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From Central Planning to Centrality: Krakow's Land Prices after Poland's Big Bang*

by

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Abstract

We examine commercial land markets in Krakow, Poland over a ten-year period of transition from socialist management to a market economy. We explore the spatial and temporal evolution of land prices over this period. In particular, we are interested in identifying trends toward or away from centrality, and in discovering whether or not these trends acted on the city center alone or over a set of centers. The data set we employ is uniquely appropriate for this purpose as the densifying force of "highest-and-best" use - typically found in market-oriented cities - was absent under four decades of socialist planning, leaving undeveloped land scattered throughout the city. Free of quality-control issues associated with disentangling the value of land from properties in which land and structures are bundled, the data offer a clean assessment of land prices within an urban area. We employ a novel, iterative approach to identify pricing centers - "nodes" of similarly-sized residuals - which we interpret as evidence of omitted spatial amenities. Using this approach, we find that the price gradient in Krakow evolved towards concentration, but concentration in several centers rather than in just one. We find that the exclusion of proximity to these centers leads to biased coefficients in the hedonic regressions; we also find that the majority of the apparent spatial autocorrelation in the aspatial regressions results from the omission of proximity to these centers.

Key Words: Land prices, land price gradient, spatial econometrics, emerging markets.

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1 Introduction

It is now clear that simple monocentric models are inadequate to represent many metropolitan areas - indeed, few cities look like von Thünen's "Isolated State" (1826). The rise of subcenters, suburban office parks and retail concentrations, "edge cities," etc. has meant that convenient parameterizations of the land-rent gradient used in applied urban research are often misspecifications of the effect of location on the price of land. This is especially true in metropolitan areas that are undergoing rapid change. It is not uncommon to see specifications for the land-rent gradient that allow neither for polycentricity nor variation over time. The complexity of the value of location *over time* is the focus of this paper.

To address this question, we model land-rent surfaces in a city undergoing rapid and substantial change. We examine the evolution of pricing for vacant lots in Krakow, Poland from 1993 to 2001. The nine-year sample period begins shortly after the implementation of the package of legal and economic reforms known as Poland's "Big Bang." The data reveal distinct variation in pricing over space and time and underscore the substantial weakness of time-invariant and/or simple monocentric models. Over the sample period, there was a substantial movement from smaller, more scattered nodes of pricing to fewer, more influential nodes.

Our approach to modeling the price surfaces over time is iterative and flexible. We estimate a hedonic regression that includes covariates that control for a parcel's access to infrastructure and its allowable uses in order to focus on residuals that contain the value of proximity to locational amenities. Our approach is to use these residuals to estimate a smooth price surface and model its significant features. Peaks on the smoothed surface are "nodes" of like-sized and -signed residuals; land near these locales systematically trades at above the price predicted by the hedonic models. Proximity to these nodes is included in subsequent hedonic regressions. This way we allow the data to reveal which locations are systematically valued over others.

We find that the city center is highly valued throughout this era, but so too are other locations. Broadly speaking, the handful of small nodes in the northwest of the city in the early years gives way to fewer, larger, and more centrally located nodes as time passes. We find that the inclusion of the proximity to these locales in the hedonic regression greatly reduces measured spatial autocorrelation. This raises the possibility that omitted spatial amenities, rather than some spatial error-generating process, may be at the root of spatial autocorrelation in other research. Surprisingly however, the inclusion of the spatial variables does not significantly impact estimated aggregate land price indexes.

The paper is organized as follows. Section 2 briefly reviews the history of Krakow, focusing on the important influence of socialism on the city's urban form. Our data are discussed in Section 3. Section 4 introduces our approach to measuring the surface of land prices and capturing its evolution. The results of this process are described in Section 5. Conclusions are drawn and extensions discussed in Section 6.

2 Krakow's Urban Form & Poland's Big Bang

Krakow's current urban landscape reflects its long history. The first evidence of Krakow as a center of economic activity dates from 965 A. D. In the 11th century, Krakow was the main seat of the first Polish kings of the Piast dynasty. Krakow has evolved into an intellectual, artistic and religious center with the second oldest university in Central Europe and a medieval town square and fortifications among other attributes that have been preserved to the present. Romanesque, Gothic, Renaissance and Baroque architectural styles are found in the more than 50 churches in Old Krakow. Surrounding the city are five rings of fortifications, the most recent reflecting Krakow's role as the northernmost fortress of the Habsburg Austro-Hungarian Empire.[1] Prior to World War I, Poland spent some 120 years partitioned among Germany, Austria and Russia. The end of World War I resulted in liberation and intensive infrastructure investment, economic growth and commercial activity. World War II and the occupation of Poland by German and, subsequently, Soviet forces left Poland under the influence of the USSR during the Cold War.

Beginning with the occupation of a redefined Poland by the Soviets in 1945, the decisions of central planners shaped the spatial development of Polish cities, often in conflict with how economic activity is arranged in market-oriented cities. By 1948, the private sector had been eliminated and a new centralized economy was being established. The government introduced previously non-existent heavy industry to Krakow in the 1950s when it built

[1] In 1978, UNESCO added the city to its list of 12 major historic sites in the world.

the sprawling Sendzimar steel mill and the adjacent model socialist town of Nowa Huta on Krakow's east-side. Later industrial development occurred in Wola, Duchaka and Nowy Biezanow to the southeast of old Krakow; high-rise housing was built nearby each. This group of communities and Nowa Huta were each established well outside the core of the old city, creating four high-density nodes in keeping with the socialist goal of providing cost effective, high-density housing close to nearby industrial employment centers. However, because food and other household needs were distributed centrally, commercial (retail) uses were not located near these high-density residential areas - in contrast to patterns typical in market-driven cities. This spatial mismatch of land uses is found throughout the city; the existence of these high-density developments in the periphery is illustrative of the durable imprint of socialism on Krakow.

The transformation away from socialist management began in 1989 with a radical package of reforms ("shock therapy") dictated by the severity of inherited economic problems and the expectation that the new regime's political capital would be rapidly consumed. The Balcerowicz Plan (Poland's "Big Bang") involved macroeconomic stabilization followed by restructuring and stimulation.[2] Macroeconomic stabilization strategies included the liberalization of prices, the raising of interest rates to a positive real level and the support of internal convertibility of the Polish currency. Critical components of the restructuring included the rapid privatization of some state-owned enterprises and the liquidation of others, the encouragement of start-up firms and the return of the ownership of real estate assets to the private sector (Slay 1994).

Poland had been in crisis prior to 1989 and was thought to face deeper economic challenges than neighboring Hungary and Czechoslovakia. But "shock therapy" proved to be among the more successful approaches to facilitating transformation away from a planned economy; Poland's contraction was shallower and shorter - and its recovery more rapid - than in neighboring countries (De Broeck and Koen 2001). After initial declines in real GDP in 1990 and 1991 of 11.6% and 7.2%, respectively, Poland experienced positive growth of 2.6% in 1992. This was followed by a period of accelerating growth between 1993 and 1995 from 3.8% to 7.0%. Growth then leveled between 1996 and 1998, averaging 5.9%. Starting in late

[2]Then Deputy Prime Minister and Minister of Finance Leszek Balcerowicz (currently, President of the National Bank of Poland) was the primary architect of the plan. He was one of a group of young economists who had worked during the 1980s to develop economic strategies for transition.

1998, Poland was squeezed by the slowdown in Western Europe and the Russian financial crisis, and GDP growth declined through 2001 - from 3.9% in 1999 to 1.0% in 2001 - as exports declined and unemployment rose. We employ these apparent shifts in the economy to define our temporal subsamples, 1993-1995, 1996-1998, and 1999-2001, which are used to track the evolution of the land-price surface over time.

The importance of centrality in urban land-use theory is based in large part on transportation costs and reservation wages. During this period of transition, increases in rents and transportation costs out-paced overall price increases. And, while difficult to document, we believe that because of rising fuel costs and the high costs of credit, the price of private automobile transportation has risen more than the cost of public transportation. Opportunity costs associated with commuting time also would have increased after 1995 as real wages increased. These factors likely impacted the geographic distribution of rents and residual land values as location and accessibility took on greater value.

According to De Broeck and Koen (2001), the impetus for economic growth in Poland between 1992 and 1998 came from manufacturing, consumer-oriented services and the greater dynamism of the private sector. Expansion of the private sector was initially led by new domestic small- to medium-sized enterprises. With foreign direct investment (FDI) picking up in 1994, the driving force behind private sector expansions shifted to the affiliates of global firms including such diverse multi-nationals as MacDonald's Restaurants, Carrefour, and IKEA. We expect that land purchases associated with the entry into Poland of these types of firms would have significantly influenced the land market as global firms competed for prime locations throughout Poland.

3 Land Market Reforms & Land Sales

The post-Soviet restructuring reestablished the bundle of property rights associated with real estate through amendments to the Constitution of Poland and the Civil Code, including forms of tenancy, transfer mechanisms, title and the rights and obligations of ownership. Costs of transfer remain relatively high at about 10% of the price declared in the notarial deed (including brokerage fees). Privatization of real property is a work in progress as previous owners and their successors have employed the courts to seek restitution of properties illegally taken by the state between 1944 and 1962. Most urban property has been municipalized by transferring ownership of real estate to newly elected local governments (Local Self Government Act of 1990) and regulating their real estate asset management and condemnation practices (1990 Amendment to the Land Management and Expropriation Act). Local governments have, to various degrees, transferred property rights to the private sector through auction, sale, exchange or grant. For example, the management and employees of a firm might be granted title to land occupied by their factory (e.g., the Sendzimar steel mill). These parcels may then enter the market for raw land as entities raise capital through asset sales.[3]

The data we use in this analysis are the set of sales of vacant parcels in Krakow.[4] We have excluded sales to government entities and cooperatives because it was impossible to determine whether these transactions occurred at market prices.[5] The remaining transactions are believed to be "arm's-length" sales between individuals, housing cooperatives, and privatized entities.

