THE ROLE OF CORRUPTION IN SKYSCRAPER DEVELOPMENT

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Abstract. Despite the global boom in skyscraper development, the drivers of skyscraper development are still somewhat poorly understood. In particular, recent research raises the question of whether non-economic factors also determine the decision to build skyscrapers. Some researchers have conceptualized the skyscraper as an expensive and socially wasteful "white elephant" project and suggested an association between corruption and skyscraper developments. This study conducts research into the role of corruption in the development of skyscrapers and hypothesizes that a low control of corruption allows to more easily realize such projects. The skyscraper data is drawn from a global dataset recording various features of skyscrapers for over 50 developed and emerging countries worldwide and the corruption data is drawn from an established corruption index. The results show that skyscraper development diffused from the least corrupt countries to more corrupt countries between 1996 and 2019. In addition, a relation between the control of corruption and skyscraper development is also found, although a positive one for all countries and a negative one for emerging market countries. This means that worldwide a decrease of corruption increases skyscraper developments, while in emerging market countries a decrease of corruption results in a decrease of skyscraper development. The role of corruption in skyscraper development thus depends on the stage of development of a country. Finally, given the severity of corruption and the fact that major capital and power is involved in the development of skyscrapers, this study's findings further underline the importance of making corruption a more central element in both real estate theory and practice.

Keywords: skyscrapers, corruption, real estate development, economic determinants, non-economic determinants

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1. Introduction

Nowadays, the sky is the limit - at least that might come across as a message when reviewing high-rise buildings internationally (Block, 2020; Glaeser, 2011). From New York City, to Rotterdam, Dubai, Lyon, Panama City, Shenzhen, Nairobi, city skylines have become denser, higher and more diverse (Al-Kodmany, 2018; Drozdz, Appert & Harris, 2018). Since the nineties, the skylines of Asian cities are most expanding, leading to a shift in the centre of gravity from the United States to Asia (Ahlfeldt, 2020; Michaelson, 2014). Globally, the ranks are about 'more' and 'higher', while we wait for the 21st century's new global icon of over a kilometre high – the Dubai Creek Tower – to finish development (Block, 2020). But while the skyscraper is 'a hallmark of 21st century', its development has not followed a single universal pattern and the drivers of skyscraper development are still somewhat poorly understood (Nethercore, 2018, p.657).

The existing body of research concentrates mainly on the economics of skyscrapers, making 'skynomics' - the study of skylines and skyscrapers using modern economics methods - an emerging field of research on its own (Honorée, Morgan & Krenn, 2018). The seminal works in this field are Barr's contributions, mainly from the United States, which conceptualise skyscraper development as a strategic and economic decision by the developer, influenced both by the developer (motives: profit and status) and the consumer's utility derived from height (Barr, 2008; Barr, 2012; Barr, 2013; Barr, Mizrach & Mundra, 2015). Worldwide, Ahlfeldt (2020) provides a synthesis of the state of knowledge on the economics of skyscrapers and other researchers delve deeper into regions or submarkets when examining the economics of skyscrapers (Barkham, Schoenmaker & Daams, 2017; Koster, van Ommeren & Rietveld, 2014). Nevertheless, recent research raises the question of whether other, non-economic factors also determine the development of skyscrapers.

Recently, several studies have begun to recognise and explore non (traditional) economic factors as drivers of skyscraper development. The line of reasoning is that the decision to build a skyscraper and its height might also be driven by motives other than purely economic consideration alone. For example, lately, cultural/institutional environments (Honorée et al., 2018), political regimes (Gjerløw & Knutsen, 2017) and regulatory stringency (Jedwab, Barr & Brueckner, 2020) are hypothesized to play a part in skyscraper development and are empirically tested. After all, the differences in the distribution of tall buildings reflect different positions within the economic hierarchy across nations but cannot be explained by these alone. These geographical differences worldwide appear to be a continuing trend worthy of investigation (Honorée et al., 2018).

A non-economic factor that has not been empirically investigated before is the role of corruption in skyscraper development. Although corruption exacts a heavy toll on the spatial development in many cities worldwide, there is 'a glaring lack of empirical studies on this phenomenon and how it affects the urban planning domain in particular' (Chiodelli, 2019, p. 1623). Michaelson (2014) is, to my knowledge, the first and last one to explicitly question the implications of skyscraper competition for global ethics. He mentions that 'skyscraping ambitions invite ethical criticism about misplaced priorities' (p. 20).

Some researchers take a critical look at the development of skyscrapers worldwide indeed. Gjerløw and Knutsen (2017) consider the skyscraper as a type of modern-day 'white elephant'. Skyscrapers are impressive modern structures, considered (internationally) prestigious and they have their own aesthetic and symbolic importance bringing international attention and legitimacy (in a similar fashion to the palaces and churches of older days) (Barr, 2012; Gjerløw & Knutsen, 2017). Admittedly, the cost-effectiveness of skyscrapers depends on a range of factors, yet, building a very tall skyscraper is, in general, very costly. For example, the Jeddah Tower was projected to cost about 1.2 billion dollars, while the total annual public expenditures for a country such a Rwanda (in 2014) was equivalent to this sum (a back-of-the-envelope calculation by Gjerløw & Knutsen, 2017). The tower is rising in Jeddah, a city in which basic infrastructure is lacking and where floods led to destruction and the death of over 500 people in 2009, merely because of the absence of a basic drainage system; 'Jeddah is a great example of corruption' (Al-Ahmed, 2009; Michaelson, 2014). In their sum, skyscrapers are considered white, or at least whitely shaded, elephants as they are expensive, often cost-inefficient and socially wasteful projects with a power-projecting purpose (Gjerløw & Knutsen, 2017; Robinson & Torvik, 2005; Shariatmadari, 2013).

But then how and why can these white(ly shaded) elephant projects be realised? Herein the role of corruption might provide an answer. Gjerløw and Knutsen (2017) state that one straightforward answer is that these projects could enhance political leader's (private) utility. They 'may prefer building skyscrapers in order to physically display the country's – and by extension its leadership's – wealth, power and capabilities' (p. 6). To build upon the example already given, the creator and leader of the Jeddah Tower is the Saudi Arabian prince and Gjerløw and Knutsen (2017) provide evidence that cost-inefficient skyscrapers are often built or part-financed by states or by actors with access to public resources. In general, the development industry has always been seen as highly dependent upon collaboration (and sometimes collusion) between the private and public sectors and is regarded by reputation as being vulnerable to corruption (Chiodelli & Moroni, 2015; Michaelson, 2014). Nevertheless, planning theorists have rarely tackled the issue of corruption directly and thoroughly, and not Michaelson nor others test these hypotheses about corruption and skyscrapers empirically.

This study will test these claims made by the ethical criticasters and considers their notion of the skyscraper as expensive and socially wasteful "white elephant" project. It is hypothesized that (1) a low control of corruption allows to more easily realize skyscrapers and that, under the assumption that emerging countries are less resistant to corruption, (2) corruption and skyscrapers development are even more associated in emerging markets. After all, Michaelson (2014) specifies his ethical criticism by stating: '*The recent history of the skyscraper is a product and symbol of industrial advancement, and thus provides a window on the world through which to examine some of the most important ethical challenges arising from economic growth in developing markets. These challenges include such tangible issues as corruption, for which opportunities and incentives multiply as markets grow in size and complexity*' (p. 21). Indeed, developing countries seem to be plagued by extreme resource misallocation (Robinson & Torvik, 2005). However, the widespread corruption in emerging economies is not because the people there are different from people elsewhere, but because the conditions 'are ripe for it' (Gray & Kaufman, 1998, p2). In other words, public officials with a high control of corruption are better constrained from enhancing their (private) utility, whether monetary or symbolic (a prestige project), and thus constrained to realise skyscraper projects, the line of reasoning is.

This paper is the first to empirically test the suggested associations between corruption and skyscrapers. The aim of this paper is to explore the role of corruption in realised skyscraper developments, globally and in emerging markets in particular. Data for the empirical analyses is drawn from the online archive of skyscrapers worldwide by The Skyscraper Center (CTBUH, 2020) which allows me to associate the number of skyscrapers per country with control of corruption, one of the Worldwide Governance Indicators (Worldbank, 2021). The data has been plotted and visualized in graphs and multiple regression specifications were programmed in STATA SE 16.0. Firstly, the skyscraper stock of 2019 is analysed to get a first, more general, impression of the association between control of corruption and skyscrapers developed. Secondly, the change in skyscraper stock between 1996 and 2019 and the role of corruption over these years will be analysed. This is as time plays an important role in the development of skyscrapers and to investigate whether the role of skyscraper development changed over the years. Thirdly, and lastly, a panel regression model is used to analyse the role of corruption in the development of skyscrapers within emerging market countries in particular. With these multiple regression analyses the aim of this research can be met as these analyses draw conclusions about individual predictor variables; i.e. can draw conclusions about the role of corruption in realised skyscraper developments.

This way, the study has both societal and academic relevance. On the one hand, it contributes to societal debates about corruption and/or skyscrapers, which both have an impact on societies all over the world. On the other hand, the study contributes to the scarce body of literature into non-economic determinants of skyscraper development and to the scarce body of literature on corruption in real estate, by providing insights into the role of corruption in skyscraper development.

2. Methods and data

2.1 Multiple regression specifications

To explore the role of corruption in realised skyscraper developments multiple regression specifications were formulated and estimated in STATA SE 16.0. Multiple regression analysis is one of the most widely used statistical procedures and popular because of its applicability, ease of interpretation and robustness to violations of the underlying assumptions (Mason & Perreault Jr, 1991). This application is in line with previous research into the determinants of skyscraper development which also adopts (multiple) regression analyses (Barr, 2012; Barr & Luo, 2018; Gjerløw & Knutsen, 2017; Honorée et al., 2018; Jedwab et al., 2020). The aim of this research can be met as this analysis can draw conclusions about individual predictor variables; i.e. can draw conclusions about the role of corruption in realised skyscraper developments. Further methodological detail, descriptive statistics, VIF calculations and test results, including the Breusch and Pagan Lagrangian multiplier test results and Hausman test results, can be found in Appendix 5.

To get a first understanding of the role of corruption in skyscraper development, the *first* specification analyses the most recent skyscraper stock (model specification (1), with the (natural logarithm of the) skyscraper stock in 2019 as dependent variable) (see appendix 4. for descriptive statistics). The multiple regression analysis run on this cross-sectional dataset makes it possible to estimate the relationship between corruption and skyscraper development, while controlling for other variables (Field, 2013). This analysis can reveal whether corruption acted on skyscraper development regardless of time, as all skyscrapers ever developed till 2019 are included in the dependent variable.

$$\ln(\text{Skyscrapers}) = \alpha_0 + \beta_1 \text{Corruptiondum}_i + \beta_2 \text{LGDPC}_i + \beta_3 \text{LPOP}_i + \beta_4 \text{LPD}_i + \beta_5 \text{UP}_i + \beta_6 \text{GDPCG}_i + \beta_7 \text{UPG}_i + \beta_8 \text{EU}_i + \varepsilon_i \quad (1)$$

where i = country; α = the constant/intercept; β_1 to β_8 = the regression coefficients for the independent and control variables; ε = the residual or error in predicting the sample data.

With this analysis the first hypothesis can be tested: a low control of corruption allows to more easily realize skyscrapers. Thus, a significant and negative coefficient for the control of corruption variable (*Corruptiondum*) is expected. If that hypothesis cannot be rejected, countries with a higher control of corruption are associated with a smaller skyscraper stock in 2019. The control variables are less of interest, but are expected to be significant and positive (GDP per capita, population total, population density, urban population and GDP per capita growth, respectively) or negative (whether the country is European: if a country is in Europe its number of skyscrapers decreases) based on previous research (see 2.4 Control variables for expectations and sources).

The *second* specification analyses the role of corruption in the skyscraper stock developed between 1996 and 2019. The skyscraper stock and its geographic gravity are said to be changing and therefore the recent drivers of skyscraper development might be different as well. To examine these changes and to create more robust and thoroughly test results the second specification attempts to explain the change in skyscraper stock over an as extended timeframe as possible: from 1996 to 2019. The results of this specification will reveal whether the role of corruption changed in the last 23 years compared to the whole skyscraper stock in 2019 analysed with the previous specification. The specification analyses the (natural logarithm of) change in skyscraper stock over the last 23 years (model specification (2)).

$$\ln(\text{dSkyscrapers}) = \alpha_0 + \beta_1 \text{Corruptiondum}_i + \beta_2 \text{LGDPC}_i + \beta_3 \text{LPOP}_i + \beta_4 \text{LPD}_i + \beta_5 \text{UP}_i + \beta_6 \text{GDPCG}_i + \beta_7 \text{UPG}_i + \beta_8 \text{EU}_i + \varepsilon_i \quad (2)$$

where i = country; α = the constant/intercept; β_1 to β_8 = the regression coefficients for the independent and control variables; ε = the residual or error in predicting the sample data.

