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

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Abstract

There is a large literature on U.S. cities measuring the extent and stringency of land-use regulations and how regulatory and geographical constraints affect important outcomes such as housing prices and economic growth. This paper studies the global extent and impact of regulatory and other constraints 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 stock of tall buildings to what the total height would have been if supply was more elastic, based on parameters from a benchmark set of countries. We also perform this analysis for U.S. states to assess the validity of our methodology. The gaps are larger for richer countries including the U.S., and for residential buildings than for commercial buildings in such countries. The gaps are driven by under-building in central areas of larger cities. These 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. Countries with older, historic structures have larger gaps, likely due to more stringent height regulations and dispersed ownership that inhibits land assembly. Lastly, the gaps correlate strongly with international measures of housing prices, sprawl, congestion, and pollution.

JEL Codes: R3, R31, R33, R38, R5, O18, O50

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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, including the U.S., housing prices are growing more rapidly than incomes (Knoll, Schularick and Steger, 2017), which may be caused by physical and regulatory barriers reducing housing supply (Green, 1999; Glaeser and Gyourko, 2003; Green, Malpezzi and Mayo, 2005; Glaeser, Gyourko and Saks, 2005, 2006; Saiz, 2010; Gyourko and Molloy, 2015; Orlando and Redfearn, 2019). In particular, cities impose various land-use regulations (Helsley and Strange, 1995; Green, 1999; Quigley and Raphael, 2005; Glaeser and Ward, 2009; Gyourko et al., 2008; Rosenthal and Ross, 2015; Gyourko et al., 2019).

Regulatory and other constraints on development 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 regulatory or geographical constraints has been studied for the U.S. (Green et al., 2005; Ihlanfeldt, 2007; Saks, 2008; Saiz, 2010; Orlando and Redfearn, 2019; Brueckner and Singh, 2020) and other countries (Green et al., 1994; Malpezzi and Mayo, 1997; Bertaud and Malpezzi, 2001a; Bertaud and Brueckner, 2005a), there are no such studies for the whole world. In addition, analyses for the U.S. compare locations *within* the U.S. and thus do not estimate the extent of these constraints in the U.S. *relative to* other developed nations. Offering such a study is the aim of this paper.

More generally, across countries, some cities appear more willing than others to construct tall buildings in their central areas as a way to accommodate economic and population growth. Cities in China, much like Chicago and New York before them, embrace tall buildings (Barr and Luo, 2021), whereas cities in India, much like most Californian cities such as Los Angeles and San Francisco, 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 (including the U.S.) 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?

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 supply-elastic 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 stock per capita 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. 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 per capita if the country's supply elasticity matched those in the benchmark group. The difference between the prediction and the country's actual stock is the *building-height gap*.

We find that the world might need to have twice as many tall buildings (6,000 Empire State Buildings) as it does currently. The gaps are larger for richer countries, especially the U.S. and European countries. Globally, the gaps are larger for office towers, due to various world regions having disproportionately large residential tall-building stocks (e.g., the MENA). However, in developed countries, the gaps are larger for residential buildings, suggesting that these countries are more open to creating jobs than to receiving residents.

Conditional on income, the gaps are strongly and positively correlated with housing prices, sprawl, road congestion, and pollution, implying that they might have important global economic and environmental consequences. In particular, such gaps might explain one fifth of the global house price boom observed since 1950 (Knoll, Schularick and Steger, 2017). As in Orlando and Redfearn (2019), the gaps constrain the growth of large cities and their central areas. However, we do not find that countries with larger gaps "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. Given the lack of global historical data on non-tall buildings, we are unable to assess whether higher-gap countries have smaller gaps in this other dimension. However, the fact that housing prices are higher in higher-gap countries suggests that any compensation via the non-tall sector is not sufficient.

Regarding the nature of these country-level gaps, we find no evidence that they are caused by geological, topographical, or seismic conditions, or differences in construction costs or home ownership across countries.[1] However, we do find that countries with more "historical" cities (cities with long histories) have higher gaps. Evidently, the gaps in these countries arise from regulations designed to protect valuable historical urban areas, motivated by cultural considerations or a desire to foster tourism. However, countries may also adopt stringent regulations for reasons unrelated to historical preservation (see Redfearn (2019) for a study on the role of historical preservation in the U.S.).

While we believe our results are novel, one limitation is that the gaps are directly estimated at the *country* level. Ideally, we would have liked to use *city*-level data to estimate city-level gaps and then obtain country-level gaps from them. To do so would require a panel data set for as many cities across the world as possible, and which would include city population, GDP, and land rent over several decades – giving us a long enough time period to run panel regressions with city fixed effects for the proper estimation of the gaps. Unfortunately, historical panel data on city incomes and land rent does not exist except in a few countries. As well, usable night lights data as a proxy for income are relatively limited, and non-existent before 1992.[2] In addition, consistent historical agricultural land rent data do not exist for the "edge" of each city of the world.

Nevertheless, we will show that our country-level gaps are correlated with city-level gaps estimated using city-level panel regressions involving city-level data where possible. More generally, we will discuss how ignoring the city size distribution of each country should not affect our results. Furthermore, within-country analyses also misses the fact that constraints on supply in specific cities may be circumvented by migration to less constrained cities in the same country, hence the need for a country-level analysis.[3]

[1]In contrast to the U.S. literature (see Rosenthal and Ross (2015) for a discussion), we do not find that the gaps 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]The radiance calibrated version of these data, which avoids issues related to top-coding in more developed cities, is only available for a few years between 1996 and 2011. Additionally, night lights also capture infrastructure supply (e.g., electricity networks and roads), hence not just economic development. Furthermore, for a given population, tall buildings may emit night lights in other ways than non-tall buildings, thus complicating the analysis of the effects of income on tall building stocks.

[3]A referee has usefully suggested that we use data on the maximum building height allowed in various

Finally, we perform a similar gap analysis using decadal U.S. state-level data from 1929 to 2017, which offers another opportunity to validate our methodology. Using the same process as at the country level, we first identify states that may be more supply elastic for various reasons (e.g., Illinois and New York). We then run panel regressions that relate building heights to a state's income, agricultural rent, and past building stock. We then use the data and the estimated coefficients to obtain the gaps for each state, finding that California might account for 48-61% of the U.S. gap. We then show that the gaps strongly correlate with the supply elasticities of Saiz (2010) and well-known measures of land-use regulations from Gyourko et al. (2008) and Saks (2008).

Our paper makes several contributions to the literature. To our knowledge, the above stylized facts and results do not appear in 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 building-height regulation varies across countries, and little is known about the determinants and effects of building-height variation globally. Finally, our method has the advantage of being replicable for any context. So far, only a few other studies have implemented this type of indirect method to measure the stringency of regulation, defined as the degree to which regulations cause development decisions to differ from free-market outcomes.[5]

The extent of land-use regulation in U.S. cities has been captured through a number of 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;

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 5). Finally, many cities' implicit thresholds are below 80 m (e.g., Paris), making this method inapplicable in many countries.

[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 (2005b).

[5]See Green et al. (1994), Green (1999), Malpezzi and Mayo (1997), Bertaud and Malpezzi (2001b), Green et al. (2005), Glaeser et al. (2005), Bertaud and Brueckner (2005a), Turner et al. (2014), Brueckner et al. (2017a), Brueckner and Singh (2018) and Albouy and Ehrlich (2018) for important works on land-use regulation.

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 *Wharton Residential Land Use Regulation Index* is based – and Gyourko et al. (2019) do not measure 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 countries. That is why *no* global measures of land-use regulations exist. Finally, such measures cannot tell us if the regulations are binding given economic conditions.

In contrast, our method of analysis is similar to that followed in the health sciences literature. Currently, two methods exist to measure and compare international mortality rates due to an environmental phenomenon (e.g., a pandemic). National agencies can compile phenomenon-related mortality information obtained from each jurisdiction, an imperfect process if jurisdictions and countries have different measurement abilities. An alternative indirect method is to perform simple regression analyses to estimate "excess mortality rates" for all jurisdictions and countries.[6] Our method is analogous to the latter approach, except that we are measuring a shortage of tall buildings.

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 strategy, that would explain income and land rent (our right-hand side variables) without also directly impacting the stock of tall buildings (at the country or city level).

The plan of the paper is as follows. Section 1 provides the conceptual foundations for the panel regressions that we run. Section 2 discusses the data. Section 3 discusses the international regression results and the associated building-height gaps. Sections 4 and 5 examine the possible determinants and effects of the gaps, respectively. Section 6 presents U.S. state analysis and reports a series of robustness checks. Section 7 concludes.

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

1. Conceptual Framework

1.1. The Standard Urban Model (SUM)

The SUM, as exposited by Brueckner (1987), Rosenthal and Ross (2015) and Duranton and Puga (2015), depicts the determination of building heights, 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.[7] 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 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

[7] 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.

agricultural rent, the income and agricultural rent coefficients should be positive.

1.2. Additional Elements

We can assume that as cities achieve higher incomes, they add more amenities, 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.

If wealthier, larger cities 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.

Finally, if we add business land-use to the residential use discussed above, 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.

These considerations suggest a regression with the existing tall-building stock as dependent variable and the lagged stock, income, and agricultural rent as covariates.[8]

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

[8]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.

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 urban 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 decadally 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.[9] For each building, we extracted information on the building's height, year of construction, usage, and other characteristics. As described in Appx. 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 all the countries in our sample buildings above 80 meters as well as their 10 tallest buildings even if some of them are below 80 meters. In the end, we use 16,369 tall buildings. Below, we will discuss how measurement error in building height stocks could impact our results.[10]

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

[9] 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

[10] 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."

agricultural land area because the latter area is missing for almost all countries before 1960.[11] 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. Below, we will discuss how measurement error in agricultural land rent could 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.[12] Knowing urban GDP, we can then reconstruct urban per capita income as urban GDP divided by urban population.[13]

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 for that year. We are also able to distinguish residential and office 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).[14]

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 office buildings from 1920 to 2017. As seen, it is only after 2000 that tall residential buildings were built at a faster pace than office buildings. Circa 2017, residential buildings and office buildings each contribute about half of the total stock of heights in the world.

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

[12] 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).

[13] Note that urban population is not consistently defined. Indeed, countries use different urban definitions. However, country fixed effects should capture any time-invariant factor. In addition, among the 158 countries ca. 2010, 50 countries use an explicit threshold to define a locality as a city, whereas 108 countries use an administrative definition (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 to downward-biased, not upward-biased, effects of urban incomes.

[14] Countries are considered democratic if they are "full" or "flawed" democracies.

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.

Finally, Figure 3 shows the absolute change in the total sum of tall building heights (km) experienced by each world city between 1950 and 2020. As we will describe in Section 6, the cities correspond to 11,719 urban agglomerations in the *Global Human Settlement* database of European Commission (2018). The ten cities that have experienced the largest changes are New York (145), Hong Kong (114), Dubai (86), Guangzhou (75), Toronto (57), Tokyo (57), Chicago (54), Shanghai (47), Jakarta (45) and Seoul (41).

3. The Gaps

Table 1 shows panel regressions for the years 1950, 1960, 1970, 1980, 1990, 2000, 2010, and 2017 (henceforth, "2020"). The explanatory variables are: 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). More precisely, for countries c and years t, the model is:

$$\text{LUHTDENS}_{c,t} = \alpha + \beta\text{LUPCGDP}_{c,t} + \gamma\text{LAGRENT}_{c,t} + \delta\text{LUHTDENS}_{c,t-10} + \theta_c + \kappa_t + \mu_{c,t}.$$

Column (1) includes 158 countries. The GDP coefficient is positive and significant, as is the lagged height-density coefficient. The coefficient on this variable is less than one, indicating that an increase in the lagged tall-building stock is associated with a less than one-for-one increase in the current stock, given that the increase in the prior stock depresses new construction. The land-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 the benchmark countries. Naturally, the GDP coefficient is larger than in col. (1). The coefficient 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 the coefficient of agricultural land rent is nil.

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 supply elastic countries. Importantly, we will show later that other approaches lead to similar selections of countries and results.

Also, based on qualitative evidence, these choices might 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, cities such as Panama City, Sao Paulo, Bangkok, and Kuala Lumpur, have undoubtedly some of the most impressive skylines in the world, especially given their country's middle-income status.

