What if Beijing had enforced the 1st or 2nd greenbelt? --- Analyses from an economic perspective

Abstract

Many fast growing cities have designated greenbelts but have failed to maintain them. This is often attributed to weak planning regulations, but there is little understanding of the underlying impacts of greenbelts on the interactions among land use control, transport supply and economic activities. This paper presents a counterfactual analytical model to examine the greenbelts' impacts on consumers' utility, producers' productivity, and their locational choices. The model establishes historic-what-if scenarios and compares what historically happened with what could have happened under alternative levels of greenbelt interventions. The model is applied to Beijing, which intended to establish two greenbelts in 1994, but large parts of the greenbelts have disappeared under fast urban expansion. The model compares the economic impacts of the greenbelts as they stood with hypothetical fully-enforced greenbelts and no-greenbelt scenarios from 1990 to 2010. The modelling results show that the two greenbelts, if fully enforced, would have decreased consumer surplus by $202 million in Beijing in 2010. To fulfil the policy aim of decentralisation, transport improvements between the city and new towns are crucial. For a more effective implementation of greenbelts in the future, development constraints could be carefully removed from non-ecologically sensitive sites which are served with good transport conditions.

Key words

Greenbelt; greenbelt evolution; policy review; counterfactual planning; land use and transport interaction; spatial equilibrium

1. Introduction

Greenbelts are a key instrument for safeguarding the environment, providing open space and containing excessive urban expansion in a large number of cities, such as London (Amati, 2008), Vienna (Amati, 2008), Melbourne (Buxton & Goodman, 2003), Hong Kong (Tang, Wong, & Lee, 2007), Seoul (Kim & Kim, 2008), and Ontario (Carter-whitney & Esakin, 2010) among others. Cities in emerging economies, for example, Beijing, Bangalore and Sao Paulo, also intended to establish greenbelts for their environmental benefits and aesthetic value (Adkin, 2009; Han & Long, 2010).

However, it is common to see greenbelt plans falter in fast expanding cities. For example, the planned greenbelt disappeared under urban expansion in Tokyo after the Second World War (Okata & Murayama, 2011). In Beijing, proposed greenbelt plans were largely ignored and large parts of the planned greenbelt areas were built upon (Han & Long, 2010; Wang, 2015). A similar situation happened to Bangalore’s greenbelt plan (Adkin, 2009). Weak planning regulation and governance are often criticised for causing such a policy deficiency (Amati, 2005; Han & Long, 2010; Yokohari, Takeuchi, Watanabe, & Yokota, 2000). However, there is a lack of research and a gap in understanding the underlying economic impacts of greenbelts on local businesses and residents in fast growing cities.

Beijing is a typical example of a fast growing city that intended to establish greenbelts for protecting the environment and providing open space for residents (Beijing Municipal Government, 1994, 2003). The idea of using green spaces to separate built-up areas, stop urban expansion and decentralise population was proposed in multiple versions of Beijing Master Plans

(Master Plans of 1958, 1982, 1991, 2004-2020, 2016-2035). The First Greenbelt (GB1) was introduced in 1994 to support the decentralisation policy proposed in the Beijing Master Plan of 1991, with a designation of 240 km^2 of green areas around the fourth ring-road preserved as a greenbelt. Nine settlements beyond GB1 were designated for absorbing population overspills from the city centre. The Second Greenbelt (GB2) was introduced in 2003 to support the decentralisation and environmental policy in the Beijing Master Plan of 2004-2020, with a further designation of 1650 km^2 of green areas between the fifth and sixth ring-roads. Eleven new towns were designated to support the population decentralisation of Beijing.

Studies have shown that Beijing's greenbelt policies increased tree canopy cover (J. Yang & Zhou, 2007), encouraged tree planting on village brownfield land (Tan, 2008), preserved the continuity of large pieces of greenspace (Gan, 2012), and safeguarded water bodies and forests (Han & Long, 2010). Although the environmental benefits of greenbelts are well-known by the public, planners were frustrated by the fact that the designated greenbelt land was encroached upon by new development arising from the fast urban expansion since the 2000s. In fact, data show that the percentage of greenfield land remaining from the proposed First Greenbelt is less than 11% (Wang, 2015). For the Second Greenbelt, although the percentage of built-up area in GB2 was planned to be under 32%, it increased from 35.7% to 40% from 2003 to 2006 (Zhang, 2007). Weak planning regulation is one reason that caused this setback (Han & Long, 2010; X. Yang, 2008), but there is little research investigating the underlying economic impacts that may have hindered the greenbelt policy's implementation in Beijing. In this research, we investigate the evolution of Beijing's greenbelts from an economic perspective to explain why some greenbelts were hard to maintain.

We examine the impacts of greenbelts on consumers and businesses through establishing historic-what-if scenarios under alternative greenbelt interventions. This method “conjectures on what might have happened in order to understand what did happen” (MacRaild & Black, 2007, p. 125). Such retrospective analyses will help to identify and explain the impacts of plans and inform future decisions. This paper intends to answer the following questions: Why have Beijing’s greenbelt policies encountered difficulties in implementation? What are the potential economic costs and benefits of the proposed (but not fully accomplished) greenbelts on residents and businesses? What can we learn from past experiences that can help to design more effective greenbelts for the future?

The following sections of this paper are arranged as follows: section 2 offers a literature review of existing models for assessing greenbelt impacts. It introduces the concept of a counterfactual history and explains how to incorporate spatial equilibrium models in a historic counterfactual framework. Section 3 presents the structure of the counterfactual model and components of the spatial equilibrium model. Section 4 applies the model to Beijing under historic-what-if scenarios. It compares the economic impacts of the remaining greenbelts as they stood in 2000 and 2010 with hypothetical fully-enforced greenbelts and no-greenbelt. The modelling results show the impacts in terms of residents and business adaption to the greenbelt, rent, household utility and productivity changes. Section 5 offers a discussion of the economic impacts of Beijing’s greenbelts, the reason that the greenbelts were hard to maintain, and summarises the strength and weaknesses of the model.

2. Literature review

Greenbelts have existed for many decades, which provides rich records for planners and policy makers to measure the impacts of greenbelts on the urban economy. One of the existing approaches to measure the impacts of a greenbelt is to carry out a before-after policy comparison of a city over a time period (Amati & Yokohari, 2006; Lee, 1999; Long, Gu, & Han, 2012). Nelson (1999) pointed out that the before-and-after temporal analysis was hindered by insufficient controls and difficulties in obtaining panel data, which is particularly difficult for fast-growing cities like Beijing.

As a paired set analytical method to temporal comparison, spatial comparison was also used to measure the impacts of greenbelts. It compares roughly comparable cities/towns with and without greenbelts at one time horizon (Nelson, 1999; Siedentop, Fina, & Krehl, 2016; Woo & Guldmann, 2011). It is worth noting that these empirical comparisons cannot fully differentiate which impacts are due to the greenbelt and which are due to other factors, for example market incentives and institutional backgrounds.

We suggest that we can truly clarify real-world impacts of a given policy by evaluating an alternative scenario that removes or strengthens that historical policy, while keeping other conditions intact. This compares a city with itself at the same point in time, so that influences from other background policies can be controlled. For example, what conditions would have been in a greenbelt city in the absence of the greenbelt? Such questions can be answered through scenario planning.

Scenario planning has been used to analyse the future outcomes of alternative planning policies, including predicting the impacts of alternative greenbelt interventions (Anas & Liu, 2007; Anas & Rhee, 2006; Jin & Echenique, 2012; Jun, 2011; Ma & Jin, 2014, 2016). The existing models first predict a benchmark scenario that is what will happen in a future time horizon following the current development trend. Then they predict alternative scenarios given different policy variations. Finally, they compare the alternatives with the benchmark. Obviously, there are background uncertainties involved when predicting the benchmark scenario, for example, the assumptions regarding total population growth and an economy's size. The validity of the model might be affected when comparing future alternatives with the benchmark due to such uncertainties.

The difficulties in controlling background uncertainties could be overcome using counterfactual history studies. The concept of counterfactual history was introduced in the 1960s. It attempts to answer historic-what-if questions know as counterfactuals, for example, what the U.S. economy would have been like in 1890 had there been no railroads (Fogel, 1964). Compared to the existing scenario planning models, the historic counterfactual model has advantages. The benchmark to compare with in such a model is what actually happened. It is therefore free of the uncertainties in background development trend assumptions, and gives confidence in interpreting modelling results.

Based on the historic counterfactual idea, Bae and Jun (2003) used a regression model to test what would have happened if there had been no greenbelt in Seoul. The model predicted the counterfactual population and employment numbers within and beyond the greenbelt. The authors suggested that counterfactual planning had much broader implications, such as to estimate how the spatial structure of a city would change if a transit rail system had never been built, or how the allocation of land uses would change in the absence of zoning.