In this analysis, we focus on those parcels destined for development as investment properties - including parcels zoned for commercial, industrial, multifamily, and mixed-uses, but excluding those zoned for single family dwellings and low-density multifamily units. This set of observations consists of 1,760 parcel sales between 1993 and late 2001.[6] Each observed sale is located spatially in a grid system allowing the computation of distance to nodes within the city. The investment property parcels are mapped against Krakow's major streets in Figure 1. The center of Krakow is considered its historic central square dating from medieval times, and is indicated on the map by a star.[7]

[3]For the most part, ownership rights have been clarified. However, due to transaction costs and the potential cloudiness of title, some private sector possessors of property have chosen not to attempt to formalize title. Still other private sector owners fearful of the costs associated with ownership (particularly of rent-controlled residential units) have not revealed their claims.

[4]The data set was originally developed by the Krakow Real Estate Institute (CREI) as part of the USAID-funded market value based property tax simulation project in Krakow in 1993 and 1994. Since that time, additional data collection efforts have yielded a database that is comprised of all land transactions in the city from 1993 through late 2001. Additional funding came from a Lincoln Institute of Land Policy research grant.

[5]There is relatively little organized public information about listings or transactions and individual real estate brokers have been reluctant to share information that they perceive has monopoly value. Although the data employed in this study is technically public information, its acquisition involves the investigation of individual files maintained in government offices not easily accessed by private citizens.

[6]In a companion paper, we examine the evolution of the low-density residential land market.

[7]This data set is slightly smaller than that found in previous versions of this paper. We have eliminated physical outliers - those far from the city center and those in sparsely developed areas. The loess surface

The transactions are distributed throughout the urban area but most are more concentrated within seven or eight kilometers of the city center. In Figure 1, nodes of sales activity are evident as are arteries and intersections adjacent to which there are groupings of transactions. Two clusters are worth noting. The first is east of the city center near the high-density residential development of Nowa Huta. The second is in the northwestern suburbs that are part of Krowodrza. The clusters are interesting for their differences. Nowa Huta is a Soviet-era high-density residential development where no commensurate retail activity was located. The proximate cluster of land sales seen in the map are largely commercial in nature and are a direct reflection of the imbalance in land use that arose during this era. The second prominent cluster is almost entirely residential. These transactions suggest that new, higher density residential development is expected in the predominately residential neighborhoods to the northwest of downtown.

In addition to location, parcel characteristics include lot size, several variables relating to access to infrastructure, and variables related to allowable use. The parcels are unimproved lots in the sense that no structure sits on the land; there is, however, variation across properties with regards to access to key infrastructure. The infrastructure variables include access to gas, heat, telephone, electricity, water, and sewage. The variables describing allowable use include dummy variables by zoning - commercial, industrial, multifamily, and mixed-use - as well as continuous variables denoting allowable intensity of use for multifamily and mixed-uses (the floor-area ratio or FAR).

Average characteristics for the parcel sales in the data set are reported in Table 1. Save two variables, the table is remarkable for the lack of variation among the infrastructure access variables. There is essentially no difference among the average characteristics of the parcels zoned for commercial, mixed-use, and multifamily purposes with regards to the availability of gas, heat, telephone, electricity, water, or sewage services. Differences do exist in the average size of the parcels - with mixed-use parcels decidedly smaller - and their location. While not statistically different, lots zoned for mixed-use are located closer, on average, to the city center. The data set is described in more detail in Dale-Johnson and Brzeski (2001). It should be noted that while the total number of parcel sales in 1,760, the total

estimates in these areas were unreliable due to small sample sizes. As a result, we can use a smaller span in the estimation of the price surface.

observations by land use exceeds this number because it relatively common to have multiple zoning designations.[8]

Table 1 also reports average real price per square meter for the entire sample period as well as the three epochs used to study the evolution of Krakow's land markets.[9] It is clear that land markets have gone through an extensive change both in level and diversity of prices. Average real price per square meter for unimproved land grew by a factor of four over the sample period. The standard devation grew by roughly the same amount. Because the land is unimproved, this increase in variation is likely to come from growing diverstiy of the premia from location. Prices varied across land uses as well. The price for commerical and mixed-use parcels grew faster than for multifamily use. These trends are also visible in Figure 2.

Figure 2 reports the volume of transactions and the composition of sales by type of zoned land use during the sample period from 1993 through 2001. The figure provides insight into how investment real estate land markets have evolved in Krakow. The total volume of transactions is relatively low in 1993, and split roughly 60%/40% between commercial and multifamily parcel sales. The volume of commercial transactions (for single use commercial activities including retail and office uses) grew most rapidly between 1994 and 1996 and then declined relative to the volume of multifamily transactions that grew steadily starting in 1995. There were few mixed-use transactions in 1993, but this share grew until 1995 and then sustained the same low volume and share of transactions throughout the time frame of analysis.

The initial growth in volume and share of commercial transactions reflects the acquisition of parcels for retail uses (e.g., shopping facilities, gas stations, fast-food restaurants) and office uses for the service sector as these sectors of the economy responded to the rapid growth in consumer demand after the Big Bang. For example, while total sales across industry sectors grew 70% between 1991 and 1998, sales of motor vehicles and trailers grew 281%, sales of office equipment and computers grew 311% and sales of radio, TV and communication equipment grew 293%. While these data are reported for all of Poland by De Broeck and Koen (2001, P. 15, Table 4), Krakow experienced the same trends and developers likely

[8]Six percent of all parcels are multiple zoned: of the 108 that are, 90 allow multifamily and another use.

[9]All prices are in real Polish Zlotys. As a point of reference, the average exhange rate between U.S. dollars and Polish Zlotys during the three epochs was 2.18, 3.17, and 4.18 Zlotys per dollar, respectively.

responded by building retail facilities to distribute products to consumers experiencing the benefits of the new market economy (hypermarkets, for example).[10]

Features of the markets for mixed-use and multifamily properties have held down sales of these parcels. Mixed-use properties were envisaged by planners as critical to their goal of limiting sprawl and creating a compact city. Developers have been reluctant to take up the challenge of building these more complicated projects, perhaps due to their lack of familiarity with mixed-use development, the challenge of assembling the necessary larger parcels in the right location for such projects, and the difficulty of obtaining the necessary capital.[11] Multifamily residential demand has been muted due to rent controls on existing rental units; controls began phasing out in the year 2000. In order to stimulate development, subsidies for construction in the multifamily sector were introduced toward the end of the 1990s. We observe coincident growth in the number of multifamily land transactions.

We focus primarily on temporal submarkets based on macroeconomic data. In order to track the changing markets for land in the years following Poland's "Big Bang," we specify three epochs: periods are 1993:1 though 1995:4 (hereafter, Epoch 1), 1996:1 through 1998:4 (Epoch 2) and 1999:1 through 2001:4 (Epoch 3). These epochs reflect periods of accelerating, flat, and declining growth in GDP, respectively.

4 Land Price & Its Measurement

In the standard conception of hedonic pricing, observed value is a function of quality flow and the unit price of quality. Thus,

(1) $V_{it} = P_t Q_{it}$

describes the relationship, where V_{it} is parcel value, P_t is the unit price of quality, and Q_{it} is the quality flow; i and t index parcel and time, respectively. To arrive at the familiar hedonic

[10] We have been able to accumulate some data on foreign entrants to Krakow's land markets, among them IKEA, Carrefour, and Selgros. Their land purchases are made largely from 1996-1998, with a significant minority made in the last years of our sample, 1999-2001. Almost no purchases by these entities were made in the early years of the transition.

[11] An example is the Nowe Miasto project, a major mixed-use redevelopment project involving office, entertainment, retail, and apartment uses adjacent to the railway station. The project was originally undertaken by Trizec Hahn, subsequently taken over by Tishman Speyer and has now been acquired by German interests. Construction has still not begun. Negotiations with land-owners - including the State Railways, the State Post Office, and the State Bus Company - have been protracted. Tishman Speyer decided to sell the project to a German developer, but on the condition that the land assembly issue is resolved.

pricing equation, take logs of both sides and reparameterize the log of quality (lnQ_{it}) as a linear function of attributes ($X_{it}\beta$):

(2) $$lnV_{it} = lnP_t + X_{it}\beta.$$

The vector X_{it} consists of all attributes which contribute to the market price of the parcel.

In practice, the dimensions across which lots are priced are too numerous to list and too costly to compile. Empirically, the residuals are the commingled effects of the excluded variables and any other noise in individual prices. That is, if X^I are included variables and X^E are those excluded, the empirical pricing equation can be written

(3) $$lnV_{it} = lnP_t + X_{it}^I\beta^I + X_{it}^E\beta^E + \varepsilon_{it}.$$

or

(4) $$lnV_{it} = lnP_t + X_{it}^I\beta^I + e_{it}.$$

Here e_{it} is the regression error, which combines the independent influence of the excluded characteristics and the idiosyncratic error.

