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Nationwide Mass Appraisal Modeling in China: Feasibility Analysis for Scalability Given Ad Valorem Property Tax Reform

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Abstract

Since 2003, the Chinese government has considered introducing an annual property tax, and while it selected six pilot cities for experimenting with the viability of a mass appraisal system rollout, has not adopted this as policy. When piloting the viability of property taxes, the Shenzhen Center for Assessment and Development of Real Estate was founded to commence citywide valuation, an initiative which coincided with the Lincoln Institute of Land Policy's foray into China in 2003 to provide expertise pertaining to topics ranging from property tax and municipal finance to public land management and land expropriation (Nunlist 2017). This paper assesses the feasibility of creating computer assisted mass appraisal (CAMA) and automated valuation models (AVMs) in China and their respective capability of conforming to IAAO valuation standards, with implications for scalability across national markets.

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Introduction

China has experienced rapid economic growth since 1978 when it adopted a policy of opening up to the world and instituting economic reform. As a consequence, between 1979 and 2003 China's Gross Domestic Product (GDP) grew at an average rate of 15 percent per annum (China Data Online 2005) and it has become the second largest economy measured by GDP. Concomitant with this explosion in GDP, China has also become one of the largest recipients of foreign direct investment (FDI), receiving net FDI inflows of US$49.3 billion in 2002, which represented an increase of 186 times from 1981 levels (World Bank 2005). Pertinently, it has seen its tax revenue grow, on average, 20 percent since the fiscal reform of 1994 (Man 2011).

This unprecedented restructuring of its economy and society has resulted in the rapid acceleration in growth and export-led industrialization, culminating in a sizeable transformation and spatial expansion within the urban environment (Chuang-Lin 2011; Ma 2002; Tang, Haila, and Wong 2006; Zhang 2009). Indeed, in the past three decades, China has seen not only the largest human migration in history but also an accelerated process of urbanization (Chan 2014; Chen, Liu and Lu 2016). This seismic expansion of Chinese cities has witnessed the urban population increasing from 17.9 percent of the total population in 1978 to 51 percent in 2011 (National Bureau of Statistics of China 2012). This unprecedented migration and urbanization process has led to structural transformations in urban neighborhoods in terms of composition and characteristics (Chen, Wu and Sung-Chan 2012; Zhu 2015). As acknowledged by Wen and Tao (2015), the urban spatial structure of big cities such as Shanghai, Beijing, and Guangzhou, has developed from monocentric to polycentric and profoundly reshaped the pattern of land use change, culminating in spatial unevenness (Cheng et al. 2006; Lin 2007; Lin and Yi 2011; Liu, Zhan, and Deng 2005).

In parallel with this dynamic urbanization and economic restructuring progression, a series of housing reforms have taken place since 1978, including the end of welfare-based housing provision (He and Wu 2007). Indeed, Tang, Haila, and Wong (2006) highlight that these housing reforms have engendered a gradual shift towards a market system with new institutions being established to enable the decentralized, monetized, and privatized allocation of housing units. Arguably, the post-1978 reforms have fundamentally transformed the nature of Chinese cities. As a consequence, the convergence of a multitude of economic, political, and social processes have stimulated heated real estate development and dramatically changed the socio-spatial landscape of Chinese cities (He and Wu 2007). Specifically, the land reform in 1987 introduced a policy of the paid transfer of land use rights, which significantly promoted urban redevelopment and considerable changes to the urban spatial structure of cities (Wu and Yeh 1999). As a result, land rent/price gradients have emerged further accelerating urban spatial restructuring in the inner city (He, Li, and Wu 2006). In tandem, housing investment also increased vastly since the early 1980s, resulting in increased living standards and a gargantuan increase in housing stock between 1981 and 1985, equating to circa 47 percent of the total housing stock developed since 1949 (Yeh and Wu 1996). As discussed by Zhang (2000), the commodification of housing was a central tenant for urban housing policy, with various reform measures—including pension fund schemes, rental subsidy increases, and sale of welfare housing—all introduced to diversify the sources of housing investment.

These wholesale changes culminated in a more monetized housing market that permitted private and individualized transactions to be achieved, a useful precondition for property taxation. Indeed, as Wang and Li (2004) estimate, over 80 percent of public housing was sold to the existing tenants over two decades from the introduction of policy reforms, with Tan et al. (2005) revealing that in the Guangzhou market, the total amount of transactions in the secondary housing market increased by over 45 percent of the total property transactions. Whilst undoubtedly in a better position, a fundamental challenge as identified by Zhang (2000) is that whilst housing reforms have created commodified and privatized housing, no single market is evident and the market structure is more akin to "hybrid" and "separate" housing markets of different categories and with diverse property right restrictions. As Tang, Haila, and Wong (2006) highlight, despite some of these improvements within the market-based housing system, continued failures of real estate (transient) services have blocked China's progress towards a fully-fledged market system in the housing sector. This point is also acknowledged by Li (2003), who revealed that the relationship between housing market segmentation and housing consumption has served to classify commodity housing into open market and subsidized housing, which has manifested in a systematic variation of household characteristics within the housing stock (in the Guangzhou region). Furthermore, Li (2003) laments that this reform policy has manufactured a position whereby different regions and cities have proceeded at a different pace which makes equitable (future) policy challenging. Similarly, Huang (2004) has argued that the local governments in different cities have behaved differently in reforming their urban housing systems, thus leading to diverse structures of local housing stock, different housing ownership and rental rates, and dissimilar patterns of housing choices and consumption across cities. These processes have been intensified by the deepening market reform evident in the early 2000s driven by state-led urban redevelopment projects, which saw traditional neighborhoods replaced with commercial housing projects and specifically commodity housing estates (CHEs) built by private real estate developers (Logan, Fang and Zhang 2010).

More recently, the Chinese government has adopted a series of policies aimed at curbing house price inflation. Two of the most important and influential of these are home purchase restriction and property tax proposals (Du and Zhang 2015). Home-purchase restriction was first introduced in Beijing in May 2010 and was progressively implemented in most major cities throughout China. This tax policy initiative prohibits resident households from buying more than two homes and non-resident households from buying more than one home. The pilot programs were implemented in Shanghai and Chongqing in January 2011 (in Shanghai the property tax targets second homes purchased after January 28, 2011, whilst the property tax enacted in Chongqing is mainly levied on high-end homes) and has generated heated debate regarding inequity and inequality (Du and Zhang 2015).

These pressing housing and policy related issues have been examined in a series of reports and academic research. In general, hedonic applications to Chinese cities are limited because of data availability, as China's free housing market is a relatively recent phenomenon (Liao and Wang

2012). Some Chinese scholars have tried to take the heterogeneity of housing products into account, using hedonic price models to study the influencing factors of housing price based on the monocentric hypothesis (Hao and Chen 2007; Ma and Li 2003; Wang and Huang 2007; Wen et al. 2005). These studies are conducted in a specific city and mainly focus on the static cross-section market but have nonetheless proven that the application of hedonic price models is feasible in the Chinese housing market (Wen and Tao, 2015).

Property Tax in China

China has eight different taxes on property (Man 2012; SAT 2012). Five of these taxes are related to real estate properties and account for approximately 22 percent of local tax revenues (Liu 2018). Three of the taxes can be classified as a property tax: the House Property Tax, the Urban and Township Land Use Tax, and the Tax on the Use of Arable Land. In the collective sense, these taxes would comprise a traditional property tax (Salm 2016); however, they are distinct due to the different types of property ownership (Keilbach and Nann 2010).

The Urban and Township Land Use Tax (1988) is a periodic tax imposed on urban land in use. The tax enables organizations and individuals to use urban state-owned land in cities, county towns, administrative towns, and industrial and mining districts. It is based on the size of land occupied multiplied by a rate per square meter. The tax rate is determined by the size of the city or town and reflects some relative locational value among the cities, but not within a city. Each provincial government determines the tax rate within the tax corridor set by the central government. Critically, the local tax authorities are allowed to exclude privately owned residential housing and rental residential housing owned by real-estate management departments.

The Tax on the Use of Arable Land (1987) is a recurrent area occupancy-based tax that is imposed on entities and individuals who use agricultural land, whether state or collectively owned, to construct houses or other non-agricultural construction. As such, it is also referred to as the Farmland Occupation Tax. The central government sets differentiated tax rates for each province.

The tax on real estate, House Property Tax (1986), is a recurrent tax levied on owners of houses located within urban areas, with rural areas excluded. According to regulation, the tax base for self-occupied houses is calculated at a modest 1.2 percent on 70–90 percent of the acquisition value of the property and rented houses at 12 percent of the rental income. To date, this tax has proven controversial as it is only imposed on houses for commercial use within urban areas, meaning that owner-occupied residential housing is excluded. Therefore, despite being a potential source of sustainable municipal revenue, China remains one of a select few countries globally to not employ a property tax on the ownership of private residential properties (Liu 2018).

Pertinently, analysis of various taxes on property also indicates that the majority of the taxes are paid at the transaction stage meaning they are non-recurrent taxes for the purpose of revenue (Salm 2016). Furthermore, as the central or the local authorities exclude owner-occupied residential properties from recurrent property taxes (as it does for both the House Property Tax and the Urban and Township Land Use Tax), this also constrains local revenue generation. This has led to significant criticism and the view that gaps in public revenue are the consequence of a tax system that is weak, encumbered, and which requires reform.

Property Tax Reform

The World Bank and the Development Research Center of the State Council (2013) proclaimed that the property tax is an important instrument to achieve a "modern, harmonious, and creative society" in China by 2030. Although China is classified as a unitary state, it has a highly deconcentrated fiscal structure (Rao 2003). The 1994 tax reform established a tax sharing system (TSS) that assigns certain tax revenues exclusively to the central or the local government level, and shares others among central government and local governments. Therefore, under the current taxation system, types and rates of all taxes are determined through a central government process, and in practical terms, local governments do not have independent tax power, or tax autonomy, meaning the generation of tax revenue from the land and property system is limited and consequently inadequate (Dai 2005; Liu 2018; Man 2011). When coupled with pressures to finance urban development, infrastructure, capital projects, and local services, many local governments have turned to measures such as borrowing funds (originally via "shadow banks"), leasing land, and sourcing other revenues in order to meet fiscal needs (Deng 2005; Man 2011). As a result, land resources have become overexploited and the tax administration cumbersome and complex (Tang, Wong and Liu 2011; Tao and Qin 2007; Wang 2005). Further, the property tax structure burden has traditionally focused on transactions as opposed to the assessed value of the property in possession, severely restricting the ability to generate public revenue from the real estate tax base which has been very buoyant due to privatization, growth and infrastructure investment (Liu, Song and Tao 2006; Man, Zheng, and Ren 2011). The current design and operation of the tax system creates problems at the local level for property tax, government finance, housing affordability, and the functioning of real estate markets (Salm 2016). This is despite the 1994 tax reform looking forward to "unified and simplified taxation, fair tax burden, rational decentralization of authority, clear distribution relationships, and sound fiscal revenue" (Hong 2013, 26). This process clearly still has some distance to travel to achieve these aims.

The second wave of reform came in 2003 and was focused on addressing excessive taxes and fees involved in real-estate development and transaction, resulting in the adoption of a uniform and standardized property tax system for fixed assets and cancellation of other taxes and fees. However, despite some glimpse of improvement, it remains questionable whether the Chinese property tax meets the requirements of a "rational" local tax, as urban residential land and houses were largely excluded from property tax payment; therefore, a major own source revenue option is not included in the tax equation (Salm 2016). A further difficulty was posed by the exclusion of urban residential property owners and migrant workers who could not alter their household registration and become residents. Accordingly, the property taxation system has been criticized due to 'narrow tax-base, numerous tax types, and high tax rates' which have acted as an impediment to the property market and served to weaken the fiscal strength of local governments (Jia and Zhou 2006; Jin 2004; Li 2005; Ma 2004; Sun and He 2006). Indeed, China's existing property tax system has been widely criticized as inefficient, costly, and inequitable (An and Wang 2005; Dai 2005; Fan and Li 2004; Gao 2005; Ma 2004; Salm 2016; Wang 2003). Whilst the Chinese government has continued to add new property taxes, the tax-bases on which they are levied have not been widened to any significant extent. As a result, there is limited potential for revenue from these property taxes to grow as property appreciates in value, particularly as some property holders are exempt from property taxation, whilst others are exempt from land use tax, urban construction and maintenance tax, and the education surcharge (Liu 2006). Those falling outside exempted categories have traditionally been incentivized to engage in tax evasion due to poor administration performance in terms of billing, collection, and enforcement (Ma 2004; Wang 2003).

Recent Developments in Property Tax Reform

The Chinese central government has been exploring the possibility of reforming its current land and property tax system since 2003, whilst at the same time putting an end to excessive taxes and fees on real estate development and transaction. Such reform aims to generate significant revenue for local governments by establishing a system to tax the existing property, premised on assessed value on an annual basis. According to Hou, Ren, and Zhang (2015), Man (2012), Salm, (2016) and Liu (2018), a stepwise chronology of property tax reform initiatives is summarized as follows:

In 2003, a resolution of the Central Committee of the Chinese Communist Party undertook to "launch a reform of taxes and fees on urban construction, levy a uniform and standardized property tax when prerequisites for it are met, then repeal related fees and charges." Following this in 2005, the Party Central Committee called for the government to "smoothly advance adoption of the property tax." In 2006, six cities were selected to conduct pilot programs on the property tax. In 2007, the Property Rights Law was passed to secure tenure of privately-owned property, and in 2009, a work report of the central government proposed "to study how to promote a reform of the property tax." In the same year, the State Reform and Development Commission recommended to "deepen the reform of real property tax and consider levying a property tax." Later, in 2010, the Party Central Committee recommended to "study the reform of the property tax." Overnight, on January 27, 2011, pilot programs to levy a recurrent "property tax" on urban residential buildings were introduced within the urban districts of the cities of Shanghai and Chongqing. The pilot programs in Shanghai and Chongqing have different implementations for the purpose of gaining insight into the differing property tax functions. They shared, however, the short-term goal of curbing rapid house price inflation. According to Hou, Ren, and Zhang (2015), Shanghai introduced a two-fold strategy which addresses registered permanent residents (i.e., *hukou*) and nonregistered permanent residents differently.

Since then, considerable progress has been made in establishing land and property registries in Chinese cities. In 2010, the State Administration of Taxation (SAT) ordered that every province must choose at least one city to experiment with property value assessment in order to verify the housing sales prices self-reported by home purchasers for the Deed Tax. In gearing up for this challenge, China has not been slow in developing its appraisal capacity. Indeed, following three decades of development, considerable headway has been made in developing computer-aided mass appraisal technology for the Chinese urban setting. The implementation of a mass appraisal system in Guangzhou was completed in 2007, providing the government with an objective and equitable property value database, providing an important tool to inform policy decisions on market regulation and to facilitate market transparency by providing reference prices to all market participants (Liu 2006).

Differing CAMA approaches have been considered and implemented in the pilot cities, such as Hangzhou, Dandong, and Chongqing. In 2005, the SAT compiled a Real Property Assessment Valuation Regulation Trial that specified 12 chapters and 40 provisions covering data collection, standards, and the archetype CAMA system. Each respective pilot cities subsequently undertook the simulation assessment calculating the tax burden and tax revenue according to different tax rate scenarios. In 2011 at least one city in each province had been selected to conduct property value assessment of newly purchased property for the collection of the Deed Tax. In early 2011, Shanghai started to collect taxes on newly purchased second homes of residents and first homes of non-residents based on transaction value, representing an important milestone for tax reform. Most recently, in 2016, an Appraisal Law was promulgated in order to set the legal status of the appraisal industry.

A further step in the nationwide introduction of the property tax was undertaken in 2014 with the establishment of the Bureau of Real Estate Registration. It is a valuation-pushed approach with little attention paid to the taxpayer service, collection, and enforcement side. The focus initially is on property registration. The registration system will be structured in such a way that all relevant departments, such as land, tax, finance, audit, statistics, and the like, will be linked to the same system. Later the bureau also will be responsible for drafting and enforcing land management regulations and resolving land disputes. Currently, the Standing Committee of the National People's Congress, China's top legislature, is working on property tax legislation with original estimated introduction in 2017, a date which has passed with no sign of imminent introduction. The legislation will most likely include taxation on both housing and land: a housing tax on homeowners and a land tax on land developers (China Daily 2014). The decision to separate homeowners and land developers indicates that the transfer of related taxes or even the land transfer fee will not be amalgamated into the new property tax.

