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Cities and Innovation

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ABSTRACT: We use a public referendum on a new air traffic concept in Berlin, Germany as a natural experiment to analyze how the interaction of tenure and capitalization effects shapes the outcome of direct democracy processes. We distinguish between homevoters, i.e., voters who are homeowners, and leasevoters, i.e., voters who lease their homes. We expect the former to be more likely to support or op-pose initiatives that positively or negatively affect the amenity value of a neighborhood because some of the related benefits or costs of the latter are neutralized by adjustments in market rents (capitalization). Our empirical results are in line with our theoretical expectations and imply that public votes on local public goods do not necessarily reflect the spatial distribution of welfare effects in mixed-tenure environments..

JEL Codes: D61, D62, H41, H71; L83, I18, R41, R58

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1. Introduction

Direct democracy is a widely used means to choose public policies in non-autocratic political economies. One typical feature of direct public votes is the "swing voter's curse" (Feddersen & Pesendorfer, 1996), which may lead to uninformed agents abstaining from a referendum. The resulting oversampling of informed agents can be welfare-enhancing if voters are like-minded, and hence, the less informed "delegate" voting to the better informed. It has been demonstrated that the outcome of referenda can lead to greater welfare than (stated preference-based) cost–benefit analyses when individuals have similar preferences, i.e., in a "common value" environment (Osborne & Turner, 2010). However, the abstention of less informed voters also strengthens the power of well-organized interest groups and can lead to outcomes that are not necessarily welfare-enhancing if the attitudes towards an initiative differ across groups of potential voters.

NIMBYism ("not in my backyard"), which often complicates the allocation of socially beneficial facilities with negative localized effects (Frey, Oberholzer-Gee, & Eichenberger, 1996), is one manifestation of this phenomenon. Opposition to NIMBY projects is frequently observed to be driven by one well-informed and engaged group: homeowners (Fischel, 2001b). Capitalization effects on residential property prices, which have been well documented for local public goods since Oates (1969), offer one compelling explanation. Because their houses are the single most important assets for the majority of homeowners, this group can be hypothesized to support initiatives that they expect to increase the values of their properties and oppose those that do not. This is the homevoter hypothesis (Fischel, 2001a). A recent strand of the literature has provided evidence that projected house price capitalization effects significantly influence the degree of support for public initiatives and projects (Ahlfeldt, 2011; Brunner & Sonstelie, 2003; Brunner, Sonstelie, & Thayer, 2001; Dehring, Depken, & Ward, 2008; Hilber & Mayer, 2009).

The literature, however, has paid less attention to the role renters play in (spatial) political bargaining and how their tenure status affects their voting decisions. Property prices and rents are expected to follow similar trends, at least in the medium term. Increasing rents force residents to reduce their housing or non-housing consumption or to move to new neighborhoods. The resulting displacement pressures have frequently been analyzed in the interdisciplinary gentrification literature, mostly utilizing qualitative methods (see, e.g., Freeman & Braconi, 2004; Lees, 2000; Marcuse, 1986; Vigdor, 2002). As argued by

Ahlfeldt (2011), assuming heterogeneous preferences and imperfect mobility, an increase in neighborhood quality should lead to a rent increase that drives renters out of their consumption optima and reduces their utility. By analyzing voting behavior in the context of a public referendum on a large-scale urban development project within a rental environment, Ahlfeldt demonstrated that 1) expected higher home prices were opposed by the local population formed by renters and 2) renters engaged in massive opposition to a project that was widely expected to appreciate the neighborhood. Hence, the theoretical implications of the capitalization effect on political activism differ for homeowner and renter environments and are ambiguous in mixed-tenure environments.

If homevoters (voters who own their homes) and leasevoters (voters who lease their homes) differ significantly in the way in which they respond to anticipated capitalization effects, there may be important implications for the allocation of local public goods or bads through processes of direct democracy. Whereas landlords would presumably respond to anticipated capitalization effects in the same way as homeowners, the renters of their properties eventually cast votes in public referenda in a given locality, as described by Cellini et al. (2010). We argue that the capitalization effect on the voting behavior of the leasevoter deserves special attention because it mitigates their incentives to vote according to the distribution of (expected) welfare effects. Therefore, in mixed-tenure environments, a spatial voting pattern does not necessarily reflect the net distribution of positive and negative amenity changes, which makes it difficult to infer the actual welfare implications of proposed projects from the results of public referenda.

We use a 2008 public referendum on the Tempelhof Airport in Berlin, Germany, as a natural experiment and a means to evaluate whether and to what extent the strength and the direction of anticipated capitalization effects on political activism depend on the local tenure mix. Partly because of its history, Berlin possessed three relatively small airports in the early 1990s. Tegel Airport and Tempelhof Airport are centrally located within the boundaries of the former West Berlin, whereas Schoenefeld Airport lies close to the south-eastern boundary of Berlin and served East Berlin during the division period. On July 4, 1996, it was decided to redevelop Schoenefeld Airport into a large-scale, international hub airport, named Berlin–Brandenburg International Airport, where all air traffic would be concentrated.

As the closure of the Tempelhof Airport, scheduled for October 31, 2008, approached, the intensity of the protests against the plan steadily increased. The Interest Group for City Airport Tempelhof eventually forced a referendum in favor of Tempelhof's remaining in operation. Although the results of the referendum were nonbinding for Berlin's city government, it was widely agreed that the referendum, if it had succeeded, would have exerted strong pressure on the city government, which would thus have been forced to rethink its decision (Nitsch, 2009). Because the extension of Schoenefeld was conditional on the closure of the two city airports, the voters essentially had to choose between the old airport concept (three airports) and a new airport concept (one airport). The vote was held on April 27, 2008. The referendum was approved by a majority of those who voted, but it failed to achieve the minimum favorable vote quorum of 25% of the total electorate. More detailed information on the history of Berlin's airports and the Tempelhof referendum is provided by Nitsch (2009) and in the web appendix.

This referendum provides us with rich variation in local costs and benefits because it was directly or indirectly connected to three airfields distributed across the city area. Another useful feature of the study area is that the Berlin housing market exhibits a large degree of spatial variation in terms of its tenure structure. We use the spatial variation in airport effects and tenure structure to detect tenure interaction effects in precinct-level voting patterns using a two-step strategy. In the first step, we provide evidence for tenure-specific heterogeneity in the way in which changes in the spatial distribution of (dis)amenities impact local voting behavior. We find that a similar positive or negative amenity change induces a voting response in a homeowner neighborhood that is four times as large as in a renter neighborhood. In the second step, we construct a measure of local pecuniary capitalization effects to separate the tenure capitalization interaction effect from the technological externality effects and amenity effects. We infer the price signal from a difference-in-difference analysis of the announcement effect on property prices. Again, we find consistent evidence of the positive interaction effect of local homeownership rates and price signals on the support for the new airport concept.

These results consistently indicate that leasevoter behavior differs substantially from homevoter behavior. Perhaps more important, these findings indicate that a vote on public facilities with localized effects does not take place in a "common value" environment, so allocation decisions may be better based on (stated preference-based) cost–benefit analyses (Osborne & Turner, 2010).

Section 2 of this paper discusses tenure interaction effects that potentially shape voting decisions theoretically. Our empirical strategy is presented in Section 3. Section 4 describes the data, including how our measures of the local homeownership rates and price signals were constructed. Our main findings are presented and discussed in Section 5, and conclusions are presented in Section 6. Details concerning the data, as well as complementary evidence and technical details, are provided in a web-based technical appendix.

2. Leasevoter and homevoter incentives

This section discusses the incentives leasevoters and homevoters face in referenda on policies with local effects. To isolate the tenure-specific component in the incentives, we decomposed the expected utility effects associated with local policies into amenity (direct utility effects) and capitalization (adjustments in rents and house prices) effects.

Leasevoter

Assume an individual who is mobile across city neighborhoods and whose utility in a given neighborhood is defined with respect to the consumption of housing services H and an arbitrary local amenity Z that varies across space.

$$U^R = f(H(r), Z), \frac{\partial f}{\partial H} > 0, \frac{\partial f}{\partial Z} > 0$$

The individual spends a fixed housing budget $\overline{W} = rH$ on housing services rented at a rental market price r. This formulation is in line with housing expenditure shares that tend to be relatively constant across population groups and geographies (Davis & Ortalo-Magné, 2011). The demand for housing is defined as follows:

$$H = \frac{\overline{W}}{r}, \frac{\partial H}{\partial r} < 0$$

Given the fixed budget, higher rents indirectly reduce utility by reducing housing consumption. To keep the renter indifferent between different levels of the amenity at different locations, the rent must adjust to offset the amenity effect.

$$\frac{\partial f}{\partial Z} = -\frac{\partial f}{\partial H}\frac{\partial H}{\partial \tilde{r}}\frac{d\tilde{r}}{dZ}, -\frac{\frac{\partial f}{\partial Z}}{\frac{\partial f}{\partial H}\frac{\partial H}{\partial \tilde{r}}} = \frac{d\tilde{r}}{dZ} > 0 \quad (1)$$

where $d\tilde{r}/dZ$ represents the individual's willingness to pay for changes in the amenity level, similar to an implicit (hedonic) price (Rosen, 1974). For a situation to be a spatial equilibrium, all individuals in the urban economy must be unable to improve their utility by moving across neighborhoods.

The utility effect of an exogenous change in local amenity levels is defined by the total derivative:

$$dU^R = \frac{\partial f}{\partial Z} dZ + \frac{\partial f}{\partial H(r)} \frac{\partial H}{\partial r} \frac{dr}{dZ} dZ, \frac{dU^R}{dZ} = \frac{\partial f}{\partial Z} + \frac{\partial f}{\partial H(r)} \frac{\partial H}{\partial r} \frac{dr}{dZ} \quad (2)$$

We focus on the discussion of positive amenity changes, but the implications hold by analogy for negative changes as well. As is evident from equation (2), the change in amenity dZ affects the utility of the individual via two channels. First, the change in amenity dZ has a direct impact on utility, triggered by the positive valuation of the amenity by the individual ($\partial f/\partial Z$); the *amenity effect*. Second, the change in amenity dZ has an indirect effect that stems from an adjustment in market rent to the amenity change (dr/rZ); the *capitalization effect*. This increase in market rent, which is driven by spatial competition and restores the spatial equilibrium, forces the individual to reduce housing consumption at the same location. In a world with homogenous preferences, the market adjustment will reflect the renter's own valuation of the amenity, i.e., $dr/dZ = d\tilde{r}/dZ$. Put differently, positive expected amenity effects will be offset by capitalization effects (increases in market rent). Given (1), the individual will therefore be indifferent to changes in the amenity.

$$\frac{dU^R}{dZ} = 0 \quad (3)$$

If, however, there are heterogeneous preferences for different amenity levels, a positive change in the local amenity should attract renters with higher amenity preferences $\partial f^*/\partial Z > \partial f/\partial Z$, so that the adjustment in the market rent will be larger than the valuation by the incumbent renter, $dr/dZ > d\tilde{r}/dZ = -[(\partial f/\partial H)(\partial H/\partial\tilde{r})d\tilde{r}/dZ]$. If the renter stays put, the reduction in housing consumption triggered by the higher market rent will more than compensate for the amenity effect from the higher amenity level. With significant mobility costs (the costs of moving house and the loss of social and cultural capital, among other costs), the individual will not be able to restore the previous utility level by moving to another neighborhood with the preferred mix of rent and amenity levels. Hence, $dU^R/dZ < 0$. The negative effect of increased rents reduces utility and lead to *leasevoter* opposition to "positive" local amenity changes.

Conversely, if rental regulations protect the renter from rent increases, the adjustment in market rent may less than fully compensate the incumbent renter for the amenity effect, i.e., $\frac{dr}{dZ} < d\tilde{r}/dZ$ and $\frac{dU^R}{dZ} > 0$.

To summarize, compared to the benchmark scenario of free markets and homogenous preferences, heterogeneous preferences decrease and rental regulations increase the likelihood that a leasevoter will support a positive amenity change, if we assume that the propensity to vote in favor of the amenity change strictly increases in the expected utility change.

Homevoter

The utility of home owners can be expressed as follows:

$$U^O = f(H(r, \bar{r}), Z)$$

where $\bar{r}$ is the net rent after tax for which owners can potentially rent out their homes. In countries with no taxation of the benefit of owner-occupied living (and no tax reduction for the costs of owner-occupied living), the net rent in equilibrium is $\bar{r} = r$. The budget constraint now takes the following form:

$$\bar{W} + \bar{r}\bar{H} = \bar{m} + rH$$

where $\bar{m}$ is a fixed periodic mortgage payment equal to the budget available for housing services ($\bar{W} = \bar{m}$) and $\bar{H}$ is the amount of housing services owned. The actual housing services H consumed, in principle, can vary in the rates at which housing services can be rented (r) or rented out ($\bar{r}$), should the owner decide to become a landlord and live in a location other than where their property is located. If the owner stays in the same neighborhood (or in his or her own property), the budget equation can be simplified to $\bar{W} = \bar{B}$, and the consumption of housing services is fixed at H=$\bar{H}$.

$$H = \frac{\bar{W} - \bar{m}}{r} + \frac{\bar{r}}{r}\bar{H}, \frac{\partial H}{\partial r} < 0, \frac{\partial H}{\partial \bar{r}} > 0$$

Note that at a given location, an owner faces the same amenity effect (Z) as a renter, so that $-(\partial f/\partial Z)/[(\partial f/\partial H)(\partial H/\partial \tilde{r})] = d\tilde{r}/dZ$ defines the valuation of the amenity. Thus, the following equilibrium condition holds:

$$-\frac{\frac{\partial f}{\partial Z}}{\frac{\partial f}{\partial H}\frac{\partial H}{\partial p}} = \frac{dr}{dZ} = \frac{d\bar{r}}{dZ} = \frac{d\tilde{r}}{dZ} \tag{4}$$

In the case of owners, unlike the case of renters, the (potential) *capitalization* effect for the owner induced by an amenity change dZ is a composite effect resulting from a change in rent paid for housing serves and a change in rent received from renting out a property.

$$\frac{dU^O}{dZ} = \frac{\partial f}{\partial Z} + \frac{\partial f}{\partial H}\frac{\partial H}{\partial r}\frac{dr}{dZ} + \frac{\partial f}{\partial H}\frac{\partial H}{\partial \bar{r}}\frac{d\bar{r}}{dZ} \tag{5}$$

If owners live in their own properties, they neither pay nor receive rent, and the utility effect is exclusively determined by the positive amenity effect.[1] The same applies if the property is rented out and preferences are homogenous ($dr/dZ = d\tilde{r}/dZ = d\bar{r}/dZ$). There is no incentive to leave the neighborhood because the effects of increases in rent paid and received on housing consumption simply cancel each other out, i.e., ($\partial H/\partial r(Z)/\partial H/\partial \bar{r}(Z) = 1$):

$$\frac{dU^O}{dZ} = \frac{\partial f}{\partial Z} \tag{6a}$$

Note that positive composite of amenity and capitalization effects differs from the situation in which the individual does not own a property and receives no net benefit (3).

