The Welfare Effects of Greenbelt Policies: Evidence from England*

By HANS R.A. KOSTER[a] *and* MOHAMMAD SAEED ZABIHIDAN[b]

This version: 8 June 2017

SUMMARY — Planning regulations affect the urban spatial structure of most cities in the Western world. One particular example are urban growth boundaries or greenbelts that prohibit new construction beyond a predefined urban fringe. In this paper we analyse the local external, internal and supply effects of these policies on the housing market. We focus on England, where 13 percent of the land area is designated as greenbelt land. Using spatial differencing, we show that the external effect of these regulations are substantial (about 15 percent) but very local (within 250 metres). In contrast to the previous literature, we find limited evidence for internal or 'own-lot' effects. We show that, due to a substantial supply effect, greenbelt policies seem to have a negative welfare effect.

JEL-code — R520, R0, R1.
Keywords — Land use regulation, urban sprawl, urban growth boundary, open space, greenbelt policies, house prices.

I. Introduction

In many countries urban development put an increasing pressure on space in and around cities. Most cities aim to regulate urban development by the imposition of several constraints on e.g. building height, the type of land use, so-called view corridors and restriction on demolition of specific buildings. Another important example is that local governments impose restrictions on the expansion of urban areas in order to reduce urban sprawl. 'Urban growth boundaries' or 'greenbelts' reduce the land available for development near the urban fringe. Greenbelts are important and cover about 13 percent of the total area in England, and are surrounding most of the larger cities in England. Also many US cities,

* This work has benefited from a VENI research grant from the Netherlands Organisation for Scientific Research. Most of this work has been done while mr. Zabihidan was visiting the Vrije Universiteit Amsterdam. Paul Cheshire, Steve Gibbons, and Christian Hilber, as well as seminar participants in London, are thanked for useful input.
[a] Corresponding author. Department of Spatial Economics, Vrije Universiteit Amsterdam, De Boelelaan 1105 1081 HV Amsterdam, e-mail: h.koster@vu.nl. The author is also affiliated with the Tinbergen Institute, Gustav Mahlerplein 117, 1082 MS Amsterdam.
[b] Faculty of Economics, Razi University of Kermanshah, Tagh-e-Bostan, 6714967346, Kermanshah-Iran, e-mail: zabihidansaeed@yahoo.com.

such as Portland (OR), Miami, Minneapolis Saint-Paul, and San Jose (CA), have urban growth boundaries.

It is well known that land use regulation does not necessarily imply welfare losses, because constraints may reduce negative land use externalities and frictions associated with development. Greenbelts are argued to protect agricultural land and secure amenity benefits from open space (Brueckner, 2001). However, when regulatory constraints do not adjust to changes in demand, these may also imply substantial economic losses.

Most studies on the effects of land use regulation so far concentrate on the regulations of housing supply and show that supply constraints are associated with increasing housing costs, a strong reduction in new construction and rapid price growth. (Mayer and Somerville, 2000; Glaeser et al., 2005; Green et al., 2005; Ihlanfeldt, 2007; Glaeser and Ward, 2009). More recently, Kok et al. (2014) find a strong link between spatial variation in the regulatory environment within a metropolitan area and the prices of undeveloped land. They relate the variation in land prices to the prices paid by consumers for housing and document that local land use regulations have positive effects on the value of houses sold in the region. Turner et al. (2014) evaluates the effect of land use regulation on the value of land and on welfare. They decompose the effects of regulation into three components: *(i)* an 'own-lot' effect, to which we refer to as the internal effect. This reflects the cost of regulatory constraints to the owner of a property; *(ii)* an external effect, which is the proclaimed positive value of regulatory constraints on one's neighbours and; *(iii)* a supply effect, which shows the effect of regulated scarcity of developable land. They find that the large negative internal effects of regulation on the value of land and welfare in regions near municipal borders and limited evidence for positive external effects of regulations. This is in line with Koster et al. (2012) who find a substantial negative internal price effect of regulation.

The number of studies that that aim to identify causal *internal* and *external* effects of land use regulation is limited and the debate on the magnitude of these effects has not been settled. In particular with respect to greenbelt policies, there is very limited evidence on welfare effects. However, greenbelt policies are under scrutiny and receive substantial criticism. For example, it has been argued that greenbelts are just making houses more expensive and do not offer any appreciable amenities to residents. This might be true if greenbelts are used for intensive livestock farming, which may have a negative impact on house prices because of pollution (Bontemps et al., 2008). On the other hand, the greenbelt ensures that houses are closer to open space, which may generate substantial positive benefits (Irwin, 2002; Anderson and West, 2006; Brander and Koetse, 2011). The internal effect should lead to a lower house price for houses located in the greenbelt, as owners cannot alter their properties and the developers are unlikely to be allowed to construct new buildings in the greenbelt, leading to a lower option value of land. Furthermore, greenbelt policies limit the number of available housing units which leads to strong price increases and lower welfare (Hilber and Vermeulen, 2015).

Our study focuses on the effects of greenbelt policies on the housing market and aims to identify local causal effects of these policies. While some previous studies have come up with sensible identification strategies, the main threat is that regulatory constraints are the strongest near the most attractive areas (e.g. close to beautiful natural areas). One is therefore inclined to find evidence for positive external effects of land use policies, while these effects may also have been present without or with less stringent regulation. We employ a cross-sectional identification spatial differencing strategy: we select only areas within maximally a kilometre of a greenbelt boundary and include boundary segment fixed effects to control for unobserved location attributes that may differ between locations and are correlated to greenbelt policies. Moreover, we estimate specifications only including observations close to straight boundary segments, so that it is unlikely that the boundary is just capturing a nice locational feature such as a river. This ensures that *locally* the greenbelt boundary can be considered as random. We then calculate the share greenbelt land within two predefined distance rings (0-250 and 250-500 metres) of each property to identify the external effect.

The results show that external effects are important but are very local (within 250 metres). The coefficients imply that prices can be up to 12 percent higher in greenbelts. This suggests that there is indeed a positive external effect of the greenbelt policy because of proximity to open space. In contrast to Turner et al. (2014) we do not find evidence for internal effects once we control for unobserved locational traits.