The 19th National Congress of the Communist Party of China, held in October 2017, continued to emphasize fiscal policy reform. Specifically, it continued to call for the deepening of taxation system reform and the improvement of the local tax system (Liu 2018). A key task is to continue the current round of fiscal policy reform by increasing the share of direct taxes. For the first time, the government recently revealed three principles for the roll out of a property tax on the ownership of private residential properties.

The Need for Property Tax Reform

As identified, the rapid urbanization process and burgeoning need for urban infrastructure investment has resulted in significant public funding deficits. Consequently, property tax reform has emerged as a major policy direction in China, with fiscal policy initiatives increasingly exploring new sources of sustainable public revenues to support fiscal capacity, most notably through land and property tax (Tang, Wong and Liu 2011). Indeed, the increasing growth in residential property values and home ownership (Oster 2007) offer a sizeable and relatively untapped basis for levying taxes for local government revenue (Li and Yu 2007; Liu 2018). As such, the need for a residential property tax in China has increasingly been a subject of academic and policy scrutiny. Property tax reform has increasingly become a focus of attention as efforts towards fiscal decentralization have heightened the need to expand fiscal revenue for local governments (Hou, Ren, and Zhang 2013; Tang et al. 2015) so they can achieve fiscal stability and independence (Man 2012; Tang et al. 2011; Wu, Gyourko, and Deng 2010). Others have examined the integration of property tax with the public leasehold system or the ability of homeowners to afford such taxation and the use of property tax as a potential macroeconomic tool to stabilize, regulate, and control the real estate market (Hou et al. 2013; Wang, Shao, Murie, and Cheng 2012), with Dale-Johnson and Zhu (2017) examining how different type and usage of property tax revenue and expenditure scenarios impact land price, house price, house rent, vacancy rate, and government revenue as well as land concession revenue.

Whilst property tax on the ownership of private residential properties is a significant missing piece in China's taxation puzzle, Liu (2018) highlights that China had missed an opportunity to implement a property tax at the time before the housing boom and highlights that if it is not implemented, the problem of finding sustainable own-source revenues for municipal finance will continue to challenge municipalities. In view of the myriad of problems relating to, *inter alia*, economic inefficiency, inequity, and cost, a preponderance of literature invariably recommends a need to reform the Chinese property tax system in favor of market value–based taxation (Bird and Slack 2007; Salm 2016). Moreover, a burgeoning corpus of literature argues that Western taxation models should be adopted (Xing 2004, Zhang 2003a, 2003b), whilst other reform proposals highlight measures such as combining taxes, reducing tax rates, adopting uniform tax rates and strengthening property tax legislation and administration (Dong 2006; Mao 2005; Ng 2006; Xiao 2005). Despite this clear need for restructuring of the Chinese taxation system, progress and reform has been piecemeal and slow. Indeed, although the implementation of a market value–based property taxation system was contemplated at the third plenary session of the 16th Chinese Communist Party Congress (October 2003), there has been relatively little progress. That said, more recently, the 19th National Congress of the Communist Party of China held in October 2017 emphasized ongoing fiscal policy reform with a focus on improvement of the local tax system. Of note is that for the first time, the government proposed principles supporting a property tax on the ownership of private residential properties (Liu 2018).

Challenges for Property Tax Reform

Although the evolving nature of fiscal reform is broadly positive, tax-based revenue generation remains limited and many sub-national governments in China continue to experience fiscal stress and incur large local debt, due to the large fiscal gap between expenditure responsibilities and revenue capacity. This is likely to continue until taxation reform resolves the issue, or governments experience financial collapse (Duda, Zhang and Dong 2005; Man 2011; Salm 2016). Furthermore, although the literature has pointed to the implementation of market value–based property taxation, there has been a paucity of attention paid to institutional constraints and the need for wholesale technological and administrative restructuring, transformation and capacity building necessary for the operation of effective local property tax, such as the collation of reliable and validated data, transparent property appraisal practices supported by computer-assisted mass appraisal technology, effective collection and enforcement mechanisms and impartial, efficient and low-cost adjudication processes.

Salm (2016) argues that the issues relating to property-related taxes in China can be grouped into a number of core issues. First, since the 1994 tax reform that introduced the Tax Sharing System (TSS) under which specific tax revenues are assigned, there has been a mismatch between local revenue and expenditure assignments. Such a mismatch continues and has also been observed in megacities where budget expenditures exceed general budget revenues, with property taxes accounting for only 5 percent of local tax revenue. In addition, local discretionary powers remain limited and local governments may only vary property tax rates within a centrally determined range. Salm further argues the Chinese local tax system is largely premised on 'windfall' tax revenues collected at the transaction stage. The size of these nonrecurrent revenues relies primarily on external determinants, and revenue can be volatile due to quantum and availability of land sold. It is also largely driven by the grant of new development rights and, as such, is sensitive to the economic cycle and unsustainable.

The constraint of state-owned land and increasing population densities are limiting sustainable revenue, meaning the windfall tax revenue model is time limited. it is well documented that property tax revenues are static due to the limited tax bases and residential exemption. At the same time, property owners live under a "veil of uncertainty" (Man 2012, 16) as despite improvements in property rights law, private property might revert to state government in the absence of land use renewal. Pilot programs are not supported with legislation which ultimately renders enforcement of property tax arrears difficult, although recent developments note that China's legislative body has now expanded the reach of property law nationally.

Further significant hurdles remain in the form of political will and public appetite. Liu (2018) highlights that the strongest opposition to the introduction of a property tax on the ownership of private residential properties emanates from the reality that over 90 percent of urban households own one or more housing units. He highlights that the central government studied the feasibility of property tax around 2000 which led to the seminal publications of Xie (2005) and Xie (2006); Liu describes this as a huge missed opportunity to have implemented the property tax, as it would have been a few years after the housing policy reform and just before the start of the housing boom. In noting the underlying resistance to property tax from homeowners, he advances a number of possible solutions for policymakers in the design and implementation of the property tax. In this context, he contends the need to reform the deficient price structure of public land leasing by introducing the property tax and public land rental charges. This structure would also give municipalities some degree of flexibility to use public land rental charges as a policy tool to stabilize land costs. Liu further contends that property tax could be introduced immediately if it were oriented towards a wide tax base and a very low rate. This may allow it to gain acceptance yet generate much-needed revenue. As an alternative, he also suggests a 'grandfathering' approach which is transitional and gradually ensures all residential properties are subject to taxation. A further approach is to allow for a period of transition by delaying the effective implementation of property tax law for a period of time to allow homeowners to adjust housing portfolios. Finally, in recognizing ongoing change, Liu (2018) argues that the whilst the majority of municipalities are not yet ready to implement property tax due to administrative and assessment exigencies, some of the large municipalities have made considerable groundwork progress and therefore have the ability to proceed with progressing property tax law. Such ready provincial governments could be rewarded with incentives or discretional rates, whilst others could be targeted with development programs.

Despite considerable progress, property tax reform in China remains nebulous, complex and enormously challenging. There remains considerable opposition to reforms from owners, investors, and local government officials, propagated by concern that the reform will curb infrastructure investment, local GDP growth and development—which is exacerbated by confusion and misunderstanding (Man 2011). In addition, an appropriate legal and regulatory framework is critically lacking, with piecemeal progress on assessment approaches and standards. Related to this is the lack of agreement as to the nuances and specifications of the tax base, exemptions, administration, rating, assessment, and allocation of tax revenues (Liu 2018). Annual tax assessed on property value is a potentially efficient revenue resource which can reduce the dependency on land transfer fees which themselves can fuel rises in property prices. Further, the advent of increasingly strident housing policy and fees restrictions has resulted in a sharp decline in land transfer fees emphasizing the need to raise more sustainable revenue in the longer term. It is suggested that employment of a property tax system can offer an incremental, efficient, equitable, and sustainable mechanism to facilitate revenue generation and lower property prices.

Rationale for Mass Appraisal

Real estate now undoubtedly plays an essential role in China's economic development and fiscal revenues are already contingent on land and property market (Nitikin, Shen, and Zou 2012). With the reduction of revenue from traditional land grants, property tax reform has emerged as a topic of concern, particularly property tax assessment and revenue capacity. Whilst the Chinese government has long recognized this and has considered the viability of the introduction of an annual property tax program and concomitant mass appraisal rollout, this has not yet been fully adopted or deployed with taxes remaining mainly at the point of sale (Nunlist 2017). Therefore, whilst property tax reform is making some progress in the research literature and to an extent in the public psyche, it remains embryonic and if it is to be become a major source of public revenue, requires support in the form of, political support, administrative structure reform and ultimately tax design and the development of assessment techniques (Man 2011). In this context, the Lincoln Institute, in partnership with the Chinese government, and subsequently the Peking University–Lincoln Institute Center for Urban Development and Land Policy (PLC) continues to support international and domestic experts in conducting research and demonstration projects on property taxation and related topics, including municipal finance to public land management and land expropriation (Nunlist 2017). This has encompassed various projects such as a pilot demonstration that established a CAMA system for the financial district of Beijing, and several other city implementations of CAMA, in anticipation of a future property tax.

As discussed, the evolution of mass appraisal practice in China dates from 2003 in Shenzhen. Since this inception mass appraisal practice development has been disjointed and varied across China, compounded by the differing valuation approaches adopted. The introduction of pilot schemes in a number of cities using dissimilar methods has also to an extent impinged upon the development of a more unified approach. The policy experimentation in Shanghai and Chongqing in 2011 (to simultaneously stabilize the housing market and local government revenue), did reveal nominal impacts on the property value. Unfortunately, they have not shed much light on potential distributional effects, considering such a diverse distribution of income and urbanization-related issues. This is compounded by the heterogeneous nature of local property tax policies and lack of uniform designation of a proper property tax reform (Cao and Hu 2016).

In addition, despite the piloting exercises and supposed ‘implementation’ of mass appraisal, property tax still has not been implemented, with the exception of real estate–related taxes charged at the point of transaction. This has become a more pressing matter in light of continued house price appreciation, tight local government budgets, and the rising income gap (Cao and Hu 2016). Central government in China has not yet decided whether to impose the property tax at a nation-wide level and whether this will take the form of a uniform rate or a regional rate as decided by local government, given the increasing regional unevenness and disparity. In reality, the most significant evidence of progress has been the introduction of the housing registration system—a useful enabler but hardly a policy tipping point (Cao and Hu 2016).

Mass Appraisal Model Development and Application

A plethora of research studies have been conducted to examine market pricing structure and determinants in housing markets and the varying approaches in terms of methodological enhancements for appraisal purposes. Indeed, housing market analysis has frequently been undertaken to examine econometric approaches, given its perceived suitability for such applications. These have fed into more recent studies which have discussed the nature, role and application of mass appraisal for property taxation in China. The topographical structure of housing markets as identified by Li et al. (2015) has significantly spatially transformed and stratified residential space and communities in Chinese cities, particularly when accounting for access to public services, which has manifested in spatial clustering. This, as Li et al. (2015) indicate, has culminated in spatial disparity in house prices coupled with fragmented local government structures with implications for equitable public service provision and the prospects for property taxation reform.

With regards to land prices and land resource allocation for urban planning and development in China, Ding, and He (2008) employed an econometric approach to test the inter-relationship between housing price and land price in the three cities of Beijing, Shanghai and Wuhan, scrutinizing the functional mechanism of land supply policy to China's real estate market control. They found that an interaction exists between housing price and land prices. More recent research by Hu et al. (2016) used a geographically weighted regression approach in Wuhan using a 10-year panel data set of residential land price. Developing an evaluation index system of resident land price their analysis highlighted three major explanatory variables (floor area ratio, distance to nearest center business district [CBD] and distance to nearest lake) to be the most important spatially varying impact factors with land price. Interestingly, they found the positive impact of floor area ratio on land price to be more influential and significant in highly developed areas than in less developed areas—signaling challenges for a floor area type assessment to be uniformly introduced. Their findings offer important evidence for formulating urban planning strategies and land pricing models for valuation purposes. Similarly, investigating the impacts of the urban structure in Hangzhou, Wen, Li, and Zhang (2012) used twenty-five explanatory variables based on 2,795 transactions to construct a hedonic price model to assess the external effects of various types of landscape on housing price.

Research has also been undertaken to address the legitimacy of mass appraisal approaches with a number of studies investigating the theoretical adoption of CAMA in China. Research by Ji and Fu (2005) reviewed the development of mass appraisal and differences between real estate tax appraisal and real estate valuation. Their work demonstrated the main advantages and shortcomings of mass appraisal in order to promote the development of China's taxation assessment approach, suggesting the appropriate methodology and technological approach and support. Yongfa and Lei (2009) have also undertaken research examining the establishment of a Mass Appraisal "system." Their research looked at specifying the most appropriate method to evaluate the price as the section benchmark price, in order to establish a dynamic adjustment system between benchmark price and the value of other properties. Similarly, Geng (2011) explored the production, development, and main operation process of mass assessment, concluding that it is necessary to use a computer aided mass assessment system to appraise real estate tax, emphasizing that the Automated Valuation Model (AVM) approach should be adopted in China as soon as possible. Pang (2008) further investigated the viability of establishing the tax base as a fundamental issue in real estate tax administration. Their research discussed the various assessing methods, before exploring the challenges for developing a database of assessment. Pang concluded that the main issue establishing the tax base is information asymmetry, proposing practical countermeasures relevant to the China context.

Geng and Li (2012) presented the concept of "municipal unity valuation" tailored to the special characteristics of the real estate market in China. In order to achieve high precision, low cost, and easy updating of the tax base, they constructed a unity valuation model for Shenzhen City, with the analysis exhibiting the approach to be applicable and pragmatic. In a similar vein, Yiping (2007) examined the applicability of mass appraisal methods in China. The research highlighted a valuation approach benchmarking land price to property value. This literature reflects research on the development of context specific appraisal approaches to establish the tax base and which illustrates a value basis is considered to be achievable moving forward.

There is also an emerging body of research which has begun to explore more than the broad concept of "mass appraisal." Liu et al. (2015) used GIS spatial analysis methods coupled with a VIKOR methodology for enhancing real estate mass appraisal. They predicted real estate prices revealing high accuracy with actual prices—concluding that their approach can provide technical support for the levy of estate duty. Lam, Yu, and Lam (2009) developed a support vector machine and entropy-based decision support system for property valuation. Applying a Particle Swarm Optimization (PSO)-based SVM model to real estate price forecasting and validated data (from Chongqing), the results show that the proposed method can be used to solve the finite sample learning, nonlinear regression and better overcome "dimension disaster." An interesting study by Wang et al. (2014) attempted to unify both qualitative and quantitative methods, to decompose the problem of appraisal of secondhand houses into levels and factors. Using an AHP approach to examine multi-story, small high-level, and high-rise buildings, they analyzed a computer aided mass assessment of real estate in order to set up a mass assessment model through a confirmatory process. The study analyzed and selected the factors affecting property price. They extracted the value-significant factors which were incorporated into a quantitative index system and further integrated into a regression model. This was used to formulate a mass assessment model and arrive at a characteristic price model. The significance of the study is that it provides a platform for establishing measurement rules for mass appraisal models.

Li and Du (2015), combined mass appraisal with Back Propagation neural network theory using housing transaction data in Kunming, the results show that the model can be used to assess the price of large numbers of similar properties. They conclude that the assessment of the real estate tax base in this region is feasible, using location, type and use in a BP ANN framework. In keeping with this, albeit relating to the commercial sector, Zhang et al. (2015) used GIS in a Spatial Error Model Mass Appraisal (SEM-MA) for commercial real estate based on spatial analysis, which dissected Shenzhen into 837 appraisal parcels and subsequently into commercial grades. Their empirical analysis demonstrates that the SEM-MA model could be widely adopted in China. They argue that this methodology can help assure fiscal independence for local governments, providing the technical support for those undergoing property tax reform. They suggest that due to obtaining all assessment results simultaneously, the equity and consistency of the results can be ensured. This, of course, is a feature of most—if not all—mass appraisal approaches.

