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Backyarding

Theory and Evidence for South Africa

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Abstract

This paper explores the incentives for backyarding, an expanding category of urban land-use in developing countries that has proliferated South Africa. The theoretical model exposes the trade-off faced by the homeowner in deciding how much backyard land to rent out: loss of yard space consumption in return for a gain in rental income. Under common forms for preferences, the homeowner's own-consumption of yard space falls as land rent increases, causing more land to be rented to backyarders. With better job access for backyarders raising land rent by increasing their willingness-to-pay, the analysis then predicts that the extent of backyarding will be higher for parcels with good job access. This hypothesis is tested by combining a satellite- based count of backyard dwellings per parcel with job-access data. The empirical results strongly confirm the prediction that better job access increases the extent of backyarding.

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Backyarding: Theory and Evidence for South Africa

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1. Introduction

Governments in most countries in the world have pursued housing subsidy schemes designed to make land and housing more affordable to targeted beneficiaries. In the cities of developing countries, where informal housing is widespread, these programs aim to facilitate access to formal housing for low-income households who would otherwise live in slums. The programs often consist of the provision of individual houses, a generous approach that builds political support among the beneciaries. Because subsidized housing schemes are run by government agencies, they must comply with formal housing norms and often end up providing plots that are significantly larger than what beneficiaries would have demanded if support came in the form of supplementary income. In the absence of legal transferability of the allocated plots (which often cannot be resold for a number of years), a likely consequence is overconsumption of space by current occupants along with land misallocation and sprawl at the city level.

South Africa offers a graphic example of consumer responses to a housing program with such features. A land-use practice known as "backyarding" has proliferated in South Africa, and it also appears to be expanding in other developing countries. Under this practice, the owner of a (typically subsized) formal house rents a portion of his yard area to occupants who live in a dwelling constructed either by formal or informal methods (yielding a backyard shack in the latter case). The presence of backyarding indicates that existing subsidized homeowners view their yard areas as excessive at prevailing land rents, encouraging them to reduce their consumption of yard space in return for cash.

Despite its emergence as the fastest growing housing type in South Africa, backyarding remains poorly understood. Moreover, it represents a unique mixture of informal and formal land-tenure modes that has not yet been recognized in the economics literature on housing in developing countries. The present paper adds to the literature on housing markets in the developing world by providing an economic analysis of backyarding, developing a theoretical model whose predictions are then tested empirically.[1] By improving our understanding of the backyarding phenomenon, the paper also helps to guide the formulation of government housing programs in the developing world, mainly by the exposing consequences of giving poor households more housing than they can reasonably use.

An appreciable share of South Africa's population, particularly the urban population, lives in backyard dwellings. According to Statistics South Africa, the number of households living in either formal or informal dwellings in backyards has increased from 1.135 million in 2011 (7.3% of the country total), to 1.835 million in 2016 (12.5% of the total). Backyarding is predominantly an urban phenomenon, with 84.2% of households that live in backyard dwellings residing in urban areas (as defined by Statistics South Africa as of 2011). Households living in backyards constituted 8.9% of urban households in 2011, rising to 13.4% by 2016. In contrast, the number of households living in informal settlements declined both in absolute and relative terms, from 9.8% of urban households in 2011 to 8.7% in 2016.

The durability of housing capital limits the adjustment of urban densities as population growth raises housing demand, and backyarding can be viewed as an efficient way of overcoming this limitation. With the durable housing stock fixed in the short run, backyarding allows an incremental increase in housing supply without the need to redevelop existing structures at higher densities, an adjustment that might take decades to unfold. The backyarding phenomenon may also indicate that yard areas in government-subsidized housing, where backyarding is most common, were too large from an overall efficiency perspective, with backyarding providing a correction to this original misallocation of resources.[2] These ideas could be illustrated formally, but doing so is beyond the scope of the paper (the argument is clear intuitively in any case).

The theoretical model developed in the paper depicts the homeowner's backyarding choice, where the amount of yard area rented to backyard households is chosen.[3] In making this choice, the homeowner trades off rental income against the loss of yard space for his own consumption. A higher land rent raises the "price" to the homeowner of a unit of yard-space consumption (the forgone income from renting it), generating the usual income and substitution effects of a price change. But the resulting negative effect of rent on own-consumption of yard space is offset by an additional positive effect that arises through an increase in the homeowner's "full income" (non-rental income plus income from renting the entire yard area). As a result, the effect of land rent on the amount of land rented out, and thus on the extent of backyarding, is ambiguous in general. A similar ambiguity arises in the labor-leisure choice, where a higher wage raises full income along with the price of leisure. This ambiguity is not present, however, when the homeowner's preferences take the Cobb-Douglas form or the more-general CES form (as long as the elasticity of substitution is reasonably high). In these familiar cases, a higher rent decreases yard-space consumption, raising the amount of yard area rented out and thus the extent of backyarding.

With backyarders willing to pay more for land near employment centers, the rent they offer rises with job access, which then tends to raise the extent of backyarding, given the positive connection between the yard area rented out and the rent level. But better job access also raises the homeowner's income net of commuting cost, which tends to reduce his willingness to rent out yard space. However, under the assumption that homeowner and backyarder earnings differ only through their extent of labor market attachment, it is shown that the net effect of job access on backyarding is positive, an effect that constitutes the main empirical prediction of the model. While the prediction may seem natural, being similar to usual association between population density and job access in urban models, the existence of the opposing effects of job access on rent and homeowner net income means that the prediction is by no means automatic.

The paper's empirical work adds to a large empirical literature on housing in developing countries, but there is little precedent for the actual empirical exercise that we carry out and thus little direct connection to any previous paper.[4] The empirical work is mainly devoted to testing the job-access prediction, and it relies on a number of data sets sourced from Cape Town's city government. The first data set comes from digital aerial photography and high-resolution satellite images, which give point locations of buildings along with an associated land-use classification per building, including informal uses. We overlaid these spatial data on a digital map of land-parcel contours from the City of Cape Town's cadastre, yielding a count of the number of backyard dwellings per land parcel. After various exclusions, our data set consists of 551,421 sample parcels. Backyarding usually involves a single dwelling, but many land parcels have multiple backyard structures.

Two additional data sets are combined in order to measure job access. The first contains employment counts by transportation zone within Cape Town. With almost 1,800 zones delineated, employment across space is finely measured. The additional data set consists of origin-destination matrices showing commute travel times between each pair of Cape Town transportation zones, with separate matrices for different modes. After assigning parcels to transportation zones, this travel time information is used to compute several gravity-type job-access measures for each parcel in the sample. Then, using a Poisson regression, the parcel-level backyarding count is regressed on a job-access measure and several additional covariates. The results strongly support the model's prediction that the extent of backyarding rises with job access.

The paper is organized as follows. Section 2 presents background information on the backyarding phenomenon. Section 3 presents the theoretical analysis, and section 4 describes the data sources. Section 5 describes the empirical framework and presents summary statistics, while section 6 presents the empirical results. Section 7 offers conclusions, showing the broader implications of the analysis by noting the emergence of backyard structures as a partial remedy for housing unaffordability in high-cost US cities, with a similar trend emerging in Europe.

2. Background information on backyarding

2.1. General features

Backyarding usually occurs on a small scale, rarely involving more than one or two self-contained dwellings constructed in the back yard of a formal dwelling. Whether constructed from permanent or non-permanent building materials, these self-contained units are distinct from secondary dwellings (e.g., flatlets) developed in compliance with planning regulations. By sharing external services such as water taps, electricity connections and outside toilets with the landlord in return for rent, the overall quality of accommodation for backyard residents is significantly better than that available in informal settlements (Beall, Crankshaw and Parnell, 2003). The photograph in Figure 1 shows a parcel in Cape Town's Gugulethu township with two backyard shacks, with the main house seen on the left.

The proliferation of backyard dwellings in Cape Town corresponds closely to the roll-out of government-subsidized and fully serviced housing properties, where surplus yard space created the opportunity for additional one- or two-room structures to be developed by the landlord, to accommodate family or earn rent.

2.2. Backyarding in Council housing

The earliest occurrence of the backyarding phenomenon can be traced to the roll-out of Council housing during the 1950s and 1960s, which was intended to accommodate migrant labor of black African and mixed descent during the height of Apartheid. Rental housing for families of mixed descent offered enough backyard space for tenants to supplement their incomes by building additional dwellings to accommodate relatives, who paid in kind (rather than through rent). Units assigned to black African households were of a highly standardised "matchbox" design: a free-standing, single-storey house with an internal floor space of between 40 and $44m^2$, situated on a plot of at least $100m^2$ (Beall et al., 2003). In black African townships, these dwellings were typically intended to accommodate paying tenants rather than relatives (Lemanski, 2009). These distinctions, however, weakened with time.

Turok and Borel-Saladin (2016, p. 11) describe backyarding as a "safety valve to absorb the pressure of popular demand to access urban livehoods". As a result, in contravention of planning legislation, municipal authorities adopted a laissez-faire stance as backyarding grew during the 1970s and 1980s. This trend accelerated further following the relaxation of Apartheid-era influx-control laws during the 1980s, which precipitated the first major wave of urbanization in South Africa. By 1994, 87% of houses in two large black African townships in Cape Town contained shacks constructed in the backyard (Lemanski, 2009). In one of them, Gugulethu, the number of backyard dwellings (9981) outnumbered formal houses (8156) (Lee, 2005).