If an owner, in response to a local amenity change, decides to move to a neighborhood with the initial amenity (Z) and rent (r) levels of the original neighborhood, there will be no amenity effect ($dZ = 0$) and no impact on the (implicit) rent paid ($dr = 0$), but there will be an expected benefit from an increase in the market rent received from the property rented out.

$$\frac{dU^O}{dZ} = \frac{\partial f}{\partial H}\frac{\partial H}{\partial \bar{r}}\frac{d\bar{r}}{dZ} \tag{6b}$$

which, as defined in (4), is equivalent to the amenity effect $\partial f/\partial Z$ in a world with homogenous preferences because $\frac{d\tilde{r}}{dZ} = \frac{d\bar{r}}{dZ}$.

If, however, preferences are heterogeneous and the change in the local rent level following the amenity change is larger than the valuation of the amenity ($d\bar{r}/dZ > d\tilde{r}/dZ$), the owner will receive a benefit from positive amenity changes above and beyond the pure

[1] The effects on rents also cancel each other out if the owner becomes a landlord but decides to rent within the same neighborhood.

amenity effect. The effect can be decomposed into a quasi-amenity effect $\partial f/\partial Z$ that is equivalent to an increase in rent, according to the valuation $\left((\partial f/\partial H)(\partial H/\partial \tilde{r})(d\tilde{r}/dZ)\right)$, and an additional utility effect that originates from the immigration of renters with higher valuations $\left((\partial f/\partial H)(\partial H/\partial \bar{r})\left((d\bar{r} - d\tilde{r})/dZ\right)\right)$:

$$\frac{dU^O}{dZ} = \frac{\partial f}{\partial H}\frac{\partial H}{\partial \tilde{r}}\frac{d\tilde{r}}{dZ} + \frac{\partial f}{\partial H}\frac{\partial H}{\partial \bar{r}}\left(\frac{d\bar{r}}{dZ} - \frac{d\tilde{r}}{dZ}\right) \qquad (7)$$

The second term captures a genuine capitalization benefit, i.e., an increase in utility that stems from an increase in wealth and is in addition to the direct amenity effect.

Assuming that the propensity to vote in favor of positive amenity changes strictlyincreases in the expected net utility change, owners will likely vote for positive amenity changes. In a world with homogenous preferences, this will essentially be a vote on the *amenity* effect. Owners, in addition, will benefit from a *capitalization* benefit in a world with heterogeneous preferences if the wealth effect is large relative to mobility costs, making it even more likely that they support positive amenity changes.

Leasevoter homevoter comparison

Equations (2) and (7) define the utility effect for an individual in different tenure scenarios. The conditions can be combined to derive testable implications for the empirical analysis of voting behavior in public referenda. We proposed two strategies to model the expected utility effect as a function of the interaction of the tenure status on the one hand and the *amenity* effect and/or *capitalization* effects on the other

In the case of *homogenous preferences*, combining equations (1) and (2) yields a renter net utility effect of zero:

$$\frac{dU^R}{dZ} = \frac{\partial f}{\partial Z} - \frac{\partial f}{\partial Z} = 0 \qquad (8)$$

For owners who live in their own properties, the resulting utility effect is simply the amenity effect:

$$\frac{dU^O}{dZ} = \frac{\partial f}{\partial Z}.$$

For owners who become landlords and rent a flat elsewhere, the same result applies because the amenity effect attached to the property transforms into a capitalization effect of the same size. The expected utility effect of leasevoters and homevoters can therefore be expressed as a function of the amenity effect and the tenure status.

$$\frac{dU}{dZ} = \frac{\partial f}{\partial Z} \times T_1, T_1 = \begin{cases} 0 \; if \; renter \\ 1 \; if \; owner \end{cases} \qquad (9)$$

Equation (9), the first of the two proposed tenure interaction equations, implies a positive interaction of the amenity effect and being a homeowner (or landlord) because owners are hedged against rent increases. Either they pay no rent at all or they benefit from increases in the rents received for renting out their own property. Owners should therefore support (oppose) any initiative more strongly than renters that is expected to improve (worsen) the amenity level of their neighborhood. This implication is consistent with the homevoter hypothesis. The positive interaction effect generalizes to the heterogeneous preferences case because the renter interaction effect, if anything, becomes negative, and the owner interaction effect must be positive as long as $\frac{\partial f}{\partial Z} > \frac{\partial f}{\partial H}\frac{\partial H}{\partial \bar{r}}\left(\frac{d\bar{r}}{dZ} - \frac{d\tilde{r}}{dZ}\right)$.

Equation (9) can be tested using measures of ownership and positive (proximity) or negative (noise) airport effects that are relatively easily accessible. From this amenity tenure interaction effect, however, it is not possible to conclude to which extent heterogeneous preferences shape voting patterns. It remains unclear whether leasevoters and homevoters holding the amenity effect constant oppose or support the capitalization effects described in the section above.

To address these questions, our second empirical approach models capitalization effects explicitly. Equation (2) defines how changes in the rental price level associated with amenity changes affect the utility of a renter. The capitalization benefit $\left((\partial f/\partial H)(\partial H/\partial r)(dr/dZ)\right)$ is expected to be negative as long as renters are not fully protected against (positive) rent adjustments. The corresponding situation for the owner is defined in (6). The effect of capitalization on expected utility depends on the valuation by the marginal renter or buyer moving into the neighborhood subsequent to the amenity change relative to the valuation by the established owners. Because the willingness to pay for a higher amenity level of those moving into the neighborhood after a positive adjustment will, if anything, be higher than the willingness of the incumbents $\left((\mathrm{d}\bar{\mathrm{r}}/dZ)/(\mathrm{d}\tilde{\mathrm{r}}/\mathrm{dZ}) \geq 1 \text{ if } dZ > 0\right)$, the capitalization benefit to the owner must be non-negative. The capitalization benefit is also non-negative for negative amenity changes, due to the potential immigration of individuals with lower amenity preferences $\left((\mathrm{d}\bar{r}/dZ)/(\mathrm{d}\tilde{r}/\mathrm{d}Z) \leq 1 \text{ if } dZ < 0\right)$. The capitalization benefit (excluding the amenity effect) is therefore strictly non-positive for renters and non-negative for owners. Combining equations (2) and (5), the capitalization tenure interaction effect is necessarily positive for the owner relative to the renter status as long as $\frac{\partial f}{\partial Z} > \frac{\partial f}{\partial H}\frac{\partial H}{\partial \bar{r}}\left(\frac{d\bar{r}}{dZ} - \frac{d\tilde{r}}{dZ}\right)$:[2]

$$\frac{dU}{dZ} = \frac{\partial f}{\partial Z} + \frac{dr}{dZ} \times T_2, T_2 = \begin{cases} \frac{\partial f}{\partial H(r)}\frac{\partial H}{\partial r(Z)} < 0 \; if \; renter \\ \frac{\partial f}{\partial H(r)}\frac{\partial H}{\partial r(Z)}\left(1 - \frac{d\bar{r}}{dz}\frac{dz}{dr}\right) \geq 0 \; if \; owner \end{cases} \quad (10)$$

Equation (10), the second of the two proposed tenure interaction equations, separates the effects related to capitalization from an amenity effect. The latter is identical for renters and owners and should reflect the (spatial) distribution of costs and benefits of an amenity change. The effects of capitalization on expected utilities, however, quantitatively and qualitatively depend on the tenure status.

In the case of positive amenity changes, capitalization has a negative impact on renter utility unless these are perfectly protected against rent increases. This is a potentially relevant scenario in many European countries where rental regulations constrain rent increases for existing contracts and restrict the termination of rental contracts by landlords, while allowing rents to be freely set for new contracts (vacancy decontrol).[3] The capitalization effect can dominate the amenity effect in a scenario with heterogeneous preferences and positive relocation costs.

The capitalization effect on the homeowner is positive if preferences are heterogeneous (and the benefits exceed relocation costs) or zero otherwise. For positive amenity changes, amenity and capitalization effects will work in the same direction and in the opposite direction as the renter capitalization effect.

[2] From the indirect demand function $H = 0 + \bar{r}/r \times \bar{H}$ we know that $\partial H/\partial r = -\bar{r}/r \times \partial H/\partial \bar{r}$, where $\bar{r}/r = 1$ in the initial situation.

[3] For an overview of rental regulations in the case of Germany, cf. Usinger (2012), esp. 125f. Cruz (2009) provides an overview of rental regulations in some 40 countries worldwide, using a wide range of measures. In the US, rent controls of various types were more widespread in the past, but have been abandoned, with few exceptions. Cf. Sims (2007) regarding the lessons to be learned from the end of rent control in Massachusetts.

3. Empirical strategy

In the previous section, we presented the expected utility effects of local amenity changes by tenure and described why homevoter and leasevoter behavior should be reflected by an interaction of amenity and capitalization effects with tenure. This section presents our two-part empirical strategy for estimating the tenure interaction effects described in equations (9) and (10).

3.1 Amenity tenure interaction effects

We start from the assumption that voters who participate in a public referendum vote to support the alternative that maximizes their expected utility. We further assume that the probability of a voter voting for an alternative increases with the expected net benefit that an initiative offers. Adopting a standard linear probability model (e.g., Dehring, et al., 2008) we set up our first empirical test as an empirical derivative of equation (9), as follows:

$$SUP_j = \alpha + \sum_k \beta_k X_{kj} + \Omega H_j + E_j + \Theta\left(H_j \times E_i\right) + \varepsilon_j \quad (11)$$

The support for the new airport project (SUP) is expressed as the percentage of "no" votes at total votes in voting precinct *j.* Unlike in the simplified theoretical environment discussed in the previous section, voters in reality differ in various ways that can affect their attitudes towards aviation. To capture the effects of the socio-demographic composition of the local voters on the expected utility of the new aviation concept and hence the voting outcome, we add a set of k control variables X_k, which are discussed in the data section. Controlling for these effects, we assume that SUP is a function of the local environmental impact E_j, which serves as a proxy for the amenity effect, and an interaction effect of E_j and the local homeownership rate H_j. Because we expect the spatial distribution of costs and benefits related to all of the airports to affect voting behavior, we set up E_j as a composite of six variables capturing the potentially countervailing proximity costs and benefits of noise exposure (N_F) and accessibility (A_F) to airport services provided by the three airports $\left(E_j = \sum_F \left(\Upsilon_F N_{Fj} + \Xi_F A_{Fj}\right), F = \{Tempelhof, Tegel, Schoenefeld\}\right)$. ΩH_j controls for voting behavior that depends on tenure but is unrelated to the amenity–tenure interaction effect. In an extension, we introduce a full set of interaction terms for socio-demographic characteristics to accommodate tenure-specific heterogeneity in observable household characteristics $\left(\sum_k \Omega_k X_{kj} \times H_j\right)$. ε_j is a zero-mean stochastic error term. We identify all parameters $\alpha, \beta_k, \Omega, \Omega_k, \Theta, \Upsilon_F, \Xi_F$ in a one-stage nonlinear least squares (NLS) estimation procedure. Using the parameters $\widehat{\Upsilon}_F$ and $\widehat{\Xi}_F$ from the one-stage NLS model, we also estimate a nonparametric variant of the amenity–tenure interaction effect using locally weighted regressions. Details are provided in the appendix.

3.2 Capitalization tenure interaction effects

Our second empirical test is an empirical implementation of equation (10) and includes a homeownership–capitalization interaction effect. To capture the capitalization effect empirically, we introduce a local price signal associated with the new airport concept S_j. Compared to specification (11), we then replace the amenity–homeownership rate $(A \times H)$ interaction term with a price signal–homeownership rate interaction term $(S \times H)$ to allow for tenure-specific heterogeneity in the capitalization effect on expected utility and voting behavior.

$$SUP_j = \alpha + \sum_k \beta_k X_{kj} + \Omega H_j + E_j + \phi S_j + \psi(H_j \times S_j) + \varepsilon_j \qquad (12)$$

Specification (12) represents the second stage in a two-stage estimation procedure, the first stage of which consists of an estimation of a price signal S_j, as described in more detail in the next section. The parameters in the second stage, $\alpha, \beta_k, \Omega, \Omega_k, \Theta, \Upsilon_F, \Xi_F, \phi, \psi$, can be estimated using OLS. To comply with the properties described above, the interaction term (ψ) must be positive (i.e., the marginal effects of the price signal must increase with the homeownership rate). The terms ΩH_j, ϕS_j, and $\psi(H_j \times S_j)$ jointly form a surface along the homeownership rate H and price signal S dimensions, with the third dimension being the capitalization effect on voting behavior $\left(\Omega H_j + \phi S_j + \psi(H_j \times S_j)\right)$. Positive capitalization benefits at high homeownership rates (controlling for the amenity effect) are indicative of anticipated wealth effects that can be realized by relocation following anticipated amenity changes, if preferences for locations are heterogeneous.

We also estimate an augmented version of equation (12) that includes the interactive terms of homeownership rate and the socio-demographic characteristics $\left(\sum_k \Omega_k X_{kj} \times H_j\right)$, as well as a full set of airport homeownership rate interactive terms $\left(H_j \times \sum_F(\Upsilon_{HF} N_{Fj} + \Xi_{HF} A_{Fj})\right)$, to disentangle tenure-specific heterogeneity in airport effects (amenity effects) from tenure-specific heterogeneity in the effect of capitalization. In addition to a range of robustness tests of equation (12), we set up a semi-parametric variant to relax the parametric constraints in the homeownership rate–capitalization interaction.

Essentially, we replace the parametric surface specification $\left(\Omega H_j + \phi S_j + \psi\left(H_j \times S_j\right)\right)$ with a set of fixed effects $(\sum_h \sum_s \psi_{hs}(BH_h \times BS_s))$. We group precincts into grid cells $(BH_h \times BS_s)$ with similar H_j and S_j values, for each of which we then estimate a fixed effect. Recovering and plotting the fixed effects yields a nonparametric homeownership rate–price signal surface estimated conditionally on the linear baseline model. A more detailed description is provided in the web appendix.

The empirical strategy outlined above depends on the use of appropriate proxy variables for airport noise (N_F), airport accessibility (A_F), homeownership (H), and price signal (S). Data are not typically readily available for these variables. Using an approach similar to Dehring et al. (2008), we assume that the property market reaction to the initial 1996 announcement of the reorganization of the airports serves as a (noisy) signal to voters about the market valuation of the new air transport concepts. We estimate this signal using an auxiliary hedonic difference-in-difference property price regression for which the challenge is to develop a specification that can accommodate the complex spatial pattern associated with increases and decreases in the noise levels and accessibility of the three airports spread across the metropolitan area. The procedure is described in section 4.3.

4. Data

This section discusses the data sources used and the procedure used to generate our proxy variables for local homeownership rates and price signals. A more detailed account of the methods used to compile our data set is presented in the web-based technical appendix.