Our data are spatially diverse, and where there are location-specific amenities among the excluded variables, the errors may be correlated across space. The most obvious example of this is the city center. Market forces value this central location for shorter commutes and amenities requiring high densities of consumers, such as restaurants, museums, mass transit, etc. Failure to include distance to city center explicitly is likely to yield spatially correlated errors, inefficient parameter estimates, and potential bias among the estimated coefficients on covariates that are spatially correlated with the omitted amenities.

This same argument can be made for others locations and their proximity to spatial amenities (or disamenities). Be they industrial sites that negatively impact surrounding residential land values or suburban high-density residential areas that generate high rents for retail, the exclusion of proximity to these subcenters may cause significant econometric problems. Of course, the city center can be identified *a priori*, but secondary clusters of amenities (either positive or negative) are less readily apparent. Our approach to discovering other nodes of pricing is an iterative one, in which an aspatial hedonic model is estimated first and then the geocoded residuals are employed to reveal which locations are more highly-valued in land markets. We interpret clusters of like-signed residuals as evidence of spatial amenities, proximity to which has been omitted in the hedonic pricing regression.

The initial model (equation 4) regresses real log price per square meter (in Polish Zlotys) on quarterly trend variables and controls for access to infrastructure (gas, heat, telephone, electricity, water, and sewage), zoning (commercial, multifamily, or mixed-use),[12] allowable density (FAR), and legal status.[13] Because we are using observations on unimproved parcels, there is no need to control for quality differences of structures on each parcel. From this first-stage regression, the geocoded residuals are used to construct a smoothed surface of residuals using locally-weighted regression (loess).

Each point on the loess surface is obtained from a regression of residuals in its neighborhood with the closest points more heavily weighted. The amount of smoothing is determined by the choice of the "window" size and the specification of the weighting function for data within each window.[14] For each point, the window size determines which observations are to be included in the local regression. These observations are weighted according to a function of distance from the surface point being estimated. We use a tri-cubic function to weight observations within each window of data; that is,

$$(5) \quad w_j^i = \left(1 - \left(\frac{dist_j^i}{max(dist_k^i)}\right)^3\right)^3 \quad ,$$

where w_i is the weighting for each observation in the local regression that estimates the surface at point i. $dist_j^i$ is the distance between points i and j; $max(dist_k^i)$ is the largest distance between the reference point i and all of the observations in the subsample determined by the window size.[15]

Our loess regressions reveal a polycentric residual surface with distinctly idiosyncratic subcenters - different heights, slopes, radii, etc. It is clear that a simple specification of

[12]These categories are not mutually exclusive, with approximately six percent of all parcels multiply defined with more than one allowable use.

[13]Real price is obtained by deflating nominal price by an aggregate consumer price index. No price index is available that is free of land prices.

[14]The window size refers to the proportion of sales used in the local regression at each point. Many window sizes were employed with little impact on the trend, ranging from more, smaller, nodes to fewer, larger, nodes. The window size used in the work presented here is 0.15, striking a balance between local specificity and adequate sample sizes. An alternative approach would be to make the window size adaptive on local density of observations. This is discussed in general in Brockmann, Gasser, and Hermann (1993); an application of an adaptive window size can be found in Clapp (2003).

[15]See Cleveland and Devlin (1988) for more on loess.

the effect of distance from the node on parcel price would be inappropriate. To account for the asymmetry across nodes, a third-degree polynomial was fit locally to each node. Each node could then be described by the parameters of the polynomial as well as two additional variables: *extent* and *influence*. The *extent* is the physical limit of influence of a node, defined as the lesser of two distances: the distance at which the polynomial function equals zero or the distance at which the function has slope zero. The intuition is that when the function reaches zero the node no longer influences prices; when the slope is zero, there must be either an adjacent node - the slope is zero where there is a boundary between the two - or the node is at the periphery. We define *influence* as the area under the curve - defined by the polynomial - from the center of the node to its *extent*. At each iteration, the node with the greatest *influence* is selected and the function (the third-order polynomial) of the distance from the center of the node - not the distance itself - is included in subsequent regressions. Beyond the extent of the node, the distance function takes the value 0.

After the first iteration, equation 4 is updated with the inclusion of an additional explanatory variable that is intended to capture the value of proximity to the first node. That is,

$$(6) \quad lnV_{it} = lnP_t + X^I_{it}\beta^I + f_1(dist_{i1}) + e_{it},$$

where $f_1(dist_{i1})$ is value of the polynomial function associated with node 1 evaluated at the distance between the center of the node and observation i. After N iterations, the updated regression becomes

$$(7) \quad lnV_{it} = lnP_t + X^I_{it}\beta^I + f_1(dist_{i1}) + f_2(dist_{i2}) + \ldots + f_N(dist_{iN}) + e_{it}.$$

We execute the procedure iteratively because of the potential overlap across nodes (using our terms: there may be nodes within the extent of other nodes). In these cases, the surface is likely to be the composite influence of several subcenters. It is likely that the influence is not symmetric: distance to the city center may influence land prices throughout Krakow including parcels within secondary subcenters, but not the reverse. Therefore the order of inclusion in the pricing regression is based on the relative *influence* of candidate nodes. With area being interpreted as total influence, nodes are included in the regression in order of their aggregate impact on parcel prices.

We developed this procedure in order to discover which parcels were valued above the price that which would be indicated in an aspatial regression. The outputs of interest from this procedure are: the hedonic pricing regressions and the coefficients on the spatial variables; the set of variables describing the location and shape of the nodes; the aggregate price indexes based on spatial and aspatial hedonic regressions; and the variograms measuring spatial autocorrelation.

5 Results

The empirical approach described above was employed using the aggregate data spanning 1993 to 2001, as well as three three-year time periods that correspond roughly with changes in Poland's macroeconomy. We find several compelling results across the aggregate and temporal subsets: First, for each time period, proximity to the discovered nodes was quite significant. This is especially true of the city center, proximity to which was found to be highly significant in all of the models. Second, it appears that the coefficients on the infrastructure variables are biased in an aspatial model, reflecting that in an aspatial model they capture both the effect of the infrastructure and the parcel's proximity to the subcenters. Third, measured spatial autocorrelation appears to be explained, to varying degrees, by the omission of these subcenters. Fourth, measured aggregate land prices appear independent of spatial amenities, as their inclusion led to no statistically significant change in the aggregate parcel price indexes. The final result is a marked variation in the location of spatial amenities over time. That is, what is compounded spatially into parcel prices in the early years is not likely to be priced the same way during later years. In particular, we find a general evolution of Krakow's land markets toward fewer, larger, more centrally located nodes.

Tables 2 through 5 report the results of the iterative regressions for the aggregated data as well as for the three epochs. The regressions using the aggregated data are reported simply to make the point that coefficients on the infrastructure variables change with the subsets of data over the three epochs: independent of the spatial evolution of prices, pooling the data appears inappropriate as attributes have significantly different implicit prices over time. Several regularities arise across epochs and across regressions within the epochs. First, the explanatory power of the models is greatly enhanced with the inclusion of the spatial variables. From the base - aspatial - model to the most inclusive spatial model, the r-squared increased by 85%, 51%, and 104%, respectively for three epochs. In other words, in the first and third sample periods, approximately *half* of the explained variation in real price per square meter is explained by proximity to the nodes. The city center is consistently the most significant node - adding just the city center to the basic aspatial regression improves the r-squared by roughly a third in all three periods. While it is common to use distance to city center as explanatory variable, it is uncommon to see proximity to other locations as well. These results clearly demonstrate the significance of secondary nodes in explaining land prices.

Within each epoch, the addition of proximity to the nodes affects the other implicit prices as well as overall explanatory power. This reveals that the some of the covariates pick up spatial pricing in addition to the contribution of the particular attribute to land price. In Table 3, for example, lot size, access to electricity and sewage, and the mixed-use zoning variable all move from highly significant to insignificant. In fact, lot size and access to electricity move from a puzzling significantly-negative influence on parcel price to insignificant - reflecting the potential bias in aspatial regressions using spatial data. It is easy to imagine that infrastructure is not randomly or uniformly distributed across the city; in the absence of spatial regressors, the estimated effect of the other covariates may be biased as a result.

It is interesting to note the lack of importance of many of the access to infrastructure variables - none are significant in the first epoch. In contrast, all of the spatial variables are highly significant. In the second epoch, the infrastructure variables take puzzling values in some cases - access to water and telephone - which may derive from multicollinearity, from correlation with other omitted variables, or simply from proximity to locational disamenities (which could be considered an omitted variable). In the third epoch, the general insignificance of the infrastructure variables returns.

Other characteristics of the parcels are the approved use of the land and the allowable intensity of use. In contrast to the infrastructure variables, the zoning variables are highly significant. The excluded category is industrial, meaning that parcels zoned for mixed-use trade at a premium relative to parcels zoned for industrial use, while those zoned for commercial and multifamily uses trade at a relative discount. The floor-to-area ratio (FAR) variables indicate that lower-density mixed-use and higher-density multifamily parcels are favored. The multifamily penalty is more easily explained than the mixed-use penalty: during this period subsidies for existing apartments were rolled back only slowly, putting new multifamily stock - and therefore the land zoned for this use - at a disadvantage.