The developments within mass appraisal, and specifically the technological innovation in terms of the interface between CAMA systems and geographic software and systems, has facilitated the augmentation of mass appraisal techniques. In this regard, China has paradoxically led the way with GIS-based 3D mass appraisal modeling, and arguably has for the Shenzhen region the most prominent 3D valuation-based system globally. This is demonstrated by Zhang et al. (2014) who applied GIS 3D modeling and analysis technology in a real estate mass appraisal setting. Integrating a procedural modeling approach and building level 2D GIS data of Shenzhen, the research generated 3D external models of buildings and a 3D internal model using vectorization of the property distribution within the target building. Using GIS visibility analysis accounting for the landscape and sunlight, the authors were able to establish quantization indexes, such as landscape visual range and sunshine duration, which is weighted to synthesize a valuation. Zhang et al. (2014) view this more precise 3D visualization effect to provide appraisers with a more intuitive and efficient view for real estate expression and to greatly improve the efficiency and accuracy of real estate appraisal. Indeed, as discussed by Nunlist (2017, 9), "the future of property assessment lies in marrying CAMA techniques with GIS tools in a system known, naturally, as "GAMA." Moreover, this system is being utilized to better execute property transaction taxes whereby only 27,106 challenges have been made[1] with only 282 assessments needing readjustment based on millions of properties valued (Nunlist 2017). Despite these heralded successes, the Shenzhen assessment project was not without challenges. Primarily due to market infancy there is a relative dearth of transaction data, which are also suggested to comprise misrepresentation—reported at artificially low prices, to avert transaction taxes (Nunlist 2017).

One of the only studies to develop a mass appraisal model conforming with international standards is by Tian (2013), who developed a multivariate model for four administrative regions (Tianqiao District, Shizhong District, Lixia District, and Huaiyin District) of Jinan. The results of model checking show that the mass appraisal based on multivariate linear regression model can and should be adopted, with predicted values in line with IAAO benchmarks relating to the COD and PRD ratios—showing them to be relatively efficient for roll-out. The findings highlighted that for future practice, CAMA and GIS can be combined for improving accuracy and fairness. A recent study conducted by Cao and Hu (2016) is one of the closest studies to examine the issue of vertical and horizonal equity when considering property tax. Indeed, Cao and Hu (2016) developed a theoretical model of property tax reform to decompose the potential impacts within

[1] Effective January (2017).

China. They utilize the China Family Panel Survey (CFPS) data to conduct a microsimulation model in order to examine any potential incidence impacts of alternative property tax designs. Their findings suggest that a uniform property tax policy would yield heterogeneous impacts across different income groups as well as different regions, mainly due to the differences in income distribution, housing prices, and the degree of the Housing Demolition program. More interesting was that their findings suggest that property tax, as a local tax, would achieve better performance if the policy design is catered to match the unique distribution of the housing ownership, income group, and consumption distributions in each area. With regards to equity, and in terms of property tax incidence, their simulation analysis suggests that utilizing tax revenue on the poor's public housing subsidy may mitigate any regressivity and make the tax more likely to be progressive in many cases. Significantly, their experimental simulations indicated that in order to maximize social welfare, it is important to set a different "waived area per capita" at local level reflecting huge heterogeneity across China. A noteworthy point also pertains to Cao and Hu's (2016) recommendations which allude to enhancement of the static-based approach to a more dynamic microsimulation when data becomes more readily available and elongated. The increase in panel data or repeated cross-section data they illustrate will permit the longer-term study of the impacts of the property tax policy on the housing market.

With the advent of the property tax piloting exercises, Du and Zhang (2015) evaluated the effects of home-purchase restrictions and the trial property taxes on housing prices in China. Modifying the method of Hsiao, by Ching and Wan (2012), they construct the counterfactual growth rates of housing prices in Beijing, Shanghai and Chongqing using the selected control cities. The authors found that purchase restrictions reduced the annual growth rate of housing prices in Beijing by 7.69 percent with the trial property tax of Chongqing impacting upon the annual growth rate of housing prices by 2.52 percent. Moreover, their analysis indicated that the trial property tax of Shanghai had no significant effect on housing prices. The results suggest that in order to 'curb' escalating housing prices, home-purchase restrictions should not be, at least in the short-run, replaced by property taxes. The trial property tax of Chongqing with higher proportion of taxable homes is more effective in curbing housing prices than the trial property tax of Shanghai.

In a similar approach, Bai and Ouyang (2014) examined the potential effect of property tax on house prices, taking advantage of a policy experiment of property taxes in Shanghai and in Chongqing in 2011. Using a counterfactual conditioned experiment, house prices in Shanghai and Chongqing without tax were estimated using house prices of the strongly correlated provinces using a long monthly time series data. The findings suggested that the introduction of a tax lowers the average housing price by 15 percent in Shanghai. The authors alluded that this may have a knock-on consequence in relation to housing consumption and utility through the "housing wealth" effect. Indeed, this wealth effect was also the focal point of Du and Li's (2010) research which suggests that these so-called "housing wealth" effects are in fact much more complicated. Utilizing panel data for 172 cities between the period 2002 to 2006, Du and Li (2010) find that the increase of house prices decreases income expenditure. They argue that Chinese homeowners are more likely to be the potential buyers later, thus constantly rising housing prices may erode consumption expenditure and the ability to save. This is akin to the study of Yang (2014) which considers the dual characters of the housing in China as both a consumption good and an investment commodity. Yang's findings highlight that there is an increasing divide between renters and homeowners based on the opportunity cost, which Yang stresses is much higher in China when property tax is non-existent. According to Yang's estimate, the elasticity of the property value on the expenditure is -12.3 percent. They also highlight that the heterogeneity in China makes it much harder to estimate the house wealth effect.

Literature Summary

Numerous studies have developed the understanding of the theoretical underpinnings of mass appraisal in China, and enhanced knowledge as to the viability of its potential rollout. The literature shows a wealth of research methodologies which can and have been adopted to assess the challenging nature of the Chinese urban form. The evolution of the drive towards implementing mass appraisal has shown promise with a number of research papers able to do this at the city/regional level, and importantly, a number which have specified the models using 'real' property transactions which was traditionally a limitation. This has undoubtedly been amplified by the increasing nature of open source data and more reliable list price data offered by more robust property companies since their introduction, as this quality and quantity of data supports increased model sophistication.

A core challenge relates to the implementation (and effects) of property tax reform. Whilst studies have emerged, they remain relatively insular to specific regions or cities, resulting in limited insights as to potential 'winners and losers' in light of any reform. Studies nonetheless have begun to emerge providing an indication of the effects if China impose a property tax, and significantly the incidence on the households. The heterogeneity of the market also presents some unique policy challenges. This can however be overcome by introducing more spatial approaches coupled with integrated technological solutions and data, which are also emerging in parallel. offering a viable opportunity to blend efficiency and accuracy within modeling frameworks ,which can be tailored on a region by region basis.

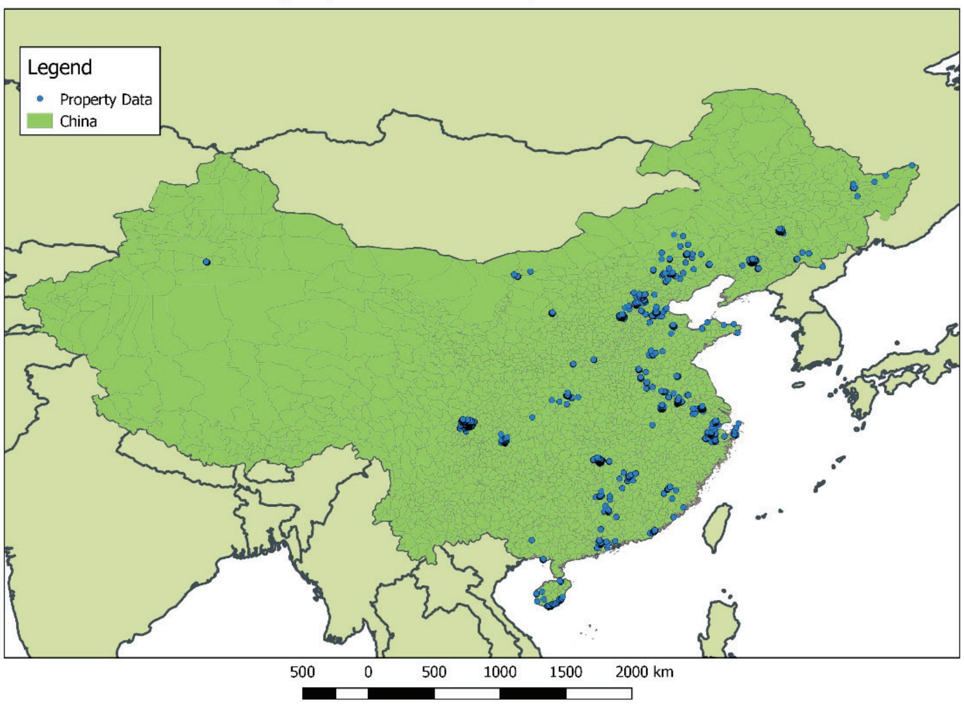
Moreover, whilst a plethora of studies have investigated the potential of using the mass appraisal approach—and the usefulness of integrating GIS to enhance data provision and for explanatory power there is an outstanding requirement for assessing whether mass appraisal models developed for China would conform to international benchmarks. The availability and robustness of data for wider application continues to be a challenge, given that existing studies are regional or city specific. While there has been extensive "refining" of sophisticated methodologies for appraisal purposes, this remains limited to a few regions and is therefore somewhat idiosyncratic in nature. There remains a "gap" in terms of a nationwide examination and feasibility analysis for CAMA scalability, given an assumption of a policy requirement for *ad valorem* property tax reform. The primary analysis which follows seeks to address this gap.

Data

Nationwide transaction data in China is relatively "thin" and difficult to obtain from official sources—which is further compounded by the extreme variation in robust sources and reporting mechanisms. Similar to a number of extant research studies conducted in China, the national real estate transaction data used here is compiled from numerous websites[2]. These websites are operated by large property companies which provide data for thousands of branches in Tier 1 to Tier 4 cities in mainland China. For example, initial inspection of one of the list sites provides coverage for 658 cities (Tier 1 to Tier 4) and 29 regions, each of which show the dissection at both the sub-district and sub-city prefectures[3]. The research utilized a web-crawling exercise with the data acquired through various private listing companies by programmed web scraper and 'crawling' methods (only where legally and ethically permissible, and not in violation of any terms of service) across the various listings, acquiring an initial extraction of 26,579 records and further supplemented with 46,857 records for the Beijing and surrounding hinterland market region, providing 73,436 observations in total (see Figure 1a and b).

Figure 1: Spatial Representation of the Data Observations

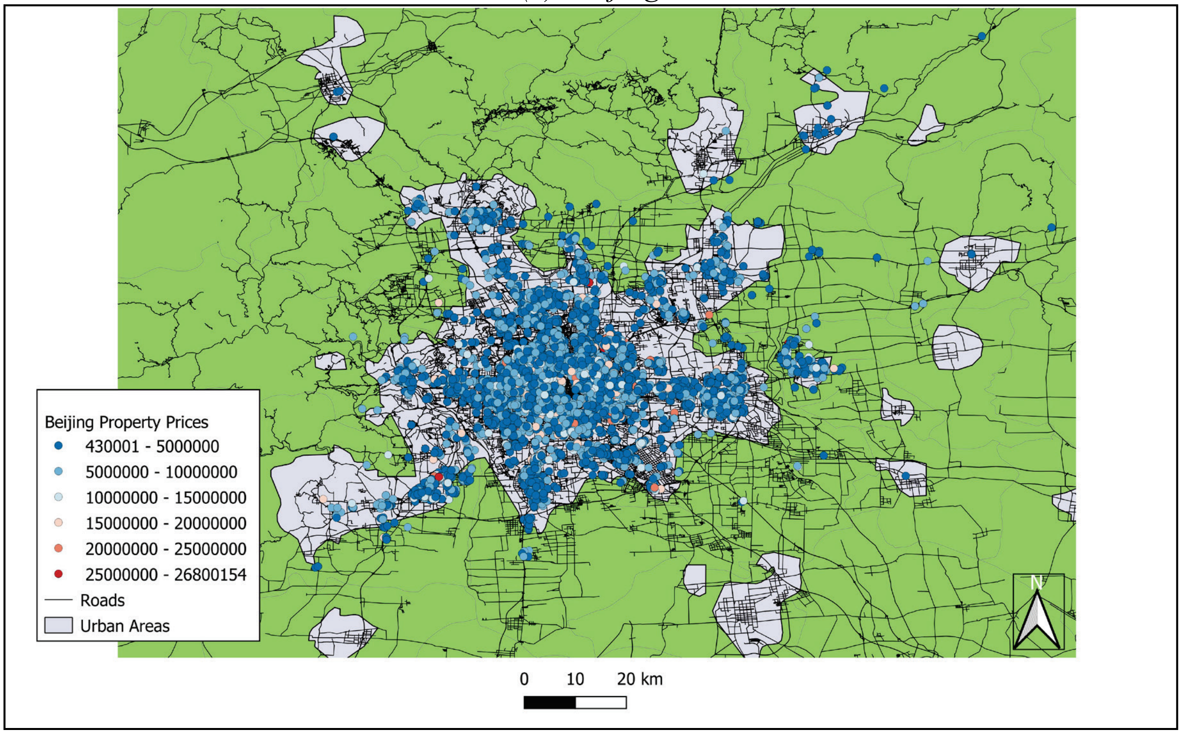
(a) National Overview



[2] http://www.fang.com/; https://www.anjuke.com/; https://www.lianjia.com

[3] As a consequence of the above websites only providing listing pricing information, we endeavored to validate the analysis for a random subset of markets using sales data from other sources in order to test for potential discrepancies and adjust accordingly.

(b) Beijing



Examination of the information contained within the listing price data is rich and encompasses a wealth of structural and neighborhood characteristics necessary for modeling purposes. An initial exploratory investigation of the variables can be observed in Table 1 below.

Table 1: Exploratory Variables and Descriptions

Variable	Description
Floor area	Size of property m^2
Average price per m2	Price of the property per m^2
General condition	Categorical specification based on assessment
View/aspect	View and orientation /direction (facing) of the property
Floor Level	Categorical (high; middle; low) of level in building block
Location	Address, X,Y of property
Build year	Year of build of property
Build type	Public or private market build
Elevator	If property (block) has an elevator
Transaction volume	Level of transactions (monthly) in a district (%Δ)
District price	Average price of property per district
Nearest subway	Distance to nearest subway (meters)
Commodity housing estates	Defined neighborhood/submarket areas for developments

The data was scrutinized for data entry error, missing observations and non-normal or non-standardized0 properties offering the potential to impact upon the model functionality and reliability. Initial frequency analysis shows a wide variation and range across a number of the property characteristics. For example, the number of bedrooms within the sample ranges from 1 to 10, nonetheless, the valid percentage of bedrooms above six equates to a mere 0.4 percent (112 observations) of the overall data, therefore purged from further exercises to facilitate model stability. This is similar for other structural characteristics such as the bathroom attribute (range from 0 to 12) and property type which illustrated a number of observations to comprise missing entry, with the property type classification of 'Others' and 'low-end house' collectively only accounting for 61 observations and therefore removed. Overall, this data cleansing exercise highlighted that a number of these erroneous data entries and problematic observations were cross-correlated thus removing 180 observations in total. Table 2 exhibits the number of observations considered problematic for each attribute.

Table 2: Problematic Observations Identified Through Data Cleansing

	National	*Beijing*
Attribute	**Problematic observations**	
Beds	32	45
Baths	39	21
Property Age	13	42
Orientation	1	5
Property Type	32	67
Specification	2	9
Regulation constraint	26	87
Multifamily or not	26	54
City[1]	27	17
Administration[2]	317	235**
Submarket[3]	74	-
Total purged obs.	180*	338
Remaining obs.	26,399	46,519

*note: Total number does not match the observations removed (multiple error or missing entry per 1 observation).