Lastly, while the U.S. and Japan are traditionally associated with skyscrapers, they have very high incomes and agricultural rents and large urban populations. They are above, but still close to, the regression line in Figure 2, thus suggesting that they do not have disproportionate stocks of tall buildings given their economic conditions. If anything, given their residual, they are only five and six countries away from being included in the benchmark set, respectively. The U.S. belonged to the benchmark set until 2010 and was among the top 10 countries in the world until 1980. As we will show later, one reason for the U.S. 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. Japan then also belonged to the benchmark set in 2010 (but not in 2020).

[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.

We then do not include China because it is not democratic and some of its tall buildings might be considered as white elephants. While it is undeniably experiencing a construction boom (its residual improved dramatically since 1980), it has also experienced significant economic, agricultural and urban population growth. In 2020, it is only one country away from not being above the 75th percentile value in the residual.[16] We will show later that results hold if we include the U.S., Japan, and China in the benchmark set.

With the UMH sample (column (4)), the GDP coefficient is three times larger than in column (1), while the agricultural rent coefficient 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.[17] 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 the variables of interest when focusing on higher income countries.

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

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

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.

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

[16]While some cities overbuild relative to current populations (Wu et al., 2016; Glaeser et al., 2017), other cities like Beijing and Shanghai have limited their construction. On average, China is building at the rate required to absorb its growing urban population (Barr and Luo, 2021). Planning officials are relatively conservative in the allowable floor area ratios (FARs). Brueckner et al. (2017b) find that the average land lease sales allow for residential and commercial FARs of about 2.4 on average. By way of comparison, Manhattan has a built FAR of 4.8, while New York City's built FAR is 1 (NYC Dept. of City Planning).

[17]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.

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* (measured in km per urban inhabitant) is then found by using the corrected antilog of $\widehat{\text{LUHTDENS}}_{2020}$ to obtain $\widehat{\text{UHTDENS}}_{2020}$.[18]

4. Rankings

Table 2 ranks the top 20 countries in terms of the two gap measures just discussed and using the H set or the UMH set as our benchmark set. Columns (1) and (3) show 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., Uzbekistan). If, instead, we focus on the ranking based on the absolute per urban capita gap (columns (2) and (4)), the list is now dominated by developed countries.

Various European countries are found in the list, which concords with common beliefs that they are more stringent in regulating heights than other nations (however and as we

[18]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).

will examine later, other factors than land-use regulations could account for the gaps). 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). 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).[19] 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.

Indeed, as can be seen in Web Appx. Fig. A2, 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 economic growth (as shown by logged urban per capita GDP). Comparing it to Web Appx. Fig. A1 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 stories high in central Paris (NY Times, 2015), which can 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 can 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

[19] 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).

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 urban population 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. An 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. In addition, in the rest of the analysis, we will also often use urban population weights.

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.

Office vs. Residential Towers. Columns (6)-(7) of Table 1 replicate columns (4)-(5) of Table 1, but with the height variable computed using residential buildings, while columns (8)-(9) use office buildings (the benchmark countries are selected using residuals that are specific to each building type).[20] For the UMH set (cols. (6) and (8)), point estimates are similar for the two types of buildings. For the H set (cols. (7) and (9)), the coefficient of income is higher for residential buildings. When using these estimates to compute the percentage-change gaps, we find that the H-based gaps are

[20]Note that the benchmark countries are the same as before with a few exceptions.

overall higher for office buildings than for residential buildings (Figure 4(a) shows their kernel distribution in 2020).[21] However, only considering positive gaps, no significant difference is obtained. The lower residential gaps observed globally are thus explained by negative gaps (i.e., excesses) in various countries. For example, Middle-Eastern and Latin American countries have disproportionately large residential tall-building stocks, possibly as a result of "white elephant" projects and/or preferences for high floor luxury condos. Finally, countries with higher, or lower, residential gaps tend to have higher, or lower, office gaps (correlation of 0.70-0.80 depending on the benchmark set used).

Richer vs. Poorer Countries. Cols. (1) and (4) of Table 3 show higher gaps in richer countries today (2020), i.e., countries with a higher log total per capita GDP (PPP, constant 1990 international $). Cols. (2)-(3) and (5)-(6) show that the residential gaps are more correlated than the office gaps with economic development.[22] Alternatively, restricting the sample to developed countries, we find that residential gaps tend to dominate office gaps (see Figure 4(b)). Thus, developed country cities might be more open to creating jobs than receiving new residents (with the caveat that this assumes that the gaps also capture regulatory constraints). One possibility is that in more developed countries, while both businesses and residents pay local taxes, local governments view residents as "costlier," since many services (e.g., schooling, sanitation, water, etc.) are publicly provided.

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.[23] 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 H-based gap instead of 8th.[24]

[21] We verify that the office gaps are significantly higher using a Kolmogorov–Smirnov test (not shown). Note that we find no significant difference for the UMH-based gaps (not shown).

[22] For countries c, the model is: $\text{GAP}_{c,2020} = \alpha + \beta\,\text{LPCGDP}_{2020} + \mu_c$. Urban population weights minimizes the low-stock issue and makes the analysis representative of the global distribution of urban populations.

[23] 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.

[24] For more details on the U.S. analysis, see Web Appx. Section C. 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***

We now turn to generating results on the determinants and effects of the gaps. Finally, we assess how sensitive our results are by implementing various robustness checks.

5. What Constraints May the Gaps Capture?

The gaps could be due to differences in construction costs, geographical constraints, dispersed ownership, land-use regulations, and institutional and cultural factors more broadly. We now examine how the gaps correlate with variables proxying for these dimensions. More precisely, we regress the gaps in 2020 on each variable. We first consider each variable one at a time as there is often limited data for each dimension. For a limited sample of countries and selected variables, we then consider some of the variables simultaneously. Note that we always control for log total per capita GDP in 2020 (PPP, constant international 1990 $), as the goal is to understand why some countries have higher gaps for a given level of economic development.[25] We then use urban population weights (2020) because it is important to study what drives the world gap, hence making the analysis representative of the global distribution of urban populations.

The results are reported in Table 4 with each panel corresponding to a separate factor. For each panel, the first column reports the coefficient when using the H-based gaps while the second column reports the coefficient when using the UMH-based gaps.

Possible Factors. First, conditional on income, we do not find that the gaps are explained by differences in construction costs. World Bank (2019a), which is responsible for producing PPPs globally, reports the price level of broad consumption categories in 2011 (relative to the world = 100). In Panel A we consider the price level of construction, which includes information on materials, labor, and equipment.[26] As seen, the coefficients are negative, not positive, and close to nil.[27] Another important aspect of construction costs is financing. In Panel B, we consider the countries' average lending rate in 1990-2020 (International Monetary Fund (2021); data often unavailable before).[28] In Panel

vs. 1.54**) whereas the coefficient of land rent is similar (0.68* vs. 0.55**). If we study the U.S. between 1870 and 1940 (N = 7; excl. the World War II decade), we obtain higher coefficients, at 2.74** and 2.22**. 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 (e.g., New York City reformed its zoning ordinance in 1961).

[25]For countries c and factor X, the exact model is: $\text{GAP}_{c,2020} = \text{c} + \phi_X \text{X}_c + \kappa \text{ LPCGDP}_{c,2020} + \mu_c$.

[26]One study on total factor productivity for the building industry in Hong Kong, arguably the world's most important skyscraper city, estimated labor costs at about 41%, materials at about 44%, plant and equipment at 7%, and about 8% for other costs, on average (Chau and Walker, 1988).

[27]Construction costs are much higher in developed economies (not shown) but we control for income.

[28]It "is the rate charged by banks on loans to the private sector." Due to high inflation in some countries,

C, we alternatively consider the 1980-2018 average of the financial institutions index of International Monetary Fund (2021).[29] As seen, no significant difference is observed.

Next, we examine if, conditional on income, geographical constraints could explain the gaps. Pagani et al. (2018) provides at a fine spatial resolution global maps of earthquake risk.[30] Using the *Global Human Settlement* (GHS) database of European Commission (2018), we obtain the GIS boundaries and 2015 population of all (11,719) 50K+ agglomerations today. Finally, we use these data to estimate population-weighted averages of earthquake risk for each country. Such measures do not correlate with the gaps (Panel D). Likewise, Shangguan et al. (2017) provides at a fine spatial resolution global maps of bedrock depth. Using the GHS data, we construct population-weighted averages of bedrock depth for each country. No significant difference is observed (Panel E). Lastly, GRID-Arendal (2016) reports the population-weighted percentage of mountain area per country. Ruggedness could negatively affect buildability or increase the need to build taller due to the lack of flat areas. We find no correlation (Panel F).

Indeed, 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 may influence skyscraper locations locally (Rosenthal and Strange, 2008; Barr et al., 2011), it is unlikely to systematically impact building construction at the country level. Indeed, more than half of the variation in bedrock depth at the GHS agglomeration level comes from *within* countries. Thus, while some locations might have overly deep bedrocks, that should not be the case of *all* locations in a same country. Furthermore, piles have been used to anchor skyscrapers for over a 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.

Panel G considers the log of the number of years since the country's largest city was founded.[31] As seen, the gaps are strongly correlated with historical settlement. In Panel

we remove outlying observations with a lending rate above the 90th percentile value in the sample.

[29] The index summarizes how developed banks are, especially related to lending to the private sector.

[30] "Global Earthquake Model Global Seismic Hazard Map (version 2018.1) depicts the geographic distribution of the Peak Ground Acceleration with a 10% probability of being exceeded in 50 years."

[31] We obtain this information by consulting the Wikipedia webpage of each city.

H (I), and focusing again on each country's largest city, we use the ratio of their 1800 (1950) population and their 2020 population (x 100). A higher ratio indicates that more of the city already existed by 1800 (1950) (obtained using the historical population data from Jedwab et al. (2021)).[32] As seen, we find some effects for 1800 and no effects for 1950, suggesting that countries with older (mostly pre-industrial) cities have larger gaps.[33]

Why do countries with more historical cities have higher gaps? It could be due to historically dispersed ownership constraining land assembly and redevelopment or land-use regulations aimed at protecting historical areas. To our knowledge, there are no globally available measures of dispersed ownership. However, we can test if countries that experienced relatively higher destruction rates during World War II (WW2) have lower gaps today. Since no such measures exist, we obtain from Wikipedia a list of bombings that took place during WW2 and their death toll, and then compute bombing-related mortality rates at the country level (as % of 1939 population). As seen in Panel J, we do not find that the gaps are negatively correlated with WW2 bombings. Since the Wikipedia list may be incomplete, in Panel K we try the overall mortality rate (Ibid.), finding no correlation. However, the lack of data on dispersed ownership in "normal" (non-WW2) times implies that we cannot discard that specific mechanism.

We then test if the gaps are higher in countries with valuable historical areas in their cities. In Panels L, M and N, we consider the log number of cultural, mixed and natural *World Heritage Sites* (WHS) ca. 2020 (UNESCO, 2020), while controlling for log total population in 2020 (mixed WHS "contain elements of both natural and cultural significance"). As seen, the gaps are positively correlated with the number of cultural WHS, which include the "historic centres" of Paris, Rome, and Vienna. The gaps are then strongly negatively correlated with natural WHS. This might be because countries with natural WHS implement policies that enforce the protection of natural areas and prevent sprawl, which should in turn lead to taller buildings, hence lower gaps.

Historical areas' value may be due to the tourism revenues they generate. However, in Panel O we do not find that the gaps correlate the log of the average number of tourist arrivals during the period 1990-2020 (World Bank (2019b); data unavailable before), while

[32]Jedwab et al. (2021) rely on data from Chandler (1987) and Wikipedia (2020d).

[33]We find similar results if we use the year the city appears in the historical population database of Chandler (1987) or historical urbanization rates (Jedwab and Vollrath, 2015) (not shown). The coefficients for the years 1850 and 1900 are in-between the coefficients for 1800 and 1950 (Ibid.).

controlling for log total population in 2020. We obtain similar non-results if we use tourism GDP data for the same period (World Bank, 2019b) (not shown), which is not surprising given that the log of tourist arrivals and the log of tourism receipts is 0.9. Indeed, while cultural WHS may be associated with higher gaps, non-cultural WHS associated with lower gaps also bring in tourists. Tall buildings, hence lower gaps, may also generate tourism, as exemplified by New York City or Hong Kong.

Thus, it is likely that historically more urbanized countries adopt land-use regulations to protect their valuable historical areas. Countries could also constrain tall building construction for other reasons, for example to create more open cities in which people can better see the sky. To our knowledge, there are almost no direct international measures of land use regulations. Nonetheless, in Panels P-S we present regression results where we regress the gaps on several indirect land-use regulation variables.