Given the positive external effect and the absence of an internal effect, will these results imply that the greenbelt policies mainly have positive welfare effects? The answer appears to be no. We show that under certain assumptions greenbelt policies imply a negative welfare effect, because of a strong supply effect that reduces the number of available housing units in greenbelt land.

This plan for the remainder of the paper is as follows. In Section II we discuss the framework of Turner et al. (2014) and apply it to greenbelts. In Section III we outline our empirical methodology, introduce the datasets and provide descriptives. Section IV outlines the results, followed by conclusions in Section V.

II. Theoretical considerations

A. External, internal and supply effects

We employ the approach of Turner et al. (2014) to identify external, internal and supply effects of land use regulation. Here we discuss the main implications and the application to greenbelts. For a fuller discussion we refer to their paper.

We assume that there are two areas, one containing urban land with regulatory restrictiveness z^U stretching from $-B$ to 0, and an area being the greenbelt stretching from 0 to B with z^G denoting the stringency of regulation in greenbelts. We assume that land use regulation is much more restrictive in the greenbelt, so that $z^G > z^U$. Agents receive a wage

w and pay housing price p_i to occupy a property at location i. We assume that all residents are indifferent between locations and receive e^{θ}. If we assume that utility is given by e^{w-p_i}, then the housing price at location i is given by:

(1) $$p_i = w - \theta + \log V_i,$$

where V_i is the locational quality of i related to supply restrictions ,where $V_i = V_i^{INT} V_i^{EXT}$

Let us define the internal effect as $V_i^{INT}(z^U, z^G)$ as follows:

(2) $$V_i^{INT}(z^U, z^G) = \begin{cases} v_i^{INT}(z^U) \text{ if } i \leq 0 \\ v_i^{INT}(z^G) \text{ if } i > 0 \end{cases}$$

Hence, this function implies a discontinuity of prices at i. Because house owners and developers are likely limited to make changes to properties in greenbelt areas or prohibit replacement of blighted houses, we expect that $v_i^{INT}(z^U) > v_i^{INT}(z^G)$, i.e. $\partial v_i^{INT}(\cdot)/\partial z < 0$.

It may also be that there is an external effect because households may enjoy open space more than urban land ($v_i^{EXT}(z^G) > v_i^{EXT}(z^U)$). On the other hand, it may also argued that urban land offers more amenities and reduces transportation costs to shops and work ($v_i^{EXT}(z^G) < v_i^{EXT}(z^U)$). The total utility derived related to external benefits at a certain location can be given as

(3) $$V_i^{EXT}(z^U, z^G) = \delta \int_{-B}^{B} f(\delta, d_{ij}) v_j^{EXT} \, \mathrm{d}j,$$

where d_{ij} is the distance between i and j and δ is a decay parameter and $f(\cdot)$ is a distance decay function, where it holds that $\partial f(\cdot)/\partial d_{ij} < 0$ and $2B$ is the total land area.

So far we ignored that regulation also has an impact on the amount of available land in greenbelts. Reducing the supply of land will inadvertently lead to higher prices of real estate. Following Turner et al. (2014), let us assume that the amount of developable land is removed from the interior of the greenbelt. In absence of regulation, the amount of land is given by $2B$, while $\partial B/\partial z^G < 0$ implying that the amount of developable land in the greenbelt is decreasing in regulatory restrictiveness.

Let us assume that the outside option is heterogeneous. We assume that the outside options are distributed as $\theta \in [0, \infty)$ and $g(\theta)$ is the p.d.f. of agents of type θ. The c.d.f. is such that $G(\theta^*) = B + B(z^G)$ and we can fill the area with households for whose outside option is worse than θ^*, where θ^* is the marginal household that decides to live in the area. The price gradient is then given by:

(4) $$p_i = w - \theta^*(z^U, z^G) + \log V_i^{INT}(z^U, z^G) + \log V_i^{EXT}(z^U, z^G),$$

This implies that when z^G goes up, fewer land is available, so that fewer households choose to live in the area implying a higher price gradient. We illustrate this in Figure 1.

Suppose that the external benefit of urban land are zero and greenbelt land offers appreciable amenities, in line with the literature that shows that households value open

