificant.

[56]We drop the District of Columbia because agricultural rent is unavailable for most of the period.

[57]To obtain a consistent series of state agricultural land area from 1929 to 2017, we use cropland/pasture area from 1945 to 2017 as our benchmark. We then use the growth rate of farmland expansion in each state before 1940 to extend that variable to 1929. Total land area is obtained from Wikipedia (2020e).

[58]We use the consumer price index of the United States to express the income variables and the agricultural land rent variables in constant 2017 dollars (Minneapolis Federal Reserve, 2020).

[59]Sources are Wikipedia (2020c) and Wikipedia (2020d).

[60]Using the 75th percentile (p75) cutoff gives the following 13 states: Delaware, Georgia, Hawaii, Illinois, Kansas, Louisiana, Minnesota, Nevada, New York, Oklahoma, Rhode Island, Utah, Washington. Using the 90th percentile (p90) cutoff gives the following 5 states: Hawaii, Illinois, Nevada, New York, Rhode Island.

In column (8) we capture commuting costs by controlling for whether there is a subway and the logs of the number subway lines and subway stations (source: Gonzalez-Navarro and Turner (2018) and Gendron-Carrier et al. (2018)) and the log of the total mileages of paved roads corresponding to "municipal / urban extensions of highway systems" or "other municipal / urban streets" in the state in year t.[61] One advantage of the U.S. regression over the international regression is that consistent panel data on urban road stocks is now available. As can be seen, the effects are mostly unchanged.

In columns (9)-(12), we control for time-invariant geographical factors interacted with year fixed effects: the logged number of significant earthquakes ever experienced (per sq km; col. (9)), the logged (population-weighted) average bedrock depth ((10)) and ruggedness in the state's urban areas ((11)), and the (population-weighted) share of urban land below sea level ((12)). Results appear to hold across all specifications.[62]

In column (13) we add geographical controls, each interacted with a year trend. These controls are total land area and the shares of land unavailable for development due to excessive slope, the presence of wetlands, or the presence of bodies of water (source: Lutz and Sand (2017)). In column (14), the geographical controls are replaced by time-interacted variables measuring the amounts of land under various types of government ownership (source: NRCM (2017)).[63] Again, the results are similar to those in column (2).

Finally, in column (15), we control for the RSMeans construction cost in the state in the same year. Indeed, as income increases, construction costs could increase, thus depressing construction. Controlling for construction costs then allows us to capture the direct effect of income. As can be seen, the estimated effects are mostly unchanged.

State Gaps. For the sample of observations used in col. (2)-(4), we take the antilog of the predicted heights and adjust it by a correction factor (Wooldridge, 2016)). We then obtain for each state the predicted sum of heights based on the regressions and compare these values with the actual stocks. In the U.S., the total stock in 2020 was 508 km of height. Using the estimates based on states above 0, the 75th percentile and the 90th percentile,

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[61] The sources are *A Quarter Century of Financing Municipal Highways, 1937-61* (Bureau of Public Roads) and the annual *Highway Statistics* reports of the U.S. Department of Transportation.

[62] See table notes for details on the underlying sources.

[63] Federal Government, State Government, Bureau of Land Management, U.S. Forest Service, National Park Service, National Wildlife Refuge, Army Corps of Engineers, Military Bases, Tribal lands.

we get 1,137, 1,474 and 2,317 km, respectively, hence gaps of 629-1,809 km, or a mid-value of 1,219 km. We found 1,468 km based on the H-set regressions in col. (3) of Table 2.

Across the three benchmark sets, California accounts for 48-61% of the U.S. gap. If we use the "above 0" benchmark set, other states that contribute to the gap are New York, Pennsylvania, Texas and Florida. Altogether, they account for 24-32% of the U.S. gap.[64]

Other Measures of Land-Use Regulations. Web Appx. Table A9 gives the results of regressions of measures of building regulations on the gaps. For the dependent variables, row 1 uses a measure of housing supply elasticity from Saiz (2010), but at the state level.[65] Row 2 uses an unweighted average of the Wharton Residential Land Use Regulation Index (Gyourko et al. (2008)), which measures the extent of building regulations for towns and cities across the U.S. The data set in Saiz (2010) also includes MSA-level values for the Wharton Index. We generate state-level weighted averages for this index, which are used as right-hand side variables in row 3. Finally, row 4 uses an index created by Saks (2008), which is the average of several building regulation indexes.

For the right-hand side variable, col. (1)-(3) use the estimated gaps. Results are based on states with a laissez-faire value above 0 in col. (1), the 75th percentile in col. (2), and the 90th percentile in col. (3). Across all gap measures, and all measures of building and land-use regulations across states, we find statistically significant relationships. These results provide evidence that the gap measures are useful indicators of land-use stringency.

World Gaps. Overall, the qualitative similarity of the state-level regressions reported in this section to the above country-level regressions increases our confidence in the country-level benchmark regression as a tool for computing building-height across the world. In particular, if we use the U.S. state estimates to obtain predicted heights and the gaps for all countries in the world, the coefficient of correlation between the H-based gap measure and the U.S. state-based gap measures is 0.74-0.76 (using urban population as weights). If we use the UMH set instead, the correlation is also high, from 0.72 when using states with a laissez-faire value above 0 to 0.89 when using states above the 90th percentile.

[64] If we use the p75 benchmark set, we get California, New York, Florida, Pennsylvania and New Jersey. If we use the p90 benchmark set, we get California, New York, New Jersey, Massachusetts and Connecticut.

[65] We create our state-level elasticities by taking a MSA-population weighted value for cities in each state.

10. Conclusion

Using a new data set on nearly all tall buildings on the planet, this paper has constructed a measure of the stringency of building-height regulations around the world. In particular, we first obtain parameters from a regression of building heights on income and agricultural rents for a benchmark set of countries that appear to have low stringency in height regulation. Using regression results for these benchmark countries, we create building-height gaps for countries around the world. We find that the world should have twice as many tall buildings (about 6,000 Empire State Buildings) as it does currently.

We then show that the gaps are relatively larger for richer countries. The evidence suggests countries with more urban planning and older, historic structures have more stringent height regulations. The restrictions are not driven by the homevoter hypothesis.

We compare the gap measures with other international measures of building regulations and show that the gap measures capture explicit building-height restrictions rather than the effects of other types of regulations. These restrictions disproportionately target tall residential buildings, not commercial buildings, and constrain the growth of large cities and their central areas. We do not find that countries with more stringent height restrictions "compensate" their urban residents: (i) by having more lenient height restrictions outside their cities' central areas; (ii) by having more lenient sprawl policies; (iii) by subsidizing transport; or (iv) by providing public housing. Conditional on income, the gaps are strongly and positively correlated with housing prices, sprawl, road congestion, and pollution, implying that building-height restrictions might have important global economic and environmental consequences. In particular, such restrictions might explain one fifth of the global house price boom observed since 1950. Future work will investigate the reason for the increasing gaps over time. Finally, we do not attempt to quantify the global welfare effects of building-height restrictions. While we show that such restrictions might have significant economic and environmental costs, they have also health, cultural and economic benefits that we cannot quantify.[66]

[66] WHR (2020) uses data from the Gallup World Poll (2014-18) to create a consistent measure of subjective well-being for 174 cities among our 158 countries. Controlling for contemporary log nominal per capita GDP and log city population size, we find, if anything, a negative correlation between life evaluation and the gaps (-0.06 for the H-based gaps and -0.08** for the UMH-based gaps; standard errors clustered at the country level; not shown). Unfortunately, we do not have enough cities to study within-country patterns.

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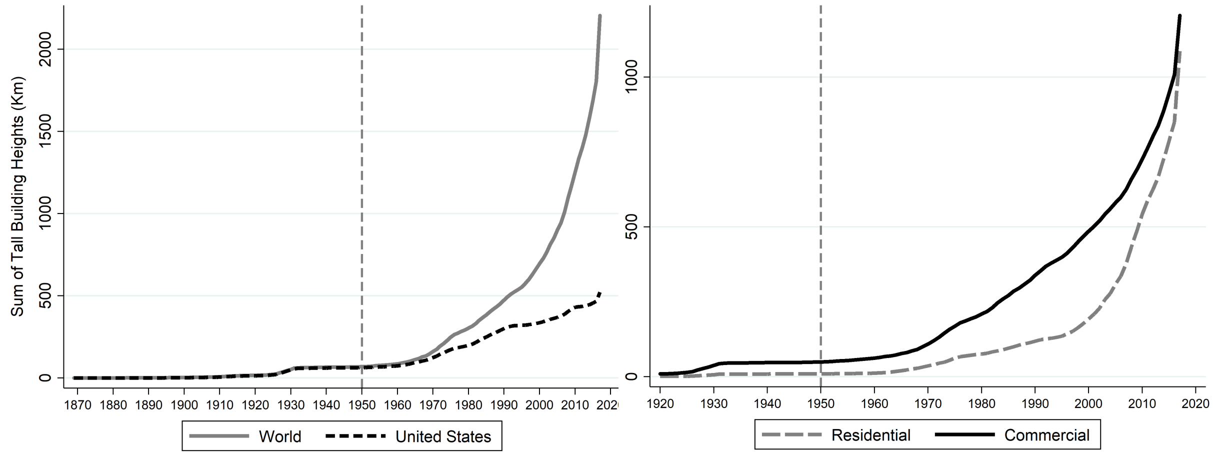
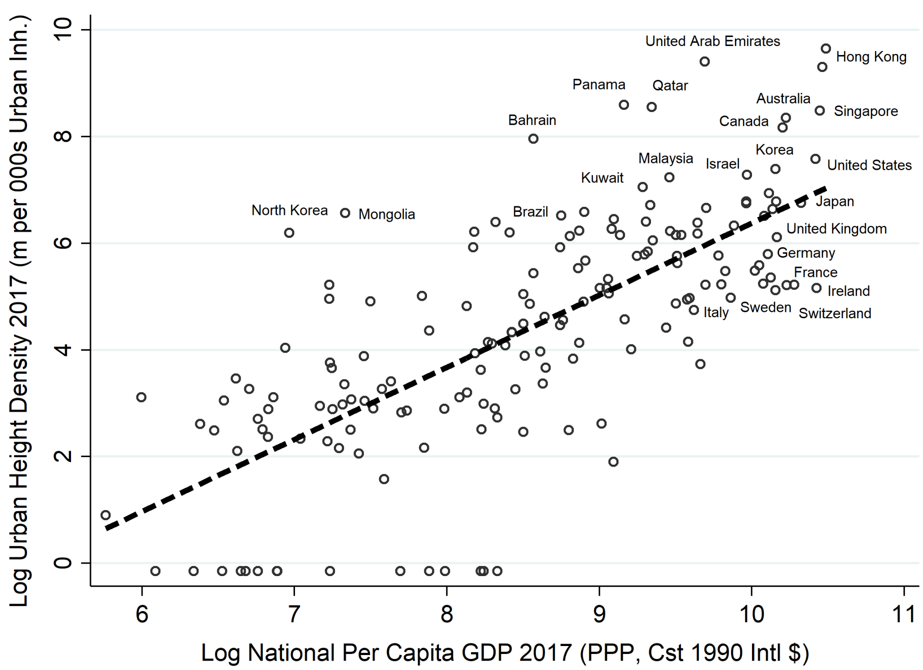
Figure 1: TALL BUILDING HEIGHTS FOR THE WORLD, 1869-2017