**Ring delineation

[1] 41 City areas (Jinchang and The general [1 and 26 obs.] removed)
[2] 195 administrative areas
[3] 972 submarket areas

Having purged erroneous and missing entries from the data, initial diagnostic analysis is undertaken to identify outliers within the sample data. There are a number of statistical based approaches for removing outliers. This research tested a combination of Cook's Distance and Mahalanobis Distance[4] to estimate the level of the influence (undue influence) of a data points with large residuals (outliers) and/or high leverage which may distort the outcome and accuracy when undertaking regression based analysis. At the aggregate level, encompassing all data, this initial inspection illustrated extreme instances of outliers, however, when disaggregated by

[4] Mahalanobis distance is a multi-dimensional generalization of the idea of measuring how many standard deviations away P is from the mean of the distribution (D). This distance is zero if P is at the mean of D and grows as P moves away from the mean along each principal component axis. If each of these axes is re-scaled to have unit variance, then the distance corresponds to standard Euclidean distance in the transformed space. The distance is thus unitless and scale-invariant and takes into account the correlations of the data set.

geographic location (city level), initial model diagnostics display relative normality in the residuals[5]. The suite of property and locational characteristics were subsequently transformed into binary state (where applicable) to permit various modeling specifications and procedures to be tested (Table 3).

Table 3: Included Variables and Transformations

Attribute	Description	Transformation
Property Age	Age of property in years	Binary (1 if 39 years old; 0 otherwise).
Orientation	Orientation of property	Binary (1 if East; 0 otherwise)
Specification	Condition and finish of property	Binary (1 if Luxury-end; 0 otherwise)
Floor Level	The level the property is located	Binary (1 if high; 0 otherwise)
Total Floors	Total number of floors in the building	Scale
Bedrooms	No. of bedrooms	Bedrooms (1 if bed1; 0 otherwise)
Bathrooms	No. of bathrooms	Bathrooms (1 if baths1; 0 otherwise)
Area	Size of property (m^2)	Scale
Property type	Type of property	Binary (1 if High-end Apartment; 0 otherwise)
City[ab]	Location City of property	Binary (1 if Baoding; 0 otherwise)
Administrative District[ab]	Administrative district a property is located	Binary (1 if Baoding; 0 otherwise)
Submarket[ab]	Submarket area a property is located	Binary (1 if Baoding; 0 otherwise)

[a]Binaries used For OLS models only. [b]. *X, Y* employed for GWR models.

Testing the Functional Form of the Data for Model Specification

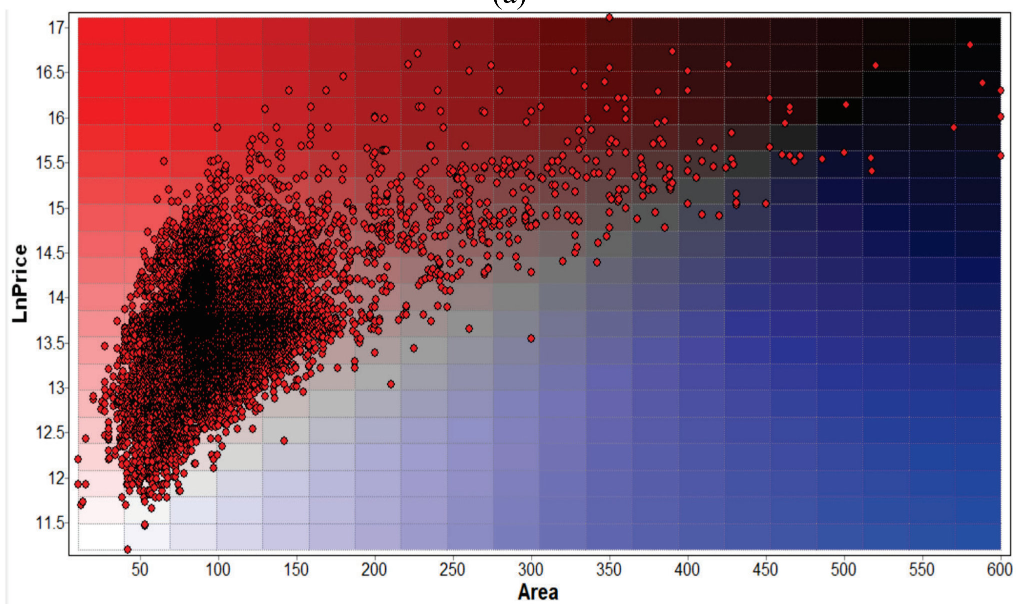
The price and area (size) variables are examined for the potential best model specification based on their level of explanation using various model specifications. Initial inspection of the relationship (Figure 2a–c) shows heteroscedasticity is evident toward the higher house price and size relationship implying neglected non-linearity may be an issue for modeling. Transformation of the sales price (Figure 2d) and area variables into their logarithmic state (*Ln*) demonstrated a reduced level of explanation between the two variables (R^2 = 28.7%; 30.9%), nonetheless conforms to statistical inference permitting more robust analysis. In this regard, further trend inspection using a polynomial fit shows increased explanation suggesting the varying underpinning relationships within the sample data which are reflective of different (terms) and depicted by geography—an important characteristic for the modeling typology adopted in the

[5] For example, the City of Baoding revealed 14 cases of standardized residuals beyond the acceptable threshold, however this is out of 1,239 observations equating to 1.12%.

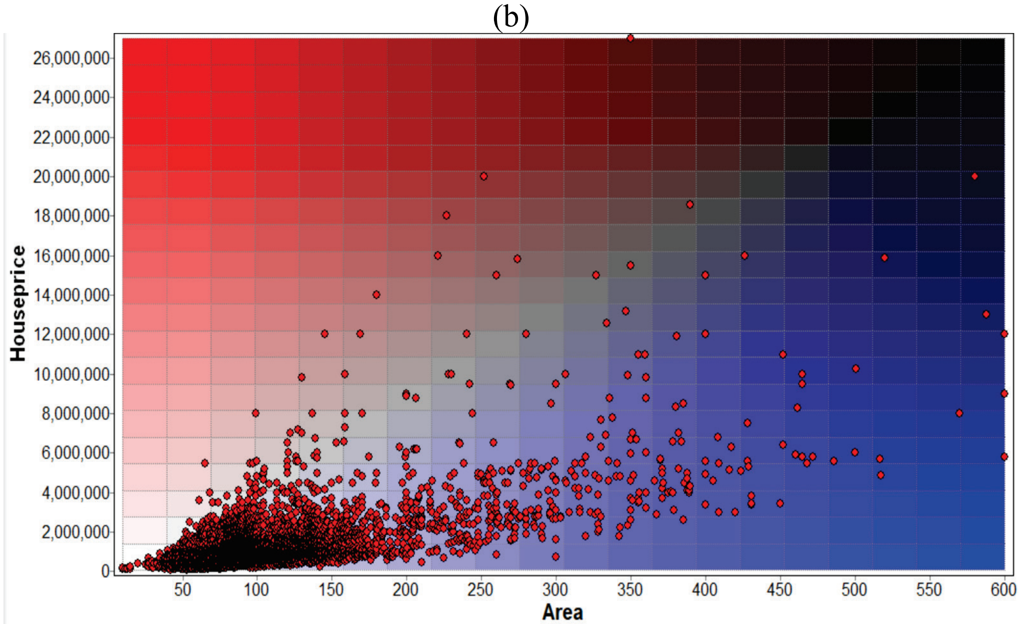
CAMA exercise(s). As a consequence, the modeling exercises utilize house prices in their natural logarithmic state to account for statistical reliability.

Figure 2: Relationship Between Price and Area (size)

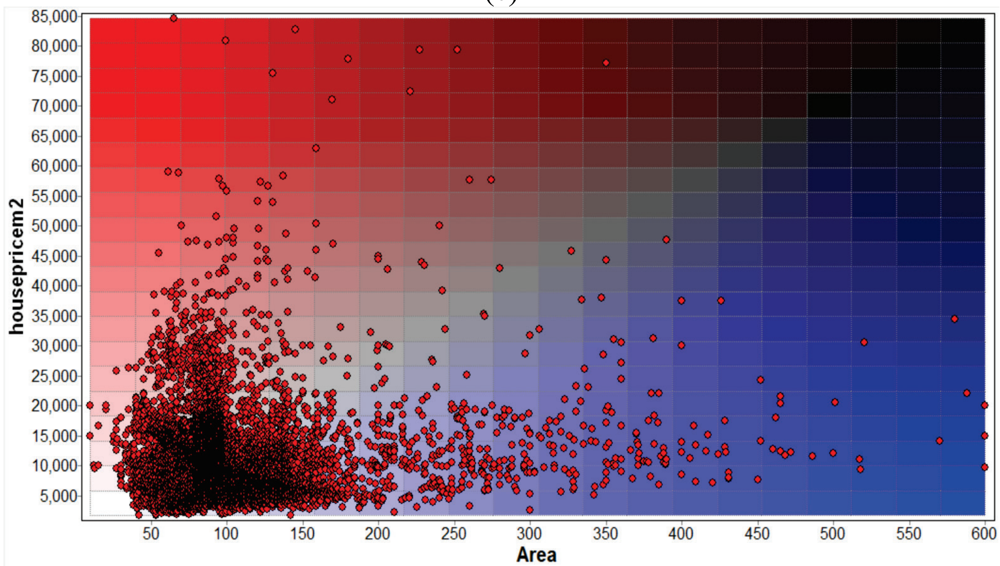
(a)



(b)

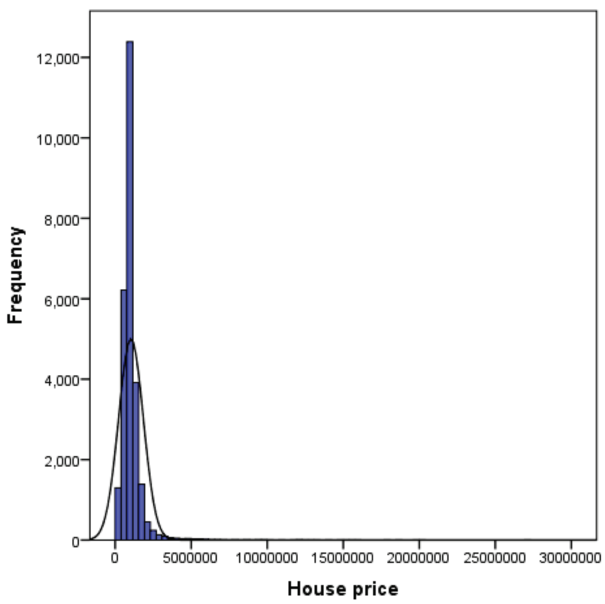


(c)

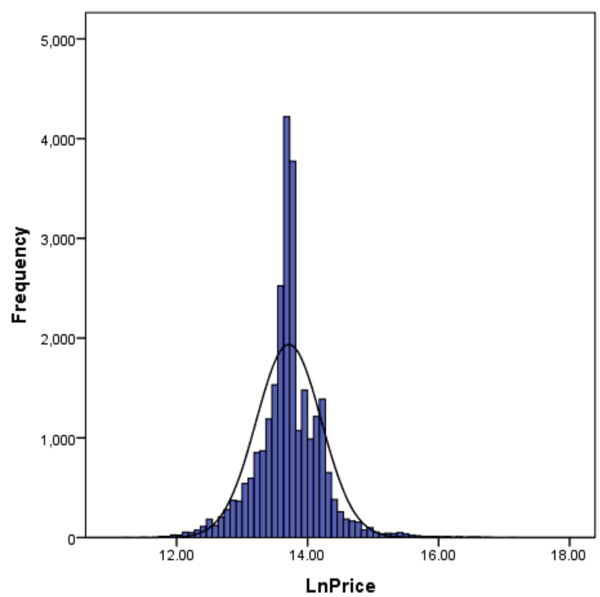


housepricem2
Area
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
50
100
150
200
250
300
350
400
450
500
550
600

(d)



Frequency
House price
12,000
10,000
8,000
6,000
4,000
2,000
0
0
5000000
10000000
15000000
20000000
25000000
30000000



Frequency
LnPrice
5,000
4,000
3,000
2,000
1,000
0
12.00
14.00
16.00
18.00

Methodology

For automated valuation models (AVMs) to produce accurate, uniform, and defensible values, the completeness and reliability of data is of fundamental concern. With regards to a policy discussion approach and the realistic consideration of an *ad valorem* property tax enactment in China, analysis of whether (or not) data is adequate and capable of yielding valuations, in-line with internationally accepted property tax standards, is needed (Deng 2005). Consequently, utilizing property transactions from varying residential markets, this research evaluates a nationwide assessment of mass appraisal valuation feasibility for the nation of China. A comparison of model performance will extend beyond typical regression diagnostics towards IAAO standard metrics which appraise valuation fairness, equity, and uniformity. This therefore determines the feasibility of creating AVMs in China capable of conforming to IAAO valuation standards, with implications for scalability across national markets. In addition to increasing the understanding of real estate markets and appropriate property tax AVM methodologies in China, this research can aid guide the adoption of valuation policy prescriptions for economies with similar markets and/or similar data to China.

Measuring Non-Uniformity and Inequity in Value-Based Property Taxation

The International Association of Assessing Officers (IAAO) creates and disseminates statistical standards by which governments may assess the uniformity and equity of property valuations (IAAO 2003). Such statistical analyses are referred to in the property tax arena as "ratio studies". The coefficient of dispersion (COD) measures uniformity of valuations—providing a measure of the variation of individual assessment-to-sale (ASR) ratios[6] around the median ASR. Lower (higher) CODs indicate that ASRs are clustered closely around the median, suggesting more (less) uniform valuations. It is represented by the following formula:

$$COD = \frac{100}{R_m}\left[\sum_{1}^{N}\frac{|R_i - R_m|}{n}\right] \tag{1}$$

where: R_m= median ASR; R_i = observed ASR of the i^{th} sale; n = number of properties sampled.

The price-related differential (PRD) is used to indicate assessment uniformity and to quantify the degree of *regressivity*, in which the low-value properties are over-assessed relative to the high-value properties, or *progressivity*, in which the low-value properties are under-assessed relative to the high-value properties. It is calculated as follows:

[6]Assessment-to-sale ratios (ASRs) are a common way to measure valuation accuracy within property tax valuation, where the estimated value of a property is divided by the sale price or in regression terminology, the predicted value (ŷ) is divided by the observed value (y); valuations with an ASR greater than (less than) one are considered overvalued (undervalued).

$$PRD = \frac{\sum_i \frac{\left[\frac{\hat{Y}_i}{Y_i}\right]}{n}}{\sum_i \left[Y_i * (\frac{\hat{Y}_i}{Y_i})\right] / \sum_i Y_i} \tag{2}$$

where: $\hat{Y}_i$ = predicted sale price of the ith sale; Y_i = observed sale price of the ith sale; n = number of properties sampled

According to the IAAO, the acceptability threshold for the PRD is 0.98 to 1.03 (IAAO 2013). If ASRs tend to decrease (increase) with price, the PRD will be greater (less) than 1.00. It indicates whether or not assessment inequity correlates with a property's value.

Valuation Methodology

There are a variety of spatial based modeling frameworks in existence for examining house prices and undertaking valuation practices—principally AVMs. As discussed by Khalid (2015), a vast number of approaches are incorporating explicit consideration of spatial effects in the estimation of hedonic price functions and market value. The need for spatial consideration within hedonic pricing models has long been a concern within the valuation arena as both supply and demand of real estate will vary across a given location as tastes, preferences, willingness, and abilities to buy fluctuate. As a consequence, this study employs both a traditional OLS and a more spatially local weighted regression methodological approach.