4 . 1 Basic data

Data from 1,201 precincts on the results of the voting on the Tempelhof referendum were obtained from the statistical office of Berlin–Brandenburg on a disaggregated basis. Of the 881,035 votes that were cast, 230,571 were cast by mail and could not be considered because of missing geographic data.[4] The voting precincts form our main analysis unit according to which all of the other data were organized using a geographic information system (GIS), the framework of the Urban and Environmental Information System of the Sen-

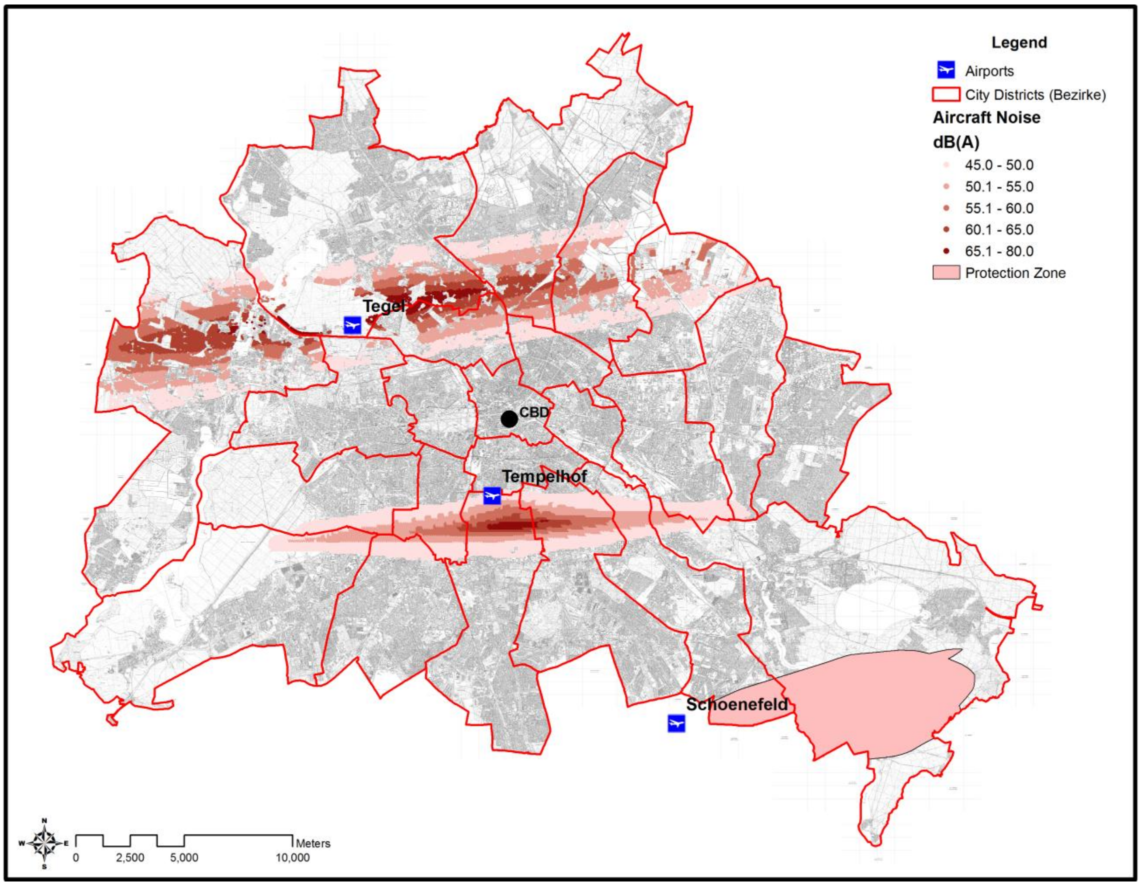
[4] Nitsch (2009) shows that the differences by district were negligible when comparing votes cast at ballot boxes and by mail.

ate Department of Berlin (Senatsverwaltung für Stadtentwicklung Berlin, 2006b), and standard area interpolation techniques (Arntz & Wilke, 2007; Goodchild & Lam, 1980). All of the distance computations were made using this GIS framework.

An official report (Laermkartierung nach Umgebungsrichtline, 09.07.2007) was used to obtain detailed information on the exposure to aircraft noise from Tegel airport at the level of 10 × 10-m grid cells. Noise levels are recorded for all developed properties within the Tegel air corridor and are expressed using a long-term sound pressure index (L_{den}) that is equivalent to the standard log-decibel scale (db). For Tempelhof, similar data were obtained from the Berlin airport's operating company. The noise data were available in the form of an electronic map that distinguishes between various zones of similar sound pressure. For Schoenefeld, which lies outside the boundaries of Berlin and whose air corridor only partly crosses Berlin's territory, the best available information was a map of the noise abatement zone (Laermschutzzone), which anticipates the expected increase in noise levels upon the opening of the new Berlin–Brandenburg International Airport.

Fig. 1 shows the locations of the three airports relative to the central business district (CBD) and illustrates the areas associated with values greater than 45 db. Note that only aircraft noise exceeding this threshold is considered in the empirical analyses. Lower levels of aircraft noise are likely to be dominated by other noise sources (Ahlfeldt & Maennig, 2011). Finally, detailed information on socio-demographic characteristics, including population, age groups, the proportions of males and non-German individuals, the unemployment rate among non-German citizens and the outcome of the 2006 state elections were available from the statistical office in Berlin. We complemented these data from the official records with estimates of the purchasing power per capita (at the post code level) derived from a report by the Consumer Research Society (Gesellschaft für Konsumforschung).

Fig 1. Noise measures



Notes: An illustration based on the Urban Environmental Information System (Senatsverwaltung für Stadtentwicklung Berlin, 2006b).

4.2 Homeownership rate

In selecting a proxy variable that we can use to approximate the homeownership rate at the precinct level, we profit from a particularity of the Berlin housing market: the segmentation of the market into 1) detached, semidetached and attached single-family houses, villas and townhouses that are almost entirely occupied by owners, and 2) typical downtown apartment buildings, which are usually five stories tall and are almost entirely occupied by renters.

It is well documented that accommodation type is an important determinant of tenure choice across European countries (Hilber, 2007), but this segregation is striking in Germany and particularly in Berlin. An analysis of the 2002 microcensus (a 1% population sample) reveals that more than 90% of one- and two-family houses are owner occupied, whereas more than 90% of dwellings in three-or-more family buildings are inhabited by renters (see the web-appendix for more detail).

The Urban Environmental Information System developed by the Senate Department (Senatsverwaltung für Stadtentwicklung Berlin, 2006a) indicates a building structure of 15,937 largely homogenous statistical blocks. Using this information, the homeownership rate (*H*) for a voting precinct can be approximated as the proportion of the total population above the age of 18 (the electorate) that lives within the boundaries of a statistical block of one- or two-family houses. We test this procedure by computing the homeownership rates for the 12 city districts (Bezirke) and comparing them to actual owner occupancy data available at this level. A linear regression of actual and estimated values yields an R^2 of slightly more than 0.75.[5] Details regarding the institutional setting, the estimation procedure and the evaluation are provided in the web-based technical appendix.

4.3 Price signal

To proxy for the price effects associated with the new Berlin airport concept, we exploit the fact that the new airport concept was announced on July 4, 1996, in the consensus decision (*Konsensbeschluss*), well in advance of the 2008 referendum. In line with Brunner et al. (2001), Dehring et. al. (2008), and Ahlfeldt (2011), we assume that at the time of the referendum, the adjustments in property prices that followed this announcement provided a price signal to homeowners (and renters) regarding the market valuation of a concentration of air traffic at the Schoenefeld site. Approval of the plans would have implied that the capitalization effects would remain persistent or be strengthened if the announcement effects were initially discounted on uncertainty. An abandonment of the plans instead would have implied that the anticipated capitalization effects would be reversed. We estimated this signal using an auxiliary hedonic property price analysis of 6,796 transactions of developed residential properties that took place within one year before and after the day of the announcement in question.[6]

[5] Imputations of variables that are not directly observable are popular in the housing economics literature. As an example, Arévalo and Ruiz-Castillo (2006) showed that market rents can be reasonably well approximated using information on the location and quality of housing..

[6] We also estimated the price effects of later announcements regarding the new airport concept but found that the adjustment was more significant for 1996 than for any later date. The data set contains all transactions related to developed residential land that took place in this period. Relatively few observations had to be excluded from the full record because of missing values for crucial characteristics. No signs of sample selection bias were found.

Our estimation equation is a combined hedonic (Rosen, 1974) and difference-in-differences specification. We investigate the effect of a treatment (the announcement of a new airport concept) while controlling for unobserved spatial heterogeneity and identify the treatment effect by comparing property prices before and after the announcement in different locations within the city. The basic structure of our identification strategy corresponds to a standard difference-in-difference setting:

$$\log(P_{it}) = \zeta TREAT_i \times POST_t + \xi TREAT_i + \sum_k \alpha_0 S_{i0} + \sum_l \gamma_l L_{il} + \sum_j ב_j SB_j + g(TREND_t) + א_{it} \quad (14)$$

where P_{it} is the transaction price of property i at time t; $TREAT_i$ is a treatment measure that captures the change in the spatial distribution of aircraft noise and airport accessibility associated with the new air traffic concept; and $POST_t$ is an indicator variable denoting the period after the announcement, so that $\zeta TREAT_i \times POST_t$ differentiates between the effects of the treatment measure before and after the announcement. The remaining terms capture observable hedonic property characteristics ($\sum_k \alpha_0 S_{i0}$) and location characteristics ($\sum_l \gamma_l L_{il}$) and unobserved time-invariant location characteristics within each of the voting precincts (the fixed effects, SB_j).[7] $g(TREND_t)$ is a third-order polynomial for a daily time trend. $א_{it}$ is a random error term. The treatment effect of the announcement of the new airport concept on property transaction prices is identified by $\zeta TREAT_i$.[8]

To develop a treatment measure $TREAT$ that can accommodate the complex spatial pattern of price adjustments associated with the increase and decrease in noise levels and accessibility of the three airports distributed across the metropolitan area, we proceed as follows. First, we define three auxiliary coordinate systems with horizontal axes that follow the runway paths of each airport F, with the vertical axes standing upright in the centers of the airfields. Second, we attach the X_{Fi} and Y_{Fi} coordinates in each of the three auxiliary coordinate systems (F) to all property transactions i. Third, we generate a set of spatial variables based on these coordinates. For each airport coordinate system F, we define

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[7] Standard errors are clustered at the precinct level.

[8] Note that unlike in the conventional difference-in-difference setting, our treatment measure $TREAT$ captures a spatially varying treatment across the entire metropolitan area (and not an effect that is specific to a treatment group). The $\zeta TREAT_i \times POST_t$ effect therefore incorporates a potential level shift across the entire metropolitan area that in a standard setting would be controlled for by including a non-interacted $POST$ variable.

third-order polynomials of the absolute value of the X-coordinate ($|X_{iF}|, |X_{iF}|^2, |X_{iF}|^3$), the Y-coordinate ($|Y_{iF}|, |Y_{iF}|^2, |Y_{iF}|^3$) and the X×Y-coordinate interaction ($|X_{iF} \times Y_{iF}|, |X_{iF} \times Y_{iF}|^2, |X_{iF} \times Y_{iF}|^3$). Fourth, we define our treatment measure $TREAT$ as a linear combination of the resulting 27 variables, which we substitute into (14) to obtain our estimation equation.

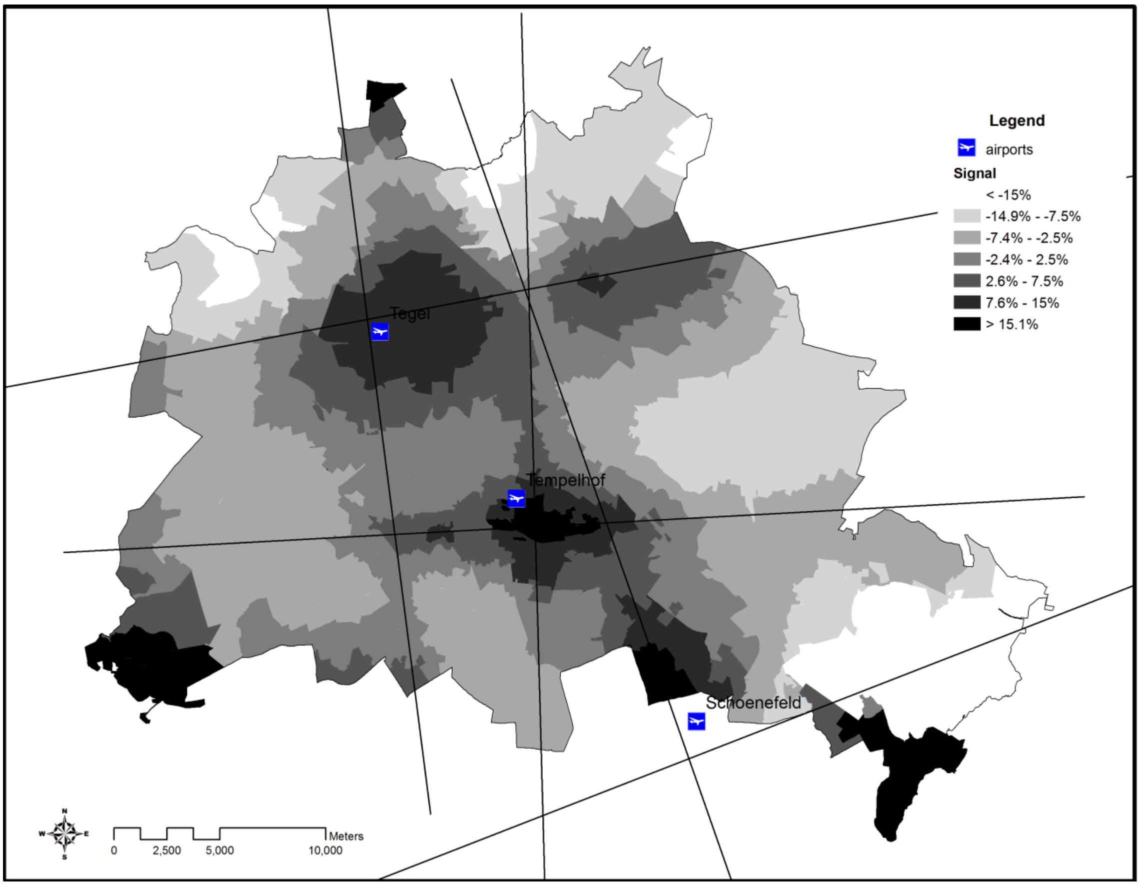
$$\log(P_{it}) = (\sum_F \sum_{n=1}^{3} [\Lambda_{nF}|X_{iF}|^n + \Lambda_{nF}|Y_{iF}|^n + \Lambda_{nF}|X_{iF} \times Y_{iF}|^n]) \times POST_t$$
$$+ \sum_F \sum_{n=1}^{3} [\xi_{nF}|X_{iF}|^n + \xi_{nF}|Y_{iF}|^n + \xi_{nF}|X_{iF} \times Y_{iF}|^n]$$
$$+ \Xi POST_t + \sum_k \alpha_0 S_{i0} + \sum_l \gamma_l L_{il} + \sum_j \beth_j SB_j + \aleph_{it} \quad (15).$$

The estimated coefficients ($\widehat{\Lambda}_{nF}$), which are jointly highly statistically significant in a Wald test, can then be used to generate our proxy for the price signal at the precinct level: $S_j = \left(\sum_F \sum_{n=1}^{3}\left[\Lambda_{nF}\left|X_{jF}\right|^n + \Lambda_{nF}\left|Y_{jF}\right|^n + \Lambda_{nF}\left|X_{jF} \times Y_{jF}\right|^n\right]\right)$, where X_{jF} and Y_{jF} are defined by analogy with X_{iF} and X_{iF} but with reference to the geographic centroid of precinct *j*.