We first use a regulatory database recently established by Shlomo Angel.[34] 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).[35] However, one 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 (e.g., cities with relatively low FARs in their peripheral areas have relatively low FARs in their central areas). It is not ideal but there is to our knowledge no other global database of land-use policies.

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 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 ca. 2015, which yields country values for 49 out of our 158 countries.

[34]Note that the results of Angel's survey have not been published yet. We obtained the data by contacting Shlomo Angel (https://marroninstitute.nyu.edu/people/shlomo-solly-angel) directly.

[35]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.

As can be seen in Panel P, our 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. Next, we consider a measure 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. Panel Q shows that the H-based gaps are higher if building regulations are of higher "quality," hence more stringent. Lastly, from Caldera and Johansson (2013) and for 21 OECD countries only, we obtain measures of the elasticity of the price responsiveness of housing supply (Panel R) and of the speed of housing supply adjustment (Panel S). We find negative correlations, suggesting lower gaps when housing markets are more responsive. The correlations are mostly insignificant given N = 21.

As discussed in Section 4., some countries may have negative gaps due to "white elephants". However, conditional on income, we do not find that the gaps correlate with: (i) a dummy if the country was democratic at any point in 2006-17 (The Economist, 2018) (Panel T); (ii) the average polity score of the country in 1950-2018 (Center for Systemic Peace, 2021) (Panel U); and (iii) the average rule of law index (Panel V) or control of corruption index (Panel W) of the country in 1996-2019 (World Bank, 2021). Thus, institutions specific to land use may matter, not institutions in general.[36]

Simultaneous Inclusion. In Table 5, we examine how the estimated coefficients of selected factors vary as we include them simultaneously. We consider the log number of years since a country's largest city was founded, the log number of cultural WHS, and the maximum FAR, while controlling for log per capita GDP and log total population. As can be seen in cols. (1)-(3) and (6)-(8), they all significantly correlate with the gaps when included one by one. When simultaneously included, sample size obviously decreases. As can be seen in cols. (4) and (9), the correlation with cultural WHS turns negative due to possible collinearity when also including the years since foundation variable. We thus omit the cultural WHS variable in cols. (5) and (10). The coefficient of the FAR variable then remains unchanged throughout. Overall, the results suggest that countries with older cities have higher gaps, either due to land-use regulations aimed at protecting historical areas and/or dispersed ownership. Land-use regulations are also independently correlated with the gaps, indicating that high-gap countries might also

[36] We find similar non-results with other *World Governance Indicators* of the World Bank.

have more stringent land-use regulations unrelated to protecting historical areas.

Land-Use Regulations. We now use our data to generate additional results related to land-use regulations. First, could historical reliance on urban planning be a possible explanation for the apparently important role of land-use regulations? Urban planning became popular in the 19th century as a response to uncontrolled urbanization. While some urban planners follow Le Corbusier in thinking that tall buildings are needed in order to make cities more compact, many "low-rise" urban planners follow Jane Jacobs (Jacobs, 1961) in seeing tall buildings as a threat to neighborhood quality (Glaeser, 2011). In Panel X of Table 4, we thus consider the logged number of renowned urban planners (Wikipedia, 2020e) while controlling for log urban population. While we find a positive correlation for the H-based gaps, it is not significant. The correlations then only slightly increase, and remain not significant, if we assign to formerly colonized developing countries the logged number of planners of their colonizer (not shown), to account for the fact that their land-use regulations may date from the colonial period.

Second, 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 gaps, in Panel Y we consider the home ownership share today (sources: Wikipedia (2020a,c); HOFINET (2020); available for 105 countries). As seen, no correlation 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.[37]

Third, Angel's database provides information on other land use regulations than the maximum FAR. More precisely, we know for the cities of 49 countries if: (i) there is a greenbelt (GB) or an urban growth boundary (UGB); (ii) there are strong zoning laws; (iii) if the government acquires land to plan for urban land expansion; and (iv) if there is a minimum allowable plot size for construction. 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 questions. First, which land-use regulations do the gaps capture? Second, do countries with stringent height restrictions "compensate" their urban residents by having lenient regulations in other dimensions?

[37]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).

First, Table 6 show how the gaps correlate with the max FAR variable and the other land-use policy variables. If we include all variables (cols. (2) and (4)), the correlation between our gap measures and the maximum FAR values increases. In addition, the coefficients of the other variables are, for the most part, not significant. The only other land use policies for which we find a significant effect are urban growth boundaries and minimum plot size. Measures aimed at controlling sprawl (GB, UGB) have negative coefficients, implying that the gaps are lower when cities cannot build "out" and have to build "up." Zoning and government planning are then associated with higher gaps. Lastly, the existence of a minimum plot size implies lower gaps since it facilitates the construction of taller structures. More generally, while the gaps are strongly correlated with building-height restrictions, they seem to capture a broader set of land-use policies.

Second, countries that stringently restrict the height of their buildings could compensate their residents by having more lenient regulations in other dimensions, for example control sprawl less. If such compensation mechanisms indeed exist, we should observe that low-FAR countries have less stringent policies in other dimensions, hence find a strong positive correlation between the maximum FAR variable and the other measures of land use regulations. However, the correlation is weakly negative in the majority of cases (col. (5)). Thus, low-FAR countries are *not less likely* to restrict sprawl through urban containment policies (-0.15 for GB and -0.12 for UGB).

6. The Gaps and other Urban Outcomes

Tables 7-8 present correlations between the gaps and measures of housing prices, sprawl, congestion, and pollution. Note that we always control for national per capita income. For a given income level, we thus examine how the gaps might have economic and environmental consequences. Controlling for income also ensures that we do not simply compare rich and poor countries. One important caveat is that the results are not causal.

Housing Prices. World Bank (2019a) reports the price level of broad consumption categories in 2011 (relative to the world = 100). In col. (1) of Table 7, we regress the price level of housing on the gaps while controlling for log nominal (national) per capita GDP (2010) (World Bank, 2019b) and using as weights urban population (2010) (N = 147). We control for nominal GDP because higher housing prices would be captured by PPP adjustments given how typically high housing expenditure shares are.[38] A unitary

[38]As discussed in Section 4., the urban population weights are important to give less weight to smaller

decrease in the H-based gap is associated with 4% lower housing prices. The magnitude of the effect is large: A one standard deviation increase in the gap (a value of 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.[39]

Countries with larger gaps could compensate their urban residents by subsidizing commuting, for example via public investments in urban transportation infrastructure. In column (2), we use the same specification but regress the price level of transportation on the gaps while also controlling for the price level of housing (N = 147). While negative coefficients are observed, the point estimates are not significant. Thus, the higher housing prices do not appear to be compensated by cheaper transportation.

Another 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 square meter 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 square meter 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 (3)-(4), we regress these measures on the gaps while controlling for log nominal (national) 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 H-based gap is associated with 24% lower housing prices (col. (3)). A one standard deviation increase in the gap is then associated with a 0.56 standard deviation increase in prices. We also find large coefficients for future housing prices (col. (4)).

Knoll et al. (2017) show that housing prices have increased faster than overall prices for 14 countries post-1950. Fig. 5 shows that the evolution of the total km gap of the 14 countries follows the evolution of mean real house prices in their sample. Cols. (5)-

countries as such countries might be more likely to mechanically have larger percentage gaps. We also need to make the analysis representative of the global distribution of urban populations.

[39]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.

(6) 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 col. (5), we keep 1960 and 2010 to study long-difference correlations. A unitary decrease in the H-based gap is associated with 29% lower prices. Alternatively, a one standard deviation increase in the gap is associated with a 0.60 standard deviation increase in prices. The short-difference correlation (col. (6)), 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 H-based gaps might have explained 22% of the global house price boom.

Next, 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 (col. (7); using the specification of cols. (1)-(2); N = 47).

Finally, given the lack of global historical data on non-tall buildings, we are unable to assess whether higher-gap countries have smaller gaps in this other dimension. However, the fact that housing prices are higher in higher-gap countries suggests that any compensation via the non-tall sector may not be sufficient. Below in Section 7, we also discuss why tall building construction might be a good proxy for overall construction.

To summarize, high-gap countries do not appear to "compensate" their urban residents by subsidizing transportation or directly providing housing to the urban poor. In the largest cities where constraints on vertical development are more likely to be binding, we found that housing prices are about 20% higher. With a 30% housing expenditure share, this would correspond to a 6 percentage decrease in purchasing power. Could tourism receipts justify such effects? First recall that we did not find any correlation between the gaps and tourism receipts. Second, in the most tourism-oriented high-gap nations, for example France and Italy, the GDP contribution of tourism is about 2.5% (which also includes tourism outside the largest cities). Thus, tourism might not be the only factor why tall building construction is constrained in high-gap countries.

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 may be that horizontal expansion is not enough to "compensate" for the lack of vertical expansion.

In col. (8), we regress total urban land area (2011) (World Bank, 2019b) on the gaps (N = 125). We control for log urban population (2010), log nominal (national) 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 constrains land expansion). We use urban population weights (2010). Land expansion is positively correlated with the gaps. A unitary increase in the H-based gap is associated with cities consuming 19% more 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 131 countries in 1975, in 1990, in 2000 and in 2015 the total population, total land area, and total built-up area (thus excluding open spaces) of all (11,719) 50K+ urban agglomerations today. In cols. (9)-(10), we use as the dependent variable the log of total city land area in t while adding country and year fixed effects and controlling for log total city population, log nominal (national) per capita GDP, and log nominal agricultural land rent in t, with the variable of interest being the gap in t (standard errors clustered at the country level). By restricting our panel analysis to the years 1975 and 2015 (N = 262), we capture how the gaps correlates with the long-difference change in urban land per capita. A unitary decrease in the H-based gap is associated with urban areas consuming 5% less land. A one standard deviation in the H-based gap is then associated with a 0.07 standard deviation increase in urban total land area. With the full panel (N = 524), elasticities are halved (col. (10)).

Simultaneously controlling for log total *built-up* area (t), col. (11)-(12) further show that the gaps correlate with sprawl. Indeed, since the outcome is total land area, these results suggest that cities in high-gap countries use more land per built-up area, i.e., have more open areas and are less compact generally (col. 13-14 are discussed later).

Theoretically, by restricting housing supply, constraints on vertical development 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, 2005a). 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. Our back-of-the-envelope calculations thus suggest that the gaps might have major economic costs globally.[40]

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 fact that the GHS database reports estimates of population and total 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 regress the log of city 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.[41] As seen in Fig. 6, the relationship is non-linear, with heights significantly increasing after 100K. 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, as expected, 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 and for the sake of simplicity, 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

[40]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.

[41]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).

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 (t) and the variables of interest are the country gaps (t) interacted with the population category dummies (1975). We include city fixed effects, country-year fixed effects, and cluster standard errors at the country level. Moreover, we control for log urban per capita GDP (PPP, 1990 constant international \$) interacted with the population dummies to capture how changes in the gaps occur in larger cities rather than the fact that gaps are becoming larger in countries with richer urban areas.[42] Lastly, we use urban population weights (t) to minimize the low-stock issue and make the analysis representative of the global distribution of urban populations.

Table 8 reports the results. The effects of the country gaps are particularly visible for larger cities (col. (1)), thus suggesting that they are associated with abnormally constrained big cities. If we use the full panel (1975, 1990, 2000, 2015) to focus on short-term correlations, the point estimates are reduced, but significant above 1,000K (col. (2)).

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).

Next, using the full panel specification, we confirm that the gaps are more constraining in the central areas of urban agglomerations (col. (3)). 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 coefficients of the gaps interacted with the city dummies are nil or negative, and not positive (col. (4)). 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 total area (cols. (5)-(6)). No correlation is found for the H-based gaps. These regressions compare relative land expansion patterns for different class sizes of cities (50-55K is the

[42] For cities a belonging to population categories p, countries c and years t, the model is: $\text{LHEIGHT}_{a,c,t} = \alpha + \Sigma_p \, \beta_p \, \mathbb{1}(\text{POP}_{a,c,1975} = p) \times \text{GAP}_{c,t} + \Sigma_p \, \gamma_p \, \mathbb{1}(\text{POP}_{a,c,1975} = p) \times \text{LUPCGDP}_{c,t} + \theta_a + \kappa_{c,t} + \mu_{a,c,t}$.

omitted category) whereas cols. (9)-(10) of Table 7 examined the total expansion of all urban areas. Since urban land expansion is correlated with the gaps at the country level, *all* class sizes of cities may be expanding spatially 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 next.