2.2. Backyarding in RDP housing

The second, larger wave of backyarding expansion occurred following the ambitious public housing program launched after the country's first democratic elections in 1994. Under the auspices of the Reconstruction and Development Program (RDP) and its successor, Breaking New Ground (BNG), the State constructed over a million fully serviced houses across South Africa. Following a standard format with a 40m^2 dwelling on a serviced residential land parcel averaging 160m^2 in size, the roll-out of so-called "RDP houses" greatly expanded the opportunity for backyarding throughout urban areas.

2.3. Landlord and tenant incentives

The improvement in living conditions enjoyed by the RDP household was rarely accompanied by an improvement in its economic prospects. In fact, the peripheral location and dormitory nature of the sprawling RDP housing settlements often resulted in poor job accessibility. In response, housing recipients became landlords by erecting and then renting out informal dwellings in their backyards. In doing so, they successfully exploited one of the few resources at their disposal: space (Govender, Barnes, and Pieper 2011).

Why do poor people live in backyard dwellings, dependent on landlords and liable for rent, rather than moving to an informal settlement and experiencing an independent and rent-free lifestyle? The principal reasons appear to include better access to services, better locations, a reduced threat of eviction, and greater personal safety (Tshangana, 2014, Lemanski, 2009). For poor households dependent on irregular and informal employment, backyard dwellings offer a degree of locational flexibility in response to economic opportunities not available with static residence in a peripheral, dormitory RDP settlement (Lemanski, 2009). Such locational flexibility is particularly attractive to newly urbanized residents seeking job opportunities (Lemanski, 2009). Perhaps counter-intuitively, both official statistics and case studies confirm that the economic and educational profiles of backyard dwellers are superior to those of their landlords (Govender et al., 2011). In addition, 2011 Census data analysed by Rabe (2017) show that backyard dwellings in Cape Town are more likely to contain a single person, and less likely to contain more than four persons, than the average dwelling in the city, consistent with the view that backyard households are more mobile than the general population. Moreover, a study of backyarding in Greater Soweto (Johannesburg) indicated that backyard tenants are significantly younger than their landlords (36 vs. 56 years for household heads) and more likely to be foreign immigrants (Beall et al., 2003).

3. Theory

The section develops a theoretical model and derives hypotheses on backyarding patterns. These predictions are then tested in the empirical analysis.

3.1. Model

In the model, the characteristics of the existing formal house are taken as given, having been determined under the RDP program or by other past formal housing development decisions. The fixed floor space of an existing house is denoted $\overline{q}$ and the yard area is denoted $\overline{y}$. With a single-storey house, the formal lot size is then $\overline{q} + \overline{y}$. Letting y denote the consumption yard space, which may be less than $\overline{y}$, and c denote nonhousing consumption, the formal homeowner's well-behaved utility function is $u(c, y, \overline{q})$. Let I denote the homeowner's income net of any commuting cost and let r denote land rent, which may depend on location (sections 3.3 and 3.4 below analyze locational effects). Then, assuming the house is owned outright, so that no current payments are required, the budget constraint is

$$c \;=\; I \;+\; r(\overline{y} - y), \tag{1}$$

where $r(\overline{y} - y)$ is the income from renting out yard space.[5] Note that the rented space equals the size $\overline{y}$ of the yard minus own-consumption y, which is multiplied by land rent r to get rental income. Observe also that this formulation assumes that, by renting out less than his total yard area, the formal homeowner can still enjoy the benefits of some open space around his house. Substituting (1) into the utility function, while recognizing that floor space stays fixed at $\overline{q}$, utility can be written as

$$u(I + r(\overline{y} - y), y, \overline{q}). \tag{2}$$

Utility in (2) is maximized by choice of y, and the first-order condition is

$$MRS \;\equiv\; \frac{u_y}{u_c} \;=\; r, \tag{3}$$

where subscripts denote partial derivatives and MRS denotes the marginal rate of substitution between yard space and c. This condition says that the MRS is set equal to the opportunity cost of yard space, namely, the rent forgone by consuming an extra square foot of y. The next section carries out comparative-static analysis of the decision problem, showing how the yard-space choice depends on the parameters of the problem, most importantly r and I.

3.2. Comparative-static analysis

Note first that, if the MRS exceeds r when y equals $\overline{y}$, so that the value of the first rented unit of yard space exceeds its opportunity cost, then no yard space is rented, with $y = \overline{y}$. Conversely, if the MRS is less than r when $y = 0$, then every marginal unit of yard space is valued at less than the opportunity cost, so that the entire yard is rented out. Assuming that neither of these conditions holds, so that an interior solution obtains, comparative-static analysis can then be carried out.[6] Totally differentiating (3) with respect to y, I, r, $\overline{y}$, and $\overline{q}$ yields

$$(-MRS_c r + MRS_y)dy \;+\; MRS_c\, dI \;+\; (MRS_c(\overline{y} - y) - 1)dr \;+\; rMRS_c\, d\overline{y} \;+\; MRS_q\, d\overline{q} \;=\; 0, \tag{4}$$

where the subscripts denote the partial derivatives of MRS.

It is straightforward to show that the term multiplying dy $(-MRS_c r + MRS_y \equiv \Omega)$ is negative when the utility function has strictly convex indifference curves.[7] In addition, normality of y implies $MRS_c > 0$, so that the absolute indifference-curve slope (given by MRS) becomes steeper moving vertically toward higher c's in the (y, c) plane (y is on the horizontal axis). Then, as an increase in I or an increase in $\overline{y}$ shifts the budget constraint (1) upward in parallel fashion, the tangency between the steepening indifference curve and the constraint will move to the right. Thus, using (4),

$$\frac{\partial y}{\partial I} \;=\; -\frac{MRS_c}{\Omega} \;>\; 0, \qquad \frac{\partial y}{\partial \overline{y}} \;=\; -\frac{rMRS_c}{\Omega} \;>\; 0, \tag{5}$$

so that higher homeowner income or a higher $\overline{y}$ causes more yard space to be consumed. Less yard space is therefore rented out when income increases, with $\overline{y} - y$ falling, although $\overline{y} - y$ could rise or fall when $\overline{y}$ increases, given that both $\overline{y}$ and y increase.

Using (2), the effect of higher land rent on y is given by

$$\frac{\partial y}{\partial r} \;=\; -\,\frac{MRS_c(\overline{y} - y) - 1}{\Omega} \;\; > (<) \;\; 0. \tag{6}$$

The effect of r is thus ambiguous, with either more or less yard space consumed as rent rises. The reason is that the usual negative substitution and income effects of a higher rent (captured respectively by the -1 and $-MRS_c\, y$ terms in the numerator of (6)) are offset by an additional positive income effect that arises because the "full income" of the consumer $(I + r\overline{y})$ rises with r (captured by the $MRS_c\,\overline{y}$ term). This ambiguity is similar to the one that arises in analysis of the labor-leisure choice, where a higher wage raises full income while also increasing the price of leisure.

The ambiguity can be seen in Figure 2, which shows the change in the budget line when r increases. If $y = \overline{y}$ in (1), then $c = I$ holds regardless of the value of r, so that the bottom endpoint of the budget line is fixed at $(\overline{y}, I)$. If $y = 0$, then $c = I + r\overline{y}$, so that the c intercept of the budget line rises when r increases, with the line rotating clockwise. Depending on how rapidly the indifference-curve slope increases moving vertically (or on how large MRS_c is), the indifference-curve tangency could move either to the right or left as a higher r rotates the budget line upward. The figure shows the latter case, where y falls. Note that, while the steepening of the budget line is the same as in the usual case of a price increase for the good measured on the horizontal axis, the difference in Figure 2 is that the budget line rotates upward around its fixed lower endpoint rather than downward around a fixed vertical intercept. This upward rotation generates the additional income effect that is not present in the usual case.

The sign of the r derivative in (6) can be checked for specific utility functions. With Cobb-Douglas preferences ($u = c^{\alpha} y^{\gamma} \overline{q}^{\theta}$),

$$y \;=\; \frac{\gamma}{\alpha + \gamma}\left(\frac{I}{r} + \overline{y}\right), \tag{7}$$

so that y decreases with r. With CES preferences ($u = [\delta c^{\beta} + (1-\delta-\mu)y^{\beta} + \mu\overline{q}^{\beta}]^{1/\beta}$),

$$y \;=\; \frac{k}{r^{\sigma-1} \;+\; k}\left(\frac{I}{r} + \overline{y}\right), \tag{8}$$

where $k > 0$ is a constant and $\sigma = 1/(\beta+1) > 0$ is the elasticity of substitution (equal to 1 in the Cobb-Douglas case). Using (8), it can be shown that y decreases with r provided that the elasticity of substitution does not lie too far below unity.[8] Therefore, as long as the consumption goods are reasonably substitutable, y decreases with r, so that higher rent causes more yard space to be rented out ($\overline{y} - y$ rises).

Finally, using (4), the effect of $\overline{q}$ on y is given by

$$\frac{\partial y}{\partial \overline{q}} \;=\; -\,\frac{MRS_q}{\Omega} \;\; > (<) \;\; 0, \tag{9}$$

with sign of MRS_q being ambiguous. MRS_q depends on two cross-derivatives of the utility function, u_{yq} and u_{cq}, which are ambiguous in sign and depend on the nature of the complementarities between the pairs of goods.

3.3. Job access and backyarding

The land rent r on which the formal homeowner bases his backyarding decision is determined by the willingness-to-pay of renters. Let M denote renter income, and let Tx denote commuting cost from a location x miles from the employment center (T is cost per round-trip mile per period). Then $M - Tx$ is the renter's disposable income, which supports nonhousing consumption C and housing consumption Q (upper case letters denote renter values). Note that with a single-storey backyard structure, Q is equal to the amount of backyard land rented.