Table A2 in the web-based technical appendix summarizes the results of the estimation of Eq. (15). Fig. 2 shows the estimated market reaction against the backdrop of the auxiliary coordinate systems. The map generally reveals positive price responses along the air corridors for the airports that were announced to be closing (Tempelhof and Tegel) and a negative reaction along the corridor for the airport that was to be expanded (Schoenefeld). The exceptions are a few precincts that are immediately adjacent to the city boundary and the existing runways of Schoenefeld, where the disutility from air noise may have exceeded a critical value and where further increases may therefore only have had a marginal impact. The positive amenity effect of having a state-of-the-art international airport nearby could therefore outweigh the negative disamenity (noise) effect. Such proximity effects would be consistent with the general appreciation in property values in the southeastern locations near the new airport but outside the air corridor. Consistent with our suppositions, the results reflect the existence of costs related to aircraft noise and benefits related to airport accessibility. More details regarding the data and methods used are presented in the web appendix.

The estimated announcement effects are plausible with respect to the historical setting and potential sorting effects. A detailed discussion is presented in the web appendix (Section 3.3), along with the results of a series of placebo regressions that support the chosen announcement date. It should further be noted that the strategy presented is not designed to provide an estimate of the total welfare effect of the new airport concept. Such combined hedonic and difference-in-difference strategies have been criticized for not appropriately accounting for general equilibrium effects of non-marginal environmental changes (e.g., Sieg & Zhang, 2012; Tra, 2010). Instead, the strategy is designed to flexibly identify spatially varying appreciation rates and produce a measure of relative appreciation within the city area.

Fig 2. The estimated price signal (1996 announcement)



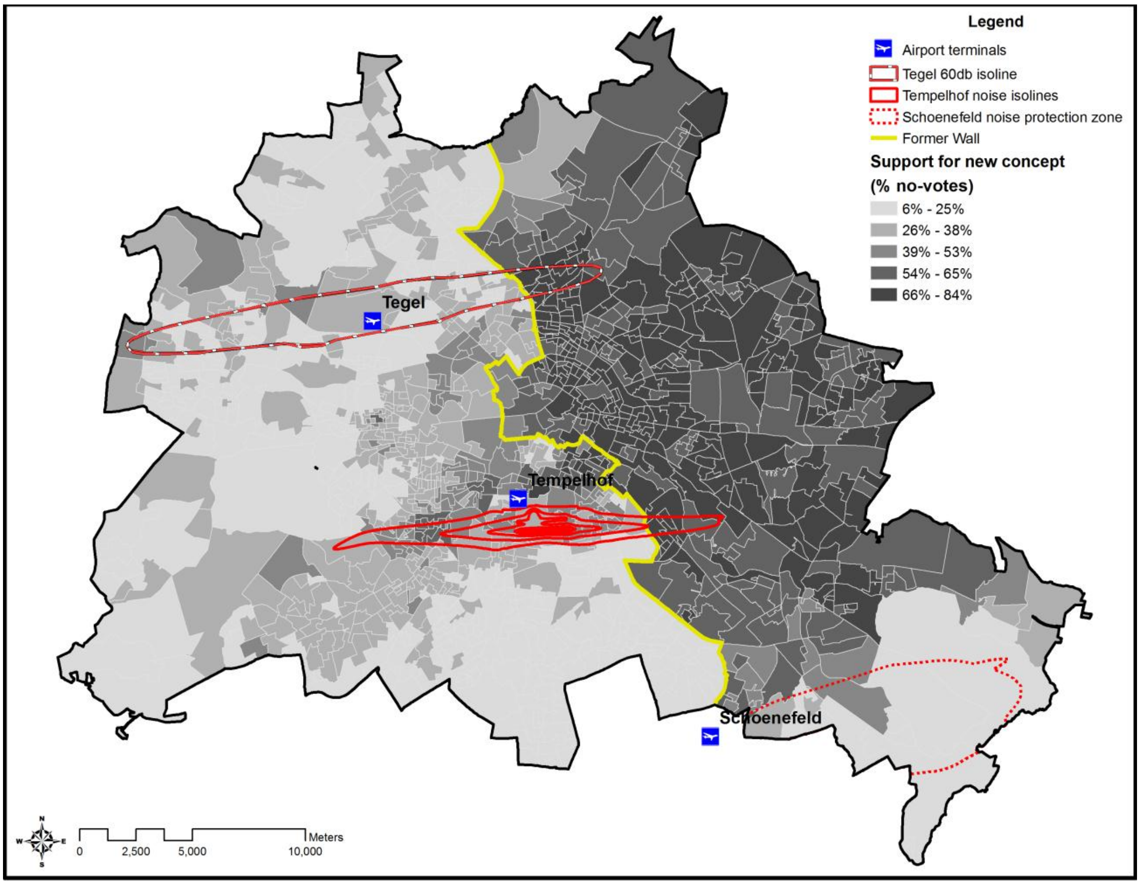
Notes: Authors' calculations and illustration. Solid black lines represent the auxiliary coordinate systems. Classes are defined based on Jenk's (1977) algorithm.

5. Results

5.1 Baseline results

Fig. 3 maps the proportions of "no" votes in the referendum on the continued operation of Tempelhof. A striking level of east–west heterogeneity is evident from the map. The (unconditional) mean approval rate is more than twice as great within the former East Berlin as it is within the former West Berlin (65% vs. 30%). Similarly impressive is the clearly reduced support for the new concept within the Schoenefeld noise zone (27%), whereas the increases in the approval rates around Tegel and Tempelhof are visible but less obvious. The effects in the immediate vicinity of the aircraft noise zones are indicative of NIMBYism and the desire to shift (Tempelhof and Tegel) or keep (Schoenefeld) airport activity away from the voters' own neighborhoods.

Fig 3. Support for the new airport concept (*SUP*)



Notes: Authors' illustration based on the Urban and Environmental Information System of the Senate of Berlin (Senatsverwaltung für Stadtentwicklung Berlin, 2006b). The classes are defined based on Jenk's (1977) algorithm.

Column I of Table 1, which shows the results of a reduced version of Eq. (11), substantiates the impressions suggested by Fig. 3. Even with differences in socioeconomic controls taken into account, the rejection rate in the eastern precincts is higher by approximately 29 percentage points. A 1-db increase in aircraft noise triggers an increase in the proportion of "no" votes by approximately 0.9 percentage points for precinct affected by Tempelhof noise and approximately 0.2 percentage points in the case of Tegel. Given the maxima of the observed noise levels for the precinct average of approximately 14 db for Tempelhof and 30 db for Tegel (these values are in excess of the 45-db threshold), these estimates indicate a substantial increase in support for the new airport concept, i.e., up to 13 (Tempelhof) and 7 (Tegel) percentage points. As expected, the effect of the Tegel air noise is weaker than that of the Tempelhof air noise because of the less direct connection of the former to the referendum, which directly addressed the closure of Tempelhof. The support for the new airport concept within the Schoenefeld noise zone is significantly reduced (32 percentage points lower) compared to the support for the project in the precincts with a similar socio-demographic structure within the boundaries of the former East Berlin. Without reference to local tenure status, these results indicate that aircraft noise was generally perceived as a disamenity by the local population.

Column II adds a set of variables for distance to the airport terminals to disentangle the estimated noise effects from the accessibility effects. Support decreases by approximately 0.9 percentage points for each 1-km reduction in distance to the Tempelhof airport. This result, which is identified in conjunction with a noise effect that is only slightly reduced, indicates that the expected gains from the alternative post-closure use of the space as a public park outweigh the expected loss of airport services. In contrast, the positive distance effect (0.34 percentage points per km) that was found for Tegel shows that the anticipated loss of access to the services provided by the largest airport was expected to outweigh the potential benefits of an uncertain alternative use for the space. It is likely that the positive coefficient of the Schoenefeld distance variables partially captures the correlated noise effects that cannot be observed directly (except through the binary noise protection zone dummy variable) and thus indicates the NIMBYism of voters attempting to avoid a concentration of air traffic in their neighborhoods.

Like the results for aircraft noise and airport accessibility, the point estimates for the socio-demographic control variables exhibit high degrees of stability across model specifications. The estimated difference in the average rejection rates for the former West Berlin and the former East Berlin is approximately 23–29 percentage points; history clearly matters. Our political variables also exhibit the expected signs, with increased support for Tempelhof (i.e., a lower share of “no” votes) in voting precincts with a high proportion of supporters of conservative parties and increased support for the new concept in precincts with more supporters of the Green party. The age variables reveal that support for the new concept was higher in all age groups relative to the baseline category of 27- to 45-year-olds. Of the baseline controls, only purchasing power and the proportion of unemployed individuals do not have a robust, significant impact.

Tab 1. Parametric estimates of proportion of "no" votes for continuation of Tempelhof (=support for new airport concept)

	Proportion of "no" votes out of the total votes (x100) (support for new airport concept)					
	(I) OLS	(II) OLS	(III) NLS	(IV) NLS	(V) OLS	(VI) OLS
(Former) East Berlin	29.121***	28.888***	25.908***	23.774***	26.045***	22.868***
(dummy)	(1.226)	(1.229)	(1.219)	(1.426)	(1.315)	(1.475)
Proportion conserva-	-0.658***	-0.671***	-0.835***	-0.967***	-0.804***	-0.945***
tive parties (x100)	(0.047)	(0.044)	(0.047)	(0.054)	(0.048)	(0.054)
Proportion green	0.944***	0.822***	0.715***	0.737***	0.716***	0.719***
party (x100)	(0.047)	(0.050)	(0.047)	(0.057)	(0.052)	(0.060)
Proportion age < 18	0.605***	0.715***	0.526***	0.570***	0.586***	0.480***
(x100)	(0.066)	(0.087)	(0.072)	(0.079)	(0.092)	(0.086)
Proportion age 18–	0.914***	0.934***	0.750***	0.762***	0.795***	0.643***
27 (x100)	(0.095)	(0.114)	(0.093)	(0.104)	(0.117)	(0.108)
Proportion age 45–	0.810***	0.827***	0.698***	0.634***	0.739***	0.590***
55 (x100)	(0.076)	(0.075)	(0.072)	(0.076)	(0.078)	(0.080)
Proportion age >55	0.601***	0.593***	0.495***	0.565***	0.519***	0.521***
(x100)	(0.044)	(0.049)	(0.045)	(0.053)	(0.051)	(0.054)
Purch. power	-0.072	0.347	0.264	0.103	0.274	-0.031
1000Euro/capita	(0.196)	(0.215)	(0.182)	(0.208)	(0.214)	(0.216)
Proportion non-	-0.058*	-0.161***	-0.118***	-0.133***	-0.142***	-0.092***
Germans (x100)	(0.033)	(0.046)	(0.032)	(0.033)	(0.042)	(0.034)
Proportion unem-	-0.120	-0.070	-0.098	-0.223**	-0.086	-0.289***
ployed (x100)	(0.096)	(0.105)	(0.083)	(0.087)	(0.101)	(0.095)
Tempelhof noise	0.948***	0.844***	0.741***	0.690***	1.012***	0.984***
(db)	(0.195)	(0.206)	(0.123)	(0.113)	(0.204)	(0.193)
Tegel noise (db)	0.231***	0.271***	0.185***	0.166***	0.291***	0.260***
	(0.038)	(0.043)	(0.034)	(0.031)	(0.042)	(0.047)
Schoenefeld noise	-32.307***	-27.068***	-7.904***	-4.989***	-29.937***	1.280
zone (dummy)	(5.497)	(5.564)	(1.646)	(1.120)	(6.728)	(8.319)
Distance to		-0.918***	-0.588***	-0.464***	-0.931***	-0.631***
Tempelhof (km)		(0.130)	(0.098)	(0.091)	(0.122)	(0.133)
Distance to Tegel		0.344**	0.182***	0.120***	0.232*	0.404***
(km)		(0.135)	(0.060)	(0.049)	(0.138)	(0.133)
Distance to Schoene-		0.404***	0.252***	0.184***	0.337***	0.322***
feld (km)		(0.090)	(0.053)	(0.046)	(0.094)	(0.112)
Homeownership rate			0.057***	-0.206	0.066***	-0.238
(H) (x100)			(0.010)	(0.224)	(0.010)	(0.255)
H x amenity treat-			0.027***	0.044***		
ment (Θ)			(0.004)	(0.005)		
Signal S from 1996					-0.153***	-0.126***
announcement x100					(0.032)	(0.040)
Signal (S) x H (ψ)					0.003***	0.002***
					(0.001)	(0.001)
Controls x H				YES		YES
Airport effects x H						YES
Observations	1201	1201	1201	1201	1201	1201
R^2	0.906	0.913	0.920	0.928	0.918	0.930
AIC	7839.1	7762.1	7644.2	7548.0	7697.1	7527.6

Notes: Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

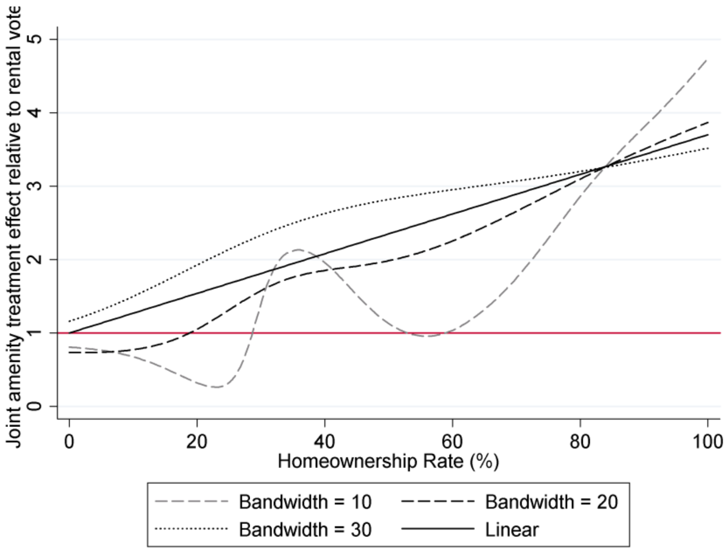
5 . 2 Amenity–tenure interaction effects

Model III in Table 1 introduces the interaction of homeownership rate H and the joint effect of the noise N and accessibility A variables $E_j = \left(\sum_F \left(\Upsilon_F N_{Fj} + \Xi_F A_{Fj}\right)\right)$, as modeled by

Eq. (11). In line with our theoretical expectations, the homeownership treatment interaction effect (Θ) is positive. Moreover, it is notable that the direction of the noise and distance effects does not change. When the joint effect of amenity changes and capitalization is considered, it appears that leasevoters (H=0) and homevoters (H=100) voted in the same direction. This is the theoretically expected result in an environment where regulations mitigate increases in rents for renters as long as they remain in their residences, so the amenity effect outweighs the capitalization effect $\left(-\frac{\partial f}{\partial Z} / \left(\frac{\partial f}{\partial H}\frac{\partial H}{\partial \widetilde{r_i}}\right) = \frac{d\widetilde{r_i}}{dZ} > \frac{dr_i}{dZ}\right)$.