Congestion: City-Level Results. Traffic congestion is available for 391 50K+ cities today (TomTom, 2019). The measure indicates by how many percentage points commuting times increase during rush hours relative to non-rush hours.[43] Congestion strongly increases with log population size (N = 391; with country FE; coef. = 3.7***; adj. R2 = 0.75). We then examine how this relationship is affected by the country gaps. We regress congestion on the gaps again interacted with the three city-size dummies. We include country fixed effects and log (national) per capita income interacted with the population category dummies, and use urban populations (2020) as weights (standard errors clustered at the country level). Larger cities are disproportionately more congested than 50-100K cities in higher-gap countries (see col. (7) of Table 8).[44] Finally, knowing the population share of each group of cities, we compute the average effect across the three groups, equal to 1.55 (significant at 10%) for the H-based gaps. Thus, a unit increase in the H-based gap is associated with 1.5% more congestion. The magnitude is large: a one standard deviation in the H-based gap possibly raises congestion by 3%. Finally, the correlation is halved and insignificant when controlling for sprawl 1975-2015 (not shown).

Pollution: Country-Level Results. With sprawl and road congestion, pollution may also increase, implying that gaps might have environmental consequences. Air pollution in cities consists of gases – mostly carbon dioxide (CO_2) and nitrogen oxides (NO_x) – and particulate matter (PM) measured by their size, such as 10 and 2.5 micrometers. CO_2, NO_x and PM have health effects. CO_2 and NO_x also contribute to global warming. Unfortunately, ground-based measures of CO_2 and NO_x are not available for enough urban areas across the world. However, there is data on PM10 and PM2.5. In columns (13)-(14) of Table 7, the dependent variables are the log levels of PM 10 (2010) and PM

[43]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/).

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

2.5 (2017) in more populated areas, respectively (World Bank, 2019b).[45] We control for log (national) 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 0.05-0.08% more pollution. A one standard deviation increase in the gaps is then associated with a 0.05-0.08 standard deviation increase in PM.

Pollution: City-Level Results. 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 (see col. (8)-(9) of Table 7). Knowing the population share of each group of cities, we obtain the average coefficient across the three groups, 0.04*-0.07** for PM10 and 0.05***-0.08*** for PM2.5 when considering H-based gaps. Thus, a one point increase in the H-based gap possibly raises pollution by 4-8%. Alternatively, a one standard deviation in the H-based gaps (= 2) may raise 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 might reduce world GDP by 0.4-0.8%.

Finally, whether for the country-level or city-level 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, the correlations of the gaps with pollution are strongly reduced (Web Appx. Table A1). Most of the pollution results thus seem explained by sprawl.

7. Robustness Checks

We now address various concerns related to: (i) the fact that our analysis is at the country, not city, level; (ii) the selection of the benchmark countries; (iii) causality; (iv) the baseline specification; and (v) non-classical measurement error in building heights.

City-Level Analysis. As explained in the introduction, global historical data on city incomes and agricultural land rents at the edge of cities do not exist, ruling out a worldwide, within-country study. However, our benchmark set of countries may not be sufficiently representative of the rest of the world in terms of city size distribution, which matters because income and land rent should affect tall building construction more in larger cities. However, if we use the GHS data set of 11,719 urban agglomerations for the year 2015, Kolmogorov-Smirnov tests suggest that the Kernel distribution of city

[45]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.

population sizes is not significantly different between the benchmark and non-benchmark countries for both sets (not shown). Next, we can directly use the GHS data set of 11,719 cities x 4 years (1975, 1990, 2000, 2015) to perform a global analysis at the city level.

Figure 6 shows for the 11,719 cities in 2015 that building heights increase non-linearly with population size. To define the set of "benchmark" cities, we thus identify cities that have disproportionately more heights for a given population size and level of national urban income and land rent. For the year 2015, we regress the log sum of heights 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) as well as log urban per capita GDP (PPP, constant international $) and log agricultural land rent (both defined at the country level), which we also interact with the six dummies.[46]

Doing so, we obtain 302 cities belonging to a high-income democratic country and whose residual is above the 75th percentile value. Including upper-middle income countries, we get 384 cities. We find a strong correlation between the country- and city-level residual values (0.68). However, the correlation is below 1 because cities have different values within a same country. For example and as expected, New York City and Milan are included in the benchmark sets whereas Los Angeles and Rome are not. One advantage of this analysis is that it includes in the benchmark set cities that were not included at the country level. One disadvantage is that it ignores the possibly low substitutability in building space demand across cities within countries, which country-level regressions do. For example, even if it is easier to build up in Milan, it may not have a large impact on Italy's total gap. Most Italian cities have disproportionately few tall buildings for their economic conditions and whether Italy's gap is reduced by Milan's higher supply elasticity ultimately depends on demand substitutability across cities.

For the H and UMH sets, we then use panel regressions 1975-2015 where the dependent variable is the log sum of heights in year t and the variables of interest are the urban income and land rent variables in year t which we interact with three dummies for whether the city has 100-500K, 500-1,000K and 1,000K+ inhabitants in 1975, respectively. We use three dummies to reduce the number of coefficients we have to track. We use 1975 because post-1975 changes in city populations are endogenous to post-1975 changes in

[46] For agglomerations a belonging to population categories p and for the year 2015, the model is: $\text{LHEIGHT}_a = \alpha + \Sigma_p\, \beta_p\, \mathbb{1}(\text{POP}_a = p) \times \text{LUPCGDP}_c + \Sigma_p\, \gamma_p\, \mathbb{1}(\text{POP}_a = p) \times \text{LAGRENT}_c + \mu_a$.

the country gaps. We then include a lag of the log sum of heights as well as city and year fixed effects and cluster standard errors at the country level.[47]

As expected, the coefficient of income is higher for larger cities. For the H set, we find 0.16 for the omitted category (50-55K) and 1.28*, 2.26*** and 2.63*** for the 55-500K, 500-1,000K and 1,000K+ categories, respectively. We find a similar gradient for the UMH set (-0.39, 0.85, 1.81** and 2.06***). Given the total population shares of the different categories of cities, the average coefficient is 2.32*** and 1.81***, respectively. While it is lower than in Table 1, it remains high. Indeed, 1,000K+ cities account for almost three fourths of urban populations. We then do not observe any gradient for land rent and the average coefficient is -0.60 and -0.12, respectively. The land rent coefficient is now negative, suggesting that the national land rent control may be really imperfect for city-level analyses. Lastly, the coefficient of past heights is about 0.20 (**) in both cases.

Using the data and the estimated coefficients, we can proceed as we did in Section 3. to obtain the percentage-change gap of each of the 11,719 world cities in each year. Using their population size as weights, we can then obtain the average gaps for each country in each year and compare them to the ones we obtained with the country-level analysis. We find a correlation of 0.60 and 0.40 for the H- and UMH-based gaps. For the H-based gaps, the correlation is relatively high. Yet, it is lower than one. However, the discrepancy could be due to: (i) the different period (1975, 1990, 2000 and 2015 vs. every ten years in 1950-2020); (ii) the benchmark sets being different; and/or (iii) the fact that the city-level analysis ignores the possibility of low within-country demand substitutability.

Nonetheless, the high correlation for the H-based gaps gives us confidence in the gaps used so far. The city-level analysis also highlights how larger cities drive the gaps. For example, Ireland has the highest gap for both the country- and city-level analyses. The gap is then five times higher for Dublin than for Cork. In Italy, among million-plus cities, Rome has a higher gap than Turin and Milan has the lowest gap but its gap is still high.

Finally, the country-level analysis may over-estimate the gaps in large countries because their cities have more area to grow (hence not necessitating tall buildings as much) and because land rent at the edge of cities is mismeasured for them. We thus

[47] For agglomerations a, population categories p and years t, the model is: $\text{LHEIGHT}_{a,t} = \alpha + \Sigma_p\ \beta_p\ \mathbb{1}(\text{POP}_{a,1975} = p) \times \text{LUPCGDP}_{c,t} + \Sigma_p\ \gamma_p\ \mathbb{1}(\text{POP}_{a,1975} = p) \times \text{LAGRENT}_{c,t} + \text{L1.LHEIGHT}_{a,t} + \theta_a + \kappa_t + \mu_{a,t}$.

study whether the absolute difference between the country- and city-based country gaps increases with log land area or the log number of cities (N = 158), actually finding negative and almost nil coefficients in both cases (-0.31/-0.26, not significant; R2 = 0.02/0.01).

Sampling Checks. The results depend on the selected benchmark countries. While our selection method has clear limitations, there is unfortunately no objective process that might help us distinguish more vs. less supply elastic countries, hence the need to assess how robust our results are to the choice of the benchmark set.

First, a Google search possibly supports the validity of the process by which we select supply elastic 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, our benchmark set does not include the U.S., Japan, and China, three countries considered as having many tall buildings. However and as discussed in Section 3., that is not necessarily the case once one accounts for the size of their urban population and their economic conditions. While some of their cities have impressive skylines, these countries also have many large cities with restricted FARs. Yet, since the three countries are close to being included in the benchmark set based on the selection residuals, we verify results hold if we include them in the benchmark set, whether the U.S. only, the U.S. and Japan or China, or the three countries altogether (see Web Appx. Table A3). When doing so, the country rankings are mostly unchanged (the correlation between the various gap measures is always above 0.90).

A related question is whether the benchmark set is sufficiently representative of the rest of the world in terms of total land area. Classical measurement error in land rent should lead us to under-estimate its coefficient and the gaps. But land rent at the edge of cities may be mismeasured for larger countries. Our benchmark sets include three large countries (Australia, Brazil, Canada) and two small countries (Hong Kong and

Singapore). If the benchmark set has too many large (or small) countries relative to the rest of the world, the estimated coefficient may affect our results.

However, land rent is likely under-estimated in larger countries (since average land rent captures more rural areas away from cities) whereas the gaps may appear larger there since development should take place more horizontally due to land availability. If anything, this should also lead to a downward bias of the coefficient/gaps. Second, we use the *OECD Regional Database* of OECD (2021) to examine for 505 regions in 36 countries (incl. 6 non-OECD countries) how much of a good proxy is national agricultural land rent for agricultural land rent in more urban regions. More precisely, the database reports agricultural GDP and total land area for each region c. 2010 (data unavailable before 2004).

For 264 regions with a metro area (a large metro area), the correlation between regional and national rent is 0.87 (0.89) in countries below the median land area in the sample and 0.80 (0.82) in countries above. While the correlation is lower in larger countries, it is still very high. Global differences in land rent mostly come from between countries, not regions within countries. Third, Kolmogorov-Smirnov tests suggest that the Kernel distribution of total land areas is not significantly different between the benchmark and non-benchmark countries for both sets (not shown).[48] Fourth, the land rent coefficient barely changes if we exclude the three large countries or the two small countries (Web Appx. Table A3). Lastly, the coefficient of income is mostly unchanged if we omit land rent (Ibid.). In all cases, the country rankings remain similar (not shown).

Finally, results hold if we drop each country one by one, so the coefficients and country rankings are not affected by any particular country in the benchmark set (not shown).

Causality. The gaps are over-estimated if the coefficients of income and land 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 land rent, we found that the correlation between the H- and UMH-based rankings was above 0.85.

Next, such bias would be a consequence of the correlation between the explanatory variables and the regression error term. This correlation could arise either from omitted

[48] We also verify that land rent strongly decreases with land area (elasticity: 0.33), and that land rent is the highest in countries where we might expect it to be the case (e.g., Hong Kong, Singapore and Taiwan).

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 is still a concern. Examples of reverse causality include a positive feedback effect from commercial buildings to incomes operating through agglomeration economies.[49] Alternatively, the supply-increasing effects of taller buildings may reduce housing prices enough to attract low-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 incomes without impacting building heights is hard to find. We thus discuss another series of results that gives us greater confidence in the coefficients. To this end, Web Appx. Table A2 shows results hold if:

(i) We include continent- or World Bank region-year fixed effects, in order to capture regional economic, institutional and cultural drivers of tall building construction that may affect building heights, urban incomes and agricultural land rent;

(ii) We include country-specific linear trends or even country-specific non-linear trends, 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 more 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 of subway lines and 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)).[50] The coefficient of income 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

[49]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.

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

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, the income coefficient would likely increase.

(iv) We add leads of the main explanatory variables to address possible reverse causality, with the variables defined as t+10. 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 and other 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 (population-weighted) average earthquake risk and bedrock depth in urban areas, the share of the population living in mountainous areas, and the price level of construction in 2011 (see Section 5. for details on the sources). Note that results also hold if we control for the other possible determinants of the gaps considered in Table 4 (not shown).