Assuming that backyarders do not acquire open space for themselves, their well-behaved utility can be written $V(C, 0, Q)$, with the Y argument set equal to zero. The renter's budget constraint is $C = M - Tx - rQ$, and substituting in V, the first-order condition for choice of Q is $V_Q/V_C = r$. In addition, rent must vary across locations x to insure locational indifference among renters. Renter utility must therefore be spatially uniform, with $V(M - Tx - rQ, 0, Q) = v$ holding, where v is a constant. Together, this condition and the first-order condition determine Q and r as functions of the model parameters, most importantly x and v, as in the standard urban model (see Brueckner (1987)). Totally differentiating the uniform-utility condition and then substituting the first-order condition yields the standard condition $\partial r/\partial x = -T/Q$, indicating that rent falls moving away from the employment center.

This conclusion can be used to investigate the spatial pattern of backyarding. Suppose for the moment that the formal homeowner does not commute to work, so that I is independent of x. Suppose also that $\partial y/\partial r < 0$, as in the Cobb-Douglas and high-σ CES cases. Then, with r falling as x increases and y inversely related to r, it follows that y increases with x, so that homeowners consume more yard space, renting out less, farther from the employment center. In other words, $dy/dx = (\partial y/\partial r)(\partial r/\partial x) > 0$.[9]

The analysis is more complex if the formal homeowner is also a commuter, in which case $I = m - tx$, where m is wage income and t is commuting cost per mile per period for the homeowner. Now, both I and r fall with x, so that the derivative

$$\frac{dy}{dx} = \underbrace{\frac{\partial y}{\partial I}}_{+}\underbrace{\frac{\partial I}{\partial x}}_{-} + \underbrace{\frac{\partial y}{\partial r}\frac{\partial r}{\partial x}}_{+} \tag{10}$$

is ambiguous in sign. Some clarity can be gained in the Cobb-Douglas case, where y depends on the ratio $I/r = (m - tx)/r$ (see (7)). Differentiating this ratio with respect to x,

$$\frac{dy}{dx} \simeq -\frac{t}{r} - \frac{m-tx}{r^2}\frac{\partial r}{\partial x} = -\frac{t}{r} + \frac{m-tx}{r^2}\frac{T}{Q} = \frac{t}{r}\left(\frac{m-tx}{rQ}\frac{T}{t} - 1\right), \tag{11}$$

where $\simeq$ means "same sign." Since $rQ = \frac{\theta}{\theta+\alpha}(M - Tx)$ in the Cobb-Douglas case (where $V(C, 0, Q) = C^{\alpha}Q^{\theta}$, the term in parenthesis in (11) equals

$$\frac{\theta+\alpha}{\theta}\,\frac{(m-tx)/t}{(M-Tx)/T} - 1, \tag{12}$$

To sign (12), suppose that income and commuting-cost differences arise only because homeowners and renters make different numbers of commute trips, showing different degrees of attachment to the labor market (with renters presumably (see Tshangana (2014)), but not necessarily, making more trips). Accordingly, suppose that each group earns income w per trip and has cost s per mile per trip, while renters make F trips and homeowners make f trips. Then $(m - tx)/t = f(w - sx)/fs = F(w - sx)/Fs = (M - Tx)/T$. The second ratio term in (12) thus equals 1, and since $(\theta + \alpha)/\theta > 1$, (12) is positive and hence $dy/dx > 0$ holds in (11). Summarizing yields

> **Proposition 1.** *If preferences are Cobb-Douglas and if income and commuting-cost differences between homeowners and renters arise only because of different numbers of commute trips (indicating different degrees of attachment to the labor market), then homeowners rent out more backyard space at locations with better job access.*

This conclusion would hold, of course, under other conditions that make (12) positive. It should be noted that, while the predicted positive association between backyarding and job access may seem natural, reflecting usual link between population density and job access in urban models, it reflects a more subtle combination of forces given the opposing effects of job access on rent and homeowner income. Therefore, Proposition 1 is by no means an automatic conclusion.

It is also interesting to note that, with minor amendments, the model developed so far would also apply to a homeowner's decision to rent out one or more rooms in his owner-occupied house. The trade-off is then between the lost use of floorspace in the house and the gain from rental income. Therefore, the analysis could provide insight into rentals of this type in the cities of the developed world, including the use of services like Airbnb.

3.4. Determination of equilibrium land rents

While the preceding analysis involves the slope of land rent as a function of x, the level of r remains to be determined. This level depends on the renter utility level v, which is determined by an equilibrium condition stating that the renter population, denoted N, fits in the available space.

To develop this condition, let $r(x, v)$ and $Q(x, v)$ denote land rent and renter housing consumption as functions of x and v (dependencies noted above). It is easily seen that $\partial Q/\partial x > 0$, as in the standard urban model, and that $\partial r/\partial v < 0$ and $\partial Q/\partial v > 0$. In addition, let

$y(r(x,v), m - tx)$ denote the homeowner's yard consumption as a function of r and I. Then the renter population density at distance x from the employment center is

$$D(x,v) \equiv \frac{[\overline{y} - y(r(x,v), m-tx)]}{Q(x,v)} \frac{1}{\overline{q}+\overline{y}}. \tag{13}$$

The first ratio term in (13) equals the number of backyarders per formal dwelling, given by yard space rented out ($\overline{y} - y$) divided by land area per backyard dwelling (Q).[10] The second ratio is formal dwellings per unit of total land area (recall that $\overline{q} + \overline{y}$ is formal lot size). If $dy/dx > 0$, then the number of backyarders per formal dwelling decreases with x since the numerator of the first ratio in (13) is decreasing in x and Q is increasing in x. With the second ratio constant, renter population density then falls as distance to the center increases. It is important to note that the first pattern (a decline in backyarders per parcel as distance increases) is the basis for the empirical work, which uses a count of backyard dwellings.

Let $[x_0, x_1]$ denote the range of locations where backyard space is available. Then, assuming a circular city, the equilibrium condition that determines the utility level v is

$$\int_{x_0}^{x_1} 2\pi x D(x,v) dx = N. \tag{14}$$

In standard fashion, the LHS of (14) is the number of renters fitting in the available backyard space, equal to the integral of renter population density times total land area over the relevant distance range. Note that this condition reflects the assumption that backyard land has no alternative use aside from occupancy by renters, implying that the entire range of potential locations will be occupied. As a result, the urban boundary condition usually seen in urban models is not present.[11]

Comparative-static analysis based on (14) can show the effect of parameters such as N on the utility level v. Since $\partial D/\partial v < 0$, it follows that v must fall when the renter population N rises. With $\partial r/\partial v < 0$, rent then rises at all locations, reflecting the greater demand pressure from a larger renter population. With $\partial y/\partial r < 0$, yard space rented out then rises, helping to eliminate the excess demand for housing due to the larger N.

4. Data sources

As explained in the introduction, the paper relies on three data sets to explore the link between backyarding and job access: a count of backyard dwellings per parcel drawn from satellite data, job data at the level of transportation zones, and origin-destination trip-time matrices. The sources of these data sets are described below.

The satellite data, provided by GeoTerraImage (Pty) Ltd. is contained in the Building Based Land Use spatial data set, which provides a land-use classification per building. The data are captured from digital ortho-corrected aerial photography and/or high-resolution ortho-rectified satellite images. It differentiates between 17 classes of residential structures, including formal residential, informal residential and backyard structures. We overlaid the aerial GTI data on a map containing individual parcel contours from the City of Cape Town's cadastre records, thus generating a count of backyard structures per parcel for 2014.[12]

Employment at the transportation-zone level for 2013 is estimated as part of the City of Cape Town's Land Use Model. The land-use model estimates the number of jobs by applying workplace density assumptions to the internal floor space of various types of non-residential buildings, as measured by the city's Valuation Department in its non-residential valuation processes. The preliminary results per transport zone are reconciled with citywide job numbers (by occupation) as published in the Statistics South Africa Labour Force Survey.

The origin-destination matrix for commute-trip times is an output of the City of Cape Town's four-step travel demand model, known as the EMME model. These four steps are (1) trip generation, (2) trip distribution, (3) mode choice and (4) route assignment. EMME was designed by INRO Consultants at the University of Montreal and adopted by the City of Cape Town in 1991. The model implements an equilibrium route assignment based on the distribution of trip origins and destinations in relation to the transport network and modal choice. On this basis, it estimates travel volumes, average trip distances and travel times between each transport zone, for each mode of transport, for the morning peak. The model is calibrated by means of General Household Transport Surveys, on-board surveys and cordon counts.

5. Empirical framework, variables, and summary statistics

The sample consists observations on 551,412 parcels in Cape Town, with the variable **count** denoting the number of backyard dwellings for the parcel. This count variable is a reasonable proxy for the amount y of yard area devoted to backyarding. The sample was derived from a larger data set consisting of more than 850,000 observations by dropping parcels whose size was above the 70th percentile in the distribution of sizes, equal to 762m^2, a value that is over five times the size of a typical RDP lot. This restriction eliminates about 255,000 observations, reducing the sample to 595,000, with the loss of only about 1,000 observations with backyard dwellings (thus allowing a better focus on the backyarding phenomenon). Deletion of observations outside a broad residential property type eliminates an additional 30,500 observations, with missing data accounting for the rest of the reduction in the sample size.

Table 1 shows the frequency distribution of the **count** variable. Most observations (over 418,000) have no backyard dwellings, while about 98,000 have one dwelling and about 26,500 have two. Sample parcels have as many as 8 backyard dwellings, although the frequencies are low beyond 4 dwellings.[13] The map in Figure 3 shows the distribution of backyarding across Cape Town, with the counts shown being generated from aggregations of transportation zones, and Figure 4 shows a neighborhood view.