With this analysis the first hypothesis - a low control of corruption allows to more easily realize skyscrapers - can be substantiated. More specifically it tests whether a low control of corruption allowed to more easily realize skyscrapers over the last 23 years. Thus, again, a significant and negative coefficient for the control of corruption variable (*Corruptiondum*) is expected. The control variables are less of interest, but are expected to be significant and positive (and negative for the European dummy) based on previous research (see 2.4 Control variables for expectations and sources), the same as for model specification (1).

The *third* specification analyses the role of corruption in emerging market countries (see appendix 4. for descriptive statistics). It is a panel regression to increase the number of observations and to make it possible to generate a more efficient estimation for the emerging market countries[1]. This specification adopts 'the number of skyscrapers developed per country, per year' as dependent variable (model specification (3)). A main strength of the panel regression is the ability to analyse data with the dimensions of both time series and cross-sections (Brooks & Tsolacos, 2010). This specification thus consists of both time and country fixed effects, to account for omitted time fixed effects (λ_t) and country fixed effects (μ_i). For example building technology might have increased over time, or geographical characteristics of a country are not included. The use of a panel enables this study to examine in more detail the adjustment process of the dependent variable (skyscrapers developed) in response to changes in the values of the independent variables (changes in the control of corruption) within a country (Brooks & Tsolacos, 2010). This will show whether changes in control of corruption in a country influenced the development of skyscrapers three years later[2].

[1] The S&P index consists of 14 emerging market countries and the MSCI index of 20 which are too few observations to interpret the results efficiently (Baltagi, 2013). The panel dataset, however, includes observations between 2005 and 2019, increasing the observations to 195 and 285 respectively. Earlier observations were not included as the WGI measured the control of corruption annually only as of 2002 and considering the three years lag 2005 is the earliest data to analyse the data systematically.

[2] An important detail of this third panel data specification concerns the need to lag the right-hand side (RHS) variables. After all, it is important to realise that it takes time to build a skyscraper and adding a lag accounts for the time between the decision to build and the completion of a skyscraper. Gjerløw and Knutsen (2017) analysed the available development time of skyscrapers over 150 meter from the CTBUH. They concluded that for almost the entire time-period, the typical skyscraper took between 3 and 4 years to develop. Their main specifications resulted in a 3 year lag for all independent variables. Barr's rationale to lag for less years is not substantiated despite the fact that he does so in several of his studies: one or two years in Barr (2012), two or three years in Barr (2013) and again one or two years in Barr and Luo (2018). Taken all together, the RHS variables in the third model are lagged three years to account for the time between deciding on a building project and it being finalized.

This dataset consists of solely emerging market countries[3], however, the World Bank does not have a list of emerging markets anymore: 'The Emerging Markets database developed by the IFC was sold to Standard & Poor's a few years ago and can be found on Standard & Poor's website.' (The World Bank, ND). The emerging market countries used for further specification of the corruption analysis are thus based on Standard & Poor (Damak et al., 2021). A second selection of emerging markets is analysed to create more robust results. The comparison data stems from MSCI, an index provider annually reporting a market classification review by striking a balance between a country's economic development and the accessibility of its market while preserving index stability (MSCI, 2020; MSCI, 2021). MSCI is considered the reference benchmark for many markets (Saidi, Prasad & Naik, 2012).

$$
\begin{aligned}
\ln\left(\mathrm{L1Skyscrapers}_{i,t}\right) \quad & \quad (3) \\
= \; & \alpha_{0,i} + \beta_1 \mathrm{lagCorruptiondum}_{i,t-3} + \beta_2 \mathrm{lagLGDPCdum}_{i,t-3} \\
& + \beta_3 \mathrm{lagLPOP}_{i,t-3} + \beta_4 \mathrm{lagLPD}_{i,t-3} + \beta_5 \mathrm{lagUP}_{i,t-3} \\
& + \beta_6 \mathrm{lagGDPCG}_{i,t-3} + \beta_7 \mathrm{lagUPG}_{i,t-3} + \beta_8 \mathrm{EU}_{i,t-3} + \mu_i + \lambda_t + \varepsilon_{i,t}
\end{aligned}
$$

where i = country; α = the constant/intercept; β_1 to β_8 = the regression coefficients for the independent and control variables which are lagged three years; ε = the residual or error in predicting the sample data; t = time; μ_i = unobserved time-invariant heterogeneities across countries; λ_t = unobserved time effect.

With this last analysis the second hypothesis - corruption and skyscrapers development are even more associated in emerging markets - can be tested, while controlling for time and country specific omitted variables as well. Thus, again, a significant and negative coefficient for the control of corruption variable (*Corruptiondum*) is expected. Also, while the control variables are still less of interest, they are expected to be significant and positive based on previous research (see 2.4 Control variables for expectations and sources), the same as for model specification (1) and (2).

2.2 Skyscraper data

Data for the dependent variable – the number of skyscrapers developed per country – is drawn from the The Skyscraper Center. The database contains all known human developments taller than 150 meters (and some lower buildings) and is constantly updated by the Council for Tall

[3] The third specification has also been applied to all countries worldwide, including both emerging and non-emerging market countries. See appendix 6 for the details.

Buildings and Urban Habitats [CTBUH]. Data for this study was collected during the summer of 2020 via skyscrapercenter.info. Data on Country, City, Building Name, Use, Material, Freestanding, Completion, Status, Height (in meters and foot) and Floors has been distracted manually for all skyscrapers, regardless missing values. This resulted in a dataset of 17.936 observations.

Several selection criteria had to be met to make it to the final dataset. Observations missing either Height (2,336 observations) or Completion data (1,622 observations) were dropped. Only skyscrapers with the status 'Completed', 'Architecturally Topped Out' or 'Structurally Topped Out' were kept[4] (dropping 948 observations) as they are likely realised in the proposed year. Lastly, skyscrapers lower than 150 meter were dropped. This selection criteria dropped 8,497 observations but two reasons justify this. Firstly, because the CTBUH has only full coverage of these buildings and the selection criteria applied by the CTBUH of buildings lower than 150 meter is unclear. Secondly, in light of this study's focus, skyscrapers with a hight of above 150 meters are more costly to construct and more impressive structures. Hence, buildings exceeding 150 meters are more likely to constitute white elephant projects of theoretical interest than buildings of, say, about 100 meters (Gjerløw & Knutsen, 2017). The operationalisation of the skyscraper in this study is therefore a building of 150 meter or higher. After selecting skyscrapers based on these criteria, the dataset contained 4,370 observations (see appendix 1. for tabulations). While the first skyscraper was developed in 1884, the gravity of skyscraper development (mean) was about 2007 (see table 1 for descriptive statistics).

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Year of development	4370	2006.7	16.457	1884	2022
Height (meters)	4370	202.2	54.752	150	828
Floors	4226	49.3	11.619	1	163

The final step in preparing the dependent variable for regression was to investigate its skewness. In real estate modelling, it is quite often the case that one or two very extreme residuals cause a rejection of the normality assumption (Brooks and Tsolacos, 2010, p. 169). As can be imagined, the number of skyscrapers developed per year is (positively) skewed (see the plot in appendix 2.). Although a possible solution is to remove outliers, this was not done deliberately to avoid a bias in the selection of countries. In line with Barr and Luo (2018) and Gjerløw and Knutsen (2017), who have the same dependent variable with right-skewed nature, the natural logarithm of

[4] These remaining observations will be referred to as developed.

(change in number of skyscraper from one year to the next +1) was employed in regression estimation (3). Formally,

$$\ln\left(\Delta S_{i,t} + 1\right) = \ln(S_{i,t} - S_{i,t-1} + 1) \tag{4}$$

where S is the number of skyscrapers, i denotes the country, and t denotes the year.

2.3 Corruption as independent variable

Corruption is a complex political, social and economic phenomenon that is, in varying degrees, prevalent in all societies around the world. However, there is no international consensus on the definition of corruption and because of the many different facets of corruption it is hard to deliver a precise, comprehensive and objective measure for the phenomenon. Nevertheless, in recent years, indicators (mostly using perception surveys) have proved very useful in conducting statistical analysis and making cross-country comparisons (Rohwer, 2009).

Although long-run data on corruption is very limited, two non-governmental organizations have a history of measuring public sector corruption. One is the Corruption Perceptions Index (CPI), published by Transparency International (TI) since 1995 (Ortiz-Ospina & Roser, 2019). However, in 2012, the methodology used to construct the index was revised to allow for year-to-year comparison of scores. Thus observations from before 2012 are not fit to make comparisons and are therefore unfit for this study (Transparancy International, 2021). The other corruption data is provided by the Worldwide Governance Indicators (WGI) project from The World Bank (1996). They attempted to improve the CPI against the TI in several ways (Kaufmann, Aart & Massimo, 1999; Rohwer, 2009). This project reports aggregated and individual governance indicators for over 200 countries and territories for six dimensions of governance, including control of corruption. '[C]ontrol of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.' (Kaufmann et al., 2010). The scores (between -2,5, a very low control of corruption, and 2,5, a very high control of corruption) may vary from one year to another 'depending on many factors such as successful implementation of policies on public sector reforms and anticorruption plans.' (Apaza, 2009, p. 140). The WGI has become among the most widely-used indicators of governance by policymakers and academics[5] (Kaufmann et al., 2007). The control of corruption value from the WGI is an established corruption index and used as independent variable in this study.

[5] Nevertheless, see appendix 3 for a more detailed review of the WGI.

2.4 Economic and non-economic control variables

To strengthen the internal validity of this study, several key variables, which capture both economic and non-economic determinants of skyscraper development, were added to the model as control variables. These control variables capture both economic and non-economic determinants of skyscraper development which are thus likely to be correlated with the stock of skyscrapers. Therefore they are added to account for alternative explanations for the proposed hypotheses (Field, 2013). However, these variables are not of interest to the study's aim. Variables were selected based on their ability to predict variance in skyscraper development based on the literature in order to clearly identify the association between skyscrapers and corruption. (Control) variables recurring in multiple academic literature were included and supplemented with more rare (but rational and/or significant) determinators of skyscraper development in existing literature. To create a dataset large and as balanced as possible, control variables were in a degree also selected upon coverage. This resulted in the selection of three different economic determinants and four different non-economic determinants covering different alternative explanations of skyscraper development. All control variables were provided by the World Development Indicators and downloaded the first of March 2021 to reflect data as much up to date as possible.

<u>GDP per capita</u>

The first economic determinant which is controlled for in this study is income, measured as (PPP-adjusted) per capita Gross Domestic Product [GDPC]. Several studies discuss a relationship between GDPC and skyscrapers as higher income could improve the feasibility of skyscraper projects (Honorée, Morgan & Krenn, 2018; Gjerløw & Knutsen, 2017). It is hypothesized and showed significant that a higher GDPC drives up skyscraper height. The variable was transformed to the natural logarithm of population, for a more normal distribution, before included in the model (*LGDPC*). In the panel dataset, the variable did not meet the correlation threshold to rule out multicollinearity (see appendix 4.) therefore the variable was cut into four equal parts to dissolve for this problem (*LGDPCdummy*).

<u>GDP per capita growth</u>

The second economic control variable is the growth rate of per capita Gross Domestic Product (*GDPCG*). Consistent with the geographic shift, it is stated that economic growth has become a more significant determinant of vertical growth in absolute and relative terms (Ahlfeldt, 2020).

Population, total

The third economic determinant controlled for in this study is the population size of a country. Size, when measured in terms of population, clearly makes a difference to a nation's role and (economic) performance (Perkins & Syrquin, 1989). For example, the use of population size as an instrument is justified as a proxy for the realization of increasing returns through market size (Ades & Di Tella, 1999). In addition, Gjerløw and Knutsen (2017) include population size in their international skyscraper analysis and theorize that larger countries should contain more skyscrapers due to scale for area-intensive housing. The variable total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The variable was transformed to the natural logarithm of population before included in the model (*LPOP*).

Population density

The first non-economic control variable is population density (people per sq. km of land area). This variable provides information about the need and desire for a city to 'built up' due to pressure for area-intensive housing as it takes surface into account (as there is no variable surface area, multicollinearity is no issue) (Gjerløw & Knutsen, 2017). This variable is calculated as midyear population divided by land area in square kilometres. The variable was transformed to the natural logarithm of population density before included in the model (*LPD*).