Finally, using the 11 different regressions in Web Appx. Table A2, 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.

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.[51] 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.[52] 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

[51] Their website says they rely on their extensive member network to gather information on buildings.
[52] Accessed on 12-11-2019: https://www.emporis.com/statistics/skyline-ranking.

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 (Fig. 7). Next, 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.[53] The correlation between decadal tall building construction and decadal cement use is high, at 0.77 (N = 870). Adding country and year FE, we obtain a correlation of 0.80 (0.99 with urban population as weights). Thus, 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. The results hold if we restrict our analysis to buildings above such thresholds, or even 150 meters, which is about the size of the tallest buildings in sub-Saharan Africa outside South Africa (Web Appx. Tables A3). While there might be concerns that tall buildings are undercounted in poorer countries, we personally doubt that the CTBUH would not systemically report buildings of such sizes in such countries, since there are so few of them. Thus, restricting the sample to higher thresholds should take care of non-classical measurement error in building heights. We then verify that the country rankings are mostly unchanged when doing so (not shown).[54] Finally, our results hold if we drop

[53]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.

[54]Until a few years ago, the tallest buildings of Angola (IMOB Business Tower), Kenya (UAP Tower), Nigeria (NECOM House) and Tanzania (PSPF Towers) were all close to 150 meters in height (information obtained from independent sources). We verify that they are all available in the CTBUH database.

heights that are imputed based on the number of floors (Ibid.).[55]

Lag of the Dependent Variable. With panel regressions, including a lagged dependent variable might introduce dynamic panel bias (Nickell, 1981). However, Web Appx. Table A3 shows that the coefficient of GDP significantly increases when omitting the lagged dependent variable, which would lead to even higher gaps (country rankings are also little affected; not shown). Note that we keep the lagged dependent variable in the baseline model because of the need to control for the durability of tall buildings.

Lastly, countries that may have developed their downtown cores to their optimal level should not build more tall buildings. Therefore, Web Appx. Table A3 shows results hold if we include the square of the lagged log urban height density in case the ability of a country's cities to redevelop "higher" is decreasing with the existing urban height density. We also try including the cube and fourth power of the variable. Country rankings are little affected (not shown). Indeed, while a few cities have "crowded" central areas, many of their buildings could still be redeveloped higher, and other cities in the same countries do not necessarily have that many tall buildings.

U.S. State Analysis. In Web Appx. Section C, we perform a similar gap analysis using decadal U.S. state-level data from 1929 to 2017, which offers another opportunity to validate our methodology. Using the same process as at the country level, we first identify states with higher residuals today, i.e., states that may be more supply elastic for various reasons. We then run panel regressions that relate building heights to a state's income, agricultural rent, and past building stock. As expected, we find higher coefficients of income and land rent when restricting the sample to the benchmark states (e.g., Illinois and New York). We then use the data and these coefficients to obtain the gaps for each state, finding that California might account for 48-61% of the U.S. gap. We then show that the gaps strongly correlate with the supply elasticities of Saiz (2010) (which also include geographical constraints) and well-known measures of land-use regulations from Gyourko et al. (2008) and Saks (2008). Finally, if we use the U.S. state coefficient estimates to obtain predicted heights and the gaps for all countries in the world, the coefficient

[55] 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.

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, at 0.72-0.89. This increases our confidence in the country-level benchmark regression as a tool for computing building-height gaps across the world.

8. Conclusion

Using a new data set on nearly all tall buildings on the planet, this paper has constructed a measure of building-height gaps 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 higher supply elasticities. Using regression results for these benchmark countries, we create building-height gaps for countries around the world. We find that the world might need to have twice as many tall buildings (about 6,000 Empire State Buildings) as it does currently.

We show that the gaps are relatively larger for richer countries, especially European countries. Globally, the gaps are larger for office towers, due to various world regions having disproportionately large residential tall-building stocks (e.g., the MENA). However, in developed countries, the gaps are relatively larger for residential buildings.

Conditional on income, the gaps are strongly and positively correlated with housing prices, sprawl, road congestion, and pollution, implying that they might have important global economic and environmental consequences. In particular, such gaps might explain one fifth of the global house price boom observed since 1950. The gaps then appear to constrain the growth of large cities and their central areas. We do not find that countries with larger building-height gaps "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.

Regarding the nature of these gaps, we find no evidence that they are caused by geological, topographical, or seismic conditions, or differences in construction costs. However, countries with more "historical" cities have higher gaps. Evidently, the gaps in these countries arise from regulations designed to protect valuable historical urban areas, motivated by cultural considerations or a desire to foster tourism. However, countries may also adopt stringent regulations for reasons unrelated to historical preservation.

Additionally, we have worked through a series of robustness checks, estimating the gaps with different specifications, and estimating gaps at the city level and U.S. state level.

Across all these tests, we find strong correlations of our country-level gap with other gap measures. The results suggest that our gap measure is an useful index of tall building supply across the world, and which emerge from various local and national frictions.

REFERENCES

Ahlfeldt, Gabriel and Jason Barr, "The Economics of Skyscrapers: A Synthesis," Technical Report 2020.

Ahlfeldt, Gabriel M and Daniel P McMillen, "Tall buildings and land values: Height and construction cost elasticities in Chicago, 1870–2010," *Review of Economics and Statistics*, 2018, *100* (5), 861–875.

Albouy, David and Gabriel Ehrlich, "Housing productivity and the social cost of land-use restrictions," *Journal of Urban Economics*, 2018, *107*, 101–120.

Barr, Jason, "Skyscrapers and the skyline: Manhattan, 1895–2004," *Real Estate Economics*, 2010, *38* (3), 567–597.

_ , "Skyscraper height," *The Journal of Real Estate Finance and Economics*, 2012, *45* (3), 723–753.

_ , *Building the skyline: The birth and growth of Manhattan's skyscrapers*, Oxford University Press, 2016.

_ and Jeffrey P Cohen, "The floor area ratio gradient: New York City, 1890–2009," *Regional Science and Urban Economics*, 2014, *48*, 110–119.

_ and Jingshu Luo, "Growing Skylines: The Economic Determinants of Skyscrapers in China," *Forthcoming in The Journal of Real Estate Finance and Economics*, 2021.

_ and Ronan Lyons, "Stop the sprawl! If we are serious about our future, we must look up," *Independent, IE*, June 2018.

_ , Troy Tassier, and Rossen Trendafilov, "Depth to Bedrock and the Formation of the Manhattan Skyline, 1890-1915," *The Journal of Economic History*, 2011, pp. 1060–1077.

Beaney, T, JM Clarke, V Jain, AK Golestaneh, G Lyons, D Salman, and A Majeed, "Excess mortality: the gold standard in measuring the impact of COVID-19 worldwide?," *J R Soc Med.*, 2020, *113* (9), 329–334.

Bertaud, Alain and Jan K. Brueckner, "Analyzing building-height restrictions: predicted impacts and welfare costs," *Regional Science and Urban Economics*, 2005, *35* (2), 109 – 125.

_ and Jan K Brueckner, "Analyzing building-height restrictions: predicted impacts and welfare costs," *Regional Science and Urban Economics*, 2005, *35* (2), 109–125.

_ and Stephen Malpezzi, "Measuring the Costs and Benefits of Urban Land Use Regulation: A Simple Model with an Application to Malaysia," *Journal of Housing Economics*, September 2001, *10* (3), 393–418.

_ and _ , "Measuring the costs and benefits of urban land use regulation: a simple model with an application to Malaysia," *Journal of Housing Economics*, 2001, *10* (3), 393–418.

Bradford, Sarah and Carl W. Condit Landau, *Rise of the New York Skyscraper, 1865-1913* 1996.

Brueckner, Jan K., "Chapter 20 The structure of urban equilibria: A unified treatment of the muth-mills model," in "Urban Economics," Vol. 2 of *Handbook of Regional and Urban Economics*, Elsevier, 1987, pp. 821 – 845.

_ and Kala Seetharam Sridhar, "Measuring welfare gains from relaxation of land-use restrictions: The case of India's building-height limits," *Regional Science and Urban Economics*, 2012, *42* (6), 1061–1067.

Brueckner, Jan K and Kala Seetharam Sridhar, "Measuring welfare gains from relaxation of land-use restrictions: The case of India's building-height limits," *Regional Science and Urban Economics*, 2012, *42* (6), 1061–1067.

Brueckner, Jan K. and Ruchi Singh, "Stringency of Land-Use Regulation: Building Heights in US Cities," Technical Report 2018.

Brueckner, Jan K and Ruchi Singh, "Stringency of land-use regulation: Building heights in us cities," *Journal of Urban Economics*, 2020, p. 103239.

Brueckner, Jan K., Shihe Fu, Yizhen Gu, and Junfu Zhang, "Measuring the Stringency of Land Use Regulation: The Case of China's Building Height Limits," *The Review of Economics and Statistics*, 2017, *99* (4), 663–677.

—, —, —, and —, "Measuring the Stringency of Land Use Regulation: The Case of China's Building Height Limits," *The Review of Economics and Statistics*, July 2017, *99* (4), 663–677.

Caldera, Aida and Asa Johansson, "The price responsiveness of housing supply in OECD countries," *Journal of Housing Economics*, 2013, *22* (3), 231–249.

CBC News, *Toronto on track to have more skyscrapers than Chicago, but will quality match quantity?* 2020.

Center for Systemic Peace, *Polity IV Project* 2021.

Chandler, Tertius, *Four Thousand Years of Urban Growth: An Historical Census* 1987.

Chau, K. W. and A. Walker, "The measurement of total factor productivity of the Hong Kong construction industry," *Construction Management and Economics*, 1988, *6* (3), 209–224.

Cheshire, Paul C. and Gerard H. Dericks, "Trophy Architects and Design as Rent-seeking: Quantifying Deadweight Losses in a Tightly Regulated Office Market," *Economica*, 2020, *87* (348), 1078–1104.

CNN, *Lotte World Tower opens in Seoul setting world records* 2017.

Duranton, Gilles and Diego Puga, *Urban Land Use*, Vol. 5 of *Handbook of Regional and Urban Economics*, Elsevier, December

Dushoff, Jonathan, Joshua B. Plotkin, Cecile Viboud, David J. D. Earn, and Lone Simonsen, "Mortality due to Influenza in the United StatesAn Annualized Regression Approach Using Multiple-Cause Mortality Data," *American Journal of Epidemiology*, 2005, *163* (2), 181–187.

Emporis, 2019.

European Commission, *Global Human Settlement* 2018.

FAO, *FAOSTAT* 2018.

Fischel, William A., *The Homevoter Hypothesis: How Home Values Influence Local Government Taxation, School Finance, and Land-Use Policies* 2001.

Gendron-Carrier, Nicolas, Marco Gonzalez-Navarro, Stefano Polloni, and Matthew A. Turner, "Subways and Urban Air Pollution," NBER Working Papers 24183, National Bureau of Economic Research, Inc January 2018.

Glaeser, Edward, *How Skyscrapers Can Save the City* 2011.

— and Joseph Gyourko, "The impact of building restrictions on housing affordability," *Economic Policy Review*, 2003, (Jun), 21–39.

— and —, "The Economic Implications of Housing Supply," *Journal of Economic Perspectives*, Winter 2018, *32* (1), 3–30.

Glaeser, Edward L. and Bryce A. Ward, "The causes and consequences of land use regulation: Evidence from Greater Boston," *Journal of Urban Economics*, May 2009, *65* (3), 265–278.

— and Joseph Gyourko, "Urban Decline and Durable Housing," *Journal of Political Economy*, April 2005, *113* (2), 345–375.

Glaeser, Edward L, Joseph Gyourko, and Raven E Saks, "Why have housing prices gone up?," *American Economic Review*, 2005, *95* (2), 329–333.

Glaeser, Edward L., Joseph Gyourko, and Raven E. Saks, "Urban growth and housing supply," *Journal of Economic Geography*, January 2006, *6* (1), 71–89.

Glaeser, Edward, Wei Huang, Yueran Ma, and Andrei Shleifer, "A Real Estate Boom with Chinese Characteristics," *The Journal of Economic Perspectives*, 2017, *31* (1), 93–116.

Glickfeld, Madelyn and Ned Levine, *Regional growth–local reaction: The enactment and effects of local growth control and management measures in California*, Lincoln Inst of Land Policy, 1992.

Globes, *Tel Aviv skyline undergoing dramatic transformation* 2017.