Table 2 shows the distribution of backyarding across Cape Town's zoning categories. While the vast majority of the observations are within residential categories, a relatively small number of observations appear in other categories, which the restriction to the broad residential property type did not eliminate. Note that observations in these categories also exhibit backyarding. As can be seen, the great majority of the parcels with backyard dwellings are in two categories: Single Residential 1 and Single Residential 2, known as SR1 and SR2. The second of these categories, SR2, is known to contain mostly RDP dwellings.[14] Smaller but still appreciable numbers of parcels with backwarding are in the General Residential 1 and 4 categories.

Given the count nature of the dependent variable **count**, we estimate a Poisson regression model. The density function for a Poisson random variable is $e^{-\lambda_i}\lambda_i^{z_i}/z_i!$, where z_i is the value of the variable for observation i and λ_i is the expected value of the variable, which depends on the explanatory variables. Assuming a log-linear model, $\lambda_i = exp(\omega' g_i)$, where ω is a coefficient vector and g_i is the vector of explanatory variables.

Four explanatory variables appear in the regressions. Two are dummy variables for the SR1 and SR2 zoning categories, which are more likely to contain parcels with backyarding than other categories (the variables are **sr1** and **sr2**). The third variable is a job-access measure, explained further below. The fourth is **parcel_area**, equal to the parcel area in square meters. At first, one might expect that larger parcels would contain more backyarders, but the likelihood that larger parcels have higher-income homeowners, who are less likely to rent to backyarders, can reverse this expectation. Recall from (5) that y depends positively on $\overline{y}$ as well as on income I and rent, so that $y(\cdot)$ in (13) can be rewritten as $y(r, I, \overline{y})$. But assuming that I is increasing in $\overline{y}$ (being written $I(\overline{y})$), the amount of yard space rented out is $\overline{y} - y = \overline{y} - y(r, I(\overline{y}), \overline{y})$. The total derivative of this expression is then

$$\frac{d(\overline{y} - y)}{d\overline{y}} \;=\; 1 - \frac{\partial y}{\partial \overline{y}} - \frac{\partial y}{\partial I}\frac{\partial I}{\partial \overline{y}}. \tag{15}$$

Since $\partial y/\partial \overline{y} > 0$, the sign of the first two terms is ambiguous (as noted earlier), but since $\partial y/\partial I > 0$, the remaining term is negative if $\partial I/\partial \overline{y} > 0$, as assumed. While the overall effect of $\overline{y}$ remains ambiguous, this inverse association between I and $\overline{y}$ thus increases the likelihood that (15) is negative and that backyarding rises as $\overline{y}$ falls. Therefore, a negative coefficient for **parcel_area** may well emerge.[15]

The job-access variables are computed using the trip-time origin-destination matrix, which is based on transportation zones (almost 1800 in number), along with data on zone-level jobs.[16] We use two job counts: total jobs in a zone, and jobs in the lowest income category among the four categories tabulated. The first job-access measure takes a gravity form, with access from zone i given by $A_i = \sum_j jobs_j/time_{ij}$, where $time_{ij}$ is trip time from zone i to zone j and either total or low-income jobs is used. The other access measure is the number of either total or low-income jobs within X minutes of zone i, where $X = 45, 60, 90, 120$. Trip times are for two different alternate modes: minibus/taxi, which are small buses that constitute the main commute mode for low-income South Africans, and regular bus. The job-access variables are thus denoted

jobs_K_X_B, where **K** = **total, lowinc,** **X** = **grav, 45, 60, 90, 120,** **B** = **taxi, bus,**

with an example being **jobs_total_45_taxi** (**grav** denotes the gravity measure). The map in Figure 5 shows the distribution of low-income jobs across Cape Town, with the counts again based on aggregations of transportation zones.

Table 3 contains the summary statistics for the variables. The mean value of **count** equals 0.323, reflecting the large number of zeroes in Table 1, the mean of **parcel_area** is 302.22m^2, and the mean distance of parcels from the Cape Town CBD is 21.1 km. The job-access measures show that jobs within X minutes of a parcel rise with X and that the low-income job access values are smaller than those for total jobs, both as expected. Even though minibus/taxi is a more popular mode for low-income residents, Table 1 shows that job access by bus is uniformly better than by minibus/taxi (only two X values, 45 and 60 minutes, are used for bus).

Before proceeding to the results, it should be noted that identification issues are unlikely to arise in the estimation. Although job and residence locations are simultaneously determined at an aggregate level, a fact that would be taken into account in studying the link between job access and residential patterns using highly aggregated spatial data, simultaneity between the current job-access measures and the backyarding **count** variable is not a concern. Since our job-access measures depend on the job location pattern across the entire metropolitan area, whereas the **count** variable captures backyarding choices on individual parcels, reverse causality from backyarding to job access will not be present. Job-access endogeneity could arise if taxi service to areas with substantial backyarding were to offer more-direct routings to job sites (routes from sparse areas may detour to collect additional passengers, reducing the access measures). Even though we do not find this argument convincing, it is possible in principle to address it by replacing the trip-time gravity measure **jobs_lowinc_grav_taxi** with a gravity measure based on straight-line distance, which removes any routing endogeneity (see below). Finally, another source of endogeneity would be sorting of landlords across areas with different job access according to their propensity to rent to backyarders. However, the model already controls for an important landlord-related variable, parcel size (a proxy for income).

A related point is that, while it might be desirable to control for other locational factors such as access to stores and public services, such data were unavailable. Use of transportation-zone fixed effects is, of course, not possible given that such variables would be perfectly correlated with the job-access measures.

6. Results

Since distance to the CBD is a standard measure of job access, it is useful to start by investigating the connection between backyarding and distance to Cape Town's CBD. If CBD distance is a good job-access measure, then backyarding should fall as distance increases. The approach is to run an ordinary least-square (OLS) regression that has **count** as the dependent variable and uses dummy variables for various 5-mile distance ranges as the explanatory variables, an approach that allows flexibility in the **count**/distance relationship. The results are shown in graphical form in Figure 6. As can been seen, backyarding is mostly increasing with distance to the CBD, in contrast to the predictions of the model. When the sample is restricted to SR1 and SR2 parcels, where most backyarding occurs, the relationship is approximately U-shaped beyond an initial short range where no backyarding is present (Figure 7), again in contrast to the model predictions.

After inspecting the maps in Figures 3 and 5, these results come as no surprise. Figure 3 shows that little backyarding occurs near the CBD, even though it contains an appreciable concentration of low income jobs. Backyarding instead seem to be occurring near the substantial job concentrations that exist outside the CBD, which are clearly seen in Figure 5. To measure the attractive force of these job concentrations, we use the superior job-access measures from Table 3 along with the other variables that are likely to affect backyarding: **sr1**, **sr2**, and **parcel_area**. All of these explanatory variables are used in Poisson regressions, which are better suited than OLS to the discrete nature of the **count** variable. These regressions are estimated with coefficient standard errors clustered at the transportation-zone level, an appropriate procedure given that the job-access variables are zone specific, thus not varying across parcels within a zone. Failure to cluster the standard errors leads to very large t-statistics that greatly overstate the true precision of the estimates.

Table 4 shows the Poisson regressions using the access measures for total jobs and the minibus/taxi mode. The coefficients for **parcel_area** are all negative and strongly statistically significant regardless of which access variable is used, showing that backyarding is more common for smaller parcels where the homeowner's income is likely to be lower, as argued above. The coefficients of the **sr1** and **sr2** dummy variables are also positive, indicating that backyarding is more common for these property types, as already seen in Table 2. Note that the **sr2** coefficient is more than double the size of the **sr1** coefficient, reflecting the greater backyarding incidence for SR2 versus SR1 properties.

Turning to the job-access variables, the estimated coefficients of all the variables except **jobs_total_120_taxi** are positive and statistically significant, showing that better job access indeed raises the extent of backyarding. These findings show the importance of controlling for parcel size along with SR1 and SR2 status in isolating the job-access effect. The insignificance of the 120-minute access coefficient probably reflects the long trip time, which, by allowing access to most of the city's jobs regardless of the parcel location, yields too little access variance across parcels to generate a significant effect.[17]

Table 5 shows the Poisson results using the access measures for low-income (as opposed to total) jobs and the minibus/taxi mode. The results are similar to those in Table 4 except that the 90-minute job access coefficient is now only marginally significant, at the 8% rather than the 5% level. Nevertheless, the lesson of this table is again that better job access increases the extent of backyarding, as predicted by the theory.[18]

Table 6 shows the results using selected job-access measures for the bus mode and both total and low-income jobs (the gravity, 45- and 60-minute variables are used). While the **parcel_area** and **sr1** and **sr2** coefficients show little change, three of the job-access coefficients are now insignificant (both gravity coefficients, as well as the 60-minute total-job coefficient). This pattern may make sense given the lower reliance of low-income Cape Town residents on bus transportation relative to the minibus/taxi mode.

Table 7 shows results when the sample is restricted to SR1 and SR2 parcels, where backyarding is most common, using the same job access variables as in Table 6, but with taxi in place of bus. The **parcel_area** coefficients are all again negative and significant, while the **sr2** coefficient is positive (SR1 parcels are now the default). Five of the six job-access variables have significant coefficients, with the **jobs_total_grav_taxi** coefficient marginally significant at the 6% level. Again, the lesson is that better job access spurs backyarding.[19]

If the sample is restricted to just SR2 parcels, the coefficient of **parcel_area** becomes positive. This outcome makes sense given that Census data show SR2 areas as mostly composed of black households with presumably similar incomes, weakening the assumed correlation between parcel size and income. With parcel size no longer a good proxy for income, the offsetting parcel-size effect (the ability of larger parcels to accommodate more backyarders) is able to dominate.