(a) Tall Building Heights, World vs. the U.S. **(b)** Residential vs. Commercial Heights, World



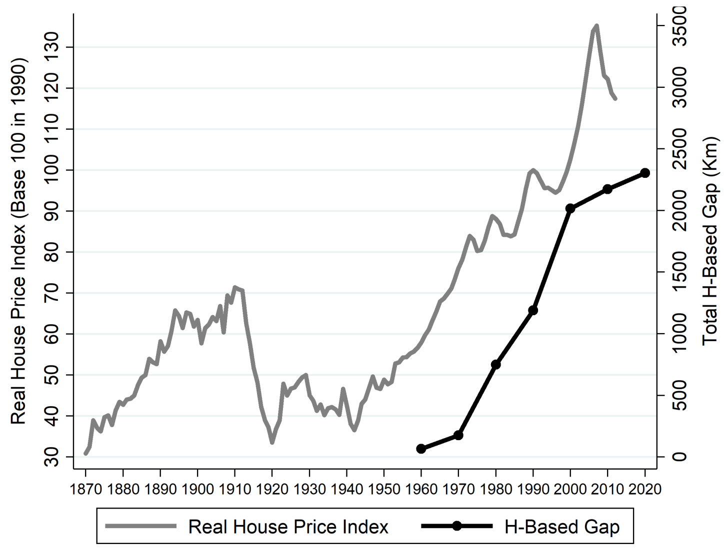
Notes: Subfigure 1(a) shows the evolution of the stock of tall building heights (m) for both the world and the United States from 1869 to 2017. Subfigure 1(b) shows the world evolution of the stock of tall building heights (m) separately for residential and commercial buildings from 1920 to 2017. The dashed vertical line shows the year 1950, the start year of our main period of study (1950-2020). See text for details.

Figure 2: URBAN HEIGHT DENSITY AND NATIONAL INCOME IN 2017



Notes: This figure shows the relationship between the log sum of tall building heights per urban capita (m per inh.) and log per capita GDP (PPP, constant 1990 international $) for 170 countries circa 2017.

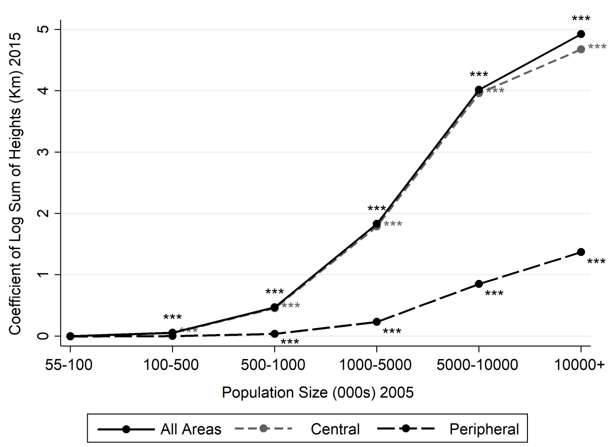
Figure 3: HOUSE PRICES & BUILDING-HEIGHT GAPS, 14 COUNTRIES, 1870-2020



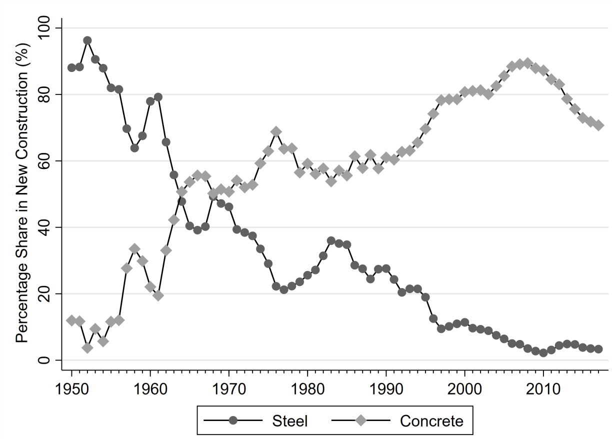
Notes: This figure shows that real house prices have dramatically increased in developed countries since the 1950s (we use the data from Knoll et al. (2017)). It also shows that the estimated total km (H-based) gap of the 14 countries has increased since 1960. More precisely, Knoll et al. (2017) reports a real house price index (base 100 in 1990) for 14 OECD countries annually from 1870 to 2012. We then obtain the average real house price index for the 14 countries in each year using the population of each country as weights.

Figure 4: CITY BUILDING HEIGHTS-POP. RELATIONSHIP AND MATERIALS USED

(a) City Building Heights-Pop. Relationship 2015



(b) Steel vs. Concrete in New Construction 1950-2017



Notes: Subfigure 4(a) shows for 11,719 agglomerations of at least 50,000 inh. in 2015 the relationship between the log sum of tall building heights (km) and the pop. size category (the omitted category is 50,000-55,000) ca. 2015. The 11,719 agglomerations in 2015 belong to 158 countries. Subfigure 4(b) shows for each year the share of new construction (weighted by building heights) that comes from buildings whose main material is steel vs. concrete. These shares are obtained using available information for 10,809 out of the 16,369 buildings in our data. We report two-year moving averages. See text for details.

Table 1: EFFECTS OF INCOME AND LAND RENT ON HEIGHTS, 1950-2020

Dep. Var.:	Log Urban Height Density (m per 000s Urban Inh.) in Year t ($LUHTDENS_t$)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Countries	All	≥ 0	< 0	$\geq$ p75 & DemUMH	$\geq$ p75 & DemH	Residential $\geq$ p75 DemUMH	DemH	Commercial $\geq$ p75 DemUMH	DemH
$LUPCGDP_t$	0.49***	0.68***	0.37***	1.54**	3.23***	1.54***	2.66***	1.27***	1.07
	[0.10]	[0.10]	[0.16]	[0.67]	[0.61]	[0.34]	[0.47]	[0.40]	[0.69]
$LAGRENT_t$	0.13	0.30**	-0.06	0.55**	0.19	0.58**	0.40	0.28	-0.03
	[0.09]	[0.13]	[0.10]	[0.26]	[0.40]	[0.22]	[0.42]	[0.16]	[0.28]
$LUHTDENS_{t-10}$	0.48***	0.46***	0.39***	0.46***	0.18	0.47***	0.45***	0.25**	0.23
	[0.03]	[0.04]	[0.03]	[0.11]	[0.12]	[0.09]	[0.11]	[0.10]	[0.14]
Cntry FE, Yr FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,106	511	595	98	56	119	56	84	56
Countries	158	73	85	14	8	17	8	12	8
Adjusted R2	0.79	0.80	0.76	0.87	0.91	0.80	0.86	0.87	0.86

Notes: Sample of 158 countries x 8 years (1950, 1960, 1970, 1980, 1990, 2000, 2010, 2020) = 1,264 obs. Since we control for the dependent variable in t-10, we lose one round of data, hence N = 1,106 (col. (1)). "Dem" countries are "full democracies" or "flawed democracies" at any point in 2006-2017. "UM" and "H" countries are upper-middle income countries and high-income countries circa 2017, respectively. "0" and "p75"correspond to the following values of the laissez-faire proxy: 0 and the 75th percentile. Col. (6)-(7) & (8)-(9): We study residential buildings and commercial buildings, respectively. Robust SEs clustered at the country level: * p<0.10, ** p<0.05, *** p<0.01.