Nonetheless, the positive homeownership interaction effect indicates that the responses of homeowners to the treatment were considerably stronger. This finding is consistent with both (a) negative capitalization effects for renters $\left(\left((\partial f/\partial H)(\partial H/\partial r)(dr/dZ)\right) < 0\right)$, potentially occurring with homogenous or heterogeneous preferences, and (b) positive capitalization effects for owners in a world with heterogeneous preferences $\left((\partial f/\partial H)(\partial H/\partial r)(d\bar{r}/dZ - d\tilde{r}/dZ) > 0\right)$. The amenity effect on the support for the new airport concept $\left(\hat{E}_j = \sum_F\left(\widehat{\Upsilon_F} N_{Fj} + \widehat{\Xi_F} A_{Fj}\right)\right)$ increases by Θ=0.027 percentage points for every one percentage point increase in the homeownership rate H. Fig. 4 plots the amenity–tenure interaction effect, comparing the linear estimate $\left(\Theta H_j\right)$ from Table 1 (III) with nonparametric locally weighted regression estimates using different bandwidths in the kernel weights (details are in the web-based appendix). The results indicate that compared to a baseline pure renter precinct $\left(H_j = 0, \hat{E}_j = 1\right)$ the amenity voting effect is about four times as large in a precinct exclusively inhabited by owners ($H_j = 100, \hat{E}_j = 3.7$ in the parametric model). At the 1st (disamenity effects dominate) and 99th percentiles (amenity effects dominate) of the joint amenity treatment $\hat{E}_j = \left(\sum_F\left(\widehat{\Upsilon_F} N_{Fj} + \widehat{\Xi_F} A_{Fj}\right)\right)$, the homeowner effect decreases/increases the treatment effect from -4.24 to -15.67 (for the 1st percentile) and from 8.67 to 32.08 (for the 99th percentile) percentage points. These are sizable numbers, given the mean approval rate of approximately 30 percentage points in West Berlin.

Fig 4. Amenity–tenure interaction effects: linear vs. nonparametric estimates



Notes: Baseline model is model III in Table 1. (Details for the nonparametric locally weighted regression estimates using different bandwidths in the kernel weights are in the web-based appendix). Bandwidths between 10 and 20 or 20 and 30 tend to produce a mix of the respective functional forms.

Alterations and extensions

It is noteworthy that the amenity–tenure interaction effect is robust to the inclusion of a full set of interaction terms of the homeownership rate and the control variables ($\sum_k X_k \times H$), which allows the homeowner effect to vary in all observable dimensions of the population. With these additional controls, the amenity interaction effect even increases (column IV).

To assess the quantitative relevance of the amenity effect and the amenity–tenure interaction effect on the voting outcome, we have conducted a counterfactual analysis of what the voting outcome might have been without these localized incentives. We use a variant of model III, using the proportion of either "yes" votes or "no" votes at the total electorate (instead of total votes) as dependent variables. We introduce the airport variables in conjunction with a full set of interaction terms of the airport variables and the homeownership rate, $\sum_F \left(\Upsilon_{FH} N_{Fj} \times H_j + \Xi_{FH} A_{Fj} \times H_j\right)$. The counterfactual voting outcome is then computed as the actual voting outcome net of the contribution of the airport variables and/or the interaction terms. We find that while the amenity effects on the voting outcome were sizable in relative terms, given the low turnout, the minimum participation quorum (which the referendum failed to satisfy) made it unlikely that NIMBYists pushing for local improvements in environmental quality could cast a decisive vote.[9] Details are in the web appendix.

5.3 Capitalization–tenure interaction effects

In column V, we proceed to the capitalization interaction model laid out in (12), using the price signal estimated according to (15). In line with the theoretical implications, the interaction effect of the homeownership rate and the price signal is positive and statistically significant. Based on the parameter estimates (on H, S, $S \times H$), the joint effect of homeownership and the price signal (and their interaction) can be visualized on a quasi-spatial 3D surface (Fig. 4). Approximately 97% of our precinct-level price signal estimates fall within the range of ±15%. The percentage values are computed from log-differences estimated using model (15), applying the standard formula by Halvorsen & Palmquist (1980). A Wald test allows us to verify that the variables are not jointly equal to zero. Fig. 4 also compares the parametric estimate of the surface to a nonparametric version of the surface. This surface is computed by grouping precincts into cells in the homeownership rate price signal grid and replacing the parametric surface variables (H, S, $S \times H$) by a set of fixed effects identifying these grid cells. The recovered fixed effects then form the nonparametric surface (details are in the web based appendix).

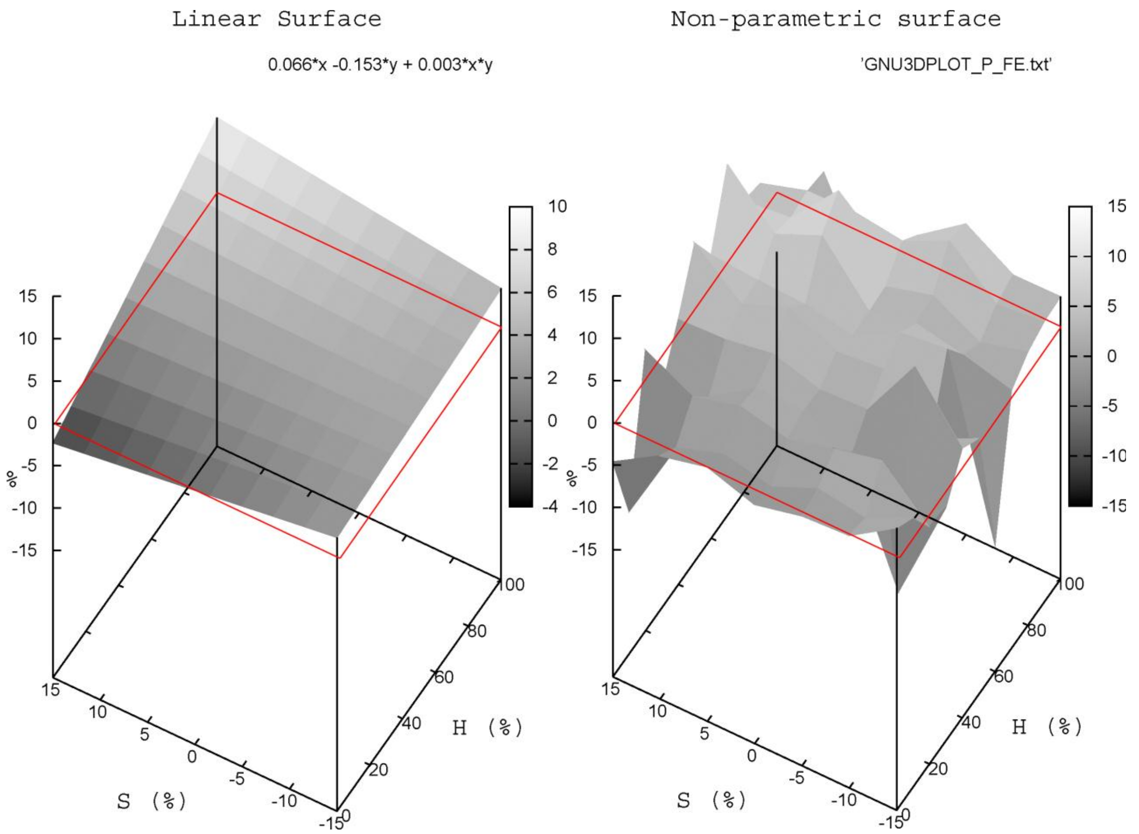
There is significantly greater support for the new airport concept in areas with both high homeownership rates and positive price signals (in the northwestern quadrant). Compared to a baseline precinct with a zero homeownership rate and a zero price signal, in a precinct with a homeownership rate of 100% and a positive price signal of approximately 15%, the share of no votes, *ceteris paribus*, increases by approximately 9 percentage points in the parametric estimate. The effect, which is conditional on the amenity effect common to renters and owners, declines with both the price signal and the homeownership rate and becomes negative for locations with positive price signals but low homeownership rates. At a +15% price signal, a comparison between two otherwise comparable hypothetical renter and homeowner precincts yields differences of approximately 12 percentage points in the linear model. Excluding two outliers, we find estimated price signals up to approximately 43%. At such price signal levels, the difference between two precincts that

[9] As shown by Herrera and Mattozzi (2010), the participation quorum requirement may well have reduced the turnout.

are fully renter- or owner-occupied amounts to approximately 20 percentage points. The nonparametric surface basically supports these insights. The renter effects are slightly stronger (in the southwestern quadrant), supporting the premise that controlling for amenity effects, renters tend to oppose the new airport concept if they expect their neighborhoods to gentrify or property values to appreciate. At negative price signals, the capitalization treatment effects are somewhat smaller. In areas with low homeownership rates and negative price signals (in the southeastern quadrant), the effects are small but mostly positive, as expected. There also seems to be a capitalization-related benefit that mitigates the effects of negative environmental changes in areas with negative price signals and high homeownership rates (in the northeastern quadrant).

These results are generally in line with the amenity capitalization models (columns III and IV), but add some important insights. The positive capitalization effect on homevoter behavior (at positive and negative price signals) indicates that heterogonous preferences play a role, and at least a proportion of homeowners takes potential wealth effects materializing with future relocations into account when making their voting decisions. Interestingly, the capitalization effects for owners seem to be particularly relevant in areas with positive price signals. The negative capitalization effect on leasevoter behavior is in line with renters facing capitalization-related costs, even though the effects seem smaller in magnitude compared to the capitalization effect on homevoters. The difference can be explained by significant regulations that severely limit the degree to which landlords can adjust the rents that they charge for rented dwellings. An alternative or potentially complementary explanation is the lower mobility costs faced by renters, which make it easier for them to readjust to accommodate their preferred combination of living costs and neighborhood quality by moving to another location.

Fig 5. Capitalization–tenure interaction effects on support for new concept (% of “no” votes



Notes: The figure illustrates the homeownership–price signal interaction effect, based on the parametric Table 1, Column 5 estimates (linear, left) and a semi-parametric version (see the web-based appendix for details). The homeownership rate H, the price signal S and the treatment effect (on the Z-axis) are depicted in percentages.

Model alterations and extensions

In addition to the semi-parametric version illustrated in Fig. 4 (right panel), we performe a series of additional alterations of Model V in Table 1. We evaluate the extent to which the results are driven by outliers in the price signal variable and consider quadratic and cubic versions of the homeownership rate–price signal surface. Moreover, we use bootstrapped standard errors, regressions weighted by the precinct electorate, spatial error correction and lag models, measures for the distance to the airport terminals based on actual road distances rather than straight lines, and higher-order polynomial distance specifications. We have also substituted the dependent variable (the share of “no” votes) for the share of “no” or “yes” votes at the total electorate. All of the results, which are consistent with the discussions based on Table 1, Column V, are presented and discussed in the web appendix.

We also estimate an extended version of Eq. (12) that features the interaction effects of the homeownership rate and both aircraft noise and airport access (E), as well as controls

(X_k) from Table 1, Column IV. In this specification, we allow preferences with regard to noise and accessibility to differ for renters versus homeowners, and we separate these preferences from the voting effects related to price expectations. Again, the results are consistent with the above discussions of the benchmark model. In particular, the estimate of the homeownership rate–price signal interaction effect, which is of primary interest, remains close to the benchmark specification (Table 1, Column VI).

6. Conclusion

We contribute to the literature that has investigated the political economy of collective decision making (e.g., Osborne & Turner, 2010) and especially the distinct incentives homeowners and renters face when participating in direct democracy. (Fischel, 2001a). The homevoter hypothesis states that homeowners vote in favor of initiatives that they perceive as increasing the value of their properties and against those that do not. This supposition has received empirical support (Brunner & Sonstelie, 2003; Brunner, et al., 2001; Dehring, et al., 2008; Hilber & Mayer, 2009) and is consistent with casual observations indicating that NIMBYs who engage in political activism against neighborhood change are often homeowners (Fischel, 2001b). While renters have received less attention in this context, capitalization effects are just as important if not more important to explain the attitudes of this group, unless they are perfectly protected from rental increases by regulation. Protests and conflicts associated with the gentrification of formerly deprived downtown areas are typical manifestations (Ahlfeldt, 2011).

Our tests of tenure interaction effects accommodate both perspectives and directly compare the behavior of homevoters to leasevoters. In analyzing a public initiative with localized effects, we develop an empirical strategy that we uses to explore the interaction effect of the tenure mix of a neighborhood using either the net amenity change or a measure of capitalization effects. We used the 2008 public referendum on the closure of Tempelhof Airport in Berlin, Germany, as a natural experiment. The closure of the airport at Tempelhof (and the one at Tegel) was a logistical, ecological, and financial component of a new aviation concept that involved replacing the three existing smaller airports, Tegel, Tempelhof, and Schoenefeld, with a new international airport located close to the Schoenefeld site. The project had direct implications for voters living in the noise or catchment areas of the three airports. The change in Berlin's airport geography, including the aircraft noise and airport accessibility effects associated with the three airports, was anticipated to generate amenity and capitalization effects with rich spatial variation. Given these factors and the substantial spatial variation in homeownership rates, this case offers an excellent opportunity to test for the presence of tenure-specific voting effects, i.e., homevoter and leasevoter behavior.

Our parametric and nonparametric estimation strategies provide consistent evidence of the positive interaction effect of local homeownership rates, net amenity changes and price signals on the support for the new aviation concept. Consistent with our theoretical expectations, the marginal effects of homeownership rate on the one hand and the net amenity change or the estimated capitalization effect on the other positively depend on each other. *Ceteris paribus*, we find increased support for the new concept in locations with high homeownership rates and positive amenity and capitalization effects. The effects are significantly reduced in similarly positively affected areas inhabited by renters. Controlling for the amenity effect, we find evidence of increased opposition in areas with positive price signals and low homeownership rates. The fact that homeowners take into account a capitalization effect is consistent with heterogeneity in preferences for location across individuals, which lead to increases (decreases) in housing value in response to positive (negative) policies above (below) the own valuation. The fact that the capitalization effect on renters turns out to be relatively small is consistent with strong regulations that shield renters from positive rent adjustments and the lower mobility costs faced by renters. This effect, however, may well vary across institutional settings.