Urban population

The second non-economic control variable is urban population (% of total population). The urbanisation rate might drive up the need, incentive and desire for a city to 'built up' as central land will become more valuable (Barr & Luo, 2018). Several studies already showed this relationship (Barr, 2012; Barr et al., 2015). The percentage urban population refers to people living in urban areas as defined by national statistical offices (*UP*).

Urban population growth

The third non-economic control variable is urban population growth (annual %) (*UPG*). As urbanization is an important factor, its growth rate capturing the urbanisation rate is as well as an increase in urban population puts even more pressure on the city (Ahlfeldt, 2020). According to Al-Kodmany (2018) the exponential increase in urban population worldwide has even become an increasingly important determinator. In addition, explosive growth of cities globally signifies the demographic transition from rural to urban and is associated with shifts from an agriculture-based economy to mass industry, technology, and service according to The World Bank (2021).

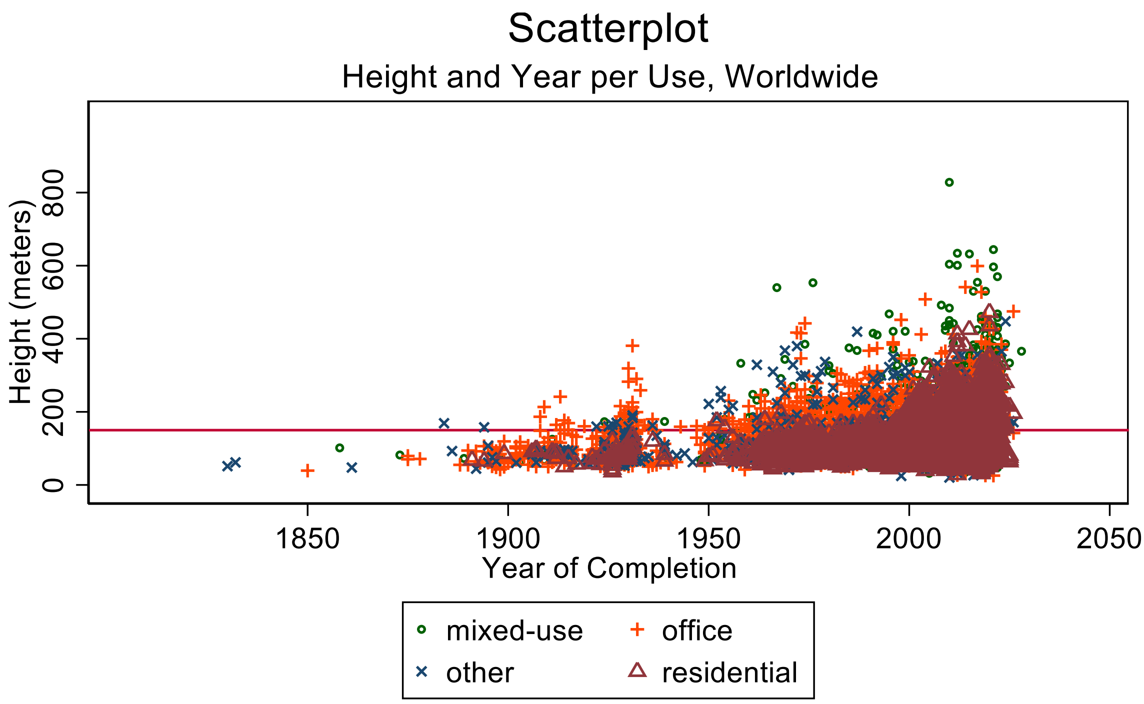
European country

The fourth non-economic control variable is the dummy variable for whether the country is European, to reflect land-use regulation strictness. Speculation about the influence of land-use regulations have been made before. However, Jedwab et al. (2020) are the first to present an international measure of regulatory stringency. Before, Barkham et al. (2017) operationalised this hypothesis in a dummy variable for European territory as they believed that land-use planning is much more intense in Europe due to the concern for the preservation of 'heritage'. And indeed, Jedwab et al. (2020) found various European countries in the percentage change gab, 'which concords with common beliefs that they are more stringent in regulating height than other nations' (Jedwab et al., 2020, p. 5). It is therefore that the operationalisation of Barkham et al. (2017) is adopted and a dummy variable for European country is created manually (*EU*).

3. Results

3.1 Skyscraper development worldwide

As it is often stated in the introduction that the skyscraper is a hallmark of 21st century, we first consider the development of skyscrapers over time.



Note: Skyscrapers are not selected on height, year of completion or status. The line indicates the 150 meter threshold.

Source: CTBUH, 2020

Figure 1 Scatterplot of skyscraper height over time, per use worldwide

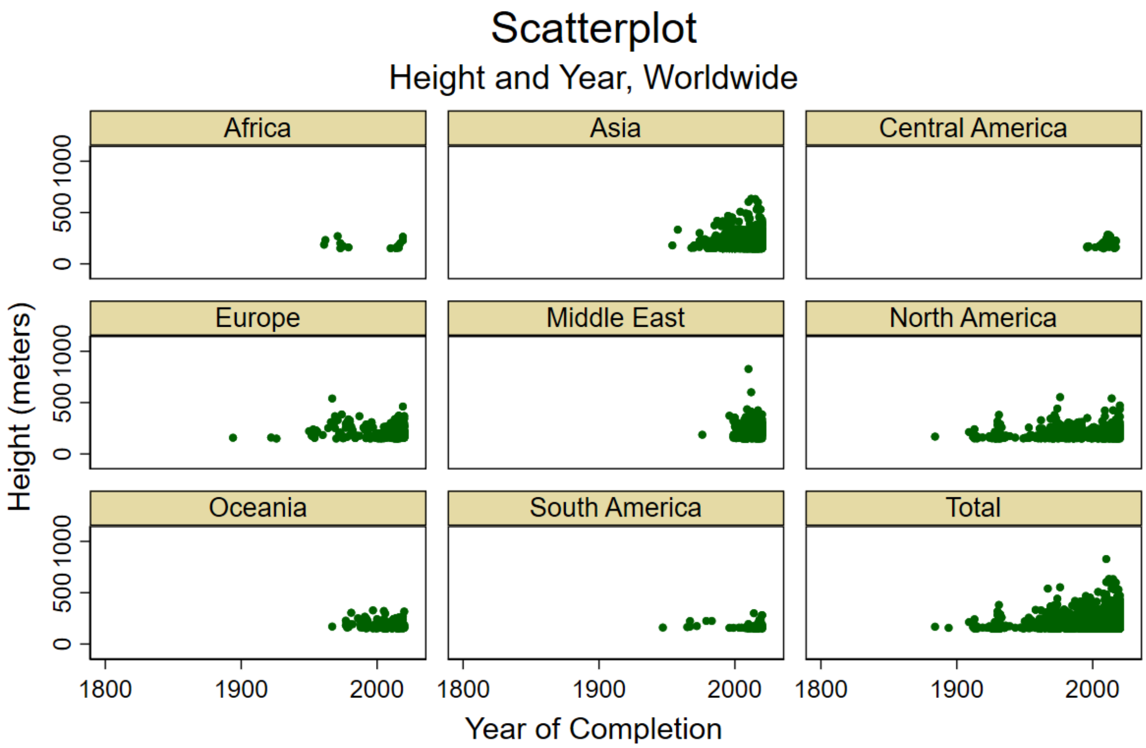
Figure 1 plots the height of the skyscraper over time and, indeed, over time skyscrapers are developed more often and higher. The first skyscraper (as defined by the 150-meter height threshold) was developed in 1884 in Washington DC, in the United States. Before that time, high rise development was constrained mostly by technological possibilities. But by the early 1890s, key innovations – the electric elevator and the steel-framed skeletal structure – were in place to remove the technological barriers to height (Ahlfeldt, 2020). After the turn of the century, the office-skyscraper[6] became the driver of the skyscraper stock.

A half century later, after the dip in skyscraper development during the second World War, the office outliers are accompanied by mixed-use[7] skyscrapers of great hight. This development of mixed-use skyscrapers is still a growing trend: the share of mixed-use skyscrapers developed over

[6] CTBUH (2021) defines single-function tall buildings as 'one where 85% or more of its total height is dedicated to a single function.'
[7] The CTBUH (2021) defines a mixed-use building as a mixed-use tall building containing 'two or more functions, where each of the functions occupies a significant proportion (15% or greater) of the tower's total space. Support areas, such as car parks and mechanical plant space, do not constitute mixed-use functions.'

the past 10 years (2010-2019) is 20% (its share over 1885-2019 is 16%). Most mixed-use skyscrapers contain as basic function residential (about 50% of buildings), hotel and office mixed-use buildings are developed less often (30% and 20%, respectively) (Generalova et al., 2018). However, as of this century, residential-skyscrapers are also increasing in number and height. Drivers of residential-skyscrapers can thus be considered more relevant than office-skyscraper drivers (CBD-kind of factors) in explaining skyscraper development of the last decennia. Given the development of skyscrapers, the statement that the skyscraper is a hallmark of 21st century is confirmed.

As it is stated in the introduction that the skyscraper is expanding geographically, making skyscraper gravity shift from the United States to Asia, we now consider the development of skyscrapers over time, per region.



Note: Skyscrapers are selected on height (150m+), year of completion (1800+) and status (Completed or Topped Out).

Source: CTBUH, 2020

Figure 2 Scatterplot of skyscraper height over time, per region

Figure 2 plots the selected skyscraper data[8] height over time, and shows the results per region in the world and confirms the second statement made in the introduction of this study as well: namely, that skyscraper development is expanding geographically, making skyscraper gravity shift from the United States to Asia. The spread of the skyscraper can perhaps best be considered in light of globalisation processes or be compared to the diffusion of innovations, a theory by Everett Rogers (1962). Europe and North America were the first two regions to ever built a skyscraper of over 150 meters before 1900. These countries can be considered pioneer countries, being the first to adopt the new technological innovations described above (Ahlfeldt, 2020; Huber, 2008). For much of the twentieth century tall building technology has been an important United States export, but it is also clear that the adaptation of skyscrapers is dependent upon a complex transmission of ideas and aesthetics (Cody, 2003; McNeill, 2005). Following North American and Europe, the skyscraper penetrated the Asian market as of 1954. The skyscraper is then still a western symbol and skyscraper development is predominantly exported by western firms, however the design process may be significantly influenced by context-specific factors (Cody, 2003; McNeill, 2008). The developmental states of southeast Asia have explicitly adopted skyscrapers as symbols of national modernization (McNeill, 2005). The Middle East is even later in contributing to the global stock but is responsible for the outlier(s). For example, both the Jeddah Tower (Saudi Arabia) and the Dubai Creek Tower (Dubai) mentioned in the introduction are outliers in the world stock. Therefore, it can thus definitely be stated that the skyscraper is a product adopted worldwide nowadays.

3.2 Skyscrapers and control of corruption worldwide

The focus of this study is to examine the role of corruption in the development of skyscrapers and analysing the skyscraper data in light of corruption (control of corruption) reveals some interesting notions.

Firstly, figure 3 shows that skyscrapers exist in both countries with a low and with a high control of corruption. The figure displays height of skyscrapers over control of corruption, instead of over time before. Skyscrapers are spread out in countries with control of corruption values between -1.5 and 2.3 on a scale of -2.5 (very low control of corruption) till 2.5 (very high control of corruption). This means that with exception of the lowest values, observations are spread out over almost the entire range of level of control of corruption, indicating that only countries with too low control of corruption have no skyscrapers developed.

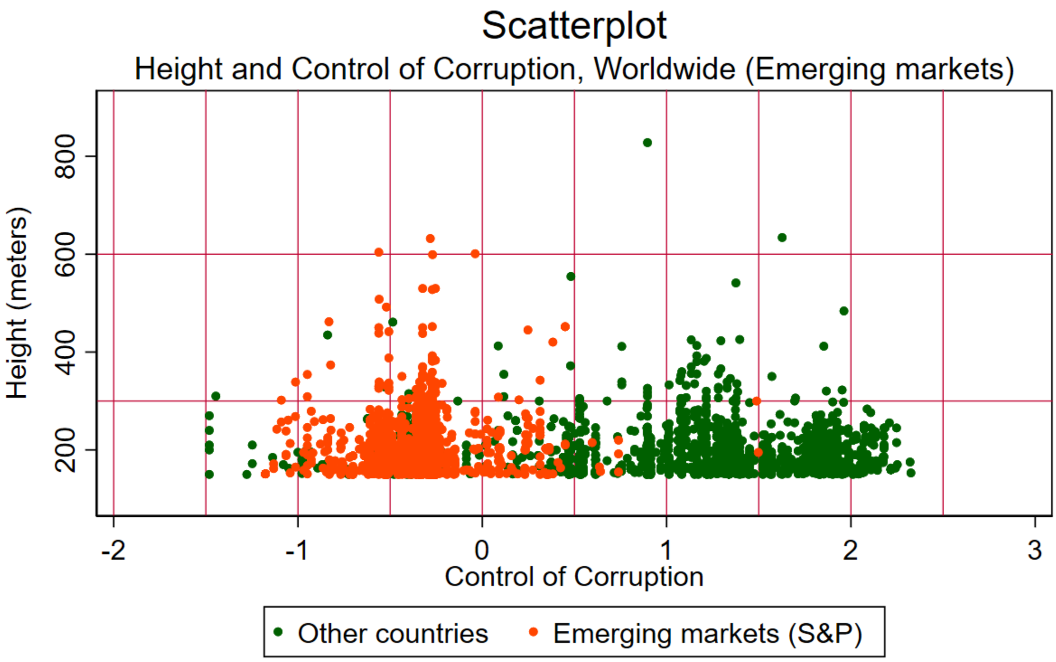
[8] Thus 150 meter and higher.