Table 2: COUNTRIES WITH THE LARGEST BUILDING-HEIGHT GAPS, 2020

	(1) Percentage Change Gap_H ($\|\Delta Gap\|$ Expressed in %)			(2) Per Capita Gap_H (Km per Mil. Urban Inh.)		(3) Total Gap_H (Km)	
Rank	Country	Gap	$\|\Delta Gap\|$	Country		Country	
1	Ireland	4.88	488	Ireland	21	United States	1468
2	Mauritius	4.51	451	Mauritius	20	Taiwan	219
3	Slovenia	3.69	369	Austria	12	Japan	174
4	Switzerland	3.61	361	Taiwan	12	United Kingdom	172
5	Uzbekistan	3.37	337	Sri Lanka	8	Germany	168
6	Norway	3.21	321	Trinidad	6	China	157
7	Austria	2.90	290	Switzerland	6	South Korea	147
8	Taiwan	2.78	278	United States	6	France	127
9	Sweden	2.77	277	Slovenia	5	Italy	82
10	Sri Lanka	2.61	261	Norway	4	Ireland	63
11	Italy	2.53	253	South Korea	4	Austria	61
12	Denmark	2.52	252	United Kingdom	3	Netherlands	46
13	Trinidad	2.50	250	Netherlands	3	Switzerland	35
14	France	2.49	249	Estonia	3	Sri Lanka	32
15	Germany	2.47	247	Germany	3	Sweden	22
16	Eq. Guinea	2.43	243	Sweden	3	Spain	22
17	Finland	2.23	223	France	2	Norway	18
18	United Kingdom	2.15	215	Denmark	2	India	17
19	Lesotho	2.12	212	Italy	2	Belgium	15
20	Portugal	2.02	202	Slovakia	2	Poland	12

Notes: The table shows the 20 countries with the largest H-based gaps in 2020. Col. (1): The gap is the percentage change in urban height density required to make the height stock similar to the benchmark set of countries. Col. (2): The gap is expressed in km of heights per urban capita. Col. (3): The gap is the total gap in km. The gaps are estimated using as our set of benchmark countries 8 democratic high-income countries whose laissez-faire value is above the 75th percentile (p75) value (col. (5) in Table 1).

Table 3: DETERMINANTS OF THE GAPS, 2020

Dependent Variable:	H-Based ... Building-Height Gap 2020							
Considered Gap$_H$:	Overall (1)	Resid. (2)	Comm. (3)	Overall (4)	Overall (5)	Overall (6)	Overall (7)	Overall (8)
LPCGDP 1950	1.63***	2.15***	-0.27*	1.48	-30.98*	1.56***	1.08***	14.58
	[0.18]	[0.25]	[0.14]	[1.18]	[15.75]	[0.19]	[0.22]	[20.84]
ΔLPCGDP 1950-2020	2.73***	3.34***	0.30**	1.81*	-35.86*	2.69***	2.52***	8.81
	[0.18]	[0.24]	[0.14]	[0.96]	[20.16]	[0.21]	[0.23]	[22.97]
Home Ownership Sh. (HO)				-0.03				-0.02
				[0.12]				[0.11]
HO*LPCGDP 1950				0.00				0.01
				[0.02]				[0.02]
HO*ΔLPCGDP 19502020				0.01				0.00
				[0.01]				[0.01]
Log Num. Renown Urban Planners pc (LUPpc)					-46.03**			20.17
					[22.60]			[29.88]
LUPpc*LPCGDP 1950					4.68**			-2.05
					[2.28]			[2.98]
LUPpc*ΔLPCGDP 19502020					5.57*			-1.03
					[2.91]			[3.31]
Log 1800 Pop. of Largest City Today (LPL1800)						-0.88***		-0.08
						[0.31]		[0.45]
LPL1800*LPCGDP 1950						0.12***		0.02
						[0.04]		[0.06]
LPL1800*ΔLPCGDP 19502020						0.01		0.00
						[0.04]		[0.05]
Log Cultural World Heritage Sites pc (LWHSpc)							-20.80***	-18.52**
							[7.78]	[7.36]
LWHSpc*LPCGDP 1950							2.50***	2.37***
							[0.87]	[0.80]
LWHSpc*ΔLPCGDP 19502020							1.39	0.73
							[1.01]	[0.90]
Observations	158	158	158	105	158	158	158	105
R-squared	0.66	0.58	0.04	0.64	0.68	0.68	0.69	0.70

Notes: Col. (1)-(7): PCGDP 1950 is log national per capita GDP (PPP, cst 1990 intl $) in 1950 and ΔLPCGDP 1950-2020 is the log change in national per capita GDP between 1950 and 2020. Col. (2)-(3): We consider the gaps based on residential buildings (resid.) or commercial buildings (comm.) only. Col. (4): We use Wikipedia (2020a) as our main source for the home ownership share in the 2010s. When the share is still missing, we rely on Wikipedia (2020f) and then HOFINET (2020) (data available for 105 countries only). Col. (5): For the number of renown urban planners (per capita), we use the list from Wikipedia (2020h). Col. (6): For the 1800 population of the largest city of each country today, we use Chandler (1987) and then Wikipedia (2020g). Col. (7): For the number of cultural World Heritage Sites (WHS) (per capita), we use the list from UNESCO (2020). Robust SEs: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 4: GAPS AND LAND USE REGULATIONS, 2020

	Dependent Variable: H-Based Gaps				Corr w/ $Gaps_H$
	(1)	(2)	(3)	(4)	(5)
Maximum Floor Area Ratio (FAR)	-0.12**	-0.15**	-0.24***	-0.32***	
	[0.04]	[0.02]	[0.00]	[0.00]	
Dummy Urban Containment		-0.29		-0.55	-0.02
		[0.80]		[0.65]	
Dummy Containment Via Green Belt		-1.35		-1.36	-0.11
		[0.40]		[0.41]	
Dummy Containment Via Urban Growth Boundary		-0.65		-0.45	-0.08
		[0.45]		[0.64]	
Dummy Full or Partial Zoning		2.44***		1.22	0.20
		[0.00]		[0.20]	
(-) Dummy Gvt Land Acquisition		-0.64		1.40	0.00
		[0.62]		[0.15]	
Dummy Min Plot Size Regulation			-1.50	-1.87	-0.04
			[0.28]	[0.28]	
Number of Months before Permit Subdivision			-0.02	0.07	0.21
			[0.64]	[0.30]	
Number of Months before Permit Building			0.11	0.16**	0.26
			[0.12]	[0.04]	
(-) Dummy Street Layout Gvt or Mixed			-1.13	-1.10	-0.14
			[0.25]	[0.16]	
(-) Dummy Infrastructure Gvt or Mixed			2.17**	1.21	0.29
			[0.05]	[0.26]	
Observations (Countries)	49	49	47	47	47-49
R-squared	0.03	0.14	0.28	0.43	Mean: 0.06

Col. (1)-(4) show the correlation between the H-based gaps and the maximum FAR values. Col. (5) shows the individual correlations between the H-based gaps and the values of the other land-use policy variables. Robust SEs: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 5: BUILDING-HEIGHT GAPS AND ECONOMIC OUTCOMES, WORLD

Panel A: Country-Level Analysis

Dep. Var.:	World Bank Regu.'19	Pro-Landlord Regime'19	World Bank '11 Price Level (100) Hous.	Transp.	Global Prop.Guide'19 Log Hous Price ($)	Price-to-Rent	Knoll et al 2017 Real Hous. Price t LongDiff	ShortDiff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gaps$_H$	0.04***	-1.74***	3.99***	-1.50	0.24***	3.51***	28.78*	14.78**
	[0.01]	[0.50]	[1.33]	[1.34]	[0.04]	[0.84]	[14.38]	[6.48]
Cntry FE, Yr FE	N	N	N	N	N	N	Y	Y
Ctrls, Wgts	N	Y	Y	Y	Y	Y	N	N
Observations	155	98	147	147	72	70	28	83
Cntries, Yrs	155, 1	98, 1	147, 1	147, 1	72, 1	70, 1	14, 2	14, 6

Dep. Var.:	Share Public Housing	Col. (10)-(14): Log Total Urban Land Area (Km) in ... World Bank '11	Col. (11)-(14): GHS t LongDiff	ShortDiff	Ctrl: Built-Up Area t LongDiff	ShortDiff	Log Particulate Matter Level (PM) 10 ('10)	2.5 ('17)
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Gaps$_H$	-0.08	0.19***	0.05**	0.03**	0.04*	0.02*	0.05**	0.07**
	[0.87]	[0.03]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.03]
Cntry FE, Yr FE	N	N	Y	Y	Y	Y	N	N
Ctrls, Wgts	Y	Y	Y	Y	Y	Y	Y	Y
Observations	48	125	262	524	262	524	146	156
Cntries, Yrs	48, 1	125, 1	131, 2	131, 4	131, 2	131, 4	146, 1	156, 1

Panel B: Urban Agglomeration-Level Analysis

Dep. Var.:	Log Sum of Heights in Year t		Cent.	Peri.	Log Area in Year t		Congestion 2017	Log PM'17 10	2.5
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
$\mathbb{1}$(100-500K)*Gap$_H$	-0.04	-0.03	-0.03	0.00	0.01	0.01	1.79**	0.04	0.04
	[0.03]	[0.02]	[0.02]	[0.00]	[0.01]	[0.02]	[0.73]	[0.03]	[0.03]
$\mathbb{1}$(500-1000K)*Gap$_H$	-0.25*	-0.11	-0.08	-0.02	0.00	0.00	2.71*	0.09**	0.08*
	[0.14]	[0.17]	[0.15]	[0.03]	[0.03]	[0.02]	[1.49]	[0.04]	[0.04]
$\mathbb{1}$(1000K+)*Gap$_H$	-0.73**	-0.56**	-0.54**	-0.15*	-0.02	0.00	1.48	0.13**	0.14***
	[0.31]	[0.25]	[0.24]	[0.09]	[0.02]	[0.01]	[1.13]	[0.05]	[0.05]
City FE, Year FE	Y	Y	Y	Y	Y	Y	N	N	N
Cntry-Yr FE, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	23,438	46,876	46,876	46,876	17,040	34,181	391	1,473	1,473
Number of Cities	11,719	11,719	11,719	11,719	11,719	11,719	391	1,473	1,473
Number of Years	2	4	4	4	2	4	1	1	1

Notes: Columns (1)-(6), (9)-(10), (15)-(16) and (23)-(25): See text for details. Columns (7)-(8): Panel regressions for 14 countries in 1960-2010 (1960, 1970, 1980, 1990, 2000, 2010). Columns (11)-(14): Panel regressions for 131 countries in 1975-2015 (1975, 1990, 2000, 2015). Columns (17)-(22): Panel regressions for 11,719 50K+ urban agglomerations in 1975-2015 (1975, 1990, 2000, 2015). We interact the country-level (H-based) gaps with three city population category dummies defined in 1975 (50-100K is the omitted category). Robust SEs (clustered at the country level in columns (7)-(8), (11)-(14) and (17)-(22)): * p<0.10, ** p<0.05, *** p<0.01.

