Riskiness of Real Estate Development: A Perspective from Urban Economics & Option Value Theory*

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Abstract

Conventionally, investment in real estate development is viewed as being riskier than investment in stabilized property assets. In this paper we define a new construct for urban economic analysis which puts this conventional wisdom in a new light. We call the new construct, the Development Asset Value Index (DAVI). The DAVI is a value index for newly-developed properties (only) in a geographical property market. It tracks longitudinal changes in the Highest & Best Use (HBU) value of locations as reflected in gross physical capital formation, and it reveals developer and landowner behavior taking advantage of the optionality inherent in land ownership. In particular, the DAVI reflects developers' use of flexibility in the exercise of the call option represented by the right (without obligation) to (re)develop the property to any legal use and density. We empirically estimate a DAVI for commercial property (i.e., central locations) and compare it with a corresponding traditional transaction price based Property Asset Price Index corrected for depreciation (PAPI), in the same geographical market. We believe that the difference primarily reflects the realized value of flexibility in land development. For our test cities of New York and Los Angeles, we find that the DAVIs display greater value growth and are smoother and less cyclical than their corresponding PAPIs. This suggests that development may be riskier than stabilized property investment *only* due to leverage effects. We also find that development density (Floor/Area Ratio) is an increasing function of the location value.

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1 Introduction

This paper presents two related analyses. The primary focus and contribution of the paper is to present the concept, and to empirically quantify examples, of what we dub a Development Asset Value Index (DAVI). This is a new construct which we believe can advance our understanding of real estate development and of the dynamics of urban location value. In this role the DAVI may also suggest some rethinking about the conventional concept that real estate development is a riskier investment than stabilized income property. Secondly, we apply and test the Highest & Best Use (HBU) construct that is the fundamental ingredient in our DAVI in order to quantify the relationship between location value and the optimal density of development in central locations.

The DAVIs that we develop in this paper are longitudinal value indexes based on market transaction prices only of newly-developed properties. We focus on commercial and multi-family properties, the types of buildings that characterize central locations in metropolitan areas (as distinguished primarily from single-family homes which characterize more peripheral or interstitial locations). By being based purely on newly-developed buildings, DAVIs reflect real estate development project values only at the time they are constructed. By explicitly not controlling for building type or density, the DAVI reflects the Highest & Best Use (HBU) of the site as of the time of development, assuming the landowner and developer are profit maximizers. By being based on the entire built project asset value (not net of land or construction costs), and by controlling for the size of the land parcel, the DAVI represents location value, effectively, project asset value per acre of land. The DAVI is thus a vivid quantification of urban dynamics, providing an indication of the long run evolution of location and land values, in particular, in central locations (as our index is based on commercial properties).

Since the DAVI metric includes both the value of the land (location and site) and the value of the physical capital formation (construction), essentially per unit of land area, it reflects the capital intensity of the development as of the time of development. Thus, the DAVI traces the evolution of central location HBU value per acre reflecting actual gross capital formation plus land value. The DAVI is thus relevant for national accounting, including building capital formation in the GDP as well as land valuation in the National Balance Sheet.

Importantly, DAVIs also reflect the behavior of the development industry, the industry that governs commercial building capital formation. This provides an additional perspective of interest in the DAVI. According to option value theory, development occurs optimally only when the current market value of the HBU exceeds a threshold profitability criterion (over construction cost), reflecting the irreversible nature of building construction. (Capozza and Helsley (1990).) Therefore, to the extent that developers act rationally, DAVIs reflect the flexibility inherent in land ownership and the property development process, as developers rationally exercise the landowners call option to build (or re-build). Landowners and developers (effectively they are one and the same for our purposes) have flexibility to choose the type and density of project, and they have flexibility to wait out downturns and to build at the time of their choosing. The DAVI reflects the way the development industry has used this flexibility.

Because DAVIs are based only on newly-built property values, they could also reflect any value that users and investors place particularly on brand-new buildings, as distinguished from existing (aging) buildings. If there is a value premium in newness per se (above and beyond the lack of regular depreciation, which we do attempt to control for), either in the space market (rents) or asset market (property market yields), then this difference from standard property value indexes will also be captured in the DAVI.

We should note another influence, or perspective, on observable differences between a DAVI and a corresponding traditional property value index. The land value component of the property value would tend to be smaller, relative to the structure value component, in properties with newly-built structures, and therefore in the DAVI (other things equal). Unlike land, the building structure component of property value over time depreciates with age (due to wear and tear and to functional or economic obsolescence). This results in the relative proportion of land value in the property increasing with the age of existing built properties. This would cause DAVIs to reflect more the dynamics of building values (construction costs), and less the dynamics of land value. Land values probably tend to be more volatile and cyclical, and to grow on average at higher rates, than construction costs (the replacement value of buildings).

However, land value includes the value of development optionality, the very type of optionality whose exercise is reflected in the value of the HBUs tracked by the DAVI. The role of land value will be explicated in Section 2 of this paper, but in general it suggests that built property values will also display some of the same option value characteristics as the DAVI, only to a lesser degree. And

DAVIs reflect the actual exercise of optionality, whereas land values reflect only the potentiality of such exercise.

To explore empirically the differences between DAVIs and corresponding traditional property price indexes, we also construct such traditional indexes, for the same general types and locations of properties as reflected in our empirically estimated DAVIs. We construct repeat-sales price indexes based on transaction prices of existing buildings. We correct these repeat-sales price indexes to remove the effect of normal building depreciation, based on empirical estimates of such depreciation (Bokhari and Geltner (2016)). We refer to such a transaction price based, depreciation-corrected existing property value index as a 'Property Asset Price Index' (PAPI).[1] While PAPIs do include a few properties with new buildings in the first sales, the vast majority of transactions are for pre-existing structures typically well over a decade old.

For comparison with the corresponding DAVIs, our estimated PAPIs reflect the evolution of the current market prices of existing built properties, corrected for depreciation, of the same general types and locations as what our DAVIs track from a development project value perspective. Unlike DAVIs, PAPIs do not directly reflect developer behavior and therefore do not reflect the exercise of optionality as noted above. PAPIs also do not purely or directly reflect actual physical capital formation, as the DAVIs do. Rather, PAPIs are dominated by the effect of money flows into and out of the stock of existing already-built investment property assets whose transaction prices are tracked by the index. Existing assets are fully exposed to the effect of money flows and other determinants of market fluctuations, while developers can use timing and other flexibility to avoid at least some of the downside of such exposure.

Empirical comparisons of the DAVIs and their corresponding PAPIs reflects how developers have actually used the flexibility inherent in land ownership optionality. How effectively is the development industry actually able to exercise this flexibility? While PAPIs reflect the full force of market demand fluctuations and money flows on the volatility and cyclicality of property market values, development flexibility could allow some transient market movements to be avoided, or outflanked by the construction of new buildings better targeted to the latest needs and preferences.

[1] We use the word 'price' here rather than 'value', because the correction for depreciation essentially holds the 'quantity' of real estate constant in the index (assuming away major capital improvements, which we try to filter out of our data). On the other hand the HBU values tracked by the DAVI do not represent constant 'quantities'. (In national accounting: 'value' = 'price' $\times$ 'quantity'.)

The valuation of newly built projects may thereby tend to reflect a longer term perspective or a more optimized product.

This could cause the price and value dynamics of the DAVI to differ from the PAPI. Such dynamics relate to the nature and magnitude of investment risk in development compared to existing, stabilized property assets. It is conventionally assumed that investment in real estate development is riskier than investment in stabilized property. While this is no doubt true, the DAVI/PAPI comparison can reveal whether development assets themselves are riskier or whether the added development investment risk is due merely to greater leverage. Development projects contain inherent operational leverage due to the fact that construction costs are not highly correlated with built asset values. But is development, including the effect of its flexibility, actually riskier at the asset level than stabilized asset investment, apart from the leverage effect?

This is an interesting and practical question, because investors likely face ways to counteract the effect of leverage. If leverage is the only source of increased risk in development, then development is arguably not fundamentally more risky from an investment perspective. Indeed, the greater optionality in development may give it favorable risk/return characteristics compared to stabilized property investment. This is the intriguing possibility that could be raised by careful comparisons of DAVI and PAPI indexes.

The empirical analysis in this paper is based on commercial and multi-family properties in the New York and Los Angeles metro areas. We obtain data on nearly all newly-built and existing such property transactions of greater than $2,500,000 value. We employ a Bayesian Local Linear Trend procedure to construct the DAVIs and corresponding PAPIs. The DAVIs are hedonic indexes and the PAPIs are repeat-sales indexes. Bayesian methodology allows us to estimate price indexes even with very small samples, which is necessary in order to focus the analysis at a granular level. We obtain good empirical results for the period 2005-2015, quite an eventful span of history as it includes a market cycle peak, crash, and recovery.

Comparison of the estimated DAVIs and corresponding PAPIs reveals that the DAVIs show greater long-run growth and are smoother and less cyclical over time. These differences suggest the value of development flexibility and that the development industry has behaved rationally at least to some degree in the sample covered in the paper. Concomitantly, they suggest that lack of optionality in existing assets leaves them more exposed to fluctuations in space market demand

and the effect of capital flows into and out of the property asset market. This suggests that, in some sense, apart from leverage, development is not riskier than existing buildings, perhaps even less risky. The greater growth trends in the DAVIs reflects growth in the HBU values of central locations, that is, increasing land values reflecting greater capital intensity of land usage.

In a second, follow-on analysis in this paper, we test a classical result from the basic principles of urban economics, that profit-maximizing development density is a positive function of location value. This analysis is motivated in part by a desire to test and confirm the reasonableness of the HBU construct that we develop in the DAVI. We are able to use this HBU metric to empirically model the density of development as a function of the location value of the site. In this cross-sectional analysis, we hold property usage type constant, and we find that density (floor/area ratio - FAR) is an increasing function of our construct of HBU value per acre (which effectively reflects location value). This finding is robust to alternative model specifications and is consistent with classical urban economic theory, and with rational development behavior. The result is interesting in its own right as a quantification of the general qualitative theory of the relationship between density and land value. But the result also helps to confirm the reasonableness of our DAVI construct.

