

**Four Centuries of Location Value:  
Implications for Real Estate Capital Gain  
in Central Places**

(running title: "Four centuries of location value")

by  
Piet M.A. Eichholtz<sup>\*</sup>  
David M. Geltner<sup>\*\*</sup>

First version: November 1996

This version: March 2002

<sup>\*</sup> Limburg Institute of Financial Economics (LIFE), Maastricht University, PO Box 616, 6200 MD Maastricht, The Netherlands; tel: (+31) 43-883838, fax: (+31) 43-258530, e-mail: p.eichholtz@berfin.unimaas.nl

<sup>\*\*</sup> Correspondence contact author, at: Department of Finance, University of Cincinnati, PO Box 21095, Cincinnati, Ohio 45221-0195, USA; tel: 513 556-7071, fax: 513 556-4891, e-mail: david.geltner@uc.edu

**Acknowledgements**

We acknowledge the helpful comments of Will MacIntosh and participants to the 1997 annual meeting of the American Real Estate and Urban Economics Association. William Goetzmann is thanked for his econometric advice and Francois Nissen for his programming help. Maastricht University provided financial support. All errors remain the responsibility of the authors.

# **Four Centuries of Location Value: Implications for Real Estate Capital Gain in Central Places**

## **Abstract**

In this paper, we construct a 347-year index of location value for the period 1628-1974 for a major section of central Amsterdam (the Herengracht). We then use this index to investigate the implications of the monocentric city model for potential long term capital gain in real estate investments in central places. Our results show that this capital gain is very close to zero in real terms, as the monocentric city model would predict. Nearly all of the real growth in location value that did occur can be attributed to two historical periods, one in the seventeenth century and the other in the mid 20th century. Both of these were rather exceptional periods in history: the former when the Herengracht was at the periphery of the expanding residential area of the city; and the latter when the Herengracht was at the periphery of the expanding commercial core of the city.

## **Introduction**

Traditional urban economics and real estate valuation literature suggests that the value of real property in urban areas can be decomposed into two major components: location value and structure value. Structure value is the value of the building on the site, while location value is the value of the location of the property relative to transportation nodes or central points. Location value is based on present and future location rent, which in turn is based on the value of the transportation cost advantage of the site for potential users of the property.

The significance of location value for real estate investors is that location value increase must be the primary source of any long-run real capital gain in the investment, as structure value tends to depreciate over time in real terms. Thus, growth in location value puts a ceiling on the

possible growth in investment capital value. Improving our knowledge of the nature of the capital gain in real estate investment is not only interesting in its own right, it may also shed light on the total investment return in real estate, as the other component of such return, the current income, is usually readily observable, so it is only the capital gain component that is questionable or problematical. For example, investors and appraisers often assume that property values will increase or at least remain constant in real terms over the long run. The question is whether this is in fact a good assumption.

The purpose of the present paper is to use a unique source of information to shed light on the growth of location value over the long run. The information source we use is the database of property transaction prices on the Herengracht canal in Amsterdam during the 347-year period from 1628 to 1974.<sup>1</sup> While our study is based on only this single location, it is interesting and unique for the extremely long time frame which it encompasses, and the extent of urban development and technological change which occurred over that time span. While there are admittedly limitations to studying a single location, Amsterdam is in some respects an ideal "laboratory" to study long-term capital gain in real estate. Large enough to be typical of the sites of much real estate investment, during the four calendar centuries crossed by our data Amsterdam witnessed both times of great change, and periods of constancy, with respect to the fundamental determinants of location value within a city.

Our is based on the construction of an index of location value changes for the Herengracht. This index is similar to the biennial repeat-sale house price index constructed in

---

The data source is described more fully in Eichholtz, 1997.

Eichholtz (1997), but differs in two important respects. First, the index we construct here reflects location value or the "usage value" of the land at its highest and best use, rather than housing value or the value restricted to use as housing, as was the case in the previous article. Second, the index we construct here differs in some statistical respects from the previous index. By using a Bayesian estimation procedure suggested by Goetzmann (1992), we are able to estimate an annual rather than biennial index, with less noise. This index appears to have pleasing statistical qualities even though during some periods we have only an average of about five repeat-sale observations per year.

The remainder of the paper is divided into four sections. First, we describe the theoretical framework for location value change over time based on a simple model of property lifecycle. Next, we present our index of the location value of the Herengracht. In the third section we relate the changes in location value to changes in the urban form and the historical development of Amsterdam. A final section concludes the paper.

## **1. The Theoretical Framework**

A simple model of property life cycle will provide a useful framework for considering capital gains in real estate investment. Our model is inspired by the model of land value as a development option, which was first put forth by Titman (1985), and elaborated by Capozza and Helsey (1990), among others. For the case of redevelopment, the model has been refined by Amin and Capozza (1993) and Childs, Riddiough and Triantis (1996).

Exhibit 1 provides a graphic view of the property life cycle. Exhibit 1 presents a picture of a single location in the city, across an entire "history" of continuous time. Time is represented on

the horizontal axis, with the discrete points in time of construction or reconstruction of the structure on this property represented by the "C" symbols. At those points in time the structure is built or rebuilt to best serve the "highest and best use" (HBU) of the site as of that point in time. This value of the newly developed or redeveloped property just after each development may be seen as tracing out the evolution of the "usage value" of the site over time, based on its HBU. This trend, indicated by the dashed line and the "U" symbols, fundamentally determines the trend in the location value of the site.

-----  
Exhibit 1  
-----

The location value of the site depicted in Exhibit 1 is generally growing over time, as seen by the upward trend in the "U"s. Of course this would not necessarily be the trend for any given site in the real world.

In a freely functioning land market location value evolves over time not only reflecting changes in the value of the site for the currently existing usage, but also reflecting the possibility of evolution of the HBU of the site. Thus, the usage to which the site is put is in long-run equilibrium both a cause and effect of the location value of the site.

The actual market value of the property at any point in time consists of two components. Structure value "S" is the value of the built structure. Just after reconstruction, structure value makes up the bulk of the property value. But the structure value declines over time as the building depreciates, both from physical obsolescence and "economic obsolescence", the latter reflecting the fact that the nature of the structure may become unsuited to the HBU of the site as

the HBU evolves over time. For example, the HBU may evolve from low-density to higher-density residential use, or from residential to commercial use. The other component "L" of the property value consists of a combination of the location value per se, which is the present value of the present and expected future location rents, plus what Capozza and Helsey (1990) have labelled the "irreversibility premium" of the redevelopment option value.

As a general rule, neither the structure value nor the location value can be purchased separately, and indeed the breakout between these two components of property value at any point in time is both practically and theoretically difficult. But the combination of structure value and location value can be observed at any point in time as the total property value "P". The change in this property value is in fact the capital gain or loss which the real estate investor faces.<sup>2</sup>

It is clear from Exhibit 1 that the growth rate of the property value "P" is generally less than the growth rate of the location value as represented by the dashed line trend in the usage value at HBU, the "U"s. If there were no depreciation of the structure, then "P" would indeed run right along the dashed line connecting the "U"s, and the usage or location value change would continuously equal the property value change, instead of this equality occurring only between the discrete reconstruction points in time. This is what we mean by the location value changes providing a theoretical ceiling to the investor's capital gain.

---

The discontinuous "jumps" in property value at the points in time of the reconstructions reflect the injection of new capital into the property via the construction process, and so do not in themselves represent a capital gain for any investor.

## 2. The Herengracht Location Value Index

The Herengracht is one of three canals circling the old medieval center of Amsterdam. The Herengracht was dug and developed in stages during the period from 1585 to 1680. Originally there were 614 lots on the canal, but frequent combination of lots has lowered that number to 487 properties in 1974. Between 1617 and 1973, 5587 transactions have taken place, but prices are only available for 4252 of those. This gives us 3851 clean and usable repeat-sale transaction pairs spanning the complete period. The record of property transaction price data, which includes all transactions through 1974, is from Van Eeghen et al. (1976). More information on this datasource, and on the nature of the Herengracht can be found in Eichholtz (1997). We have used the Herengracht property transactions data to estimate a repeat sales property value index for the Herengracht spanning the entire 1617-1974 period. However, since we only have information on inflation for the period 1628-1974, our real valued index can only cover this latter span. As noted, one difference between this index and the one reported previously by Eichholtz (op.cit.) is that in the present case we have not controlled for the use of properties. If property value increased because of a change in use from residential to office, the present index will record that increase in value. We therefore regard the present index as coming reasonably close to a location value index, reflecting the evolution of the HBU over time.

Thus, we want to estimate an index which reflects the “U”s in Exhibit 1. Transactions prices only allow us to observe the property values “P”, and as can be seen in Exhibit 1, individual repeat sales pairs may over- or under-estimate the location value growth depicted by the “U”s. For example, if the two sales occur between reconstructions, the growth in HBU value will tend to be underestimated due to the effect of depreciation of the structure. On the other

hand, if the two sales straddle one or more reconstructions on the property, then the two sales may overestimate the growth in HBU value if the first sale was when the older structure was old while the second sale was when the newer structure was new. However, we have a number of transaction pairs spanning any given year, so the estimated index is an average of transaction pairs which over-estimate, under-estimate, and closely approximate the location value growth. We therefore consider it likely that our index gives a good representation of the rate of growth of the location value on the Herengracht.

This is especially so because of a unique feature of the Herengracht: it has always, throughout all four centuries, been one of the most fashionable addresses in Amsterdam. As a result, high quality structures tended to be built on it, and these structures tended to be continuously maintained well and kept for very long periods of time, even as the HBU may have changed from single-family to multi-family residential and to commercial uses. In essence, the Herengracht comes close to approximating a situation in which there is essentially no structural depreciation or obsolescence. Physical upkeep and improvements are clearly made in the structures, but these tend to occur in very small increments, almost continuously through time. This facilitates the ability of our index to reflect the changes in the HBU location value of the Herengracht.

Another difference between the present index and the one presented in Eichholtz (1997) is the statistical method used to estimate the index. Eichholtz uses a hedonic repeated measures estimation method, based on the three-stage repeat sales regression technique developed by Case and Shiller (1987, 1989) and Shiller (1993). However, the transaction observations for the Herengracht are relatively scarce, most strongly so in the 17th century, when an average of a little

over 5 sale-pairs per year is available. That is why we have employed the Bayesian repeat-sales regression estimation technique described in Goetzmann (1992). Goetzmann demonstrates that this approach allows an index to be estimated that is not too noisy even when data is scarce. This has allowed us to estimate an annual index, rather than a biennial index as in Eichholtz (1997), and with less apparent estimation error.

In the Goetzmann technique, a parameter "k" represents the relation between true variation in the returns over time versus observed transaction price dispersion caused purely by noise or transaction error. By varying "k" one introduces greater or lesser degrees of smoothing of the index to filter out the random noise. If one selects the "k" parameter value which results in an index whose volatility and autocorrelation match one's prior conceptions of the likely true values of these moments for such a real estate index, then this approach may be viewed as a generalized method of moments procedure (Hansen and Singleton, 1982) in which the estimated index represents the least-squared error estimates conforming with those prior perceptions of the true underlying index. In the present case we have used the value  $k=1$ , which results in an estimated index whose volatility is around 10 percent per year, with slightly positive autocorrelation not statistically different from zero. This amount of volatility and autocorrelation seems reasonable, based on studies of real estate return series in the US and UK.<sup>3</sup>

The descriptive statistics for the estimated annual location value return index are summarized in the table in Exhibit 2, and the graph in Exhibit 3 traces out an index of the location value levels in real terms. The entire estimated index is presented in the Appendix.

---

See, for example, Fisher, Geltner and Webb (1994) and Barkham and Geltner (1994).