<u>OLS (Spatial Regime) Model</u>

The basic objective of multiple regression analysis is to develop a strong predictive relationship between property characteristics and value, so that the latter can be estimated through knowledge of the former. The semi-log linear fit is applied within the modeling frameworks due to computational efficiency and interpretability which provides useful interpretations of the independent variable coefficients in terms of their elasticity in respect to the dependent variable. The semi-log specification is as follows:

$$LnY = \beta_0 + \beta_1.X_1 + \beta_2.X_2 ....\beta_n.X_n + \varepsilon \tag{3}$$

Where; LnY is the dependent variable (log of sale price), $X_1......X_n$ are the independent variables; $B_0 ....\beta_n$ are parameters to be estimated; with ε the error term.

To evaluate the percentage effect, a variation of the equation suggested by Halvorsen and Palmquist (1980) for the semi-log model specification is applied. They point out that unlike a continuous variable, the coefficient of a dummy variable, multiplied by 100, does not represent the usual percentage effect of that variable on the dependent variable. The estimated true percentage effect of a dummy variable is therefore equal to:

$$100(e^{bn} - 1) \text{ or } g = \exp([\alpha]) \text{ -1,} \tag{4}$$

where the relative effect on the dependent variable of the presence of the factor represented by the dummy variable bn.

Geographically Weighted Regression Model

Locally weighted regression (LWR) is an extension of traditional ordinary least squares (OLS) that has demonstrated, in certain cases, superior performance with respect to explanatory power (Brunson et al. 1996; Brunson 1998). Geographically weighted regression (GWR) is an LWR technique allows observations in closer geographic proximity a subject property to receive more consideration than those further away (Fotheringham et al. 2002). Real estate markets characteristically behave differently over geographic space, and price determinants may vary greatly by location. Conventional OLS models are often unable to accurately account for spatial variation, resulting in a spatial correlation of error terms (spatial autocorrelation) with dummy variables used to capture and isolate locational variations not fully correcting for spatial autocorrelation (Fotheringham et al. 2002; McMillen 2010). With regard to IAAO ratio study standards, evaluation estimates produced by GWR mass appraisal models have been shown to achieve superior results in comparison to OLS models (Bidanset and Lombard 2014; Borst and McCluskey 2008; Lockwood and Rossini 2011; McCluskey et al. 2013; Moore 2009; Moore and Myers 2010). GWR is represented by the following formula:

$$yi = \beta 0(xi,yi) + \sum \beta k\,(xi,yi)xik + \varepsilon i \qquad (5)$$

where: $y_i = i^{\text{th}}$ sale; β_0 = model intercept; $\beta_k = k^{\text{th}}$ coefficient; $x_{ik} = k^{\text{th}}$ variable for the i^{th} sale; ε_i = error term of the i^{th} sale; $(x_{i,}\ y_i)$ = xy coordinates of the i^{th} regression point.

The approach allows coefficients to vary continuously over the study area, and a set of coefficients can be estimated at any location—typically on a grid so that a coefficient surface can be visualized and interrogated for relationship heterogeneity. GWR makes a point-wise calibration concerning a "bump of influence" around each regression point where nearer observations have more influence in estimating the local set of coefficients than observations farther away (Fotheringham et al. 1998). In essence, GWR measures the inherent relationships around each regression point i, where each set of regression coefficients is estimated by weighted least squares. Within this study, the weighting scheme Wi is calculated with a kernel function based on the proximities between regression point i and the N data points nearby. A number of kernel functions can be used for the weighting scheme, a plethora of kernel densities which can be implemented which can have varying impact upon ratio study performance[7]. In GWR, an nXn spatial weights matrix is constructed to indicate the weight applied to each observation, assigned relative to the subject based on geographic distance:

$$w_{ij} = exp[-d_{ij}/b^2] \qquad (6)$$

where: w_{ij} = weight applied to the j^{th} property at regression point i; d_{ij} = geographical distance in kilometers between regression point i and property j ; b = geographical bandwidth.

[7] See Gollini et al. (2013) and Bidanset and Lombard (2014b) for a full discussion.

The bandwidth in GWR specifies the radius of the weighting function and can either be a fixed distance or adaptive (based on nearest-neighords). An optimized bandwidth may be identified based on various conditions but is most commonly that which corresponds to a minimized cross-validation (CV) or Akaike information criterion-corrected (AICc) scores (Fotheringham et al. 2002). This kernel specifies how weights are calculated and assigned to the observations with the kernel implemented shown to impact ratio study performance (Bidanset and Lombard 2014b, Bidanset and Lombard 2016; Bidanset et al. 2017). This study utilizes the Akaike Information Criterion (AIC) (Akaike 1973) which accounts for model parsimony (i.e., a trade-off between prediction accuracy and complexity). This research subsequently compares ratio study performance of each of the kernel approaches across provinces in China, identifying mass appraisal modeling approaches that optimize property tax fairness and equity. The Spatial function Bi-Squared, Adaptive Kernel using 10–15 percent neighbors is employed utilizing an Optimization using the Golden Section Search and the Akaike Information Criterion (AICc).

Model Selection and Multi-Model Inference

To ensure model parsimony and appropriate model selection, initial testing of parameter selection was undertaken to reduce model complexity without reducing model predictability. This model selection procedure, based on minimising the Akaike Information Criteria(c), ensures retention of the highest level of explanation as depicted by the Adjusted R^2, is undertaken to reduce the model form and examine the most parsimonious spatial model and remove unwanted influential variables and multicollinearity. This procedure estimates the relative quality of the models for the given set of data, relative to each of the other models premised on the relative information lost by a given model: the less information a model loses, the higher the quality of that model. This therefore estimates the trade-off between the 'goodness of fit' of the model and the simplicity of the model. The AIC(c) statistic is based on the maximum likelihood of estimating parameters, $\boldsymbol{\beta_i}$, where the probability of the observed data would be as large as possible computed as its small sample corrected version as this is asymptotic to the standard version[8]. Within this research, this process is based on 12 variables selected culminating in 2,047 models tested. The results of the selection procedure filtered by the AIC(c) revealed that the most parsimonious model form excluded the restricted (embargoed) sale variable and higher community parameter estimates for the best OLS model, indicating that they do not add value in terms of importance and significance (Table 5).

[8] See De Smith et al. (2007) for a full discussion.

Table 5: OLS Model Selection Procedure Sorted by Akaike Information Criterion (AICc)

Model Num.	Variables (#)	R^2	Cond. Num	AICc	Delta AICc	L(gi|x)	AICc wi
Mod #90	1, 2, 3, 4, 5, 6, 8, 10, 11	0.305	2.787	28340.4	0	1	0.234
Mod #75	1, 2, 3, 4, 6, 7, 8, 9, 11	0.305	2.819	28340.7	0.317	0.854	0.2
Mod #27	1, 2, 3, 4, 5, 6, 8, 9, 11	0.305	2.79	28342.1	1.782	0.41	0.096
Mod #89	1, 2, 3, 4, 6, 8, 9, 10, 11	0.305	2.79	28342.3	1.925	0.382	0.089
Mod #12	1, 2, 3, 4, 5, 6, 7, 8, 9, 11	0.305	2.822	28342.5	2.099	0.35	0.082
Mod #74	1, 2, 3, 4, 6, 7, 8, 9, 10, 11	0.305	2.822	28342.6	2.224	0.329	0.077
Mod #93	1, 2, 3, 4, 6, 8, 11	0.305	2.787	28343.75	3.4	0.183	0.043
Mod #26	1, 2, 3, 4, 5, 6, 8, 9, 10, 11	0.305	2.793	28344.06	3.707	0.157	0.037
Mod #78	1, 2, 3, 4, 6, 7, 8, 11	0.305	2.819	28344.1	3.745	0.154	0.036
Mod #11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	0.305	2.825	28344.36	4.007	0.135	0.032
Mod #30	1, 2, 3, 4, 5, 6, 8, 11	0.305	2.79	28345.51	5.159	0.076	0.018

*Parameter estimates averaged across 2,047 OLS models using Akaike Weights (AICc wi)

[#1]:Area;[#2]:Bed;[#3]:Bath;[#4]:Type;[#5]:Floor_Level;[#6]:Finish(condition);[#7]:Restrict_sale;[#8]:Multifamily;[#9]:Higher_Comm; [#10]:Orientation;[#11]:Build_Yr

Empirical Results

A series of log-linear models are developed to investigate the nature of the deterministic effect of the structural and locational characteristics on property price. The models are developed systematically in order to establish the various levels of significance attributable to the property characteristics and varying levels of spatial geography. A noticeable and interesting finding illustrates that there appears to be a challenge in terms of the property size (area) and price relationship which commands a relatively low level of explanation, in comparison with other traditional real estate markets—challenging the basis of market value. The base OLS models (excluding any spatial representation) comprising property structural characteristics show 37.7 percent of explanation, again a finding which is generally lower than expected. When factoring in each respective city into the model architecture this shows significant improvement in terms of explanation (77.6 percent). Introducing further spatial dummy variables based on "administrative" areas and at the more granular level, "submarkets,"[9] the explanation increases to 87.6 percent, providing an excellent basis for undertaking mass appraisal exercises.

[9] These submarkets comprise delineated government districts.

Table 6: OLS and GWR Logarithmic Model Summary

Model	*F-stat*	R^2	*Adj.* R^2
OLS (City + Admin + Sub)	176.271***	0.881	0.876
OLS (City +Admin)	475.243***	0.828	0.826
OLS (City)	913.559***	0.776	0.776
OLS (Base)	262.755***	0.378	0.377
GWR	-	0.823	0.811

b. Dependent Variable: LnPrice. ***denotes 99% significance. Full model coefficients available upon request.

Prediction Accuracy: PRD and COD Ratio Performance Measures

Initial investigation examining two IAAO benchmarks, namely the PRD and COD, for the overall models can be evidenced in Table 7. As expected, the base models neglecting spatial information perform relatively poorly for both ratio measures and signify poor uniformity of appraised values and depict regressivity whereby high valued properties are under-assessed relative to low value properties. This is also evident for the COD statistic which display relatively high dispersion of assessed value from the median. When factoring in the locational characteristics, the log (City + Admin) model fails nominally outside both ratio standards thresholds. Both fully specified spatial models (City + Admin + Sub) meet the IAAO accepted thresholds for the PRD, with the log model inside the range widely accepted for the COD and the Linear model marginally outside the threshold.

Table 7: PRD and COD Ratios

	PRD	COD	COV (Median)
Log (Base)	1.166	0.315	44.4%
Log (City)	1.050	0.178	25.9%
Log (City + Admin)	1.035	0.155	22.9%
Log (City + Admin +Sub)	1.024	0.125	18.4%
GWR	0.971	0.152	24.2%

Note: The COV is the Coefficient of Variation.

City Level OLS Models

Dissecting the data by each city region is further undertaken in order to examine the feasibility of specification of an *ad valorem* model at this level under a uniform model archetype. Table 8 displays the overall level of explanation per each represented city in the data sample. The results show a variation in the OLS model performance, exhibiting good model fits with high levels of explanation evident (Changsha, 88%; Chengde, 90%). Nonetheless, there are instances of poor model explanation (such as Shangqiu, 26%; Benxi, 24.1%) which require further investigation for value determining parameters and omitted variable bias. Accordingly, examination of the ratio benchmarks for uniformity and horizontal and vertical equity reveal a large number of the City models to conform to the accepted thresholds for both the OLS and in-sample (training) data performance ratio measurement. These results indicate that there is, on first viewing, a valid basis for developing mass appraisal systems across China's urban housing markets evidenced by the high levels of model explanation and conformance with the ratio standards across both the global GWR (training) and OLS modeling frameworks. When specifying the GWR testing (out-of-sample) model predictability, there appears to be some considerable movement in terms of the ratio benchmark performance, some of which become very poor and change from being marginally regressive to acutely progressive (and vice versa). This behavior is arguably reflective of the underpinning spatial structure of some of the markets in these cities. Indeed, two manifest issues which might appear to impact upon this are the floor area-price basis which culminates in some areas of low explanation. In some cities, basic market assumptions for in-sample versus out-of-sample testing do not conform due to discontinuities in the urban form. This is as a consequence of structural characteristics, such as community estates, which act to demarcate and regulate spatial continuity and thus price differentials based on implicit and explicit pricing based on non-continuous spatial patterns. In essence, the complex mosaic of spatial concentration as a byproduct of market characteristics cannot be explained adequately by a hold-out sample. As a result, more on-the-ground market contextualization is required for some cities upon initial inspection of the data, to complement the introduction of a mass appraisal approach.

Table 8: City-Level Prediction Accuracy

			OLS		GWR training		GWR testing	
City	Adj. R^2	Obs.	PRD	COD	PRD	COD	PRD	COD
Baishan	0.774	580	1.029	13.9	0.9672	7.41	0.436	19.65
Baoding	0.356	1239	1.041	14.6	1.034	11.15	1.177	15.16
Bayinnaoer	0.809	299	1.011	7.8	0.9995	2.6	0.657	12.77
Bengbu	0.877	97	1.004	3.8	0.9689	3.87	1.063	18.19
Benxi	0.241	109	1.014	8.7	0.9045	2.65	0.94	9.934
Binzhou	0.681	116	1.024	11.5	0.9962	3.91	0.777	15.88
Bozhou	0.556	397	1.029	13	0.9867	3.94	1.238	20.60
Cangzhou	0.772	2430	1.023	11.7	0.9946	2.01	1.017	8.052
Changchun	0.582	234	1.009	7.4	1.0363	3.2	1.043	27.99
Changsha	0.880	1580	1.03	14.3	0.9856	4.31	1.498	10.64
Changzhou	0.548	1422	1.016	8.8	0.9975	2.26	0.974	31.98
Chengde	0.904	1929	1.02	11.9	0.9967	2.99	1.059	16.26
Chengdu	0.831	2072	1.015	10.2	0.9937	3.36	0.662	16.35
Chenzhou	0.827	1605	1.02	13.9	0.9976	3.1	1.016	7.781
Chifeng	0.779	838	1.005	4.7	1.0006	1.72	1.167	6.209
Chongqing	0.800	246	1.004	4.7	1.0021	2.51	0.683	18.41
Chuzhou	0.524	1010	1.029	13.8	0.9756	4.97	0.862	6.327
Gian	0.485	461	1.001	2.7	0.9996	0.9	1.586	8.455
Hefei	0.691	544	1.003	3.5	1.0431	2.17	0.511	24.87
Jiamusi	0.741	325	1.029	13.7	0.968	4.86	0.947	12.06
Jiangmen	0.530	466	1.005	5.2	1.0266	2.02	0.951	9.956
jiaxing	0.261	111	1.02	10.5	0.9878	2.17	-	-
Jining	0.823	61	1.006	5.4	1.0246	4.13	-	-
Jiyuan	0.739	105	1.005	5.4	1.0026	2.1	-	-

			OLS		GWR training		GWR testing	
Sanming	0.685	429	1.023	11.7	0.9985	4.28	1.053	11.744
Sanya	0.849	572	1.03	14.7	1.0519	3.43	0.875	22.358
Shangqiu	0.313	202	1.019	9.3	1.0023	2.1	0.796	12.847
Shantou	0.261	649	1.013	8.2	0.9996	1.71	0.999	7.2
Shaoguan	0.708	624	1.01	7.2	0.9985	2.3	0.805	8.416
Shaoxing	0.449	1075	1.047	16.1	0.9957	4.44	1.063	12.63
Shenyang	0.784	1212	1.032	14.2	1.0031	5.22	0.888	23.938
Shijiazhuang	0.890	1373	1.012	8.3	0.9922	2.65	1.552	20.858
Shiyan	0.739	992	1.025	12.5	0.9984	3.53	0.657	13.192
Suqian	0.459	61	1.013	8.6	1.0083	3.73	-	-
The north sea	0.427	100	1.02	10	0.8472	2.66	-	-
The rising sun	0.854	437	1.027	12.6	0.9861	4.66	0.523	21.668
Yulin.	0.304	194	1.043	16.4	0.9975	4.5	0.682	10.166
Zhoushan	0.924	150	1.009	5.7	1.0017	5.13	-	-

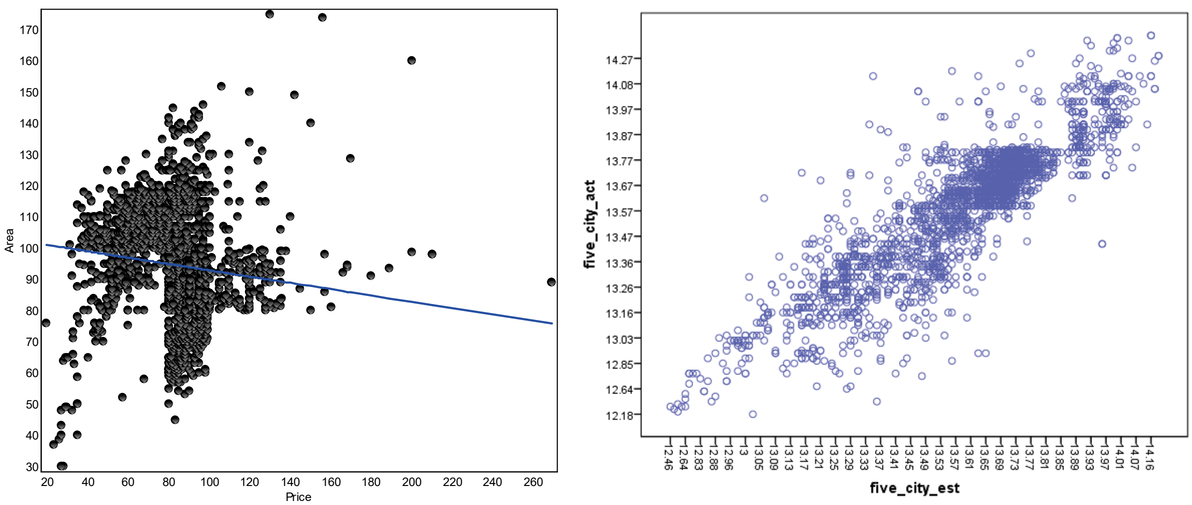
Note: Missing values are a consequence of inadequate sample size for hold-out models.