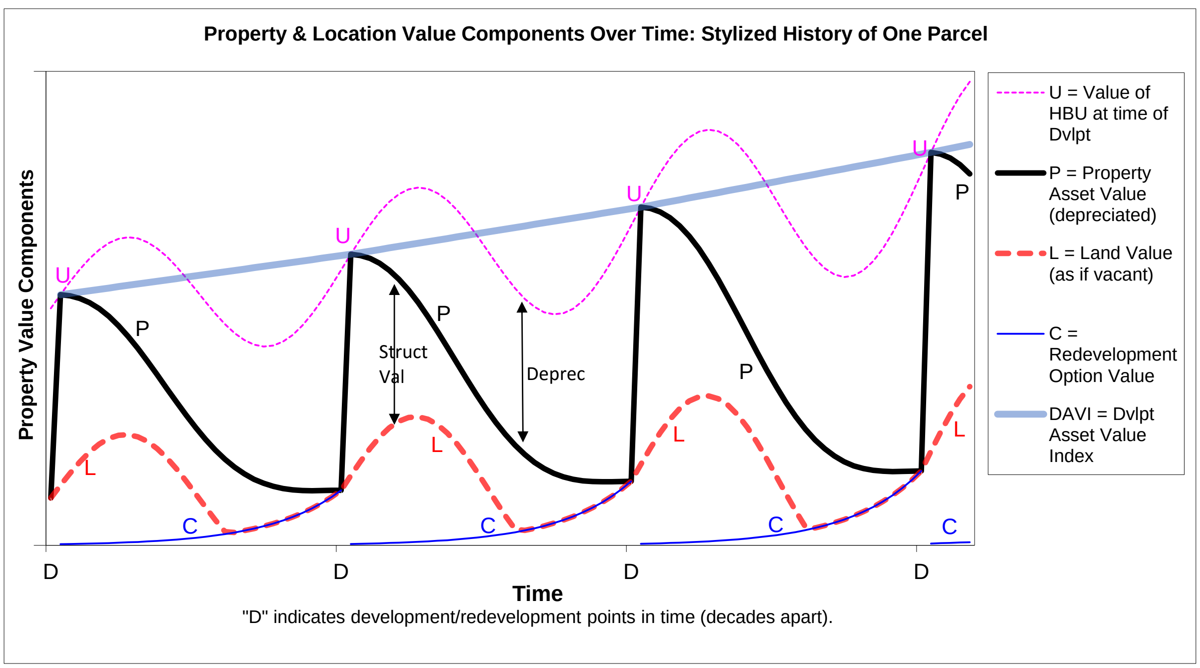
Overall, we generally obtain consistent results across both the New York and Los Angeles transaction samples, both regarding the longitudinal DAVI/PAPI comparison and also regarding the cross-sectional location value effect on density. However, we also find interesting specific differences between New York and Los Angeles.

The remainder of the paper is structured as follows. Section 2 explicates the basic conceptual framework underlying the DAVI construct. Section 3 provides a review of related literature. Section 4 describes the empirical data and provides a detailed description of the empirical model. Section 5 presents the empirical estimates. In section 6, we discuss the results focusing on the comparison of the DAVI and PAPI indexes. Section 7 presents our analysis of the relationship of development density and location value. Finally, section 8 provides a brief summary conclusion.

2 Conceptual Framework

Figure 1 presents a stylized picture of the framework underlying the primary focus of this paper, the development and analysis of the DAVIs. The graph represents a single location across a long span of time indicated on the horizontal axis. The vertical axis indicates the value of various components and perspectives of the property. The figure is for just a single location or site, over a very long history, which simplifies the picture to the basics. The empirically derived indexes developed later in this paper represent aggregates across many such individual properties. Thus, the Figure can allow us to see conceptually what in essence the DAVI is measuring and how it is related to other important and more traditional metrics.

Figure 1: **Stylized Conceptual Framework for the DAVI.**



At points in time indicated by "D" on the horizontal axis, the site is developed (or redeveloped), meaning that large amounts of financial capital are invested to produce major new physical capital assets, one or more building structures on the site (gross capital formation in NIPA terminology). At those points in time, it is to be assumed that the site is developed to its HBU as-if-vacant, that is, the most profitable development possible for that site at that point in time.[2] (This assumption

[2]In this context, 'profit' refers to the difference between the value of the newly-built property minus the construction costs, such that the HBU maximizes the land value.

follows from the assumption of rational profit-maximizing behavior on the part of landowners and developers.)

This HBU value is indicated by the U points across the top of the chart. Over time, the HBU as-if-vacant evolves, reflecting both secular trends and capital flows that affect property asset values. The dashed pink line represents the HBU as-if-vacant for the site across continuous time, even though the site is not actually redeveloped except at the discrete D points in time. The cyclical movements in the U line are a stylized representation of the effect of all the volatility and cyclicality inducing factors affecting the property markets, such as the flow of capital into and out of the asset class, as well as changes in the fundamentals of the market.

Meanwhile, between the redevelopment D points in time, the existing building structure on the site gradually depreciates from a combination of physical wear & tear, functional obsolescence, and economic obsolescence. This last type of obsolescence, which is also called external obsolescence, reflects the redevelopment call option in the context of changes in the physical HBU of the site as-if-vacant and of the internal depreciation of the structure. (The redevelopment option becomes more valuable as its underlying asset, the current HBU as-if-vacant, evolves away from the existing building, and also as the existing building depreciates in value.)

The solid, black line labeled P traces the property asset market value across continuous time, what the property would sell for at any given time. The P value is thus the value of the asset for which there is a well-functioning market, the asset that is actually traded, and therefore for which we can directly observe empirical value indications from transaction prices. The vertical jumps in P at the D points reflect the investment of new capital to build the new building(s). In between these redevelopments, the P index in Figure 1 corresponds essentially to standard property value indexes that are estimated empirically, except that Figure 1 represents only a single property whereas the transaction price indexes reflect the empirical aggregation across many properties.

The land value, labeled L and traced by the dashed red line, reflects what the property would sell for if it were vacant. By the residual theory of land value, this equals the value of the current HBU as-if-vacant (indicated by the pink U dashed line at the top) minus the construction cost of building the new building(s) that would be required for that current HBU. The ratio of L to U (the new development land value fraction, site acquisition cost as a fraction of completed project value) usually remains approximately the same over time in a given location as of the time when redevelopment is optimal (at the D points), though this is not a necessary assumption.[3]

In Figure 1 the land value between the redevelopment points is slightly simplified and stylized, represented by the maximum of either the current HBU minus construction costs for that HBU (the current exercise value of the option) or the speculative value of the redevelopment option without a requirement for immediate exercise. The latter value will be the greater during the troughs of downturns in the market, as option value reflects the value of exercise timing flexibility, the 'right-without-obligation' nature of the option, which truncates the downside tail of the net value of development and gives the option always a positive value.

In between redevelopment points in time, the difference between the property asset value (P) and the land value (L) is the structure value, as depreciated. (This modified reverse application of the residual theory of land value is arguably just an accounting convention, as in fact there is no market for the existing structure separate from its location/site, hence, no market value, and the construction cost of the existing structure is sunk, hence, no opportunity cost from the classical marginal cost perspective of microeconomics.) In Figure 1 there is no line that represents structure value (StructVal), nor that represents accumulated depreciation (Deprec), but these constructs are indicated by the vertical value differences shown by the double-pointed vertical arrows and the equation:[4]

$$U - Deprec = P = L + StructVal \tag{1}$$

$$\implies StructVal = U - L - Deprec.$$

The blue line labeled "C" at the bottom of the chart is the value of the redevelopment call option. As with the land value line, the call option value is somewhat simplified and stylized. In reality the redevelopment call option does not exist as a separate legal claim or asset, but resides in the ownership of the land (assuming that the property is a fee simple estate, with redevelopment rights unencumbered by any ground lease). The call option value C is a part of the land value

[3]According to option value theory, the benefit/cost ratio that optimally triggers option exercise, i.e., (re)development in this case, is a function of interest rates, the payout ratio or current cash yield rate in the property market, and the volatility in the property market. In the urban land context the trigger benefit/cost ratio reflects and includes the Capozza-Helsley "irreversibility premium".

[4]Note that economic obsolescence is correctly charged against structure value, and actually reflects increased land value.

L[5]. The redevelopment call option can be exercised at any time, and obtains the value of the new HBU upon the payment of the construction cost of building that HBU as part of the strike price (exercise cost) of the option.

If there is already a pre-existing building on the site (which there always will be after its initial development), then part of the redevelopment call option strike price includes not only the demolition cost of that structure (essentially as part of the construction cost of the new structure) but also the opportunity cost of the existing building in the sense of the present value of any net rents which that building could continue to generate on the site in the future. (This opportunity cost component of the option strike price does not appear explicitly in Figure 1.)

The call option value (C) is very small just after (re)development, because of the high opportunity cost of the (new) existing building relative to the HBU value. Over time, as the existing building depreciates, and as the HBU evolves, the redevelopment option gets deeper and deeper in the money, and ultimately it becomes sufficiently profitable to demolish the existing structure and redevelop the site, thereby triggering the next redevelopment (D point on the horizontal axis).

At the times of optimal redevelopment (D), the entire value of the property is the value of this redevelopment call option, which also by definition equals the land value, as the structure at that point has no further economic value. (Economic obsolescence, what makes it optimal to demolish the existing structure, is charged against the pre-existing structure value, as clearly, an asset that optimally should be demolished no longer has any economic value in itself.)