While the three sets of regressions reveal that location and allowable use are the strongest indicators of land price, they do not show the location of the nodes that have been included in the regressions. Moreover, they do not indicate whether or not land prices reveal trends to concentration or to deconcentration. Table 6 reports summary statistics that address this question. The table reports four sets of information on nodes discovered using our iterative approach. For each epoch, and the aggregated data, the table lists the location, extent, area, and average slope for each statistically significant node. The table makes clear two trends. First, there are fewer significant nodes over time. From the first epoch to the third, the number of significant nodes falls from six to five and, finally, to four. Moreover, the area under the locally-fitted surface increases. Referred to earlier as *influence*, the area under the local polynomial represents premia paid for proximity to a particular node. The city center earns a greater total premium over time.

Less apparent from the table is the movement of pricing nodes over time. In the first epoch, the secondary nodes are primarily in the northwest of the city, but appear predominantly in the northeast during the second epoch. This evolution can be seen in Figures 4 through 6. The figures show the estimated price surface - after controlling for differential access to infrastructure and allowable uses - from the northeast looking to the southwest. Figure 4 shows a distinctly polycentric pricing surface with a node at the city center that is smaller in area than the nodes in the northwest of the city. The interpretation of this is that more total premia was paid for parcels there than in the city center.

By the second epoch, from 1996-1998, the city center had become dominant with regard to pricing for proximity. And, nodes appeared north and south of the city center where they had not been previously. The pricing surface in the northeast and northwest consolidated somewhat with three significant nodes where there had been five in the previous epoch. By the final epoch, from 1999-2001, the city center was by far the most important node with regard to pricing, while only three other significant nodes remained, spanning the northern half of Krakow.

Interpreting the evolution of the price surface will require more data than we currently have. Anecdotally, however, we can appeal to several features of Krakow's economy during this post-Big Bang period. First, transportation costs and reservation wages appear to have risen; both would work to raise the cost of locations further from the city center or other employment and service centers. This may explain a portion of the strong movement toward centricity as markets recognize, and bid up, parcels with advantageous locations. A second feature may be more important, though. Krakow's city center is amenity rich, as the main square has become home to a high concentration of restaurants, cafes, retail shops, and cultural attractions. With no opportunity to redevelop at higher density, it is no surprise that prices there have risen. Note that there are few actual raw land transactions within the historic urban core. However, there are land sales in adjacent areas. It is the accessibility of these sales to the urban core that is reflected in the concentration of higher prices shown in Figures 4 through 6.

The evolution of the secondary nodes is less straightforward. We suspect that at least two forces led to the apparent movement of the nodes. First, recall that socialist management left high-density housing in the suburbs with little or no retail to service the resident population. Part of the pricing concentrations in the northeast and northwest are likely to be driven by retail developers bidding for prime locations near large numbers of existing consumers. A second influence on the price surface may come from foreign investors looking to enter a market that holds great promise. Here developers (for example, of hypermarkets such as Carrefour or Selgros) are less interested in established populations than in intersections of transportation links.

At this point, we lack the data to delve more deeply into the evolution of the secondary nodes. In particular, we cannot yet address why one secondary node experienced concentration over time, while over the same sample period another appeared and then disappeared. For now, the results demonstrate a clear evolution of the price surface, if not an explanation for the changes over time. The results support two conclusions. First, Krakow is polycentric and, second, the extent of polycentricity changes over time. Variation in the price surface of land is an empirical fact that complicates statistical research. Aspatial models omit variables that are important determinants of price.

One curious result is shown in Figure 6. The figure plots two price indexes and their respective 95% confidence intervals for land during the full sample period, 1993-2001. The first is derived from the aspatial housing model, a hedonic pricing regression with no nodes included. The second (dashed) line in Figure 6 shows the estimated price levels for land based on a hedonic regression with all significant nodes included. There is no significant effect on measured aggregate land prices as the result of the inclusion of the spatial nodes. The confidence intervals are fairly wide, but the similarity of the point estimates suggests that the spatial variation in the price surface does not influence aggregate prices.

This leads to one further result: measured spatial autocorrelation appears to be substantially reduced by accounting for omitted spatial variables. This is apparent in Figures 8 through 11. It is worth noting that spatial autocorrelation may have its origins in proximity to locales for which there are no controls. This appears to be the case in Krakow, suggesting that controlling globally for spatial autocorrelation may be inappropriate. Applying an average spatial correlation of two distributions - those correlated by joint exposure to spatial amenities and those that are not - to all observations may be incorrect for both populations.

6 Conclusions & Extensions

The primary finding we present in this paper is evidence of an evolving, transient price surface for vacant parcels of land in Krakow, Poland. As an economy undergoing substantial transformation during the sample period, Krakow is clearly not typical of all metropolitan areas. That said, change comes to all metropolitan areas - Buffalo has lost half its population since World War II, while the population of Los Angeles has increased by 30% in last 25 years and is expected to almost double over the next 25 years. These demographic shifts are likely to alter the distribution of residences and employment. Changes in the location of these activities imply changes in the price of land - price changes that occur asymmetrically across a metropolitan area. There are numerous factors that influence the choices that economic actors make which result in aggregate changes in the land-rent gradient or price surface.

In Krakow, we find pricing reflects concentration around the city center as well as around several subcenters. This is consistent with several hypotheses. Concentration toward the center follows from the rise of reservations wages and increases in the cost of transportation. Rising prices in the secondary centers could arise from the mismatch of land uses left over from socialist management of land markets. We suspect that the model socialist communities that married heavy industry and high-density residential development left a large population of underserved consumers that retail developers are competing for in bidding up the price of proximal land. We believe the same is true of foreign hypermarkets bidding up the price of locations near major transportation intersections. We are actively seeking data to explore these conjectures. At this point, however, we are confident that the land markets are settling on a smaller number of more influential centers. This is clearly true by the end of the sample period relative to beginning of the period.

Evolution of the price surface points out several flaws in simple empirical models of urban areas. Neither time-invariant nor simple parametric models of the land-rent gradient would be appropriate for Krakow during this period. To employ either is to misspecify the pricing function for land and may lead to biased and misleading coefficients on parcel attributes. While not leading to statistically different aggregate price indexes, the naïve aspatial models consistently produce parameter estimates that are at odds with the more complete models that include the spatial variables.

The iterative method developed in order to "discover" the pricing nodes clearly is a starting point for research into the fundamentals that produced such substantial changes over the sample period. The next step - already underway - is an exploration of the locations of the nodes and what it is that generated the apparent proximity premia. Of course, the nodes are estimated with error, leaving some room for interpretation of the coordinates. However, the spatial variables - these nodes of pricing - are consistently the most precisely estimated of all the regression variables. Moreover, because our observations are unimproved parcels, these estimates are free of any complication arising from the difficult task of separating land and structure values from improved properties.

It is no surprise to find that location matters. This may be the most well-known fact about land markets. That said, location matters differently over time. The concentration of some nodes, while others appear and disappear, suggest that the "location, location, location" maxim be appended with "and timing." The price gradient reflects fundamentals that can change - and change rapidly at times. The complexity of the price surface and its evolution should give pause to researchers hoping to control for location by simply including a time-invariant measure of distance to only one location. While the city center is clearly a valued location, its influence on land prices changes over time, as does the influence of other subcenters. Empirical models of metropolitan areas should reflect these dynamics.

References

Basu, S., and T. G. Thibodeau (1998): "Analysis of Spatial Autocorrelation in House Prices," *Journal of Real Estate Finance and Economics.*, Volume 17, 61–85.

Bertaud, A. (1999): "Cracow in the Twenty First Century: Princes or Merchants?," *World Bank Working Paper*, (8), 1–39.

Bertaud, A., and B. Renaud (1997): "Socialist Cities without Land Markets," *Journal of Urban Economics*, 41, 137–151.

Brockmann, M., T. Gasser, and E. Hermann (1993): "Locally Adaptive Bandwidth Choice for Kernal Regression Estimators," *Journal of the American Statistical Association*, 88(424).

Clapp, J. M. (2003): "A Semiparametric Method for Valuing Residential Location: An Application to Automated Valuation," *Journal of Real Estate Finance and Economics*, 27(3), 303–320.

Cleveland, W. S., and S. J. Devlin (1988): "Locally Weighted Regression: An Approach to Regression Analysis by Local Fitting," *Journal of the American Statistical Association*, 83(403), 596–610.

Dale-Johnson, D., and W. J. Brzeski (2001): "Land Price Data and Land Value Functions in Cracow, Poland," *Lincoln Institute of Land Policy Working Paper*, (WP01DD1).

De Broeck, M., and V. Koen (2001): "The "Soaring Eagle": Anatomy of the Polish Take-off in the 1990s," *Comparative Economic Studies*, XLIII, 1–33.

Dubin, R. A., R. K. Pace, and T. G. Thibodeau (1999): "Spatial Autoregression Techniques for Real Estate Data," *Journal of Real Estate Literature*, 7, 79–95.

Gillen, K., T. G. Thibodeau, and S. Wachter (2001): "Anisotropic Autocorrelation in House Prices," *Journal of Real Estate Finance and Economics.*

Slay, B. (1994): *The Polish Economy: Crisis, Reform and Transformation.* Princeton: Princeton University Press.

von Thünen, J. H. (1966): *The Isolated State: An English Edition of der Isolierte Staat.* Oxford, New York: Pergammon Press.