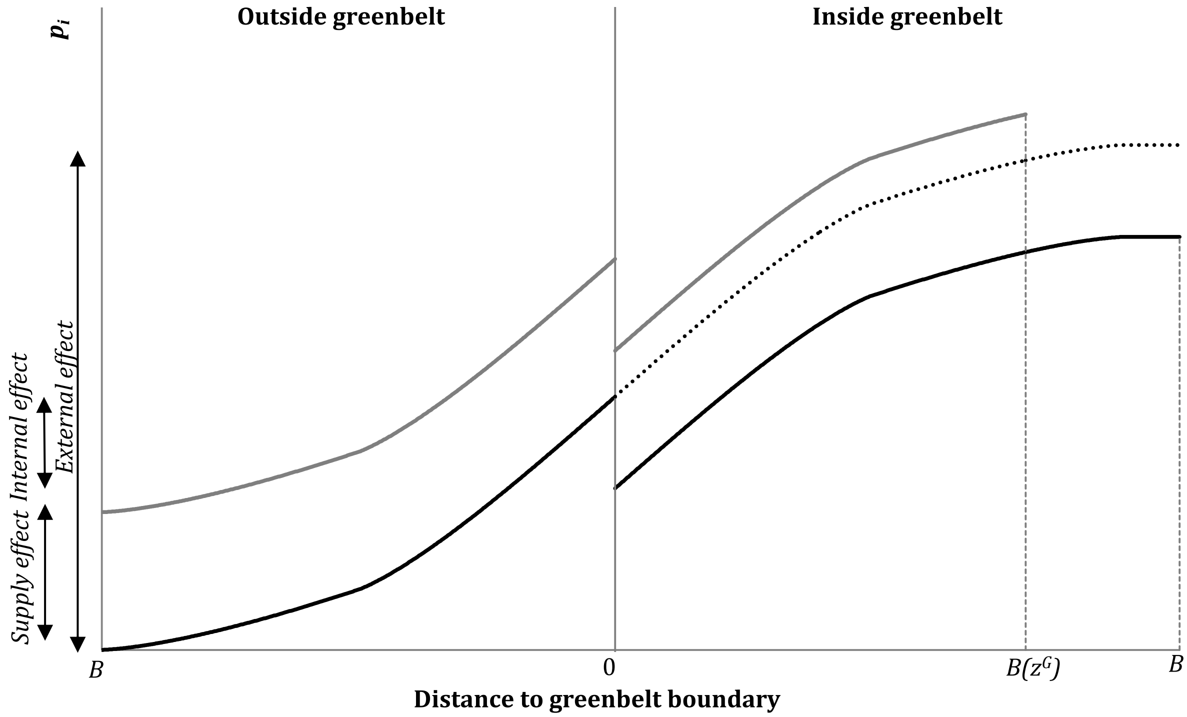

FIGURE 1 — PRICE GRADIENTS AROUND THE GREENBELT BOUNDARY

space (Irwin, 2002; Rouwendal and Van der Straaten, 2008; Vermeulen and Rouwendal, 2014). In absence of an internal price effect, the dotted black line in Figure 1 shows that prices will always be higher in the greenbelt , in particular when i is further away from the greenbelt boundary. If there would be internal price effect, the prices may be lower in the greenbelt if the internal effect is large enough. Once greenbelt policies also have an impact on the supply of land so that the amount of developable land is reduced from $2B$ to $B + B(z^G)$ the price gradient shifts up, because fewer houses are available and only households with a low enough θ^* will locate in this area.

B. Measuring the welfare effect

Before we introduce the econometric framework to estimate the relative sizes of the different price effect we aim to investigate the changes in welfare through changes of land use regulation. We examine a change from z^U to z^G, with $z_0^G = z^U$ and $z_1^G > z^U$. The aggregate land rent as a measure of consumers' surplus is used. The welfare effect of regulation is given by:

(5) $$\mathcal{W}_1 - \mathcal{W}_0 = \int_{-B}^{B(z_1^G)} p_i(z^U, z_1^G)\mathrm{d}i - \int_{-B}^{B} p_i(z^U, z_0^G)\mathrm{d}i,$$

Let us define $\Delta = B - B(z_1^G)$. Turner et al. (2014) show that if regulation implies external and internal price effects, the total welfare effect can be approximated by:

(6) $$\mathcal{W}_1 - \mathcal{W}_0 \approx 2B\left(p\left(B(z_1^G)\right) - p\left(B(z^U)\right)\right) - p(B(z_0^G))\Delta,$$

The first part of the above equation captures the change in welfare due to changes in the internal and external price effects. The second component is the welfare effect due to a reduction in the supply of land.

In this paper we do not have information on parcel prices, but on house prices. We can approximate the welfare effect first by calculating the effect of the internal and external effect on house prices. Then, we calculate the effect of regulation *on the number of housing units* on both sides of the boundary so that Δ represents the difference in the number of housing units due to greenbelt policies.

III. Methodology, data and descriptives

A. Empirical methodology

We are interested in the local economic effects of greenbelt policies on house prices. We make a distinction between an *internal*, *external* and *supply* effect. Following Turner et al., (2014) we re-emphasise that internal effects change discretely at the boundary: within the greenbelt more stringent regulations apply, because house owners are not allowed to make substantial changes to their properties without a permit and new construction is essentially barred. The external effect is measured by the share of greenbelt land within 250 and within 250-500 metre rings. Positive externalities such as having good access to open space and negative externalities such as a bad smell from intensive livestock farming are expected to be very local. Let then p_{it} be the log house price in postcode i in year t, g_i a dummy indicating whether a property is in a greenbelt, s_{it} be the share greenbelt land within a given distance band, and λ_t are year fixed effects to control for price trends. Note however that for our period of analysis (2009-2013), greenbelt boundaries were essentially unchanged. The locations of greenbelts are of course non-random and by definition located at the urban fringe far away from the city centre. In the analysis we therefore only include observations that are within one kilometre of a greenbelt boundary. A somewhat naïve specification to be estimated is as follows:

(7) $$p_{it} = \alpha_1 s_i + \alpha_2 g_i + \lambda_t + \epsilon_{it},$$

where α_1, α_2 and λ_t are parameters to be estimated, and ϵ_{it} is an identically and independently distributed error term.

One may argue that s_i and g_i may be correlated to housing attributes; houses with particular price-increasing characteristics may be disproportionally located in greenbelts. For example, because of historic city limits, properties in greenbelts may be disproportionally detached, while houses outside greenbelts may come in the form of apartments or terraced housing. To mitigate this problem we include housing characteristics, denoted by h_{it}. The housing dataset does not provide very detailed information on housing characteristics. We therefore complement these data by gathering data on the output-area level, which are very small areas. These data also provide information on demographic characteristics, such as the share of rental housing. In this way we at least partly control for sorting effects due to greenbelt policies (Bayer et al., 2007). Let us then define neighbourhood characteristics by n_i. One may still be concerned that there is correlation with unobservable characteristics of a location. Since the greenbelt of London is the largest, and London is one the most expensive cities in England, we may find a positive correlation s_i, g_i and p_{it}, while this is not due to greenbelt policies. We therefore include local authority fixed effects λ_ℓ. We then estimate the following specification:

(8) $$p_{it} = \alpha_1 s_i + \alpha_2 g_i + \alpha_3 h_{it} + \alpha_4 n_i + \lambda_\ell + \lambda_t + \epsilon_{it}.$$

Note that α_3, α_4 and μ_ℓ are additional parameters to be estimated.

A concern with the above specification is that also at the local level greenbelt boundaries are not random and for example follow the course of rivers or woodland edges. If we find a positive effect of greenbelts, this may be caused by the fact that areas close to the greenbelt boundary are close to natural amenities that are not necessarily a result of greenbelt policies. In other words, without those policies the same level of natural amenities would have been achieved. To mitigate this problem, we first will include fixed effects for every straight greenbelt boundary segment, denoted by $\lambda_\mathcal{S}$. To make this approach even more convincing we only will observations that are near straight segments that are longer than, let's say, 100 metres. As argued by Turner et al. (2014), when boundaries are straight there are less likely to capture natural features and more likely to be the result of administrative decisions. We then have:

(9) $$p_{it} = \alpha_1 s_i + \alpha_2 g_i + \alpha_3 h_{it} + \alpha_4 n_i + \lambda_\mathcal{S} + \lambda_t + \epsilon_{it},$$

where ζ and $\lambda_\mathcal{S}$ are additional parameters to be estimated.