Secondly, singling out supertall and megatall buildings does not indicate that these skyscrapers of great hight are associated with a certain level of corruption. This line of reasoning might derive from the idea that skyscrapers of great height might be more susceptible to corruption, both as higher skyscrapers are more cost-inefficient thus depending on corruption to be realised financially, and due to the prestige that comes with great height which public officials might pursuit (Barr, 2012; Gjerløw & Knutsen, 2017). The CTBUH (2021) classes tall buildings that achieve significant heights in two additional sub-groups: a "supertall" is a tall building 300 meters (984 feet) or taller, and a "megatall" is a tall building 600 meters (1,968 feet) or taller. In figure 3, tall buildings are clustered in countries with a control of corruption value of around -0.4 and around 1.2. Besides, 95 out of 162 tall buildings are developed in countries with a negative control of corruption value. This is slightly more than half of all tall buildings developed. There are five megatall buildings in 2020, of which three are developed in countries with a control of corruption value below zero. The highest skyscraper is developed in the United Arab Emirates (2010), a country that scores a 0.896 for control of corruption. These facts indicate that again no clear distinction in supertall building nor mega-tall building development can be made between countries with a negative control of corruption value (thus more corrupt countries) and countries with a positive control of corruption value (thus less corrupt countries).

Thirdly, what does stand out is, in figure 3, emerging market countries, as compared to other countries[9], are shown to dominate in the negative control of corruption range. They are mainly clustered at the lowest half of control of corruption, representing more corrupt countries. The statement made about the corruption being widespread in developing countries (Gray & Kaufman, 1998; Robinson & Torvik, 2005) thus seems justified, as this figure shows the (relatively) low control of corruption in emerging markets.

Fourthly, emerging market countries do develop skyscrapers as well. The skyscrapers in emerging market countries are a substantial part of the world's total skyscraper stock. The cluster around -0.4 consists mainly of emerging market countries. In addition, about half of the tall buildings (76 out of 162) and the three megatall buildings with a control of corruption below zero are in emerging markets.

[9] Please recall that only emerging market countries are the only subdivision made, so 'other countries' can also be interpret as all non-emerging market countries by S&P.



Note: Skyscrapers are selected on height (150m+), year of completion (1800+) and status (Completed or Topped Out). The horizontal lines mark threshold for 'supertall buildings' (300m+) and 'megatall' (600m+) as indicated by the CTBUH.

Source: CTBUH, 2020 and The World Bank, 2021

Figure 3 Scatterplot of height and control of corruption, worldwide (emerging markets)

In sum, based on this figure no clear association can be predicted or confirmed between skyscraper development and corruption worldwide so far. The distribution of skyscrapers and their height is comparable for emerging market countries and other countries, however the emerging market countries are more on the low control of corruption side of the plot and the other (non-emerging) countries are most dominant on the high control of corruption side of the plot. A direct relationship cannot be proven based on this figure, but can be done with a multiple regression model.

3.4 Explanatory factors: skyscraper stock in 2019

Model 1 in table 2, which follows equation 1, is set out to explain the number of skyscrapers developed in a country until 2019 based on the control of corruption. Although the descriptive figure (figure 3) does not show a conclusive result about the association between corruption and skyscraper development worldwide, the first model does confirm a significant relationship.

Corruption is thus a significant[10] explanation for the skyscraper stock of a country. For all three categories the coefficient is positive, indicating that a higher level of control of corruption (compared to the very low control of corruption) results in an increase in the number of skyscrapers developed in a country[11]. Countries with a control of corruption value above the very low control of corruption category have on average over 100%[12] more skyscrapers developed until 2019 compared to countries with a very low control of corruption. However, this model explains only 14,6% of the variance and control variables, for other factors which may be correlated with the stock of skyscrapers, are not included yet.

Model 2 in table 2 does include control variables as well, increasing the model's explanatory power to 69,3%. However, not all control of corruption categories are significant anymore. Only the low control of corruption is significant in explaining the skyscraper stock in a country in 2019, with a significance of 5%. The coefficient is still positive, indicating that skyscrapers developed in a country with a low control of corruption changes (increases) on average by 128.5% compared to countries with a very low control of corruption. So, the model shows that, when controlled for economic and non-economic factors, the number of skyscrapers developed in a country until 2019 is significantly influenced by whether the country has a low control of corruption, as compared to a very low control of corruption country.

[10] The p-value on this dummy variable shows that the differences between categories are significant at 1 and 5 percent.

[11] The coefficient of the low control of corruption category is 1.911, of the high control of corruption category 1.378, and of the very high control of corruption 1.774. That means that the difference in skyscraper development between a country with a very low control of corruption (the reference group) and: a country with a low control of corruption is 191.1%, a country with a high control of corruption is 137.8%, and a country with a very high control of corruption is 177.4%.

[12] 100x (coefficient) percentage

Table 2 Regression results of cross-section analyses 2019

VARIABLES	(1) All countries Corruption	(2) All countries Corruption + control
Control of Corruption (dummy) = 2, Low Control of Corruption [a]	1.911***	1.285**
	(0.652)	(0.484)
Control of Corruption (dummy) = 3, High Control of Corruption [b]	1.378**	0.812
	(0.652)	(0.612)
Control of Corruption (dummy) = 4, Very high Control of Corruption [c]	1.774***	0.356
	(0.661)	(0.719)
GDP per capita (log), PPP (current international $)		1.777***
		(0.400)
Population, total (log)		0.723***
		(0.113)
Population density (people per sq. km of land area) (log)		0.204**
		(0.0983)
Urban population (% of total population)		-0.00887
		(0.0136)
GDP per capita growth (annual %)		0.0591
		(0.0692)
Urban population growth (annual %)		0.0163
		(0.189)
Whether country in Europe		-1.565***
		(0.473)
Constant	1.041**	-28.67***
	(0.475)	(4.610)
Observations	65	63
R-squared	0.146	0.693

Note: dependent variable is the natural logarithm of skyscraper stock in 2019. The reference category of the control of corruption variable is 1, Very low Control of Corruption. Standard errors in parentheses with *** , **, * indicating significant at 1%, 5% and 10%, respectively.
a Control of corruption values between -.690 and -.141
b Control of corruption values between -.141 and 1.27
c Control of corruption values above 1.27

As for the control variables, as expected GDP per capita, population (total) and population density are significant (respectively, at 1%, 1% and 5%[13]) and positive in explaining the number of skyscrapers developed until 2019. The EU dummy, indirectly measuring the urban planning stringency, is significant (at 1%) and negative: if a country is in Europe its number of skyscrapers decreases with 156.5%. Urban population and both growth indicators, GDPC growth and population growth, are not significant.

In sum, controlled for other variables, in explaining the skyscraper stock between countries, it matters if a country has a low control of corruption compared to a very low control of corruption. Countries with a low control of corruption compared to countries with a very low control of corruption have, on average, a larger total stock of skyscrapers as per 2019.

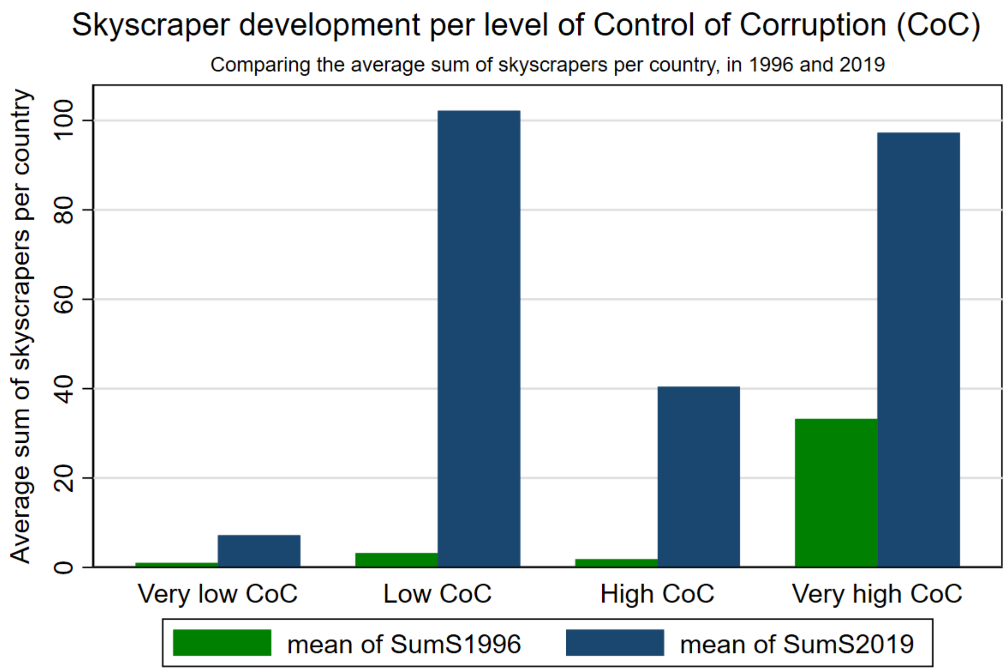
[13] The significance level is the probability of rejecting the null hypothesis when it is true. The null hypothesis is that the coefficient is equal to zero (no effect). For example, the significance level of population (0.01) indicates a 1% risk of a the coefficient having no effect.

3.3 Skyscrapers and control of corruption between 1996 and 2019

As showed in figure 1, the development of skyscrapers has increased over time and, as showed in figure 2, so has its diffusion over regions. Whether this can be attributed to different skyscraper drivers being of importance might be a possible explanation for the different patterns. It might therefore be relevant to analyse the development of skyscrapers in relation to control of corruption over time. The widest range allowed by the data on control of corruption is between 1996 and 2019.

The average skyscraper stock per country has been graphed in figure 4 per category of control of corruption. In 1996, countries without a very high control of corruption had barely any skyscrapers developed. Countries with a low control of corruption had on average slightly more skyscrapers developed than countries with a high control of corruption. For skyscrapers added to the skyscraper stock in 1996, it might thus have been a precondition for a country to have a very high control of corruption to develop any skyscrapers. However, if this direct relationship really is the case or whether it is instead just an association between control of corruption and (economic) factors other than skyscraper development cannot be concluded yet.

Nevertheless, in 2019 the skyscraper distribution changed tremendously: countries with a low control of corruption caught-up and now dominate the average skyscraper stock. On average, a country with a low control of corruption has the most skyscrapers developed in 2019. Also the average sum of skyscrapers in countries with a high control of corruption increased. Countries with a very low control of corruption increased their average sum of skyscrapers, however lag relatively behind compared to the other three categories. For the year 2019, it can thus be concluded that only countries with a very low control of corruption developed barely any skyscrapers.



Note: Skyscrapers are selected on height (150m+), year of completion (1800+) and status (Completed or Topped Out).

Source: CTBUH, 2020 and The World Bank, 2021

Figure 4 Graph of skyscraper development per level of control of corruption

Thus, while in 1996 skyscrapers were predominantly developed in the least corrupt countries, 23 years later skyscraper developments diffused to more corrupt countries with now on average the most skyscrapers in countries with a low control of corruption. However, there is an exception for the most corrupt countries which have on average still relatively few skyscrapers developed. In the last years it might thus be the case that skyscraper development is indeed more appealing in more corrupt countries, perhaps just because of the lower control of corruption levels. Such a direct relationship can be tested with a multiple regression model.

3.5 Explanatory factors: difference in skyscraper stock between 1996 and 2019

Figure 4 revealed the importance of the factor time for the analysis and raises the question if there exists an increasing role for corruption in skyscraper development. Therefore, the next regression results will show the role of corruption in the skyscraper stock developed in the last 23 years, controlled for changes in the economic and population structure of countries.