The marginal effects of the variables are shown in Table 8, using the regression from Table 5 with access variable **jobs_lowinc_60_taxi**. The table shows the hypothetical change in the explanatory variable along with the percentage change in the expected number of backyarders. A 50m^2 reduction in the parcel size (from a mean of 302) leads to a 10% increase in the expected number of backyarders, while a 38,000 increase in the job-access variable (equal to one standard deviation from Table 3) leads to an 11% increase in the expected number of backyarders. Changing a parcel from non-SR1,SR2 status to SR1 or SR2 status raises the expected number of backyarders by 61% or 220% respectively. The marginal effects from the other regressions are similar in magnitude.

To get a sense of the meaning of these percentage changes, recall that the mean of the **count** variable is 0.323. The 11% increase in the expected number of backyarders due to improved job access translates almost exactly into 11% of this mean, or 0.035. The implication is that the job-access improvement leads approximately to an extra 1/30th of a backyarder per parcel, or a new backyarder for every 30th parcel. The impact of the 50m^2 decrease in parcel area (which yields a 10%, as opposed to 11%, increase in the expected number of backyarders) is very similar.

7. Conclusion

This paper explores the incentives for backyarding, an expanding category of South African land-use. In doing so, the paper provides the first treatment in the economics literature of a new category of land-use in developing countries, which represents a unique mixture of informal and formal tenure modes. The theoretical model exposes the trade-off faced by the homeowner in deciding how much backyard land to rent out: loss of yard space consumption in return for a gain in rental income. Higher rent raises the opportunity cost of own-consumption of yard space (depressing it), but the gain in rental income from higher rent has the opposite effect, leading to an ambiguous net impact of rent on consumption. Under common forms for preferences, however, the homeowner's own-consumption of yard space falls as land rent increases, causing more land to be rented to backyarders. Better job access, which raises the land rent backyarders are willing to pay, then tends to lead to more backyarding, but it also raises the homeowner's income net of commuting cost, which leads to less backyarding. Under a natural assumption, the net effect is an increase in backyarding, leading to a predicted positive association between job access and the extent of backyarding. This result matches the usual connection between job access and population density in urban models, but it comes from a subtler combination of effects.

This hypothesis is tested by combining a satellite-based count of backyard dwellings per parcel with job-access data, which come from job data at the level of transportation zones together with an origin-destination matrix showing trip times between zones. The empirical results strongly confirm the prediction that better job access increases the extent of backyarding. In addition, the estimated inverse relationship between backyarding and parcel size suggests that lower homeowner income (associated with small parcels) may spur backyarding, as also predicted by the model.

Thus, using information from a number of remarkable data sets, the paper provides unique insights into a land-use practice that is mostly absent in developed Western countries, even though it bears some resemblance to room rentals by homeowners under an Airbnb-style arrangement. An understanding of the forces that drive the backyarding phenomenon, particularly the link to job access, is potentially useful to South African city planners as they attempt to manage the evolution of their urban areas. For example, transport policies that increase job access would lead to more backyarding in the affected areas, while policies that raise employment for homeowners would reduce it. Planners should also recognize that, even though backyarding may be technically illegal and often unsightly, it generates short-run efficiencies by raising the density of land-use in response to higher housing demand, without the need for wholesale redevelopment of the housing stock (an adjustment that would occur over a longer period).

The paper's exploration of the backyarding phenomenon suggests possible adjustments to housing subsidy policies in South Africa and other developing countries, highlighting the consequences of giving poor households more housing than they can use. Where policies have taken this form, however, the paper suggests that facilitating the development of a rental market for backyard structures is a smart way to allow poor homeowners to generate supplementary income while at the same time increasing the private supply of affordable housing and densifying cities.

Finally, although the focus has been on a developing country, the paper may have relevance for housing affordability issues in the US. Construction and rental of formal backyard dwellings could be a way of raising homeowner incomes while easing housing shortages in areas with high housing costs. This possibility echoes the growing "yes in my backyard" movement evident in cities such as New York, Los Angeles and San Francisco. In California, the demand for more-affordable forms of housing led to a 2016 state law easing building-permit delivery for backyard structures (known in the US as accessory dwelling units or ADUs), and an increasing number of state and local governments are envisioning similar legislation.[20] Thus, there are reasons to believe that the South African pattern could be a rising phenomenon that will become common in many different contexts, from similar shack structures in the cities of low-income countries to more comfortable mini-houses in the expensive cities of the developed world.

Photo: M. Friedman

Figure 1: Backyard shacks

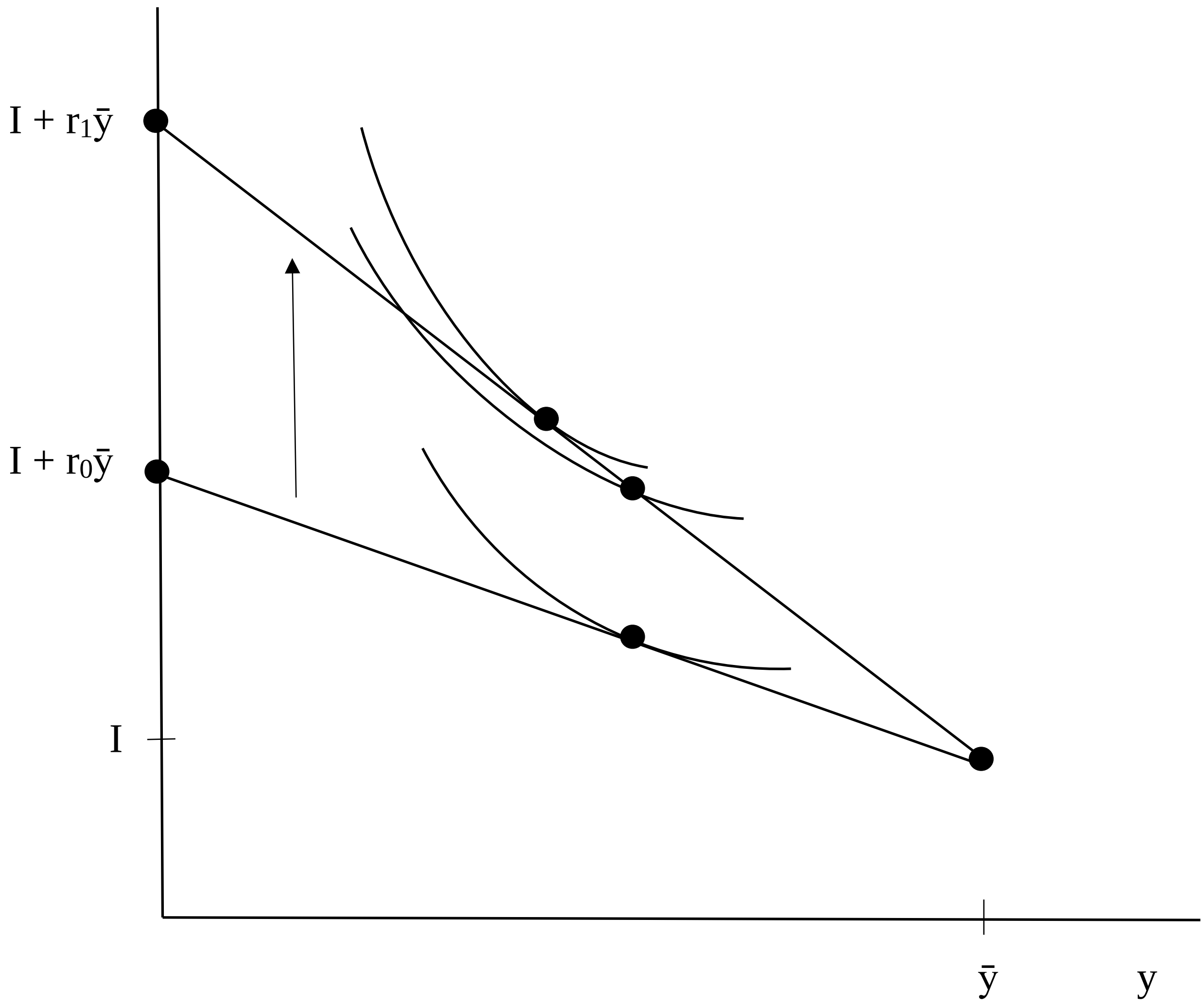
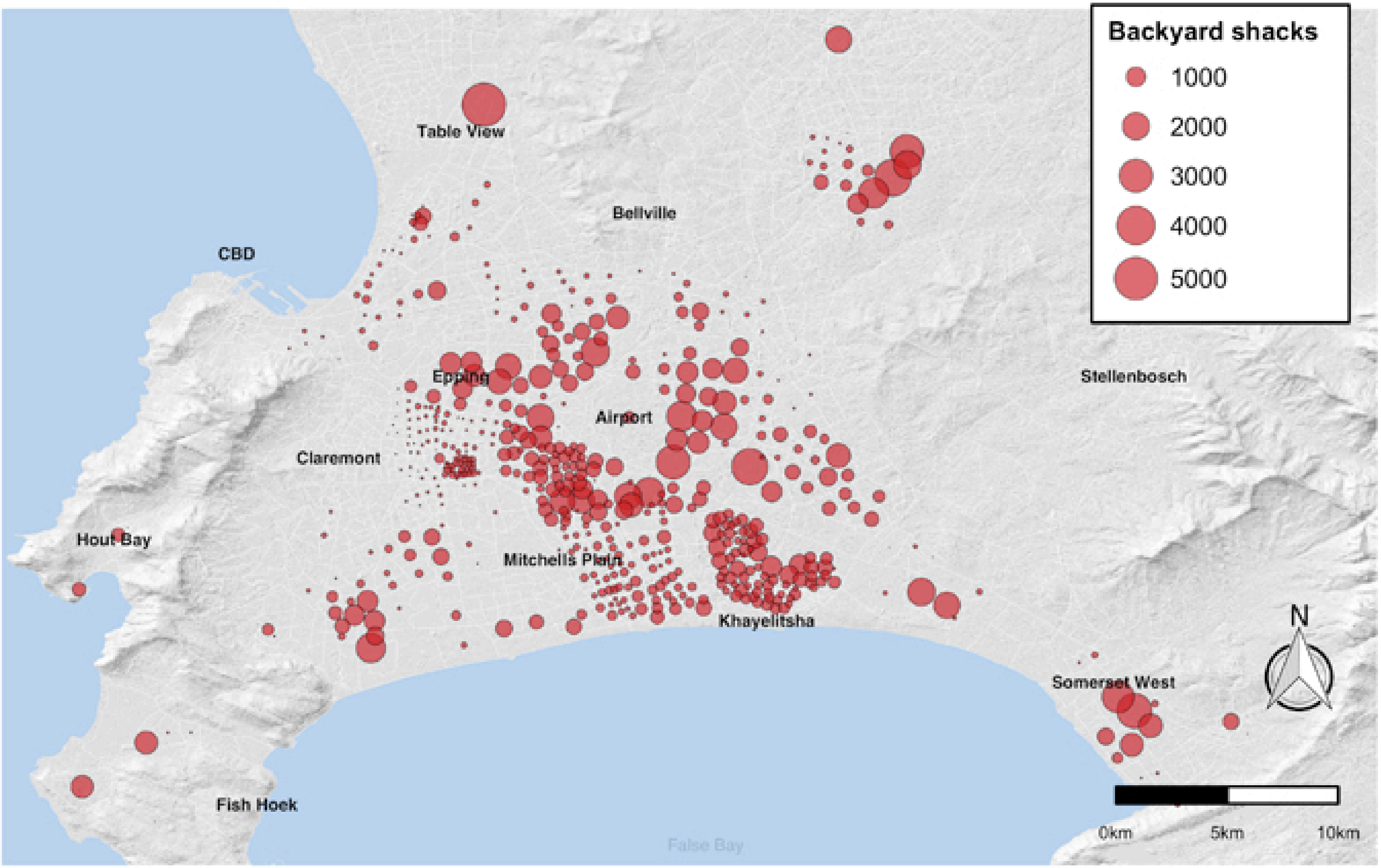