To estimate the supply effect we will also estimate specifications where we replace the house price p_{it} by the number of dwellings in each output area in the Census year 2011 on both sides of the greenbelt boundary. Let d_{it} be the log of the number of dwellings in each output area and o_i the share of the output area in the greenbelt. Then:

(10) $$d_i = \beta_1 o_i + \beta_2 a_i + \beta_3 n_i + \mu_\mathcal{S} + \xi_{it},$$

where β_1, β_2, β_3 and $\mu_\mathcal{S}$ and are parameters to be estimated and ξ_{it} is the error term.

B. Data and descriptives

We make use of three datasets. The first dataset contains the universe of housing transactions from England from the Land Registry. We focus on transactions that occur within a kilometre of the greenbelt boundary. We drop observations of prices that are above £ 2.5 million or below £ 25,000 (less than 0.25 percent of the data), but we make sure that our results are not driven by this selection. Because we have information on greenbelt

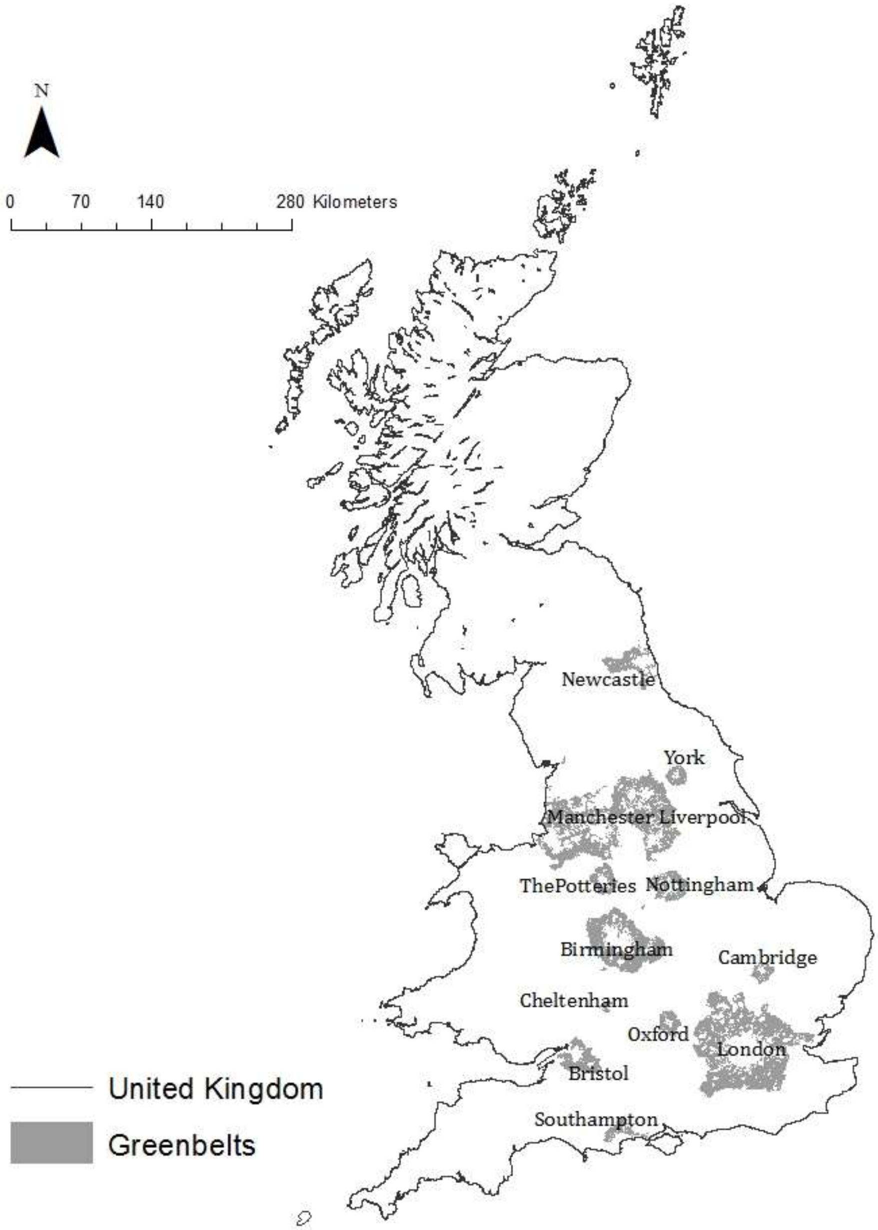

FIGURE 2 — ENGLAND'S GREENBELTS

boundaries from 2011, we keep observations between 2009 and 2013. The Land Registry data further provides information on house type (detached, semi-detached, terraced or flat), whether is leasehold or freehold, and whether it is newly built. We further gather information on housing characteristics from the 2011 Census, such as average number of

TABLE 1 — DESCRIPTIVE STATISTICS FOR THE HOUSING TRANSACTIONS DATA

	mean	sd	min	max
Price of property *(in £)*	228,239.1609	163,564.1265	25,000	2500000
In greenbelt	0.0284			
Distance to greenbelt boundary *(in km)*	0.4336	0.2847	0	1
Share in greenbelt 0-250m	0.0948	0.1997	0	1
Share in greenbelt 250-500m	0.1569	0.2180	0	1
Housing type - detached	0.2288			
Housing type - semi-detached	0.3193			
Housing type - terraced	0.2779			
Housing type - flat	0.1740			
House newly built	0.0850			
Ownership type - freehold	0.7974			
Length of nearest greenbelt boundary stretch *(in m)*	33.0715	78.8957	0	2,375

Notes: We have 346,953 observations within one kilometre of greenbelt boundaries. We also use information from the Census at the Output Area level. These data include the total number of dwellings in an output area, the average number of rooms, share of properties with central heating, share properties that are detached, semi-detached, terraced, or flats. We further have information on the share of temporary accommodation, the share of social rental housing and private rental housing.

rooms, the share of owner-occupied housing and the share of properties with central heating. The latter data is available at the Output Area level – the lowest geographical level at which census estimates are provided. Because housing is relatively homogeneous within output areas, the additional characteristics may serve as additional controls for housing characteristics. The 2011 Census data also provides information on the number of dwellings in each output area, enabling us to come up with an estimate for the supply effect.