If the different incentives to engage in political bargaining that we find for renters and owners are also influential beyond our study area, there are important implications for the allocation of public facilities with localized effects and particularly for their allocation via direct democracy processes. Our results clearly suggest that individuals have diverse preferences concerning (public) facilities with localized effects, which may suggest that decisions regarding such facilities are better based on social cost-benefit analyses, especially those based on revealed preference approaches (e.g., using travel cost and hedonic data) (Osborne & Turner, 2010). In the long run, a political process based on referenda will not necessarily lead to the allocation of local public goods according to their welfare impact. Instead, it could lead to the concentration of public facilities with negative local externalities (local public bads) in areas that are dominated by renters, whereas homeowners may attract facilities with positive local externalities (local public goods). There are, however, a number of tools that may reduce the difference between homevoter and leasevoter behavior. Our results indicate that rental regulations that protect incumbent residents from rent increases make renters behave more like homeowners. Similarly, levies charged after a house is sold to compensate owners for capitalization effects due to public policies that affect housing values could make homeowners behave more like renters. Finally, minimum participation (or favorable vote) quorums can significantly limit the ability of well-organized interest groups (e.g., NIMBYists) to shape the voting outcome at the margin.

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Technical Appendix to

"Homevoters vs. leasevoters:

A spatial analysis of airport effects"[*]

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1 Introduction

This technical appendix complements the main paper by providing additional details on data and methods and complementary evidence. Section 2 outlines the political and institutional background of the referendum on the new Berlin airport concept in detail. Section 3 gives additional detail on our estimation strategy. First, we present the locally weighted regression approach used to isolate the non-linear amenity–tenure interaction effect. Second, we present our strategy for computing a counterfactual election outcome. Third, we present a more detailed description of the semi-parametric estimation procedure used to identify the conditional nonlinear price signal–homeownership rate surface function. Section 4 describes the data in detail, including how the proxies for the homeownership rate and the price signal were constructed. Section 5 complements the evidence provided in the main document with the counterfactual analysis and robustness checks. This appendix is not designed to replace but rather to complement the main paper. To improve readability, it replicates some paragraphs of the main paper.

2 The 2008 referendum on the new Berlin airport concept

Partly because of its history, Berlin possessed three relatively small airports in the early 1990s. Tegel and Tempelhof are centrally located within the boundaries of the former West Berlin, whereas Schoenefeld lies close to the southeastern boundaries of Berlin and served East Berlin during the division period. It was argued that a major, state-of-the-art airport was necessary to improve Berlin's international connectivity and competitiveness and to attract new businesses. In addition, the two city airports in the former West Berlin exposed a densely populated area to noise, pollution, and crash risks. On July 4, 1996, the so-called "consensus decision" (*Konsensbeschluss*) was established among the mayor of Berlin, Eberhard Diepgen; Brandenburg's state governor, Manfred Stolpe; and the transport minister of the Federal Republic of Germany, Matthias Wissmann. These individuals decided to redevelop Schoenefeld into a large-scale, international hub airport named Berlin–Brandenburg International, where all air traffic would be concentrated, and to close Tegel and Tempelhof.

Both city airports provided much better accessibility for many residents and businesses than did the more remote Schoenefeld. As a result, businesses and passenger lobbies challenged the decision, taking legal action and employing other tactics. After years of legal and public disputes, the Berlin Senate released a "funded notification" (*fundierter Bescheid*) requiring the closure of Tempelhof in August 2006. That decision was also challenged, but eventually, after another revision, the decision was upheld by the Federal Administrative Court of Germany (*Bundesverwaltungsgericht*), which is the court of last resort.

The Tempelhof closure was scheduled for October 31, 2008. As this date approached, the intensity of the protests against the plan steadily increased. Opposition to the closure of Tempelhof was more strenuous than opposition to the closure of Tegel because the former change was imminent, whereas Tegel would remain in operation until the opening of Berlin–Brandenburg International. In addition, Tempelhof was the object of strong emotional attachment as a result of its history. Tempelhof was Berlin's most important access point during the 1948–49 airlift and brought supplies to the residents of West Berlin during the Berlin Blockade.

It is important to note that the closure of Tempelhof, in addition to reducing noise and affecting access to flight connections, promised to have another important local effect. Although the future use of the airfield has not been decided, the authorities have long emphasized the potential of the site for public use. The airfield was opened to the public in October 2010, which made it one of the city's largest public parks (Tempelhofer Feld) and a widely appreciated amenity. Simultaneously, rigid heritage legislation ensures the preservation of the former terminal buildings, which were constructed prior to WWII. In light of the relatively limited number of flights offered by the airport, the (expected) benefits of gaining access to this public park could be expected to more than compensate the local residents for any reduction in airport accessibility. Nonetheless, the Interest Group for City Airport Tempelhof eventually forced a referendum in favor of Tempelhof's remaining in operation. Although the results of the referendum were nonbinding for the Berlin city government, it was widely agreed that the referendum, if it had succeeded, would have exerted strong pressure on the city government, which thus would have been forced to rethink its decision (Nitsch, 2009).

The vote was held on April 27, 2008. The referendum was approved by the majority of those who voted, but it failed to achieve the minimum favorable vote quorum of 25% of the total electorate. More detailed information on the history of Berlin's airports and the Tempelhof referendum is provided by Nitsch (2009).

3 Empirical strategy

3.1 Amenity tenure–interaction: Locally weighted regressions

In this section, we explain the estimation procedure for the nonparametric locally weighted regression estimates displayed in Fig. 4 of the main paper. Locally weighted regressions belong to the class of nonparametric approaches and essentially imply that for each observation (here precincts), a weighted regression is estimated based on a kernel (Cleveland & Devlin, 1988; McMillen, 1996; McMillen & Redfearn, 2010). Equation (11) from the main paper can then be rewritten with precinct-specific coefficients. We merge the individual airport effects estimated from the NLS estimates reported in the main paper (Table, 1, III) into one treatment variable in this procedure $\left(\hat{E}_j = \sum_F \left(\hat{\Upsilon}_F N_{Fj} + \hat{\Xi}_F A_{Fj}\right)\right)$.

$$SUP_j = \alpha_j + \sum_k \beta_{kj} X_{kj} + \Omega_j H_j + \sigma_j \hat{E}_j + \Theta_j \left(H_j \times \hat{E}_j\right) + \tilde{\varepsilon}_j$$

In each local regression for $\tilde{j}$, we assign a kernel weight $w_{j\tilde{j}}$ to observation j, which depends on a bandwidth B and the difference between the homeownership rate at $\tilde{j}$ and j.

$$w_{j\tilde{j}} = \frac{1}{B\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{H_j - H_{\tilde{j}}}{B}\right)^2}$$

Each series of locally weighted regressions produces a full set of precinct-specific parameters Θ_j. The resulting nonlinear function depends on the bandwidth B, where larger values generate greater smoothing. Fig. 4 in the main paper plots the resulting functions with relatively small (10) and large (30) bandwidths.

3.2 Amenity–tenure interaction: Counterfactual analysis of NIMBY effects

For the sake of brevity, we refer to local patterns in the voting pattern as NIMBYism (where NIMBY stands for "not in my back yard"). NIMBYism can be motivated by the desire to shift away or keep away negative environmental factors (e.g., noise). To determine how relevant NIMBYism was in the referendum in absolute terms and how likely it is to change electoral outcomes in similar scenarios, we construct a counterfactual that indicates what the election outcome might have been in the absence of NIMBYism. Following the example of Ahlfeldt (2011), we model the share of "yes" and "no" votes within the total electorate as reflections of both the attitudes towards the referendum and the incentives to participate in it generated by aircraft noise and airport accessibility, which together indicate the net distribution of the airport closure effects on the total population:

$$PE_j = \sum_k \delta_k X_{jk} + \sum_F (\rho_F N_{jF} + \lambda_F D_{jF}) + \sum_F [(\varsigma_F N_{jF} + \omega_F D_{jF}) \times H_j] + \varepsilon_j$$

where PE is the fraction of either “yes” or “no” votes divided by the number of eligible voters (the electorate) and where the other variables are defined as before. We separate the homeowner effect from a baseline effect that captures the expected change in the amenity distribution (aircraft noise and airport accessibility) and incentives to renters. We make this distinction using a full set of interaction terms with the local homeownership rate H_j, where the assumption is that the extra incentives to the homeowners that are reflected in the coefficients of the interaction terms stem from the anticipated capital gains/losses.

With this specification, it is possible to compute the local contribution to the total number of “yes” or “no” votes by airport, which is important because the “push” and “pull” factors may work in opposite directions for Tempelhof and Tegel on the one hand and for Schoenefeld on the other.

$$TE_F = \frac{1}{100} \sum_j \left(\hat{\rho}_F N_{jF} - \hat{\lambda}_F (DM_F - D_{jF}) \right) \times EL_j$$

$$TE_F^H = \frac{1}{100} \sum_j \left(\hat{\varsigma}_F N_{jF} - \hat{\omega}_F (DM_F - D_{jF}) \right) \times EL_j$$

where TE_F is the baseline effect attributed to each of the three airports $F = \{Tegel, Schoenefeld, and\ Tempelhof\}$, TE_F^H is the respective homeowner effect, DM_F is the maximum distance of airport F from precinct j in the area, and EL is the precinct-level total electorate (the population over the age of 18). The relevance of NIMBYism can then be evaluated quantitatively by comparing the overall contributions of the “yes” and “no” votes to the effective outcome and to the counterfactual scenario adjusted for localized phenomena.

3 . 3 Capitalization–tenure interaction: Nonlinear signal homeownership surface

This section explains the generation of the semiparametric homeownership rate–price signal surface displayed in Fig. 5 of the main paper in greater detail. The aim of our empirical strategy is to estimate the price signal–homeownership rate surface function f(S, H)

without imposing parametric constraints and conditional on amenity $\left(\sum_F\left(\eta_F N_{Fj} + \sigma_F A_{Fj}\right)\right)$ and socio-demographic $\left(\sum_k \beta_k X_{kj}\right)$ factors.

$$SUP_j = \alpha + \sum\nolimits_k \beta_k X_{kj} + \sum\nolimits_F \left(\eta_F N_{Fj} + \sigma_F A_{Fj}\right) + f\left(S_j, H_j\right) + \varepsilon_j$$

Because the functional form of the interaction effect of the price signal and the homeownership rate is not known a priori, we used a semi-parametric estimation strategy that can accommodate complex nonlinear effects along both dimensions and the interaction of the two surface variables.

We create a discrete grid of cells to which voting precincts are allocated based on the local price signal and homeownership rate. The boundaries of these cells are determined by "bins" for price signal and homeownership rate values that are defined as follows:

1) Eleven bins BH_h along the homeownership rate dimension for precincts with rates of H_j =0, 0<H_j≤10%, 10%<H_j≤20%, and so forth in increments of 10%.

2) Seven bins BS_s along the price signal dimension for precincts with S_j ≤ -15%, -15% >S_j ≤ -10%,…, -5% >S_j ≤ 0%, 0% < S_j ≤ 5%, 10% < S_j ≤ 15%,…., S_j > 15%.

As in a spatial X/Y-coordinate system, each combination of indicator variables/bins along the two dimensions H and S forms a specific grid cell $(BH_h \times BS_s)$. These grid cells can be used to replace the parametric formulation of the homeownership rate–price signal interaction effect in equation (12) $\left(\Omega H_j + \phi S_j + \psi\left(H_j \times S_j\right)\right)$.

$$SUP_j = \alpha + \sum\nolimits_k \beta_k X_{kj} + E_j + \sum\nolimits_h \sum\nolimits_s \psi_{hs}(BH_h \times BS_s) + \varepsilon_j$$

We estimate this specification with fixed effects for each grid cell $(BH_h \times BS_s)$. This specification is similar to the use of location-specific fixed effects in house price capitalization research to capture otherwise unobservable location features (distributed along the X/Y dimensions).

4 Data

In this section, we provide a more detailed description of how the data set was compiled, especially with regard to the homeownership rates and the announcement effects on property prices, which are not readily observable. The next section introduces the main components of our data, which were obtained from official sources. Section 3.2 explains how we define our local homeownership proxy and provides relevant background regarding the particularities of Berlin's housing markets and an empirical assessment of the method to replicate actual homeownership rates on a larger geographic scale. Section 3.3 complements the data section of the main paper by presenting the baseline results obtained using the estimated hedonic property price model.

4.1 Noise, voting and socio-demographic data

Noise data

Among the most important baseline variables for the purpose of this analysis are those that capture exposure to aircraft noise within the neighborhoods affected by the three Berlin airports. From an official report (Laermkartierung nach Umgebungsrichtline, 09.07.2007), we obtain detailed information on the exposure to aircraft noise from Tegel at the level of 10 × 10-m grid cells. The noise map for Tegel and its air corridors covers large parts of the northern half of the city. The noise levels are recorded for all of the developed properties within this area and expressed using a long-term sound pressure index (L_{den}) that is equivalent to the standard log-decibel scale (db). Using a geographic information system (GIS), the information on aircraft noise is aggregated at the precinct level using the representative means for the noise observations in each voting precinct.

For Tempelhof, the data were obtained from the Berlin Airports' operating company (Flughafengesellschaft) in the form of an electronic map on which iso-sound pressure zones of 50–55, 55–60, 60–65, 65–67 and greater than 67 dB(A) are identified. Ahlfeldt and Maennig (2011) employed a regression-based interpolation to obtain a continuous sound surface within a 100 × 100-m grid for areas that experience sound pressure above 45 db. Here, our process was similar to the one that we used with the Tegel noise data: we merged Ahlfeldt and Maennig's estimates with an electronic map of polling districts in a GIS environment. Using standard geographic interpolation techniques (Goodchild & Lam, 1980), we generated precinct-level noise averages weighted by the shares of the precincts' surface areas that fall into selected noise zones.

No detailed noise maps were available for Schoenefeld, which lies outside the boundaries of Berlin and whose air corridor only crosses Berlin's territory to a small extent. The only available information was a map of the restricted development area that incorporated the assumption that noise levels would increase considerably when the new international airport, Berlin–Brandenburg International, was opened. We employed this information in our empirical analyses by defining indicator variables that have a value of one for property transactions and precincts that have centroids within the noise zone and that have a value of zero otherwise.

Fig. 1 in the main paper illustrates the noise surfaces for values greater than 45 db. As discussed in the main paper, only aircraft noise exceeding this threshold is considered in the empirical analyses. Lower levels of aircraft noise are likely to be dominated by other noise sources and are not likely to influence property prices (Ahlfeldt & Maennig, 2011). We define all of the noise variables for Tegel and Tempelhof such that they express the number of db above the 45-db threshold, e.g., values of 5, 10, and 15 correspond to 50, 55, and 60 db, respectively. Values below 45 db were set to zero to reflect levels of aircraft noise that were indistinguishable from other types of noise.