First, Model 1 in table 3, which follows equation 2, simply explains the number of skyscrapers developed between 1996 and 2019 in a country based on the control of corruption. Consistent with the results from the 2019 skyscraper stock, corruption appears to be significant in explaining the number of skyscrapers developed between 1996-2019 in a country. For all three categories the coefficient is positive, indicating that a higher control of corruption (compared to a country with a very low control of corruption) results in an increase in number of skyscrapers developed in a country[14]. Although the exact coefficients are different, still, countries with a control of corruption value above the very low control of corruption category have on average over 100% more skyscrapers developed until 2019 compared to countries with a very low control of corruption. This model explains only 18,1% of the variance and controls for other factors is not included yet.

Model 2 in table 3 now includes control variables as well, increasing the explanatory power of the model from 18.1% to 72.6%. However, not all control of corruption categories are significant anymore. As with the 2019 based model, only the low control of corruption is significant (also at 5%) in explaining the number of skyscrapers in a country. The coefficient is still positive, indicating that skyscrapers developed in a country with a low control of corruption, compared to countries with a very low control of corruption, changes (increases) on average by 99.3%. So, when controlling for economic and non-economic factors it turns out that the number of skyscrapers developed in a country between 1996 and 2019 is significantly influenced by whether the country has a low control of corruption, but not if the control of corruption is high or very high, compared to a very low control of corruption country. This conclusion is consistent with the conclusion drawn over the 2019 skyscraper stock. Based on these corresponding results, the role of corruption appears not to have changed over the last 23 years compared to the entire skyscraper stock in 2019.

[14] The coefficient of the low control of corruption category is 2.015, of the high control of corruption category 1.639, and of the very high control of corruption 1.838. That means that the difference in skyscraper development between a country with a very low control of corruption (the reference group) and: a country with a low control of corruption is 201.5%, a country with a high control of corruption is 163.9%, and a country with a very high control of corruption is 183.8%.

Table 3 Regression results of skyscraper stock difference between 1996 and 2019

VARIABLES	(1) 1996-2019 Corruption	(2) 1996-2019 Corruption + control
Control of Corruption (dummy) = 2, low control of corruption [a]	2.015***	0.993**
	(0.641)	(0.481)
Control of Corruption (dummy) = 3, High control of corruption [b]	1.639**	0.678
	(0.650)	(0.582)
Control of Corruption (dummy) = 4, Very high control of corruption [c]	1.838***	0.251
	(0.661)	(0.690)
GDP per capita (log), PPP (current international $)		1.780***
		(0.384)
Population, total (log)		0.664***
		(0.118)
Population density (people per sq. km of land area) (log)		0.221**
		(0.0919)
Urban population (% of total population)		-0.0106
		(0.0131)
GDP per capita growth (annual %)		0.0993
		(0.0669)
Urban population growth (annual %)		-0.0766
		(0.181)
Whether country in Europe (dummy)		-2.175***
		(0.453)
Constant	1.049**	-27.28***
	(0.476)	(4.636)
Observations	58	56
R-squared	0.181	0.726

Note: dependent variable is the natural logarithm of the difference in skyscraper stock between 2019 and 1996. The reference category of the control of corruption variable is 1, Very low Control of Corruption. Standard errors in parentheses with *** , **, * indicating significant at 1%, 5% and 10%, respectively.

a Control of corruption values between -.690 and -.141

b Control of corruption values between -.141 and 1.27

c Control of corruption values above 1.27

As for the control variables, the same factors have the same significance and its coefficients have the same direction. So neither these variables seem to have changed over time explaining skyscrapers compared to the entire skyscrapers stock in 2019.

In sum, controlled for other variables, in explaining skyscraper development between countries over the time period 1996 to 2019 it matters if a country has a low control of corruption compared to a very low control of corruption. Countries with a low control of corruption compared to countries with a very low control of corruption have, on average, more skyscrapers developed between 1996 and 2019. These results are consistent with the findings for the entire skyscraper stock in 2019. It can thus be said that the same determinants are significant in explaining skyscraper development and an increase (or decrease) in the importance of corruption is not proven.

3.6 Explanatory factors: emerging market countries

So far, this result section has conducted research on all countries which developed skyscrapers to investigated the hypothesis that more corrupt countries develop more skyscrapers. However, the second hypothesis concerns special attention to emerging markets as Michaelson (2014) specifically associated the influence of corruption with emerging markets. The panel data makes it possible to run a regression on the emerging market countries sub selection, selected by both S&P and MSCI.

Table 4, which follows equation 3[15], shows the role of corruption in explaining the development of skyscrapers in emerging market countries. For emerging market countries it is significant if the control of corruption increases to low (compared to very low). These results might be influenced by the association between emerging market countries and lower control of corruption values, as displayed in figure 3. However, even more striking is the direction of the sign: in both cases, the coefficient is negative, indicating that an increase in control of corruption from very low to low results in a decrease of skyscraper development three years later[16]. Thus, if an emerging market country becomes less corrupt than very corrupt, fewer skyscrapers will be developed. This is contrary to all previous results analysing all countries worldwide. Both models (1 and 2 in table 4) explain over 80% of the variation within the emerging market countries (84.9% and 82.1%).

[15] This regression equation has also been applied to all countries worldwide, including both emerging and non-emerging market countries. See appendix 7 for the results.
[16] For S&P emerging market countries, if a country changes from a very low control of corruption to a low control of corruption 12.2% fewer skyscrapers will be developed. For MSCI emerging market countries this increase in control of corruption results in 9.69% fewer skyscrapers developed.

Table 4 Regression results regressions emerging markets 2005-2019

VARIABLES	(1) S&P Emerging markets	(2) MSCI Emerging markets
Control of Corruption		
Control of corruption (dummy) = low [a]	-0.122*	-0.0969**
	(0.0657)	(0.0425)
Control of corruption (dummy) = high [b]	-0.0508	0.0424
	(0.0964)	(0.107)
Control of corruption (dummy) = very high [c]	0.179	0.0403
	(0.182)	(0.262)
GDP per capita (log), PPP (current international $)		
GDP per capita (dummy) = low	0.233	0.329*
	(0.205)	(0.177)
GDP per capita (dummy) = high	0.0749	0.260
	(0.317)	(0.272)
GDP per capita (dummy) = very high	0.0493	0.547
	(0.459)	(0.378)
Population, total (log)	-19.73***	-18.53**
	(4.509)	(7.728)
Population density (people per sq. km of land area) (log)	21.69***	18.13**
	(5.026)	(7.481)
Urban population (% of total population)	0.0879**	0.0849***
	(0.0352)	(0.0267)
GDP per capita growth (annual %)	0.00680	0.0207*
	(0.0138)	(0.0114)
Urban population growth (annual %)	0.0892	0.0943***
	(0.199)	(0.0199)
Constant	266.2***	243.1**
	(63.57)	(104.3)
Observations	195	285
R-squared	0.849	0.821
Country FE	YES	YES
Year FE	YES	YES
Number of CountryID	13	19

Note: Dependent variable is the natural logarithm of skyscrapers added to stock that year + 1 in emerging market countries. The reference category of the control of corruption variable is 1, Very low Control of Corruption. The reference category of the GDP per capita variable is very low. Standard errors in parentheses with *** , **, * indicating significant at 1%, 5% and 10%, respectively.

a Control of corruption values between -.690 and -.141

b Control of corruption values between -.141 and 1.27

c Control of corruption values above 1.27

As for the control variables, in only one model the low GDP per Capita category is significant at 10% and positive (MSCI model (2) in table 4). This is contrary to all previous models explaining skyscraper development between countries, in which GDP per Capita was a significant determinant. However, now only emerging market countries are analysed, which are typically low income countries. When high income countries are excluded, income differences are thus not that important anymore in explaining skyscraper development. In both models, population (total) is significant and negative, the same as in the country fixed effect models (models (3) and (4) in table 4), and population density and urban population are significant and positive. In the MSCI model (model 2 in table 4) both growth determinants are significant, and positive, as well.

In sum, controlled for other variables, in explaining skyscraper development within emerging market countries it matters if a country has a low control of corruption compared to a very low control of corruption. Emerging market countries which become less corrupt developed, on average, fewer skyscrapers. This is contrary to the previous results in which all countries were analysed and a decrease of corruption led to an increase in the development of skyscrapers.

4. Discussion

4.1 Implications of the results

The analyses carried out in this study used an established corruption index to investigate the role of corruption in the development of skyscrapers. The results showed that between countries, a higher control of corruption increased the number of skyscrapers developed, but only significantly so if the control of corruption is low to very low. The current study thus contributes to the scarce body of literature into non-economic determinants of skyscraper development and to the scarce body of literature on corruption in real estate, by providing insights into the role of corruption in skyscraper development.

In addition, two other findings of this study should be addressed to evaluate the hypotheses of this study. Contradicting to this study's first hypothesis is the sign direction of the control of corruption category coefficients (compared to a very low control of corruption) in analysing the global dataset. The sign is not negative as suggested, but a relative increase in the control of corruption (compared to a very low control) is found to be positive e.g. results in more skyscrapers developed. Therefore, Michaelson's (2014) claim that skyscrapers are associated with corruption might be supported, however not in the way his reasoning suggested.

Therefore, the first hypothesis of this study, which drew on Michaelson's reasoning that a low control of corruption allows countries to more easily realize skyscrapers, can be rejected based on the findings of my analysis. In contrast, however, my finding of a significant negative relationship of the low control of corruption (compared to very low control) within emerging market countries suggests that the role of corruption depends on the stage of development of a country. This negative relationship is in line with this study's second hypothesis. These last results might thus offer support for the specified claim by Michaelson (2014) that skyscraper development is (more) subject to corruption and his argued ethical criticism about misplaced priorities seem to be reasonable, but only so in the specific case of emerging market countries.

4.2 Data implications

The analyses carried out in this study used the control of corruption as a determinant of skyscraper development. Regardless of the results, a note of caution is due here because of the complex role of corruption. Although its measurement is discussed already in the data section and the use of the control of corruption value from the WGI is an established index, one should consider the implications. Nonetheless, corruption is hard to measure as it is not directly visible and therefor the reliability of the measurement is compromised (Field, 2013; Rohwer, 2009). It is even more important to consider the implications hereof for the emerging market analyses. After all, especially the characteristic making the emerging markets ripe for corruption makes it hard to trust the corruption measurement as 'transparency is not as reliable as in developed economies' (Hoang, 2018).

In addition, the WGI measures the control of corruption in a country in general, not in the real estate sector specifically. The invalidity of the measurement is therefore not fully excluded (Field, 2013). No assumption have been made about whether corruption in the real estate industry is much more corrupt than others (or other professions) as there is no strong evidence out there (Krieger, 1994). However, it is claimed that corruption in urban planning is even harder to identify (and punish) because of high discretion in town planning decision (Chiodelli & Moroni, 2015). Nonetheless, further research into corruption in skyscraper development should improve both the validity as the reliability of corruption research. For example by delving deeper in specific countries[17] or cases, or by generating real estate corruption data specifically as well. Given the severity of corruption, this is an important issue for future research.

4.3 Possible mechanisms of corruption in skyscraper development

Still, we know little about the exact mechanisms behind corruption in skyscraper development. One possible explanation for the positive relation between skyscraper development and control of corruption in the global dataset might be attributed to the basics of investing: finding a balance between risk and returns. Whether an investment will provide a competitive or adequate return is among others dependent on the differences of risk (Brueggeman & Fisher, 2010). Real estate investment risk is engaged in the real estate investment losses and one type of risk is political risk, including corruption levels (Austin, 1996; ML & Wp, 2012). It might be the case that worldwide, more often a safe investment strategy with high levels of risk aversion is chosen and thus skyscrapers are mostly developed in countries with less political risks e.g. corruption present. In the overview of skyscraper stock in 1996 this was strongly reflected: by far most skyscrapers were

[17] See for example an analysis of corruption in Chinese real estate by Zhu (2012) or corruption in Chinese skyscraper construction by Barr and Luo (2018).

developed in countries with a very high control of corruption. However, the strategy with this level of risk (corruption) aversion[18] does not apply anymore as, as the graph showed, in the last decades skyscrapers are more often developed in countries with a low and high control of corruption. A possible explanation for the increased popular investment asset has to do with the diffusion theory and/or the saturation of the skyscraper market in countries with a very high control of corruption. Perhaps a combination of both, as the skyscraper market has proven its durability, adaptation of this asset expanded in the last 20 years to new markets were potential returns outweighed potential risks of corruption. Nevertheless, this is done with some caution, as the skyscraper stock in countries with a very low control of corruption is still lagging behind. The positive relationship between control of corruption and skyscraper development also is in line with this reasoning.