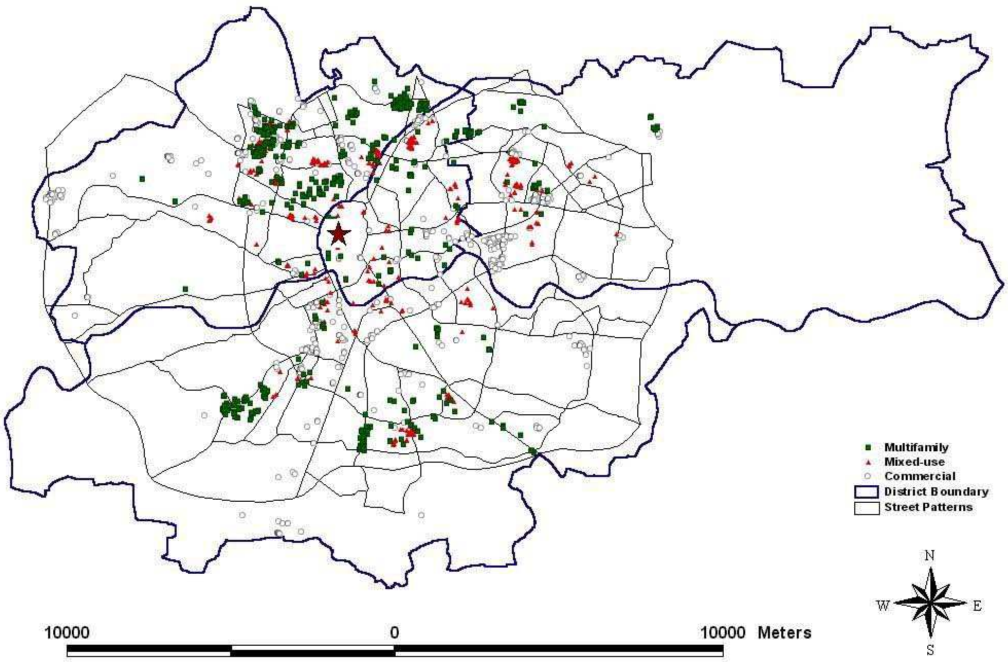

Figure 2: Volume of Investment Property Sales and Share by Product Type

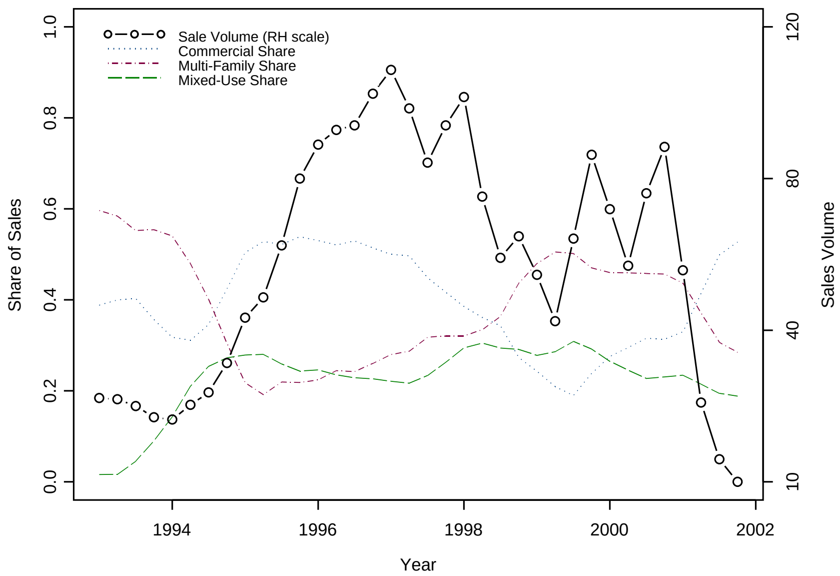

Table 1: Average Parcel Characteristics
(Standard Deviation in Parentheses)

	All Parcels	Commercial	Mixed-Use	Multifamily	Industrial
Observations[a]	1760	692	476	690	12
Parcel Attribute Statistics					
Parcel Size[b]	2164	2687	1305	2486	909
	(5052)	(6631)	(2565)	(4563)	(1632)
Dist. to Center[c]	4043	4167	3666	4214	3535
	(1354)	(1185)	(1432)	(1369)	(733)
Gas[d]	2.85	2.84	2.95	2.75	3.00
	(0.82)	(0.79)	(0.83)	(0.86)	-
Heat[d]	2.24	2.41	2.28	1.99	2.33
	(1.10)	(1.05)	(1.12)	(1.10)	(0.78)
Telephone[d]	2.83	2.82	2.86	2.80	3.08
	(0.74)	(0.74)	(0.74)	(0.78)	(0.29)
Electricity[d]	3.04	3.01	3.15	2.95	3.83
	(0.89)	(0.87)	(0.96)	(0.87)	(0.39)
Water[d]	2.89	2.84	3.02	2.82	3.83
	(0.85)	(0.82)	(0.90)	(0.87)	(0.39)
Sewage[d]	2.83	2.84	2.98	2.67	4.00
	(0.90)	(0.80)	(0.87)	(1.02)	-
Parcel Price Statistics[e]					
Real Price/m^2	46.5	40.2	52.1	47.1	52.1
1993-2001	(59.9)	(54.1)	(65.7)	(59.0)	(73.9)
Real Price/m^2	18.4	14.8	18.5	22.2	18.5
1993-1995	(14.8)	(12.8)	(13.9)	(16.3)	-
Real Price/m^2	39.3	41.0	38.9	34.7	63.1
1996-1998	(45.0)	(48.8)	(43.5)	(38.2)	(83.4)
Real Price/m^2	80.8	72.4	91.9	73.8	19.3
1999-2001	(83.2)	(80.1)	(88.5)	(78.5)	(9.94)

Notes on Observations & Units of Measurement:

a - Total zoned parcels exceeds total parcels because many have multiple allowable uses.

b - in square meters

c - in meters

d - five-point scale from 'no access' (=1) to 'ready-to-use' (=5)

e - Real price per square meter is in Polish Zlotys

Table 2: Regression Results: Aggregate Sales, 1993-2001
(t-Statistics in Parentheses)

Model	**Basic**	**I**	**II**	**III**	**IV**	**V**
R-Squared	0.311	0.333	0.363	0.377	0.383	0.389
Degrees of Freedom	1711	1710	1709	1708	1707	1706
Intercept	3.449	3.248	2.887	2.782	2.799	2.752
	(14.60)	(13.89)	(12.44)	(12.08)	(12.20)	(12.04)
ln(Lot Size)	-0.047	-0.025	-0.004	0.006	0.005	0.006
	(3.35)	(1.79)	(0.28)	(0.44)	(0.34)	(0.47)
Gas	-0.013	-0.018	-0.023	-0.030	-0.026	-0.019
	(0.21)	(0.31)	(0.39)	(0.51)	(0.44)	(0.34)
Heat	0.085	0.096	0.134	0.117	0.101	0.101
	(3.50)	(3.98)	(5.62)	(4.91)	(4.21)	(4.25)
Telephone	0.023	0.067	0.065	0.056	0.066	0.066
	(0.42)	(1.21)	(1.20)	(1.05)	(1.25)	(1.24)
Electricity	0.003	-0.001	-0.011	-0.001	-0.024	-0.043
	(0.06)	(0.03)	(0.25)	(0.02)	(0.52)	(0.93)
Water	-0.160	-0.193	-0.143	-0.132	-0.119	-0.106
	(2.63)	(3.21)	(2.43)	(2.26)	(2.04)	(1.83)
Sewage	0.112	0.107	0.055	0.048	0.054	0.057
	(2.46)	(2.39)	(1.23)	(1.09)	(1.24)	(1.31)
Mixed-Use	1.493	1.512	1.432	1.006	1.234	0.513
	(3.54)	(3.64)	(3.53)	(2.47)	(3.01)	(1.16)
Multifamily	-0.663	-0.701	-0.758	-0.762	-0.716	-0.695
	(3.66)	(3.93)	(4.35)	(4.42)	(4.16)	(4.06)
Commercial	-0.342	-0.349	-0.389	-0.349	-0.342	-0.332
	(3.39)	(3.52)	(4.00)	(3.62)	(3.56)	(3.48)
Mixed-Use FAR	-1.205	-1.235	-1.249	-0.958	-1.111	-0.636
	(4.19)	(4.36)	(4.51)	(3.44)	(3.97)	(2.13)
Multifamily FAR	0.343	0.392	0.375	0.382	0.349	0.341
	(1.99)	(2.31)	(2.25)	(2.32)	(2.13)	(2.09)
$f(Distance_1)$	-	1.463	1.680	1.731	1.765	1.863
	-	(7.63)	(8.88)	(9.24)	(9.45)	(9.96)
$f(Distance_2)$	-	-	1.168	1.349	1.274	1.354
	-	-	(9.00)	(10.24)	(9.62)	(10.17)
$f(Distance_3)$	-	-	-	1.788	1.807	1.365
	-	-	-	(6.09)	(6.18)	(4.43)
$f(Distance_4)$	-	-	-	-	1.676	1.639
	-	-	-	-	(3.94)	(3.87)
$f(Distance_5)$	-	-	-	-	-	2.950
	-	-	-	-	-	(4.31)

Table 3: Regression Results: Commercial Sales, 1993-1995
(t-Statistics in Parentheses)