The redevelopment call option (C) is a derivative of the HBU as-if-vacant value (U, represented in continuous time by the pink dashed line), equivalent to a dynamically varying levered long position in that underlying asset. This makes the call option value very volatile, with an investment risk factor that is a multiple of that of its underlying asset, hence requiring a high expected return (the option's opportunity cost of capital - OCC - or discount rate). Since the option pays no dividends, its entire OCC must come from expected growth in value, which results in a high growth rate in the secular trend in the blue line as represented in the Figure.

[5]If K is the construction cost of the current HBU (pink line in figure 1), then land value can be written as: L = max(U-K; C). This suggests why land value will never go below the value of redevelopment call option. Clapp, Jou, and Lee (2012) show that the redevelopment call option is also part of the property asset value (P). In usual scenarios, if the difference between structure value (P) and land value (L) is high, it is costly to exercise the land redevelopment call option. However, in the case of substantial rent increase, there might be value associated with the option to redevelop to higher intensity per unit land value.

Because the landowner/developer has the flexibility to wait out sharp downturns in the property market (and indeed, lenders will try to avoid financing construction at such times), rational development would tend to dry up during sharp downturns in the property market (represented by the troughs of the cycles in the dashed pink line). While lags in construction and other frictions as well as imperfect information will prevent this rationality from playing out perfectly in reality ex post, we might imagine that such rationality will tend to prevail on average in general. This assumption is what is depicted in Figure 1, as the D points do not occur at the troughs of the market cycle.

Thus, the transaction price observations represented in the DAVI (only newly-built properties) will tend not to exhibit property market downturns as much or as sharply as the continuous HBU index (pink-dashed line) or as the existing-property asset price index (P).[6] In this case, the empirical DAVI will tend to appear smoother and less cyclical than the property market represented by a traditional existing-property asset transaction price index.

In the stylized picture of a single site shown in Figure 1, the DAVI is the turquoise line connecting the newly-developed project values, the U values only at the D points in time. The DAVI reflects the actual timing of actual development projects. Though a figure representing a single property makes the picture very simple, it reveals the essence of the difference between the DAVI, which traces only the values of newly-developed properties (turquoise line at top), and a traditional property value index, which traces property asset market prices between reconstruction points (black line).

The Figure also reveals how, if we could remove the effect of structure depreciation from the traditional 'P' value index (the black line), we would convert that traditional index essentially into an HBU index. Per equation (1) above: U = P + Deprec. The only difference between the black (P) line and the dashed pink (U) line is the accumulated structure depreciation.[7] Because depreciation includes the effect of economic obsolescence, a depreciation-corrected price index, removing the effect of structure depreciation, would convert the traditional index of 'P' into an index of 'U'. Empirically observed property prices (P) reflect the redevelopment option value component of the land value component of the property asset. This includes the flexibility to develop the new HBU

[6]'P' is buffered against downturns in 'U' only by the land value component, which cannot go below zero. Gains in 'L' reflect depreciation of the existing structure, which reduces the structure value component of 'P'.

[7]Recall that such depreciation redounds to the benefit of the land value, because it either reduces the strike price of the redevelopment option and/or increases the value of that option's underlying asset, the new HBU asset that could be developed (which causes economic obsolescence of the existing structure).

of the site. The only difference between the depreciation-corrected P index and the DAVI index is that the building structures in the former index already exist and cannot avoid the effect of market downturns.

The depreciation-corrected 'P' index is effectively what we are calling the PAPI. Thus, our DAVI/PAPI comparison is essentially a comparison between the two top lines in Figure 1, the smooth turquoise DAVI line versus the cyclical pink U line represented by the PAPI. Of course, the empirical index comparison is at an aggregate level, across many properties, while Figure 1 represents a single site.

From a broader perspective, we suggest that the DAVI/PAPI comparison could reflect three phenomena. First, most obviously and rationally, there is the difference we have just described, caused by the flexibility reflected in the DAVI (based on the optionality in the development process). This is the ability of the call option to avoid the worst of the down markets, while the existing structures that dominate in the PAPI are fully exposed.

Secondly, less likely and less rationally but a behavioral possibility, the depreciation correction in the PAPI might not be able to fully reflect a preference purely for newness per se. If such preference is not well revealed in empirical evidence about net depreciation (which we use to correct the directly-estimated 'P' index for depreciation), then the PAPI will not reflect the newness preference whereas the DAVI will, since the DAVI is based only on very new buildings.

A third possible source of difference is the larger building value fraction in new property asset value, introduced in Section 1. As compared to the PAPI, the DAVI reflects a relatively greater structure value component of property value (smaller land value fraction). Since, structure value is less risky than land value, DAVI (as compared to PAPI) is expected to be smoother. However, our discussion here of Figure 1 and Equation (1), and the careful definition of building depreciation (including economic obsolescence), reveals that this third source of DAVI/PAPI difference should not negate or undercut the first source, the effect of development flexibility. Indeed, the larger building value component reflected in the DAVI represents the effect of the exercise of the development optionality that is the first source of DAVI-PAPI difference noted above.

Figure 1 shows how the DAVI differs essentially from a land value index (solid turquoise line versus dashed-red line). Land values, as traditionally defined, reflect what the property would sell for if it were vacant at each point in time. Presumably this would reflect the current state of the property market, including reflecting the volatility and cyclicality in that market as it responds to capital flows into and out of the asset class (as reflected in the dashed pink U line at the top). The dashed-red land value line (L) is essentially parallel to the dashed-pink current HBU market value line (U), reflecting the subtraction of the relatively-constant construction cost.[8] The returns to the land index are effectively largely just levered versions of the returns to the HBU index (the PAPI).[9] However, as noted previously, the land value will never go below zero, in fact, will never go below the value of the redevelopment call option, since the land includes this option, and the landowner is never forced to develop when the net present value (NPV) of development is negative. (Lags and imperfect information, or irrational behavior, may thwart this principle in reality, but Figure 1 reflects the normative pattern.)

In summary, considering all of the above, we expect empirically observed differences between DAVIs and PAPIs to primarily reflect the effect of development flexibility, the exercise of the optionality in land ownership (development rights) as actually managed by developers. This can explain why and how we would expect the DAVI to be smoother or less cyclical, than the corresponding PAPI. We would also expect a higher secular growth trend in commercial property DAVIs to the extent that central location HBUs are becoming more capital intensive (more valuable per acre). This would be particularly true in dynamic, growing urban areas. Of course, if the development industry is effectively unable to take advantage of the optionality that in principle exists in land ownership, then we would not observe the flexibility based types of differences between the DAVI and the PAPI. We would expect DAVI/PAPI differences to vary across markets, probably as reflected across different metropolitan areas. This is part of the motivation of our empirical analysis.

3 Literature Review

We believe that the Development Asset Value Index as we are defining it here is a new construct in the literature. As a result, there is not a pre-existing body of literature that is directly or

[8] Recall that the continuous HBU value index (dashed pink 'U' line) is represented empirically by our depreciation-corrected PAPI derived from the directly estimated 'P' transaction price index.

[9] In the analogy to financial leverage, land corresponds to equity, and construction cost corresponds to debt, in a capital structure model of the HBU asset value. Construction costs are relatively constant and stable over time, compared to property asset market prices, because construction is a produced good, with considerable supply elasticity.

immediately precedent to this paper. There have long been (and ubiquitously are) indexes or indicators of newly built housing prices. But housing is not investment property, and do not reflect central location values. Still, comparisons of new houses versus resale houses could be another indicator of some of the theoretical points we are raising.

There are three strands of literature that are relevant to the present study. One strand comes from the appraisal profession and classical microeconomics, regarding the economics of land use, including the fundamental concepts of the residual theory of land value, the land bid-rent function, and the Highest and Best Use (HBU) of land sites. Another relevant strand of literature comes from urban economics and financial economics regarding the nature of land ownership as a development call option, thereby including the relevant economics of call options. A third relevant strand of literature comes from real estate and urban economics regarding property life cycles and the decomposition of property value into land and structure components. A complete review of all of these relevant strands of literature is beyond the scope of this paper, but in this section we provide a brief summary of each.

The first above-noted strand of literature, classical land valuation theory, has its roots in the nineteenth century in the seminal works of Ricardo (1817) and von Thünen (1826). As elaborated in standard appraisal textbooks, a key point is that land is a derivative good whose demand is derived from the demand for other, final products that require land for their production. A fundamental result is the Residual Theory of Land Value, which states that land value is what is left over after subtracting the cost of mobile production factors from the value of what the land site can produce (e.g., see Miller, Jones, and Roulac (1995)). Von Thunen's concept of the bid-rent function suggests that each location will in equilibrium be devoted to the use which can produce the greatest residual, hence, the simultaneous maximization of the land value and the national product. This is the concept of Highest and Best Use (HBU), which has become somewhat formalized and institutionalized in the appraisal profession. (The Appraisal Institute (1996) is an official handbook; Sussna (1989) provides a more legalistic perspective; or see Lusht (1997), for a more readable text.) In the urban context, the "use" of land (the "U" in "HBU") is characterized by both the type of structure (office, retail, apartment, etc) as well as the density of the development (Floor to Area Ratio – FAR). HBU therefore involves the optimization of both usage type and density (Dotzour et al. (1990)).

These fundamental principles of residual land value, bid-rent, and HBU result in the classical model of spatial economics known as the Monocentric City, which, though originating fundamentally in von Thunen's work, was elaborated in its modern urban focus by Alonso (1964), Muth (1969), and Mills (1972), among others. Along with older geographical models of urban form, notably the Park and Burgess (1925) Concentric Ring Model, the Monocentric City Model essentially explains why and how, in the modern metropolis, central locations have higher land values than peripheral locations and also are the sites of higher intensity development including commercial and multi-family residential properties of the type studied in the present paper. While these models are essentially cross-sectional in nature, the same principles applied dynamically over time yield the basic concepts of neighborhood and property life cycle, that the HBU of a given location can evolve over time as changes in the demographics and economic base of the city as well as changes in infrastructure, technology, and preferences affect the bid-rent functions for different types of buildings at a given location.