Figure 2: The effect of a rent increase

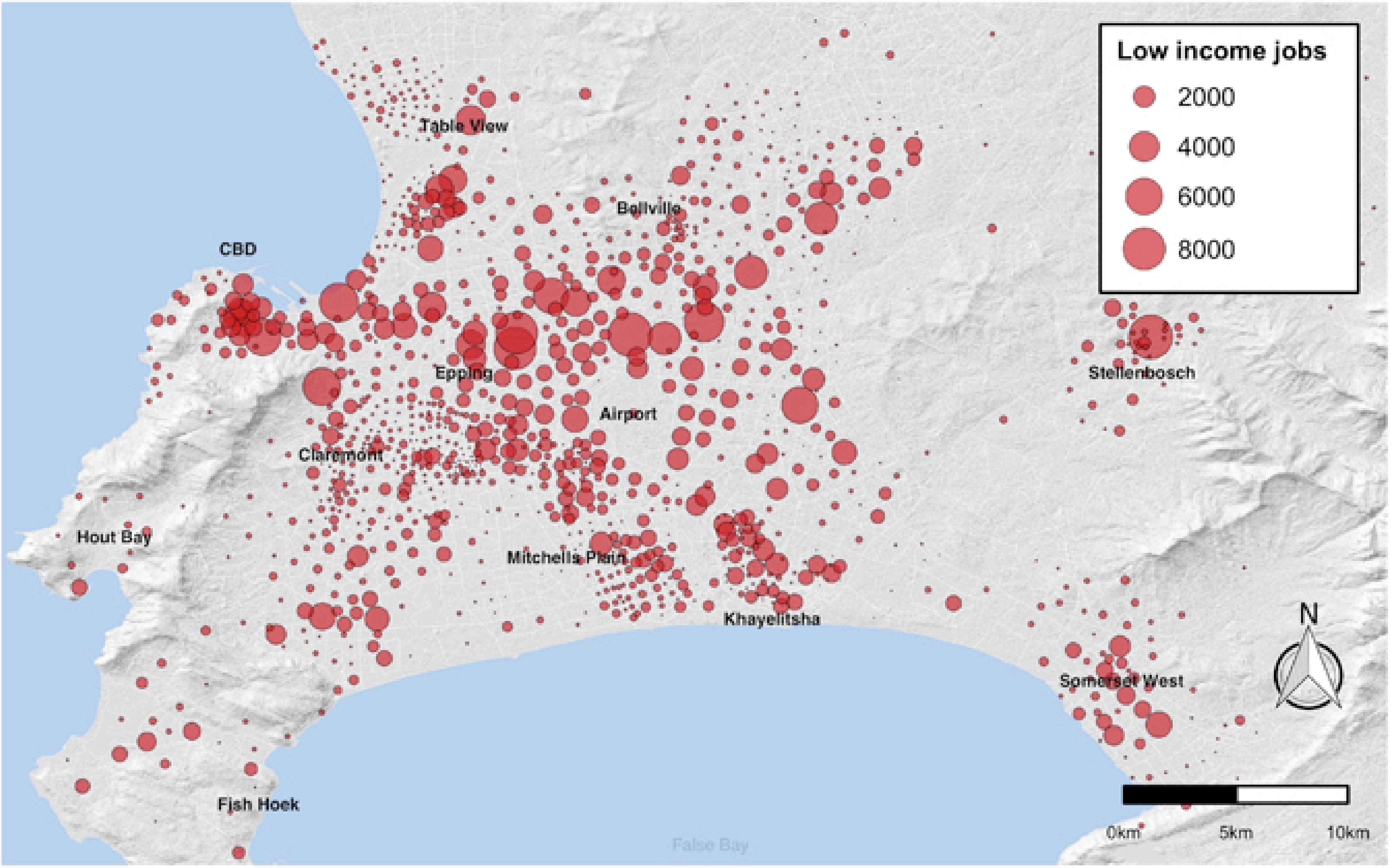


Source: GeoTerraImage, Building Based Land Use data set, 2014, and City of Cape Town

Figure 3: Location of backyarders

Source: GeoTerra Image, Building Based Land Use data set, 2014, and City of Cape Town