Voting data

The data on the voting results for the Tempelhof referendum were obtained from the state statistical office in Berlin–Brandenburg. Of the 881,035 votes that were cast, 650,464 votes could be used in the empirical analyses. These results are available as aggregated outcomes at the level of 1,201 voting precincts and were merged with an electronic map of the precinct boundaries via a unique identifier variable. The remaining mail-in votes could not be considered because of missing geo-references.[1] We used a GIS framework to merge the voting outcome with 2008 data on socio-demographic characteristics that were available for 15,937 statistical blocks (data regarding population, age groups, the proportion of males, and the population of non-German citizens), 191 zip codes (data regarding purchasing power), 338 traffic cells (data regarding unemployment rates), and 2,424 small voting precincts (data regarding voting in the 2006 state elections). These data were obtained from the statistical office in Berlin, with the exception of the data on purchasing power, which were originally derived from a report by the Consumer Research Society (Gesellschaft für Konsumforschung). Again, standard area interpolation techniques (Arntz &

[1] Nitsch (2009) has shown that the differences by district are negligible when the votes cast at ballot boxes and by mail are compared.

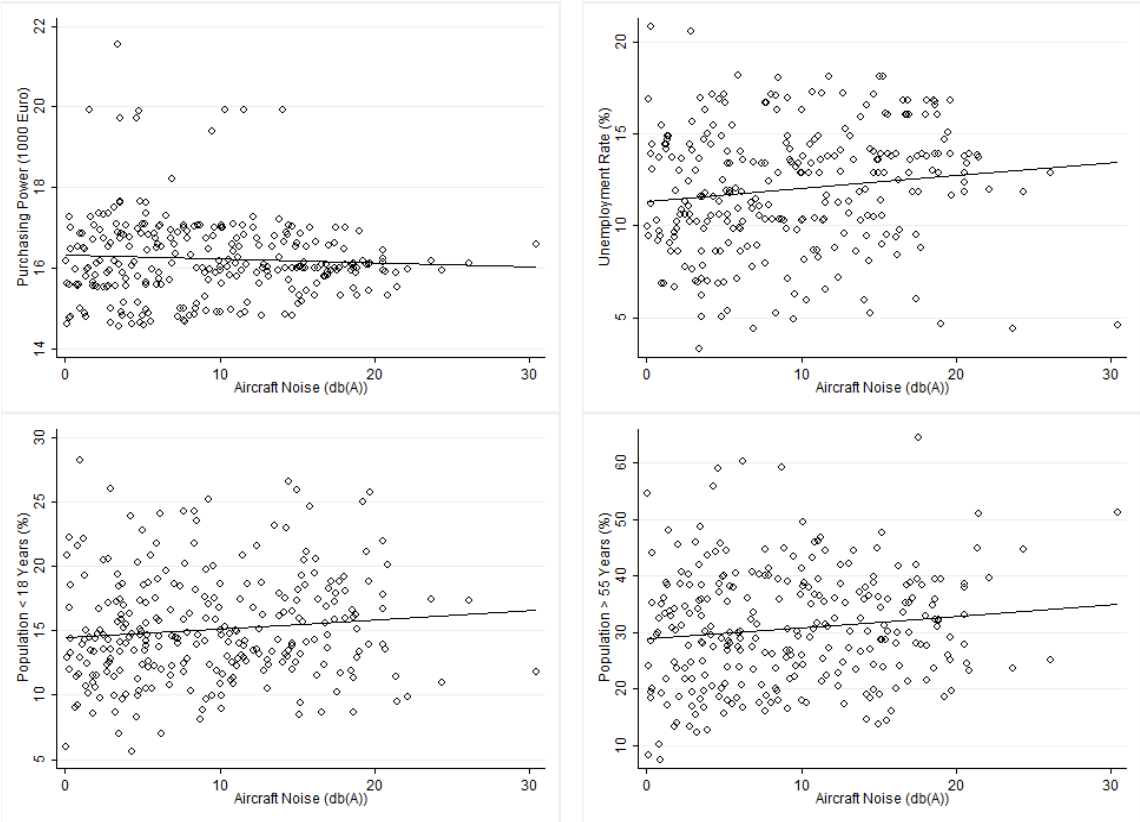
Wilke, 2007; Goodchild & Lam, 1980) were used to aggregate all of the data to the level of the 1,201 precincts in a GIS environment.

Socio-economic and demographic controls

Based on these data sources, we compile our baseline data set to control for the socioeconomic and demographic characteristics of the local population. To account for the possibility that the residents of the former East Berlin feel less attached to a West Berlin airport, we include an indicator variable in the vector of location variables that is set to one for the precincts within the boundaries of the former East Berlin. The proportion of votes by the major conservative opposition parties in the 2006 federal elections is included to take into account the loyalties, strategic effects, attachments, and lifestyle preferences of the supporters of the Christian Democratic Party and those of the Liberals, who strongly supported the referendum. The proportion of Green party voters (Die Grünen) is included to take into account this group's particular sensitivity to environmental issues. The proportions of various age groups are included because households in different life stages may perceive different (dis)utilities as associated with airports. Purchasing power per capita is included to reflect environmental preferences that are correlated with income. Given that only EU citizens were entitled to vote in the referendum, the proportion of the non-German population serves mainly as a neighborhood variable that helps us to account for the unobserved characteristics that are correlated with the proportion of the population that is foreign born.

These variables are included to control for any heterogeneous preferences regarding the new airport concept that are correlated with these attributes. Heterogeneous preference can lead to the sorting of residents with specific preferences into certain neighborhoods. Because of the costs of relocation, these residents may engage in NIMBYism to attempt to prevent changes to their neighborhoods. It is difficult to illustrate the presence of such sorting because preferences regarding aircraft noise and airport accessibility cannot be observed directly. To the degree that these unobservable preferences are correlated with observable socio-economic characteristics, their spatial distribution yields some insight into the presence of sorting. Fig. A1 compares the spatial distribution of aircraft noise to selected socio-demographic characteristics at the precinct level. The scatter plots show the weak but notable correlations between the presence of aircraft noise and the local unemployment rate and the proportions of selected age groups in the local population.

Fig. A1. Residential sorting



Notes: Noise is measured by the sound pressure (db) exceeding 45 db(A).

4 . 2 Approximation of the homeownership rate

Although our data set is unusually rich with respect to hedonic property characteristics, including location features, proxies for noise, and precinct attributes, confidentiality rules prevent us from determining homeownership rates directly at a highly disaggregated spatial level. Because we require a proxy variable that can help us to approximate these rates at the precinct level, we make use of a particularity of the Berlin housing market: its segmentation into detached, semidetached, and attached single-family houses, villas, and townhouses, which are almost entirely occupied by owners, and typical downtown apartment buildings, which are usually five stories tall and almost entirely occupied by renters.

It is well documented that accommodation type is an important determinant of tenure choice across European countries (Hilber, 2007), but this segregation is particularly striking in Germany and in Berlin in particular. The low number of three-or-more-family houses inhabited by owners in Berlin results from the heavily subsidized supply of apartments for rent and the restrictive policy on rent levels and rent increases that existed in West Berlin until 1980, both of which led to rent levels in Berlin that were significantly below those of comparable German cities. This unique attribute of Berlin persists to the present day. Until the end of the German Democratic Republic (GDR), it was almost impossible to privately own an apartment in East Berlin, but it was possible to own a single-family house. In addition, unemployment rates in Berlin were high (13.84% in 2008[2]) compared to national levels, and incomes were low. Finally, the percentage of single-person households was approximately 53.3% and increasing (46.0% in 1998, 50.1% in 2003), whereas the number of three-or-more-person households (which are traditionally those that purchase real estate) is shrinking (Amt für Statistik Berlin–Brandenburg, 2008). This market segregation becomes apparent in the German microcensus data. Because no full population census was conducted after 1987, the microcensus (which provides data for a 1% population sample) currently represents the most detailed household database maintained by the German Federal Statistical Office. Table 1 displays a subsample of the 2002 microcensus that has been anonymized and made publicly available by the statistical office.[3] In this representative sample, more than 90% of one- and two-family houses are occupied by owners, and more than 90% of the inhabitants of dwellings in three-or-more family houses are occupied by tenants.

Tab. A1. Tenure status by dwelling type in Germany and Berlin

Tenure status by dwelling type in Germany

	Dwelling units ≤ 2		Dwelling units > 2		Total
	Total	%	Total	%	
Owner	10,372	78.68%	1,943	16.60%	12,315
Tenant	2,632	19.97%	9,542	81.53%	12,174
Subtenant	178	1.35%	218	1.86%	396
Total	13,182		11,703		24,885

Tenure status by dwelling type in Berlin

	Dwelling units ≤ 2		Dwelling units > 2		Total
	Total	%	Total	%	
Owner	134	90.54%	54	6.42%	188
Tenant	14	9.46%	777	92.39%	791
Subtenant	0	0.00%	10	1.19%	10
Total	148		841		989

[2] Available at website http://www.statistik-berlin-brandenburg.de, last accessed on 18 July 2012.

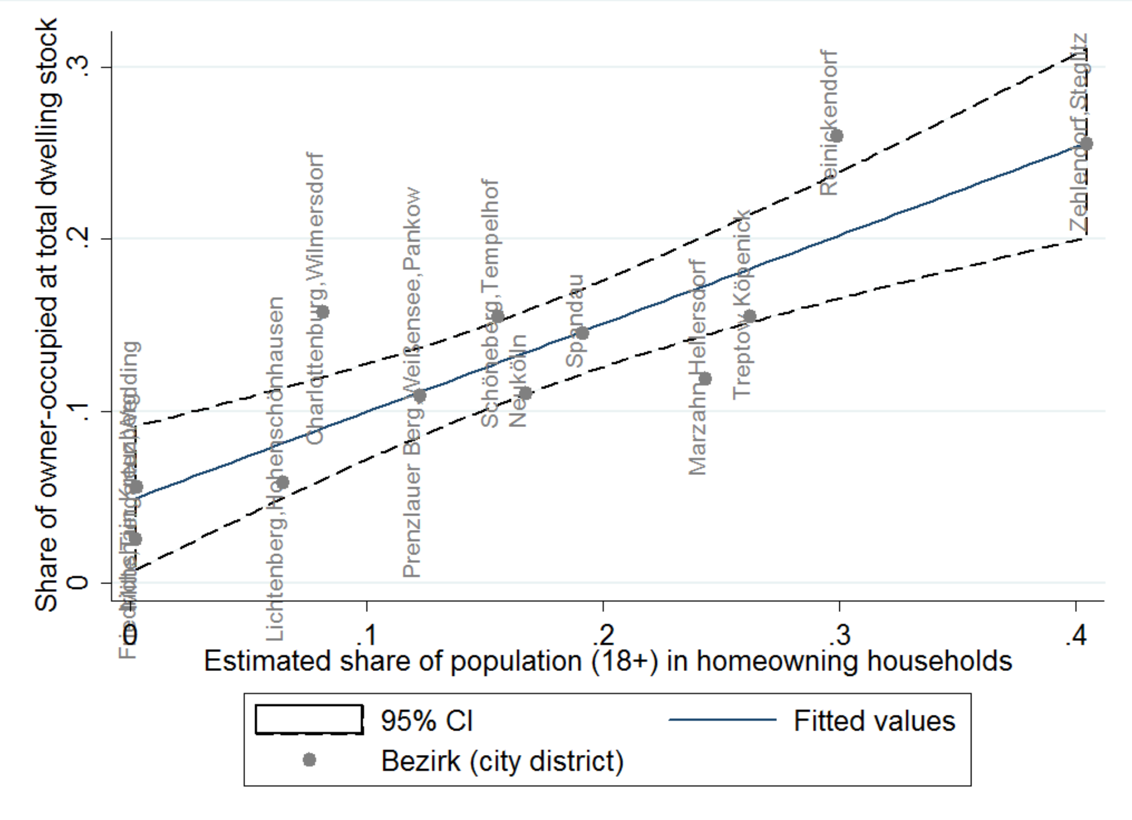
[3] The data set can be accessed at http://www.forschungsdatenzentrum.de/bestand/mikrozensus/cf/2002/index.asp

The Urban Environmental Information System of the Senate Department characterizes 15,937 statistical blocks using a range of homogeneity criteria, including building structure. Based on the assumptions presented above, the homeownership rate (*HR*) for a voting precinct *j* can be approximated as the proportion of the total population above the age of 18 (the electorate or *EL*) within the voting precinct that lives within the boundaries of a statistical block *k* that features single-family homes (*SF*):

$$H_j = \frac{\sum_k SF_{kj} \times EL_{kj}}{\sum_k EL_{kj}}$$

Our homeownership proxy based on the city district figures performs reasonably well, as revealed by its approximately linear relationship with the observable share of owner-occupied dwellings within the total dwelling stock (Fig. A2). A regression of the observed proportion of owner-occupied dwellings with our estimated homeownership rate at the district level yields an R^2 slightly greater than 0.75. Our estimated homeownership rates are slightly larger than the proportion of owner-occupied dwellings, most likely because we analyze the members of the local population who are 18 years old or older and because a relatively larger number of people live in one- or two-family houses. This consideration is important for the purpose of our analysis because this is the population of potential voters in which we are interested.

Fig. A2. Estimated vs. current homeownership rate (at Bezirke level)



Notes: The percentage of owner-occupied dwellings in the total dwelling stock was taken from the 2008 IBB Property Market Report (Immobilienmarktbericht) and reflects the situation on December 31, 2007.

4.3 Price signals and announcement effects

One requirement of our empirical strategy is a proxy variable for the expected effect of the initiative in question on local prices. Throughout our analyses, we assume that current prices reflect discounted future rent streams and that, in the absence of regulation, prices and rents move in tandem.

As discussed in Section 4.3 of the main paper, we estimate a price signal using the property market responses to the 1996 announcement of the new Berlin airport concept. Our estimation strategy builds on a long tradition within the hedonic property literature of assuming that all of the associated costs and benefits of specific property attributes fully capitalize into prices (Rosen, 1974). We attribute changes in (log) prices $\Delta \log(P_i)$ to the location of a property relative to the three airports ($F = \{Tempelhof, Tegel, Schoenefeld\}$), which we express in terms of X_F and Y_F coordinates (and the interactions of both) in the auxiliary airport coordinate systems using a flexible cubic functional form.

$$\Delta\log(P_i) = \sum_F \sum_{n=1}^{3} [\Lambda_{nF}|X_{iF}|^n + \Lambda_{nF}|Y_{iF}|^n + \Lambda_{nF}|X_{iF} \times Y_{iF}|^n]$$

These locational price adjustments can be estimated conditional individual property and location characteristics based on the following hedonic equation:

$$\log(P_{it}) = \left(\sum_F \sum_{n=1}^{3} [\Lambda_{nF}|X_{iF}|^n + \Lambda_{nF}|Y_{iF}|^n + \Lambda_{nF}|X_{iF} \times Y_{iF}|^n]\right) \times POST_t + \sum_F \sum_{n=1}^{3} [\xi_{nF}|X_{iF}|^n + \xi_{nF}|Y_{iF}|^n + \xi_{nF}|X_{iF} \times Y_{iF}|^n] + \sum_k \alpha_0 S_{i0} + \sum_l \gamma_l L_{il} \sum_j \Theta_j SB_j + \Omega_{it}$$

where P_{it} is the price per land area of property i sold on day t and S_o and L_l are broad sets of structural and locational characteristics. *POST* is an indicator variable that denotes the time after the announcement and SB_j is a full set of voting precinct-fixed effects to control for unobserved time-invariant spatial heterogeneity. We also cluster the standard errors at the same level to facilitate shifts in the mean and variance of the error across space.