The second relevant strand of literature comes from both financial economics and urban economics with the development of option value theory and its application to capital budgeting decisions (instigating a real estate development project is such a decision) and to urban form. Titman (1985) first pointed out that developable land could be viewed as a call option and the development process as the exercise of that option, with the value of the underlying asset being the gross value of the newly completed project and the strike price its construction cost. McDonald and Siegel (1986) pointed out the value of waiting to invest in physical capital projects. In the present context, the implication is that a land site will usually have a value greater than the NPV of its current HBU development project (defined as completed value minus construction cost gross of land cost), which could be interpreted as an enhancement to the classical residual theory. Capozza and Helsley (1990) integrated the option model into the Monocentric City model and demonstrated that under uncertainty developers would wait for an irreversibility premium in rent before converting land to more intensive use. Extensions were made to the question of optimal redevelopment (Amin and Capozza (1993)), optimal density of development (Capozza and Li (1994)), and the option value in the ability to choose among different land uses (Geltner, Riddiough, and Stojanovic (1996)). The general implications of this strand of literature are that the flexibility that the landowner/developer has in the choice of the type and density of building as well as in the timing of the (re)development adds value to the land while tending to delay (re)development such that it occurs later and at a greater density (FAR) the greater is the uncertainty in the real estate market (as represented by property asset price volatility).

The third strand of literature with some tangency to the present paper is a fairly recent set of papers focusing on the decomposition of property value into land and structure components. Most of this literature has focused on single-family housing, examining how the proportion of property asset value that is attributable to land (rather than structure) affects the price dynamics of the property. Bostic, Longhofer, and Redfearn (2007) showed that properties with greater land value proportion (what they refer to as land leverage) exhibited greater price appreciation. This is true in terms of first moment: expected returns or price secular trend. But there is also a risk (second moment) aspect, which is that properties with higher land component (”land leverage”) would be more risky. Since DAVIs track only newly-built properties, and such properties have the lowest land value fractions (over the life cycle), we have noted how this has implications for the nature DAVI dynamics, including likely less volatility than traditional indexes of existing built properties. These points are consistent with our stylized portrayal of property life cycle in Figure 1. First, property asset value, P, declines more slowly as the structure becomes more depreciated, leaving the property asset with a larger proportion of land value. Second, at ”D” points, structure (land) value is a larger (smaller) fraction of property value. Davis and Heathcote (2007) and Davis and Palumbo (2008) have empirically quantified the magnitude of the land and structure value components broadly in U.S. single-family housing, finding that in major urban areas in the 21^{st} century, land is typically close to half of the total property asset value considering the age of (hence accumulated depreciation in) the average structure.

4 Data

4.1 Development Asset Value Index (DAVI)

The data for this study has been provided by Real Capital Analytics Inc (RCA), from their database of commercial property transactions in the New York City (NYC) and Los Angeles (LA) metropolitan areas. We further divide these metros into sub regions which are NYC proper (composed of Manhattan and the NYC Outer Boroughs), NYC rest (consisting of the NYC suburbs), LA proper

(LA-County), and LA rest (Inland Empire and Orange County). Our sample for DAVI contains first transactions of newly developed commercial and multi-family properties in the NYC and LA metros from 2000 to 2015. Our sample is limited to properties with transaction prices greater than $2.5 million. For the DAVI, we further restrict our sample to properties sold within 5 years of construction and properties with a maximum land size of 10 acres. We use 3 samples to estimate the DAVI: properties sold during the year of construction completion, within 1 year of construction completion, and within 5 years of construction completion. Given this 5-year age criterion, we estimate the DAVIs only from 2005 through 2015.

Our definition of commercial and multi-family properties is limited to office, retail, and apartments. We do not include industrial properties in present analysis since they are often located far from city centers, whereas, as noted at the outset of this paper, our focus is on HBU value evolution in central places.

As noted, for our expanded sample estimations, we include properties sold as much as five years after completion of construction. For such properties sold subsequent to construction, we convert its sale price value to the equivalent as if it were sold immediately, by deflating the actual transaction price using the traditional property value index (P) that we also construct in this study (see S ections 4.2, 5.2, and 6.2). The 'P' index is constructed using repeat-sale transactions of properties in the NYC and LA metropolitans (similar to the newly-built properties, only including existing buildings).

Panel A in table 1 presents the summary statistics for the main variables related to newly−built properties which are used to estimate the DAVIs. [10] The average age of the 'new' properties when they are sold is 2.25 years (from the year of construction completion). As shown in the online appendix, total transaction price, transaction price per acre, and property density as measured by floor area ratio (FAR) are highest for New York proper followed by LA proper, New York rest, and LA rest respectively. For new developments, the average size of land parcel is 1.67 acres, average structure size is 42960 square feet and average property density is 0.99.

We present the land size statistics in the form of land splines. The development value of a property depends on the size of the land lot, but we do not expect this effect to be linear. The

[10] In online appendix, we also present summary statistics for DAVI at the sub market level - NYC proper, NYC rest, LA proper, and LA rest.

average value per square foot of land decreases as the size of the land lot increases (Lusht (1997)). We model this by controlling for land size in the form of splines. Splines are a parsimonious way to address the non-linearity issue, useful in our sparse data context. As per Colwell (1998), when it is not possible to fit k points using a linear function, a solution would be to divide the data into ranges and fit a low-degree polynomial between each of the points. Spline functions are piecewise assemblages of functions used to fit a number of points. In other words, splines are essentially piecewise polynomials whose different polynomial segments are tied together at a series of knots in a way that insures certain continuity properties (Randall (1999)). Splines can model local behavior without changing the global fit. As Bao and Wan (2004) point out, spline smoothing is particularly suitable for hedonic analysis given that hedonic data is usually unevenly spaced and many of the property attributes are qualitative in nature. In the present study, we split the land size in 3 ranges - small (upto 1.2 acres), medium (between 1.2 to 3 acres) and large (between 3 to 10 acres). Hence the split looks like: $LS = LS^s + LS^m + LS^l$. For example, if land size is 10 acres, then LS^s is 1.2 acres, LS^m is 1.8 acres, and LS^l is 7 acres.

Table 1: **Summary statistics.** This table provides the summary statistics for the main variables used to estimate the DAVI (panel A) and 'P' index (panel B) . Age is the number of years from construction completion to the sale of properties. Transaction price is the price paid for the property. Deflated transaction price is the property transaction price deflated to the year of construction (using the traditional repeat-sale price index (P)). Land lot size is measured in acres and structure size is measured in square feet. Land splines were measured by splitting the land size into 3 ranges: LS^s is 0-1.2 acres, LS^m is 1.2-3 acres, and LS^l is 3-10 acres. Floor/Area Ratio (FAR) is calculated as the ratio of structure size in square feet divided by land size in square feet.

	Panel A: DAVI				Panel B: P Index			
	Mean	Median	SD	Obs.	Mean	Median	SD	Obs.
Age	2.25	2.00	1.70	792	50.71	47.00	20.90	23,497
Transaction price (million USD)	16.15	6.65	30.38	792	15.56	15.39	0.90	24,053
Deflated transaction price (million USD)	15.62	6.63	33.57	792	–	–	–	–
Land size in acre	1.67	1.00	1.85	792	1.15	0.48	1.65	24,053
Transaction price per acre	17.56	6.14	28.51	792	18.51	9.74	27.09	24,053
Structure size in square feet (x 1000)	42.96	16.00	70.49	792	47.22	25.99	70.61	24,053
1^{st} Land spline (LS^s)	0.84	1.00	0.39	792	0.62	0.48	0.41	24,053
2^{nd} Land spline (LS^m)	0.47	0.00	0.69	792	0.29	0.00	0.60	24,053
3^{rd} Land spline (LS^l)	0.36	0.00	1.10	792	0.24	0.00	0.93	24,053
Floor area ratio (FAR)	0.99	0.33	1.48	792	1.87	1.00	2.20	24,053

4.2 Property Asset Price Index (PAPI)

We estimate traditional property asset value index (P) using RCA data for all the properties during our sample period $2000 - 2015$. The 'P' index is constructed using repeat-sale transactions of all the commercial and multi-family properties (office, retail, and apartment). In contrast to DAVI sample which includes only properties that were built after year 2000, sample for 'P' index includes properties that were built both before and after 2000 and transacted at-least two times during our sample period $2000 - 2015$. We apply same data filters, which were used for the DAVI construction, to construct the 'P' index, that is, we estimate 'P' index for NYC and LA metropolitans (which are further sub-divided into NYC proper, NYC rest, LA proper, and LA rest). We limit data sample to only commercial and multi-family properties with transaction prices greater than $2.5 million and maximum land size 10 acres. Panel B of table 1 presents summary statistics of the variables used to construct the 'P' index. [11]

Number of observations suggest that new developments represent only 3.29% of all the property transactions. All the properties that were transacted during time period 2000-2015 have an average age of 50.71 years. Mean transaction price for all sample is comparable to mean transaction price of newly-built properties. Compared to all properties (majority of which are existing properties), average land size is bigger but the structure size is smaller for new developments. FAR statistic shows that property density is almost double for the existing properties as compared to the new developments.

As noted in section 2, 'P' index (solid black line in figure 1) reflects depreciation. Therefore, we correct the 'P' index for the net depreciation. We refer this depreciation-corrected existing property price index as PAPI. Following Francke and Minne (2017), we use the concept of depreciating properties using three age related sources of decline in property value: physical, functional, and economic obsolescence of the building structure. Using this approach, Bokhari and Geltner (2016) find that on an average newly built property depreciates at a rate of 1.82% per year. Hence, we correct the 'P' index by using the depreciation rate of 1.82% per year to obtain PAPI.

[11] In online appendix, we also present summary statistics for 'P' index at the sub market level - NYC proper, NYC rest, LA proper, and LA rest.