Inspired by the idea of counterfactual history, we build a general spatial equilibrium model and put it into a recursive modelling framework as done by Jin, Echenique and Hagreaves (2013). In this framework, the spatial equilibrium model explores the interactions amongst the labour market, product market, and the housing and business floorspace market. The recursive structure compares a city under different hypothetical policies to what actually happened over a historic time period, so that the inertia of a certain policy from a previous modelling time horizon can be passed onto the next horizon.

3. Methodology

In this section, we first explain the recursive counterfactual modelling structure, and then we describe each component of the spatial equilibrium model. The recursive counterfactual structure establishes a platform on which the historic spatial equilibrium conditions can be compared with historic-what-if conditions. The spatial equilibrium model explores interactions between producers, consumers and their locational choices, subject to floorspace supplies as a result of a greenbelt constraint. The comparable measures from the modelling outputs are the number of residents and jobs, rents, productivity and household utility in different areas of the city.

3.1. Recursive counterfactual modelling structure

The recursive counterfactual modelling structure includes two groups of spatial equilibrium models (refer to Figure 1). The first is the reference group. This group consists of 3 cross-sectional spatial equilibrium models that reproduce what happened in the past. The second is the counterfactual group, which consists of spatial equilibrium models under historic-what-if assumptions. The model starts from a calibrated base year *t* and runs to future year *t+20*, taking information from both endogenous spatial equilibrium conditions from previous years and exogenous policy inputs that are defined by the user.

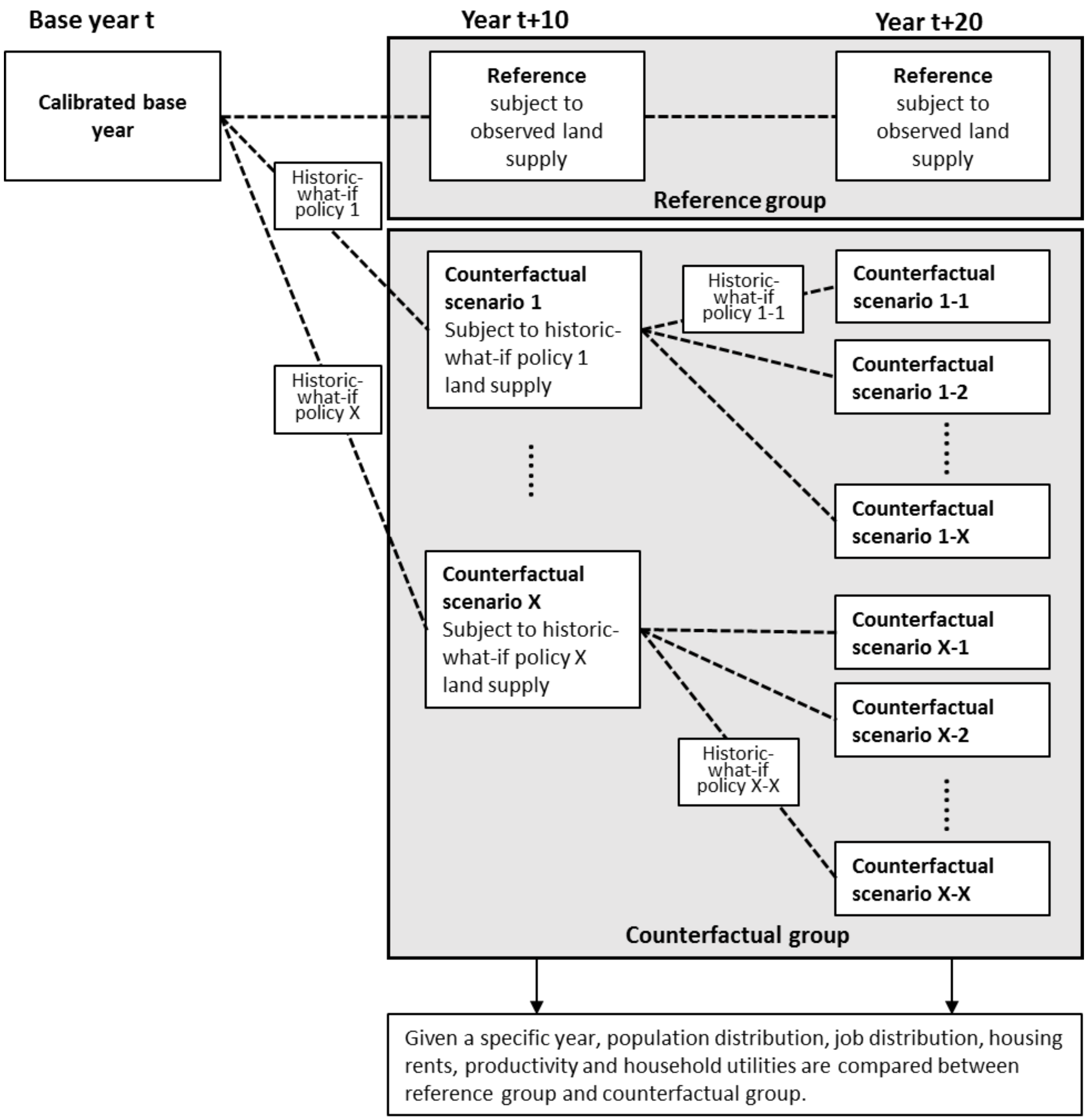

Figure 1 Counterfactual modelling structure

3.2. Spatial equilibrium modelling components

Following the tradition of Anas and Liu (2007) and Jin, Echenique and Hargreaves (2013), the spatial equilibrium model for producer and consumer behaviour follows a parsimonious design. This allows the users of the model to understand and easily check the causal relationships between producers, consumers and their locational choices. The spatial equilibrium model does not currently include an explicit agency for developers or government, although these can be added at a later date which will result in a more complex model to calibrate and use. Taxes are not modelled explicitly; instead, the model assumes that the city balances its consumption with its production, and any increase in the property sales/rental income is shared equally among all households. The choice of this structure is to highlight the key interactions that are most relevant to the broad thrust of urban development and its impacts on production and consumer welfare.

Spatially, the modelled area is divided into discrete but contiguous model zones. Spatial activities can move within and between zones and the choice of location is modelled on a zonal scale. Urban development is represented in terms of changes in the stock of housing and business floorspace, all of which are inputs into the model periodically based on exogenous greenbelt policy scenarios and endogenous economic performance.

3.2.1. Consumers

Following the random utility framework as put forward by McFadden (1974), an individual in the population in socio-economic group f , living in zone i and working in zone j has a utility function U_{fij} which can be written in the form:

$$U_{fij} = V_{fij} + e_{fij} \quad \text{[Equation 1]}$$

$V_{fij} \in (-\infty, +\infty)$ is non-stochastic and reflects the representative taste of the population, and $e_{fij} \in (-\infty, +\infty)$ is stochastic and reflects the idiosyncrasies of the population, which measures the unobserved utility variance among individuals. The non-stochastic observed utility V_{fij} consists of three parts: the quantity of retail goods and services a consumer buys, the quantity of floorspace he/she rents, and the time he/she contributes to leisure. The non-stochastic utility V_{fij} of an individual in socio-economic group *f* as a consumer, living in zone *i*, working in zone *j* and shopping in zone *z* is written as:

$$V_{fij} = \alpha_f \ln\left(\sum\nolimits_r \left(\sum\nolimits_z Z_{rzfij}\right)^{\eta_f}\right)^{\frac{1}{\eta_f}} + \beta_f \ln\left(\sum\nolimits_h \left(b_{hfi}\right)^{\sigma_f}\right)^{\frac{1}{\sigma_f}} + \gamma_f \ln l_{fij} \quad \text{[Equation 2]}$$

$\alpha_f > 0, \beta_f > 0, \gamma_f > 0$ are the shares of disposable income spent on the retail goods and service Z_{rzfij}, housing floorspace b_{hfi}, and annual leisure time l_{fij} respectively. Constant returns to scale is achieved by defining $\alpha_f + \beta_f + \gamma_f = 1$. From the consumer's side of the model, the subscripts *r* and *h* stand for the type of goods and services and the type of housing floorspace respectively. $\frac{1}{1-\eta_f} > 0$ and $\frac{1}{1-\sigma_f} > 0$ are respectively the elasticities of substitution between any two retail goods and any two types of housing.