-----  
Exhibits 2 and 3  
-----

The overall impression from Exhibit 3 is that for most of the 347-year history real location values on the Herengracht did not show a long-term growth trend, although they did have significant ups and downs. The overall average annual growth is slightly positive, at 0.56% per year, but this has resulted largely from the first few decades in the 17th century and the last few decades in the mid 20th century.<sup>4</sup> There seems to be faint visual evidence of an approximately 50-year cycle during some periods of the history, though the null hypothesis of a unit root in the value levels cannot be rejected, and indeed Exhibit 3 looks visually very much like a random walk.<sup>5</sup>

Starting from an arbitrary base value of 1.0 in 1628, the index hovered around the 2.0 level for almost all of the history examined here, albeit with substantial fluctuations and semi-permanent deviations up to 50% above and below the long-run average value being maintained for decades at a time. Only in the 20th century, and in particular since the end of World War II, has there been an apparently major increase in real locational value to levels substantially above

---

If we viewed the index for the three centuries from 1650 to 1950, for example, there would be virtually zero long-term real growth in location value.

Both augmented Dickey-Fuller and Phillips-Perron tests were carried out, both with and without intercepts and time trends, and with varying numbers of lags. In no case could we reject the unit root null hypothesis.

an index value of 3.0. The last few years prior to 1974 witnessed a jump almost to 7.0, after spending most of the 1960s hovering around 5.0.

It is perhaps instructive to compare this result with the real index presented in Eichholtz (1997), which controlled for the change in land usage. That index does not reveal the major jump in real value in the mid-20th century, and ends at a value of only 2.2 (also starting from 1.0 in 1628). This suggests that absent the change in HBU from housing to commercial during the past century, there would have been virtually no major real increase in location value. Thus, the substantial growth in location value witnessed in the past century in Exhibit 3 is apparently associated with the change in HBU from residential to commercial (largely office).<sup>6</sup>

### **3. Urban Form and Changes in Location Value Growth**

Classical urban spatial economic theory suggests that several characteristics should influence the growth in location value within a city. The key characteristics include population, density (or radius to the urban periphery), transportation technology, and real per capita income. The effect which these characteristics have on location value growth may depend on whether the location is closer to the center or the periphery of the urbanized area.<sup>7</sup>

One of the advantages of Amsterdam as a laboratory for examining the link between urban development and location value growth is the length and quality of the historical

---

Interestingly, since the end of our data in 1974, the Amsterdam authorities have made it much more difficult to convert buildings on the Herengracht from residential to commercial use, as the city is attempting to maintain a residential character in its center.

<sup>7</sup> e.g., transportation improvements may increase location value for locations near the periphery of the urban area, while decreasing location value for locations near the center of the city, *et.par.*

information available concerning these relevant characteristics. We can characterize all of the above-noted determinants of location value growth with reasonable accuracy for the entire 347-year history which our index covers. This allows a direct examination of the relationship between long-term trends in urban development and the long-run growth rate of the location value of a site which, at first near the periphery of the urban area, gradually became a much more central site, as the radius of the city expanded.

While data is not of sufficient quality or reliability to allow a formal quantitative analysis of the causal relationships, interesting insight can be obtained by partitioning the 347-year history into nine periods, each of which is of varying calendar length but relatively homogeneous in terms of the direction of the trend in the five major determining variables: Population, Radius/density, Transport technology, Real income, and whether the Herengracht was during the period relatively close to the center or periphery of the built-up region of Amsterdam. For each period, we examine the average real value level of the location value index at the beginning and end of the period, and draw an approximate quantitative conclusion about the average growth rate of location value during the period. These periods and our findings are summarized in the table in Exhibit 4. Each period is depicted graphically with the familiar rent gradient cross-sections showing the relative changes in the implied rent gradient and city radius during the period. These are shown in Exhibits 5 through 19.

-----  
Exhibits 4 through 13  
-----

A brief walk through the history of Herengracht location values revealed by this analysis may add to our understanding about likely long-term capital gains in real estate investment. Our first period is from 1628 to 1688, a period characterized by substantial growth in both population and area of the city. This was the "Golden Age" of the Dutch Republic, a period when Holland led the world in trade, shipbuilding, and urbanization. Amsterdam's population nearly doubled, from 110,000 to 200,000, making it one of the three largest cities in Europe. This period was, however, punctuated by plagues and wars, some of the latter having either favorable or unfavorable effects on the foreign trade which was the basis of the economy (Eichholtz, 1997) This period is pictured in Exhibits 5a and 5b. By the end of the period the Herengracht nominal location value had grown some 90 percent, which amounts to almost 1 percent per year, but this overall performance encompassed substantial volatility and a major rise-and-fall in property values within the period, as seen in Exhibit 5b. The evidence regarding the rent gradient shown in Exhibit 5a suggests that the city's rent gradient declined during this period, reflecting the reduction in urban density associated with Amsterdam's bursting forth from its medieval boundaries. Such expansion was no doubt made possible by the substantial growth in real income during the period. In effect, higher per capita income enabled citizens to purchase more land for urban consumption. The fact that the Herengracht's location value grew during this period in spite of a major decline in Amsterdam's rent gradient suggests that this growth was due primarily to the Herengracht's location at that time near the periphery of the expanding urban area.

Our second period is a long century of something close to stagnation, from 1688 to 1790, a period that saw only very slight population and income growth, or technological and social development in the Netherlands, and little or no expansion of Amsterdam. It was during the 18th

century that Holland lost its preeminent position on the world stage to England and France.

During this period the Herengracht location value index was a bit more stable than it had been during the previous century, as it went from a level of 1.9 to around 2.5. As we see from Exhibit 6a, the growth in Herengracht's location value was due to some combination of slight increases in the rent gradient and/or in the urban radius, reflecting the very modest growth of the period.

Our third period is the Revolutionary and Napoleonic era from 1791 through 1815. This quarter-century was a low point in Dutch history, characterized by devastating wars and the conquest and occupation by the French under Napoleon. Real incomes certainly declined during this period, as did Amsterdam's population from 220,000 to 180,000. The result was the worst plunge in history in the Herengracht's location value, with the index level falling from around 2.5 to 0.8, a decline of 68%. As we see in Exhibit 7a, this resulted from the decline in the rent gradient which was caused primarily by the reduction in real income, which reduced the value-of-time component of transportation cost, and secondarily by the reduction in urban density due to the population loss.

The fourth period we define is a period of weak recovery, from 1816 to mid-century, after the fall of Napoleon and the founding of the Dutch monarchy. During this period Amsterdam failed to partake much in the industrial revolution which was affecting other parts of Western Europe and North America, and there were lingering political problems resulting in the breakup between Belgium and Holland. Nevertheless, Amsterdam recovered its 18th century population level, and the Herengracht location value index grew from 0.8 to 1.3 due to a modest increase in the rent gradient, as seen in Exhibit 8a.

Our fifth period is from 1851 through 1880, a period in which industrial development finally took off in the Netherlands. Amsterdam saw considerable real income growth and the

fastest population growth since the 17th century. Yet during this period the city was still dependent on pre-mechanized transport means. The first trams, horse-powered, were not developed until 1875, so the city could not really expand much in area. The result was a substantial increase in the rent gradient, due to the increased population density as well as the growth in per capita income, which had an effect on the time value component of travel cost. As we see in Exhibit 9a, this resulted in a more-than-doubling of the Herengracht location value, from 1.2 to 2.6.

The sixth period is from 1881 through 1913. This period witnessed the continuation of the industrial development and income growth which had begun in the previous period, but now also with the first substantial urban transportation technological development since ancient times. Beginning in the 1870s, by the 1890s extensive networks of trams (streetcars) were in operation. Though at first horse-powered, by 1905 the system was entirely electrified. Steam-powered railroads also began serving suburban areas in the late 1870s. These transportation improvements allowed the first major expansion in the spatial area of Amsterdam since the 17th century. Indeed, the spatial expansion was great enough that the overall urban density did not increase even though the city was experiencing extremely rapid population growth, from 320,000 to 588,000 during the period. The transportation improvements of the period not only kept the urban population density from growing, but reduced travel times so that the rent gradient declined in spite of the significant increase in real per capita incomes during this period. The result was that the Herengracht location value did not grow during this period, as the reduction in the rent gradient just balanced off the effect of the expansion in urban radius, as depicted in Exhibit 10a.

The seventh period includes World War I and the 1920s, from 1914 through 1930. Although the Netherlands was neutral during the First World War, the foreign trade on which her economy had always been dependent was negatively affected by the war. The 1920s, however, saw an economic recovery, as well as a continuation of population growth to 750,000. Although the automobile became used by wealthy people during this period, the 1920s did not see the mass use of automobiles in the Netherlands such as occurred at that time in the United States. The lack of major transportation developments, combined with land use controls, resulted in only a slight increase in the urban development boundary, to an average radius of about 2.5 kilometers. This probably did permit a slight reduction in density, however, even with the population growth. By this time the Herengracht was clearly closer to the center of the city than to the periphery. Monocentric city theory suggests that normally density reductions will tend to cause declines in the location values near the center. So how do we explain the substantial increase in Herengracht location value during the 1920s, from a level of around 2.5 to 4.0? For one thing, this was the first period which saw a number of conversions of houses to office use on the Herengracht. Part of the increase in property prices during the 1920s may have been based on speculation about future growth in rents, perhaps based on the possibility of such conversions: the evolution of HBU is one of the natural sources of growth in location value. While the Herengracht was near the center of the residential land use in Amsterdam, it was near the periphery of the expanding CBD, where the vast majority of commercial land use was located.

The eighth period we identify is that of the Depression and World War II, in which Holland was occupied by Germany. This sad period saw a drastic decline in real income, leading

to a severe drop in the rent gradient from essentially stagnant urban boundaries, resulting in a halving in the Herengracht location value, from an index level of 4.0 to 2.0 by 1946.

The final period we identify, the Postwar Recovery and Boom period from 1947 to 1974, is perhaps the most dramatic of all. The Herengracht location value apparently more than tripled in real terms during this period, starting especially in the mid to late 1950s and continuing into the 1970s. All factors were positive during this period. Conversions of houses to offices on the Herengracht became frequent. Amsterdam's metropolitan population was growing moderately from 820,000 to over 1.2 million. This was a period of spectacular real income growth in the Netherlands as in all of Western Europe. The rapid growth of the mass use of the automobile, as well as substantial improvements to rail transport, combined with the growth in income to allow an unprecedented expansion in the effective urban radius, in spite of some of the strictest land use controls in the world aimed at the prevention of American style urban sprawl. It seems likely that the growth of Herengracht value during this period was driven by actual and potential conversion of usage from residential to commercial (although this expansion of the commercial core was no doubt based in part on the underlying growth in real income, and the conversion to commercial use typically occurred without demolition of the old structures).

#### **4. Conclusion**

What does our analysis allow us to say about the nature and typical magnitude which real estate investors can expect in the way of capital gain over the long run? First of all, at risk of stating the obvious, we must point out that although our analysis is indeed very long-term, it encompasses only one city and only a small part of that city. The reader is cautioned against drawing too general conclusions.

Nevertheless, as noted, Amsterdam is in some respects a useful "laboratory" for this type of analysis. Holland is the densest and most intensively farmed country in the Western World. This, and the country's age-old struggle against flood, may account for the Netherlands having some of the earliest and strictest land use planning and controls in the world. These controls act to keep spatial expansion of cities such as Amsterdam to a minimum. It is likely that in almost any other country, other things being equal, the spatial expansion of Amsterdam would have been greater than it was. Monocentric theory reveals clearly that higher density and restrictions on spatial expansion tend to increase the growth rate in location values near the center of the city. So it seems unlikely that Herengracht location value would have grown faster in other countries experiencing similar rates of population and income growth. In this sense, our analysis represents a sort of "upper bound".

Furthermore, we have noted that the change in the location value of a site over time, what has been measured here, represents a ceiling on the rate of capital gain that can be earned over the long run by an investor in property, because the depreciation of any structure on the property must be subtracted from the change in the location value of the site. Here again, the Herengracht

represents an upper bound, because its structures tend to be used for centuries. With all this in mind, the 0.56 percent average annual real growth rate in the Herengracht's location value over the 346-year history presented here may be viewed as rather low. It suggests that real capital gains for unlevered real estate investments will be negative in most cases, at least over the long run. As noted, this empirical finding is not surprising in the light of monocentric theory. In addition, it is interesting to realize that virtually all of the net growth in real location value on the Herengracht over the 346-year period can be attributed to a couple of decades in the 17th century and a couple of decades in the latter half of the 20th century, both of which were rather exceptional periods in history. In the former period the Herengracht was at the periphery of the expanding residential area of the city. In the latter period the Herengracht was at the periphery of the expanding commercial core of the city. In both cases a conversion in the highest and best use of the land (from agricultural to urban residential, and then from residential to commercial) underpinned the jump in real location value.