5 Methodology

5.1 Development Asset Value Index (DAVI)

In this section, we present the methodology used to construct DAVI indexes for the New York and Los Angeles metropolitans. DAVIs are hedonic indexes where we control for the various characteristics of the new developments to construct them.

We run the following specification to construct the DAVIs. The idea is to base the index only on newly-built properties. However, not all brand-new buildings are sold right away, and our estimation must be based on actual transaction prices. Thus, while we analyze a small sample of properties that were indeed sold in the same year they were built, for robustness we expand our sample to also consider samples of properties which were sold within one year, and five years of construction, adjusting the sale prices to control for market movements in the meantime. Our basic model is as follows in Equation (2):

$$\ln P_{i,t} = \alpha_0 + \beta^l l_{i,t}^{Size,Subloc} + (d_{i,t}^{Time} \times loc_{i,t}) \cdot \beta^{Time} + \epsilon_{i,t} \tag{2}$$

The dependent variable is the log of newly-built property transaction price. Our main independent variable, $(d_{i,t}^{Time} \times loc_{i,t})$, is the interaction of the time of sale and location dummies. β^{Time} is the corresponding coefficient vector. The vector β^{Time} is the DAVI we are interested in. Subloc represents dummies for sub$-$locations (Manhattan, Flushing, and LA city) and Size represents the size of the land parcel. α_0 is a constant and the subscripts i $= 1, ..., N$ and t $= 1, ..., T$ denote an individual properties and time; where N is the number of properties and T is the number of time periods. The error term ϵ_{it} is assumed to be independently normally distributed with mean zero and variance σ_ϵ^2.

To address problems associated with small samples, we fit our model to time series hedonic data using a Bayesian approach. Specifically, we use a Bayesian local linear trend model with regressors. This model is a stochastic generalization of the classic constant-trend regression model. Bayesian analysis was first introduced in the real estate price index literature by Goetzmann (1992), who specified the prior distribution of the price level (μ) to be normally distributed, $\mu \sim N(\kappa, \sigma_\eta^2)$. This implies a random walk with drift for the log value index, $\mu_t, where: \mu_{t+1} = \mu_t + \kappa + \eta_t$. The variance parameters of the model (the signal σ_η^2 and noise σ_ϵ^2) are estimated in a first step and plugged into the second step of the Bayesian procedure. However, this may lead to biased estimates of the variances.

Francke (2010) generalized this model by assuming that the trend component follows a local linear trend, and by providing the log likelihood function $l(p; \sigma_\eta^2, \sigma_\epsilon^2)$ to estimate the signal σ_η^2 and noise σ_ϵ^2 directly (for example by maximum likelihood), avoiding the somewhat ad hoc two-step procedure of Goetzmann (1992). Our methodology adapts the local linear trend model discussed in Francke (2010).

β^{Time} or β_t in equation (2) is assumed to be a scalar stochastic trend process in the form of a local linear trend model, in which both the level and slope can vary over time. The local linear trend model is given by

$$\beta_{t+1} = \beta_t + \kappa_t + \eta_t, \qquad \eta_t \sim N(0, \sigma_\eta^2) \tag{3}$$

$$\kappa_{t+1} = \kappa_t + \zeta_t, \qquad \zeta_t \sim N(0, \sigma_\zeta^2) \tag{4}$$

where β_t is the log time index at time t and κ is the drift term. Local linear trend models are very flexible and includes different specifications as special cases, like linear trend ($\eta_t = \zeta_t = 0$), random walk ($\sigma_\zeta^2 = 0$ and $\kappa_1 = 0$), random walk with drift ($\sigma_\zeta^2 = 0$) (Goetzmann (1992)) and smoothed trend ($\sigma_\eta^2 = 0$) (Andrew (1989)). Note that we estimate the variance parameter.

The local linear trend hedonic model is provided by equations (2)-(4) and is estimated by Markov Chained Monte Carlo (MCMC) simulations. More specifically we use Gibbs sampling. The model can be expressed as a linear regression model with a prior for β, induced by the local linear trend model (3)-(4). The local linear trend hedonic model is an example of a structural time series model. A structural time series model is a model in which the trend, error terms, plus other relevant components, are modeled explicitly. In contrast to the traditional time-dummy variable approach, the structural time series model enables the prediction of the price level based on the preceding and subsequent information. Hence this approach provides estimates of the price level even when we have very few or even no observations. State space models have been successfully used to estimate hedonic price indexes, for example, see Schwann (1998), Francke and Vos (2000), and Francke and Vos (2004).

5.2 Property Asset Price Index (PAPI)

To show the effect of land (re)-development option and preference for newness, we compare DAVI constructed using methodology described in previous section, with PAPI. PAPI is depreciation corrected P index, a traditional repeat sale index of the actual transaction price evolution of properties with existing (aged) buildings. The repeat sales model is introduced by Bailey, Muth, and Nourse (1963) and a number of adaptions of this original model is given in the real estate literature. Using the Bailey, Muth, and Nourse (1963) notation, for a pair of sales of a given property i, prices and indexes are related by the following expression:

$$\frac{P_{it}}{P_{is}} = \frac{B_t}{B_s} \cdot \frac{\epsilon_{it}}{\epsilon_{is}} \tag{5}$$

A standard repeat sale model in 'first differences' can be written as below. Specifically, for a pair of sales of a given property i, property prices and indexes on a logarithmic scale are related by following equation:

$$p_{it} - p_{is} = \beta_t - \beta_s + \epsilon_{it} - \epsilon_{is} \tag{6}$$

where p_{it} is the log transaction price of property $i, i = 1, ..., n$ at time $t, t = 1, ..., T$. For a pair of sales, s is the time at the first sale and t the time at the second ($t > s$). β_t is the property price index at time t. In other words, β_t is a time varying constant, capturing the log price movement over time. We assume for the purpose of identification $\beta_1 = 0$. The error term ϵ_{it} is assumed to be independently normally distributed with mean zero and variance σ^2_ϵ.

Since our purpose is to compare DAVI with PAPI, we use the same bayesian local linear trend model but in the repeat-sale context to create the P index. The local linear trend repeat sale model is provided by equations (6), (3), and (4). In the standard repeat sales model it is typically assumed that the β_t's are fixed unknown parameters. As noted in section 5.1, in the local linear trend model, β_t is a scalar stochastic trend process, in which both the level and slope can very over time.

6 Results & Comparison

6.1 Development Asset Value Index (DAVI)

This section presents the DAVI index construction and estimation results of the Bayesian local linear trend model. Table 2 presents the results of our main specification. The dependent variable is the natural log of property value. Columns 1, 2, and 3 present analysis for the samples where a newly developed property is sold within five, one and same year of construction.

The estimated models are reasonable. As expected, land size has a positive and significant effect on the property value. However, as the coefficients of the 1^{st}, 2^{nd}, and 3^{rd} splines show, this effect is not linear. Specifically, the first land spline has the biggest effect followed by the second and third splines. This provides evidence that marginal effect of land size on the HBU value per acre decreases as the size of the land parcel increases.

We control for Manhattan, Flushing, and LA city locations. As expected, the Manhattan and LA proper dummies have a positive coefficient, while the Flushing dummy has a negative loading on property prices. In column [3], we consider only those properties which were sold in the year of construction. This reduces the number of observation to only 133.

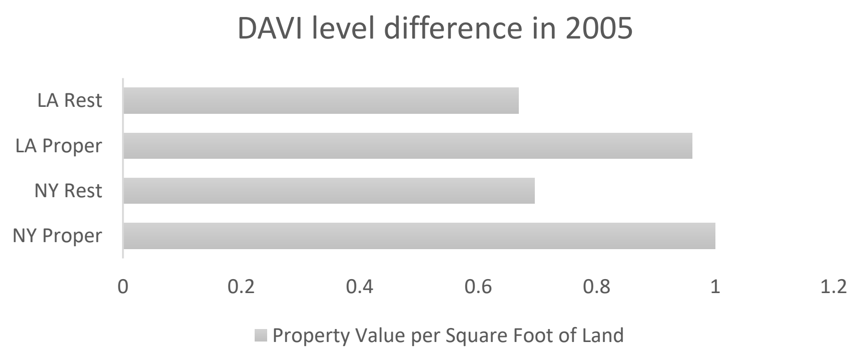
We construct DAVI indexes from 2005. We set the inception value to 0 (in logs) in year 2005. (We do the same for the PAPIs that we estimate in Section 6.2, to make the indexes easy to compare visually). Of course, the initial value of indexes is arbitrary and contains no information about relative absolute values, making cross-sectional comparisons of value levels impossible purely from the indexes. To give some idea of the relative cross-sectional values, Figure 2 presents the initial levels of the DAVIs for each region. The values in Figure 2 have been converted from logs to actual price levels. Note that NY proper presented the highest DAVI starting value level in 2005, followed by LA proper, NYC rest, and LA rest respectively.

Figures 3 to 5 present DAVIs constructed using Bayesian analysis for different sub-samples of the properties. Figure 3 represents the largest sample, as it includes 'newly-built', properties sold up to five years after construction completion. (As noted, prices are deflated back to the time of construction completion using the price indexes developed in Section 5.2.) The Figure shows that by the end of the sample period (2015), the DAVI of commercial properties was highest for

Table 2: **Estimation Results.** This table reports the results of the Bayesian estimates of the specification in equations (2) − (4). The dependent variable is the natural log of property value. Columns [1] to [3] presents results of for properties which were sold within five, one, and zero years of construction respectively. Property prices in columns [1] and [2] were deflated to the year of construction using traditional property value index (P). All the columns contains interaction of location and time dummies.