3.2.2. Producers

The production function follows a hybrid Cobb-Douglas constant elasticity of substitution form. The output X_{rj} of a certain industrial type *r* (which produces type *r* goods and services) in a zone *j* is:

$$X_{rj} = E_{rj} K_r^{\nu_r} \left(\sum_f L_{rfj}^{\theta_r}\right)^{\frac{\delta_r}{\theta_r}} \left(\sum_k B_{rkj}^{\zeta_r}\right)^{\frac{\mu_r}{\zeta_r}} \prod_s \left(Y_{rsj}\right)^{\gamma_{rs}} \quad \text{[Equation 3]}$$

In this hybrid Cobb-Douglas constant elasticity of substitution function, primary inputs are capital K_r, labour force L_{rfj}, business floorspace B_{rkj} and intermediate inputs Y_{rsj}. The subscripts *f*, *k* and *s* stand for the socio-economic level of a worker, the type of floorspace used for production, and the type of intermediate inputs respectively. $E_{rj} > 0$ is a scale parameter to convert production input into monetary terms. $E_{rj} = 1$ when production inputs are already counted in monetary terms. This production function is rendered constant returns to scale by setting $\nu_r + \delta_r + \mu_r + \sum_s \gamma_{rs} = 1$ ($\nu_r > 0, \delta_r > 0, \mu_r > 0, \gamma_{rs} > 0$). The elasticity of substitution between any two types of labour forces and building floorspace are $\frac{1}{1-\theta_r} > 0$ and $\frac{1}{1-\zeta_r} > 0$ respectively. At this initial stage of the model, two simplifications are applied to this production function. Firstly, the city is assumed to produce only one kind of conceptual composite goods and service. Secondly, only the labour and floorspace inputs are included for the model as done by Anas and Rhee (2006), because they are the most relevant inputs to affect the interactions between a producer's locational choice and the land use constraint from the greenbelt.

3.2.3. Locational choice

The locational utility υ_{fij} for an individual in socio-economic group *f* living in zone *i* and working in zone *j* is specified as:

$$\upsilon_{fij} = V_{fij} - d_{fij} + E_{fij} \quad \text{[Equation 4]}$$

V_{fij} is the consumption utility specified in [Equation 2]. $d_{fij} = \phi_f c_{fij} + t_{ij}$>0 is the travel disutility. It is the cost of travel, including two parts: $c_{fij} > 0$ is the monetary travel cost from zone *i* to *j*, converted by the marginal utility of money $\phi_f > 0$ into generalised travel time. $t_{ij} > 0$ is the travel time from zone *i* to *j*. $E_{fij} \in (-\infty, +\infty)$ is the residual attractiveness term which is calibrated empirically in order to match the observed zonal numbers of residents and jobs. E_{fij} represents the utilities that are not captured in the consumption utility V_{fij}. The amenity value of the greenbelt is included in the residual attractiveness term E_{fij}.

To derive the probability of locational choice for a combined employment-residence decision, a discrete choice model is adopted by specifying the distribution of the idiosyncratic utilities $e_{fij} \in (-\infty, +\infty)$. Assuming e_{fij} follows a Gumbel distribution as specified in Anas and Liu (2007) and Jin, Echenique and Hargreaves (2013), the probability of the combined locational choice can be derived through a logit form. The probability P_{fij} for an individual in socio-economic level *f*, living in zone *i* and working in zone *j* is:

$$P_{fij} = \frac{S_i \exp\left(\lambda_f v_{fij}\right)}{\sum_{mn} S_m \exp\left(\lambda_f v_{fmn}\right)} \qquad \text{[Equation 5]}$$

$$\sum_{ij} P_{fij} = 1$$

$S_i > 0$ is a size parameter that corrects for the bias introduced by the uneven sizes of zones in the model. In this model, housing floorspace in each residential zone *i* is S_i. $\lambda_f > 0$ is the concentration parameter for residential location choice. At one extreme, as $\lambda_f \to \infty$, taste of idiosyncrasies vanish and all individuals choose their locations identically. At the other extreme, as $\lambda_f \rightarrow 0$, all individuals choose randomly. The finite λ_f has empirical validity as it is calibrated to match the observed commuting distance.

3.2.4. Spatial equilibrium conditions

Conditional on the travel disutility d_{fij}, the spatial equilibrium model requires the following standard assumptions, subject to the zonal floorspace stock constraints for business floorspace B_{rkj} and housing floorspace b_{hfi}, which are defined through the design of greenbelt policies; 1) All consumers maximise utility subject to the housing floorspace, money and time constraints; 2) All producers minimise cost subject to the input factors, which are the floorspace and labour provision; 3) A zero profit condition is set for producers in an open competitive market which means the price paid by the consumer equals the producer's cost. The market has zero excess demand in the floorspace market, labour market and product market. In the labour market, total working hours demanded equals total non-leisure hours minus travel time. In the product market, total goods and services produced equals total goods and service consumed by consumers.

4. What if Beijing had enforced the 1st or 2nd greenbelt?

4.1. Model zones

The theoretical model is then applied to test historic-what-if scenarios in Beijing. Spatially, the model divides Beijing into 130 zones according to the existing jiedao (subdistrict) boundaries and transport links. Jiedaos in the city centre and far suburb are merged into larger zones because the spatial variations within these zones are not the main focus in this paper. Greenbelt constraints on urban development are represented in terms of changes in the stock of housing and business floorspace in each zone. The 130 zones in Beijing Municipality are classified into seven broad types in order to represent the impacts of the two greenbelts on different areas of the city. We refer to previous studies by Ma and Jin (2014) to define these zone types (see Figure 2).

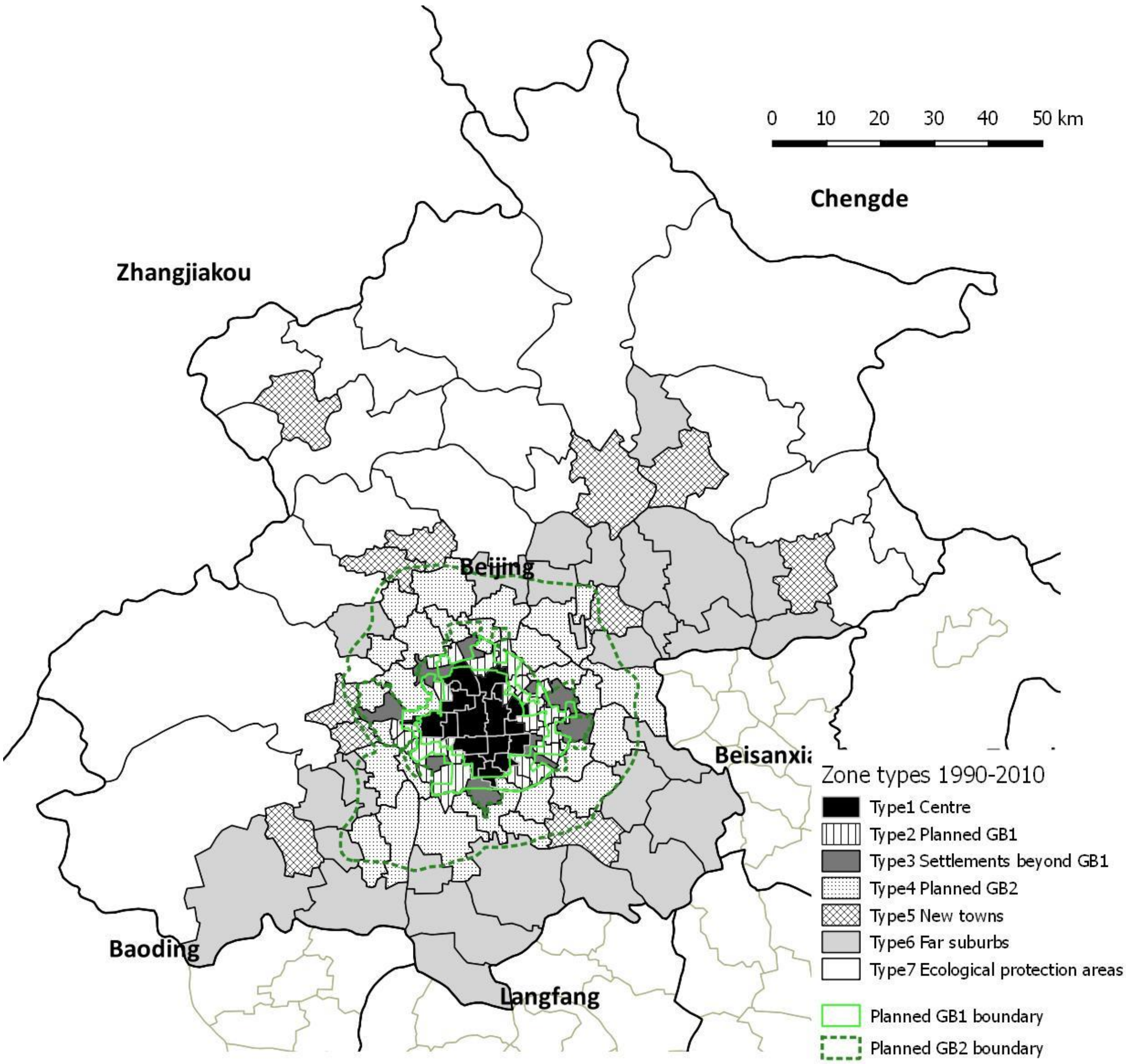

Figure 2 Zone categories in the Beijing Municipality in 1990

There are 20 zones categorised as GB1 and 23 zones as GB2. Boundaries do not fully comply with the greenbelt policies, because zones are defined by transport networks and administrative boundaries, not by greenbelt policy boundaries. However, this zoning is able to show the ring shapes of the two greenbelts.