Information on greenbelts in 2012 is obtained from the Department of Communities and Local Governments (DCLG). Each local authority digitised land use information and DCLG merged these separate datasets. Figure 2 shows the different greenbelts in Great Britain. Greenbelts do not necessarily seem to be contiguous zones, but there are many small towns that are entirely surrounded by greenbelt land. In this paper, we are mainly interested in the *inner and outer boundaries* of greenbelts, as these capture the actual urban growth boundaries. Hence, we determine the inner and outer boundaries and calculate the distance of each property to the nearest inner or outer boundary of a greenbelt. Properties that are in towns that are entirely surrounded by greenbelts are excluded from the dataset. Furthermore, because the inner and outer boundary of the Manchester-Liverpool greenbelt is hard to identify, we exclude this greenbelt and the related transactions from the dataset. This leaves us with 346,953 observations within one km of the inner or outer boundary of 11 greenbelts (Birmingham, Bristol, Cambridge, Cheltenham, London, Newcastle, Nottingham, Oxford, The Potteries, Southampton, and York).

TABLE 2 — DESCRIPTIVE STATISTICS FOR OUTPUT AREAS

	mean	sd	min	max
Number of housing units	127.9358	21.3073	18.0000	264.0000
Share of each output area in the greenbelt	0.1318	0.2790	0.0000	1.0000
Area size of output area in hectare	29.1165	112.1879	0.1602	3,199.9668
Average number of rooms per household	66.3458	82.1561	0.0160	2,375.2913
Share of properties with central heating	5.4437	0.9516	1.4000	10.0000
Share of terraced properties	0.9787	0.0240	0.6527	1.0000
Share of detached properties	0.2245	0.2171	0.0000	0.9717
Share of semi-detached properties	0.2201	0.2534	0.0000	1.0000
Share of flats	0.3666	0.2554	0.0000	1.0000
Share of caravans	0.1851	0.2375	0.0000	1.0000
Share owner-occupied housing	0.0036	0.0376	0.0000	0.9161
share social rent/council housing	0.6764	0.2343	0.0060	1.0000
share private rentals	0.1747	0.2126	0.0000	0.9860
Length of nearest greenbelt boundary stretch *(in m)*	0.1489	0.1252	0.0000	0.9480

Notes: We have 19,651 output areas within one kilometre of greenbelt boundaries.

Table 1 reports descriptive statistics. We show that the average price of a property near a greenbelt is £ 228,239, which is very close to the national average (£ 233,534). Only 2 percent of the observations are in the greenbelt, which is not too surprising as greenbelts are designed to not include highly developed areas. The average distance to the greenbelt is 434 metres; about one-third of the observations is within 250 metres of the greenbelt boundary. From the data we also observe that areas close to the greenbelt boundaries are not very dense areas, as almost 55 percent of the properties are detached or semi-detached. This is even higher in greenbelts, where it is more than 70 percent. The average length of a straight greenbelt boundary stretch is 33 metres and about 7 percent of the observations is near a straight stretch that is at least 100 metres.

IV. Results

A. Internal and external effects

Our first aim is to find out whether internal and external effects of greenbelt policies are important. Table 3 report the results.

In column (1) we estimate a naïve specification where we regress prices on the share greenbelt land within 0-250 and 250-500 metres, as well as a dummy indicating whether a property is in a greenbelt, while controlling for year fixed effects. The coefficients indicate that the share of greenbelt land within 250 metres has a strong and positive effect. A ten percentage point increase in the share of greenbelt land increases prices with 4 percent. Somewhat surprisingly, we find a *negative* effect beyond 250 metres. Also, we find that properties that are just in the greenbelt seem to be $(e^{0.2045} - 1) = 23$ percent more

TABLE 3 — ORDINARY-LEAST-SQUARES RESULTS – INTERNAL AND EXTERNAL EFFECTS

(Dependent variable: the logarithm of the house price)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No controls	Local authority fixed effects	Boundary stretch fixed effects	Boundary stretch >100m	Include OA characteristics	<750m from boundary	<500m from boundary	<250m from boundary
Share in greenbelt 0-250m	0.2697***	0.0845***	0.0867***	0.1351***	0.1303***	0.1459***	0.1548***	0.1167*
	(0.0342)	(0.0199)	(0.0206)	(0.0500)	(0.0452)	(0.0491)	(0.0530)	(0.0606)
Share in greenbelt 250-500m	-0.0382	0.0081	0.0115	0.0021	-0.0531	-0.0546	-0.0521	0.0533
	(0.0278)	(0.0164)	(0.0185)	(0.0557)	(0.0472)	(0.0537)	(0.0670)	(0.1275)
In greenbelt	0.3249***	0.1554***	0.1367***	0.0698	0.0884	0.0303	0.0090	-0.0708
	(0.0260)	(0.0188)	(0.0270)	(0.0647)	(0.0600)	(0.0597)	(0.0698)	(0.0707)
Housing type - detached		0.6141***	0.4360***	0.4358***	0.3925***	0.3914***	0.3850***	0.3876***
		(0.0045)	(0.0034)	(0.0117)	(0.0116)	(0.0135)	(0.0159)	(0.0207)
Housing type - semi-detached		0.1642***	0.1254***	0.1134***	0.0983***	0.0949***	0.0900***	0.0936***
		(0.0031)	(0.0022)	(0.0076)	(0.0073)	(0.0081)	(0.0093)	(0.0123)
Housing type - flat		-0.1832***	-0.2468***	-0.2306***	-0.2277***	-0.2097***	-0.2098***	-0.2265***
		(0.0087)	(0.0070)	(0.0256)	(0.0247)	(0.0288)	(0.0345)	(0.0431)
House newly built		0.1700***	0.1682***	0.1685***	0.1644***	0.1614***	0.1414***	0.1134***
		(0.0085)	(0.0071)	(0.0287)	(0.0257)	(0.0285)	(0.0343)	(0.0409)
Ownership type - freehold		0.1176***	0.1929***	0.2305***	0.2349***	0.2493***	0.2473***	0.2628***
		(0.0079)	(0.0064)	(0.0257)	(0.0251)	(0.0290)	(0.0346)	(0.0445)
Output area characteristics (9)	No	No	No	No	Yes	Yes	Yes	Yes
Local authority fixed effects (168)	No	Yes	No	No	No	No	No	No
Boundary stretch fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	346,953	346,953	346,953	24,424	24,424	20,140	15,590	8,888
R^2	0.0342	0.6169	0.8206	0.7949	0.8085	0.8117	0.8159	0.8461