Dependent Var: ln(Property Value)	Bayesian (Age $\leq$ 5) [1]	Bayesian (Age $\leq$ 1) [2]	Bayesian (Age = 0) [3]
1^{st} land spline	0.867	0.796	0.647
2^{nd} land spline	0.344	0.417	0.471
3^{rd} land spline	0.185	0.120	0.100
Year 2005 level - NY proper	0.000	0.000	0.000
Year 2005 level - NY rest	-0.364	0.126	-0.250
Year 2005 level - LA proper	-0.040	0.339	0.014
Year 2005 level - LA rest	-0.404	0.002	-0.315
Manhattan dummy	0.208	0.241	-0.768
Flushing dummy	-1.195	-0.057	-0.493
LA dummy	0.576	0.659	0.737
Intercept	14.830	14.410	14.590
Location & time dummies	Yes	Yes	Yes
Observations	792	343	133
Sigma/RMSE	0.798	0.758	0.727
Sigma.eta	0.178	0.146	0.184
Sigma.kappa	0.100	0.099	0.127

Figure 2: **Initial Level Difference.** This bar plot presents the initial level difference in DAVI in year 2005 for various regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County).



NYC proper, followed by LA proper (the two central cities), and then by NYC rest and LA rest respectively (the outlying areas).

Figure 4 presents DAVIs obtained from the intermediate sized sample based on the 'newly-built' criterion extending to sales only one year beyond the construction completion year. The resulting indexes remain essentially robust to the previously reported findings.

Figure 3: **DAVI.** Graph presents the DAVIs for regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County). The indexes were calculated using bayesian estimation for properties which were sold within five years after their construction. The development value is estimated by deflating the transaction price to the year of construction.

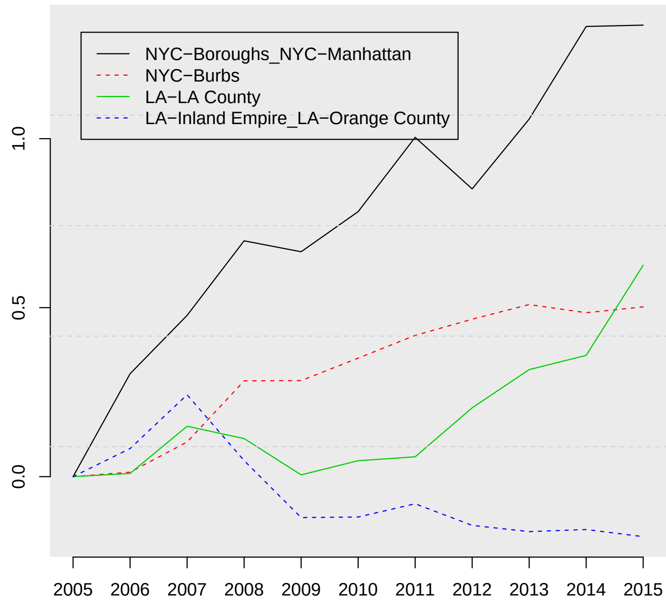
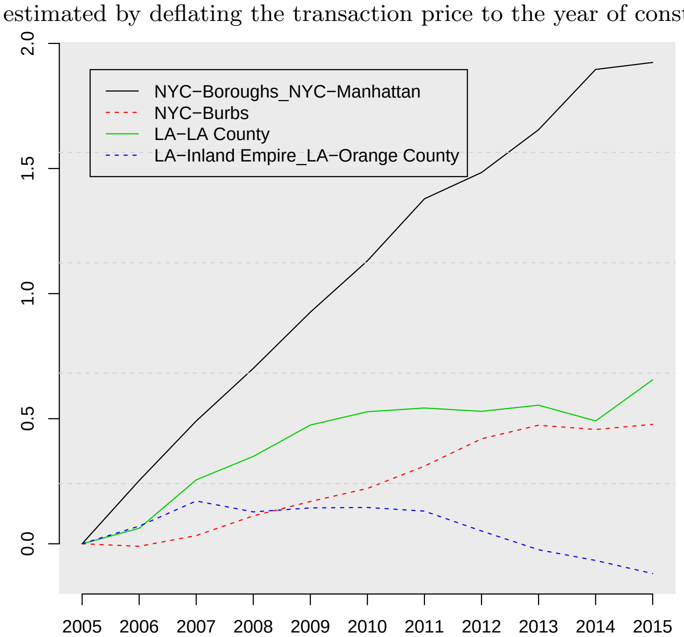
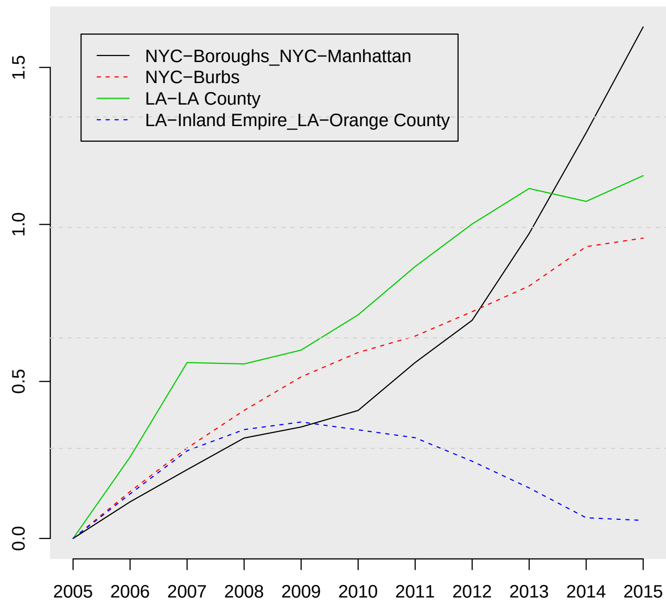


Figure 4: **DAVI.** Graph presents the DAVIs for regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County). The indexes were calculated using bayesian estimation for properties which were sold within one year after their construction. The development value is estimated by deflating the transaction price to the year of construction.



Finally, the DAVIs in Figure 5 are based on the narrowest (but in some sense 'purest') sample, only properties sold in the same year as construction completion. We see again results essentially robust to the previously seen findings in Figures 3 and 4. Statistics of all the DAVIs constructed using the different sub-samples are presented in table 3 in the next sub-section.

Figure 5: **DAVI.** Graph presents the DAVIs for regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County). The indexes were calculated using bayesian estimation for properties which were sold during the same year of their construction.



6.2 Property Asset Price Index (PAPI)

In this section, we present a comparison of our new construct DAVI with the PAPI index. The first step is to produce a traditional repeat-sale index of the actual transaction price evolution of properties with existing (aged) buildings. This is the index labeled 'P' in Figure 1 in Section 2. As described in section 5.2, we use local linear trend repeat sales model to estimate the 'P' index

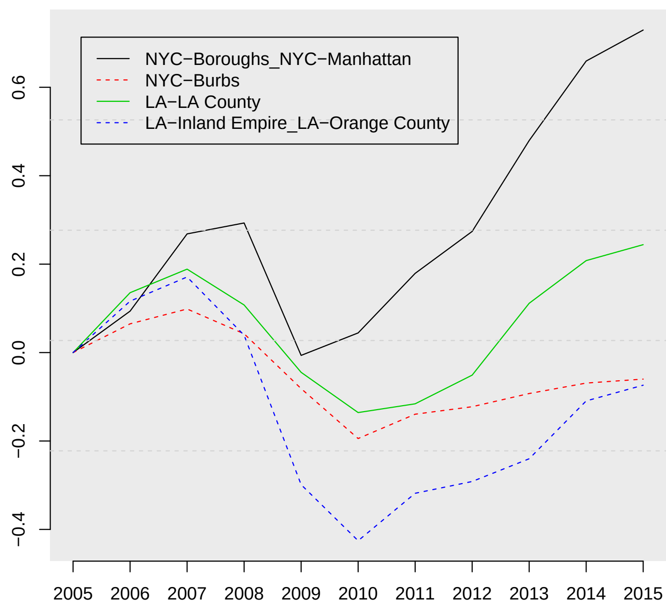
Figure 6 depicts the log price indexes constructed using repeat-sale transaction values of commercial properties.[12] As noted, Figure 6 shows 'P' value indexes (using the terminology of Section 2), original property asset value indexes without controlling for the effect of depreciation. These indexes thus directly reflect the price change experiences of the average investors in these types of

[12] We also compare repeat-sale indexes by property type - office, retail, and apartment. In the online appendix, we present various graphs and diagnostics of the PAPIs by property type.

properties in NYC and Los Angeles over the given history. (The investors do experience depreciation.)

It is interesting to note that all of the regions in our study exhibited a broadly similar price path during 2005-15, as measured by the ‘P’ indexes. In particular, they show strong growth for the first few years, the peak of the boom, then they exhibit the price crash associated with the Global Financial Crisis during 2008-10, followed by a recovery up through 2015. While the magnitude of the movements in these three phases does vary across the regions, in general we see greater commonality of price paths here in the ‘P’ indexes than we did in the DAVIs that we described in the previous Section. In particular, recall that the DAVI for NYC proper displayed very low correlation with rest of the regions.

Figure 6: **P Index.** Graph presents the repeat sale index for the existing properties for regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County). Three property types - Office, Retail, and Apartment were considered for the construction of the P index.



Our next step is to correct the ‘P’ indexes of Figure 6 for depreciation, to convert them into the ‘PAPI’ construct that we defined in Section 2, the depreciation-corrected existing property indexes that essentially track the HBU values over time (the continuous ‘U’ values in the dashed pink line of Figure 1 in Section 2). Such PAPIs are our focus of comparison with the DAVIs described in the previous Section.

To correct the ‘P’ indexes for deprecation, we follow (Bokhari and Geltner 2016) and apply an average depreciation rate of 1.82% per year for relatively new commercial properties. Figure 7 presents the resulting PAPIs after correcting for depreciation. Comparing the DAVIs in Figures 3, 4, and 5, in Section 6.1 with figure 7, we find that, compared to PAPIs, DAVIs show greater long run growth and are smoother and less cyclical over time (lower amplitude downturn).