Model	**Basic**	**I**	**II**	**III**	**IV**	**V**	**VI**
R-Squared	0.246	0.319	0.368	0.385	0.413	0.435	0.455
Degrees of Freedom	391	390	389	388	387	386	385
Intercept	3.196	3.030	2.687	2.623	2.563	2.487	2.397
	(7.51)	(7.47)	(6.78)	(6.69)	(6.68)	(6.59)	(6.45)
ln(Lot Size)	-0.140	-0.107	-0.096	-0.088	-0.068	-0.054	-0.041
	(4.63)	(3.68)	(3.39)	(3.13)	(2.44)	(1.97)	(1.51)
Gas	0.024	-0.026	-0.055	-0.061	-0.063	-0.064	-0.044
	(0.19)	(0.22)	(0.47)	(0.54)	(0.56)	(0.58)	(0.41)
Heat	-0.046	-0.070	0.042	0.032	0.001	-0.034	-0.052
	(1.10)	(1.74)	(0.97)	(0.73)	(0.02)	(0.78)	(1.23)
Telephone	0.278	0.263	0.227	0.219	0.215	0.187	0.148
	(2.95)	(2.93)	(2.62)	(2.55)	(2.57)	(2.26)	(1.81)
Electricity	-0.223	-0.222	-0.137	-0.117	-0.110	-0.089	-0.062
	(2.43)	(2.54)	(1.60)	(1.38)	(1.33)	(1.08)	(0.77)
Water	-0.004	0.017	0.018	0.039	0.043	0.056	0.052
	(0.03)	(0.14)	(0.16)	(0.34)	(0.38)	(0.50)	(0.48)
Sewage	0.206	0.202	0.098	0.073	0.052	0.048	0.029
	(2.12)	(2.19)	(1.08)	(0.81)	(0.59)	(0.55)	(0.33)
Mixed-Use	1.644	1.703	2.369	2.044	1.517	1.175	1.122
	(2.09)	(2.28)	(3.24)	(2.80)	(2.10)	(1.64)	(1.59)
Multifamily	-0.189	-0.302	-0.472	-0.446	-0.379	-0.295	-0.235
	(0.58)	(0.97)	(1.56)	(1.49)	(1.29)	(1.02)	(0.83)
Commercial	-0.359	-0.289	-0.227	-0.213	-0.131	-0.095	-0.051
	(1.50)	(1.27)	(1.03)	(0.97)	(0.61)	(0.45)	(0.25)
Mixed-Use FAR	-1.307	-1.349	-1.786	-1.564	-1.162	-0.896	-0.873
	(2.50)	(2.71)	(3.67)	(3.22)	(2.40)	(1.87)	(1.85)
Multifamily FAR	0.206	0.349	0.516	0.491	0.435	0.359	0.295
	(0.66)	(1.18)	(1.79)	(1.73)	(1.56)	(1.31)	(1.09)
$f(Distance_1)$	-	1.651	2.042	2.100	2.152	2.290	2.470
	-	(6.47)	(7.96)	(8.27)	(8.66)	(9.27)	(9.98)
$f(Distance_2)$	-	-	1.069	1.127	0.753	0.816	0.936
	-	-	(5.48)	(5.82)	(3.62)	(3.98)	(4.59)
$f(Distance_3)$	-	-	-	1.690	1.963	2.238	2.076
	-	-	-	(3.23)	(3.80)	(4.37)	(4.11)
$f(Distance_4)$	-	-	-	-	1.543	1.495	1.711
	-	-	-	-	(4.36)	(4.29)	(4.93)
$f(Distance_5)$	-	-	-	-	-	2.860	2.956
	-	-	-	-	-	(3.84)	(4.03)
$f(Distance_6)$	-	-	-	-	-	-	1.868
	-	-	-	-	-	-	(3.78)

Table 4: Regression Results: Commercial Sales, 1996-1998
(t-Statistics in Parentheses)

Model	**Basic**	**I**	**II**	**III**	**IV**	**V**	**VI**
R-Squared	0.154	0.197	0.201	0.216	0.219	0.221	0.232
Degrees of Freedom	805	804	803	802	801	800	799
Intercept	3.504	3.055	3.078	3.063	3.069	3.077	2.951
	(12.52)	(10.86)	(10.95)	(11.00)	(11.03)	(11.07)	(10.59)
ln(Lot Size)	-0.053	-0.009	-0.012	-0.005	-0.007	-0.007	-0.007
	(2.38)	(0.39)	(0.50)	(0.22)	(0.33)	(0.30)	(0.31)
Gas	0.203	0.208	0.219	0.211	0.216	0.216	0.250
	(1.95)	(2.06)	(2.17)	(2.11)	(2.15)	(2.16)	(2.50)
Heat	0.151	0.139	0.120	0.128	0.128	0.129	0.153
	(4.24)	(3.99)	(3.34)	(3.58)	(3.58)	(3.62)	(4.25)
Telephone	-0.268	-0.207	-0.199	-0.169	-0.182	-0.181	-0.188
	(3.14)	(2.47)	(2.39)	(2.03)	(2.18)	(2.18)	(2.27)
Electricity	-0.069	-0.086	-0.077	-0.073	-0.061	-0.071	-0.094
	(0.80)	(1.02)	(0.91)	(0.88)	(0.73)	(0.84)	(1.13)
Water	-0.250	-0.258	-0.270	-0.283	-0.293	-0.287	-0.258
	(2.44)	(2.58)	(2.70)	(2.86)	(2.96)	(2.89)	(2.61)
Sewage	0.291	0.253	0.247	0.220	0.219	0.218	0.200
	(3.67)	(3.27)	(3.20)	(2.85)	(2.84)	(2.83)	(2.61)
Mixed-Use	1.578	1.315	1.485	1.503	1.255	1.242	0.994
	(2.38)	(2.03)	(2.28)	(2.33)	(1.90)	(1.88)	(1.51)
Multifamily	-0.939	-0.987	-0.948	-0.971	-0.958	-1.047	-1.121
	(3.23)	(3.48)	(3.34)	(3.45)	(3.41)	(3.65)	(3.92)
Commercial	-0.254	-0.223	-0.256	-0.249	-0.233	-0.253	-0.327
	(1.74)	(1.56)	(1.78)	(1.75)	(1.64)	(1.77)	(2.28)
Mixed-Use FAR	-1.299	-1.167	-1.319	-1.332	-1.177	-1.178	-1.071
	(2.92)	(2.69)	(3.00)	(3.06)	(2.65)	(2.65)	(2.42)
Multifamily FAR	0.518	0.517	0.472	0.498	0.488	0.556	0.562
	(2.02)	(2.07)	(1.89)	(2.01)	(1.97)	(2.21)	(2.25)
$f(Distance_1)$	-	1.346	1.481	1.338	1.331	1.359	1.313
	-	(6.58)	(6.91)	(6.21)	(6.18)	(6.30)	(6.11)
$f(Distance_2)$	-	-	0.630	0.615	0.673	0.703	0.870
	-	-	(2.08)	(2.05)	(2.23)	(2.33)	(2.86)
$f(Distance_3)$	-	-	-	1.349	1.400	1.404	1.557
	-	-	-	(3.94)	(4.08)	(4.10)	(4.53)
$f(Distance_4)$	-	-	-	-	0.690	0.705	1.032
	-	-	-	-	(1.71)	(1.74)	(2.50)
$f(Distance_5)$	-	-	-	-	-	1.793	2.239
	-	-	-	-	-	(1.49)	(1.86)
$f(Distance_6)$	-	-	-	-	-	-	1.363
	-	-	-	-	-	-	(3.40)

Table 5: Regression Results: Commercial Sales, 1999-2001
(t-Statistics in Parentheses)

Model	**Basic**	**I**	**II**	**III**	**IV**
R-Squared	0.137	0.189	0.218	0.256	0.280
Degrees of Freedom	492	491	490	489	488
Intercept	4.007	3.693	3.675	3.547	3.481
	(14.52)	(13.49)	(13.66)	(13.43)	(13.36)
ln(Lot Size)	0.013	0.030	0.043	0.059	0.058
	(0.57)	(1.35)	(1.96)	(2.72)	(2.71)
Gas	-0.077	-0.059	-0.075	-0.098	-0.100
	(0.81)	(0.64)	(0.83)	(1.10)	(1.15)
Heat	0.099	0.093	0.181	0.130	0.097
	(1.86)	(1.80)	(3.30)	(2.40)	(1.79)
Telephone	-0.095	-0.023	-0.027	-0.030	0.025
	(0.89)	(0.22)	(0.26)	(0.30)	(0.25)
Electricity	0.138	0.136	0.123	0.160	0.087
	(1.78)	(1.80)	(1.66)	(2.20)	(1.17)
Water	-0.100	-0.154	-0.155	-0.160	-0.098
	(1.00)	(1.57)	(1.61)	(1.70)	(1.04)
Sewage	0.047	0.056	0.006	0.023	0.017
	(0.65)	(0.80)	(0.09)	(0.34)	(0.25)
Mixed-Use	1.354	1.133	1.432	1.036	1.550
	(1.79)	(1.54)	(1.97)	(1.45)	(2.17)
Multifamily	-0.736	-0.696	-0.639	-0.734	-0.737
	(2.24)	(2.18)	(2.04)	(2.39)	(2.43)
Commercial	-0.506	-0.529	-0.576	-0.465	-0.457
	(2.74)	(2.96)	(3.27)	(2.68)	(2.67)
Mixed-Use FAR	-1.107	-0.986	-1.266	-0.935	-1.271
	(2.10)	(1.93)	(2.49)	(1.87)	(2.54)
Multifamily FAR	0.284	0.277	0.168	0.294	0.335
	(0.81)	(0.81)	(0.50)	(0.89)	(1.03)
$f(Distance_1)$	-	1.163	1.316	1.436	1.521
	-	(5.61)	(6.36)	(7.05)	(7.55)
$f(Distance_2)$	-	-	0.956	1.075	1.152
	-	-	(4.25)	(4.87)	(5.28)
$f(Distance_3)$	-	-	-	2.453	2.569
	-	-	-	(4.97)	(5.28)
$f(Distance_4)$	-	-	-	-	1.453
	-	-	-	-	(4.03)