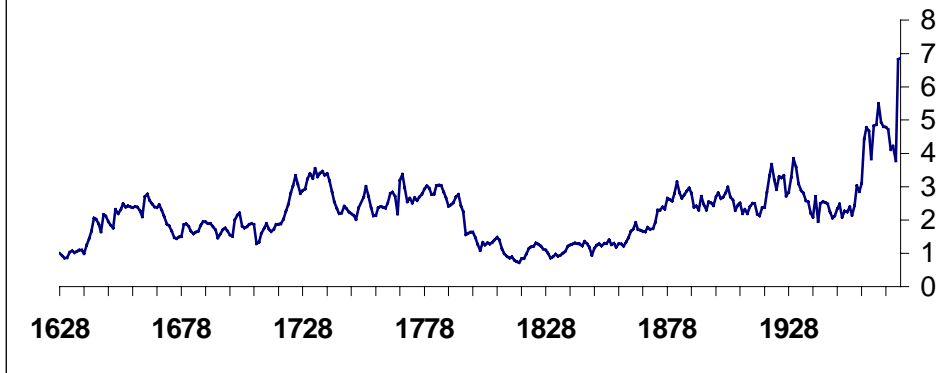
On the more positive side, however, it is also interesting that the greatest period of growth in the Herengracht's location value occurred when the canal was very centrally located in the metropolitan region and when rapid transportation technological and infrastructural improvements were occurring. This suggests, contrary to some current prognostications, that technological improvements will not necessarily reduce the value of central places. Growth in real per capita income can lead to favorable changes in HBU which drive the capital gain process in property investment.

**Exhibit 2: Summary Statistics of Herengracht Location Value Annual Return Index**

Period:	Nominal			Real		
	Mean	Std.Dev.	Signal/ Noise*	Mean	Std.Dev.	Signal/ Noise*
1628-1974	1.28%	9.96%	2.2	0.56%	10.63%	2.35
1628-1699	1.00%	7.74%	1.04	0.59%	9.63%	1.29
1700-1799	0.13%	8.36%	1.94	-0.03%	10.35%	2.40
1800-1899	0.49%	8.09%	2.30	0.65%	8.95%	2.55
1900-1974	4.15%	14.61%	4.27	1.19%	13.70%	4.00

\*Signal to Noise Ratio: Longitudinal standard deviation of estimated returns divided by the average standard error of the annual return estimates.

**Exhibit 3: Annual Herengracht Location Value Index  
in Real Terms (1628 = 1)**



#### Exhibit 4: Periods of Relative Homogeneity in Variables Determining Location Value for the Herengracht

Periods		Variables Determining Location Value				Herengracht Location Value			
Period	Commentary	Population Change	Radius & Density*	Transport Technology	Real Income	Location**	Index Level, Beginning	Index Level, Ending	Real Annual Growth Rate
1628-1688	Growth plus wars & plagues	110,000 to 200,000	r up 0.7 to 1.4 D down 143 to 65	Pre-mechanical	Growth with ups & downs Trade base	Periphery	1.0	1.9	+0.9%
1689-1790	From trade to finance	200,000 to 220,000	r level 1.4 D up 65 to 71	Pre-mechanical	Slow growth Trade and finance base	Equidistant	1.9	2.5	+0.3%
1791-1815	War & French occupation	220,000 to 180,000	r level 1.4 D down 71 to 58	Pre-mechanical	Decline	Equidistant	2.5	0.8	-4.6%
1816-1850	Recovery	180,000 to 225,000	r level 1.4 D up 58 to 73	Pre-mechanical	Slow growth industrialization	No Equidistant	0.8	1.2	+1.2%
1851-1880	Industrialization before trams	225,000 to 320,000	r level 1.4 D up 73 to 104	Pre-mechanical	Growth	Equidistant	1.2	2.5	+2.4%

continued  
next page

\* r = Average radius from city center to edge of continuous built-up area of Amsterdam in kilometers; D = Density in 000/km<sup>2</sup>

\*\* Periphery if closer to the urban periphery than to the center; Equidistant when between center and periphery; Central if closer to the center than to the periphery.

**Exhibit 4 (continued): Periods of Relative Homogeneity in Variables Determining Location Value for the Herengracht**

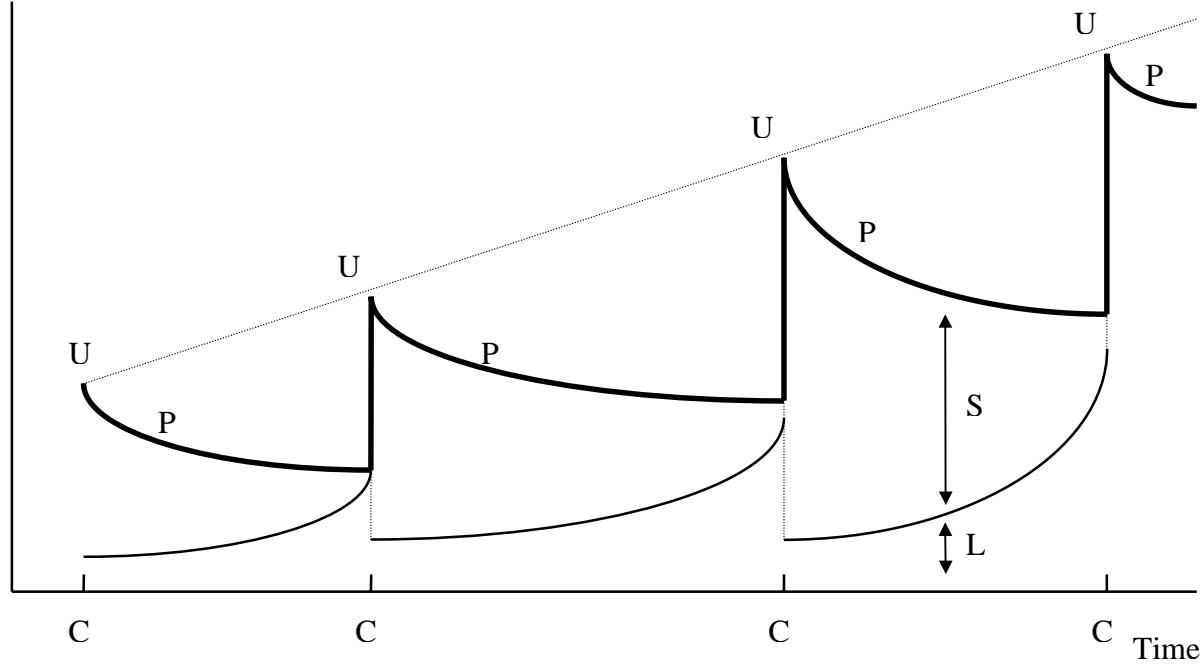
Period		Variables Determining Location Value				Herengracht Location Value			
Period	Commentary	Population Change	Radius & Density*	Transport Technology	Real Income	Location**	Index Level, Beginning	Index Level, Ending	Real Annual Growth Rate
1881-1913	Industrialization & trams	320,000 to 588,000	r up 1.4 to 2.0 D down 104 to 94	Tram network development	Growth	Central	2.5	2.5	0
1914-1930	WWI & 20s boom Some office HBU	588,000 to 750,000	r up 2.0 to 2.5 D down 94 to 76	Mainly trams Auto introduced	Stagnation during WWI, then growth	Central	2.5	4.0	+2.9%
1931-1946	Depression & WWII	750,000 to 820,000	r level 2.5 D up 76 to 84	Mainly trams Some autos	Decline	Central	4.0	2.0	-4.3%
1947-1974	Recovery & boom Much office HBU	820,000 to 1,200,000	r up 2.5 to 8.0 D down 84 to 12	Autos in mass use Trams	Rapid growth	Central	2.0	6.9	4.4%
1628-1974	Tremendous urban growth & development	100,000 to 1,200,000	r up 0.7 to 8.0 D down 143 to 12	Foot/horse to Tram to Auto	Tremendous growth	Periphery to central	1	6.9	0.6%

\* Radius to edge of continuous built-up area in kilometers; Density in 000/km<sup>2</sup>.

\*\* Periphery if closer to the urban periphery than to the center; Equidistant when between center and periphery; Central if closer to the center than to the periphery.

**Exhibit 1:** Components of Property Value over Time

Property  
Value  
Components

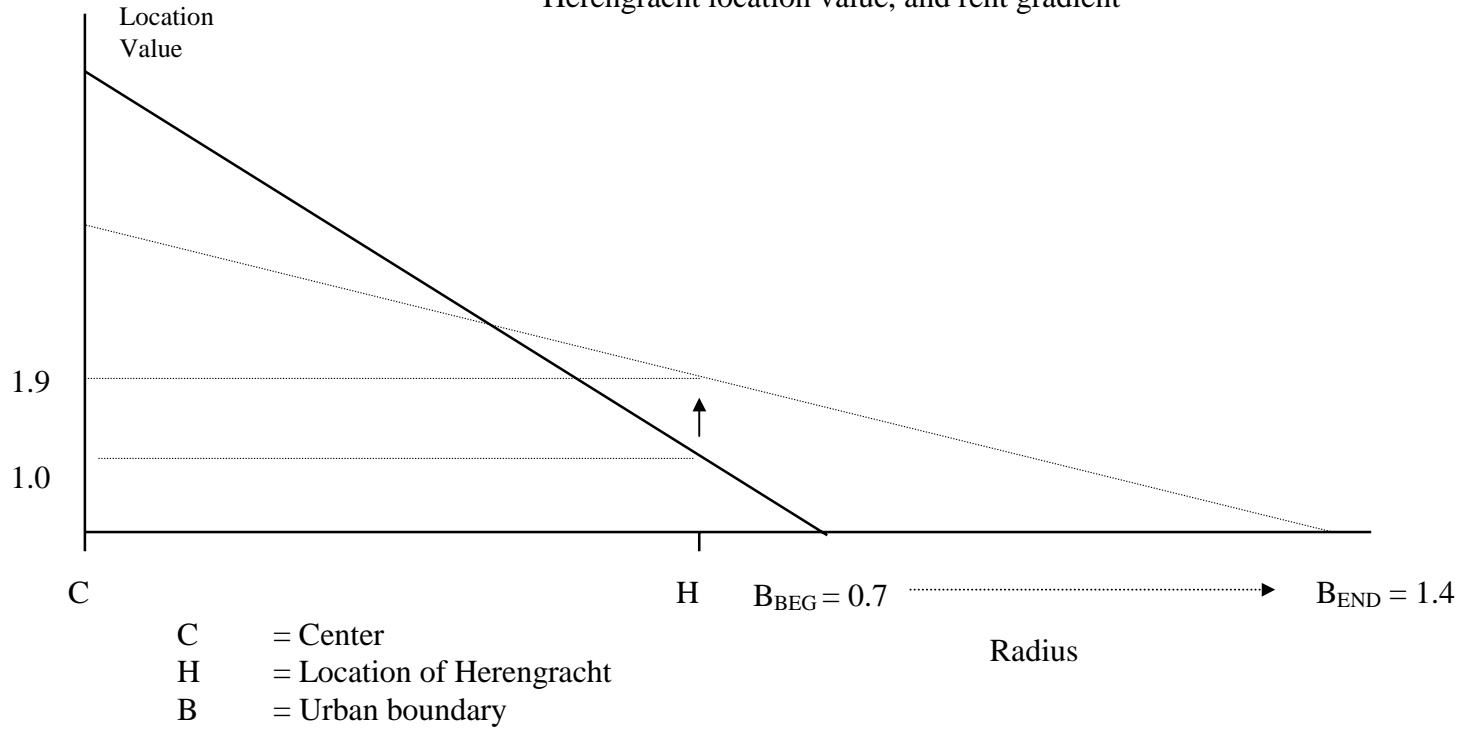


- C = Construction / reconstruction points in time
- U = Usage value at highest and best use at time of reconstruction
- P = Property value
- S = Structure value
- L = Location and redevelopment option value