Testing the Scalability of Modeling Frameworks

At the global level, the ratio benchmarks suggest that a large number of the cities appear to conform to the accepted thresholds. Nonetheless, this would not be practical or feasible in terms of a mass appraisal approach and more micro-level analysis is required for implementation. Therefore, we select a random assortment of five (spatially dissimilar) cities (Baoding[1,239]; Bayinnaoer [299]; Bengbu [97]; Chongqing [246]; Chuzhou [1,010]) in order to test a more regional (or subset) model to examine the level of performance and the spatial variation (for differing sample sizes) of the included characteristics such as property size (area) coefficients in a more municipal setting. This approach forms the basis of estimation, from a CAMA perspective, of spatial heterogeneity and determination of value significant attributes for predictive estimation of the sold versus unsold stock. Examination of the price and area relationship provides an insight as to the differing trends across each distinct region. It is clearly manifest that there are marginal or partial differences in the fundamental floor area and price association spatially as observed in Figure 3, giving rise to homoscedastic and heteroscedastic bias in the adoption of a wider model at this level. Nonetheless, employing a reduced model structure to account for significant predictors across all city jurisdictions, the GWR model shows an R^2 of 76.3% (F=109.182, p<.001). The results show a differing pricing effect across the coefficient ranges signifying a marginal effect, in a spatial sense, with floor area commanding a pricing effect of 0.0048 at the lower quartile to 0.011 at the upper quartile. In terms of model inequity and uniformity, the PRD statistic equates to 1.19 with the COD equal to 26 percent signalling elevated levels of regressivity and dispersion outside the accepted ratio benchmarks for inequity and uniformity conformance. As Figure 3 exhibits, the predictive accuracy shows structural breaks and, to a large extent, homogeneity of variance, with various tangential "column" structures evident in the data. It also shows aspects of heteroscedasticity indicating inflated variances which present questions concerning model structure and further investigation of techniques for increasing robustness such as boosted regression trees, lasso regression, and random forest regression algorithm.

The findings seemingly infer that more regionally based CAMA models would be presented with a number of core challenges even with the application of a consistent parameter subset. The varying and almost chaotic nature of the price and floor area (size) relationship—compounded by spatial (dis)aggregation—would make the introduction of a mass appraisal system at this scale demanding if not infeasible. In saying that, international practice would, in any case, suggest that bespoke models should be developed for each district and/or metropolitan area.

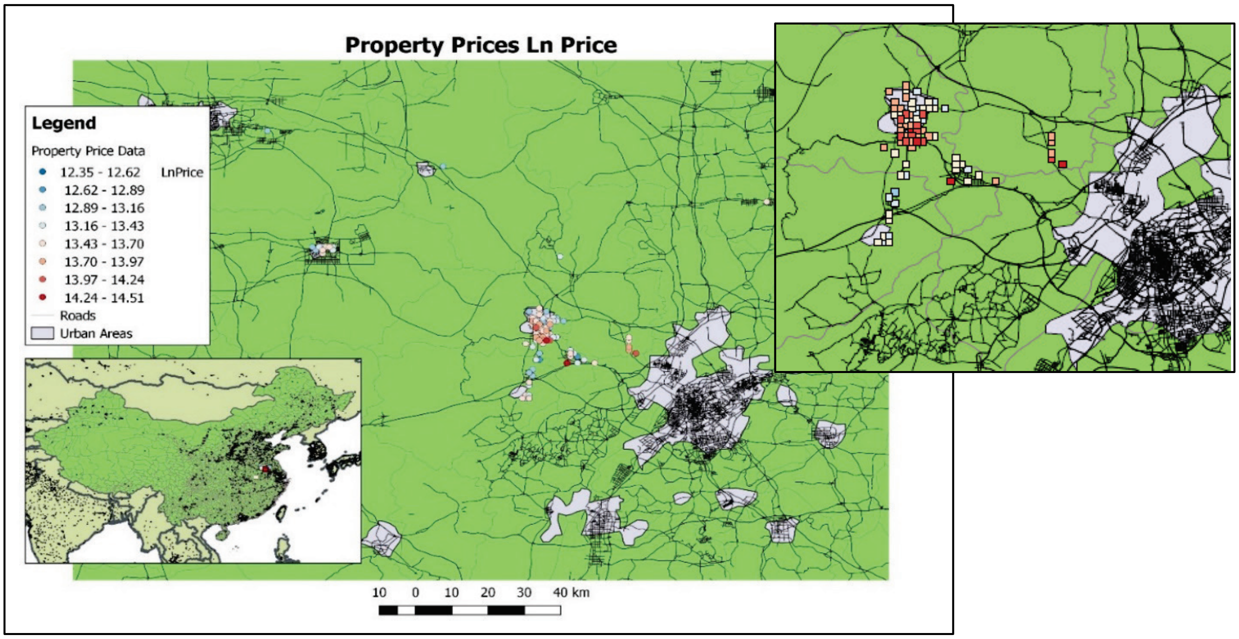
Figure 3: Price*Area Relationship and Predictive Accuracy of Regional-Level Analysis



Administrative City-Level Models

The analysis is extended to examine the feasibility of "city" based mass appraisal models within particular locales. Undertaking this exercise demonstrates the application of the data subset accounting for differing sample sizes and the viability of the data. This analysis takes account of three Cities (Chuzhou, Baoding, and Beijing) in order to rationalize the feasibility of the development of city-based valuation models for spatial and market differentiation. Chuzhou is a prefecture-level city in eastern Anhui Province, China comprised of two administrative divisions, two districts, four counties, and two county-level cities. The listed price evidence for Chuzhou city area captures data from seven out of the eight administrative divisions at the administrative district and submarket level (Figure 4). Similarly, Baoding is a prefecture-level city in central Hebei province, approximately 150 kilometers southwest of Beijing and constitutes three urban districts and two counties. Baoding is ranked 7th amongst 13 Chinese cities with a population of over 10 million. Finally, Beijing is analyzed due to its stature being the capital city and is governed as a municipality under the direct administration of central government with 16 urban, suburban, and rural districts.

Figure 4: Chuzhou Price Data



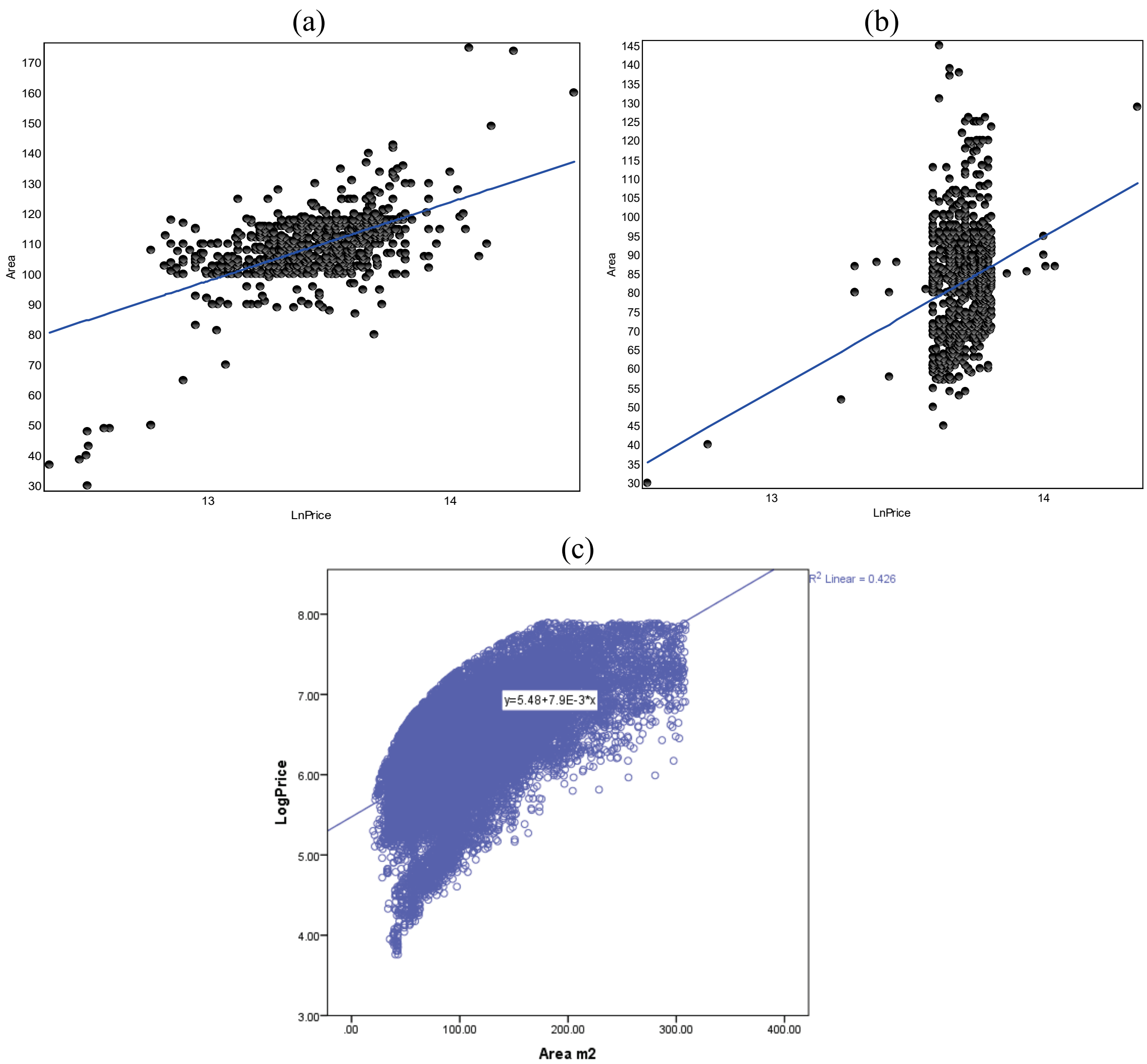
In terms of market characteristics, the Chuzhou market reveals that three-bedroom properties represent 93.4 percent of the list market, a similar trait for two apartments comprising two bathrooms which account for 95.7 percent of the data. Apartments comprise 98.8 percent with the specification of no decoration representing 99.3 percent and south orientation[10] accounting for 98.5%. The Baoding market data exhibits apartments to represent 99.4 percent of the list prices, constituting 83.5 percent with two bedrooms. Over 95 percent of the sample data reveals properties to comprise a high-end specification. The data illustrates high homogeneity in the housing stock, therefore on initial inspection portrays feasibility for mass appraisal exercises. The data for Beijing is relatively rich, in modeling terms, and demonstrates a consistent spatial coverage (albeit in the urban core) as depicted previously in Figure 1b. The composition of the property stock for the analysis shows more variation and heterogeneity as opposed to the other prefectural cities examined. This is perhaps understandable given its long history and arguably more established market system. The data shows two-bedroom properties to represent 47 percent of the sample with one-bedroom properties constituting 16.7% and three bedrooms accounting for 29.3 percent. Studio apartments dominate with 90.3 percent, duplexes represent 6.3 percent, and houses making up the remainder. One living room apartments equate to 70.9 percent with apartments comprising two living areas representing 24.5 percent, a similar position for the number of bathrooms which reveal one-bathroom apartments to account for 71.3 percent and two bathrooms 24.9 percent respectively.

The price by floor area relationships for each city can be observed in Figure 5. For the Chuzhou market, the price-size relationship reveals a 34 percent level of explanation thereby providing a relatively stable basis for determining market value. In contrast, for Baoding city, the level of explanation is more characteristic and reflective of inelasticity in terms of price versus size

[10] This coefficient encompasses the range from southeast to southwest.

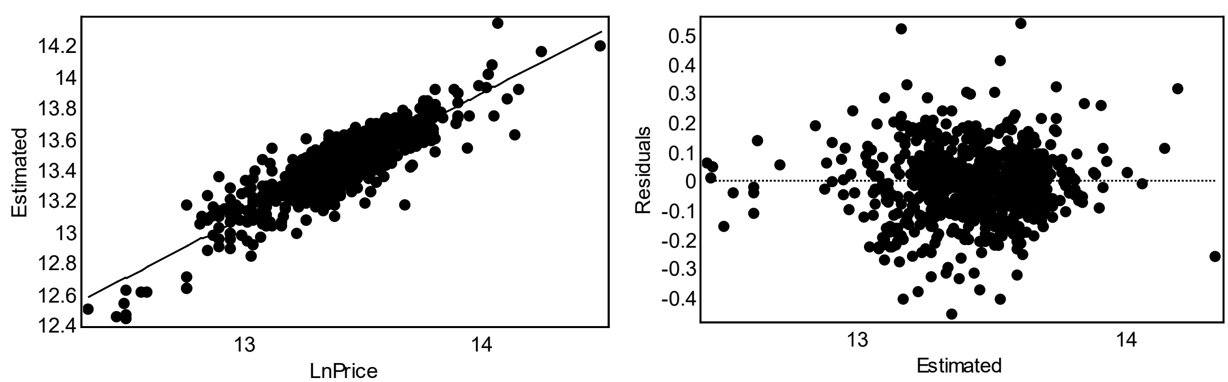
variation. Indeed, this seemingly poses challenges for any floor area–based tax model and presents a few issues for AVM approaches at the city level. With regards to Beijing (Figure 5c), the floor area and log price relationship explains 42.6 percent, although heteroscedasticity with skewness present in the area parameter. Nonetheless, the relationship for the Beijing market provides a good basis for a floor area market AVM.