Table 6: Node Data: Commercial Sales

Full Sample Period: 1993-2001

Iteration/ Node	Relative Longitude	Relative Latitude	Node Extent	Node Area	Average Slope
1	842	-572	2841	1062	-0.67
2	-2020	1487	4169	1185	-0.32
3	2603	1716	2182	787	-0.28
4	181	2859	1128	252	-0.42
5	1722	2859	881	133	-0.33
Mean	666	1670	2236	683	-0.40

Epoch 1: 1993-1995

Iteration/ Node	Relative Longitude	Relative Latitude	Node Extent	Node Area	Average Slope
1	381	-662	2520	1282	-1.17
2	-3235	1814	3191	1176	-0.51
3	2722	689	1740	561	-0.30
4	-1746	1364	2288	626	-0.41
5	-682	3165	1506	233	-0.09
6	1871	2039	2351	692	-0.18
Mean	-115	1402	2266	762	-0.44

Epoch 2: 1996-1998

Iteration/ Node	Relative Longitude	Relative Latitude	Node Extent	Node Area	Average Slope
1	-404	810	3726	1455	-1.15
2	4360	1266	1747	971	-0.54
3	1112	-787	1620	707	-0.76
4	1762	2635	2099	508	-0.37
6	-2136	3548	1588	326	-0.11
Mean	939	1495	2156	793	-0.59

Epoch 3: 1999-2001

Iteration/ Node	Relative Longitude	Relative Latitude	Node Extent	Node Area	Average Slope
1	-77	-429	3142	1909	-0.71
2	-2479	2713	2020	644	-0.52
3	2325	1591	2123	694	-0.23
4	360	2937	1347	553	-0.74
Mean	32	1703	2158	950	-0.55