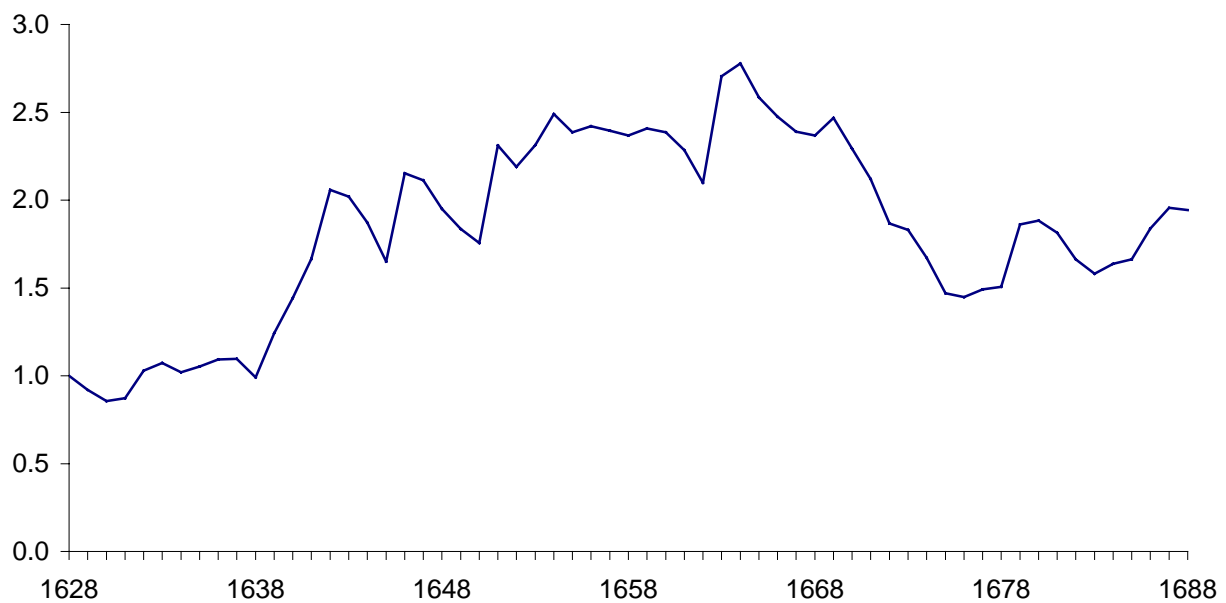
**Exhibit 5a; 1622-88:**

Growth with Wars & Plagues

Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient

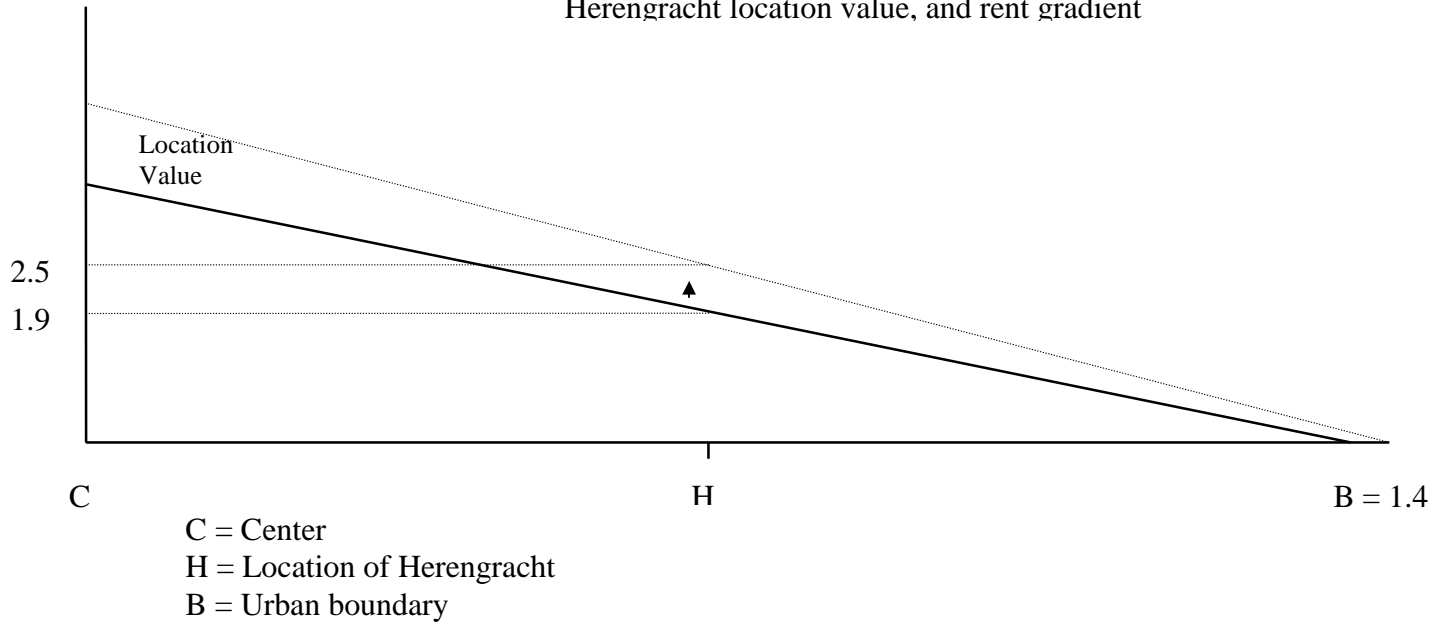


**Exhibit 5b; 1628-1688:** Herengracht Real Location Value Index

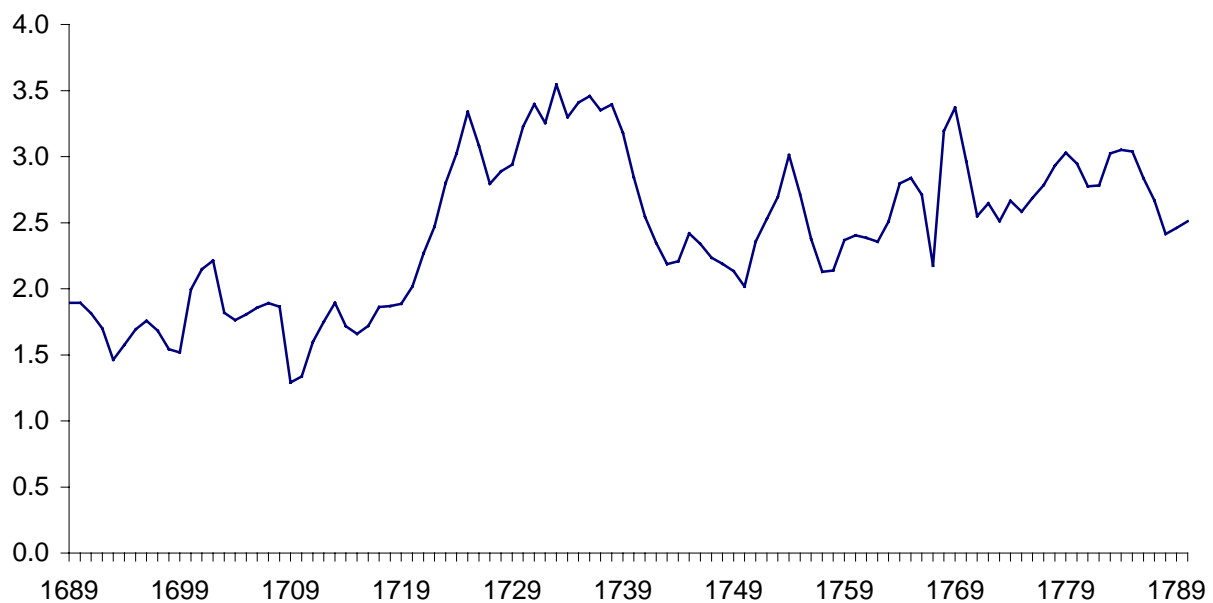


**Exhibit 6a: 1689-1790: Slow Growth**

Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient

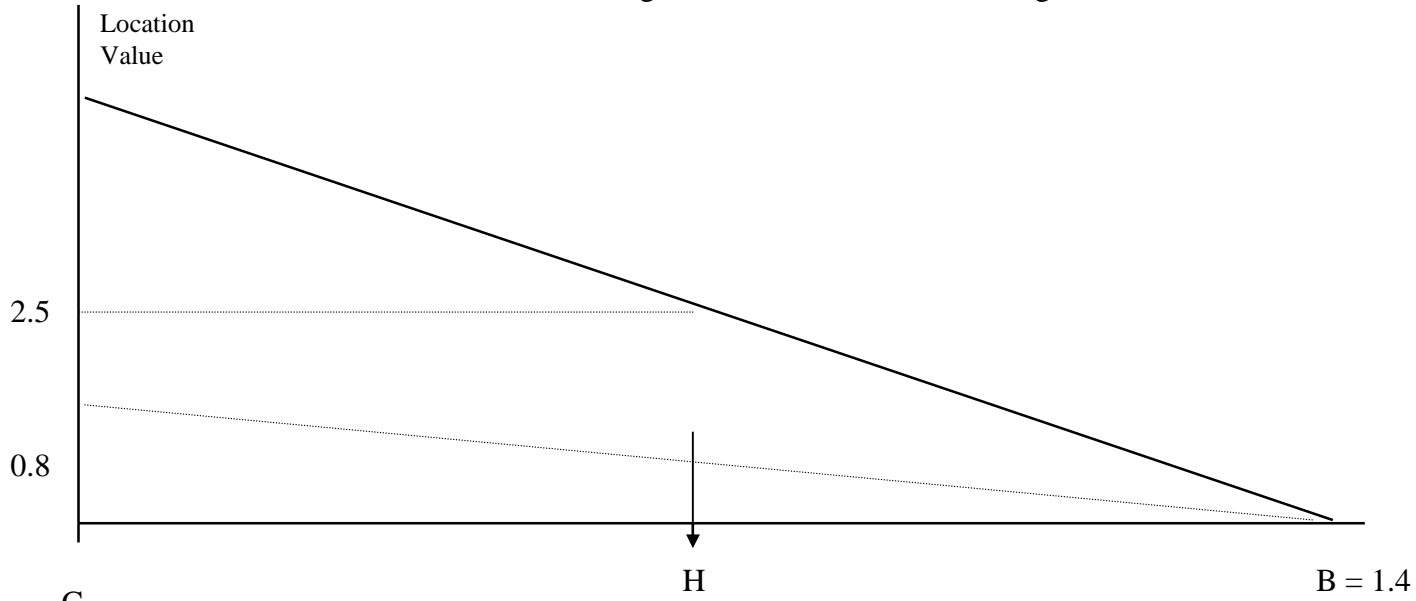


**Exhibit 6b; 1689-1790: Herengracht Real Location Value Index**



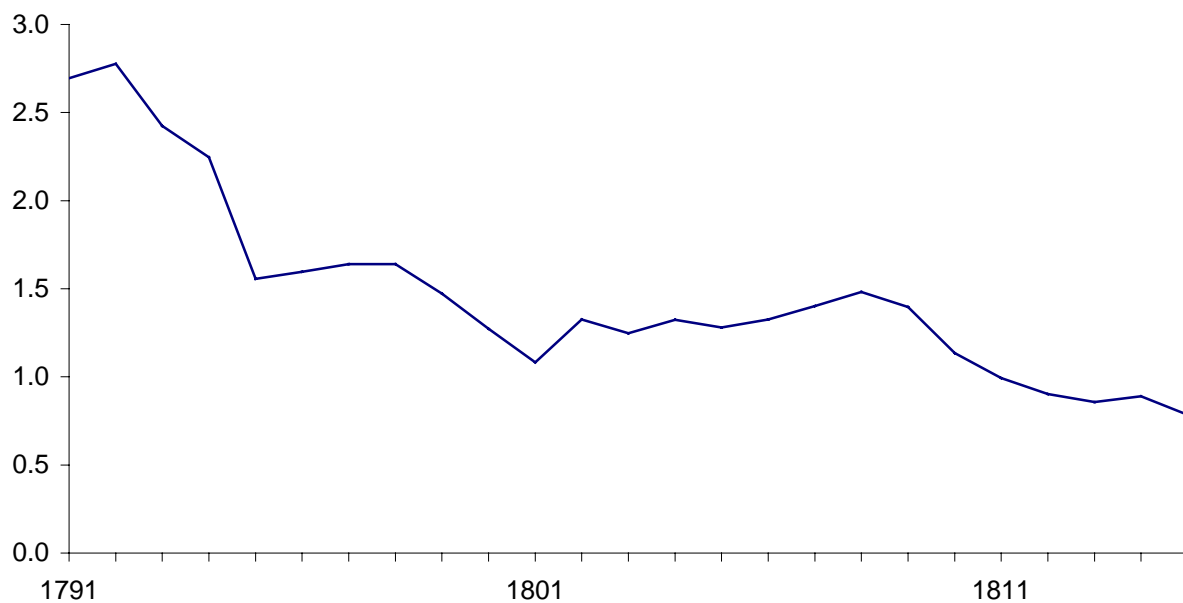
**Exhibit 7a: 1791-1815: War & Occupation**

Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient



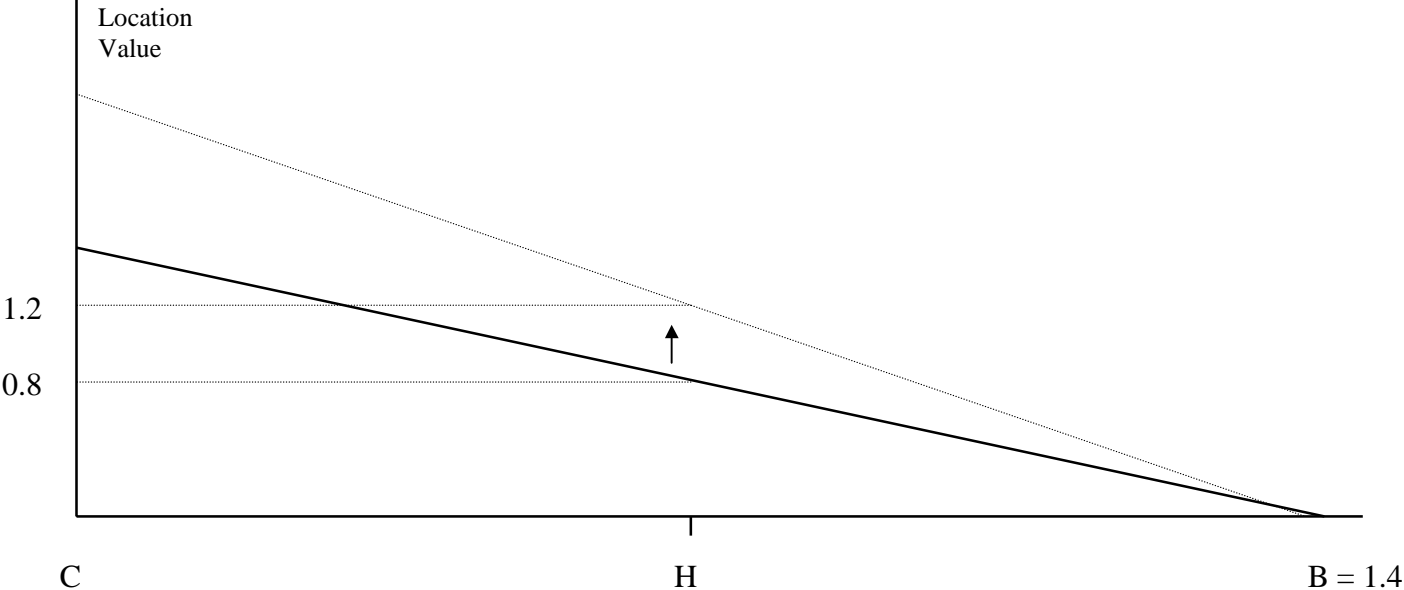
C = Center  
H = Location of Herengracht  
B = Urban boundary

**Exhibit 7b; 1791-1815: Herengracht Real Location Value Index**



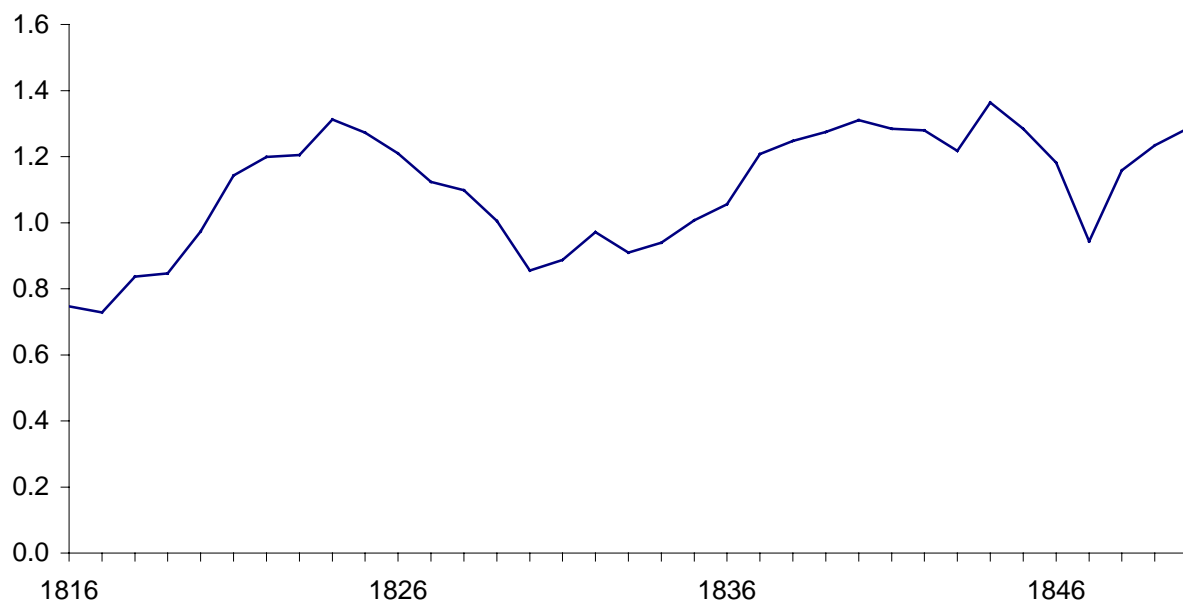
**Exhibit 8a; 1816-1850: Recovery**

Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient



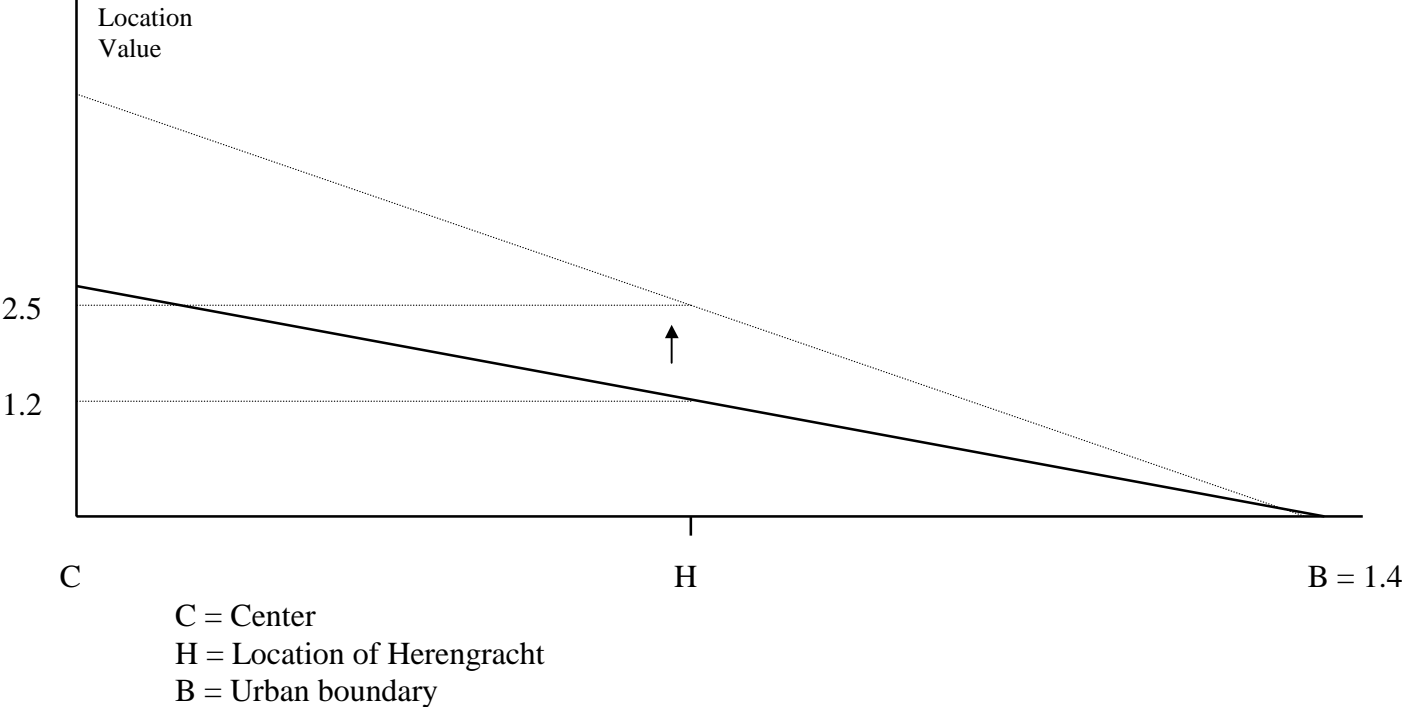
C = Center  
H = Location of Herengracht  
B = Urban boundary