Figure 4: Neighborhood View



Source, Land Use Model, City of Cape Town, 2013

Figure 5: Location of low-income jobs

Figure 6: Backyarders as a function of CBD distance

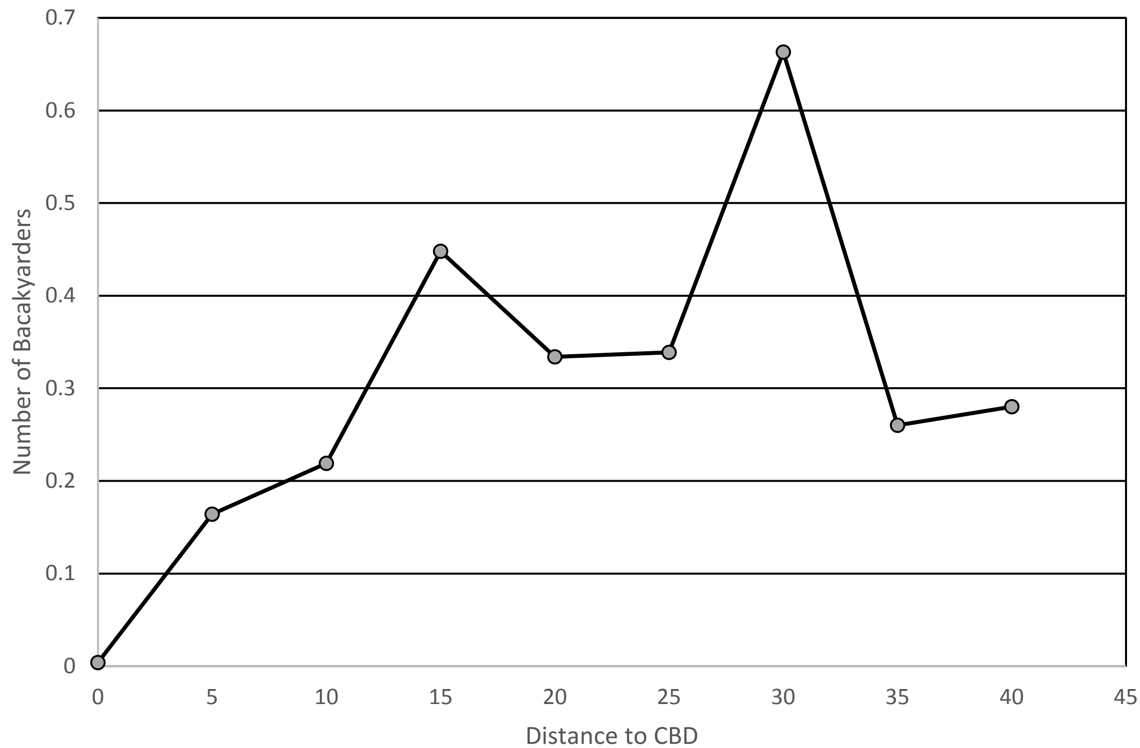


Figure 7: Backyarders as a function of CBD distance--
SR1, SR2 parcels

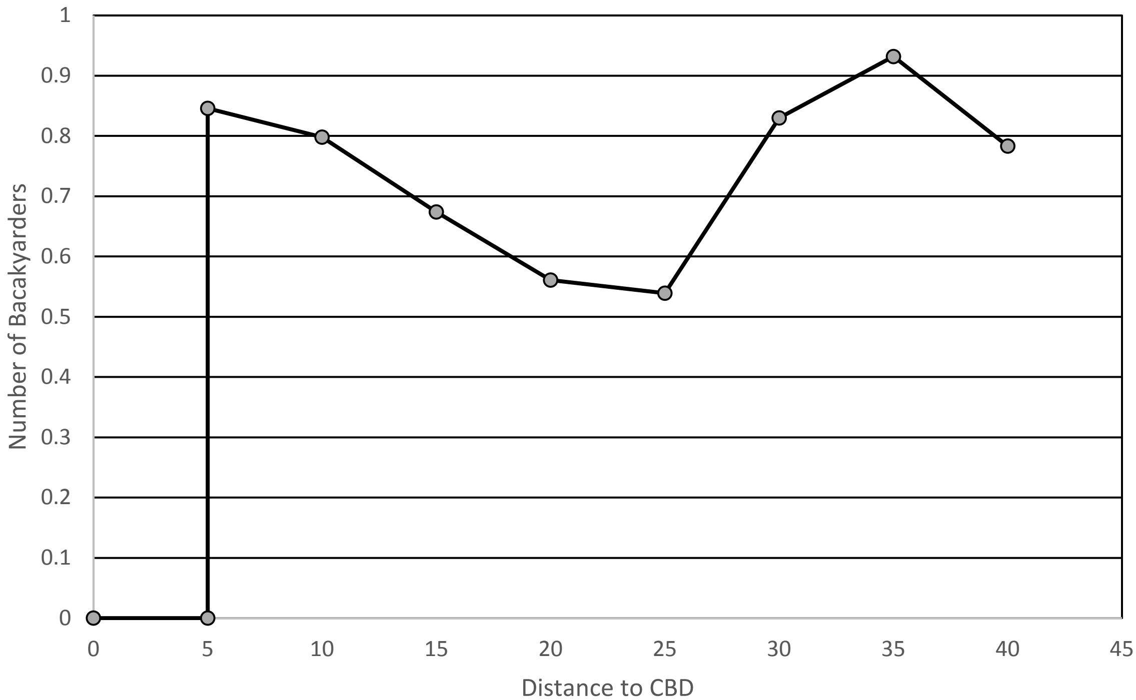


Table 1: Backyard Count Frequency

Count	*Frequency*	*Percent*	*Cumulative*
0	418,754	75.94	75.94
1	98,037	17.78	93.72
2	26,532	4.81	98.53
3	6,174	1.12	99.65
4	1,471	0.27	99.92
5	349	0.06	99.98
6	78	0.01	100.00
7	15	0.00	100.00
8	11	0.00	100.00
Total	551,421		

Table 2: Backyarding Frequency Across Zoning Categories

	Backyarding?		
Zoning Category	*No*	*Yes*	*Total*
Agricultural	180	19	199
Community 1: Local	91	18	109
Community 2 : Regional	84	3	87
General Business 1	564	53	617
General Business 2	136	14	150
General Business 3	15	0	15
General Business 4	209	32	241
General Business 5	51	1	52
General Industrial 1	19	1	20
General Industrial 2	66	2	68
General Residential 1	55,593	8,079	63,672
General Residential 2	14,573	434	15,007
General Residential 3	1,938	0	1,938
General Residential 4	15,397	4,278	19,675
General Residential 5	270	0	270
General Residential 6	1	0	1
Limited Use Zone	76	8	84
Local Business 1	47	2	49
Local Business 2	584	24	608
Mixed Use 1	8	0	8
Mixed Use 2	801	14	815
Mixed Use 3	29	0	29
Open Space 2 : Public	370	56	426
Open Space 3: Special	18	0	18
Rural	125	35	160
Single Residential 1 (SR1)	236,552	48,573	285,125
Single Residential 2 (SR2)	90,488	70,995	161,483
Transport 1	23	2	25
Transport 2	314	19	333
Utility	132	5	137
Total	418,754	132,667	551,421

Table 3: Summary Statistics

VARIABLE	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
count	551,421	0.323	0.658	0	8
parcel_area	551,421	302.22	178.84	0.133	762.0
distance	551,421	21.1	9.1	0.656	50.3
jobs_total_grav_taxi	551,621	19,243.3	6,826.5	0.219	54,145.8
jobs_total_45_taxi	551,621	48,378.6	64,973.5	0	428,155.0
jobs_total_60_taxi	551,621	137,525.4	145,485.6	0	684,519.0
jobs_total_90_taxi	551,621	510,719.0	402,339.0	0	1,465,416.0
jobs_total_120_taxi	551,621	1,008,236.0	557,354.9	0	1,792,191.0
jobs_lowinc_grav_taxi	551,621	4,950.6	1,828.8	0.055	12,928.8
jobs_lowinc_45_taxi	551,621	13,026.9	15,398.6	0	88,227.0
jobs_lowinc_60_taxi	551,621	37,047.4	37,804.8	0	175,237.0
jobs_lowinc_90_taxi	551,621	132,308.0	99,766.4	0	362,607.0
jobs_lowinc_120_taxi	551,621	252,799.8	138,135.0	0	444,484.0
jobs_total_grav_bus	552,098	22,653.1	10,771.7	0.219	66,785.0
jobs_total_45_bus	552,098	117,217.0	128,940.0	0	712,153.0
jobs_total_60_bus	552,098	286,031.3	299,390.5	0	1,235,940.0
jobs_lowinc_grav_bus	552,098	5,705.7	2,650.9	0.055	16,348.9
jobs_lowinc_45_bus	552,098	31,427.8	32,871.7	0	165,619.0
jobs_lowinc_60_bus	552,098	75,176.1	74,187.2	0	291,930.0

Table 4: Effect of Job Access by Taxi on Backyard Count (Total Jobs)

VARIABLES	(1)	(2)	(3)	(4)	(5)
parcel_area	-0.00170**	-0.00182**	-0.00184**	-0.00180**	-0.00175**
	(-6.896)	(-7.477)	(-7.508)	(-7.334)	(-6.875)
sr1	0.443*	0.498*	0.482*	0.464*	0.449*
	(2.355)	(2.541)	(2.519)	(2.446)	(2.331)
sr2	1.159**	1.228**	1.192**	1.169**	1.163**
	(6.052)	(6.074)	(6.157)	(6.063)	(5.942)
jobs_total_grav_taxi	0.0201**				
	(2.873)				
jobs_total_45_taxi		0.00141*			
		(2.552)			
jobs_total_60_taxi			0.000672**		
			(2.894)		
jobs_total_90_taxi				0.000214*	
				(2.050)	
jobs_total_120_taxi					8.48e-05
					(0.915)
Constant	-1.780**	-1.466**	-1.469**	-1.479**	-1.457**
	(-7.741)	(-7.033)	(-7.428)	(-7.440)	(-6.658)
Observations	551,421	551,421	551,421	551,421	551,421

Robust z-statistics in parentheses

** $p<0.01$, * $p<0.05$

Table 5: Effect of Job Access by Taxi on Backyard Count (Low Income Jobs)

VARIABLES	(1)	(2)	(3)	(4)	(5)
parcel_area	-0.00164**	-0.00183**	-0.00182**	-0.00177**	-0.00175**
	(-6.685)	(-7.563)	(-7.484)	(-7.170)	(-6.766)
sr1	0.430*	0.487*	0.475*	0.458*	0.452*
	(2.312)	(2.548)	(2.508)	(2.411)	(2.330)
sr2	1.110**	1.197**	1.162**	1.155**	1.161**
	(5.780)	(6.165)	(6.022)	(5.938)	(5.887)
jobs_lowinc_grav_taxi	0.0887**				
	(3.336)				
jobs_lowinc_45_taxi		0.00747**			
		(3.760)			
jobs_lowinc_60_taxi			0.00271**		
			(2.981)		
jobs_lowinc_90_taxi				0.000808	
				(1.774)	
jobs_lowinc_120_taxi					0.000307
					(0.784)
Constant	-1.831**	-1.482**	-1.468**	-1.478**	-1.450**
	(-8.321)	(-7.471)	(-7.595)	(-7.415)	(-6.615)
Observations	551,421	551,421	551,421	551,421	551,421

Robust z-statistics in parentheses

** p<0.01, * p<0.05

Table 6: Effect of Job Access by Bus on Backyard Count

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
parcel_area	-0.00184**	-0.00188**	-0.00187**	-0.00183**	-0.00187**	-0.00187**
	(-7.354)	(-7.523)	(-7.423)	(-7.352)	(-7.442)	(-7.378)
sr1	0.496**	0.524**	0.513**	0.498**	0.530**	0.516**
	(2.619)	(2.786)	(2.748)	(2.635)	(2.838)	(2.764)
sr2	1.204**	1.228**	1.221**	1.210**	1.230**	1.224**
	(6.345)	(6.528)	(6.516)	(6.396)	(6.581)	(6.536)
jobs_total_grav_bus	0.00518					
	(1.242)					
jobs_total_45_bus		0.000734*				
		(2.263)				
jobs_total_60_bus			0.000258			
			(1.794)			
jobs_lowinc_grav_bus				0.0246		
				(1.334)		
jobs_lowinc_45_bus					0.00320*	
					(2.356)	
jobs_lowinc_60_bus						0.00117*
						(2.002)
Constant	-1.499**	-1.480**	-1.460**	-1.526**	-1.501**	-1.478**
	(-7.247)	(-7.715)	(-7.691)	(-7.193)	(-7.878)	(-7.809)
Observations	551,421	551,421	551,421	551,421	551,421	551,421