Notes: In columns (4)-(8) we only include observations for which the nearest straight greenbelt boundary stretch is at least 100 metres. In column (6), (7) and (8) we only keep observations that are within 750, 500 and 250 metres of the greenbelt boundary, respectively. Standard errors are clustered at the output area and in parentheses; *** p<0.01, ** p<0.5, * p<0.10.

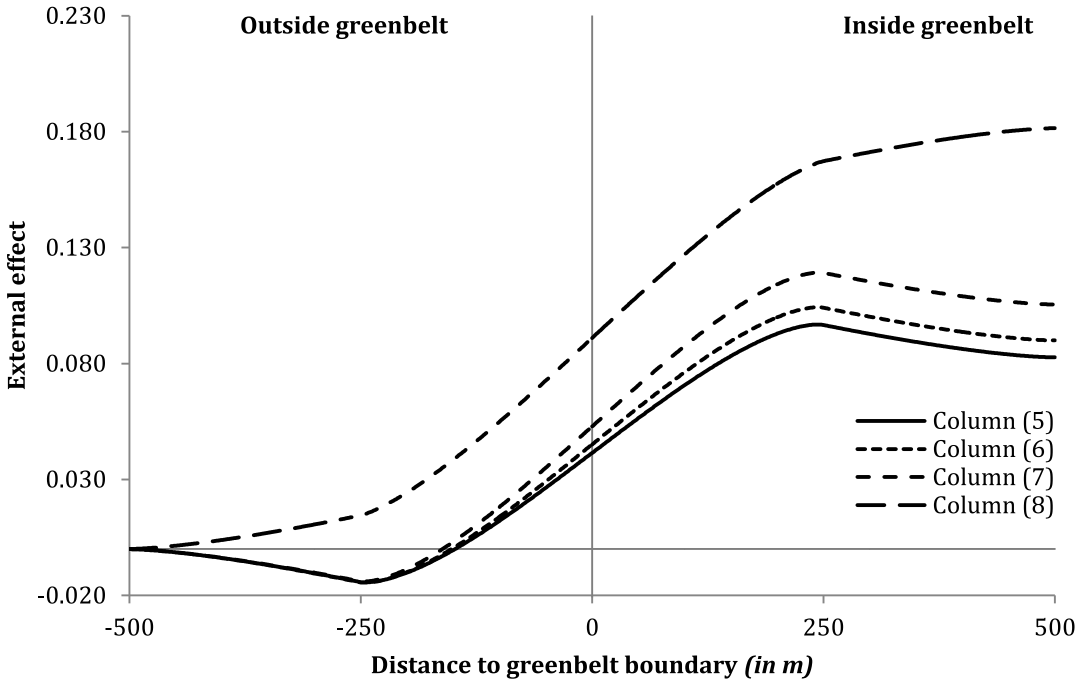

FIGURE 3 — EXTERNAL EFFECT OF GREENBELT POLICIES

expensive, which would seem to point towards a substantial *positive* internal effect. However, we do not interpret this as a causal effect, because it is likely that omitted housing characteristics are correlate with the greenbelt dummy (e.g. the fact that there are more (semi-)detached properties in the greenbelt). Indeed, when we control for some elementary housing attributes and include 168 local authority fixed effects in column (2), the internal effect is reduced with more than 40 percent.[1] Further, the effect of share greenbelt land within 250 metres is again positive, but substantially lower. The effect of greenbelt land beyond 250 metres is statistically insignificant and close to zero.

One may argue that greenbelt boundaries follow particular attractive geographical features, such as rivers, woodland edges, or crest. To mitigate this issue we include fixed effects for every nearest straight boundary stretch in column (3) in Table 3, which should capture all relevant geographical features that are correlated with the boundary shape. The results are similar; we find a positive effect of greenbelt land within 250 metres and a strong positive internal effect.

[1] The coefficients related to control variables are intuitive. We find that detached and semi-detached are (substantially) more expensive than terraced housing, while flats are cheaper. Newly built houses are about 18.5 percent more expensive and freehold implies a price premium of 12.5 percent.

One may still argue that winding boundaries may capture attractive geographic features that is not a direct result of planning regulation. Following Turner et al. (2014) we therefore only keep observations near relatively straight boundary stretches, as straight boundary stretches are unlikely to be part of nature. Column (4) therefore only include observations near stretches of at least 100 metres, which reduces the observations with 93 percent. Despite the strong reduction in observations, the results are very similar. The coefficients related to the external effect suggest that a ten percentage point increase in the share of greenbelt land within 250 metres raises the house price with 1.3 percent. Beyond 250 metres, the effect is very close to zero and highly statistically insignificant. Also, the internal effect, captured by the greenbelt dummy, is now much smaller and not statistically significant from zero at conventional levels. This result continues to hold if we include 9 output area characteristics related to the quality of housing.

In the last three columns we reduce the distance to the boundary as to further improve the likelihood that we measure causal effects. It is shown that the coefficient related to greenbelt land within 250 metres is very robust and is statistically significant in all specifications, even if we only include observations within a mere 250 metres of the greenbelt boundary. Beyond 250 metres the coefficient is highly statistically significant in all specifications. The same holds for the greenbelt dummy.