WEB APPENDIX: NOT FOR PUBLICATION

A Details on the Building Heights Data

The original data set of CTBUH (2018) (accessed between January 2017 and January 2018) has 27,652 *tall buildings*. Once we keep "buildings" and "tower-buildings" that are completed or about to be completed, we are left with 19,132 tall buildings.

Heights. According to the website of CTBUH (2018), they do not use a consistent definition of tall buildings across all cities. We thus study how heights vary across the data set. To do so, we need to obtain height for as many buildings as possible.

For most buildings, we know height to tip of the building (no matter the function of the highest element) and/or height to the architectural top of the building (which may include spires but excludes antennaes) and/or height to the highest occupied floor and/or height of the observatory of the building if there is one and/or the number of floors above ground. Height to the highest occupied floor may be the best measure but it is only available for 11.6% of buildings whereas architectural height is available for 84.7% of them, height to the tip 60.6% of them, height to the observatory 1.1% of them, and the number of floors 98.2% of them. We thus use architectural height as our main measure.

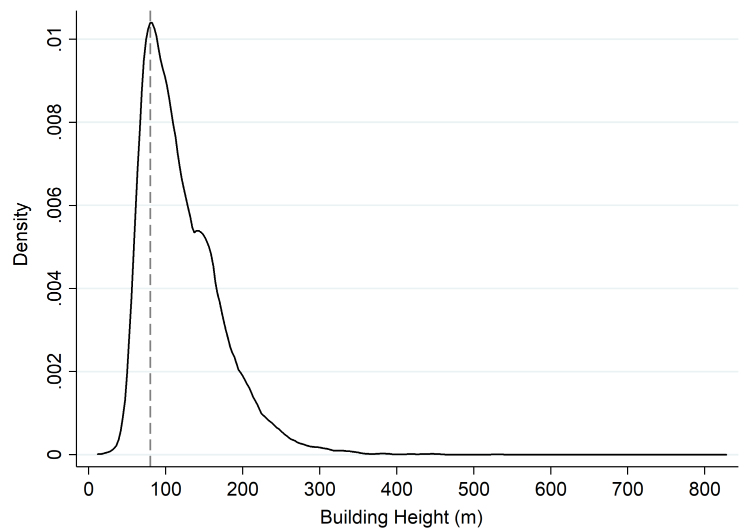
Since it is missing for 15.3% of buildings, we impute it when possible with data on height to the tip (correlation between architectural height and this height = 0.99), then data on height to the highest occupied floor (correlation = 0.98), then data on height to the observatory (correlation = 0.96). We then regress our measure of height on the number of floors and find a coefficient of 3.8***, which indicates that a floor corresponds to 4 meters for most buildings in the world (95% conf. interval = [3.77; 3.87]). We can then impute heights for the remaining buildings. In the end, we obtain a consistent measure of heights (m) for 99.6% of buildings (N = 19,132). We nonetheless verify results hold if we use architectural height or height not using information on number of floors.

As can be seen in Web Appendix Figure A1 (on the next page) which plots the Kernel distribution of building heights in the data set, the mode of the distribution is 80 m. Since cities are likely to have more buildings below 80 m than above 80 m, and since the distribution of buildings is relatively smooth after 80 m, this suggests that the data set mostly captures buildings above 80 m. Thus, the data set is likely unreliable for buildings below 80 m. However, since some countries may have few tall buildings above 80 m, and since some height data may be available for some relatively important local buildings below 80 m, we keep the 16,369 buildings above 80 m and/or buildings in the top 10 in the country today. This guarantees that few countries have no building data at all.

Year of Construction. For most buildings, we know the year of completion and/or the year construction started and/or the year construction was proposed. We use the year of completion as our main measure (available for 96.6% of buildings). For the remaining buildings, we impute the year of completion using information on the year construction started (corr. with the year of completion = 0.99), then the year construction was proposed (0.97). On average, a building is completed 5.5 years after construction is proposed and 3.3 years after it starts. We obtain the year of completion for 96.8% of buildings.

Function. The function(s) of the buildings is available for 98.9% of buildings. Many buildings have multiple functions. Among buildings for which we know the function, 49.9% of them are used for *residential* purposes and 41.8% of them include offices. Other important functions include hotels (11.8%) and retail (3.9%). In our analysis, we define as *commercial* buildings with the function "office", "hotel" and/or "retail".

Figure A1: KERNEL DISTRIBUTION OF TALL BUILDING HEIGHTS



The mode of the Kernel distribution of all building heights in the CTBUH data set is 80 m.

B Details on the Cost of Building-Height Restrictions

Theoretically, by restricting housing supply, height restrictions raise the price per unit of housing throughout the city while causing the urban footprint to expand. Residents experience a combination of higher housing prices and longer commutes. For the resident at the edge of the city, the welfare loss comes entirely from a longer commute. With utilities equalized within the city, the welfare loss for each resident equals the increase in commuting cost for the edge resident (Bertaud and Brueckner, 2005).

Suppose a country has n identical cities and let $urban\_area$ denote the size of each city.

Then our dependent variable in the urban area regression is $n * urban\_area$, so that the regressions relate $\log(n*urban\_area)$ to GAP and other variables, with the GAP coefficient denoted β. Letting ΔGAP denote the change in GAP, differentiation of this relationship shows that

$$\frac{n * \triangle urban\_area}{n * urban\_area} = \frac{\triangle urban\_area}{urban\_area} = \beta \triangle \text{GAP} \tag{1}$$

With $urban\_area$ equal to $\pi\overline{x}^2$ for a circular city, where $\overline{x}$ is the distance to the edge,

$$\frac{\triangle urban\_area}{urban\_area} = \frac{2\pi\overline{x} \triangle \overline{x}}{\pi\overline{x}^2} = 2\frac{\triangle\overline{x}}{\overline{x}} \tag{2}$$

Combining 1 and 2 yields $\triangle\overline{x}/\overline{x} = \beta\Delta\text{GAP}/2$. If GAP increases by one standard deviation (≈ 2), then the percentage increase in $\overline{x}$ is equal to β. Finally, since commuting cost is proportional to distance traveled, β equals the percentage increase in the edge resident's commuting cost. The final step is to assume that the edge resident's commuting cost is a fixed proportion λ of individual gross income y. Then, the absolute increase in the edge resident's commuting cost from the greater GAP equals $\beta\lambda y$. Thus, $\beta\lambda y$ equals the individual welfare cost of a one standard deviation increase in GAP.

In Brueckner (2007), the edge resident spends 14-19% of income on commuting. Given β = 0.05 (col. (11) of Table 5), $\beta\lambda$ = 0.007-0.01. Thus, the welfare loss from a one-standard-deviation increase in GAP is close to one percent of urban income.