Gollin, Douglas, Remi Jedwab, and Dietrich Vollrath, "Urbanization with and without industrialization," *Journal of Economic Growth*, 2015, *21* (1), 35–70.

Gonzalez-Navarro, Marco and Matthew A. Turner, "Subways and urban growth: Evidence from earth," *Journal of Urban Economics*, 2018, *108* (C), 85–106.

GPG, *The World's Most Expensive Cities* 2019.

Green, Richard K., "Land Use Regulation and the Price of Housing in a Suburban Wisconsin County," *Journal of Housing Economics*, June 1999, *8* (2), 144–159.

—, Stephen Malpezzi, and Kerry Vandell, "Urban Regulations and the Price of Land and Housing in Korea," *Journal of Housing Economics*, 1994, *3* (4), 330–356.

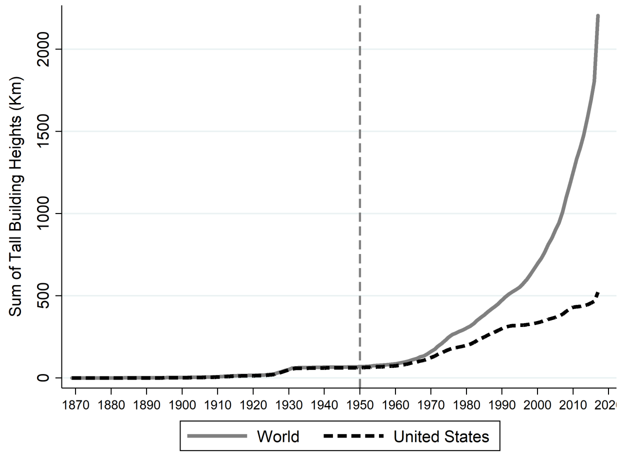
—, —, and Stephen K. Mayo, "Metropolitan-Specific Estimates of the Price Elasticity of Supply of

Housing, and Their Sources," *American Economic Review*, May 2005, *95* (2), 334–339.
GRID-Arendal, *Percentage of Mountain Area per Country* 2016.
Gyourko, Joseph, Albert Saiz, and Anita Summers, "A new measure of the local regulatory environment for housing markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies*, 2008, *45* (3), 693–729.
— and Raven Molloy, "Regulation and Housing Supply," in Gilles Duranton, J. V. Henderson, and William C. Strange, eds., *Handbook of Regional and Urban Economics*, Vol. 5 of *Handbook of Regional and Urban Economics*, Elsevier, 2015, chapter 0, pp. 1289–1337.
— , Christopher Mayer, and Todd Sinai, "Superstar Cities," *American Economic Journal: Economic Policy*, November 2013, *5* (4), 167–199.
— , Jonathan Hartley, and Jacob Krimmel, "The Local Residential Land Use Regulatory Environment Across U.S. Housing Markets: Evidence from a New Wharton Index," Working Paper 26573, National Bureau of Economic Research December 2019.
Helsley, Robert W. and William C. Strange, "Strategic growth controls," *Regional Science and Urban Economics*, 1995, *25* (4), 435 – 460. Recent Advances in Urban Economics and Land Use: A Special Issue in Honour of Hiroyuki Yamada.
HOFINET, *Housing Market Data* 2020.
Hsieh, Chang-Tai and Enrico Moretti, "Housing constraints and spatial misallocation," *American Economic Journal: Macroeconomics*, 2019, *11* (2), 1–39.
Ihlanfeldt, Keith R, "The effect of land use regulation on housing and land prices," *Journal of Urban Economics*, 2007, *61* (3), 420–435.
International Monetary Fund, *International Financial Statistics Database* 2021.
Jackson, Kristoffer Kip, "Regulation, land constraints, and California′s boom and bust," *Regional Science and Urban Economics*, 2018, *68*, 130–147.
Jacobs, Jane, *The Death and Life of Great American Cities* 1961.
Jedwab, Remi and Dietrich Vollrath, "Urbanization without growth in historical perspective," *Explorations in Economic History*, 2015, *58* (C), 1–21.
— , Daniel Pereira, and Mark Roberts, "Cities of workers, children or seniors? Stylized facts and possible implications for growth in a global sample of cities," *Regional Science and Urban Economics*, 2021, *87*, 103610.
Knoll, Katharina, Moritz Schularick, and Thomas Steger, "No Price Like Home: Global House Prices, 1870-2012," *American Economic Review*, February 2017, *107* (2), 331–53.
Liu, Crocker H., Stuart S. Rosenthal, and William C. Strange, "Building Specialization, Anchor Tenants and Agglomeration Economies," 2017.
Liu, Crocker H, Stuart S Rosenthal, and William C Strange, "The vertical city: Rent gradients, spatial structure, and agglomeration economies," *Journal of Urban Economics*, 2018, *106*, 101–122.
Liu, Crocker H., Stuart S. Rosenthal, and William C. Strange, "Employment density and agglomeration economies in tall buildings," *Regional Science and Urban Economics*, 2020, *84*, 103555.
Maddison, Angus, *Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD* 2008.
Malpezzi, Stephen and Stephen K. Mayo, "Getting Housing Incentives Right: A Case Study of the Effects of Regulation, Taxes, and Subsidies on Housing Supply in Malaysia," *Land Economics*, 1997, *73* (3), 372–391.
Nickell, Stephen J, "Biases in Dynamic Models with Fixed Effects," *Econometrica*, November 1981, *49* (6), 1417–1426.
NY Times, *South Korea Joins Rush to Build Ever Taller Buildings* 2011.
— , *Seven Leading Architects Defend the World's Most Hated Buildings* 2015.
OECD, *OECD.Stat* 2020.
— , *OECD.Stat* 2021.
Orlando, Anthony W. and Christian L. Redfearn, "Lost in the Aggregate: Lessons from a Local Index of Housing Supply Elasticities," Technical Report 2019.
Pagani, M., J. Garcia-Pelaez, R. Gee, K. Johnson, V. Poggi, R. Styron, G. Weatherill, M. Simionato, D. Vigano, L. Danciu, and D. Monelli, *Global Earthquake Model (GEM) Seismic Hazard Map (version 2018.1 - December 2018)* 2018.
Quigley, John M. and Steven Raphael, "Regulation and the High Cost of Housing in California,"

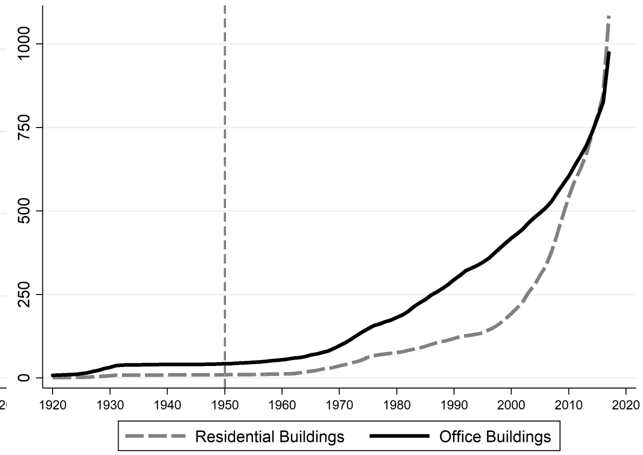
American Economic Review, May 2005, *95* (2), 323–328.
Redfearn, Christian L., "Do Housing Markets Value History? It Depends Submarkets and Their Impact on Assessing Historic Preservation Zones," Technical Report 2019.
Romer, Paul, *Cities Need to Make Room* 2020.
Rosenthal, Stuart and William Strange, "The attenuation of human capital spillovers," *Journal of Urban Economics*, 2008, *64* (2), 373–389.
Rosenthal, Stuart S. and Stephen L. Ross, "Change and Persistence in the Economic Status of Neighborhoods and Cities," in Gilles Duranton, J. V. Henderson, and William C. Strange, eds., *Handbook of Regional and Urban Economics*, Vol. 5 of *Handbook of Regional and Urban Economics*, Elsevier, 2015, chapter 0, pp. 1047–1120.
Saiz, Albert, "The geographic determinants of housing supply," *The Quarterly Journal of Economics*, 2010, *125* (3), 1253–1296.
Saks, Raven E, "Job creation and housing construction: Constraints on metropolitan area employment growth," *Journal of Urban Economics*, 2008, *64* (1), 178–195.
Scicolone, Maria, *Developing Skyscraper Districts: La Defense* 2012.
Shangguan, Wei, Tomislav Hengl, Jorge Mendes de Jesus, Hua Yuan, and Yongjiu Dai, "Mapping the global depth to bedrock for land surface modeling," *Journal of Advances in Modeling Earth Systems*, 2017, *9* (1), 65–88.
Stewart, Peter, *Height vs. history Tall buildings in the heart of London* 2016.
The Conversation, *Taming wild cities: the tall buildings of Australia show why we need strong design guidelines* 2019.
The Economist, *Democracy Index 2018: Me too? Political participation, protest and democracy* 2018.
The Irish Times, *Ugly, dated Dublin: Learning to love our concrete jungle* 2019.
TomTom, *TomTom Traffic Index* 2019.
Turner, Matthew A, Andrew Haughwout, and Wilbert Van Der Klaauw, "Land use regulation and welfare," *Econometrica*, 2014, *82* (4), 1341–1403.
UN-Habitat, *World Cities Report: The Value of Sustainable Urbanization* 2020.
UNESCO, *World Heritage List* 2020.
United Nations, *World Urbanization Prospects: The 2018 Revision* 2018.
V., Rafael A. Irizarry Kiang Mathew and Caroline O. Buckee, "Every Body Counts: Measuring Mortality From the COVID-19 Pandemic," *Annals of Internal Medicine*, 2020, *173* (12), 1004–1007.
Vogel-Misicka, Susan, *Towering over Switzerland: The high-rise trend* 2011.
Wang, Aaron J, "The Evolution of Seismic Engineering and Design of Ultra Tall Buildings in China Innovations and Sustainability," *International Journal of High-Rise Buildings*, 2016, *5* (3), 221–232.
WHO, *Estimation of population mortality in crisis-affected populations: Guidance for humanitarian coordination mechanisms* 2018.
— , *Global Ambient Air Quality Database* 2019.
Wikipedia, *List of countries by home ownership rate* 2020.
— , *List of Notable Architects* 2020.
— , *Owner Occupancy* 2020.
— , *Timeline of City X* 2020.
— , *Urban planners by nationality* 2020.
Wooldridge, Jeffrey M, *Introductory econometrics: A modern approach*, Nelson Education, 2016.
World Bank, *World Development Report: Reshaping Economic Geography* 2009.
— , *The Cost of Air Pollution : Strengthening the Economic Case for Action* 2016.
— , *World Development Indicators* 2018.
— , *International Comparison Program* 2019.
— , *World Development Indicators* 2019.
— , *World Governance Indicators* 2021.
Wu, Jing, Joseph Gyourko, and Yongheng Deng, "Evaluating the risk of Chinese housing markets: What we know and what we need to know," *China Economic Review*, 2016, *39*, 91–114.

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

(a) Tall Building Heights, World vs. the U.S.