In Figure 3 we plot the external effect of regulation for the last four columns displayed in Table 3. It is shown that all specifications lead to very similar predictions about the external effect. For most specifications, the external effect due to greenbelt policies is about 10 percent (if we compare a locations that are 500 metres away from the greenbelt boundary). The only exception is the last specification where we only include observations within 250 metres of the boundary (column (8)), which predicts an effect up to 18 percent.

B. Supply effect

Table 4 reports results regarding the supply effect. Because we lack information on land values and land use, we regress the logarithm of the number of dwellings on the share of each output area in the greenbelt instead. Because the number of dwellings may be a direct function of its size we control for the area size of an output area in all specifications.

Column (1) is a parsimonious specification that shows that when an output area is in the greenbelt (so the share would be equal to one), the number of dwellings is $(e^{-0.0781} - 1) =$ 7.5 percent lower. When we control for local authority fixed effects in column (2), we show that the number of dwellings is 8.5 percent lower. However, local authority fixed effects are unlikely to control for all unobserved traits that may cause dwelling density to be higher outside greenbelts. We therefore control for boundary segment fixed effects in column (3). The results highlight that the impact of being in the greenbelt then becomes stronger:

TABLE 4 — ORDINARY-LEAST-SQUARES RESULTS – SUPPLY EFFECT

(Dependent variable: the logarithm of dwellings)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	No controls	Local authority fixed effects	Boundary stretch fixed effects	Boundary stretch >100m	Include OA characteristics	<750m from boundary	<500m from boundary	<250m from boundary
Share in greenbelt	-0.0781***	-0.0888***	-0.1938***	-0.1855***	-0.1998***	-0.2235***	-0.2710***	-0.4070***
	(0.0059)	(0.0061)	(0.0176)	(0.0243)	(0.0241)	(0.0274)	(0.0356)	(0.0641)
Area size *(in log)*	0.0171***	0.0240***	0.0701***	0.0683***	0.0796***	0.0975***	0.1311***	0.2142***
	(0.0014)	(0.0016)	(0.0033)	(0.0065)	(0.0068)	(0.0085)	(0.0128)	(0.0283)
Output area characteristics (9)	No	No	No	No	Yes	Yes	Yes	Yes
Local authority fixed effects (168)	No	Yes	No	No	No	No	No	No
Boundary stretch fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19,651	19,651	19,651	4,277	4,277	3,615	2,789	1,651
R^2	0.0097	0.0414	0.7104	0.6754	0.6882	0.7346	0.8016	0.9317

Notes: In columns (4)-(8) we only include observations for which the nearest straight greenbelt boundary stretch is at least 100 metres. In column (6), (7) and (8) we only keep observations that are within 750, 500 and 250 metres of the greenbelt boundary, respectively. Standard errors are in parentheses; *** p<0.01, ** p<0.5, * p<0.10.

output areas that are fully in the greenbelt host 17.6 percent fewer dwellings. A similar figure is obtained once we only focus on boundary segments that are larger than 100 metres in column (4).

In column (5) of Table 4 we include other output area characteristics, such as the average room size, the share of properties with central heating and share of detached housing. However, this hardly impacts the coefficient of interest. Columns (6) and (7) only include output areas within 750 and 500 metres of the greenbelt boundary. The coefficients are similar albeit a bit higher than the baseline coefficients in previous specifications. When we only include observations within 250 metres of the greenbelt boundary the effect of being in the greenbelt becomes about twice as strong: output areas that are in a greenbelt seem to have 33.4 percent fewer dwellings. However, we note that the standard error is somewhat larger due to a lower number of observations.

Hence, the results unequivocally suggest that greenbelt policies strongly restrict the number of residential properties in greenbelts, which is in line with anecdotal evidence on urban growth boundaries.

C. Welfare effect

The last step in the empirical analysis is to take into account all the estimates and calculate the net welfare effect of regulation. The total welfare effect of greenbelt policies $\mathcal{W}_G$ for greenbelt G is then approximated by:

$$\mathcal{W}_G \approx \left(\hat{\alpha}_1 \bar{s}_G + \left(\hat{\alpha}_2 + \hat{\beta}_1\right)\bar{g}_G\right) \times \underline{p_G} \times D_G, \tag{11}$$

where $\underline{p_G}$ is the house price outside the greenbelt one kilometre away from the greenbelt boundary and D_G is the total number of dwellings that are in and around greenbelt G. We estimate $\underline{p_G}$ for each greenbelt separately by taking the median prices between 1000 and 1500 metres from the greenbelt boundary. $\bar{s}_G$ and $\bar{g}_G$ are the average share of properties that are within 0-250 or 250-500 metres, and the share of properties that are in the greenbelt respectively. Note that the external effect $\hat{\alpha}_1$ is positive, supply effect $\hat{\beta}_1$ is negative, while the sign of the internal effect is indeterminate.

We have to make some simplifying assumptions, so the estimates based on (11) should be interpreted with caution. First, our coefficients are based on observations within one kilometre of the greenbelt boundary and therefore one may argue that these are mainly local treatment effects. This in particular holds for the supply effect. However, by extrapolating our results to the full dataset we assume that the local average treatment effects are indeed average treatment effects.

Further, we calculate the price $\underline{p}$ outside the greenbelt as a reference. However, if housing types change discontinuously at the boundary with housing in greenbelts being more attractive (e.g. more detached housing in greenbelts), $\mathcal{W}_G$ will likely be an underestimate. However, if $\underline{p}$ is incorrect, the results are the same up to a proportionality constant and the qualitative conclusions will not change.

The results per greenbelt are listed in Table 5. The standard errors are estimated using the delta method. We first focus on the specification listed in column (3) in Table 3 and Table 4. We show that for all greenbelts there is a statistically significant positive external effect. However, it seems also that there is a *positive* and statistically significant internal effect, which may suggest that we have an omitted variable bias. Despite a significant and meaningful negative supply effect, the welfare effect is positive and weakly significant in most greenbelts.

However, if we turn to the more believable specification related to the results displayed in (5) in Table 3 and Table 4, we do not find statistically significant internal effects in any of the greenbelts. The external effect, however, is positive. For example, for the London greenbelt, the total external effect is about £ 14 billion. It appears that in most cases the supply effect is of a similar magnitude as the external effect. Hence, although the welfare effect is negative in most cases, it is far from being statistically significant.