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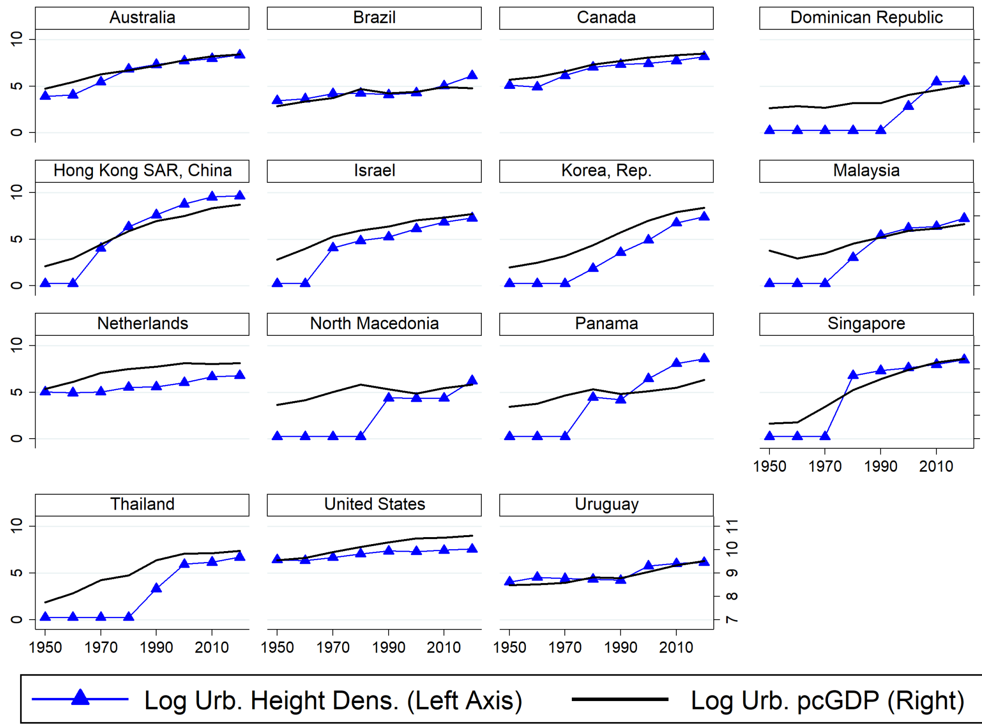
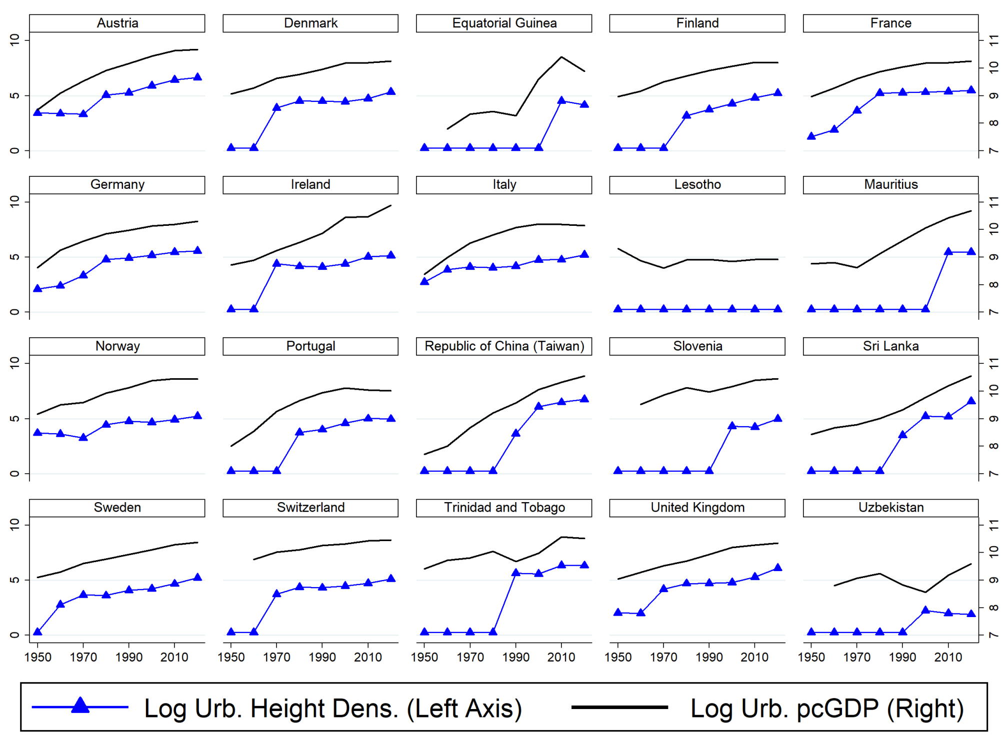
Figure A2: HEIGHTS & INCOME FOR THE 14 UMH COUNTRIES & THE U.S. 1950-2020



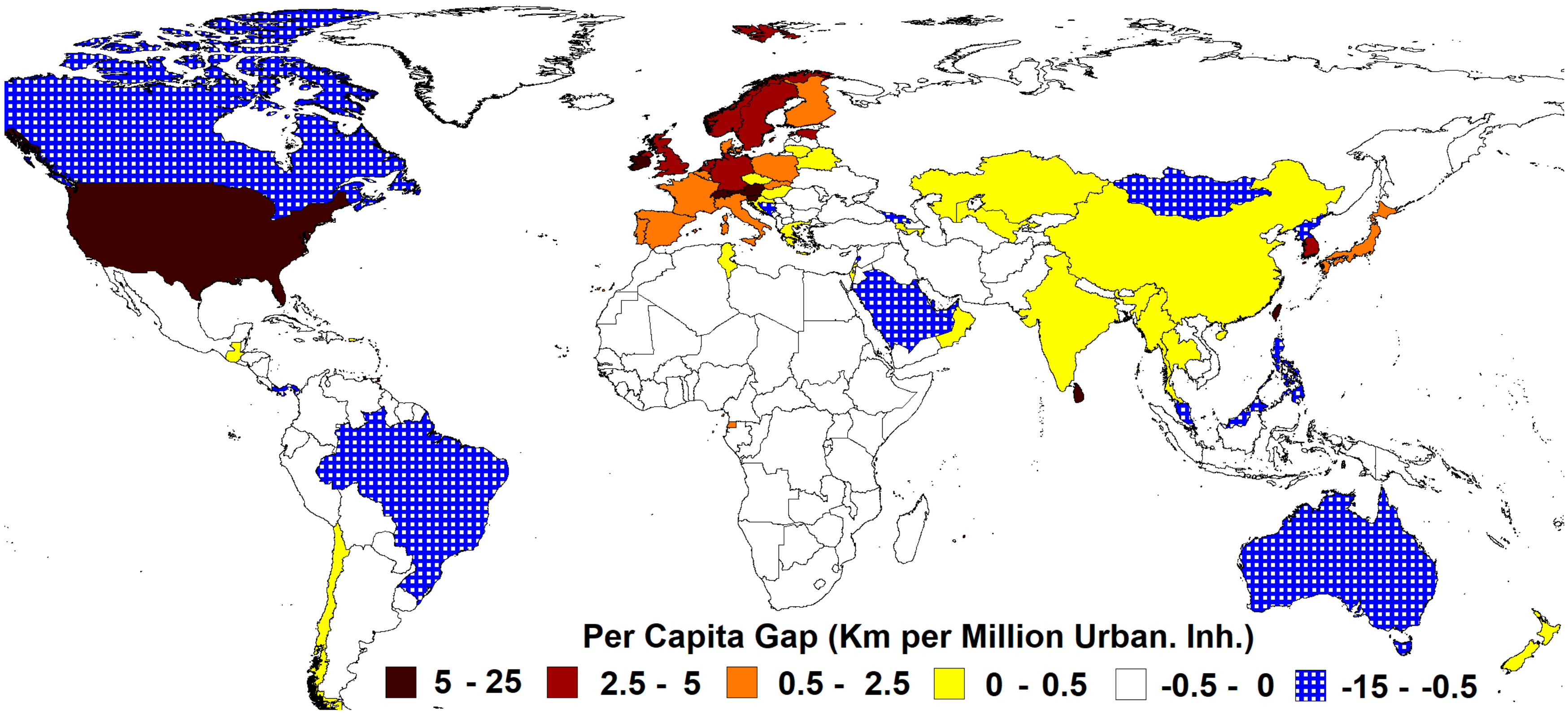
This figure shows for the period 1950-2020 the respective evolutions of (logged) urban height density and (logged) urban per capita GDP for the 14 UMH countries as well as the U.S.

Figure A3: HEIGHTS & INCOME FOR 20 COUNTRIES OF TABLE 2 COL.(1) 1950-2020



This figure shows for the period 1950-2020 the respective evolutions of (logged) urban height density and (logged) urban per capita GDP for the 20 countries with the highest H-based gaps.

Figure A4: PER CAPITA H-BASED GAPS FOR ALL COUNTRIES, 2020



This figure shows the H-based gaps per urban capita (km per million urban inhabitants) for 158 countries circa 2020. Positive gaps are shown in dark brown, dark red, orange or yellow. Negative gaps (= excess of tall building heights) are shown in blue (dotted patterns).

Table A1: DETERMINANTS OF THE UMH-BASED GAPS, 2020

Dependent Variable:	UMH-Based ... Building-Height Gap 2020							
Considered Gap$_{UMH}$:	Overall	Resid.	Comm.	Overall	Overall	Overall	Overall	Overall
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LPCGDP 1950	0.81***	0.69***	-0.03	0.91	-40.82*	0.55**	0.14	15.72
	[0.23]	[0.25]	[0.16]	[1.55]	[22.27]	[0.23]	[0.27]	[20.91]
ΔLPCGDP 1950-2020	1.99***	1.85***	0.83***	0.81	-48.58**	1.75***	1.82***	4.00
	[0.20]	[0.23]	[0.16]	[1.53]	[23.49]	[0.23]	[0.25]	[22.82]
Home Ownership Share (HO)				0.01				-0.06
				[0.15]				[0.13]
HO*LPCGDP 1950				-0.00				0.01
				[0.02]				[0.02]
HO*ΔLPCGDP 19502020				0.01				0.01
				[0.02]				[0.01]
Log Urb. Planners pc (LUPpc)					-59.79*			22.90
					[31.81]			[29.59]
LUPpc*LPCGDP 1950					5.98*			-2.43
					[3.22]			[2.97]
LUPpc*ΔLPCGDP 19502020					7.30**			-0.52
					[3.40]			[3.29]
Log 1800 Pop. Largest City (LPL1800)						-0.74**		0.25
						[0.36]		[0.61]
LPL1800*LPCGDP 1950						0.12***		-0.01
						[0.05]		[0.08]
LPL1800*ΔLPCGDP 19502020						0.01		-0.00
						[0.05]		[0.06]
Log World Heritage Sites pc (LWHSpc)							-24.91**	-23.07**
							[10.69]	[10.03]
LWHSpc*LPCGDP 1950							3.07**	3.00***
							[1.18]	[1.06]
LWHSpc*ΔLPCGDP 19502020							1.27	0.31
							[1.31]	[1.29]
Observations	158	158	158	105	158	158	158	105
Adjusted R-squared	0.38	0.26	0.13	0.27	0.42	0.41	0.43	0.44

This table shows that the results of Table 3 hold when we use the UMH-based gaps instead of the H-based gaps. Col. (1)-(7): PCGDP 1950 is log national per capita GDP (PPP, cst 1990 intl $) in 1950 and ΔLPCGDP 1950-2020 is the log change in per capita GDP between 1950 and 2020. Col. (2)-(3): We consider the gaps based on residential buildings (resid.) or commercial buildings (comm.) only. Col. (4): The home ownership share is available for the 2010s (N = 105). Col. (5): We use the log of the number of renown urban planners per capita today. Col. (6): We use the log of the 1800 population of the largest city today. Col. (7): We use the log of the number of cultural World Heritage Sites per capita today. Robust SEs: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A2: UMH-BASED GAPS AND LAND USE REGULATIONS, 2020