Continuing discussing a potential mechanism behind the results, the risk-return balance turns out to be more different for emerging market countries. Despite the fact that emerging markets still draw trillions of dollars from investors which are apparently not that frightened by the global risks, apparently this line of reasoning cannot be applied to the drivers of skyscraper development in emerging markets (Hoang, 2018; Tran, 2017). After all, a negative relationship was found in skyscraper development in emerging market countries, where a low control of corruption compared to a very low control of corruption results in fewer skyscrapers developed. So this increase in control of corruption apparently is not translated in less risk so more investments in emerging market countries, but the relationship might reflect work in economic sociology. This work suggests that in emerging markets, which are characterised by a combination of rapid economic growth and institutional uncertainty, to facilitate cooperation, interpersonal networks, access to political elites and social relations are crucial (Hoang, 2018; Marquis & Raynard, 2015). Thus, in emerging market countries with a very low control of corruption, corruption in those relations can make it possible to realise (whitely shaded) skyscraper projects. Perhaps the desire for status and the prestige function of the skyscraper drive public officials to help realise these projects illegally (Barr, 2012; Gjerløw & Knutsen, 2017). However, if the control of corruption increases, corruption to realise skyscraper projects is less possible in those relations.

Regardless these possible mechanisms, the observation that the variable is significant in many cases demonstrates the importance of the issue. Especially given the fact that corruption in urban planning is even harder to identify (and punish) because of high discretion in town planning decision (Chiodelli & Moroni, 2015). The severity of corruption in skyscraper development is also

[18] All investors are assumed to be risk averse, which means that they require a higher expected return as compensation for incurring additional risk. However, the trade-off interpretation is dependent on the investor's attitude toward risk (Brueggeman & Fisher, 2010, p. 429).

due to the large amounts of capital and power involved in these development projects (Gjerløw & Knutsen, 2017; Honorée et al., 2018). This study only discussed possible mechanisms behind the corruption in skyscraper development and other research should be consulted or conducted for concrete and effective anti-corruption strategies[19]. After all, corruption imposes political, economic and environmental costs on societies around the world and not only causes serious damage to individual economies, countries, and regions but also to humanity as a whole (Chiodelli, 2019; Ortiz-Ospina & Roser, 2019). Therefore, irrespective of which strategy will be most suitable for skyscraper practices, it seems useful to grasp the importance of making the issue of corruption a more central element in both real estate theory and practice.

Conclusion

This study has investigated the role of corruption in the development of skyscrapers worldwide and in emerging market countries empirically by analysing detailed global data in a regression context. The raw data indicated that skyscraper development diffused from the least corrupt countries to more corrupt countries over 1996-2019. Main results showed that worldwide less corruption increased the number of skyscrapers developed, but only consistently significant so if the control of corruption is low compared to very. This did not change over the last 23 years. However, the role of corruption in skyscraper development depends on the stage of development of a country as the opposite results were found for emerging market countries. In these countries an increase in the control of corruption, from very low to low, led to fewer skyscrapers developed. So this study showed that skyscraper development is subject to corruption and argued ethical criticism about misplaced priorities seems to be reasonable, but only so in the specific case of emerging market countries.

[19] See for example Chiodelli and Moroni (2015) for specific anti-corruption in land-use recommendations.

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Appendix

1. Skyscraper tabulations

Tabulation of Status and Use

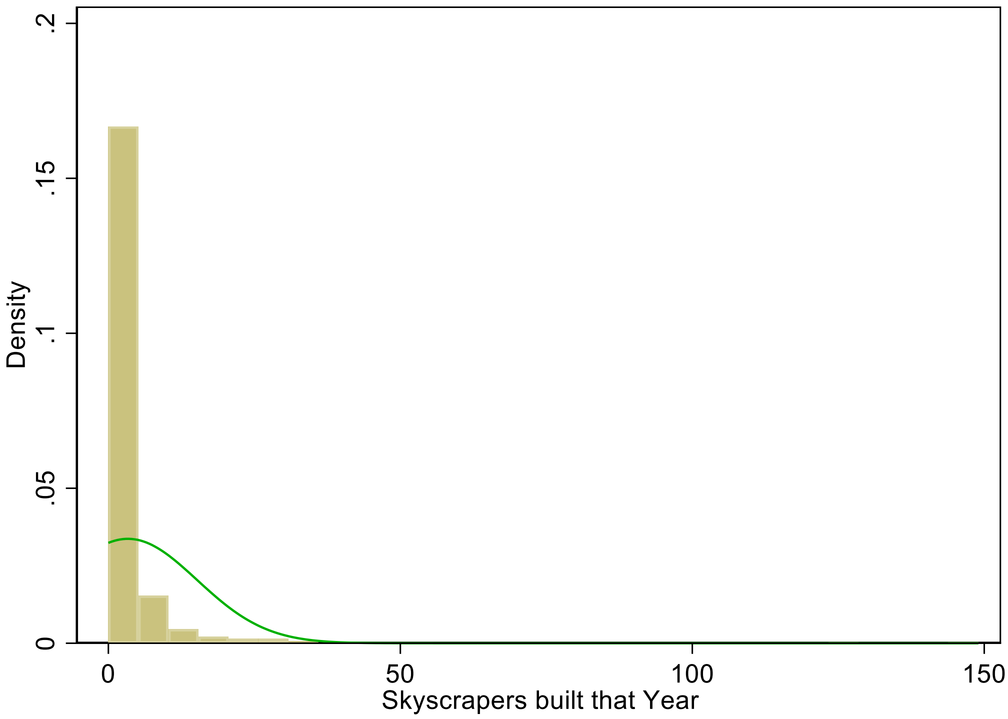
Status of Skyscraper	Use of Skyscraper				
	mixed-use	office	other	residential	Total
Completed	735	1441	237	1688	4101
	17.92	35.14	5.78	41.16	100.00
Architecturally Topped Out	64	73	17	82	236
	27.12	30.93	7.20	34.75	100.00
Structurally Topped Out	14	5	3	11	33
	42.42	15.15	9.09	33.33	100.00
Total	813	1519	257	1781	4370
	18.60	34.76	5.88	40.76	100.00

First row has frequencies and second row has row percentages

Tabulation of Region

Region	Freq.	Percent
Africa	16	0.37
Asia	2566	58.72
Central America	54	1.24
Europe	256	5.86
Middle East	401	9.18
North America	885	20.25
Oceania	115	2.63
South America	77	1.76
Total	4370	100.00

2. Right-skewed nature of the dependent variable number of Skyscrapers



3. Review of the independent variable: corruption

Nevertheless, the WGI can be reviewed and substantiated. As pointed out, the concept of corruption is complex and perhaps in a way immeasurable as it cannot be measured directly (Rohwer, 2009). However, two arguments can be made in favour of the WGI to downplay this issue. Firstly, the usefulness of the aggregate indicators in the WGI stems from the fact that by averaging information from many different data sources they are 1) ''able to conveniently summarize the wealth of existing information on governance'' and 2) ''able to smooth out some of the inevitable idiosyncracies of individual measures of governance and so be more informative about the broad notions of governance they are intended to measure than any individual data source'' (Kaufmann et al., 2007, p. 1). Compared to the CPI, the WGI seems therefore more informative as for example in 2008, the WGI control of corruption indicator used the 11 different data sources from the CPI, as well as 14 others not used in the CPI (Rohwer, 2009). Secondly, Ortiz-Ospina and Roser (2019) state that ''although precise corruption measurement is difficult, there is a clear correlation between perception and behaviour; so available corruption data does provide valuable information that, when interpreted carefully, can both tell us something important about our world as well as contribute to the development of effective policies''.

A second review of the WGI calls into question the usefulness of the Worldwide Governance Indicators for making comparisons of governance over time and across countries. For example, Arndt and Oman (2006, p. 68) argue that the WGI '...do not allow for a reliable comparison of levels of governance over time..." ''since only a relatively small number of countries experience changes in governance that are large enough to be considered statistically significant'' (Kaufmann et al., 2007, p. 10). Again, two counterarguments can be made. Firstly, it seems unreasonable to accuse the WGI of the fact that many countries do not experience significant changes in governance or corruption (Kaufmann et al., 2007). The CPI from TI also demonstrates scores which are 'fairly stable, and drastic changes in ranking are not very common' between 2012 and 2018 (Ortiz-Ospina & Roser, 2019). Secondly, Kaufmann et al. (2007) respond to this particular critique by analysing the overlap of confidence intervals for the control of corruption indicator in 2005 of over 20 countries and conclude that ''[w]hile we continue to emphasize to users that many of the small differences between countries may well be neither statistically or practically significant, we also emphasize that a great many significant differences between countries can in fact be established using our aggregate indicators'' (p. 11). To compensate for the relative small changes in corruption over time, it is considered important in this study to analyse corruption over a longer period.

4. Descriptive statistics

Descriptive Statistics 2019

Variable	Obs	Mean	Std. Dev.	Min	Max
Skyscrapers developed + 1 (log)	60	.787	1.056	0	4.511
control of corruption	59	.247	.439	-1.44	2.284
GDP per capita (log)	57	9.974	.92	7.816	11.659
Population, total (log)	59	17.094	1.753	10.547	21.044
Population density (log)	59	4.964	1.752	1.146	9.908
Urban population	59	70.861	21.751	18.311	100
European country (1 = yes)	60	.267	.446	0	1
GDP per capita growth	58	1.991	3.113	-4.168	11.945
Urban population growth	59	1.851	1.2	-.319	5.24

Descriptive Statistics emerging markets S&P (MSCI)

Variable	Obs	Mean	Std. Dev.	Min	Max
Skyscrapers developed + 1 (log)	196(280)	1.195(1.246)	1.114(1.126)	0 (0)	5.011 (5.011)
control of corruption	196(280)	-.167(-0.46)	.583(.659)	-1.132 (-1.132)	1.582 (1.582)
GDP per capita (log)	182(266)	9.472(9.752)	.667(.969)	7.813 (7.813)	10.957 (11.861)
Population, total (log)	182(266)	18.388(17.811)	1.338(1.698)	16.61 (13.432)	21.044 (21.044)
Population density (log)	182(266)	4.224(4.515)	1.071(1.051)	2.433 (2.346)	6.099 (6.264)
Urban population	182(266)	67.917(69.273)	17.928(21.022)	29.569 (28.572)	91.627 (100)
European country (1 = yes)	196(280)	.137(.096)	.345(.296)	0 (0)	1 (1)
GDP per capita growth	182(266)	3.356(2.885)	3.401(4.004)	-6.854 (-15.151)	13.636 (15.989)
Urban population growth	182(266)	1.918(2.86)	.942(2.937)	-.469 (-.469)	3.675 (17.763)

5. Assumptions and statistical tests for the main models

OLS assumptions

Five assumptions are made relating to the CLRM which are required to show that the estimation technique, ordinary least squares, have a number of desirable properties, and also so that hypothesis tests regarding the coefficient estimates could be conducted validly (Brooks and Tsolacos, 2010, p. 136).

The first assumption requires that the average value of the errors is zero. In fact, if a constant term is included in the regression equation, this assumption will never be violated (Brooks and Tsolacos, 2010, p. 137). The second assumption is the assumption of homoscedasticity i.e. the variance of the errors is constant. For panel data, this assumption will be tested with the Modified Wald test for groupwise heteroskedasticity in fixed effect regression model (see below). The null hypothesis is rejected as the p-value is below 0.05 (0.0000). This means that the variance of the errors is not constant. The solution to meet this assumption anyways is to run the regression with robust standard errors, which is implemented in the research design. The third assumption states that the covariance between the error terms over time/cross-sectionally is zero i.e. the errors are uncorrelated with one another (Brooks and Tsolacos, 2010, p. 144). Due to the difficulty of interpreting graphical methods, a formal statistical test is applied. Often this is Durbin and Watson's (1951) test for first-order autocorrelation or the Breusch-Godfrey test for autocorrelation up to the rth order (Brooks and Tsolacos, 2010, p. 149-155). The Wooldridge test for autocorrelation in panel data is carried out and presented below. The fourth assumption states that these is no relationship between the error and corresponding x variable. The fifth states the disturbances are normally distributed (Brooks and Tsolacos, 2010, p. 167). The disturbances are normally distributed as can be seen in the two plots below: the standardized normal probability plot and quantiles of the disturbances need to approximately follow the line in order to be normally distributed and they are.