In the last set of results listed in Table 5 we use the estimates in column (8) in Table 3 and Table 4. Because there we only include observations within 250 metres of the boundary, the standard errors are higher. Hence, we only find a statistically significant external effect in the Birmingham and London greenbelts. The internal effect has the expected negative sign in all greenbelts but is far from being statistically significant. The supply effect, however, is strong and negative in all greenbelts. For example, in the Birmingham greenbelt, the supply effect amounts to almost £ 9 billion. If we calculate the total welfare effect, we find negative and significant effects for the Birmingham and London greenbelts. In particular for London we find a negative welfare estimate of £ 38 billion, which seems large.

Hence, dependent on the specification we find that the external and supply effect are of a similar magnitude so that the welfare effect is not statistically significant different from zero. However, if we take the most stringent specification, the losses due to greenbelt policies can be large, in particular in areas with high house prices, such as London.

TABLE 5 — WELFARE EFFECTS

	Specification in column (3)				Specification in column (5)				Specification in column (8)			
	External	Internal	Supply	Welfare	External	Internal	Supply	Welfare	External	Internal	Supply	Welfare
Birmingham	2620	3007	-4200	1427	1598	1944	-4330	-788	4787	-1558	-8820	-5591
Bristol	936	1161	-1584	513	598	751	-1633	-284	1696	-602	-3327	-2233
Cambridge	505	625	-859	271	337	404	-885	-144	908	-324	-1803	-1219
Cheltenham	147	158	-240	65	88	102	-247	-58	270	-82	-504	-316
London	14268	16877	-23626	7519	8869	10909	-24354	-4577	25984	-8745	-49613	-32374
Newcastle	714	781	-1071	423	396	505	-1104	-203	1325	-404	-2249	-1328
Nottingham	875	1046	-1414	508	529	676	-1457	-252	1603	-542	-2969	-1908
Oxford	596	685	-991	290	363	443	-1021	-216	1090	-355	-2081	-1345
Bournemouth	743	899	-1226	416	467	581	-1264	-216	1351	-466	-2575	-1690
The Potteries	445	535	-727	252	283	345	-750	-121	807	-277	-1527	-997
York	375	417	-620	172	231	269	-639	-139	684	-216	-1302	-834

Notes: The numbers are in million pounds.

V. Conclusions

Planning regulations affect the urban spatial structure of most cities in the Western world. One particular example are urban growth boundaries or greenbelts that prohibit new construction beyond a predefined urban fringe. In this paper we analyse the local external and internal effects of these policies for England on the housing market. Using spatial differencing, we show that the external effect of these regulations are substantial (about 15 percent) but very local (within 250 metres). We find limited evidence for internal or 'own-lot' effects. We find that, due to a substantial supply effects, greenbelt policies seem to decrease welfare.

References

Anderson, S. T., and West, S. E. (2006). Open Space, Residential Property Values, and Spatial Context. *Regional Science and Urban Economics*, *36*(6), 773–789.

Bayer, P., Ferreira, F., and McMillan, R. (2007). A Unified Framework for Measuring Preferences for Schools and Neighborhoods. *Journal of Political Economy*, *115*(4), 588–638.

Bontemps, C., Simioni, M., and Surry, Y. (2008). Semiparametric Hedonic Price Models: Assessing the Effects of Agricultural Nonpoint Source Pollution. *Journal of Applied Econometrics*, *23*(6), 825–842.

Brander, L. M., and Koetse, M. J. (2011). The Value of Urban Open Space: Meta-analyses of Contingent Valuation and Hedonic Pricing Results. *Journal of Environmental Management*, *92*(10), 2763–2773.

Brueckner, J. K. (2001). Urban Sprawl: Lessons from Urban Economics. *Brookings-Wharton Papers on Urban Affairs*, *2001*(1), 65–97.

Glaeser, E. L., Gyourko, J., and Saks, R. E. (2005). Why have Housing Prices Gone up? *American Economic Review*.

Glaeser, E. L., and Ward, B. A. (2009). The Causes and Consequences of Land Use Regulation: Evidence from Greater Boston. *Journal of Urban Economics*, *65*(3), 265–278.

Green, R. K., Malpezzi, S., and Mayo, S. K. (2005). Metropolitan-Specific Estimates of the Price Elasticity of Supply of Housing, and their Sources. *American Economic Review*, *95*(2), 334–339.

Hilber, C. A. L., and Vermeulen, W. V. (2015). The Impact of Supply Constraints on House Prices in England. *The Economic Journal*, Forthcoming.

Ihlanfeldt, K. R. (2007). The Effect of Land Use Regulation on Housing and Land Prices. *Journal of Urban Economics*, *61*(3), 420–435.

Irwin, E. G. (2002). The Effects of Open Space on Residential Property Values. *Land Economics*, *78*(4), 465–480.

Kok, N., Monkkonen, P., and Quigley, J. M. (2014). Land Use Regulations and the Value of Land and Housing: An Intra-metropolitan Analysis. *Journal of Urban Economics*, *81*, 136–148.

Koster, H. R. A., Van Ommeren, J. N., and Rietveld, P. (2012). Bombs, Boundaries and Buildings: a Regression-discontinuity Approach to Measure Costs of Housing Supply Restrictions. *Regional Science and Urban Economics*, *42*(4), 631–641.

Mayer, C. J., and Somerville, C. T. (2000). Land use regulation and new construction. *Regional Science and Urban Economics*, *30*(6), 639–662.

Rouwendal, J., and Van der Straaten, J. W. (2008). The Costs and Benefits of Providing Open Space in Cities. *Tinbergen Institute Discussion Paper TI 2008-001/3*.

Turner, M. A., Haughwout, A., and Van der Klaauw, W. (2014). Land Use Regulation and Welfare. *Econometrica*, *82*(4), 1341–1403.

Vermeulen, W. V., and Rouwendal, J. (2014). On the Value of Foregone Open Space in Sprawling Cities. *Journal of Regional Science*, *54*(1), 61–69.