	Dependent Variable: UMH-Based Gaps				Corr w/ Gaps$_{UMH}$
	(1)	(2)	(3)	(4)	(5)
Maximum Floor Area Ratio (FAR)	-0.20**	-0.20**	-0.32***	-0.37***	
	[0.01]	[0.01]	[0.00]	[0.00]	
Dummy Urban Containment		0.98		0.42	0.10
		[0.34]		[0.75]	
Dummy Containment Via Green Belt		-0.87		-1.47	0.00
		[0.58]		[0.42]	
Dummy Containment Via Urban Growth Boundary		-1.61		-1.05	-0.17
		[0.10]		[0.35]	
Dummy Full or Partial Zoning		1.37		0.68	0.14
		[0.21]		[0.43]	
(-) Dummy Gvt Land Acquisition		-0.53		0.94	-0.03
		[0.68]		[0.37]	
Dummy Min Plot Size Regulation			-1.96	-2.06	-0.15
			[0.11]	[0.15]	
Number of Months before Permit Subdivision			-0.04	0.04	0.10
			[0.45]	[0.55]	
Number of Months before Permit Building			0.12	0.15	0.19
			[0.22]	[0.16]	
(-) Dummy Street Layout Gvt or Mixed			-1.70	-1.59*	-0.28
			[0.11]	[0.10]	
(-) Dummy Infrastructure Gvt or Mixed			1.20	0.45	0.02
			[0.24]	[0.72]	
Observations (Countries)	49	49	47	47	47-49
R-squared	0.08	0.18	0.30	0.41	Mean: -0.01

This table shows that the results of Table 4 hold when we use the UMH-based gaps instead of the H-based gaps. Col. (1)-(4) show the correlation between the UMH-based gaps and the maximum FAR values. Col. (5) shows the individual correlations between the UMH-based gaps and the values of the other land-use policy variables. Robust SEs: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A3: BUILDING-HEIGHT GAPS AND ECONOMIC OUTCOMES, WORLD

Dep. Var.:	Log PM10		Log PM2.5		Dep. Var.:	Log PM10 '17		Log PM2.5 '17	
	(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
Gap$_H$	0.05**	0.03	0.07**	0.04	$\mathbb{1}$(100-500K)*Gap$_H$	0.04	0.02	0.04	0.03
	[0.02]	[0.03]	[0.03]	[0.03]		[0.03]	[0.03]	[0.03]	[0.03]
					$\mathbb{1}$(500-1000K)*Gap$_H$	0.09**	0.06*	0.08*	0.05
						[0.04]	[0.04]	[0.04]	[0.04]
					$\mathbb{1}$(1000K+)*Gap$_H$	0.13**	0.09	0.14***	0.09
						[0.05]	[0.06]	[0.05]	[0.06]
Gap$_{UMH}$	0.05**	0.03	0.08***	0.04	$\mathbb{1}$(100-500K)*Gap$_{UMH}$	0.02	0.01	0.03*	0.01
	[0.02]	[0.02]	[0.02]	[0.03]		[0.02]	[0.02]	[0.02]	[0.02]
					$\mathbb{1}$(500-1000K)*Gap$_{UMH}$	0.06**	0.04	0.06***	0.04**
						[0.02]	[0.02]	[0.02]	[0.02]
					$\mathbb{1}$(1000K+)*Gap$_{UMH}$	0.07**	0.03	0.08***	0.04
						[0.03]	[0.04]	[0.03]	[0.04]
Ctrls Sprawl	N	Y	N	Y	Ctrls Sprawl	N	Y	N	Y
Ctrls, Wgts	Y	Y	Y	Y	Ctrls, Wgts	Y	Y	Y	Y
Obs.	146	146	156	156	Obs.	1,473	1,473	1,473	1,473

This table shows that the effects of the gaps on pollution are strongly reduced when controlling for sprawl. The sprawl controls include log land area and log city population in 2015 (source: *Global Human Settlements* database), and their squares. See text for details. Robust SEs (clustered at the country level in columns (5)-(8)): * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4: UMH-BASED GAPS AND ECONOMIC OUTCOMES, WORLD

Panel A: Country-Level Analysis

Source:	World	Pro-	World Bank '11		Global Prop.Guide'19		Knoll et al 2017	
Dep. Var.:	Bank	Landlord	Price Level (100)		Log Hous	Price-	Real Hous. Price t	
	Regu.'19	Regime'19	Hous.	Transp.	Price ($)	to-Rent	LongDiff	ShortDiff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gaps$_{UMH}$	0.04***	-1.15**	3.32***	-0.67	0.18***	2.78***	13.27	8.33
	[0.01]	[0.48]	[1.19]	[1.30]	[0.04]	[0.60]	[16.62]	[6.01]
Cntry FE, Yr FE	N	N	N	N	N	N	Y	Y
Ctrls, Wgts	N	Y	Y	Y	Y	Y	N	N
Observations	49	47	147	147	72	70	28	83
Cntries, Yrs	49, 1	47, 1	147, 1	147, 1	72, 1	70, 1	14, 2	14, 6

Dep. Var.:	Share	Col. (10)-(14): Log Total Urban Land Area (Km) in ...					Log Particulate	
	Public	World	Col. (11)-(14): GHS t		Ctrl: Built-Up Area t		Matter Level (PM)	
	Housing	Bank '11	LongDiff	ShortDiff	LongDiff	ShortDiff	10 ('10)	2.5 ('17)
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Gaps$_{UMH}$	0.29	0.22***	0.06***	0.03**	0.05*	0.02*	0.05**	0.08***
	[0.61]	[0.04]	[0.02]	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]
Cntry FE, Yr FE	N	N	Y	Y	Y	Y	N	N
Ctrls, Wgts	Y	Y	Y	Y	Y	Y	Y	Y
Observations	48	125	262	524	262	524	146	156
Cntries, Yrs	48, 1	125, 1	131, 2	131, 4	131, 2	131, 4	146, 1	156, 1

Panel B: Urban Agglomeration-Level Analysis

Dep. Var.:	Log Sum of Heights in Year t				Log Area		Congestion	Log PM'17	
			Cent.	Peri.	in Year t		2017	10	2.5
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
$\mathbb{1}$(100-500K)*Gap$_{UMH}$	-0.02	-0.02	-0.02	0.00	0.05	0.04**	1.14***	0.02	0.03*
	[0.04]	[0.01]	[0.01]	[0.00]	[0.03]	[0.02]	[0.37]	[0.02]	[0.02]
$\mathbb{1}$(500-1000K)*Gap$_{UMH}$	-0.17	-0.13	-0.10	0.01	0.09	0.05	1.43*	0.06**	0.06***
	[0.32]	[0.12]	[0.12]	[0.04]	[0.06]	[0.03]	[0.77]	[0.02]	[0.02]
$\mathbb{1}$(1000K+)*Gap$_{UMH}$	-0.85	-0.68***	-0.68***	-0.01	-0.02	0.01**	1.04	0.07**	0.08***
	[0.56]	[0.17]	[0.16]	[0.13]	[0.05]	[0.01]	[0.64]	[0.03]	[0.03]
City FE, Year FE	Y	Y	Y	Y	Y	Y	N	N	N
Cntry-Yr FE, Ctrls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	23,438	46,876	46,876	46,876	17,040	34,181	391	1,473	1,473
Number of Cities	11,719	11,719	11,719	11,719	11,719	11,719	391	1,473	1,473
Number of Years	2	4	4	4	2	4	1	1	1

This table shows that the results of Table 5 hold if we use the UMH-based gaps instead of the H-based gaps. See text for details. Robust SE clustered at the country level in col. (7)-(8) and (11)-(14) of Panel A as well as in Panel B.

Table A5: EFFECTS FOR THE WORLD, ROBUSTNESS CHECKS

Dep. Var.:	Gap (Log Urban Height Density (m per 000s Urban Inh.) in Year t ($LUHTDENS_t$))					
Check:	Baseline	Continent -Year FE	Region -Year FE	Country Trend	Country Trend Sq.	Ctrls for Commuting
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: H Set (56 Observations; 8 Countries)					
$LUPCGDP_t$	3.23***	3.00***	3.28***	6.06**	6.91*	4.07***
	[0.61]	[0.47]	[0.49]	[2.13]	[2.99]	[0.40]
$LAGRENT_t$	0.19	-0.07	-0.25	-0.45	-0.41	0.18
	[0.40]	[0.48]	[0.85]	[0.59]	[0.80]	[0.31]
	Panel B: UMH Set (98 Observations; 14 Countries)					
$LUPCGDP_t$	1.54**	1.97**	1.95**	3.32**	3.91*	1.83*
	[0.67]	[0.82]	[0.75]	[1.32]	[2.06]	[0.88]
$LAGRENT_t$	0.55**	0.63**	0.59*	-0.05	-0.05	0.55**
	[0.26]	[0.29]	[0.31]	[0.61]	[0.76]	[0.22]
Check:	Effects of the Variables		Log. Num Earthquakes x Year FE	Log Bedrock Depth (m) x Year FE	Share Elev. < Sea Level x Year FE	Ruggedness SD of Elev. x Year FE
	t	t+10 (Leads)				
	(7)		(8)	(9)	(10)	(11)
	Panel A: H Set (56 Observations; 8 Countries)					
$LUPCGDP_t$	4.96**	-1.43	2.88***	2.87***	3.44***	3.13***
	[1.99]	[0.68]	[0.40]	[0.60]	[0.67]	[0.57]
$LAGRENT_t$	0.08	0.28	0.08	0.40	0.15	0.10
	[0.68]	[0.71]	[0.41]	[0.29]	[0.48]	[0.58]
	Panel B: UMH Set (98 Observations; 14 Countries)					
$LUPCGDP_t$	2.35***	-0.59	1.44**	1.66*	1.52*	1.53**
	[0.65]	[0.83]	[0.56]	[0.79]	[0.72]	[0.70]
$LAGRENT_t$	0.44	0.31	0.77**	0.43**	0.51	0.55*
	[0.78]	[0.74]	[0.26]	[0.18]	[0.29]	[0.28]