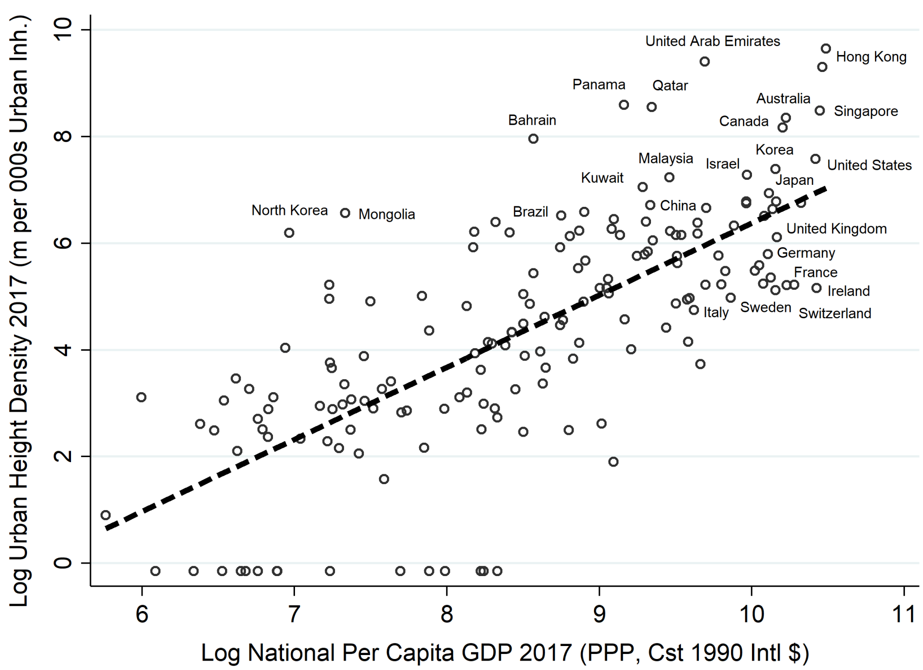


(b) Residential vs. Office Heights, World



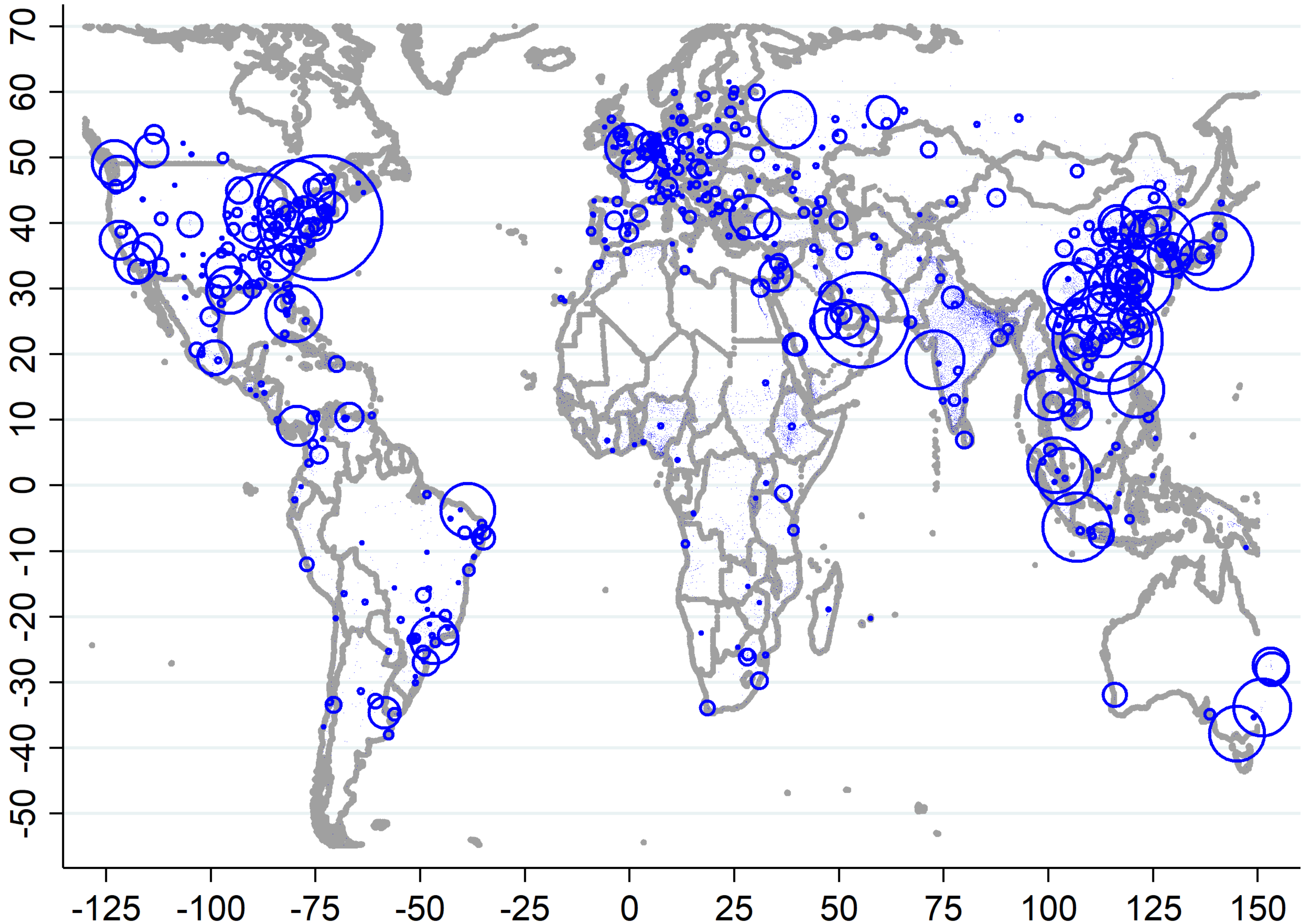
Notes: Subfigure 1(a) shows the evolution of the stock of tall building heights (m) for both the world and the United States from 1869 to 2017. Subfigure 1(b) shows the world evolution of the stock of tall building heights (m) separately for residential and office buildings from 1920 to 2017. The dashed 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



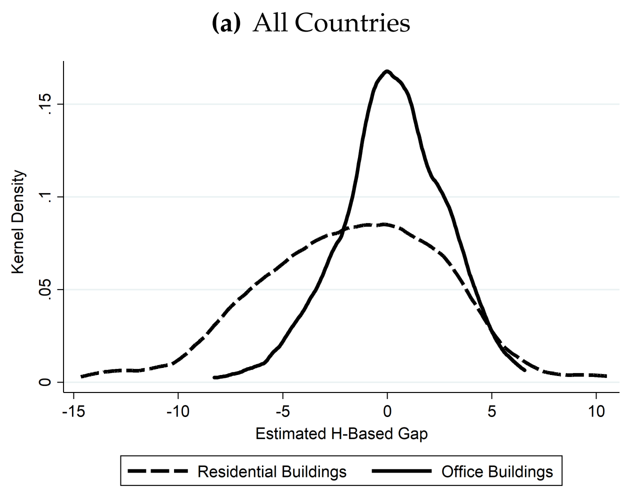
Notes: This figure shows the relationship between the log sum of tall building heights per urban capita (m per inh.) and log per capita GDP (PPP, constant 1990 international $) for 170 countries circa 2017.

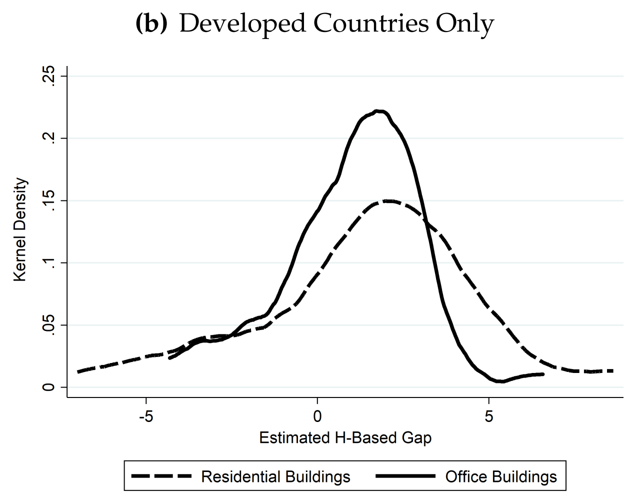
Figure 3: Absolute Change in the Total Sum of Tall Building Heights (Km) 1950-2020



Notes: This figure shows for 11,719 agglomerations of at least 50,000 inhabitants in 2015 the absolute change in their total stock of tall building heights (km) between 1975 and 2015. Mean = 3.60 (km); Median = 0.45; SD = 11.19; Min = 0.08; Max = 145.41.

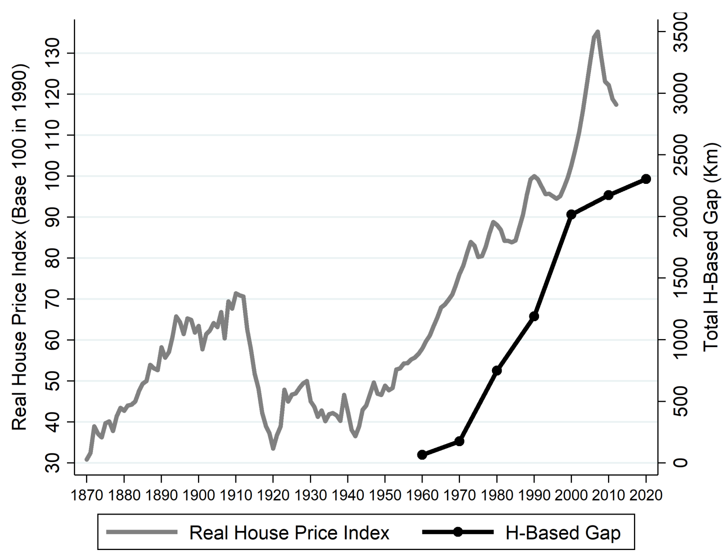
Figure 4: GLOBAL DISTRIBUTION OF THE RESIDENTIAL AND OFFICE GAPS, 2020





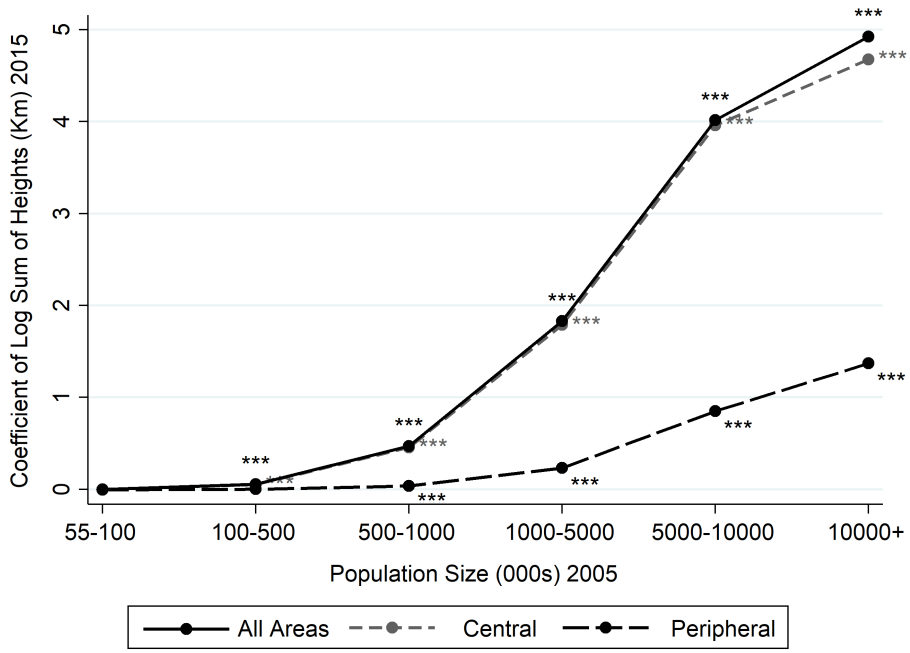
Notes: Subfigure 4(a) shows for the 158 countries of our sample circa 2020 the Kernel distributions of the H-based percentage-change gaps separately for residential buildings and office buildings. Subfigure 4(b) shows the same Kernel distributions for 47 developed (i.e., high-income) countries as of 2020.

Figure 5: HOUSE PRICES & BUILDING-HEIGHT GAPS, 14 COUNTRIES, 1870-2020



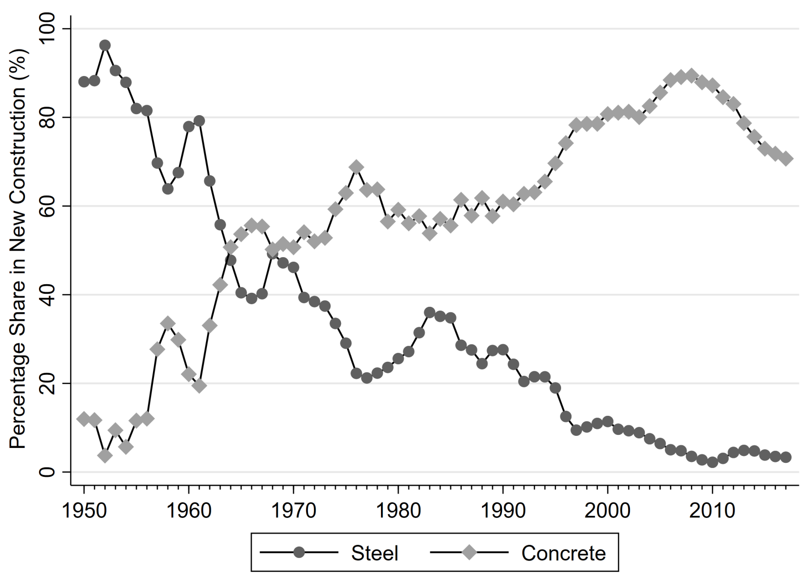
Notes: This figure shows that real house prices have dramatically increased in developed countries since the 1950s (we use the data from Knoll et al. (2017)). It also shows that the estimated total km (H-based) gap of the 14 countries has increased since 1960. More precisely, Knoll et al. (2017) reports 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 6: CITY BUILDING HEIGHTS-POPULATION RELATIONSHIP, 2015



Notes: This figure shows for 11,719 agglomerations of at least 50,000 inhabitants in 2015 the relationship between the log sum of tall building heights (km) and the population size category (the omitted category is 50,000-55,000) ca. 2015. The 11,719 agglomerations in 2015 belong to 158 countries.