Figure 5: Price and Area Relationship in Chuzhou, Baoding and Beijing



In terms of city model performance, for the Chuzhou region, the model shows an 82.4% level of explanation significant at the 1 percent level ($F = 31.06$, $p<.001$). The model coefficients (Appendix A) show floor area (property size) to be a significant determinant with both the bedrooms and bathroom coefficients conforming to expectation, although one-bedrooms are outside any acceptable level of significance ($p>0.5$). The results also signal that the floor level the property is situated on is a significant parameter for value, in this instance inferring that units located on the lowest floors command more of a premium, a finding also evident for newer properties. The estimates also illustrate different price effects (and significance) across delineated submarket areas. In addition, the GWR model displays an (Pseudo) R^2 of 79.1% (F = 38.22, p<.001). The local R^2 statistics within the GWR model, highlight high spatial depiction of the model performance with the R^2 values ranging from 24 to 94 percent and illustrate where the model has more enhanced performance (Appendix A). The GWR model parameter estimates clearly illustrate the spatial variation in the market pricing and the effect of the various property characteristics. The property size coefficient (Area) displays an increased effect across the quartiles (Appendix A). This is also symptomatic for the bedroom, bathroom, floor range, and age coefficients which all exhibit both negative and positive influences across the market geography. Accounting for this spatial variation offers important insights and provides a strong spatial basis for isolating market areas where model performance is weak for tailoring more local mass appraisal systems. Indeed, it provides insights regarding further investigation and aspects which need to be accounted for in terms of understanding market substitution, the spatial nature of value, significant coefficients, and thus mass appraisal efficacy. In terms of model stability, the standard residual diagnostics (histogram of residuals and the plot of the observed versus predicted values) show the model to be stable with limited error variance and normally distributed residuals (Figure 6).

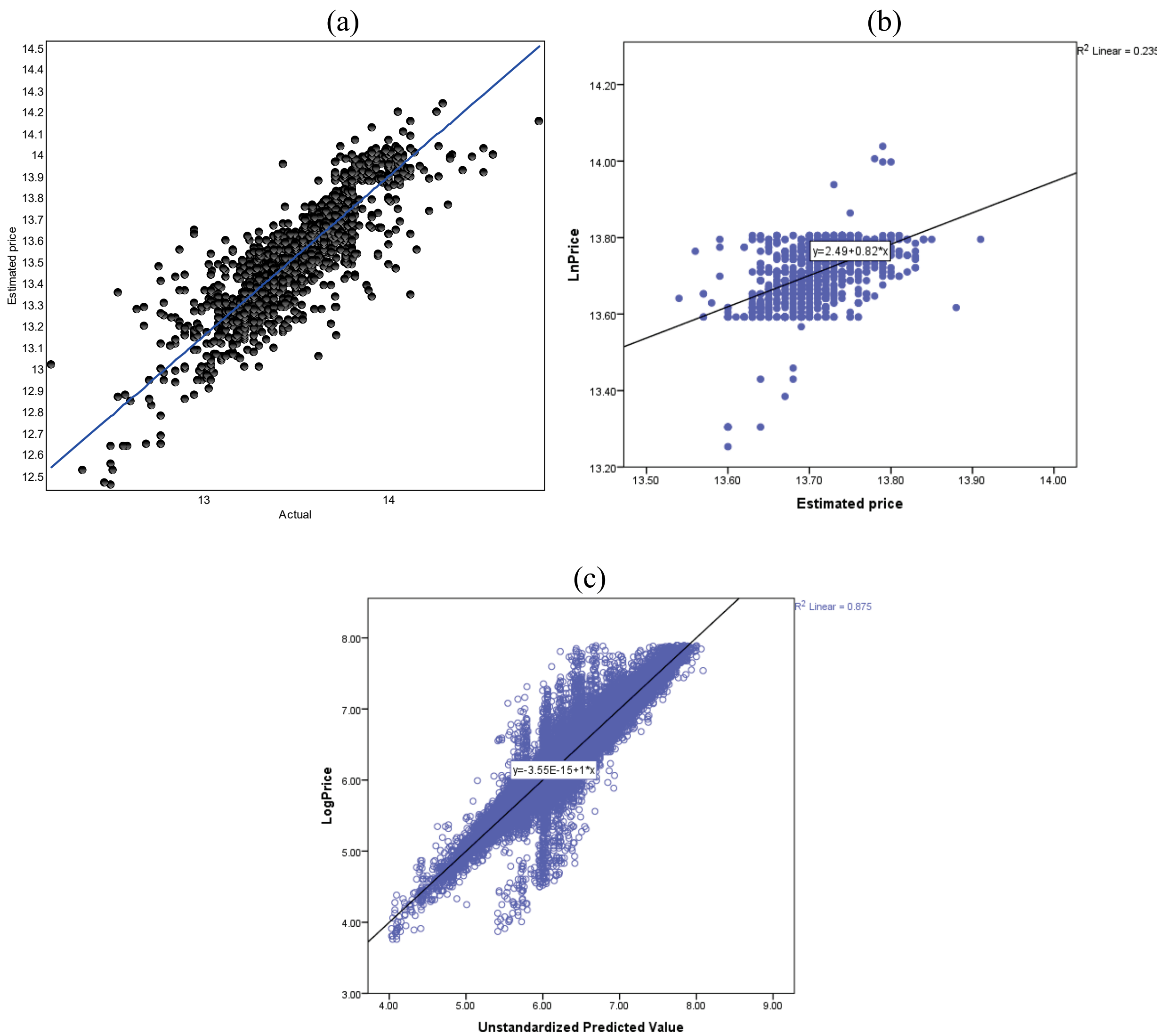
Figure 6: Estimate and Actual Log-Prices and Residuals



For Baoding, model coefficients are presented in Appendix A. The model explanation exhibits an R^2 of 35.6% (F =8.601, p<.001). The model significant parameters reveal a number of archetype physical characteristics demonstrate statistical significance such as floor area, age and low floor level providing a platform for more investigative analysis for implementation of a CAMA approach, whilst clearly demonstrating that investigation to identify additional value significant attributes (such as "site positive"/"site negative") or further spatial delineation would be required prior to operationalisation. Moreover, for the Beijing market, the overall model performs strongly in terms of predictive accuracy (87.5 percent). Given the increased heterogeneity of the Beijing market, the nature of the property stock variation by type and age and relativity of market size, the findings clearly illustrate that market features and characteristics can be readily used and integrated into a mass appraisal system.

Turning to the uniformity and equitability standards, the model evaluation for Chuzhou city falls within the accepted threshold of the ratio benchmarks revealing a PRD of 1.029 which displays slight regressivity and a COD of 13.8 percent. The results suggest good feasibility for introducing *ad valorem*-based tax assessment in this city area. These findings are complimented with the GWR model where the PRD equates to 1.012 with the COD equal to 8.2 percent, providing greater model accuracy and reliability—and pertinently, demonstrates the viability of introducing a fair and equitable property tax. This is also evidenced in the scatterplot (Figure 7) which highlights the association between the predicted value and actual values. With regards to Baoding city, the ratio standards are better than expected given the relatively poor level of explanation (35.8 percent). Analysis of Figure 7(b) shows Baoding to comprise a PRD of 1.083 and a COD of 12.04 showing it to conform to uniformity and a degree of regressivity. This is undoubtedly due to the high degree of market homogeneity in the market (sample data) as the data clusters symmetrically. With regards to Beijing, the predictive accuracy of the actual versus the predicted shows a noteworthy and in large parts deterministic relationship. The PRD (1.01) and COD of 13.1 percent indicates that a mass appraisal model could be adopted and operationalized.

Figure 7: Actual Versus Predicted Values for Chuzhou, Baoding, and Beijing



Discussion

The general OLS models show predictive competency from the general set of property and spatial characteristics—a process which is uniform across the cities included. Pertinently, the global mass appraisal performed diligently for an overall model accounting for spatial dummies with ratio statistics falling within acceptable IAAO benchmarks. This was also evident for the mass GWR-based assessment, nonetheless this was demonstrated to be more sporadic when applying the hold-out sample—signifying some preliminary challenges for using the "sold" housing stock characteristics to value the unsold stock in China at this spatial scale. Analysis at the city level highlights increased levels of spatial concentration in geographic clusters, inferring price variation at the same location. These instances of spatial containment appear to be resulting in distinct market structures resulting in different pricing levels certainly vertically (based on the floor level) and marginally horizontally across the developments within each designated housing estate. This spatial clustering is compounded by the high homogeneity of the housing stock which are priced similarly, marginally (partial differences) and differently all at the corresponding locations. Indeed, whilst the city models are not without their "local" challenges, this also affords an opportunity, and the feasibility, to build very robust and standardized models which can readily be adjusted for each region. Nevertheless, it must be noted that a simple pricing on a m^2 basis could present challenges given the reduced level of explanation against price (of floor area) as depicted by lower R^2 values than traditionally observed in market economies. Significantly, deterministic traditional market structures evident in China are not fully in line with Western economics, which employ highly specified hedonic models (+ spatial models). There appears to be instances of model over-fitting which requires further investigation for fruitful adoption of mass appraisal exercises, perhaps indicative of rapid, (new) homogenous development. The level of explanation being achieved is without accounting for market tastes or embedding any further socio-economic (market based) profiling symbolizes the necessity to apply more basic model formats, initially to ascertain value significant market characteristics. Indeed, a consideration for both feasibility and scalability is the concept of 'Community' or 'scheme' based valuation models—which may be achievable if wider amenities and facilities are implicit in the pricing of housing estates and developments. This could also take the form of more simplified valuation approaches such as calibrating floor area to create a value weighted floor area and then undertaking a banding approach.

Examination of additional spatial approaches presents some areas for further discussion and investigation. Eigenvector-based Spatial Filtering is initially tested to investigate other achievable spatially based approaches for analysis. This approach calculates eigenvectors using a centered distance connectivity matrix using geographic coordinates which truncates the distance using a maximum distance calculation which connects all sampling units under a minimum decision tree criterion. Model parameters are used to guide the filter selection which is premised upon a minimization of Moran's I threshold ($p<.05$). Initial screening for undertaking this method illustrates that at the city level (Chuzhou), the given set of coordinate variables and connectivity criterion yields no reliable filters, which is a consequence of the (usually simple) spatial distribution and shape of domain. This is indicative of high geographic clustering and little variation signaling spatial representation shows elevated levels of autocorrelation across the distance class units for the estimated and the residuals. This poses challenges for the ratio analysis and whether there is over-fitting or because the relative homogeneity of the stock and limited variation spatially. This warrants further analysis in terms of integration into mass appraisal modeling.

Conclusions

The analysis has been based on a large dataset of list prices of residential property drawn from a number of Tier 1 to Tier 4 cities in China. The datasets utilized provide evidence of the scale and nature of market information available to underpin mass appraisal activity in China. Any operationalized tax policy would almost certainly develop more sophisticated datasets, potentially linked to achieved prices from verified market transactions (ordinarily derived from transfer tax declarations). It must also be acknowledged that any such dataset may not adequately represent the full range of properties which would require to be valued in a full *ad valorem* exercise—perhaps being skewed towards newer properties or overly spatially concentrated, leaving older properties and some locations under-represented. Nevertheless, it does represent a significant data resource which covers many of the major population centers and prefecture-level cities and is therefore a solid 'test bed' to investigate both the feasibility and scalability questions central to this research. With regards to the feasibility question: it is evident that it is possible to acquire significant datasets of property prices and associated (potentially) value significant attributes, which are ostensibly in the public domain and subject to scrutiny. This in itself is a considerable finding, as many emerging economies do not have 'live' market data sources to access for this type of research.

After routine data cleansing and purging exercises, initial modeling using standard and multiplicative OLS approaches, augmented by GWR techniques allows us to adequately model the list prices in line with internationally accepted benchmarks of accuracy and uniformity, with increasing performance achieved as the crucial element of location is more explicitly included within the model specification. To the extent that the data is representative of the population at large, the initial findings suggest that mass appraisal is practically feasible for urban areas in China—adequate market data appears to exist which meets the requirements for hedonic analysis, particularly with a spatial dimension.

In terms of scalability, it must be acknowledged that the results are not uniform across all markets. There are areas which have limited data and cannot adequately be modelled, a dimension to be mindful of for mass appraisal exercises. Operationalization activities may adequately address this aspect as discovery of adequate data may be possible. In some areas the models perform slightly less well and may require better data or more tailored calibration. Several models appear to work *too well*, raising concerns regarding the data and the underlying pricing mechanism, which may be being overtly driven by a more rudimentary or "simplistic" pricing mechanism in largely new, large scale and uniform development areas. This may well "unwind" as more properties enter the resale markets and normal market forces begin to take precedence over a developer input cost model of pricing. It is also clear that there are many ways in which submarket calibration could be carried out, with physical aspects such as the pricing effect of altitude in high rise developments not being uniform from place to place (perhaps driven by view, air quality parameters, or issues such as elevator maintenance, perceived fire safety having a pricing effect but without appropriate parameters contained within the data).

However, it is highly unlikely that a single model form would be deployed across such a vast socio-economic and physical geography, so this is entirely acceptable.

One important dimension which has surfaced during the model building exercises is the issue pertaining to market structure, topography and the value enhancing attributes. The complex non-continuous urban form and structure, principally the designation of "community value" appears to create isolated or non-continuous pricing relationships which seemingly prohibits the varying nature of price determination. These "distinctive" market characteristics appear to distort wider scalability of introducing basic tax models for CAMA exercises and appears to be a barrier for implementation of any spatial framework to be introduced. Indeed, an inherent problem is that more simplified approaches may not conform to accuracy and face challenges in particular jurisdictions of fundamental market value basics (such as the lack of a strong floor area to value relationship), with more sophisticated approaches simultaneously risking the introduction of both omitted variable bias and mis-attribution issues, whilst being essential for trying to explain extreme locational fluctuations. Furthermore, when testing more enhanced spatial modeling frameworks (namely Spatial Error, Spatial Lag and Conditional Autoregressive models, in addition to the GWR), to account for spatial heterogeneity and model accuracy, a consistent challenge regarding singularity for the spatial weighting matrices emerged.

The main finding is that from place to place, and with few exceptions, available market evidence can facilitate an adequate basic valuation exercise. From a number of typical value significant attributes, robust models can be built which conform with horizontal and vertical inequity tests. In this regard it can be argued that there are no fundamental barriers to scalability. The model findings thus demonstrate a good ability to utilize value capture–based coefficients in a wider model with more tailored models also showing promise at the city and administrative level.

The scale and nature of the data sourced and deployed for this research augers well for efforts to operationalize mass appraisal in China, at least within the 'market sector'. Some areas which demonstrate very narrow pricing variation, or areas with thinner markets may well benefit from consideration of more simplified approaches, particularly in the billing mechanism, such as banding, particularly from the benefits and efficiency of taxation perspective, but there is nevertheless adequate evidence that recognizably modern mass appraisal approaches can be devised and deployed to support national coverage of a property tax in China. To implement a nationwide *ad valorem* property tax, China needs to become more transparent with transacted market data. Setting that debate aside, it needs to address the basic questions as to what market characteristics are available and significant (statistically) in the sold stock minority, in order to apply these to the unsold majority, for equitable and fruitful implementation of an *ad valorem* property taxation moving forward. Whilst this augers well, it must always be recognized that whilst appraisal is both necessary and challenging, and whilst this research suggests that it is viable, the resulting tax base is primarily a sharing mechanism. The ultimate success of any property tax introduced will depend upon the wider administration aspects of discovery, billing, collection and enforcement and will be measured by the size, efficiency, stability and buoyancy of the vital municipal revenues it generates.