Col. (1) replicate the baseline results. Additional columns show that the results tend to hold for additional ten specifications. Col. (2)-(3) include continent (5)-year FE and World Bank region (7)-year FE, respectively. Col. (4)-(5) include country-specific linear trends and non-linear trends, respectively. Col. (6): We control for whether there is a subway and the log numbers of subway lines and subway stations in the country in t as well as the mean percentage share of country roads (incl. non-urban roads) that is paved during the period 1990-2017 interacted with a linear year trend. Col. (7) include the variables of interest defined in t+10. Col. (8): We control for the logged number of significant earthquakes that ever took place (per sq km) interacted with year FE. Col. (9): We control for the log of average (pop.-weighted) bedrock depth in the country's urban areas interacted with year FE. More precisely, we use the 30 seconds version of the bedrock depth data of Shangguan et al. (2017). We then use city boundaries from CIESIN (2017) (incl. all cities $\geq$ 1,000) to obtain the mean pop.(2000)-weighted average of bedrock depth (m). Col. (10)-(11): In col. (10), we control for the average (pop.-weighted) share of urban land that is located below sea level interacted with year FE. In col. (11), we control for the average (pop.-weighted) standard deviation of elevation in the country's urban areas interacted with year FE. We use the 15 arc-seconds version (breakline emphasis) of the elevation data from USGS (2010) and construct pop.-weighted averages for all cities in CIESIN (2017). Robust SEs clust. at the country level: * p<0.10, ** p<0.05, *** p<0.01.

Table A6: FURTHER ROBUSTNESS CHECKS FOR THE H SET REGRESSIONS

Dep. Var.:	Log Urban Height Density (m per 000s Urban Inh.) in Year t (LUHTDENS$_t$)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Baseline	Incl. U.S.	Wt UrbPop	Wt 1/UrbPop	No HKG SGP	Resid. 1980
LUPCGDP	3.23***	3.23***	2.75***	4.20***	2.59***	2.18**
	[0.61]	[0.63]	[0.33]	[0.45]	[0.41]	[0.96]
LAGRENT	0.19	0.24	0.07	0.46	-0.34	0.06
	[0.40]	[0.39]	[0.32]	[0.55]	[0.25]	[0.24]
	(7)	(8)	(9)	(10)	(11)	(12)
	No Gvt/Relig	No Top 5	Post-1980	≥25p(100)	≥Med(125)	≥Mean(135)
LUPCGDP	2.89***	3.22***	2.68***	2.53***	2.32*	2.39**
	[0.56]	[0.61]	[0.76]	[0.66]	[1.05]	[1.00]
LAGRENT	0.08	0.19	0.41	0.31	0.78	0.67
	[0.39]	[0.39]	[0.52]	[0.56]	[0.69]	[0.69]
	(13)	(14)	(15)	(16)	(17)	(18)
	No Floors	Undergr.	NoLagUHT	LagUHT*YrFE	LagUHTsq	Lags Vars
LUPCGDP	3.07***	3.17***	3.73***	2.67***	3.25***	3.27**
	[0.67]	[0.61]	[0.32]	[0.44]	[0.70]	[1.14]
LAGRENT	0.55	0.20	-0.10	-0.10	0.21	0.51
	[0.41]	[0.39]	[0.45]	[0.30]	[0.44]	[0.57]
	(19)	(20)	(21)	(22)	(23)	(24)
	5Yr Periods	15Yr Periods	TotalGDP	NoUrbLand	Ag Land	Drop Large
LUPCGDP	2.21***	4.10***	2.29**	3.23***	3.56***	3.28***
	[0.49]	[1.10]	[0.79]	[0.61]	[0.73]	[0.66]
LAGRENT	0.55	0.42	0.01	0.19	-0.45*	0.25
	[0.35]	[0.49]	[0.36]	[0.40]	[0.23]	[0.48]
Cntry FE, Yr FE	Y	Y	Y	Y	Y	Y
Lag LHUT	Y	Y	Y	Y	Y	Y

This table shows that the baseline results based on the H-based gaps tend to hold if we implement various robustness checks related to specification or choice of variables. The main sample has 56 observations (8 countries) from 1950-2020. Col. (2): Adding the U.S. to the set. Col. (3)-(4): Using urban pop. or (1/urban pop.) in t as weights. Col. (5) Excl. Hong Kong and Singapore. Col. (6): Using 1980 residuals to select the countries in the set. Col. (7): Excl. government or religious buildings. Col. (8): Excl. buildings among top 5 tallest at any point in 1950-2017. Col. (9): We interact the variables with a post-1980 dummy and reports the post-1980 effects only. Col. (10)-(12): Keeping buildings above the 25th percentile (100m), median (125m) or mean (135m) height in the data. Col. (13): Not using heights imputed based on the number of floors. Col. (14): Adding heights coming from underground floors. Col. (15): Not adding a lag of log urban height density. Col. (16): Interacting the lag of log urban height density with year FE. Col. (17): Adding the square of log urban height density. Col. (18): Adding lags of the two variables of interest and reporting the combined contemporaneous and lagged effects. Col. (19)-(20): Using 5-year or 15-year periods. Col. (21): Using log national per capital GDP (PPP). Col. (22)-(23): Land rent defined as agricultural GDP (t) divided by non-urban land (1990) or agricultural land area (t). Col. (24): Excl. countries with total land area above the mean in the sample. Robust SEs clust. at the country level: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A7: FURTHER ROBUSTNESS CHECKS FOR THE UMH SET REGRESSIONS

Dep. Var.:	Log Urban Height Density (m per 000s Urban Inh.) in Year t (LUHTDENS$_t$)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Baseline	Incl. U.S.	Wt UrbPop	Wt 1/UrbPop	No HKG SGP	Resid. 1980
LUPCGDP	1.54**	1.53**	2.02***	1.27*	1.21**	1.00**
	[0.67]	[0.68]	[0.44]	[0.60]	[0.53]	[0.40]
LAGRENT	0.55**	0.59**	0.20	0.58	0.37	0.29
	[0.26]	[0.25]	[0.28]	[0.58]	[0.29]	[0.22]
	(7)	(8)	(9)	(10)	(11)	(12)
	No Gvt/Relig	No Top 5	Post-1980	≥25p (100)	≥Med.(125)	≥Mean(135)
LUPCGDP	2.02**	1.54**	1.42***	1.92*	2.02*	2.09**
	[0.68]	[0.67]	[0.43]	[0.94]	[0.96]	[0.96]
LAGRENT	0.64**	0.55*	0.14	0.53	0.71*	0.81**
	[0.24]	[0.25]	[0.39]	[0.32]	[0.35]	[0.34]
	(13)	(14)	(15)	(16)	(17)	(18)
	No Floors	Undergr.	NoLagUHT	LagUHT*YrFE	LagUHTsq	Lags Vars
LUPCGDP	1.75**	1.53**	2.51***	1.29*	1.64**	1.28*
	[0.72]	[0.66]	[0.70]	[0.64]	[0.62]	[0.64]
LAGRENT	0.63**	0.55**	0.53	-0.01	0.12	0.77***
	[0.27]	[0.25]	[0.33]	[0.35]	[0.40]	[0.23]
	(19)	(20)	(21)	(22)	(23)	(24)
	5Yr Periods	15Yr Periods	TotalGDP	NoUrbLand	Ag Land	Drop Large
LUPCGDP	1.10***	2.20	1.42**	1.54**	1.32**	1.48*
	[0.36]	[1.27]	[0.59]	[0.67]	[0.55]	[0.68]
LAGRENT	0.65***	1.19***	0.27	0.55**	0.15	0.61*
	[0.17]	[0.26]	[0.20]	[0.26]	[0.32]	[0.29]
Cntry FE, Yr FE	Y	Y	Y	Y	Y	Y
Lag LHUT	Y	Y	Y	Y	Y	Y

This table shows that the baseline results based on the UMH-based gaps tend to hold if we implement various robustness checks related to specification or choice of variables. The main sample has 98 observations (14 countries) from 1950-2020. Col. (2): Adding the U.S. to the set. Col. (3)-(4): Using urban pop. or (1/urban pop.) in t as weights. Col. (5) Excl. Hong Kong and Singapore. Col. (6): Using 1980 residuals to select the countries in the set. Col. (7): Excl. government or religious buildings. Col. (8): Excl. buildings among top 5 tallest at any point in 1950-2017. Col. (9): We interact the variables with a post-1980 dummy and reports the post-1980 effects only. Col. (10)-(12): Keeping buildings above the 25th percentile (100m), median (125m) or mean (135m) height in the data. Col. (13): Not using heights imputed based on the number of floors. Col. (14): Adding heights coming from underground floors. Col. (15): Not adding a lag of log urban height density. Col. (16): Interacting the lag of log urban height density with year FE. Col. (17): Adding the square of log urban height density. Col. (18): Adding lags of the two variables of interest and reporting the combined contemporaneous and lagged effects. Col. (19)-(20): Using 5-year or 15-year periods. Col. (21): Using log national per capital GDP (PPP). Col. (22)-(23): Land rent defined as agricultural GDP (t) divided by non-urban land (1990) or agricultural land area (t). Col. (24): Excl. countries with total land area above the mean in the sample. Robust SEs clust. at the country level: * p<0.10, ** p<0.05, *** p<0.01.