4.2. Counterfactual scenarios

Starting from a no-greenbelt base year 1990, the model runs through two decades till 2010. The policy variations are solely the existence of the greenbelts. We push the variations to the extreme by assuming the greenbelt as either fully enforced with no more excess building or that it never existed. By comparing the historic pattern with fully-enforced greenbelt scenarios or no-greenbelt scenarios, the counterfactual economic impacts of greenbelts or no-greenbelt can be estimated.

From year 1990 to year 2000, GB1 is the policy variable. There are two scenarios which are Scenario S1 - a stringent GB1, or Scenario N1 - no GB1. From year 2000 to year 2010, GB2 is the policy variable. There are four scenarios stemming from the previous decade: Scenario S1-S2 is to implement a second stringent greenbelt in addition to the first one, so that the city will have an expanded green system; Scenario S1-N2 is to keep the first stringent greenbelt, but no further action of the second greenbelt will be put forward; Scenario N1-S2 is to implement a stringent GB2 based on the condition that no GB1 has been designed; Scenario N1-N2 follows a no-greenbelt policy. The “no greenbelt” scenarios do not mean that all of the greenbelt land would be built upon. In such scenarios, development is allowed to happen in the two greenbelts following market demand. The development can happen in the form of densification in existing towns and villages, or it can be new construction in greenfield land. If the greenfield land is designated Basic Cultivated Land in Beijing, we assume a new piece of land in the far suburb with the same land area would be designated as new Basic Cultivate Land in order to conserve the total amount of Basic Cultivated Land in Beijing. Table 1 lists zone types and land use variations by scenario. Figure 3 summarises the order of scenario design.

Table 1 Zone types and land use variations by scenario

	Number of zones	**Scenarios**						
		Reference 2000, 2010	**S1**	**N1**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Type 1	17	The central city encircled by GB1						
Type 2	20	The planned GB1 area, land use varies according to scenario specifications.						
		Observed land supply	*Fully enforced GB1*	*No growth control in 2000*	*Fully enforced GB1*	*Fully enforced GB1*	*No growth control in 2010*	*No growth control in 2010*
Type 3	9	The settlements between the designated GB1 and GB2						
Type 4	23	The planned GB2 area, land use varies according to scenario specifications.						
		Observed land supply	*No growth control in 2000*	*No growth control in 2000*	*Fully enforced GB2*	*No growth control in 2010*	*Fully enforced GB2*	*No growth control in 2010*
Type 5	16	The new towns beyond the designated GB2						
Type 6	27	The far suburb						
Type 7	18	The ecological protection area						

Apart from revealing the impacts of the existence of greenbelts, the reason for designing the four scenarios in such an order is to also measure the impacts of two variables associated with greenbelts: the locations and sizes of the greenbelts. Scenario S1-N2 represents the spatial structure of a narrow greenbelt implemented right next to the urban built-up area. Scenario N1-

S2 represents the spatial structure of a wide greenbelt implemented before the development actually reaches the urban fringe.

The counterfactual scenarios will be compared with the reference scenarios, namely the 2000 Reference and the 2010 Reference. The References take the observed supply of floorspace from 1990 to 2010 as inputs, while the inputs for the counterfactual scenarios are predicted from the 1990 model subject to the supply of greenbelt-specified floorspace.

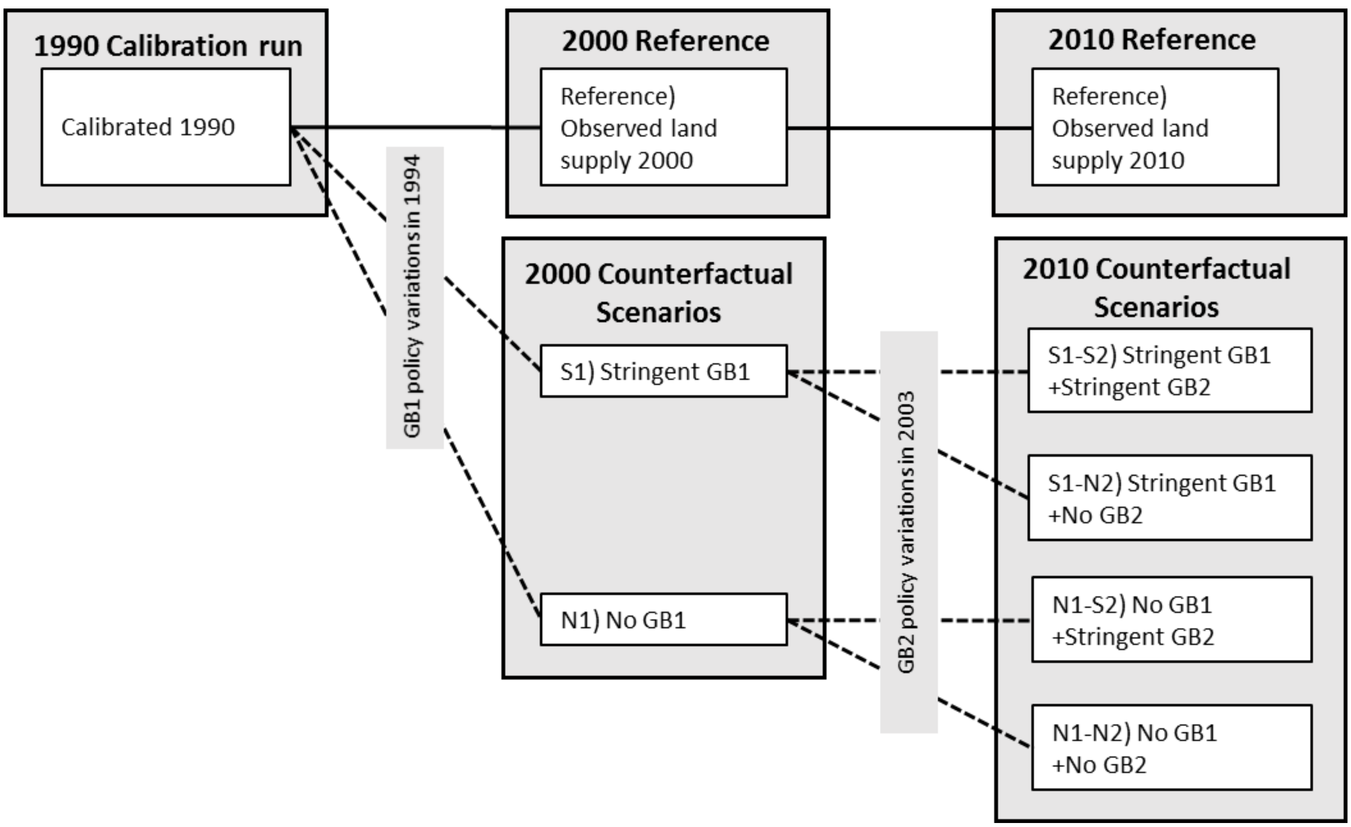

Figure 3 Counterfactual scenarios

4.3. Scenario inputs

The scenarios in the same year have the same demographic settings: the same number of households and jobs, the same family size and income. The model deals with the job-residence location choices of employed residents. For non-employed residents, the model treats them as dependents of employed residents and that they do not make a job-residence location choice. Therefore, in Table 2 the total number of employed residents equals the total number of workers. The total floorspace stocks across scenarios are the same. Differences are represented only in the location of floorspace supply. The conserved total floorspace supplies make the comparisons for rent among scenarios consistent.

Table 2 Inputs for year 1990, 2000 and 2010

Year	**1990**	**2000**	**2010**
Total employed residents (thousands)	6271	7116	11805
Total workers (thousands)	6271	7116	11805
Income per person per year (RMB)	3871	8641	22246
Household size (persons per household)	3.20	2.90	2.45
Total housing supply (m^2)	169,723,859	284,832,535	575,393,422
Total business floorspace supply (m^2)	125,420,000	142,331,749	236,824,134

In terms of transport, it is assumed that transport conditions remain the same for the same year across scenarios. This is to say that there is no planned transport improvement to support decentralising population beyond the greenbelts. Such an assumption allows us to test if greenbelt policies would work effectively without coordinating transport.

For each zone type in each scenario, we define a specific growth rate for business and housing floorspace from base year 1990. For year 2000, Scenario S1 represents a stringent greenbelt plan with intensively developed fringe settlements, which means only 2% growth is allowed in GB1 from 1990 to 2000 according to the First Greenbelt policy (Beijing Municipal Government, 1994). Scenario N1 represents a “no greenbelt” pattern, in which we deliberately eliminate the growth control in the designated GB1 area. For the rural zones beyond GB1 in both scenarios, a natural growth rate of 5% is applied.