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Appendix A

OLS Model Coefficients for Chuzhou

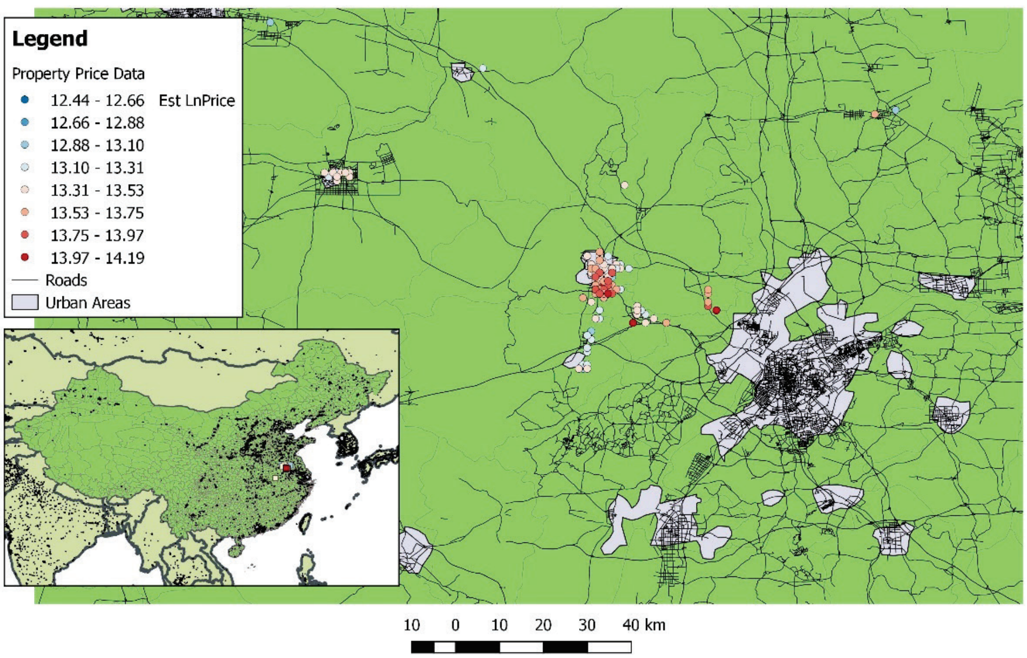
	B	t	Sig.	Tolerance	VIF
(Constant)	12.139	149.422	0.000		
Area	0.011	15.885	0.000	0.495	2.022
Bed1	-0.059	-0.647	0.518	0.336	2.980
Bed2	-0.071	-1.761	0.079	0.888	1.126
Bed4	0.174	5.544	0.000	0.896	1.117
Bath2	0.068	1.790	0.074	0.510	1.962
Bath3	0.369	4.591	0.000	0.665	1.503
Specification Low-end	-0.230	-1.865	0.063	0.985	1.015
Specification High-end	0.165	1.990	0.047	0.875	1.143
Specification Mid-end	-0.117	-1.322	0.187	0.734	1.412
High-end Apartment	0.000	0.002	0.998	0.488	2.050
House	0.015	0.135	0.893	0.853	1.172
multifamily (No)	-0.011	-0.910	0.363	0.952	1.050
East Ori	-0.031	-0.522	0.602	0.833	1.200
West Ori	-0.073	-0.394	0.694	0.875	1.142
North Ori	-0.108	-1.223	0.222	0.962	1.040
Floor range low	0.051	3.750	0.000	0.833	1.201
Floor range low-low	0.631	6.859	0.000	0.887	1.127
Floor range High	0.004	0.300	0.764	0.883	1.133
Age 1	-0.007	-0.383	0.701	0.659	1.518
Age 2	0.072	3.612	0.000	0.681	1.468
Age 3	0.105	5.738	0.000	0.561	1.783
Age 4	0.120	5.514	0.000	0.671	1.490
Age 5	0.071	3.026	0.003	0.731	1.367
Age 6	0.048	1.993	0.046	0.718	1.392
Age 7	0.062	1.045	0.296	0.955	1.047
Age 8	0.033	1.109	0.268	0.813	1.230
Age 9	-0.130	-1.000	0.317	0.887	1.128
Age 10	-0.087	-1.111	0.267	0.971	1.030
Age 11	0.087	0.490	0.624	0.946	1.057
Age 13	0.033	0.324	0.746	0.963	1.039
Age 18	-0.028	-0.159	0.874	0.991	1.009
Submarket Reed {langya}	0.001	0.055	0.956	0.869	1.151
Submarket Tianchang	0.320	6.746	0.000	0.965	1.036
Submarket Nanqiao	-0.170	-4.366	0.000	0.965	1.036
Submarket fengyang	-0.369	-2.070	0.039	0.945	1.058
Submarket Lai'an	-0.182	-3.542	0.000	0.958	1.044
Submarket mingguang	-0.397	-2.279	0.023	0.989	1.011
Submarket quanjiao	-0.217	-10.843	0.000	0.907	1.103

GWR Coefficients for Chuzhou

Variable	Minimum	Lwr Quartile	Median	Upr Quartile	Maximum
Constant	8.26318	11.89868	12.16343	12.49154	13.17878
Area	0.00026	0.00819	0.01036	0.01284	0.025
Bed	-0.19211	-0.05196	0.04959	0.12309	0.50621
Bath	-0.34554	-0.01933	0.0495	0.10495	0.52754
Age Prop	-0.1185	-0.01406	-0.00543	0.00342	0.01853
Total no. floors	-0.00578	-0.00135	-0.00027	0.00286	0.01711

Spatial function: Bi-Squared; Adaptive Kernel: 15% neighbours. Optimization using The Golden Section Search, and Akaike Information Criterion (AICc).

Figure: GWR Model Estimated Prices for Chuzhou



OLS Model Coefficients for Baoding

	B	t	Sig.
(Constant)	13.243	497.320	0.000
Area	0.004	15.896	0.000
Bed 1	-0.077	-4.560	0.000
Bed 3	-0.013	-1.803	0.072
Bed 4	-0.039	-0.542	0.588
Bath 3	0.032	0.449	0.653
specification No-decoration	0.002	0.125	0.901
East Ori	0.002	0.151	0.880
West Ori	0.046	2.332	0.020

	B	t	Sig.
North Ori	-0.047	-1.862	0.063
Floor range low	-0.006	-1.087	0.277
Age 0.0	0.009	0.822	0.411
Age 1.0	0.001	0.047	0.962
Age 2.0	0.050	4.167	0.000
Age 3.0	0.011	0.917	0.360
Age 4.0	0.023	1.726	0.085
Age 5.0	0.034	2.757	0.006
Age 6.0	0.038	3.174	0.002
Age 7.0	0.043	1.728	0.084
Age 9.0	0.006	0.333	0.739
Age 10.0	0.014	1.078	0.281
Age 11.0	0.006	0.155	0.877
Age 12.0	0.034	2.150	0.032
Age 13.0	0.038	3.226	0.001
Age 14.0	0.026	1.547	0.122
Age 15.0	0.011	0.916	0.360
Age 16.0	-0.003	-0.170	0.865
Age 17.0	-0.017	-0.709	0.478
Age 19.0	0.004	0.304	0.761
Age 20.0	-0.007	-0.689	0.491
Age 21.0	0.035	1.405	0.160
Age 23.0	0.006	0.180	0.857
Bath 1.0	0.010	1.910	0.056
High-end Apartment	0.026	0.832	0.406
House	0.163	3.077	0.002
specification Low-end	0.011	0.802	0.423
Multifamily	0.005	1.164	0.245
Floor range High	-0.005	-0.850	0.395
Floor range low-low	-0.030	-1.850	0.065
Age 8.0	0.026	2.197	0.028
Age 22.0	0.013	0.435	0.664
Age 24.0	0.045	0.893	0.372
Age 25.0	-0.028	-0.381	0.703
Age 28.0	0.016	0.309	0.757
Submarket Agriculture ecology garden	0.048	1.489	0.137
Submarket AnXin	0.196	2.732	0.006
Submarket Baoding 7	0.154	7.255	0.000
Submarket Baoding academy	0.051	2.449	0.014
Submarket DE letter culture park	0.119	11.240	0.000
Submarket Development zone	0.141	7.843	0.000
Submarket DingXing	0.043	0.839	0.402

	B	t	Sig.
Submarket Electricity valley industrial park	0.174	8.445	0.000
Submarket Gaobeidian surrounding	0.008	0.457	0.648
Submarket GuLian lotus pond	0.127	10.432	0.000
Submarket Han jiang village	0.142	1.992	0.047
Submarket Hebei nongda	0.109	8.463	0.000
Submarket Hebei primary school	0.136	10.127	0.000
Submarket High open area	0.152	8.803	0.000
Submarket I came	0.334	4.628	0.000
Submarket Jiang in urban and rural areas	0.055	0.775	0.439
Submarket King shop	0.122	5.184	0.000
Submarket LaiShui	-0.035	-2.179	0.029
Submarket Large volume of sales	-0.014	-0.425	0.671
Submarket Lianchi district government	0.194	10.739	0.000
Submarket Longtan park	0.138	10.894	0.000
Submarket Military academy square	0.150	5.524	0.000
Submarket Outside the northwest sanhuan	0.107	1.509	0.132
Submarket Provincial hospital	0.147	9.352	0.000
Submarket Qing yuan district government	0.013	0.618	0.537
Submarket QuYang	0.072	1.380	0.168
Submarket Should the city	0.073	1.446	0.148
Submarket South township	0.040	1.240	0.215
Submarket TV park	0.169	7.727	0.000
Submarket The Great Wall automobile industrial park	0.214	2.978	0.003
Submarket The city	0.020	1.955	0.051
Submarket The east lake area	0.181	6.480	0.000
Submarket The northeast outside the third ring road	-0.003	-0.082	0.935
Submarket The people's square	0.144	9.669	0.000
Submarket The railway station	0.144	8.824	0.000
Submarket The twin towers	0.124	3.340	0.001
Submarket The zoo	0.160	8.522	0.000
Submarket Three primary school righteousness	0.121	6.129	0.000
Submarket West lugang	0.090	5.701	0.000
Submarket Xiong county	0.031	1.283	0.200

	B	t	Sig.
Submarket Xu Shui district government	0.057	3.833	0.000
Submarket Zhuozhou bilingual school	0.172	5.654	0.000
Submarket Zhuozhou surrounding	0.100	11.146	0.000
Submarket downtown	0.100	3.225	0.001
Submarket huambo	0.154	7.891	0.000
Submarket volunteers	-0.204	-4.733	0.000
Submarket yihsien	-0.019	-0.455	0.649

Appendix B: Full Model (with spatial community representation)

	B	Std. Error	Beta	t	sig
(Constant)	6.063	0.004		1568.524	0.000
Beds=1.0	-0.270	0.003	-0.184	-80.801	0.000
Beds=3.0	0.199	0.003	0.166	69.560	0.000
Beds=4.0	0.388	0.006	0.162	66.056	0.000
Beds=5.0	0.417	0.011	0.082	36.907	0.000
Beds=6.0	0.390	0.022	0.035	17.726	0.000
Beds=7.0	0.539	0.064	0.016	8.487	0.000
Beds=8.0	0.394	0.158	0.005	2.491	0.013
Living=0.0	-0.209	0.007	-0.068	-31.089	0.000
Living=2.0	0.078	0.003	0.061	25.630	0.000
Living=3.0	0.144	0.012	0.025	11.605	0.000
Baths=2.0	0.165	0.004	0.131	46.201	0.000
Baths=3.0	0.351	0.008	0.113	42.543	0.000
Baths=4.0	0.485	0.015	0.070	32.005	0.000
Baths=5.0	0.710	0.050	0.028	14.263	0.000
Build_Ori=East	-0.002	0.003	-0.002	-0.778	0.437
Build_Ori=North	-0.119	0.007	-0.035	-16.625	0.000
Build_Ori=West	-0.013	0.003	-0.008	-3.642	0.000
Type=dulplex flat	-0.044	0.006	-0.014	-7.048	0.000
Type=other	-0.051	0.006	-0.017	-8.293	0.000
Standard=other	-0.052	0.003	-0.035	-16.117	0.000
Standard=simple	-0.035	0.002	-0.031	-14.851	0.000
Heatingtype=Independent	0.002	0.004	0.001	0.483	0.629
Floorlevel=ground floor	-0.015	0.004	-0.009	-4.230	0.000
Floorlevel=high floor	0.002	0.003	0.001	0.710	0.478
Floorlevel=low floor	0.004	0.003	0.003	1.436	0.151
Floorlevel=top floor	-0.002	0.003	-0.002	-0.757	0.449
Community=	0.166	0.102	0.003	1.620	0.105
Community=10AM 新坐标	0.164	0.038	0.007	4.268	0.000
Community=10 号名邸	0.979	0.205	0.008	4.780	0.000
Community=11 站	-0.078	0.118	-0.001	-0.660	0.509
Community=45 所 2 区	-1.104	0.102	-0.019	-10.781	0.000
Community=621 小区	0.061	0.072	0.001	0.836	0.403
Community=78 墅	0.761	0.145	0.009	5.245	0.000
Community=8 哩岛	-0.101	0.053	-0.003	-1.901	0.057
Community=@北京	-1.043	0.084	-0.022	-12.462	0.000
Community=A 派公寓	0.639	0.073	0.015	8.803	0.000
Community=BOBO 自由城	0.262	0.068	0.007	3.835	0.000
Community=CBD 传奇	0.384	0.045	0.015	8.555	0.000
Community=CBD 国际高尔夫别墅	0.461	0.205	0.004	2.249	0.025
Community=CBD 总部公寓一期	0.741	0.062	0.021	11.991	0.000

	B	Std. Error	Beta	t	sig
Community=CBD 总部公寓二期	0.638	0.077	0.014	8.237	0.000
Community=CLASS	1.003	0.102	0.017	9.790	0.000
Community=DBC 加州小镇	-0.016	0.048	-0.001	-0.334	0.738
Community=DBC 加州小镇 C 区	0.040	0.053	0.001	0.748	0.454
Community=K2 清水湾	-0.009	0.038	0.000	-0.232	0.817
Community=K2 玉蘭湾	0.201	0.040	0.009	4.983	0.000
Community=M5 朗峰	-0.200	0.103	-0.003	-1.952	0.051
Community=MASTER 领域	0.171	0.069	0.004	2.490	0.013
Community=SOHO 北京公馆	1.053	0.092	0.020	11.477	0.000
Community=SOHO 现代城	0.402	0.029	0.024	13.887	0.000
Community=TBD 云集中心	-0.037	0.053	-0.001	-0.705	0.481
Community=UHN 国际村	0.748	0.028	0.047	27.120	0.000
Community=US 联邦公寓	0.837	0.068	0.021	12.246	0.000
Community=V7 九间堂	0.488	0.145	0.006	3.361	0.001
Community=gogo 新世代	0.007	0.038	0.000	0.192	0.848
Community=一万米家园	-0.431	0.068	-0.011	-6.305	0.000
Community=一品亦庄	0.255	0.092	0.005	2.780	0.005
Community=一幅画卷	0.024	0.118	0.000	0.205	0.838
Community=一栋洋房	0.285	0.145	0.003	1.969	0.049
Community=一栋苑	0.028	0.205	0.000	0.135	0.893
Community=一瓶	1.181	0.118	0.017	9.985	0.000
Community=一瓶四和院	0.618	0.145	0.007	4.263	0.000
Community=七一宿舍	-0.433	0.102	-0.007	-4.227	0.000
Community=七彩华园	0.475	0.092	0.009	5.188	0.000
Community=七星园	-0.066	0.065	-0.002	-1.021	0.307
Community=七棵树东大街 120 号院	-0.324	0.205	-0.003	-1.581	0.114
Community=七棵树东大街小区	-0.632	0.102	-0.011	-6.171	0.000
Community=七省办	0.205	0.145	0.002	1.416	0.157
Community=七贤村	0.337	0.205	0.003	1.647	0.099
Community=七里庄路	-0.239	0.205	-0.002	-1.170	0.242
Community=七里庄路 18 号院	-0.293	0.205	-0.002	-1.431	0.152
Community=万事吉公寓	0.447	0.145	0.005	3.087	0.002
Community=万博苑	0.752	0.068	0.019	11.002	0.000
Community=万和世家	1.017	0.084	0.021	12.157	0.000
Community=万国城 MOMA	1.068	0.034	0.054	31.117	0.000
Community=万地名苑	0.093	0.205	0.001	0.455	0.649

	B	Std. Error	Beta	t	sig
Community=万寿园	0.803	0.102	0.014	7.840	0.000
Community=万寿寺北里	0.152	0.118	0.002	1.283	0.200
Community=万寿路 15 号院	0.670	0.205	0.006	3.271	0.001
Community=万寿路 18 号院	0.243	0.205	0.002	1.189	0.234
Community=万寿路 1 号院	0.100	0.092	0.002	1.093	0.274
Community=万寿路 24 号院	0.356	0.205	0.003	1.738	0.082
Community=万寿路 4 号院	0.720	0.205	0.006	3.515	0.000
Community=万寿路甲 15 号院五区	0.339	0.205	0.003	1.655	0.098
Community=万寿路甲 15 号院四区	0.436	0.145	0.005	3.012	0.003
Community=万寿路西街 11 号院	0.381	0.092	0.007	4.162	0.000

Note: A parsimonious number of community locales are presented, the other 4,884 are available upon request