Table A8: INCOME, LAND RENT & BUILDING HEIGHTS, U.S. STATES, 1930-2020

Dep. Var.:	Log Sum of Urban Heights (m) in Year t ($LUHT_t$)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
States:	All	Resid.'17	Resid.'17	Resid.'17	≥ 0	≥ 0	≥ 0	≥ 0
Test:		≥ 0	$\geq$ p75	$\geq$ p90	Region Year FE	State Trend	Effects of Vars t	t+10 (Leads)
$LUGDP_t$	0.39***	0.57***	0.58***	0.57**	0.48**	0.29	0.56*	0.11
	[0.09]	[0.10]	[0.11]	[0.13]	[0.23]	[0.26]	[0.29]	[0.33]
$LAGRENT_t$	0.08**	0.1	0.16	0.48	0.11*	0.12	0.13	-0.04
	[0.04]	[0.06]	[0.11]	[0.31]	[0.06]	[0.09]	[0.08]	[0.07]
$LUHT_{t-10}$	0.83***	0.76***	0.71***	0.76***	0.80***	0.38***	0.75***	
	[0.03]	[0.04]	[0.06]	[0.08]	[0.05]	[0.07]	[0.05]	
Observations	447	222	116	44	222	222	222	222
State FE, Yr FE	Y	Y	Y	Y	Y	Y	Y	Y
	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
States:	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0
Test:	Ctrls Commut. Costs	Log. Num Quakes x Yr FE	L.Bedrock Depth (m) x Yr FE	Share Elev. <SeaLevel x Yr FE	Rugged. SD Elev. x Yr FE	Geography U.S. Spec. x Yr FE	Land Protect. x Yr FE	Construct. Costs Year t
$LUGDP_t$	0.56***	0.64***	0.62***	0.59***	0.57***	0.60***	0.62***	0.59***
	[0.12]	[0.11]	[0.12]	[0.10]	[0.10]	[0.13]	[0.21]	[0.09]
$LAGRENT_t$	0.08	0.07	0.08	0.10*	0.10	0.05	0.09	0.1
	[0.05]	[0.06]	[0.06]	[0.06]	[0.07]	[0.04]	[0.07]	[0.06]
$LUHT_{t-10}$	0.72***	0.76***	0.75***	0.77***	0.76***	0.73***	0.74***	0.75***
	[0.04]	[0.05]	[0.06]	[0.04]	[0.04]	[0.06]	[0.06]	[0.04]
Observations	222	222	222	222	222	222	222	222
State FE, Yr FE	Y	Y	Y	Y	Y	Y	Y	Y

This table shows for 50 U.S. states x 10 years (1930, 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2010, 2020) = 500 observations the effects of log total urban income ($LUGDP_t$), log agricultural rent ($LAGRENT_t$) and the log of the past urban height stock ($LUHT_{t-10}$). Col. (2),(3) and (4) eliminate states with residuals below 0, the 75th percentile, and the 90th percentile in a 2017 regression using log total urban income and log agricultural rent as covariates. Col. (5)-(15): We keep states with residuals above 0. The columns show that results hold when we include additional controls (see table notes just below for details on each specification). Since we control for the dependent variable in t-10, we lose one round of data. In addition, a few states have missing income data before 1950, hence N = 447 (col. (1)). **Col. (5)-(6):** We include 9 census region-year FE and state-specific linear trends, respectively. **Col. (7)** shows the effect of adding ten-year leads of the GDP and agricultural-rent variables, whose coefficients are insignificant. **Col. (8):** We capture commuting costs by controlling for whether there is a subway and the logs of the number subway lines and subway stations in the state in year t (source: Gonzalez-Navarro and Turner (2018) and Gendron-Carrier et al. (2018)) and the log of the total mileages of paved roads corresponding to "municipal / urban extensions of highway systems" or "other municipal / urban streets". The sources are *A Quarter Century of Financing Municipal Highways, 1937-61* (Bureau of Public Roads) and the annual *Highway Statistics* reports of the U.S. Department of Transportation. **Col. (9):** We control for the logged number of significant earthquakes that ever took place (per sq km) interacted with year FE. **Col. (10):** We control for the log of average (pop.-weighted) bedrock depth in the state's urban areas interacted with year FE. More precisely, we use the 30 seconds version of the bedrock depth data of Shangguan et al. (2017). We then use city boundaries from CIESIN (2017) (incl. all cities $\geq$ 1,000) to obtain the mean pop.(2000)-weighted average of bedrock depth (m). **Col. (11)-(12):** In col. (11), we control for the average (pop.-weighted) share of urban land that is located below sea level interacted with year FE. In col. (12), we control for the average (pop.-weighted) standard deviation of elevation in the state's urban areas interacted with year FE. We use the 15 arc-seconds version (breakline emphasis) of the elevation data from USGS (2010) and construct pop.-weighted averages for all cities in CIESIN (2017). **Col. (13):** We add U.S.-specific geographical controls, each interacted with a year trend: total land area and the shares of land unavailable for development due to excessive slope, the presence of wetlands, or the presence of bodies of water (source: Lutz and Sand (2017)). **Col. (14):** The geographical controls are replaced by time-interacted variables measuring the amounts of land under various types of government ownership (source: NRCM (2017)): federal government, state government, Bureau of Land Management, U.S. Forest Service, National Park Service, National Wildlife Refuge, Army Corps of Engineers, Military Bases, Tribal lands. **Col. (15):** We control for the RSMeans construction cost in the state in the same year. Indeed, as income increases, construction costs could increase, thus depressing construction. Controlling for construction costs then allows us to capture the direct effect of income. Robust SEs clustered at the state level: * p<0.10, ** p<0.05, *** p<0.01.

Table A9: GAPS AND LAND USE REGULATIONS, UNITED STATES, CIRCA 2010

	Effect of the Estimated State Gap (circa 2010) Based on ...								
	(1) States ≥ 0			(2) States $\geq$ p75			(3) States ≥ 90		
Dep. Var.:	Coef.	Obs.	R2	Coef.	Obs.	R2	Coef.	Obs.	R2
1. Saiz Elasticity	-0.54*	47	0.13	-0.61**	47	0.13	-1.30***	47	0.19
	[0.29]			[0.30]			[0.46]		
2. Wharton Index	0.81**	48	0.14	1.08**	48	0.2	2.12***	48	0.24
	[0.40]			[0.41]			[0.64]		
3. Wharton (Saiz)	0.69*	47	0.11	0.91**	47	0.14	1.89***	47	0.19
	[0.37]			[0.39]			[0.65]		
4. Saks: Combined	0.63**	33	0.27	0.74**	33	0.29	1.45***	33	0.36
	[0.30]			[0.32]			[0.45]		

This table shows the correlation between the estimated U.S. state gaps based on states with a laissez-faire value above 0 (col. (1)) or the 75th (col. (2)) or 90th (col. (3)) percentile of the laissez-faire value in the data (see Table A8) and existing measures of land use regulations circa 2010 (see text for details on each measure). Robust SE: * p<0.10, ** p<0.05, *** p<0.01.

Table A10: COUNTRIES WITH THE LARGEST UMH- AND H-BASED GAPS 2020

	(1) Percentage Change Gap_H		(2) Per Capita Gap_H (Km per Mil. Urb. Inh.)		(3) Percentage Change Gap_{UMH}		(4) Per Capita Gap_{UMH} (Km per Mil. Urb. Inh.)	
Rank	Country	Gap	Country	Gap	Country	Gap	Country	Gap
1	Ireland	4.88	Ireland	21	Mauritius	6.06	Mauritius	16.1
2	Mauritius	4.51	Mauritius	20	Uzbekistan	5.14	Taiwan	12.4
3	Slovenia	3.69	Austria	12	Taiwan	4.57	Netherlands	4.9
4	Switzerland	3.61	Taiwan	12	Switzerland	4.15	Sri Lanka	3.4
5	Uzbekistan	3.37	Sri Lanka	8	Ireland	4.13	S. Korea	3.4
6	Norway	3.21	Trinidad	6	Slovenia	4.06	Ireland	1.6
7	Austria	2.9	Switzerland	6	Italy	3.93	Switzerland	1.5
8	Taiwan	2.78	United States	6	Netherlands	3.72	Austria	1.4
9	Sweden	2.77	Slovenia	5	Sri Lanka	3.58	Italy	1.3
10	Sri Lanka	2.61	Norway	4	P. Rico	3.58	Slovenia	1.2
11	Italy	2.53	South Korea	4	Syria	3.5	Japan	1.1
12	Denmark	2.52	United Kingdom	3	Guatemala	3.47	France	0.8
13	Trinidad	2.5	Netherlands	3	Armenia	3.37	Belgium	0.6
14	France	2.49	Estonia	3	France	3.26	United Kingdom	0.6
15	Germany	2.47	Germany	3	Denmark	3.21	Denmark	0.6
16	Eq. Guinea	2.43	Sweden	3	Lesotho	3.18	Germany	0.6
17	Finland	2.23	France	2	Portugal	3.06	Armenia	0.5
18	United Kingdom	2.15	Denmark	2	India	3.05	Trinidad	0.4
19	Lesotho	2.12	Italy	2	Germany	2.98	Portugal	0.3
20	Portugal	2.02	Slovakia	2	S. Korea	2.96	India	0.2

Notes: **The table shows the 20 countries with the largest H- and UMH-based gaps in 2020.** Col. (1) & (3): The percentage gap is the percentage change in urban height density required to make the height stock similar to the selected benchmark set of countries (for example, 4.88 means 488%). Col. (2) & (4): The per capita gap is expressed in km of heights per million urban capita.