Similarly, for year 2010, based on the floorspace supplies from the previous decade, a 2% growth rate from the previous decade is used for the greenbelts in the stringent growth scenarios. For the zones outside GB2, a natural growth rate of 5% is used. Natural growth means the spontaneous expansion through extension of the existing buildings or infilling development in built-up areas. In practice, the enforcement policies for GB1 and GB2 are different in many ways. They have different regulatory approaches to creating greenspaces or preserving existing greenspaces, for example, through reducing the footprint of old village sites or designating statutory No-Construction Areas. However, the model deals with the total amount of floorspace development as a result of enforcement policies, not the process of policy enforcement regarding land area preservation.

For the zones which are not specified above, the floorspace increases proportionally according to the stock sizes in the previous decade. In this way the total floorspace stocks are kept identical across scenarios. This proportional distribution reflects development inertia, that is, development is more likely to happen in places that are already partially built-up. Figure 4 reports floorspace inputs.

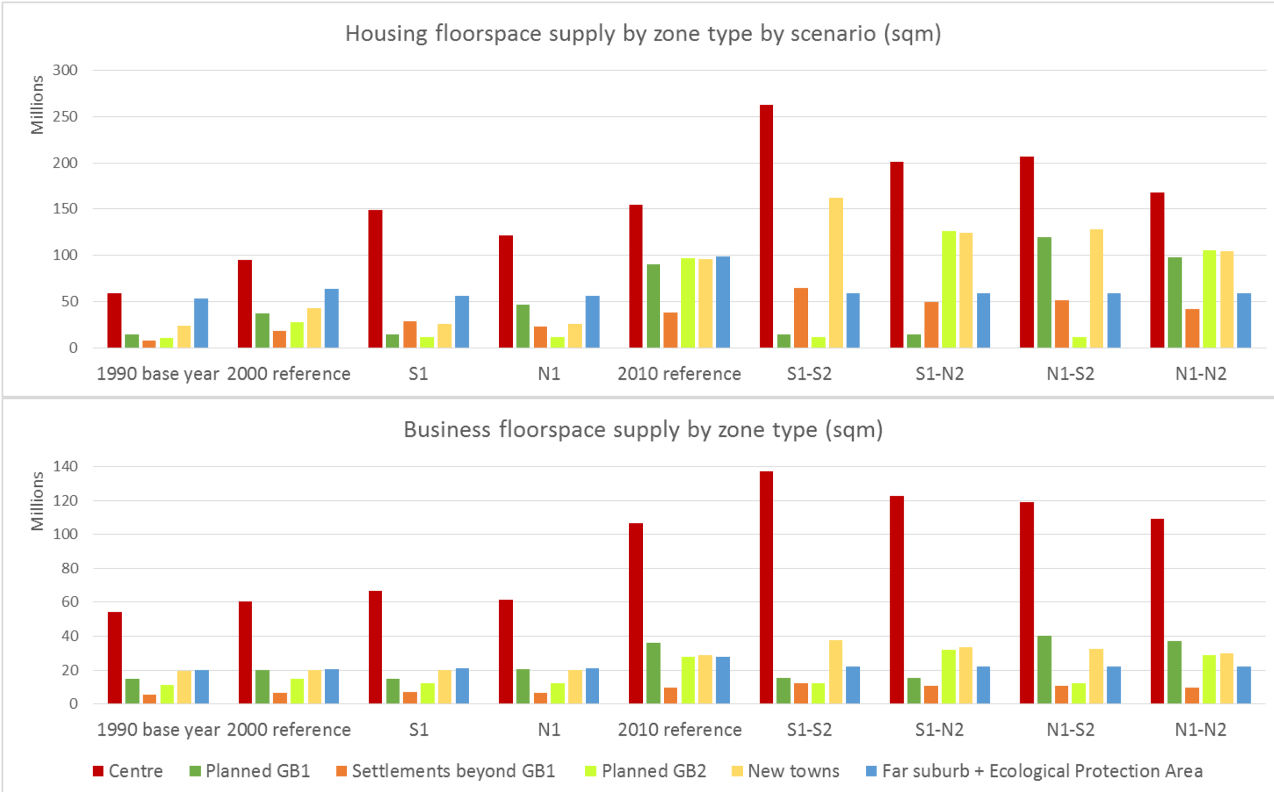

Figure 4 Floorspace supply by zone type by scenario

4.4. Model runs and results

The model is calibrated using data from 1990. The main data inputs are estimated quantities of housing and business floorspace from the research done by Ma and Jin (2015) and the estimated average morning peak (6.30am-9.30am) travel times and costs by origin-destination zone pairs from the research done by Deng, Denman, Zachariadis, & Jin (2015). The modelled number of zonal employed residents and jobs are compared with the observed values to refine parameters by adjusting the zonal residual E_{fij} in [Equation 4]. After calibration, we input the parameters and zonal residual attractiveness of the calibrated 1990 model to reproduce the observed zonal employed residents and jobs in 2000 and 2010 for validation purposes. We then use the calibrated parameters and residual attractiveness terms in 1990 to predict the historic-what-if scenarios in year 2000 and 2010. Price levels are all converted to 2010. The model will reveal differences in spatial distributions of residents and jobs, the counterfactual rents, industry productivities and household utilities across scenarios.

4.4.1. Distribution of residents and jobs

Figure 5 reports resident and job distributions across scenarios. We first examine what would happen with a full-realisation of the designated greenbelts, namely comparing Scenario S1 to the 2000 Reference, and comparing Scenario S1-S2 to the 2010 Reference. A stringent enforcement of GB1 in 2000 would engender further concentration of population and jobs in the city centre. The establishment of GB2 in 2010 reinforces such effects, as more than 60% of the jobs and residents remain in the city centre in Scenario S1-S2, and 2% more employed residents live beyond GB2 compared to the 2010 Reference. In these alternative runs, transport conditions stay the same as the two reference scenarios. As the greenbelts are not an option to live in, without transport improvement people tend to move inward instead of outward and the city centre becomes more compact.

Secondly, we analyse what would happen in the absence of greenbelts, namely comparing Scenario N1 to the 2000 Reference, and comparing Scenario N1-N2 to the 2010 Reference. In both the 2000 Reference and Scenario N1, GB1 contains about 20% of the total population and jobs. In both the 2010 Reference and Scenario N1-N2, the two greenbelts together contain about 40% of the total population and jobs. The counterfactual simulations show that without greenbelts, the distribution of employed residents and jobs are not dissimilar to what actually happened. It suggests that the designation of greenbelts in Beijing hardly deterred development during the modelling period 1990 to 2010.

The two hybrid scenarios (Scenario S1-N2 and Scenario N1-S2) in 2010 show that different sizes and locations of greenbelts will trigger different spatial distributions of residents and jobs. Scenario S1-N2 represents a smaller greenbelt which is close to the city centre. Consequently, people tend to live beyond GB1, seeking lower rent and bigger properties. Scenario N1-S2 represents a wide greenbelt. Consequently, residents spread into GB1in the near suburb but do not go beyond GB2. It is worth noting that in either case, without improvements in transportation, designated settlements beyond GB1 and new towns beyond GB2 would not become major residence and employment centres.

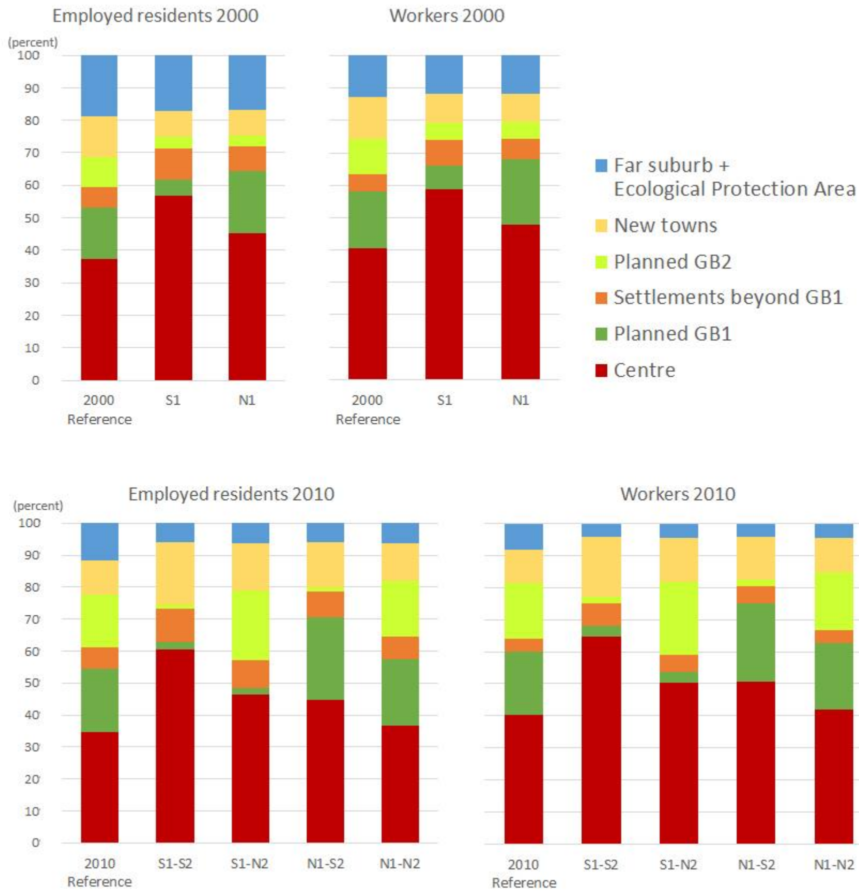

Figure 5 Comparisons among observed and modelled employed residents and workers in 2000 (top) and in 2010 (bottom)