Robust z-statistics in parentheses

** p<0.01, * p<0.05

Table 7: **Effect of Job Access by Taxi on Backyard Count, RS1 and RS2 parcels**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
parcel_area	-0.00176**	-0.00190**	-0.00189**	-0.00173**	-0.00188**	-0.00186**
	(-6.870)	(-7.506)	(-7.355)	(-6.770)	(-7.463)	(-7.289)
sr2	0.706**	0.737**	0.702**	0.682**	0.701**	0.682**
	(6.420)	(6.759)	(6.482)	(6.155)	(6.513)	(6.145)
jobs_total_grav_taxi	0.0144					
	(1.902)					
jobs_total_45_taxi		0.00224**				
		(4.365)				
jobs_total_60_taxi			0.000713**			
			(3.060)			
jobs_lowinc_grav_taxi				0.0585*		
				(2.201)		
jobs_lowinc_45_taxi					0.00784**	
					(4.167)	
jobs_lowinc_60_taxi						0.00237**
						(2.627)
Constant	-1.198**	-0.994**	-0.977**	-1.216**	-0.984**	-0.968**
	(-5.932)	(-7.742)	(-7.833)	(-6.476)	(-7.848)	(-7.773)
Observations	446,608	446,608	446,608	446,608	446,608	446,608

Robust z-statistics in parentheses
** $p<0.01$, * $p<0.05$

Table 8: Marginal Effects

VARIABLE	*Change*	*% Effect on expected number of backyarders*
parcel_area	$50m^2$ decrease	10% increase
sr1	increase from 0 to 1	61% increase
sr2	increase from 0 to 1	220% increase
jobs_lowinc_60_taxi	38,000 increase (1 std. dev.)	11% increase

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Footnotes

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[1]Selod and Tobin (2018) offer a related analysis that explores a tenure-security continuum offered by different kinds of property rights in Mali.

[2]A Brazilian colleague pointed out that slum residents in Brazil will sometimes rent out the rooftop of their house for construction of an additional informal dwelling, an alternative approach to raising neighborhood density.

[3]Among other theoretical work on housing in developing countries, some focuses on squatting, with contributions by Jimenez (1984), Hoy and Jimenez (1991), Turnbull (2008), Brueckner and Selod (2009), Brueckner (2013a), and Shah (2014) (see Brueckner and Lall, 2015, for a survey). Theoretical papers on informality more generally include Brueckner (1996), Heikkila and Lin (2014), Cavalcanti, da Mata and Santos (2018), Posada (2018), Cai, Selod and Steinbuks (2018), and Selod and Tobin (2018).

[4]For other empirical work on housing in developing countries by economists, see Follain, Lim and Renaud (1980), Follain and Jimenez (1985), Friedman, Jimenez and Mayo (1988), Lanjouw and Levy (2002), Field (2005), Kapoor and le Blanc (2008), Galiani and Schargrodsky (2010), Hidalgo, Naidu, Nichter and Richardson (2010), Feler and Henderson (2011), Marx, Stoker and Suri (2013), Brueckner (2013b), Cavalcanti et al. (2018).

[5]The cost of constructing the informal backyard dwelling, which is assumed to negligible, is ignored.

[6]It could be argued that extreme poverty will always push the homeowner to a corner solution, where the entire backyard is rented out. However, even for poor households, the resulting congestion on the parcel could be undesirable, making retention of some yard area worthwhile.

[7]The derivative of MRS moving downhill along an indifference curve is $MRS_c(\partial c/\partial y)+MRS_y$,

where $\partial c/\partial y$ is the change in c as y increases. Since $\partial c/\partial y$ equals $-MRS$, which in turn equals $-r$ from (3), the expression above equals Ω. For the indifference curve to become flatter moving downhill along it (for the curve to be convex), MRS must fall, or $\Omega < 0$.

[8]The derivative of (8) with respect to r has the same sign as $k\overline{y}r^{\sigma}(1-\sigma) - kI\sigma r^{\sigma-1} - k^2 I$, where $k = (\delta/(1-\delta-\mu))^{-\sigma}$. This expression is positive for $\sigma \geq 1$ and for a range of σ values below 1.

[9]If $\partial y/\partial r > 0$ holds, this pattern would be reversed.

[10]Note that the model allows the number of backyard renters per formal homeowner to be a fractional value, ignoring the integer requirement.

[11]The equilibrium condition in (14) ignores other informal housing in the city. To take such housing into account, suppose that inferior access to utilities in non-backyard informal housing leads to a rent discount, with rent given by $\widetilde{r}(x,v) = r(x,v) - \rho$. In response to this lower rent, informal land consumption outside the backyard area will be $\widetilde{Q}(x,v)$, larger than $Q(x,v)$. Let $\widetilde{D}(x,v) = 1/\widetilde{Q}(x,v)$ denote non-backyard informal population density, and let $\overline{x} > x_0$ and $\widehat{x} \leq x_1$ denote the outer and inner ranges of the non-backyard informal area, which includes land outside the backyard area and possibly inside of it as well (closer to the job center). Then the population fitting inside the backyard and non-backyard informal areas equals the LHS of (14) plus $\int_{\overline{x}}^{x_0} 2\pi\widetilde{D}(x,v)dx + \int_{x_1}^{\widehat{x}} 2\pi\widetilde{D}(x,v)dx$. The new equilibrium condition requires that this amended expression equals N, which now denotes the overall informal population. Assuming that $\widehat{x}$ is exogenous, so that the informal sector does not compete with the formal housing sector located inside $\widehat{x}$ for access to land (as in Brueckner, 1996), only one additional equilibrium condition is needed. This condition says that informal rent at the edge $\overline{x}$ of the city equals the agricultural rent r_a, so that $\widetilde{r}(\overline{x},v) = r_a$. Together, these two conditions determine $\overline{x}$ and v. Comparative-static analysis based on these equilibrium conditions yields the same conclusions regarding backyard housing as those coming from (14).

[12]The aerial data do not give a formal/informal distinction for backyard structures, but GTI assigns these categories based on broad neighborhood patterns. Backyard structures in well-to-do neighborhoods with large houses are assumed to be formal (i.e., “granny flats”), whereas backyard structures in poor neighborhoods containing small houses are assumed to be informal.

[13]An alternative, but dispreferred, backyarding measure is backyarding “density”, or **count** divided by parcel area.

[14]The longer names for SR1 and SR2 are "Single Residential: Conventional Housing" and "Single Residential : Incremental Housing," respectively. There is no consolidated spatially enabled database of public housing delivered over the last few decades, but "Incremental Housing" (SR2) is a good proxy for land parcels with such housing.

[15]This analysis holds the size $\overline{q}$ of the main dwelling fixed as $\overline{y}$ varies, so that parcel area $\overline{q}+\overline{y}$ varies in step with $\overline{y}$. Suppose instead that larger yards are associated with larger dwellings, with $\overline{q} = \rho\overline{y}$. Then the derivative of y with respect to parcel area equals $1/(1+\rho)$ times $dy/d\overline{y}$. But $dy/d\overline{y}$ now includes a new term capturing the effect of $\overline{q}$ on y, with the RHS of (15) now including $-(\partial y/\partial\overline{q})(\partial\overline{q}/\partial\overline{y}) = -\rho\partial y/\partial\overline{q}$. Given (9), this expression is ambiguous in sign. However, the negative income effect in (15) still provides a force that tends to make backyarding fall as parcel size rises.

[16]The backyard count variable is generated for 990 of these transportation zones, with the omitted zones lying outside the low-income areas that contain informal backyard structures.

[17]To address the routing-endogeneity concern discussed earlier, we ran Poisson regressions with gravity job-access measures based on straight-line distance rather than travel time, one for total jobs and one for low-income jobs. The job-access coefficients in both regressions are only marginally significant, but we view this outcome as reflecting the inferiority of the distance-based variables rather than as evidence of endogeneity. Indeed, regressions of the various trip-time job-access measures on the distance-based measure show weak relationships.

[18]The qualitative results in Tables 4 and 5 are unchanged when the job-access measures are computed using the natural logs of total and low-income jobs.

[19]Land value data per square meter for vacant residential land has been derived from the City of Cape Town 2015 Valuation Roll. Average land value is computed for transport zones with a representative sample of vacant residential properties (designated as E04 by the City of Cape Town Valuation Department). When this land-value measure is used in place of the job-access variable in the Poisson regressions, the results are unsatisfactory. However, since these land values show little relationship to job access for SR1 and SR2 parcels, it appears that they do not capture the willingness-to-pay for land of backyarders, perhaps being more representative of the formal land market. As a result, the land-value data are not very useful in testing the hypotheses suggested by the theory.

[20]Los Angeles is also considering a $75,000 subsidy for construction of ADUs intended for rental to homeless people. For websites tracking the California experience with ADUs as well as parallel developments in Paris, see

`https://www.curbed.com/2018/1/16/16897014/adus-development-us`

`https://www.businessinsider.com/granny-flat-law-solution-california-`

affordable-housing-shortage-2017-3

https://www.csmonitor.com/World/Europe/2018/0301/Nonprofit-group-builds-tiny-homes-for-refugees-in-Parisian-private-gardens