**Exhibit 8b; 1816-1850: Herengracht Real Location Value Index**

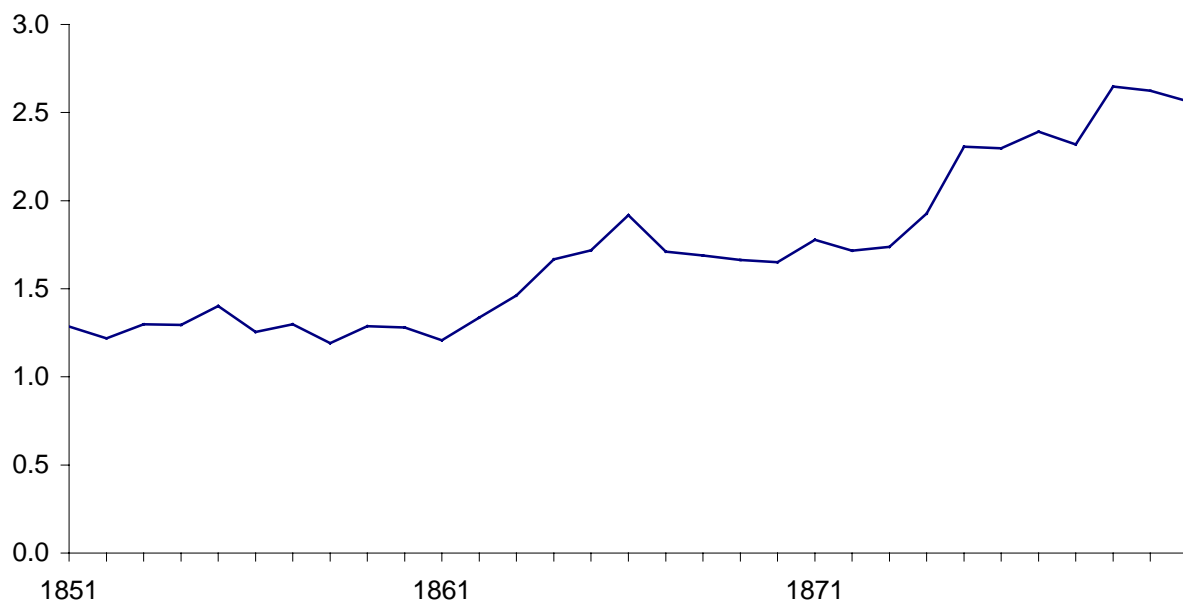


**Exhibit 9a; 1851-1880: Industrialization before Trams**

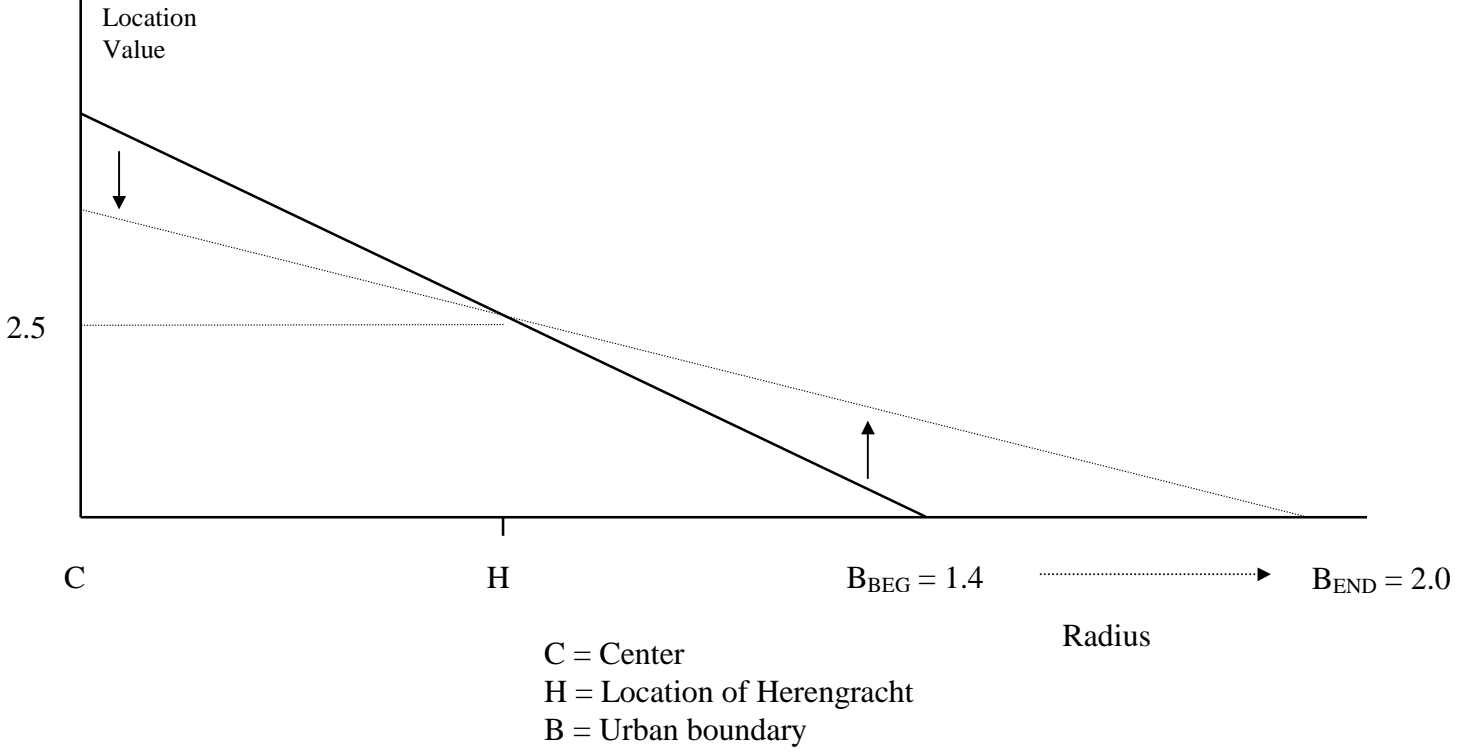
Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient



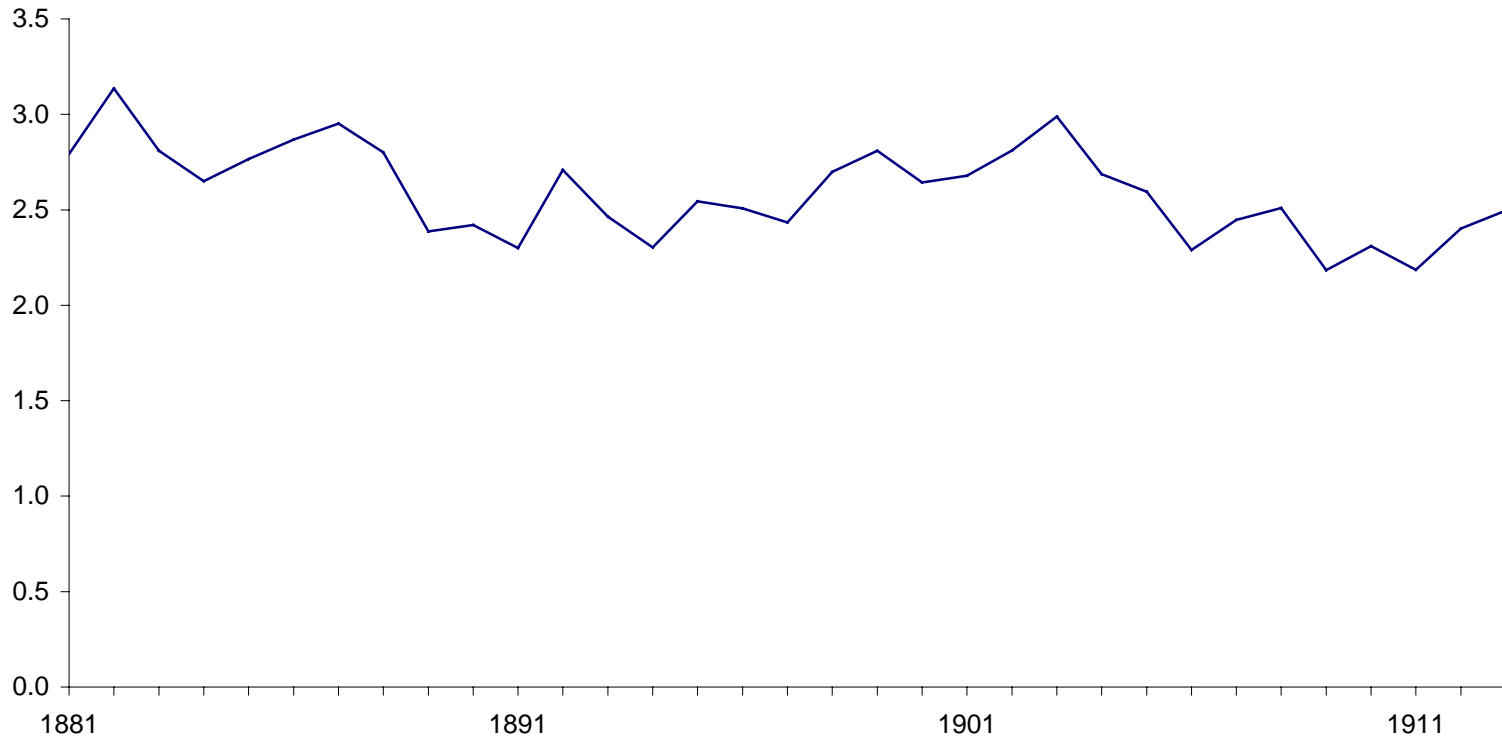
**Exhibit 9b; 1851-1880: Herengracht Real Location Value Index**



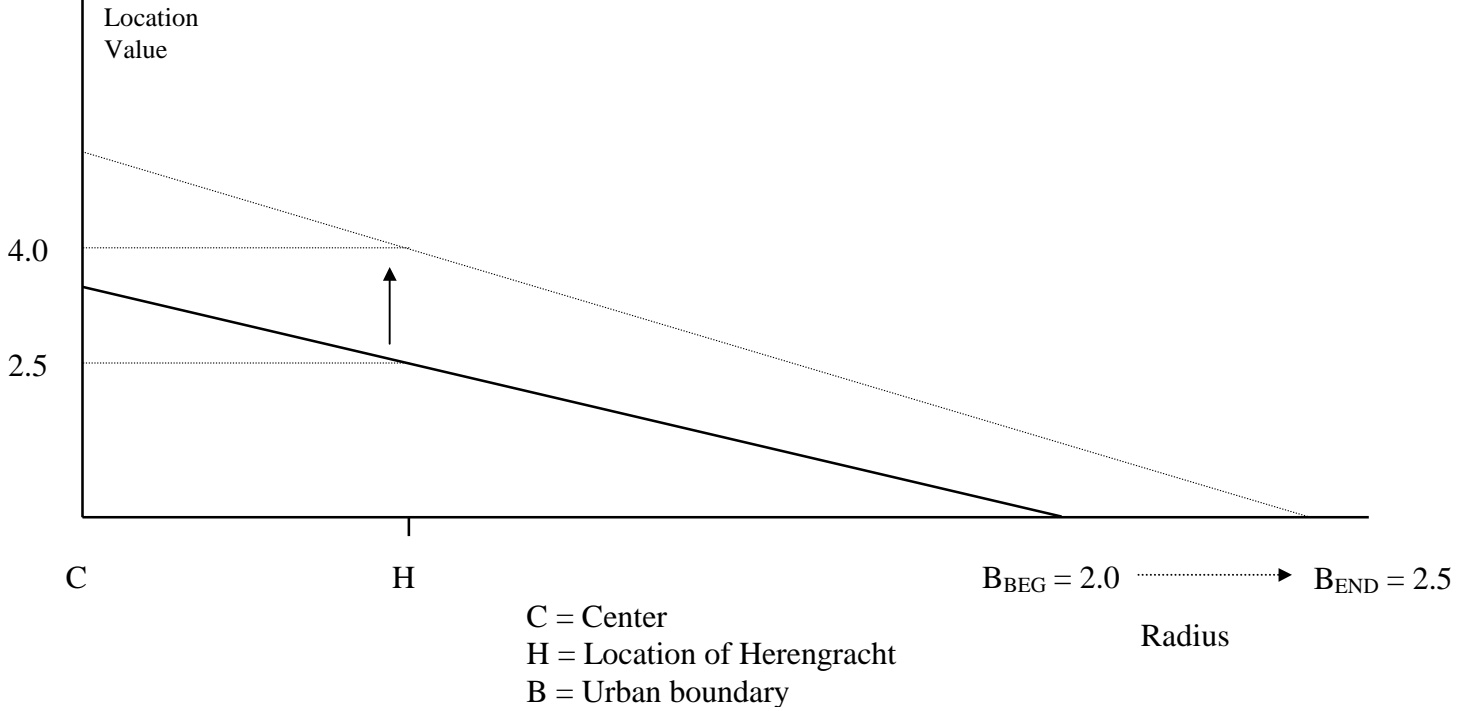
**Exhibit 10a; 1881-1913: Industrialization and Trams**  
 Cross-section of implied approximate changes in radius,  
 Herengracht location value, and rent gradient