4.4.2. Housing rent

Figure 6 shows the rent gradients in different scenarios in 2010. For the no-greenbelt scenario (Scenario N1-N2), rent levels reflect the direct market effects and drop from the centre to the suburb. Such a gradient is also observed in the 2010 Reference, which suggests that the remaining greenbelts did not significantly influence housing rents.

The decrease of housing rent in greenbelt areas can be found in the stringent greenbelt scenario, as well as the hybrid greenbelt scenarios. This can be explained by the modelling mechanism. In the model, housing rent is determined by housing floorspace supply as a result of the greenbelt intervention and the numbers of residents as housing demand. Land use control has made the greenbelt areas less attractive to urban economic activities, which in turn suppresses demand, and rent decreases. Taking Scenario S1-S2 as an example, if GB1 was fully implemented, the housing floorspace supply in GB1 would only be about 15 million m^2. Compared to the existing 90 million m^2 housing floorspace in 2010, housing supply in Scenario S1-S2 is 84% less. Meanwhile, the model predicted a decline in the total number of residents in GB1 of 89% compared to the observed number of residents (250 thousand versus 2.3 million). As a result, the rent in GB1 becomes lower than the observed rent in the 2010 Reference, because housing demand decreases more than housing supply.

On the other hand, it is worth noting that greenbelt areas offer better environmental quality which may attract more people. This amenity value of greenbelts is counted in the residual attractiveness E_{fij} in [Equation 4]. This term is calibrated to match the spatial pattern in 1990 and kept constant to 2010. Therefore, any potential increase of amenity value from 1990 to 2010 may be underestimated and thus the magnitude of rent decrease in greenbelt zones may be overestimated in 2010.

Regarding the city centre, if greenbelts were fully protected, as shown in Scenario S1-S2, more people would live in the city centre. However, rents in our model are not pushed up substantially. According to the same modelling mechanism explained above, this is because the increase of housing supply in the city surpasses the increase of housing demand. The findings suggest that under stringent greenbelt scenarios, counterfactual rents in the centre would stay stable, conditional on the centre being included in the housing supply which would have been built on the greenbelt land. However, in reality, such a floorspace increase is difficult to achieve in

Beijing’s city centre. This implies that if greenbelts were fully protected and the expected floorspace supply could not be fulfilled, rent in the centre might reach an even higher level.

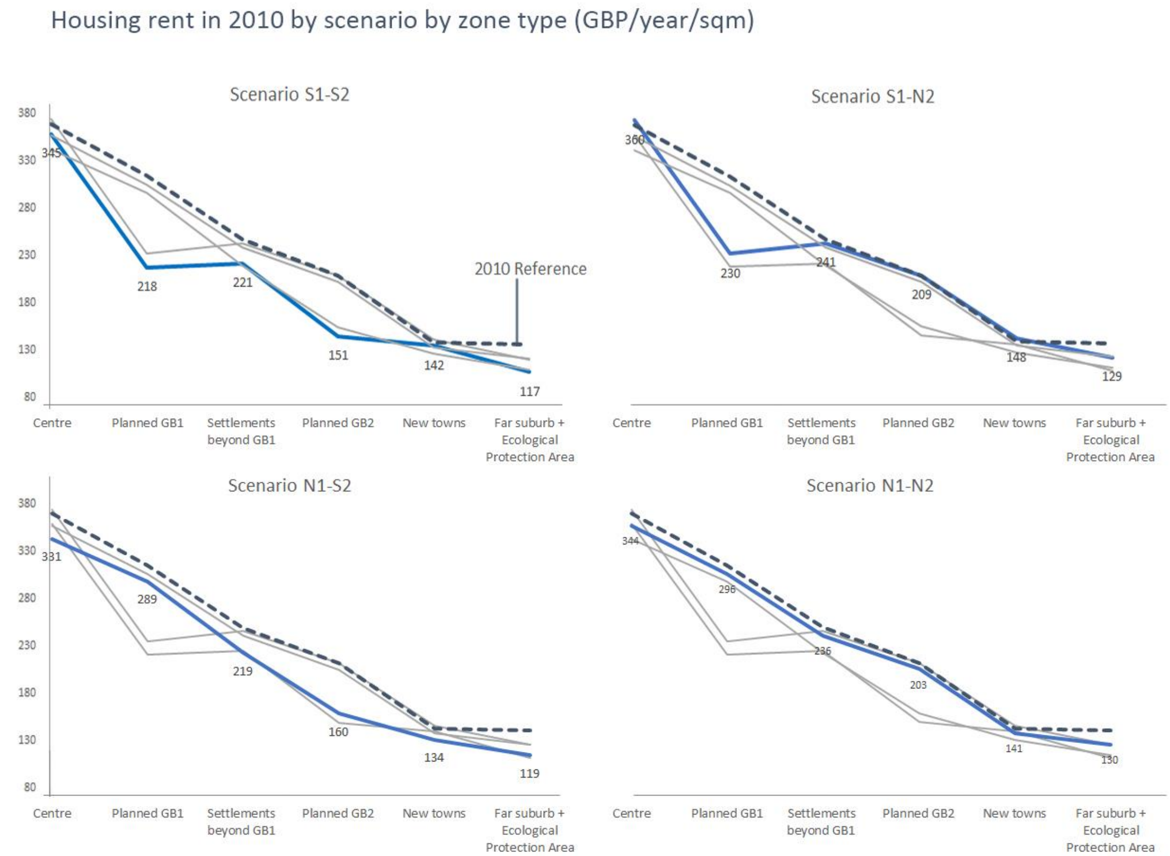

Figure 6 Housing rent in 2010

4.4.3. Productivity

In the model, productivity is represented as the quantity of composite goods and services produced. From the producer’s side, it is defined by two factors: the inputs of workers and business floorspace (refer to [Equation 3]). Total production across scenarios is listed in Table 3. Production by zone type in 2010 is reported in Figure 7.

Table 3 Production quantities across scenarios

	1990	2000 Scenarios			2010 Scenarios				
Scenarios	**Base**	**Ref**	**S1**	**N1**	**Ref**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Total production (million units)	3985	4545	4521	4528	7419	7446	7377	7451	7407