Figure 3: Price Surface - Aggregate Data, 1993-2001

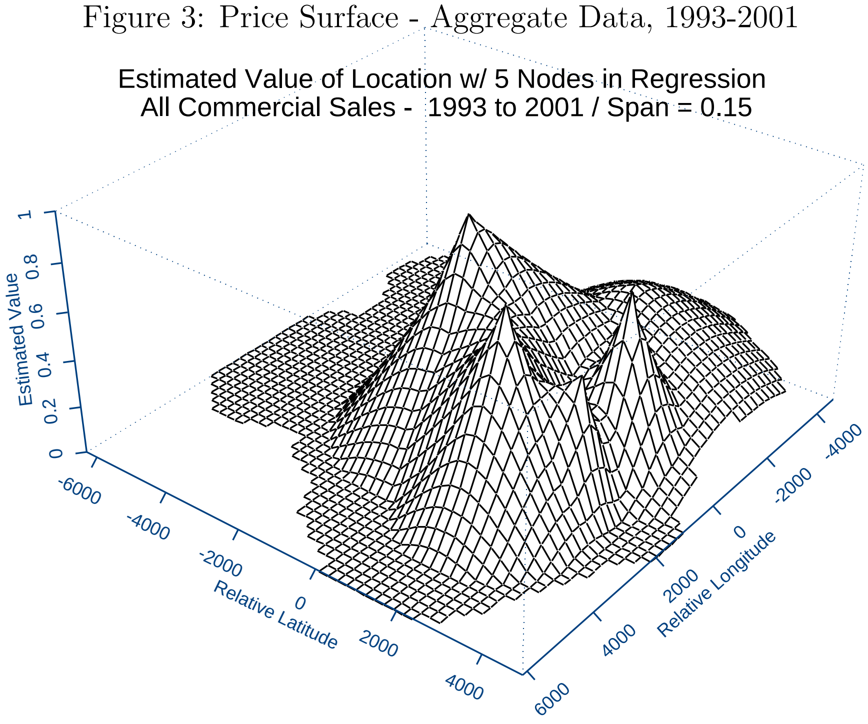

Figure 4: Price Surface - Epoch 1, 1993-1995

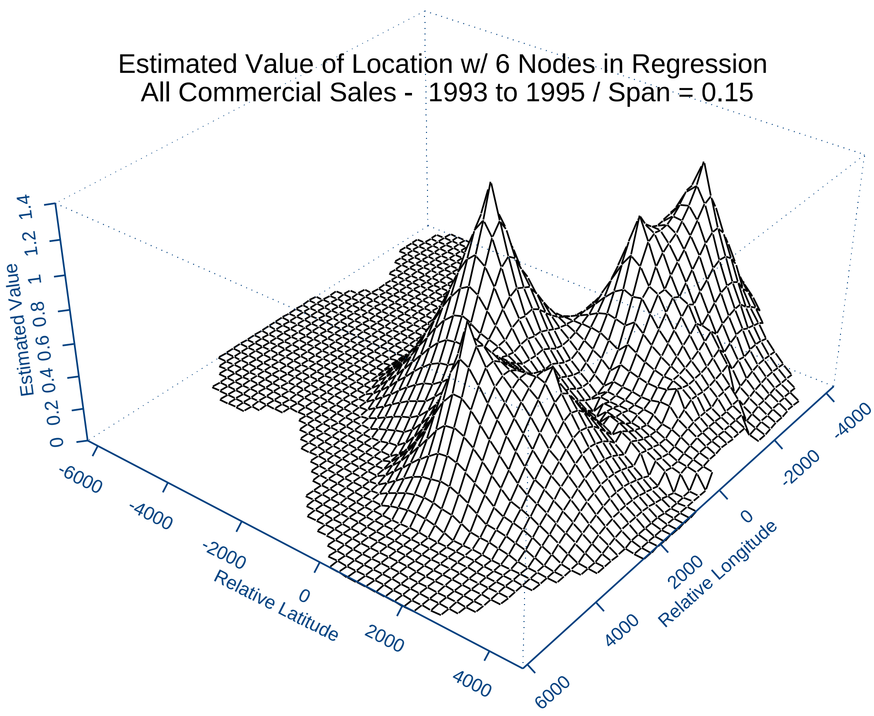

Figure 5: Price Surface - Epoch 2, 1996-1998

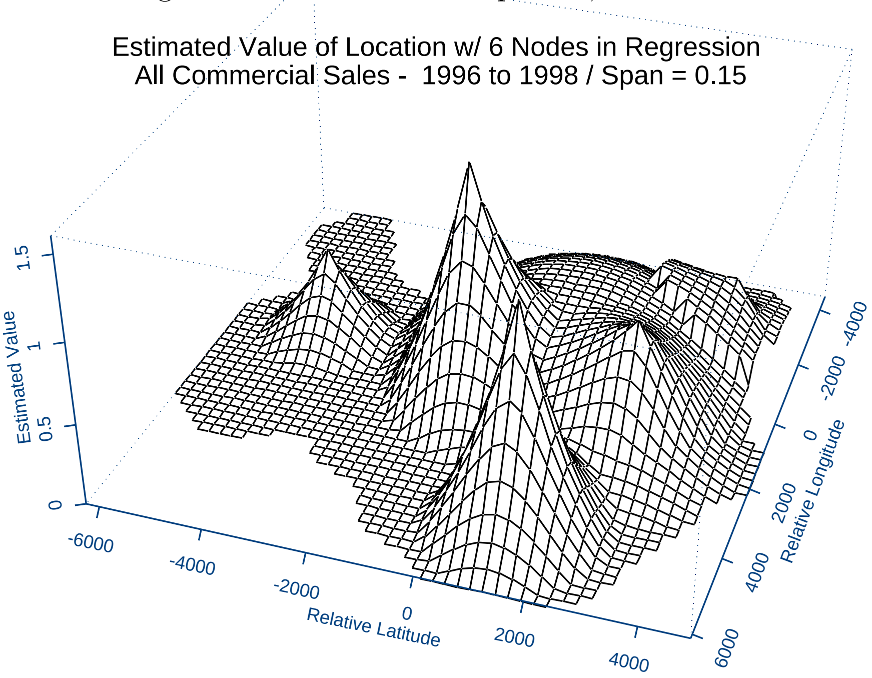

Figure 6: Price Surface - Epoch 3, 1999-2001

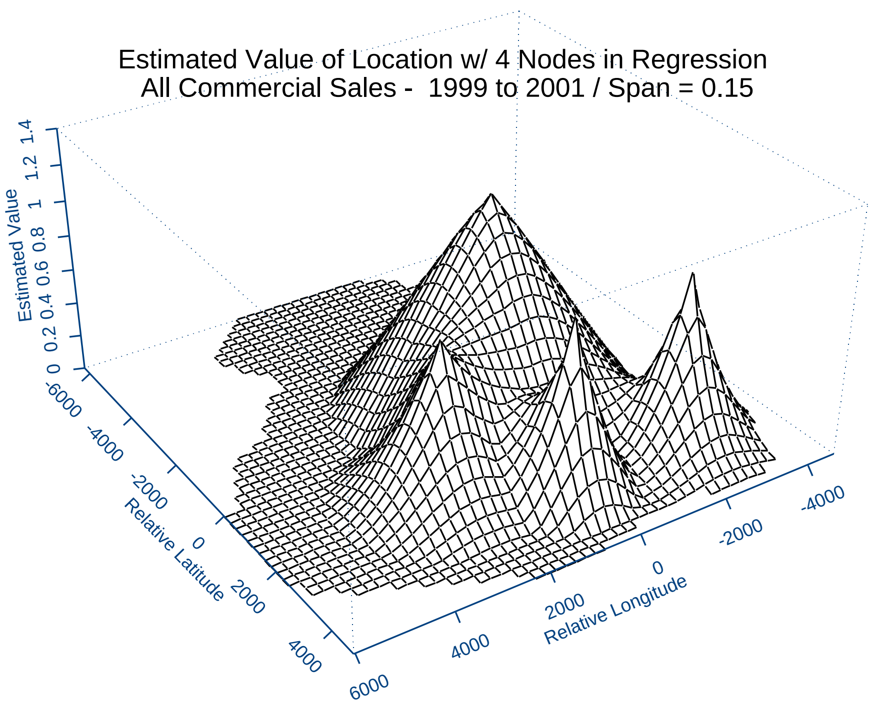

Figure 7: Aggregate Land Prices
Before & After Pricing Spatial Amenities

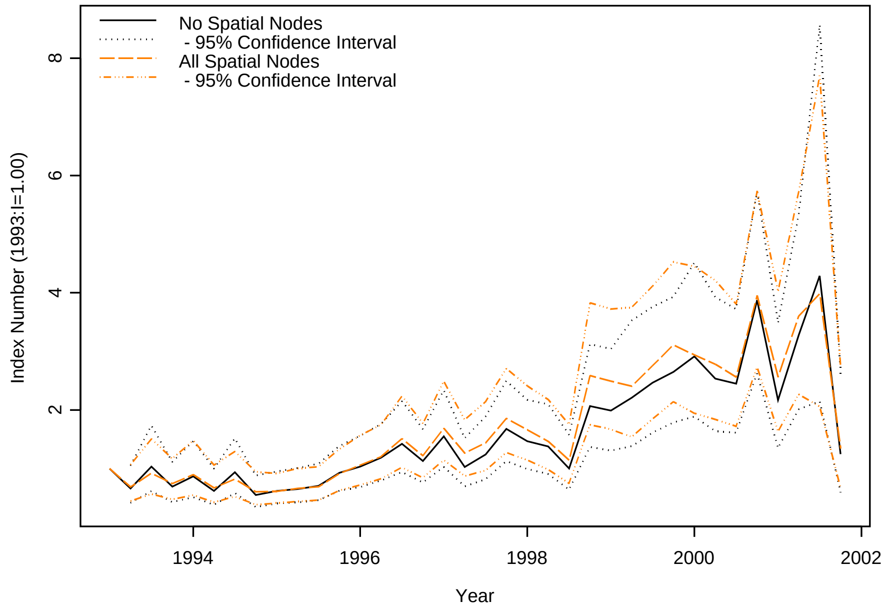

Figure 8: Spatial Autocorrelation - Aggregate Data, 1993-2001

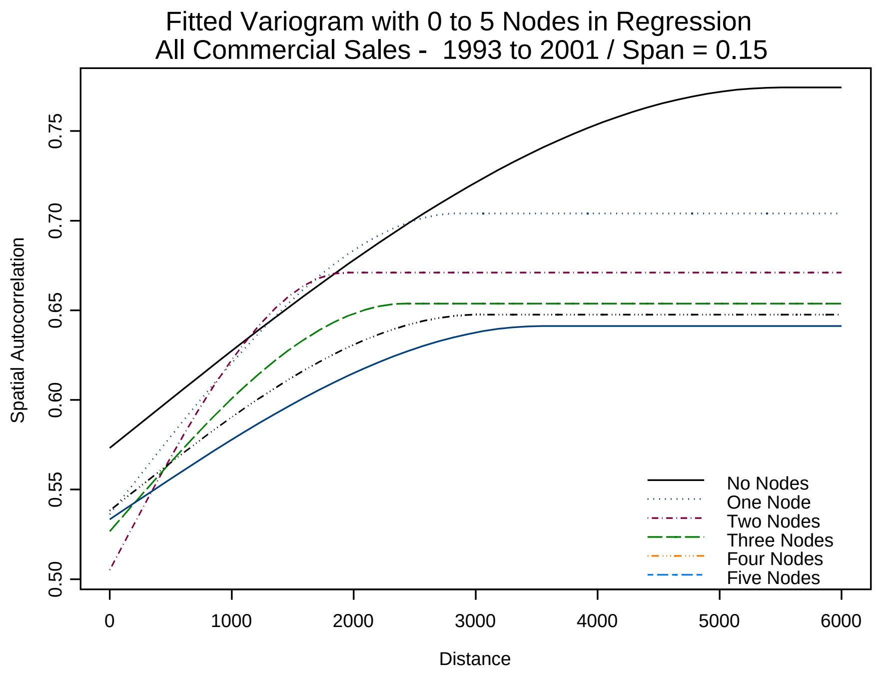

Figure 9: Spatial Autocorrelation - Epoch 1, 1993-1995

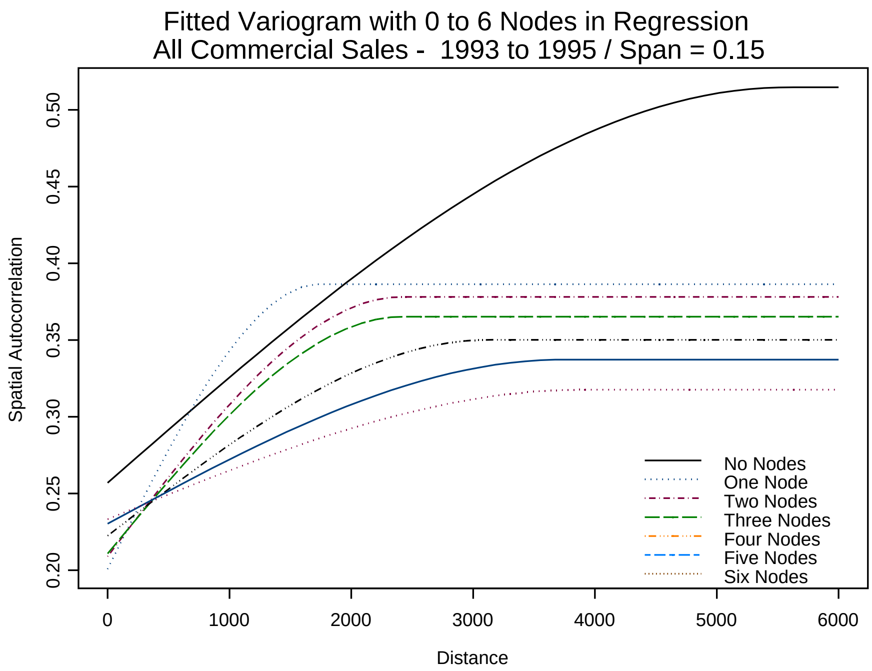

Figure 10: Spatial Autocorrelation - Epoch 2, 1996-1998

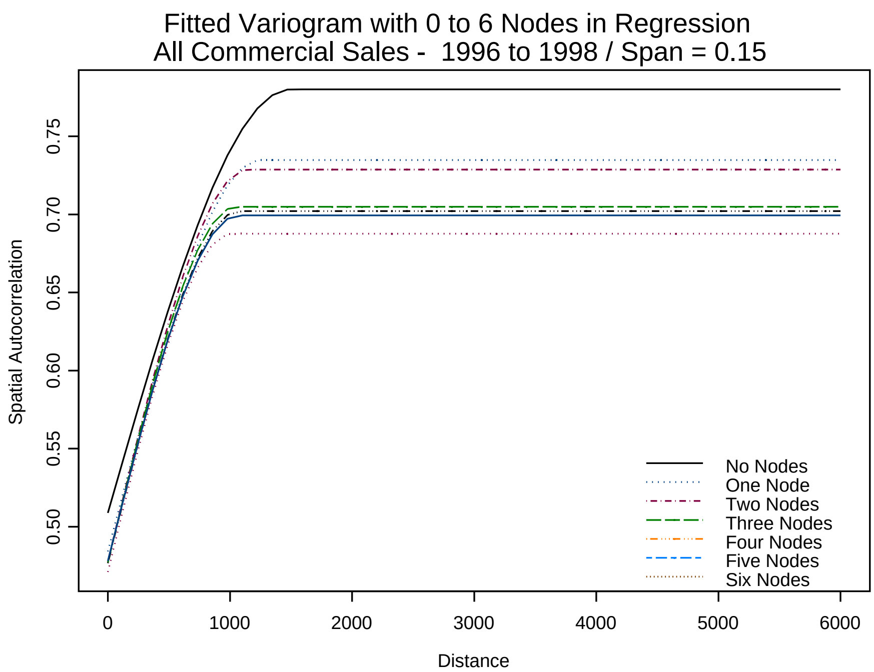

Figure 11: Spatial Autocorrelation - Epoch 3, 1999-2001