Figure 7: STEEL VS. CONCRETE IN NEW CONSTRUCTION, 1950-2017



Notes: This figure 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.

Table 1: INCOME AND LAND RENT AND BUILDING 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	Office $\geq$ p75 DemUMH	DemH
LUPCGDP$_t$	0.49***	0.68***	0.37***	1.54**	3.23***	1.54***	2.66***	1.79**	1.61
	[0.10]	[0.10]	[0.16]	[0.67]	[0.61]	[0.34]	[0.47]	[0.55]	[1.32]
LAGRENT$_t$	0.13	0.30**	-0.06	0.55**	0.19	0.58**	0.40	0.47	0.28
	[0.09]	[0.13]	[0.10]	[0.26]	[0.40]	[0.22]	[0.42]	[0.31]	[0.61]
LUHTDENS$_{t-10}$	0.48***	0.46***	0.39***	0.46***	0.18	0.47***	0.45***	0.34*	0.40*
	[0.03]	[0.04]	[0.03]	[0.11]	[0.12]	[0.09]	[0.11]	[0.16]	[0.20]
Cntry FE, Yr FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,106	511	595	98	56	119	56	70	49
Countries	158	73	85	14	8	17	8	10	7
Adjusted R2	0.79	0.80	0.76	0.87	0.91	0.80	0.86	0.84	0.83

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 selection residual: 0 and the 75th percentile. Col. (6)-(7) & (8)-(9): We study residential buildings and office buildings, respectively. Robust SEs clustered at the country level: * p<0.10, ** p<0.05, *** p<0.01.

Table 2: 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: Col. (1) & (3): The gap is the percentage change in urban height density required to make the height stock similar to the selected benchmark set of countries (e.g., 4.88 means 488%). Col. (2) & (4): The gap is expressed in km of heights per million urban capita.

Table 3: THE GAPS AND ECONOMIC DEVELOPMENT, 2020

Dependent Variable:	H-Based Pct-Change Gap 2020			UMH-Based Pct-Change Gap 2020		
Considered Gap:	(1) All	(2) Resid.	(3) Office	(4) All	(5) Resid.	(6) Office
LPCGDP 2020	1.88***	2.48***	0.62**	0.97***	0.92***	0.69**
	[0.20]	[0.27]	[0.26]	[0.32]	[0.33]	[0.32]
Observations	158	158	158	158	158	158
R-squared	0.58	0.55	0.10	0.16	0.12	0.09

Notes: LPCGDP 2020 is log national per capita GDP (PPP, cst 1990 intl $) in 2020. Columns (2)-(3) and (5)-(6): We consider the gaps based on residential buildings (Resid.) or office buildings (Office) only. We use urban population weights (2020). Robust SEs.

Table 4: POSSIBLE DETERMINANTS OF THE GAPS, 2020

Dependent Variable: Pct Change-Change Gap 2020 (1st Column = H-Based; 2nd Column = UMH-Based)										
RHS:	A Log Const Cost		B Log Lend Rate		C Fin Inst Dvt		D Log Earthquake		E Log Bedrock	
β	-0.11	-0.37	-0.09	-0.52	-0.98	-1.58	0.38	0.77	-0.63	-0.77
	[0.41]	[0.50]	[0.40]	[0.55]	[1.40]	[2.27]	[0.49]	[0.64]	[0.46]	[0.64]
Obs.	144	144	114	114	147	147	156	156	158	158
RHS:	F Share Mountain		G Log Foundation		H Pop Sh. 1800		I Pop Sh. 1950		J WW2 Sh. Bomb	
β	0.00	-0.00	0.92***	1.42***	0.11*	0.15*	-0.01	-0.00	0.32	1.41**
	[0.02]	[0.02]	[0.25]	[0.29]	[0.06]	[0.08]	[0.00]	[0.01]	[0.49]	[0.68]
Obs.	158	158	158	158	158	158	158	158	158	158
RHS:	K WW2 Mort Rate		L Log Cult WHS		M Log Mix WHS		N Log Nat WHS		O Log Tourists	
β	-0.01	-0.02	0.51**	0.64*	-0.69*	-1.01*	-1.08***	-1.84***	-0.37	-0.28
	[0.06]	[0.10]	[0.25]	[0.38]	[0.39]	[0.54]	[0.28]	[0.38]	[0.33]	[0.24]
Obs.	158	158	157	157	157	157	157	157	152	152
RHS:	P Max FAR		Q Quality Ctrl		R Hous P. Ela.		S Speed Hous S.		T Democracy	
β	-0.13***	-0.20**	0.04**	0.04	-1.00	-0.60	-2.54*	-1.05	0.12	0.20
	[0.01]	[0.02]	[0.02]	[0.02]	[0.67]	[0.39]	[1.28]	[0.99]	[0.62]	[0.88]
Obs.	49	49	155	155	21	21	21	21	158	158
RHS:	U Polity Score		V Rule of Law		W Ctrl Corrupt.		X Log Urb Plan.		Y Home Own.	
β	0.03	0.02	0.29	0.19	-0.07	-0.34	0.22	0.02	0.02	0.01
	[0.05]	[0.07]	[0.36]	[0.56]	[0.24]	[0.42]	[0.22]	[0.32]	[0.02]	[0.01]
Obs.	156	156	157	157	157	157	158	158	105	105

Notes: This table shows the correlations between the H-based gaps (1st column of each panel) or the UMH-based gaps (2nd column) and various potential determinants of the gaps. We always control for log national per capita GDP (PPP, cst 1990 intl $) ca. 2020 and use urban population weights. Each coefficient corresponds to a separate regression. Robust SEs: * p<0.10, ** p<0.05, *** p<0.01.

Table 5: DETERMINANTS OF THE GAPS, SIMULTANEOUS INCLUSION, 2020

Dep. Var.:	H-Based Pct Change-Change Gap 2020					UMH-Based Pct Change-Change Gap 2020				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log Yrs Founded	0.84***			1.23**	0.90***	1.29***			2.05***	1.46***
	[0.23]			[0.53]	[0.31]	[0.26]			[0.59]	[0.37]
Log Cultural WHS		0.51**		-0.59			0.64*		-1.05	
		[0.25]		[0.55]			[0.38]		[0.68]	
Max FAR			-0.12***	-0.11***	-0.14***			-0.19***	-0.17**	-0.21***
			[0.04]	[0.04]	[0.04]			[0.06]	[0.07]	[0.06]
Obs.	157	157	49	49	49	157	157	49	49	49
R-squared	0.69	0.63	0.58	0.68	0.68	0.46	0.29	0.29	0.56	0.53

Notes: This table shows the correlations between the H- or UMH-based gaps and various potential determinants of the gaps. We always control for log national per capita GDP (PPP, cst 1990 intl $) and log total pop. ca. 2020 and use urban pop. weights. Robust SEs.

Table 6: GAPS AND LAND USE REGULATIONS, 2020

Dependent Variable:	H-Based Gaps		UMH-Based Gaps		Corr w / Max FAR
	(1)	(2)	(3)	(4)	(5)
Maximum Floor Area Ratio (FAR)	-0.13***	-0.19***	-0.20**	-0.27**	
	[0.006]	[0.003]	[0.016]	[0.014]	
Dummy Green Belt (GB)		-0.67		-0.83	-0.15 n.s.
		[0.448]		[0.527]	
Dummy Urban Growth Boundary (UGB)		-1.46*		-1.38	-0.12 n.s.
		[0.053]		[0.208]	
Dummy Full or Partial Zoning		0.63		1.04	-0.03 n.s.
		[0.376]		[0.405]	
Dummy Gvt Land Acquisition		0.68		0.83	-0.09 n.s.
		[0.272]		[0.421]	
Dummy Min Plot Size Regulation		-2.02**		-2.43*	-0.20 n.s.
		[0.027]		[0.085]	
Observations	49	49	49	49	49
R-squared	0.51	0.66	0.12	0.28	_

Notes: Columns (1)-(2) and columns (3)-(4) show the conditional correlation between the H-based gaps and the UMH-based gaps and the maximum FAR values and the values of the other land-use policy variables. Column (5) shows the individual conditional correlations between the maximum FAR values and the values of the other land-use policy variables. We control for log national per capita GDP in 2020 and use urban pop. weights (2020). Robust SEs: n.s. (not significant) $p>0.10$, * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 7: GAPS AND ECONOMIC OUTCOMES, COUNTRY-LEVEL ANALYSIS

Dep. Var.:	World Bank '11 Price Level (100) Housing	World Bank '11 Price Level (100) Transp.	Global Prop. Guide'19 Log Hous Price ($)	Global Prop. Guide'19 Price-to-Rent	Knoll et al 2017 Real Hous. Price t Long-Diff	Knoll et al 2017 Real Hous. Price t Short-Diff	Share Public Housing
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gaps_H	3.99***	-1.50	0.24***	3.51***	28.78*	14.78**	-0.08
	[1.33]	[1.34]	[0.04]	[0.84]	[14.38]	[6.48]	[0.87]
Gaps_{UMH}	3.32***	-0.67	0.18***	2.78***	13.27	8.33	0.29
	[1.19]	[1.30]	[0.04]	[0.60]	[16.62]	[6.01]	[0.61]
Country, Year FE	N	N	N	N	Y	Y	N
Controls, Weights	Y	Y	Y	Y	N	N	Y
Observations	147	147	72	70	28	83	48

Dep. Var.:	Col. (8)-(12): Log Total Urban Land Area (Km) in ... World Bank '11	Col. (9)-(10): GHS t Long-Diff	Col. (9)-(10): GHS t Short-Diff	Ctrl: Built-Up Area t Long-Diff	Ctrl: Built-Up Area t Short-Diff	Log Particulate Matter Level (PM) 10 ('10)	Log Particulate Matter Level (PM) 2.5 ('17)
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Gaps_H	0.19***	0.05**	0.03**	0.04*	0.02*	0.05**	0.07**
	[0.03]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.03]
Gaps_{UMH}	0.22***	0.06***	0.03**	0.05*	0.02*	0.05**	0.08***
	[0.04]	[0.02]	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]
Country, Year FE	N	Y	Y	Y	Y	N	N
Controls, Weights	Y	Y	Y	Y	Y	Y	Y
Observations	125	262	524	262	524	146	156

Notes: Columns (1)-(4), (7)-(8), and (13)-(14): See text for details on the specifications. Columns (5)-(6): Panel regressions for 14 countries in 1960-2010 (1960, 1970, 1980, 1990, 2000, 2010). Long-diff: We consider the first and last years only. Columns (9)-(12): Panel regressions for 131 countries in 1975-2015 (1975, 1990, 2000, 2015). Long-diff: We consider the first and last years only. Robust SEs (clustered at the country level when using panel regressions in columns (5)-(6) and (9)-(12)): * p<0.10, ** p<0.05, *** p<0.01.

Table 8: GAPS AND ECONOMIC OUTCOMES, CITY-LEVEL ANALYSIS

Dep. Var.:	Log Sum of Heights in Year t				Log Area in Year t		Congestion Level 2017	Log PM'17	
			Central Areas	Periph. Areas				10	2.5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: H Gaps:									
𝟙(100-500K)*Gap	-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]
𝟙(500-1000K)*Gap	-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]
𝟙(1000K+)*Gap	-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]
Panel B: UMH Gaps:									
𝟙(100-500K)*Gap	-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]
𝟙(500-1000K)*Gap	-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]
𝟙(1000K+)*Gap	-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, Year FE	Y	Y	Y	Y	Y	Y	N	N	N
Country-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	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 (7)-(9): See text for details on the specifications. Columns (1)-(6): Panel regressions for 11,719 50K+ GHS urban agglomerations in 1975-2015 (1975, 1990, 2000, 2015). We interact the country-level gaps with three city population category dummies defined in 1975 (50-100K is the omitted category). Robust SEs clustered at the country level: * p<0.10, ** p<0.05, *** p<0.01.