Table 4 Standardized normal probability plot

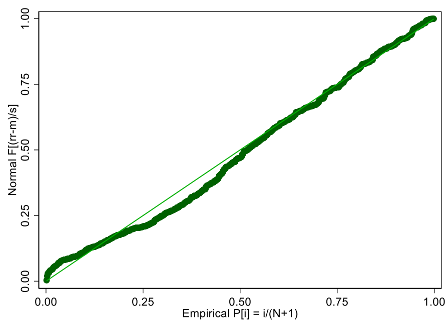
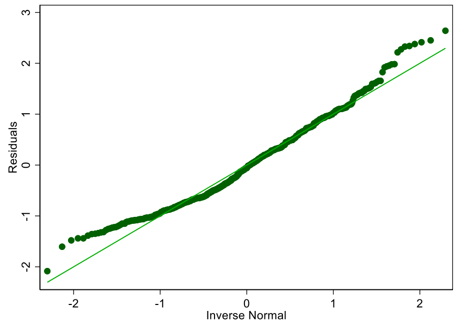
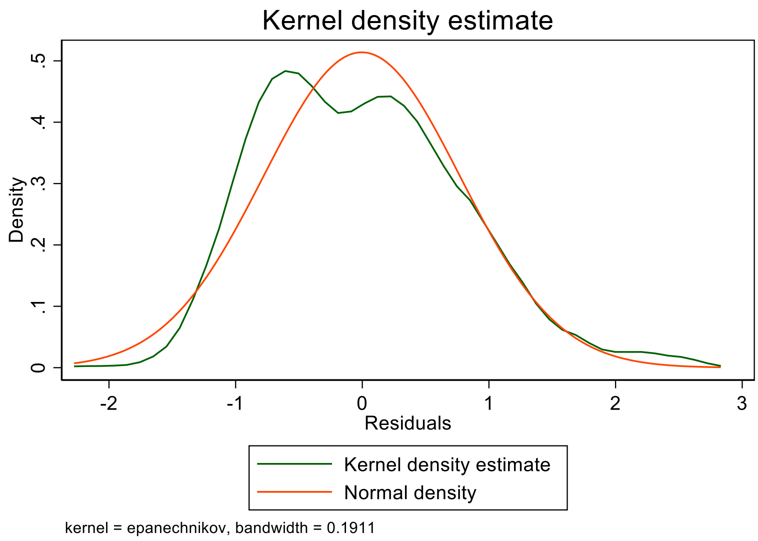


Table 5 Quantiles of the disturbances against quantiles of normal distribution



The kernel density estimates, the results graphed, examine the density estimates overlayed by a normal density for comparison.



Multicollinearity

An important consideration is whether the data contains multicollinearity. Multicollinearity is present when independent variables are highly correlated (Brooks and Tsolacos, 2010). If this is present, the regression will be very sensitive to small changes in the specification and makes the confidence intervals for the parameters very wide, leading to inappropriate conclusions from significance tests (Brooks and Tsolacos, 2010).

It is argued that multicollinearity is presence at a correlation coefficient of >=0.8 and VIF-values should be <10 to prevent multicollinearity (Brooks and Tsolacos, 2010; O'brien, 2007). All VIF-values of the variables used in this study are well below the threshold. Almost all right-handside variables are well below the threshold as well. Only the lagLGDPC (the lag of gross domestic product per capita) variable might be responsible for more biased regression coefficients as it correlates above 0.8 with the urbanisation variable (0.8445). The VIF-value is not problematic. Even though the variable is only a control variable and not of direct interest, the value has been transformed into a dummy variable to lower the correlation.

	L1Skys~s	lagCor~n	lagLGDPC	lagLPOP	lagLPD	lagRIR	lagUP	EU	lagGDPCG	lagUPG
L1Skyscrap~s	1.0000									
lagCorrupt~n	0.1879	1.0000								
lagLGDPC	0.1700	0.7197	1.0000							
lagLPOP	0.4037	-0.3056	-0.5232	1.0000						
lagLPD	0.0384	0.0067	0.1644	-0.2384	1.0000					
lagRIR	-0.0339	-0.1147	-0.0886	0.0364	-0.0730	1.0000				
lagUP	0.0447	0.6009	0.8445	-0.5077	0.0690	0.0014	1.0000			
EU	-0.2818	0.1033	0.0977	-0.1495	-0.0043	-0.0313	-0.0243	1.0000		
lagGDPCG	0.1153	-0.1862	-0.2439	0.1046	0.0863	-0.0519	-0.2842	-0.0416	1.0000	
lagUPG	-0.0488	-0.1888	-0.0609	-0.1605	0.0661	0.0140	-0.0385	-0.3506	-0.0734	1.0000

Variable	VIF	1/VIF
lagLGDPC	5.30	0.188598
lagUP	4.07	0.245558
lagCorrupt~n	2.24	0.445603
lagLPOP	1.66	0.602421
lagUPG	1.32	0.755196
EU	1.30	0.769907
lagLPD	1.14	0.880389
lagGDPCG	1.13	0.883990
lagRIR	1.04	0.961315
Mean VIF	2.13	

After transformation of lagGDPC into dummies:

	L1Skys~s	lagCor~n	lagLGD~m	lagLPOP	lagLPD	lagRIR	lagUP	EU	lagGDPCG	lagUPG
L1Skyscrap~s	1.0000									
lagCorrupt~n	0.1879	1.0000								
lagLGDPCdum	0.1689	0.7432	1.0000							
lagLPOP	0.4037	-0.3056	-0.4902	1.0000						
lagLPD	0.0384	0.0067	0.1598	-0.2384	1.0000					
lagRIR	-0.0339	-0.1147	-0.0832	0.0364	-0.0730	1.0000				
lagUP	0.0447	0.6009	0.7789	-0.5077	0.0690	0.0014	1.0000			
EU	-0.2818	0.1033	0.0582	-0.1495	-0.0043	-0.0313	-0.0243	1.0000		
lagGDPCG	0.1153	-0.1862	-0.2607	0.1046	0.0863	-0.0519	-0.2842	-0.0416	1.0000	
lagUPG	-0.0488	-0.1888	-0.0609	-0.1605	0.0661	0.0140	-0.0385	-0.3506	-0.0734	1.0000

Tests for the most adequate model

A Breusch and Pagan Lagrangian multiplier test for random effects can help determine the choice between a simple OLS regression or a random effects regression. In this study, the extended dataset favours a panel data regression over a simple OLS regression as the Breusch and Pagan Lagrangian multiplier test found evidence of significant differences across countries (P=0.0000).

The Hausman test determined that the fixed-effects model, as opposed to the random effects model, is the most efficient estimator. Fixed effects help to control for omitted variables or effects between markets that are constant over time, reflecting certain local market characteristics

(Brooks & Tsolacos, 2010). This model will account for unobserved heterogeneity and produces unbiased coefficient estimates. Nevertheless, it is important to realise that the choice between the fixed- and random-effects model is not undisputed and has generated a hot debate in the panel data econometrics literature (Baltagi, 2008). However, in skyscraper literature a panel regression with country and/or time fixed effects are common (Gjerløw & Knutsen, 2017; Jedwab, Barr & Brueckner, 2020; Barr & Luo, 2018).

Breusch and Pagan Lagrangian multiplier test for random effects

```
Breusch and Pagan Lagrangian multiplier test for random effects

        L1Skyscrapers[CountryID,t] = Xb + u[CountryID] + e[CountryID,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               L1Skysc~s |   1.119189       1.057917
                       e |   .2318087       .4814652
                       u |   .5121906       .7156749

        Test:   Var(u) = 0
                             chibar2(01) =   962.96
                          Prob > chibar2 =   0.0000
```

The Breusch and Pagan Lagrangian multiplier test (LM) for random effects helps to decide between a simple OLS regression and a random effects regression. The null hypothesis is that variance across entities (here: countries) is zero i.e. no significant difference across units = no panel effect. After running the random effects model, the LM test rejects the null and concludes that a random effects model is appropriate. This is, evidence of significant differences across countries.

Hausman test

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lagCorrupt~n	.1936049	.1968715	-.0032666	.1474452
lagLGDPCdum				
2	.3122009	.452943	-.1407421	.0443113
3	.1471088	.3388194	-.1917106	.0804278
4	.7174219	.8740367	-.1566148	.1306129
lagLPOP	-14.99756	.3647983	-15.36236	5.36328
lagLPD	14.55437	.0645793	14.48979	5.42498
lagRIR	.0004073	-.0009165	.0013238	.0008497
lagUP	.0496195	.001719	.0479006	.0163066
lagGDPCG	-.0046986	.0016803	-.0063789	.

```
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       21.18
                Prob>chi2 =      0.0067
                (V_b-V_B is not positive definite)
```

The Hausman test helps to decide between fixed or random effects. The null hypothesis is that the preferred model is random effects vs. the alternative the fixed effects. In other words, it tests whether the unique errors (ui) are correlated with the regressors, the null hypothesis is they are not. After running both the fixed effects model and the random effects model, saving the estimates and performing the test, the result favours the fixed model over the random model.

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (47)   =    12808.18
Prob>chi2 =        0.0000
```

The modified Wald test helps to detect heteroskedasticity in the fixed effect regression model. The null hypothesis is homoskedasticity i.e. constant variance. The test rejects the null and presence of heteroskedasticity can be concluded. Therefore, heteroskedasticity-robust standard errors (also known as Huber/White or sandwich estimators) are obtained with the option ‘robust’.

Testing for time-fixed effects

```
( 1)  Year = 0
( 2)  Yeardummy8 = 0
( 3)  Yeardummy9 = 0
( 4)  Yeardummy10 = 0
( 5)  Yeardummy11 = 0
( 6)  Yeardummy12 = 0
( 7)  Yeardummy13 = 0
( 8)  Yeardummy14 = 0
( 9)  Yeardummy15 = 0
(10)  Yeardummy16 = 0

      F( 10,   421) =    1.22
           Prob > F =    0.2741
```

This test helps to detect whether time fixed effects are needed in the fixed-effects model. It is a joint test to see if the dummies for all years are equal to zero. If that is the case, no time fixed effects are needed. The test result fails to reject the null that the coefficients for all years are jointly equal to zero, therefore no time fixed-effects are needed in this case. However, it can be argued to still apply these effects and it is done by other research as well. Therefore this study still applies the effects, but for robustness also models without these effects will be presented.

Testing for serial correlation

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      45) =      0.733
           Prob > F =      0.3965
```

The Wooldridge test for autocorrelation in panel data helps to detect serial correlation, which causes the R-square to be higher and the standard errors of the coefficients to be smaller than they actually are. The null hypothesis is no serial correlation. The test fails to reject the null and it can thus be concluded that the data does not have first-order autocorrelation. This to be expected as serial correlation apply to macro panels with long time series. To cluster at country-level is therefore not needed.

6. Methods of the panel regression specification worldwide

Although the estimations of the cross-sectional regressions are perfectly capable to provide valuable information about the relationship of a real estate market series (skyscraper stock) with economic or other variables (control of corruption), it also has its downsides. Typically the sample size is smaller, while a larger sample size is typically required to lower the risk of error (Brooks & Tsolacos, 2010). And indeed, the number of observations in the first and second cross-sectional regression model is relatively low: 63 and 56 respectively.

To increase the number of observations and generate a more efficient estimation, cross-sectional time series (panel) regressions were run in addition (Baltagi, 2013). This analysis makes it possible to examine both between and also within-country effects of corruption. This specification adopts 'the number of skyscrapers developed per country, per year' as dependent variable (model specification (4)). The use of a panel enables this study to examine in more detail the adjustment process of the dependent variable (skyscrapers developed) in response to changes in the values of the independent variables (changes in the control of corruption) within a country (Brooks & Tsolacos, 2010). This will show whether changes (increases or decreases) in control of corruption in a country influenced the development of skyscrapers. The dataset was therefore extended with 15 years[20]: covering skyscraper development in more than 50 countries between 2005 and 2019. An important detail of this third panel data specification concerns the need to lag the right-hand side (RHS) variables[21]. Further methodological detail, descriptive statistics, VIF calculations and test results, including the Breusch and Pagan Lagrangian multiplier test results and Hausman test results, can be found in appendix 5.

A main strength of panel regression is the ability to analyse data with the dimensions of both time series and cross-sections (Brooks & Tsolacos, 2010). This specification thus consists of both time and country fixed effects, which are individually analysed as well by constructing this specification incrementally. In total, four regressions are run on the panel data between 2005 and 2019. The first regression excludes country and time fixed-effects, hence serves as a reference regression. However, it can be imagined that time plays an important role in the increasing skyscraper

[20] The WGI measured the control of corruption annually only as of 2002 and considering the three years lag 2005 is the earliest data to analyse the data systematically.