As discussed in Section 2, we attribute the reduced volatility and cycle amplitude to the exercise of optionality, the flexibility inherent in the property development process (landowner's call option to choose the development time, type and density of the property). We attribute the greater growth trend to a secular increase in the HBU value, the ‘location value’, of central places in the NYC and LA metro areas. We admit that, to an extent, the differences between the DAVIs of Section 6.1 and the PAPIs here may also reflect the preference for ‘newness per se’ in buildings and DAVI (as compared to PAPI) having smaller land value component (as described in Section 2).

Figure 7: **Depreciation corrected P Index.** Graph presents the PAPI, i.e. the repeat sales for existing properties, corrected for net depreciation, for regions - NYC proper (NYC-Manhattan and NYC-Boroughs), NYC rest (NYC-Burbs), LA proper (LA-County), and LA rest (LA-Inland Empire and LA-Orange County). Three property types - Office, Retail, and Apartment were considered for the construction of the PAPI.

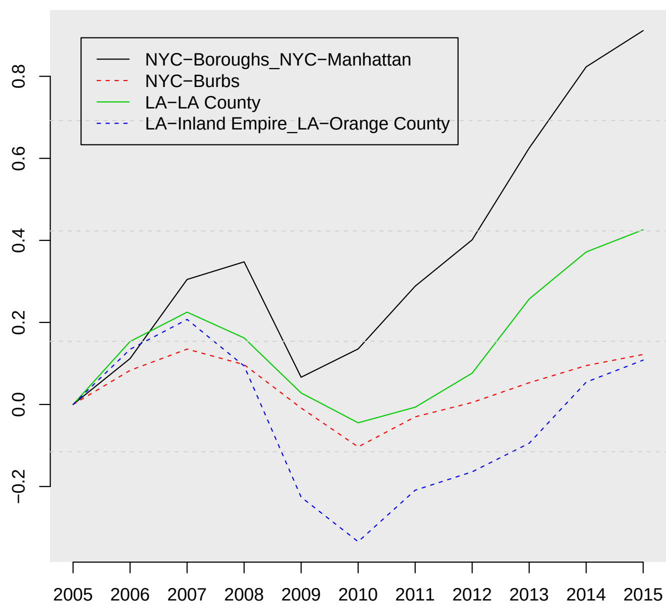


Table 3 presents various statistics to compare the DAVIs with the PAPIs. Panels A and B present the diagnostics of ‘P’ indexes not corrected for depreciation, and the PAPIs as corrected for depreciation, respectively. Panels D, E, and F present DAVIs diagnostics for properties sold within five years of construction, within one year of construction, and in the same year of construction, respectively. Panel C presents the average of statistics in panel D, E, and F.

We obtain higher mean returns for the DAVI (panel C) as compared to PAPI (panel B). The higher mean return reflects the growth in central location value over the history. It also reflects landowners and developers rationally utilizing (to an extent if not perfectly) land redevelopment optionality to wait out the downturns (recent financial crisis of $2007 - 2010$), and perhaps to adjust the type and scale of development. Hence to an extent, DAVIs reflect the exercise of the land redevelopment option and rational behavior on the part of landowners and developers.

On the other hand, the PAPIs show a clear and substantial decline during the crisis period (2007-2010). As noted in Section 2, the existing built stock is subject to the full price impacts of money flows both out of and into the asset class, making the PAPIs more volatile and cyclical. Comparing the standard deviations of returns (volatilities), we find that on an average the DAVIs (panel C) are less volatile than the PAPIs (panel B). This is also likely a reflection of the rational exercise of the flexibility in development investment.

To look at the effect of the Global Financial Crisis (2007-2010), we calculate crisis-range as the magnitude of the price drop during that period (as usual, in log levels). We find that on average, the DAVIs mostly did not even fall during the Crisis (Panel C). Except for LA rest, the DAVIs remained positive for all the regions. On the other hand, crisis badly hit the PAPIs (Panel B).

We also find that compared to DAVI (panel C), both 1-lag autocorrelation and pearson correlation is higher for the PAPI (panel B). This provides evidence that the real estate market fails to follow the random walk hypothesis. The random walk specification is typical for describing financial markets as it is consistent with the efficient-market hypothesis (Fama (1995)), implying that prices cannot be predicted. However, there is good reason to believe that the real estate market ought to be less efficient than the financial markets.

Table 3: **DAVI vs PAPI.** This table presents various statistics for comparing the Development Asset Value Indexes (DAVIs) with the corresponding Property Asset Price Indexes (PAPIs). Panel A presents the 'P' index without the depreciation correction. Panel B presents the PAPI i.e. P index after correcting for depreciation. Panel D, E, and F present DAVI for newly (re)developed properties sold within 5, 1, and 0 year(s) of construction, respectively. Panel C presents average of statistics presented in panel D, E, and F.

	mean.Returns	sd.Returns	acf.Returns (lag 1)	Crisis Range (2007-2010)	correlation (NYC Proper)	correlation (NYC Rest)	correlation (LA Proper)
Panel A: 'P' Index without correcting for depreciation							
NYC Proper	0.073	0.144	0.216	-0.224			
NYC Rest	-0.006	0.068	0.403	-0.293	0.760		
LA Proper	0.024	0.103	0.589	-0.324	0.793	0.887	
LA Rest	-0.007	0.148	0.441	-0.596	0.894	0.932	0.880
Panel B: PAPI ('P' Index after correcting for depreciation)							
NYC Proper	0.091	0.144	0.216	-0.169			
NYC Rest	0.012	0.068	0.403	-0.238	0.760		
LA Proper	0.043	0.103	0.589	-0.270	0.793	0.887	
LA Rest	0.011	0.148	0.441	-0.542	0.894	0.932	0.880
Panel C: DAVI - average statistics of panels D, E, and F							
NYC Proper	0.163	0.110	0.082	0.379			
NYC Rest	0.065	0.046	0.173	0.247	-0.135		
LA Proper	0.082	0.097	0.104	0.107	-0.259	0.023	
LA Rest	-0.008	0.084	0.398	-0.107	0.153	-0.002	0.514
Panel D: DAVI - properties sold within 5 years of construction							
NYC Proper	0.134	0.148	-0.288	0.307			
NYC Rest	0.05	0.057	-0.013	0.248	0.131		
LA Proper	0.063	0.106	0.044	-0.102	-0.28	-0.118	
LA Rest	-0.018	0.106	0.086	-0.362	0.39	-0.232	0.423
Panel E: DAVI - properties sold within 1 year of construction							
NYC Proper	0.192	0.073	-0.141	0.640			
NYC Rest	0.048	0.041	0.331	0.188	-0.175		
LA Proper	0.066	0.08	0.078	0.272	-0.183	-0.02	
LA Rest	-0.012	0.06	0.393	-0.026	0.579	-0.342	0.526
Panel F: DAVI - properties sold in the same year of construction							
NYC Proper	0.163	0.109	0.674	0.189			
NYC Rest	0.096	0.039	0.202	0.304	-0.362		
LA Proper	0.116	0.106	0.191	0.152	-0.313	0.207	
LA Rest	0.006	0.086	0.716	0.067	-0.509	0.568	0.593

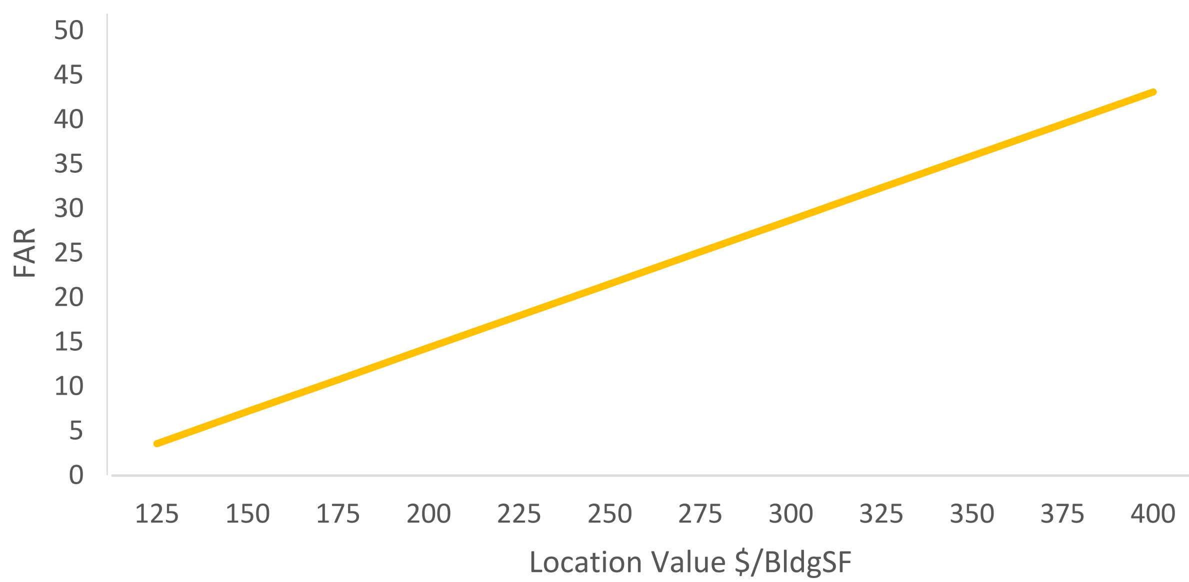
7 Implications for Optimal Density and Central Location Value

To assess reasonableness and robustness of the HBU construct that we develop in the DAVI, we test a classical urban economic theory that the optimal development density of a property is an increasing function of location value. This is of course an interesting theory to test in its own right, and in particular to help to quantify the relationship. Specifically in this section, we empirically examine how the HBU value construct reflected in our DAVI affects the density of commercial properties.