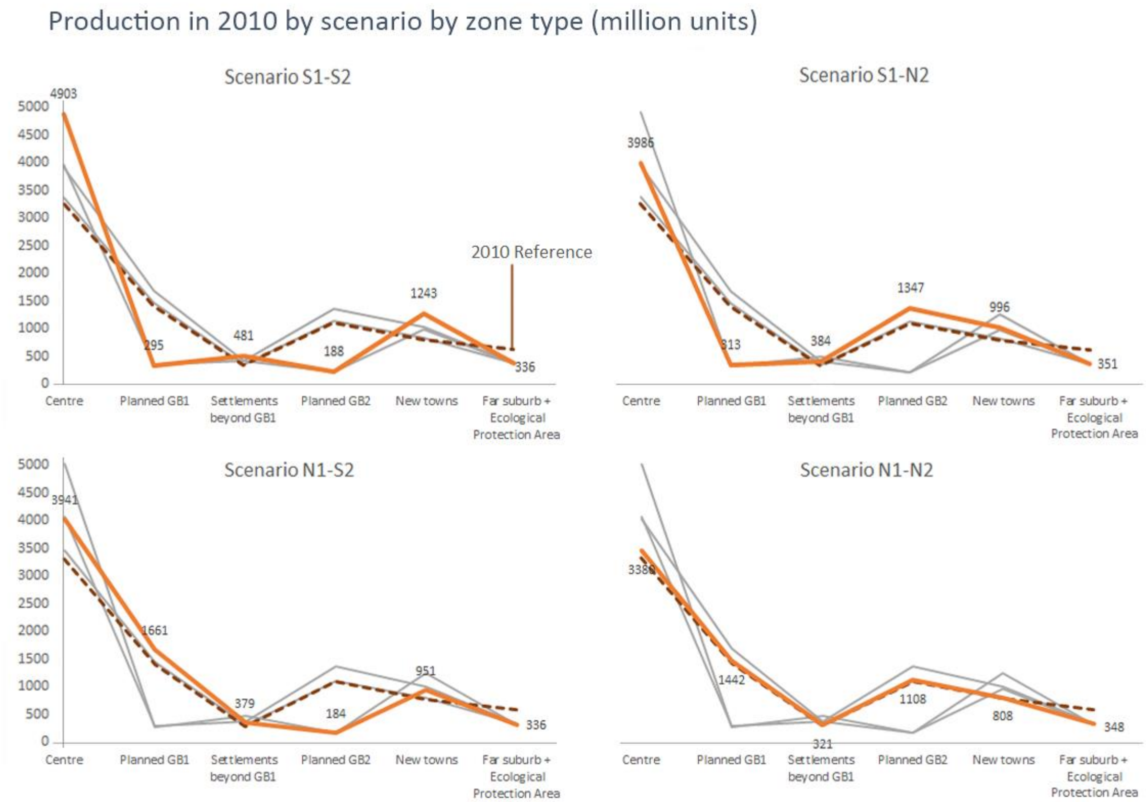

Figure 7 Production in 2010

In 2010, in terms of total production, Scenario S1-N2 has the lowest productivity, while Scenario N1-S2 has the highest productivity. Apart from Type 2 planned GB1 and Type 4 planned GB2 zones, production elsewhere is of similar quantity. The difference is essentially a trade-off between the planned GB1 and GB2. Because planned GB1 zones are closer to the centre and have better transport accessibility, they attract more labour and floorspace inputs than planned GB2 zones. As a result, planned GB1 in Scenario N1-S2 is more productive than planned GB2 in Scenario S1-N2, even though it is much a smaller area.

4.4.4. Utility level changes

Household utility is an indicator to measure the overall economic well-being of the household (refer to [Equation 2] for the components of household utility). As shown in Table 4, the overall utility levels in reference scenarios increase from 1990 to 2010, because of increases in income. All of the alternative scenarios reduce utility levels compared to the 2000 Reference and 2010 Reference.

Table 4 Utility levels across scenarios

	1990	2000 Scenarios			2010 Scenarios				
Scenarios	**Base**	**Ref**	**S1**	**N1**	**Ref**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Average household utility	7.907	7.972	7.972	7.971	7.974	7.968	7.969	7.973	7.973
Consumer surplus as percentage of money income %, compared to References	-	-	-0.4%	-0.3%	-	-2.5%	-2.1%	-0.4%	-0.4%

Figure 8 presents utility levels spatially. In 2000, if a stringent GB1 is implemented (Scenario S1), utility in the city centre and new towns will drop while other zones will see a marginal increase. Households in GB1 will benefit due to lower rent. In 2010, if a stringent GB2 is added to the stringent GB1 (Scenario S1-S2), most suburban zones will see an increase in household utility. However, utility in the city centre, where 64% of households reside, decreases further. As the rent level in the city centre is relatively stable (see Figure 6), drops in utility are mainly because the labour supply is higher than production demands, so wages drop. If no GB2 is added to the stringent GB1 (Scenario S1-N2), the overall drop will be 2.1% for Beijing. The small and stringent GB1 appears to be uneconomic in both scenarios.

In 2000, if GB1 is removed (Scenario N1), the demand for housing in the city centre will be relieved and the south of the city centre sees a small increase in utility. In 2010, if a stringent GB2 was put forward without a previous GB1 intervention (Scenario N1-S2), apart from the centre, most zones are better-off. Compared to the single existence of a small greenbelt (Scenario S1-N2), a large one seems to be more appropriate. This is because GB2 does not increase rent in the main city as much as GB1 does and because releasing the constraint from GB1 will increase productivity for the whole city. The last scenario, Scenario N1-N2, is a free-market scenario and causes an overall increase within the GB2 outer boundary. However overall utility is still slightly lower than 2010 Reference.

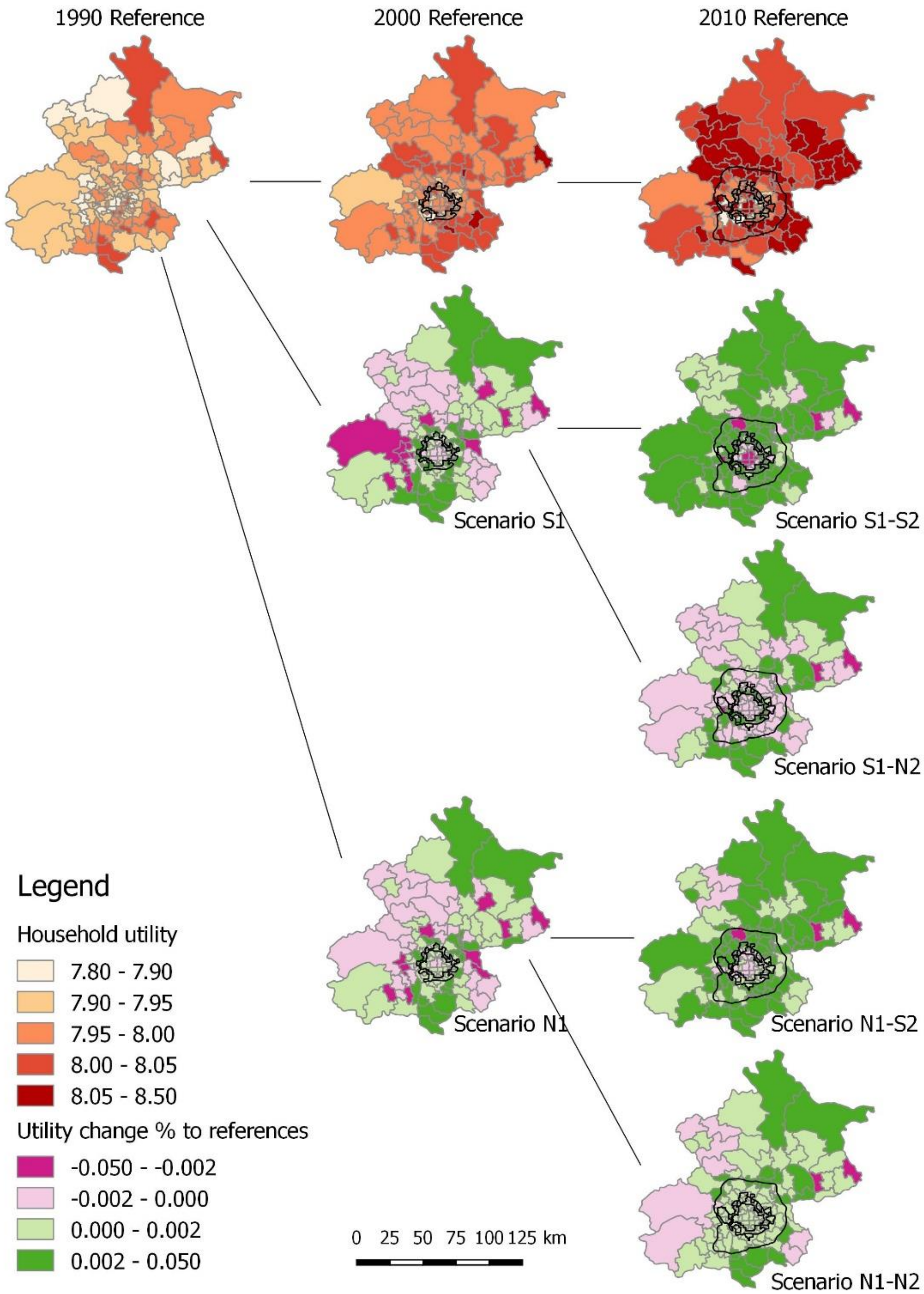

Figure 8 Household utility among scenarios

Overall consumer surplus, ΔC, as a household well-being measure, is defined as the change in average household utility divided by the average marginal utility of money (Jin, Y., Echenique, M., & Hargreaves, A. J. 2013).

$$\Delta C = \frac{\left(\overline{U}_{Alternative} - \overline{U}_{Reference}\right)}{\frac{1}{2}\left(\frac{1}{\overline{\Omega}_{Alternative}} + \frac{1}{\overline{\Omega}_{Reference}}\right)} \qquad \text{[Equation 6]}$$

$\overline{U}_{Reference}$ and $\overline{U}_{Alternative}$ are the average household utilities; $\overline{\Omega}_{Reference}$ and $\overline{\Omega}_{Alternative}$ are the average household incomes for the reference and alternative scenarios, respectively. Using Equation 6, we convert the utility change into consumer surplus at 2010 price level. The decrease of consumer surplus in Scenario S1-S2 is the largest. With two fully-enforced stringent greenbelts in 2010, consumer surplus would drop by $202 million per year for the city. Better options would be Scenario N1-N2, which is the free market scenario, and Scenario N1-S2 which is the wide greenbelt scenario. Compared to the Reference 2010, both scenarios would still drop consumer surplus by $31 million for Beijing. Although the decreases in consumer surplus are similar in the two scenarios, compared to Scenario N1-N2, Scenario N1-S2 preserves more greenfield land for Beijing. If transport conditions from the centre to new towns are improved in Scenario N1-S2, the overcrowding issue in the city centre might be resolved. In that case, we would need to test the potential of a wide greenbelt in improving the overall utility level given different transport inputs into the model.