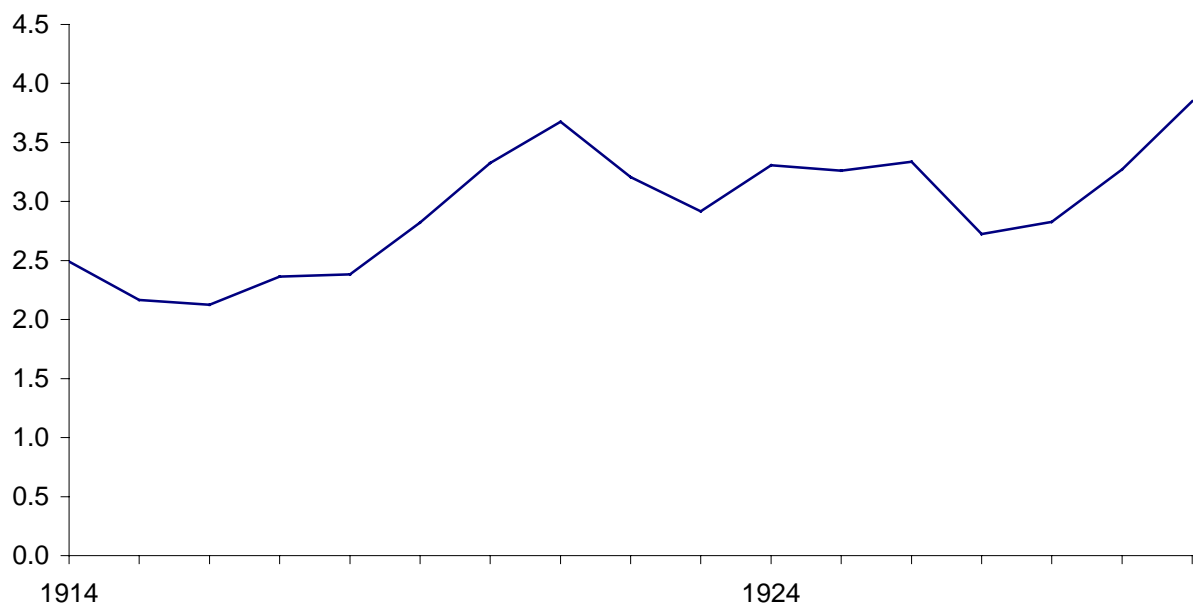
**Exhibit 10b; 1881-1913: Herengracht Real Location Value Index**



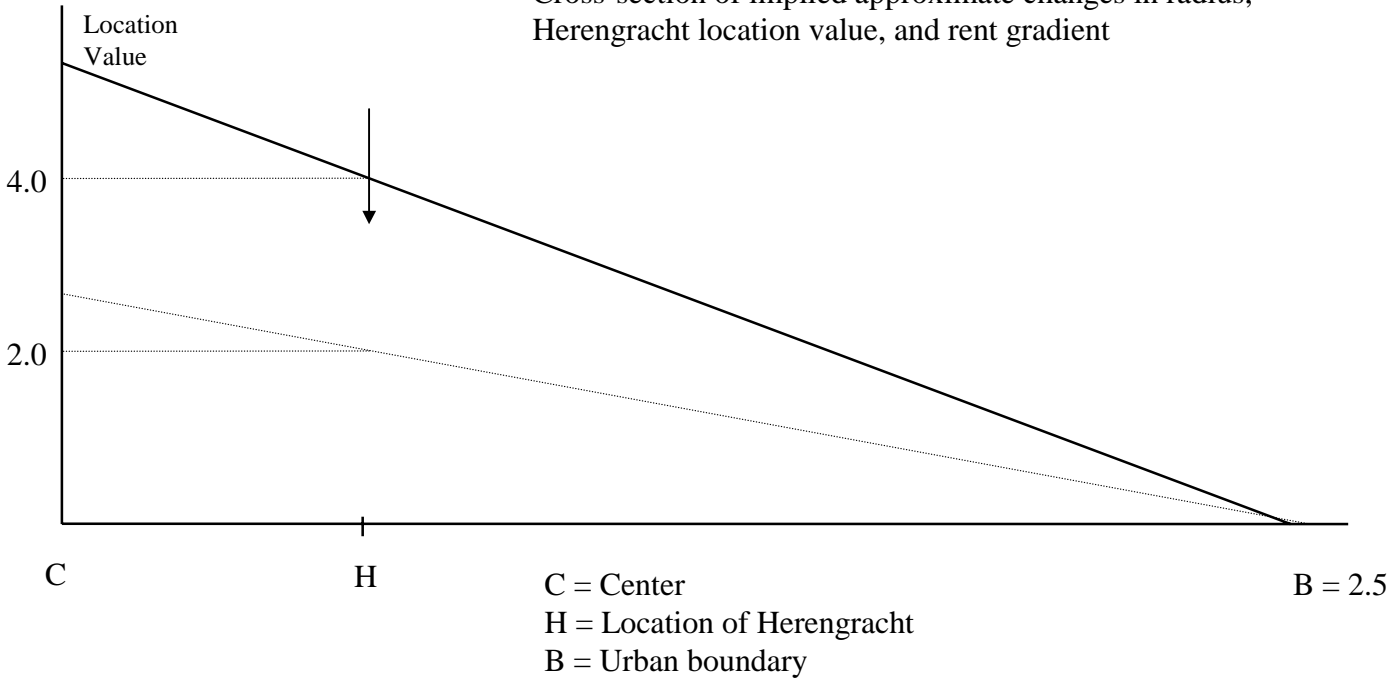
**Exhibit 11a; 1914-1930: World War I and 1920s Boom**  
 Cross-section of implied approximate changes in radius,  
 Herengracht location value, and rent gradient



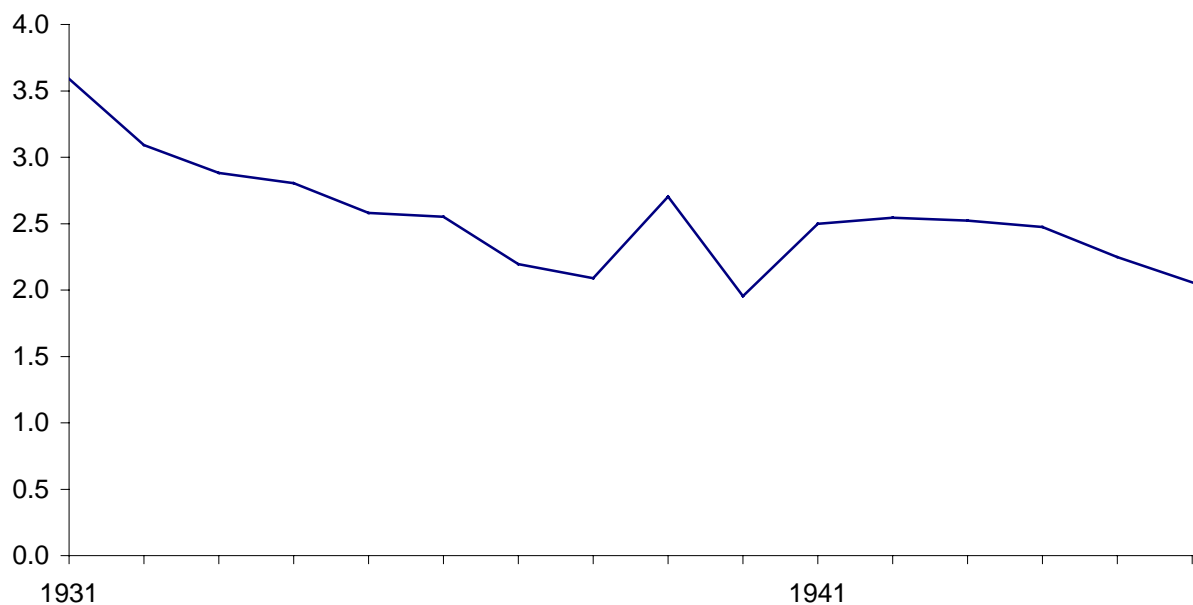
**Exhibit 11b; 1914-1930: Herengracht Real Location Value Index**



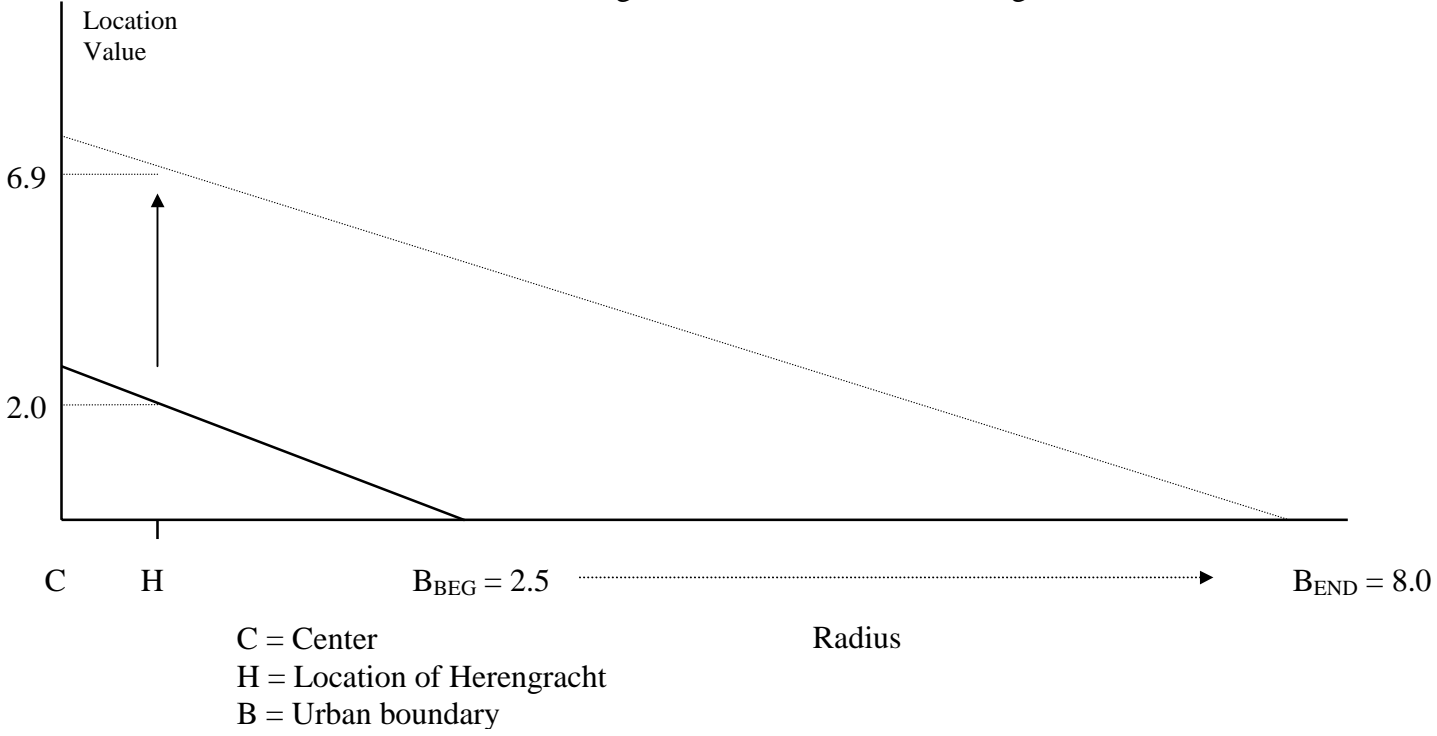
**Exhibit 12a; 1931-1946: Depression & World War II**  
Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient



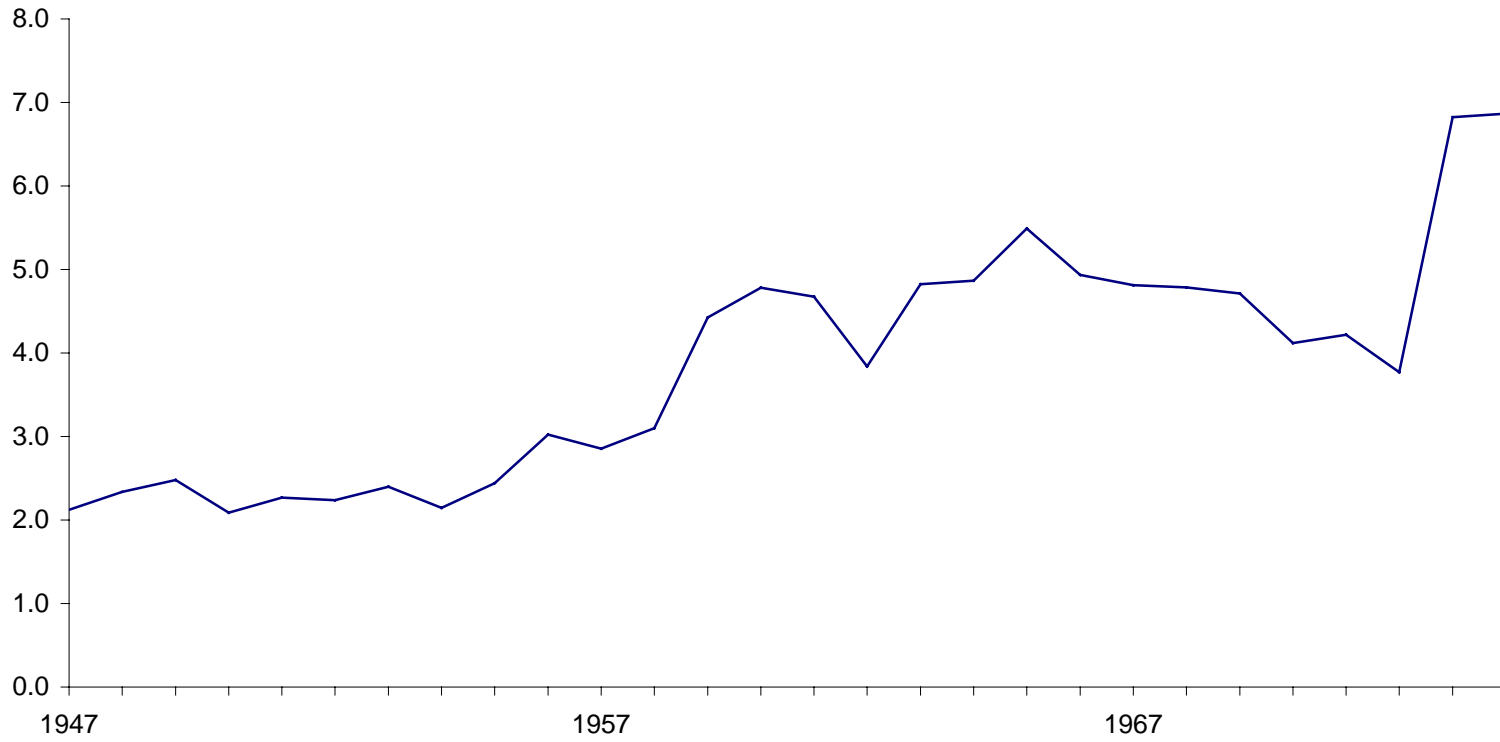
**Exhibit 12b; 1931-1946: Herengracht Real Location Value Index**



**Exhibit 13a; 1947-1974: Post-war Recovery & Boom**  
Cross-section of implied approximate changes in radius,  
Herengracht location value, and rent gradient



**Exhibit 13b; 1947-1974: Herengracht Real Location Value Index**



## References

- Alonso, W., *Location & Land Use*, Harvard University Press, Cambridge, MA, 1964.
- Amin, K. & D.R. Capozza, "Sequential Development", *Journal of Urban Economics* 34: 142-158, 1993.
- Bailey, M.J., R.F. Muth and H.O. Nourse, "A Regression Method for Real Estate Price Index Construction", *Journal of the American Statistical Association*, 58: 933-942, 1963.
- Barkham, R. & D. Geltner, "Unsmoothing British Valuation-Based Returns Without Assuming an Efficient Market", *Journal of Property Research* 11: 81-95, 1994.
- Capozza, D. & R. Helsey, "The Stochastic City", *Journal of Urban Economics* 28: 295-306, September 1990.
- Case, K.E. and R.J. Shiller, "Prices of Single-Family Homes since 1970: New Indexes for Four Cities", *New England Economic Review* 73: 45-56, September/October 1987.
- Case, K.E. and R.J. Shiller, "The Efficiency of the Market for Single Family Homes", *American Economic Review* 79: 125-137, 1989.
- Childs, P.D., T.J. Riddiough & A.J. Triantis, "Mixed Uses and the Redevelopment Option", *Real Estate Economics* 24: 317-339, 1996.
- DiPasquale, D. & W. Wheaton, *Urban Economics & Real Estate Markets*, Prentice Hall, Englewood Cliffs, NJ, 1996.
- Eichholtz, P.M.A., "A Long Run House Price Index: The *Herengracht* Index, 1628-1973", *Real Estate Economics* 25: 175-192, 1997.
- Fisher, J., D. Geltner & R.B. Webb; "Value Indices of Commercial Real Estate: A Comparison of Index Construction Methods", *Journal of Real Estate Finance & Economics* 9: 137-164, 1994.
- Goetzmann, W.N., "The Accuracy of Real Estate Indices: Repeat Sale Estimators", *Journal of Real Estate Finance & Economics* 5: 5-54, March 1992.
- Hansen, L.P. & K. Singleton, "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models", *Econometrica* 50: 1269-1286, 1982.
- Muth, R., *Cities & Housing*, University of Chicago Press, Chicago, 1969.

Shiller, R.J., *Macro Markets*, Oxford University Press, Oxford, 1993.

Titman, S., "Urban Land Prices Under Uncertainty", *American Economic Review* 75: 505-514, 1985.

Van Eeghen, I.H., G. Rosegaarde Bisschop en H.F. Wijnen, *Vier eeuwen Herengracht*, published for Het Genootschap Amstelodanum, Stadsdrukkerij Amsterdam, Amsterdam, 1976.

**Appendix: Annual Herengracht Location Value Index in Real Terms (1628 = 1)**

<b>Vaar</b>		<b>Vaar</b>		<b>Vaar</b>		<b>Vaar</b>	
1628	1.00	1657	2.40	1686	1.84	1715	1.66
1629	0.92	1658	2.37	1687	1.96	1716	1.72
1630	0.86	1659	2.41	1688	1.94	1717	1.86
1631	0.87	1660	2.39	1689	1.89	1718	1.87
1632	1.03	1661	2.28	1690	1.89	1719	1.89
1633	1.07	1662	2.10	1691	1.81	1720	2.02
1634	1.02	1663	2.71	1692	1.70	1721	2.27
1635	1.05	1664	2.78	1693	1.46	1722	2.47
1636	1.09	1665	2.58	1694	1.58	1723	2.80
1637	1.10	1666	2.47	1695	1.69	1724	3.02
1638	0.99	1667	2.39	1696	1.76	1725	3.34
1639	1.24	1668	2.37	1697	1.68	1726	3.08
1640	1.44	1669	2.47	1698	1.54	1727	2.79
1641	1.67	1670	2.29	1699	1.52	1728	2.89
1642	2.06	1671	2.12	1700	2.00	1729	2.94
1643	2.02	1672	1.87	1701	2.15	1730	3.23
1644	1.87	1673	1.83	1702	2.21	1731	3.40
1645	1.65	1674	1.67	1703	1.82	1732	3.25
1646	2.15	1675	1.47	1704	1.76	1733	3.55
1647	2.11	1676	1.45	1705	1.81	1734	3.30
1648	1.95	1677	1.49	1706	1.86	1735	3.41
1649	1.84	1678	1.51	1707	1.89	1736	3.46
1650	1.76	1679	1.86	1708	1.86	1737	3.35
1651	2.31	1680	1.88	1709	1.29	1738	3.40
1652	2.19	1681	1.81	1710	1.34	1739	3.18
1653	2.31	1682	1.66	1711	1.60	1740	2.84
1654	2.49	1683	1.58	1712	1.75	1741	2.55
1655	2.39	1684	1.64	1713	1.89	1742	2.35
1656	2.42	1685	1.66	1714	1.72	1743	2.19

**Appendix (Continued): Annual Herengracht Location Value Index in Real Terms (1628 = 1)**

Vaar		Vaar		Vaar		Vaar	
1744	2.21	1773	2.51	1802	1.32	1831	0.89
1745	2.42	1774	2.67	1803	1.25	1832	0.97
1746	2.34	1775	2.58	1804	1.32	1833	0.91
1747	2.24	1776	2.69	1805	1.28	1834	0.94
1748	2.19	1777	2.79	1806	1.32	1835	1.01
1749	2.13	1778	2.93	1807	1.40	1836	1.06
1750	2.02	1779	3.03	1808	1.48	1837	1.21
1751	2.36	1780	2.95	1809	1.40	1838	1.25
1752	2.53	1781	2.77	1810	1.13	1839	1.27
1753	2.69	1782	2.78	1811	0.99	1840	1.31
1754	3.01	1783	3.03	1812	0.90	1841	1.28
1755	2.71	1784	3.05	1813	0.86	1842	1.28
1756	2.38	1785	3.04	1814	0.89	1843	1.22
1757	2.13	1786	2.84	1815	0.79	1844	1.36
1758	2.14	1787	2.67	1816	0.75	1845	1.28
1759	2.37	1788	2.42	1817	0.73	1846	1.18
1760	2.40	1789	2.46	1818	0.84	1847	0.94
1761	2.38	1790	2.51	1819	0.85	1848	1.16
1762	2.36	1791	2.70	1820	0.97	1849	1.23
1763	2.51	1792	2.78	1821	1.14	1850	1.29
1764	2.80	1793	2.42	1822	1.20	1851	1.22
1765	2.84	1794	2.25	1823	1.21	1852	1.30
1766	2.71	1795	1.56	1824	1.31	1853	1.29
1767	2.18	1796	1.60	1825	1.27	1854	1.40
1768	3.19	1797	1.64	1826	1.21	1855	1.26
1769	3.37	1798	1.64	1827	1.12	1856	1.30
1770	2.96	1799	1.47	1828	1.10	1857	1.19
1771	2.55	1800	1.27	1829	1.01	1858	1.29
1772	2.65	1801	1.08	1830	0.86	1859	1.28

**Appendix (Continued): Annual Herengracht Location Value Index in Real Terms (1628 = 1)**

<b>Vaar</b>		<b>Vaar</b>		<b>Vaar</b>		<b>Vaar</b>	
1860	1.21	1889	2.39	1918	2.38	1947	2.12
1861	1.34	1890	2.42	1919	2.82	1948	2.34
1862	1.46	1891	2.30	1920	3.32	1949	2.48
1863	1.67	1892	2.71	1921	3.68	1950	2.09
1864	1.72	1893	2.46	1922	3.21	1951	2.27
1865	1.92	1894	2.30	1923	2.92	1952	2.24
1866	1.71	1895	2.54	1924	3.31	1953	2.40
1867	1.69	1896	2.51	1925	3.26	1954	2.14
1868	1.66	1897	2.43	1926	3.34	1955	2.44
1869	1.65	1898	2.70	1927	2.73	1956	3.02
1870	1.78	1899	2.81	1928	2.83	1957	2.86
1871	1.72	1900	2.64	1929	3.27	1958	3.10
1872	1.74	1901	2.68	1930	3.85	1959	4.43
1873	1.93	1902	2.81	1931	3.59	1960	4.78
1874	2.31	1903	2.99	1932	3.09	1961	4.68
1875	2.30	1904	2.69	1933	2.88	1962	3.84
1876	2.39	1905	2.59	1934	2.81	1963	4.82
1877	2.32	1906	2.29	1935	2.58	1964	4.86
1878	2.65	1907	2.45	1936	2.55	1965	5.49
1879	2.62	1908	2.51	1937	2.19	1966	4.93
1880	2.56	1909	2.18	1938	2.09	1967	4.81
1881	2.79	1910	2.31	1939	2.70	1968	4.79
1882	3.14	1911	2.19	1940	1.95	1969	4.71
1883	2.81	1912	2.40	1941	2.50	1970	4.12
1884	2.65	1913	2.50	1942	2.54	1971	4.22
1885	2.77	1914	2.49	1943	2.52	1972	3.77
1886	2.87	1915	2.17	1944	2.47	1973	6.82
1887	2.95	1916	2.12	1945	2.25	1974	6.87
1888	2.80	1917	2.36	1946	2.06		