A widely used measure of density of buildings is the Floor-to-Area Ratio (FAR). By definition, the FAR for a land parcel is the ratio of the total floor area of the building(s) on the land to the land area of parcel. For example, a two-story buiding with 10,000 square feet of floor area in each story built on a one-acre (43,560 square feet) site has a FAR of 20,000/43,560 = 0.46.

We presume that, at the time of (re)development, the HBU of the site reflects the optimal (profit-maxmizing) FAR, maximizing the land value within any legal and physical constraints. Figure 8 depicts the relationship between FAR and location value. [13]

Figure 8: **Optimal Floor Area Ratio (FAR) and Location Value.** This figure depicts the optimal level of FAR as a function of location value. FAR is defined as the ratio of the total floor area of the building(s) to total land area of the parcel.



[13] Figure 8 follows from DiPasquale and Wheaton (1996) which define the relationship between land residual value and FAR.

We run multiple specifications to test this classical result of relationship between optimal development density and location value. DAVI is essentially capturing the location value (in the form of HBU) at each time period t at a particular geographical location. Therefore, we expect regressing DAVI on FAR should result in a (positive) relationship shown in figure 8. To start with, we run the following specifications in order to capture the effect of the HBU value on the FAR. (Note that the DAVI construct quantifies the HBU value.)

$$\ln FAR_{i,t} = \alpha + \beta \cdot DAVI_{i,t} + \epsilon_{i,t} \tag{7}$$

$$\ln S_{i,t} = \alpha + \beta \cdot DAVI_{i,t} + \gamma^{l} \cdot l_{i,t}^{Size} + \epsilon_{i,t} \tag{8}$$

Where $FAR_{i,t}$ is the property density measured as floor area ratio, $S_{i,t}$ is the structure size in square feet. DAVI is the development value index and l^{Size} represents 3 splines for land size. We run specification in equation (8) to capture the non-linear effect of land size on structure size. This allows us to confirm that our test is robust to the non−linear effect of different land size parcels.

Next to address the concern that optimal property density may vary for different property types, we also control for the types of commercial properties to control for the level of optimal development value for different property types. Specifically, we estimate:

$$\ln FAR_{i,t} = \alpha + \beta \cdot DAVI_{i,t} + \beta^{P\_type} \cdot d_{i,t}^{P\_type} + \epsilon_{i,t} \tag{9}$$

$$\ln S_{i,t} = \alpha + \beta \cdot DAVI_{i,t} + \beta^{l} \cdot l_{i,t}^{Size} + \beta^{P\_type} \cdot d_{i,t}^{P\_type} + \epsilon_{i,t} \tag{10}$$

where P_*type* represents the property type.

Table 4 presents the results about the effect of DAVI on FAR. We run our model for different sub-samples of properties. In panel A, we analyze properties which were sold in the same year of construction. Similarly, panel B and C analyzes properties which were sold within one year of construction and within five years of construction respectively. Within each panels we run four different specifications as presented in equations (7) − (10). Column [1] presents the basic specification with DAVI as the only independent variable. We find that across all the panels this coefficient is comparable, positive, and significant implying a positive effect of DAVI on FAR. Note that the Adj. R^2 of this model with only 1 variable (plus constant) is already 0.2 on average, implying that - indeed - our DAVI explains a large part of the variance in the FAR.

In column [2], we also control for the properties types as one may argue that different properties have different optimal density. We consider 3 property types in our study - office, retail, and apartment. Controlling for property types brings the DAVI coefficient to almost half but it is still positive, significant, and consistent across all the 3 panels. On the other hand, we find that property types, office and retail have a negative effect on property density while property type, apartment (part of the intercept) has a positive effect on the property density.

Specification in column [3] controls for 3 splines of land size as property density may differ in land size splines. As expected, DAVI coefficient is positive and significant across all the panels. Land size also has a positive and significant effect on structure size.

Finally, column 4 presents the complete model controlling for both property types and splines of land size. DAVI is found to have a positive and significant effect on property density. 1^{st} land spline has highest coefficient followed by 2^{nd}, and 3^{rd} splines suggesting that the effect of land size on structure size decreases as size of the land parcel increases. Property types - office and retail dummies have negative while apartment dummy has a positive effect on property density. As column 4 in panel C shows, our model has an adjusted R^2 of 68.3%.

Table 4: **DAVI and Structure Density.** This table reports the results of the OLS regressions as specified in equations (7)-(10). The dependent variable in the first 2 columns of each panel is FAR which is calculated as the ratio of structure size in square feet divided by land size in square feet. Dependent variable in last 2 columns of each panel is the structure size in square feet. In each panel, column 1 is the base specification, column 2 controls for property types, column 3 controls for linear splines of land size, and column 4 controls for both linear splines of land size and property types. In columns 2 and 4, property type - apartments is omitted and is part of the intercept. T-statistics are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Vars:	Panel A: Age = 0				Panel B: Age $\leq$ 1				Panel C: Age $\leq$ 5			
FAR ([1], [2]) **Structure Size ([3], [4])**	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
DAVI	1.018***	0.520***	0.963***	0.545***	1.063***	0.527***	0.840***	0.375***	1.328***	0.732***	0.861***	0.470***
	(6.09)	(3.60)	(6.65)	(4.33)	(10.15)	(6.40)	(8.20)	(4.83)	(12.94)	(10.04)	(8.87)	(6.84)
1^{st} land spline			0.374	0.748***			0.640***	0.959***			0.398***	0.987***
			(1.45)	(3.54)			(3.64)	(7.59)			(3.50)	(12.19)
2^{nd} land spline			0.541***	0.447***			0.555***	0.416***			0.589***	0.413***
			(3.41)	(3.50)			(5.01)	(5.25)			(7.73)	(7.80)
3^{rd} land spline			0.156**	0.159**			0.158***	0.180***			0.196***	0.204***
			(2.22)	(2.81)			(2.69)	(4.32)			(4.96)	(7.49)
Prop type = Office		-1.371^{***}		-1.097^{***}		-1.104^{***}		-1.078^{***}		-1.043^{***}		-0.954^{***}
		(-5.31)		(-4.79)		(-7.70)		(-8.31)		(-12.31)		(-12.43)
Prop type = Retail		-1.698^{***}		-1.460^{***}		-1.743^{***}		-1.660^{***}		-1.891^{***}		-1.712^{***}
		(-8.90)		(-8.59)		(-17.37)		(-18.11)		(-29.97)		(-29.20)
Intercept	-1.567^{***}	0.076	8.618***	9.726***	-1.336^{***}	0.159	8.642***	9.825***	-1.100^{***}	0.347***	9.013***	9.869***
	(-13.12)	(0.37)	(37.71)	(43.46)	(-19.95)	(1.57)	(53.91)	(73.62)	(-23.57)	(5.72)	(91.53)	(129.31)
Observations	133	133	133	133	343	343	343	343	792	792	792	792
Adjusted R^2	0.215	0.506	0.446	0.646	0.230	0.592	0.371	0.681	0.174	0.618	0.334	0.683

8 Conclusion

In this paper we define a new construct for urban economic analysis, the development asset value index (DAVI). We argue that this construct represents the evolution of Highest and Best Use (HBU) value, 'location value' in a meaningful sense. We focus the metric on central locations in urban areas, by analyzing income-producing commercial and multi-family properties of greater than $2.5 million value.

We compare the DAVI metric with a corresponding traditional property price index corrected for depreciation, dubbed the PAPI. We compare the DAVIs and the PAPIs in an empirical analysis of central and outer regions of the New York and Los Angeles metro areas during 2005-2015. We observe that the DAVIs are strikingly less volatile and less cyclical than their corresponding PAPIs, and display a greater growth trend over time. The DAVIs were largely unaffected by the Global Financial Crisis of 2007-09.

We believe these differences between the DAVI and PAPI performance are explained by the theoretical differences between the two metrics. The PAPIs are essentially 'constant quantity' price indexes, representing existing built assets that are fully exposed to both secular and transient shifts in the space and asset markets, buffeted by the ebb and flow of demand for space of particular types and locations and demand for investment in real estate assets. The DAVIs reflect the behavior of the real estate development industry and the valuation of brand-new, HBU buildings of the type, and at the time and place, of the developers' choosing.

The difference in value evolution over time reflected in our empirical comparison between the DAVIs and PAPIs of central locations in New York and Los Angeles reflects the great flexibility that developers have, compared to existing fixed assets. Development represents the exercise of the call option inherent in land ownership. Optionality exists in several dimensions, including timing, scale, and type of structure. Of course, developments produce brand-new buildings, and this in itself may also have a unique (if fleeting) value.

This throws new light on the conventional wisdom that investment in development is more risky than investment in existing, stabilized property assets. The added risk in development investment appears to derive largely only from the leverage that is inherent in development projects, caused by the construction cost (which is not generally highly correlated with the ex post value of the built assets in the property market). The effect of such leverage can be engineered away by offsetting investments in bonds. If investors could invest in a fund that focuses only on development projects, maintaining a very young average age of buildings in the pool, the result could be a real estate investment strategy of less risk than unlevered investment in stabilized existing built properties. At least, this is what our findings in New York and Los Angeles appear to suggest.

In a related follow-on analysis, we also study the relationship between HBU value and the density of development measured by the Floor/Area Ratio (FAR). Recognizing that HBU value corresponds essentially to land value, we confirm and quantify the classical principle of urban economic theory that higher location values should be developed to greater capital intensity. As our measure of HBU value is essentially the same as our DAVI metric, this exercise also helps to confirm the meaningfulness of the DAVI metric.

This study has implications for a wider audience. It may be of interest in national income and product accounting, as the DAVI metric tracks the formation of physical capital, which is directly reflected in the gross domestic product (GDP). And HBU evolution essentially underlies land value evolution, which is relevant to the national balance sheet. Finally, we believe that the DAVI metric is of interest in its own right for urban economists. Exploration and analysis of DAVIs can contribute to our understanding of urban location value dynamics, as well as of the behavior of the real estate development industry, the industry that directly builds our cities.

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