5. Discussions and conclusions

5.1. Policy implications

Firstly, the modelling results show that if there had been fully-enforced greenbelts, economic well-being would decrease. This indicates that the planned greenbelts would bring some negative economic impacts to the city, including decreasing productivity, decreasing household utility, and concentrating residents in the expensive city centre. The effects of increasing population and employment density in the city centre were also found in research done by Bae and Jun (2003) and other studies. For example, Hall (1974) and Evans and Hartwich (2006) found that London's greenbelt increased population density in the main city which pushed housing prices up.

The reasons for the concentration in the city centre in Beijing are 1) there is no transport improvement from the centre to the suburb, 2) in the model, we did not limit floorspace development in the centre, so more business and residents are attracted to locate there, and 3) amenity values of greenbelts stayed constant from 1990 to 2010. As the city centre became more crowded, the model did not assume that greenbelt areas became more attractive due to the amenities it generated, so it did not encourage residents to move to the suburban area. The fully-enforced greenbelt plans assumed that housing and business floorspace would need to increase by 50% in the city centre to accommodate the increasing demands from households and business activities. This is very hard for the already overcrowded centre in Beijing. On the other hand, we would like to point out that a full-realisation of greenbelts would provide environmental benefits, but this model currently does not compare overall benefits to costs. Instead, the findings indicate that the potential negative economic impacts from the planned greenbelts may have hindered the policy's implementation. An integrated assessment from both environmental and economic perspectives is recommended in future policy design.

Secondly, the modelling results show that if there had been no greenbelts, the spatial distribution of residents, jobs, rents and productivity would not change too much from what it was in 2010. This indicates that the implemented greenbelts did not perform effectively in urban containment. No-greenbelt scenarios reduce the floorspace demand in the main city and utility levels see a small increase in 2010. However, the overall consumer surplus for the whole municipality will still decrease by 0.4% in 2010. The spatial distribution of economic activities will be more dispersed and more greenbelt land will be developed.

In terms of size, Scenario S1-N2 shows that a small and narrow greenbelt does not fulfil the aim of urban containment, as people can easily cross it and build beyond the small greenbelt. Scenario N1-S2 shows that a large and wide greenbelt performs better in containing population and jobs within the designated greenbelt boundary. This finding is different from the findings in Bae and Jun (2003) and Freestone (2002), as their research has shown that the greenbelts decentralised population to places beyond the greenbelts while confining jobs in the city centre, which caused a jobs-housing imbalance. The situation in Beijing is different, because without transport improvements, economic activities would not be diverted to new towns easily and a wide greenbelt would still cause overconcentration in the main city.

In terms of location, modelling results suggest a greenbelt should be placed at a distance from the urban built-up edge to give development a buffer area to contain future growth. Scenario S1-N2 shows that a greenbelt right next to the immediate urban built-up boundary is harmful. Such an area is normally productive and could have been used to enhance the productivity of the city.

Such an immediate greenbelt would cause a substantial decrease in consumer surplus. On the contrary, Scenario N1-S2 shows that a greenbelt which gives a development buffer zone in advance performs better in terms of consumer’s well-being.

The modelling results show that greenbelt interventions could greatly affect household welfare and impact the economic performance of Beijing. Although existing studies have proved environmental benefits from greenbelts (Carter-whitney & Esakin, 2010; Han & Long, 2010; J. Yang & Zhou, 2007), findings from this paper show that some negative economic impacts may have largely impeded policy implementation. As the urban expansion of Beijing sped up after 2010, the greenbelt implementations are under even greater pressure, and stringent greenbelt policies are unlikely to be suitable. Meanwhile, no-greenbelt intervention is not beneficial either, as it decreases greenspaces in Beijing while economic well-being is not improved.

We suggest that when revising current greenbelt plans and designating future greenbelts, sites with good transport conditions in the designated greenbelt, if not ecologically sensitive, could be allowed for development, while the implications for environment and natural ecology should be carefully assessed alongside the development plan. Meanwhile, to fulfil the aim of relieving the overconcentration in the city centre and redistributing populations to new towns, it is crucial to improve the transport connections between the city and new towns, so that the in-between greenfield land around the city can be preserved more effectively and greenbelt policies implemented more smoothly.

5.2. Intellectual contributions and future work

This counterfactual model offers a tool to measure the potential economic costs and benefits between alternative propositions. It quantifies the impacts of greenbelts through three cross-sections over two decades. Compared to independent cross-sectional predictions, the recursive modelling structure is capable of showing the effects of chronic and large scale land use changes. A temporal dimension enables it to reveal the growth inertia and path dependency of greenbelt evolution from the previous decade.

The ultimate aim of this model is to answer what-if questions about future greenbelt policy interventions. However, it is necessary to have an often omitted stage of reviewing and understanding the historic performances of a certain policy. Such revisions not only provide insight into future policy design, but also provide a better understanding of the model's prediction capability and validity. This is carried out here through reproducing the reference scenarios of 2000 and 2010 under a calibrated 1990 model. A validated model gives a stronger platform for testing real-world scenarios. Furthermore, compared to what-if tests of future scenarios, the historic-what-if tests are simpler to analyse, because such tests are free of the uncertainties in background trend assumptions, and they are run under better controlled conditions. It is therefore a logical step towards building valid prediction models for future scenarios.

The spatial equilibrium model presented in this paper is a parsimonious model that reveals the basic interactions among the labour market, housing market and product market with a fairly small number of easy-to-interpret parameters. The model can be extended to reflect the more precise socio-economic, land use and transport context of Beijing in greater granularity. The amenity value of greenbelts can be better captured under smaller geographical zones as well. Moreover, the model does not develop a platform for comparing overall costs (including economic costs and other potential costs) with overall benefits (including environmental benefits and other potential benefits) of greenbelts. In the future, the model can interface with other models that are specialised in quantifying environmental impacts to generate a more complete picture to assist decision making.

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List of Tables

Table 1 Zone types and land use variations by scenario

	Number of zones	Scenarios						
		Reference 2000, 2010	**S1**	**N1**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Type 1	17	The central city encircled by GB1						
Type 2	20	The planned GB1 area, land use varies according to scenario specifications.						
		Observed land supply	*Fully enforced GB1*	*No growth control in 2000*	*Fully enforced GB1*	*Fully enforced GB1*	*No growth control in 2010*	*No growth control in 2010*
Type 3	9	The settlements between the designated GB1 and GB2						
Type 4	23	The planned GB2 area, land use varies according to scenario specifications.						
		Observed land supply	*No growth control in 2000*	*No growth control in 2000*	*Fully enforced GB2*	*No growth control in 2010*	*Fully enforced GB2*	*No growth control in 2010*
Type 5	16	The new towns beyond the designated GB2						
Type 6	27	The far suburb						
Type 7	18	The ecological protection area						

Table 2 Inputs for year 1990, 2000 and 2010

Year	**1990**	**2000**	**2010**
Total employed residents (thousands)	6271	7116	11805
Total workers (thousands)	6271	7116	11805
Income per person per year (RMB)	3871	8641	22246
Household size (persons per household)	3.20	2.90	2.45
Total housing supply (m^2)	169,723,859	284,832,535	575,393,422
Total business floorspace supply (m^2)	125,420,000	142,331,749	236,824,134

Table 3 Production quantities across scenarios

	1990	2000 Scenarios			2010 Scenarios				
Scenarios	**Base**	**Ref**	**S1**	**N1**	**Ref**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Total production (million units)	3985	4545	4521	4528	7419	7446	7377	7451	7407

Table 4 Utility levels across scenarios

	1990	2000 Scenarios			2010 Scenarios				
Scenarios	**Base**	**Ref**	**S1**	**N1**	**Ref**	**S1-S2**	**S1-N2**	**N1-S2**	**N1-N2**
Average household utility	7.907	7.972	7.972	7.971	7.974	7.968	7.969	7.973	7.973
Consumer surplus as percentage of money income %, compared to References	-	-	-0.4%	-0.3%	-	-2.5%	-2.1%	-0.4%	-0.4%