[21] After all, it is important to realise that it takes time to build a skyscraper and adding a lag accounts for the time between the decision to build and the completion of a skyscraper. Gjerløw and Knutsen (2017) analysed the available development time of skyscrapers over 150 meter from the CTBUH. They concluded that for almost the entire time-period, the typical skyscraper took between 3 and 4 years to develop. Their main specifications resulted in a 3 year lag for all independent variables. Barr's rationale to lag for less years is not substantiated despite the fact that he does so in several of his studies: one or two years in Barr (2012), two or three years in Barr (2013) and again one or two years in Barr and Luo (2018). Taken all together, the RHS variables in the third model are lagged three years to account for the time between deciding on a building project and it being finalized.

development. For example building technology might have increased over time or architectural trends favour skyscrapers globally. To account for such omitted global factors, the second regression includes time fixed effects (λ_t). But it can also be imagined that country-specific factors play a role, for example factors related to cultural affinity for skyscrapers or geographical characteristics of a country. Therefore, the third regression includes country fixed effects (μ_i) to account for such omitted country factors. Finally, the fourth regression includes both time and country fixed effects (specification (4))[22]. Including these fixed effects incrementally helps analysing the role of time and country specific effects and its possible influence on the estimation of the role of corruption. In all regressions of specification (4), the control of corruption is central.

$$
\begin{aligned}
\ln(\mathrm{L1Skyscrapers}_{i,t}) &\qquad (4) \\
= \alpha_{0,i} + \beta_1 \mathrm{lagCorruptiondum}_{i,t-3} + \beta_2 \mathrm{lagLGDPCdum}_{i,t-3} \\
+ \beta_3 \mathrm{lagLPOP}_{i,t-3} + \beta_4 \mathrm{lagLPD}_{i,t-3} + \beta_5 \mathrm{lagUP}_{i,t-3} \\
+ \beta_6 \mathrm{lagGDPCG}_{i,t-3} + \beta_7 \mathrm{lagUPG}_{i,t-3} + \beta_8 \mathrm{EU}_{i,t-3} + \mu_i + \lambda_t + \varepsilon_{i,t}
\end{aligned}
$$

where i = country; α = the constant/intercept; β_1 to β_8 = the regression coefficients for the independent and control variables which are lagged three years; ε = the residual or error in predicting the sample data; t = time; μ_i = unobserved time-invariant heterogeneities across countries; λ_t = unobserved time effect.

[22] However, including spatial fixed effects needs some remarks. Grouping data has become an important way to account for omitted, often time or individual, variables (Moulton, 1987). As not all variables that are correlated with the corruption variable can be observed, omitted variable bias may occur (Daams, Sijtsma & Veneri, 2019). Failure to incorporate group effects can have serious consequences as coefficient estimation can be inefficient and standard errors can get large downwards bias (Moulton, 1987). However, including spatial fixed effects needs to be done deliberately. If spatial controls are not defined at the right level, interpretation of the results cannot be done without hesitation. Of particular concern is the presence of unobserved variables that occur at varying spatial scales above that of the individual property (Abbot & Klaiber, 2011). Spatial controls may over-reduce the variance of the data in case of a too narrow definition of spatial controls and spatial controls may not mitigate omitted variable bias effectively in case of a too broad definition of spatial controls (Abbott & Klaiber, 2011; Daams et al., 2016; 2019). For this study, these considerations have to be taken into account as this might be the case in analysing corruption, as effects on many different levels might be conceivable. However, control of corruption is measured at country level and support for including country fixed effects in analysing skyscraper determinants can be found in Gjerløw and Knutsen (2017) and Jedwab et al. (2020). Another remark on including spatial fixed effects is that by applying country fixed effects a comparison between countries is not possible anymore as the results should be interpreted as within-country effects. However, as discussed many countries do not experience significant changes in corruption over time. This might be problematic as '[f]ixed-effects will not work well with data for which within-cluster variation is minimal or for slow changing variables over time'(Torres-Reyna, 2007, p. 10). To mitigate this limitation, an as large timeframe as possible has been used. Nevertheless, given these remarks the results of the fixed effect models (models 3 and 4 in table 5, and 1 and 2 in table 4) should be interpreted with caution.

With this analysis the first hypothesis - that a low control of corruption allows to more easily realize skyscrapers - can be substantiated. This time, there is also controlled for time and country specific omitted variables. Again, a significant and negative coefficient for the control of corruption variable (*Corruptiondum*) is expected and the control variables are expected to be significant and positive (negative for the European dummy) based on previous research (see 2.4 Control variables for expectations and sources), the same as for model specification (1), (2) and (3).

7. Results of explanatory factors: skyscrapers developed per year

The panel regression equation can also be applied to the dataset containing both emerging market countries and non-emerging countries. This way, skyscraper development worldwide can be analysed per year, making it possible to estimate the effect of changes in control of corruption on skyscraper development three years later. With this model, these changes will be examined both between countries (model 1 and 2 in table 8) and within-countries (model 3 and 4 in table 8), while controlling for other skyscraper determinants.

Between countries

Model 1 in table 8 is the starting model, without country nor time fixed effects, and analyses the determinants of annual skyscraper development, between 2005 and 2019. The model explains only 48.7% of the variance. In this model, all three categories of control of corruption are significant at 1% and positive, indicating that a country with a higher control of corruption has more skyscrapers developed three years later compared to a country with a very low control of corruption. Note that this model includes control variables as well.[23]

However, previous results in this study already showed the importance of time in the development of skyscrapers. To analyse the influence of time on the number of skyscrapers developed per year, model 2 in table 8 is an expansion of the previous model as the factor time is included, controlling for global changes over time which are omitted as variables. For example, the key innovation of the elevator or development material (Ahlfeldt, 2020). The explanatory power of the model increased only slightly by adding time fixed effects: now 50% of the variance is explained. However, the results are robust to the factor time: compared to the model without controlling for time trends all determinants are still significant with the same level and with the same positive (negative) sign. The importance of the control of corruption (and other variables) thus cannot be assigned to time trends which are omitted as variables in this model and still a country with a higher control of corruption has more skyscrapers developed three years later compared to a country with a very low control of corruption.

Within-countries

[23] In the previous models (in table 2 and 3), when controlled for other skyscraper determinants, only the low control of corruption (compared to the very low control of corruption category) was significant. In explaining skyscraper development per year the difference between all countries in control of corruption level compared to countries with a very low control of corruption is thus significant in explaining an increase in skyscraper development.

With country fixed effects it is possible to analyse the effects of change in control of corruption on the number of skyscrapers developed per year within a country. Model 3 in table 8 explains 79,1% of the within-country variance. It shows that within a country, all control of corruption coefficients are significant and positive in explaining the number of skyscrapers developed three years later, indicating that within a country an increase in the control of corruption (compared to a very low control of corruption) leads to more skyscraper development three years later[24].

Also within countries, the significance and positive sign of the role of corruption in the development of skyscrapers is robust to the factor time. Still all categories of control of corruption are significant at the same level and positive, indicating that within-countries a higher than very low control of corruption leads to an increase in skyscraper development three years later. In this fourth model (in table 8), which follows equation 3, both time trends and country specific characteristics have been controlled for as both could influence the development of skyscrapers at the same time. The inclusion of the time fixed effects increase the explanatory power of the model only slightly (to 79.6%). However, this might be understandable as the data is only covering 14 years and no major (technological) breakthroughs have occurred in these years influencing the development of skyscrapers.

[24] This conclusion takes into account country specific characteristics which are not included in the model but might also influence the development of skyscrapers worldwide. For example, geographic differences and/or cultural preferences might be of importance.

Table 8 Regression results of regressions explaining number of skyscrapers developed per year (2005-2019)

VARIABLES	(1) No FE	(2) Year FE	(3) Country FE	(4) Country and Year FE
Control of Corruption				
Control of corruption (dummy) = low [a]	0.630***	0.627***	0.248**	0.252**
	(0.0895)	(0.0902)	(0.114)	(0.121)
Control of corruption (dummy) = high [b]	0.819***	0.823***	0.352*	0.347*
	(0.121)	(0.121)	(0.196)	(0.198)
Control of corruption (dummy) = very high [c]	0.630***	0.622***	0.603*	0.563*
	(0.142)	(0.146)	(0.319)	(0.311)
GDP per capita (log), PPP (current international $)				
GDP per capita (dummy) = low	0.560***	0.555***	0.327**	0.363**
	(0.123)	(0.123)	(0.151)	(0.151)
GDP per capita (dummy) = high	0.693***	0.687***	0.330	0.407
	(0.145)	(0.143)	(0.241)	(0.249)
GDP per capita (dummy) = very high	1.080***	1.246***	0.560*	0.690**
	(0.160)	(0.159)	(0.286)	(0.297)
Population, total (log)	0.397***	0.400***	-14.90***	-13.45**
	(0.0327)	(0.0323)	(5.330)	(5.465)
Population density (people per sq. km of land area) (log)	0.0788***	0.0741***	15.02***	13.87**
	(0.0235)	(0.0237)	(5.365)	(5.446)
Urban population (% of total population)	-0.000606	-0.000160	0.0399**	0.0530**
	(0.00237)	(0.00240)	(0.0175)	(0.0253)
European country (1 = yes)	-0.536***	-0.530***		
	(0.0997)	(0.101)		
GDP per capita growth (annual %)	0.0407***	0.0513***	0.00150	0.00475
	(0.00918)	(0.0105)	(0.00535)	(0.00732)
Urban population growth (annual %)	0.0151***	0.0173***	0.0667***	0.0751***
	(0.0227)	(0.0219)	(0.0192)	(0.0199)
Constant	-7.467***	105.2	180.4***	160.1**
	(0.708)	(335.0)	(65.66)	(68.01)
Observations	531	531	684	684
R-squared	0.487	0.500	0.791	0.796
Country FE	NO	NO	YES	YES
Year FE	NO	YES	NO	YES
Number of CountryID			57	57

Note: dependent variable is the natural logarithm of skyscrapers added to stock that year + 1. The reference category of the control of corruption variable is 1, Very low Control of Corruption. The reference category of the GDP per capita variable is very low. Standard errors in parentheses with *** , **, * indicating significant at 1%, 5% and 10%, respectively.

a Control of corruption values between -.690 and -.141

b Control of corruption values between -.141 and 1.27

c Control of corruption values above 1.27

As for the control variables, while the between country results (model (1) and (2) in table 8) are as expected[25] the control variables in the within-country results (model (3) and (4) in table 8) are slightly different than before[26]. However, the control variables are not that much of interest.

[25] All variables, except urban population and urban population growth, are significant at 1% and have the expected sign direction. This suggests that for skyscraper development population size and the density people live in is more important than whether they tend to live in urban areas.

[26] The high GDP per Capita category is not significant anymore, while the low (5%) and very high (10%) are still significant and positive. The total population is still significant at 1%, however the sign is negative contrary to the expectations. This would indicate that an increase in population leads to fewer skyscrapers

In sum, controlled for other variables, in explaining skyscraper development between countries it matters which category of control of corruption is present while in explaining the skyscraper stock (of 2019, and change between 1996 and 2019) only the low control of corruption category was significant. Still, the relationship worldwide is negative which is consistent with the results from the other, first two, models. Not influenced by time, a country with a higher control of corruption has more skyscrapers developed three years later compared to a country with a very low control of corruption. In explaining skyscraper development within-countries it also matters which category of control of corruption is present compared to a very low control of corruption before. In explaining skyscraper development within-countries an increase in control of corruption leads to an increase in skyscraper development three years later. Again, time is not influencing this. The negative relationship is consistent with all previous results analysing data worldwide, but is contrary to the relationship within emerging market countries. Different mechanisms seem to play a part and the role of corruption in skyscraper development thus depends on the stage of development of a country.

developed. The negative sign of the total population variable sounds not logical, is contradicting to evidence showed in previous research (Barr & Luo, 2018; Gjerløw & Knutsen, 2017) and contradicting to the results from the previous models. It is therefore plausible that the addition of country fixed effects in this model is the culprit. As warned for in the methodology, spatial controls can produce misleading conclusions and ultimately generate biased estimates due to the absorption of important information into the fixed effects (Abbot & Klaiber, 2011; Daams et al., 2019). However, the control variables are not of interest in this study. Population density is still significant at 1% and has a positive sign. What changed, is the insignificance of GDP per Capita growth indicating that an increasing (decreasing) growth rate does not lead to more (less) skyscrapers developed. What changed as well, is that urban population and urban population growth are significant (5% and 1%, respectively) and both positive. Within a country urban population and its growth thus do lead to more skyscrapers developed. Adding the time fixed effects influences the control variables slightly. Although the GDP per capita category very high is more significant (5% instead of 10%) and population and population density are less significant (5% instead of 1%), the remainder of the control variables (significance and sign direction) stays the same. So as well for the control variables, the factor time seems to be not that much of a game changer in explaining skyscraper development over the last years.