Column I in Table A2 presents the results. The estimated "implicit" prices of the property attributes considered are in line with our expectations. The location control variables are less informative because they are estimated conditional on a fine grid of voter precinct effects and are only included to account for the residual within-precinct variation. We therefore omit these results. Columns II and III report the results of the estimates conducted using separate subsamples of single-family and multi-family homes. As discussed in the data section, these market segments are dominated by owners and renters, respectively. We use the resulting price signals as robustness checks, as described in the next section. In each model (I–III), the variables used to capture the price signal pass a Wald test of joint significance.

Tab. A2. Prices signal estimation: Hedonic estimates

	(I)	
	Coeff.	S.E.
Single family house	0.035	(0.036)
Floor Space Index (FSI)	0.824^{***}	(0.050)
FSI squared	-0.075^{***}	(0.009)
Plot Area (m²)	-0.000^{**}	(0.000)
Plot Area squared	0.000	(0.000)
Story	-0.012	(0.010)
Age (Years)	-0.014^{***}	(0.001)
Age (Years) squared	0.000^{***}	(0.000)
Condition: Good	0.306^{***}	(0.031)
Condition: Bad	-0.181^{***}	(0.024)
Extra flat in attic	0.092^{***}	(0.019)
Elevator	0.417^{***}	(0.087)
Basement	0.057^{***}	(0.022)
Underground car park	0.000	(.)
Charge for infrastructure	-0.017	(0.027)
Not occupied by renter	0.136^{***}	(0.029)
Share at sec. structure	-3.482^{**}	(1.355)
Urban renewal area	-0.002	(0.016)
Treat x POST Wald test (p-value)	0.030	
Location Controls	YES	
Precinct Effects	YES	
Daily Trend (3rd-order polynomial)	YES	
TREAT	YES	
TREAT x POST	YES	
Period	1 YEAR +/- ANN.	
Observations	6796	
R^2	0.794	
AIC	5768.0	

Notes: In all of the models, the dependent variable is the log of price per square meter of land. Location controls include Dist. to Center (km), Dist. to Water (km), Dist. to Green (km), Dist. to Station (km), Dist. to Main St. (km), Street Noise (db), Dist. to Industry (km), Landmarks within 600 m, Dist. to Landmark (km), and Dist. to School (km). *TREAT* includes the (cubic) X and Y coordinates and interaction terms of the auxiliary coordinate systems. The standard errors are clustered on voting precincts. **/*/+ denote significance at the 1/5/10% levels.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

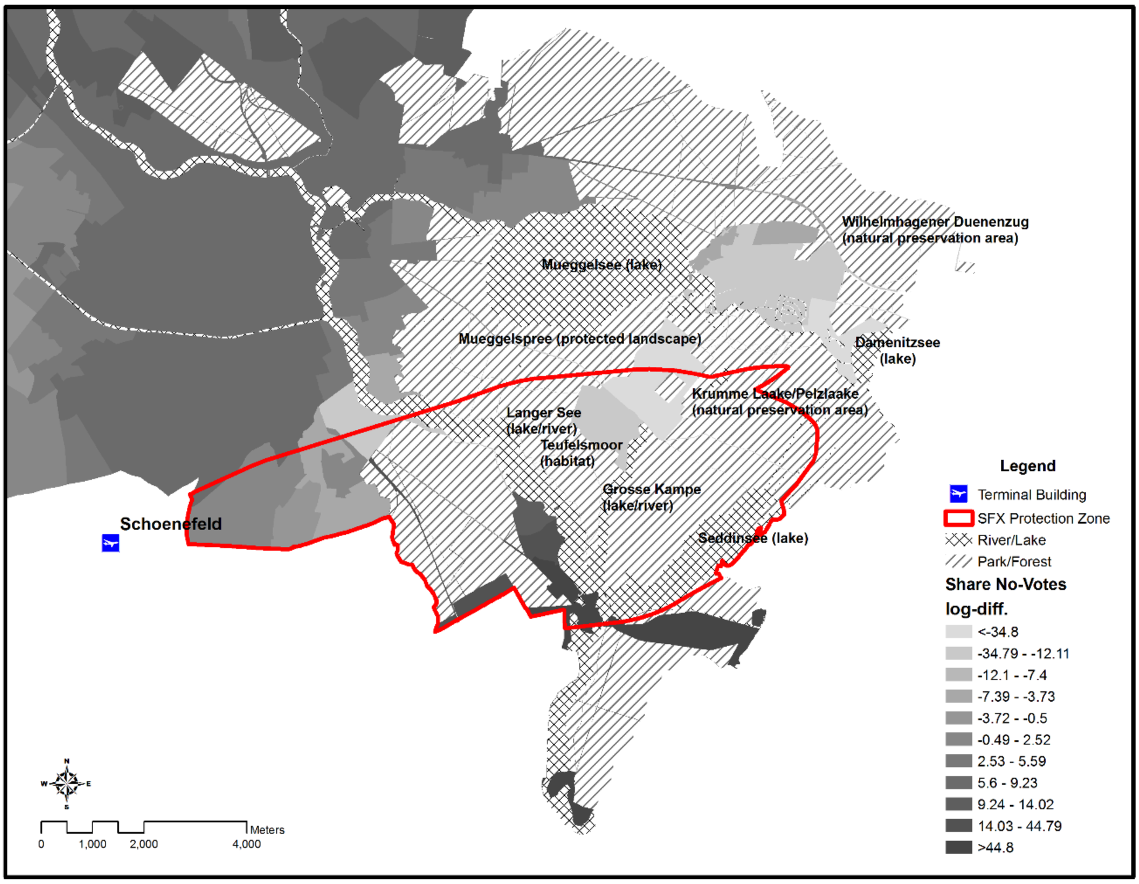
The spatial pattern of the estimated announcement effects is shown in Fig. 2 in the main text. These effects show a relatively large degree of variation in property price adjustments, ranging from less than −15% to more than 15%. Although these extreme values may seem relatively large for announcement effects, our estimates are conclusive, given a number of particularities.

Both the positive and the negative extreme values relate to voting precincts in the far southeast region of the city that fall within the air corridor of the new international airport. The precincts that are adjacent to the airfield were already exposed to high levels of aircraft noise but experienced a strong increase in value because they are now nearly within walking distance of the new airport. The resulting opportunities for new uses of real estate (e.g., as accommodations for shift workers and crew members) may explain the pronounced reaction of the property prices within an area that was formerly barely attractive. Similarly, the new airport concept has generated a nonmarginal shift in aircraft noise in an area that was previously very attractive due to its favorable natural environment, which includes lakes and forests (see Fig. A3). Given the average noise effect of -0.6% per db aircraft noise in the literature (Ahlfeldt & Maennig, 2011; Nelson, 2004), a 30% reduction in property prices (which we find for some precincts in the Schoenefeld area) would correspond to an anticipated increase in airport noise of approximately 50 db. Although reliable estimates of future (and current) sound pressure levels are not available, an increase of this magnitude seems somewhat unlikely. However, given the particular natural environment, which includes nature preserves, it seems realistic that the current inhabitants have an above-average valuation of the environmental quality of their surroundings, which could explain the disproportionate drop in value.

For the other two airports, the increase in prices is more consistent with conventional noise estimates. The announcement effects have values of up to approximately 23% in the Tempelhof noise zone and 13% in the Tegel noise zone. Taking the abovementioned average noise effect as a benchmark, we find that these results imply reductions in noise pressure of approximately 38 db (Tempelhof) and 22 db (Tegel). This decrease for Tempelhof is greater than the difference between current noise levels (see Fig. 1 in the main text) and the 45-db threshold, below which no effects are to be expected (Ahlfeldt & Maennig, 2011). It is important to note, however, that the increase in prices may reflect not only an anticipated reduction in noise but also expected utility from enhanced access to the airfield as a recreational space.

Moreover, some care is required in applying cross-sectional noise estimates to nonmarginal changes in the distribution of aircraft noise, due to potential sorting effects. As discussed above, it is difficult to investigate sorting with respect to aircraft noise because preferences regarding noise are not directly observable. Fig. A1 suggests that some sorting may have taken place. Assuming a nonmarginal reduction in aircraft noise, the neighborhood will become attractive to other populations. This prediction is especially important given the location of the airport. Almost the entire air corridor of Tempelhof falls within central and highly accessible areas that include typical historic architecture and urban design that dates back to the nineteenth-century Hobrecht Plan (Strohmeyer, 2000), as is typical of areas that have experienced gentrification (Ahlfeldt, 2011). Berlin, a symbol of a particularly urban lifestyle, attracts some 120,000 to 150,000 immigrants annually. With the dissipation of significant environmental disutilities, the areas in question become attractive to potential gentrifiers. Hence, the observed property price appreciation effect includes both a reduction in the disamenity level and an anticipated increase in the environmental quality of the area among new marginal buyers or renters. Together, these effects can explain the significant appreciation of residential property prices in the Tempelhof area relative to the expected effects of aircraft noise as derived from the cross-sectional analyses. For Tegel, where the future use of the airfield remains uncertain, the price signal and the implied noise effects are broadly in line with the actual distribution of aircraft noise.

Fig. A3. Schoenefeld noise impacted area



Notes: Authors' illustration based on data from the urban and environmental information system of the Berlin Senate Department (Senatsverwaltung für Stadtentwicklung Berlin, 2006)

Although the magnitude of the effect seems plausible given the aforementioned sorting effects, the nature of the announcement must be considered to understand why nearly full capitalization should be expected more than 10 years prior to the opening of the new airport. At the time the decision was made, the topic had been discussed intensively by the government, the public and the media. Schoenefeld was only one of more than 10 initially proposed options and was only seventh in the initial rankings. Even in the last stage of the selection process, there were three serious options remaining: Schoenefeld and sites in Sperenberg and Jueterbog-Ost, which were previously used for military purposes. Both of the latter alternatives offered significant advantages in terms of 24-hour airport operations because of their location in sparsely populated areas. However, the eventual decision was the result of a complex bargaining process among state and federal administrative and political bodies that considered several environmental and economic factors: accessibility, the exposure of the population to noise, biodiversity, and the cost of new infrastructure. Thus, the decision was difficult to foresee. Once the decision was made, however, it was largely taken as given.

At that time (1996), the planning authorities had an acceptable record of completing the development and infrastructure projects needed to restructure a city that had been divided for almost 50 years. The reintegration and necessary upgrading of severed urban rail lines, telecommunication networks, and electricity, gas, and sewage systems were completed fairly quickly. The new government district and commercial developments along Friedrichstrasse and Potsdamer Platz had already begun to massively reshape the appearance of the central city by 1996. Moreover, construction was initiated on a new mainline rail connection that crossed the city from north to south and a new central rail station at the intersection of the new rail line with the old east–west line. New road and rail tunnels crossing the government district and the River Spree were also constructed.

In this environment, the strengthened planning authorities had sufficient credibility to instill confidence that the new airport would be completed once the plan was announced. In this context, we would expect the largest price reaction to the new airport concept to occur concurrent with the announcement of the final plans. To evaluate the validity of this assumption, we run a series of placebo treatment regressions in which we used the property price changes ($\Delta\log(P_i)$) implied by the benchmark regression (see above in this section) as the treatment (T_i).

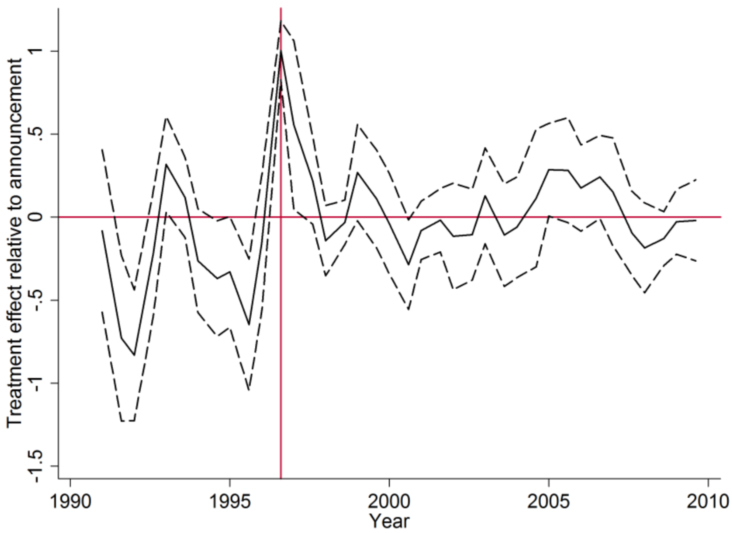
$$T_i = \sum_F \sum_{n=1}^{3} \left[\widehat{\Lambda_{nF}} |X_{iF}|^n + \widehat{\Lambda_{nF}} |Y_{iF}|^n + \widehat{\Lambda_{nF}} |X_{iF} \times Y_{iF}|^n\right]$$

The treatment is used in reduced-form placebo regressions q where we consider January 1 and July 1 of the years from 1991 to 2009 as the intervention dates. As in the benchmark announcement regressions, we focus on one-year windows before and after the placebo intervention.

$$\log(P_{it}) = \aleph_q^{POST} TREAT_i \times POST_{tq} + \aleph_{\mathrm{i}} TREAT_i + \sum_k \alpha_{0q} S_{i0} + \sum_l \gamma_{lq} L_{il} + \sum_j \Theta_{jq} SB_j + \Omega_{itq}$$

By construction, the treatment coefficient $\aleph_q^{POST}$ indicates the placebo treatment effect relative to the date when we expect the adjustments (June 2, 1996). The results are illustrated in Fig. A4, which plots the size of the placebo effects relative to the price effects in June 1996. The figure has at least three striking features. First, none of the placebo effects are close to the price effects in terms of magnitude. Second, the effects are only significantly different from zero for two additional dates. Third, the degree of volatility is significantly larger before the announcement than after the announcement. These findings indicate that the announcement was the relevant event, removing a great degree of uncertainty from the market and inducing capitalization effects.

Fig. A4. Placebo treatment effects



Notes: This figure presents the estimates for the placebo regressions relative to the announcement effects on prices associated with the July 4, 1996 announcement benchmark.

5 Results

5.1 Amenity–interaction effects: results of counterfactual analysis of NIMBY effects

The results presented in section 5.2 of the main paper indicate the presence of (expected) utility effects that depend on anticipated changes in aircraft noise and airport accessibility and on their interaction with the tenure status of the local population. Because these effects are local, they may generate local political activism, as postulated by the homevoter hypothesis.

To assess the quantitative relevance of NIMBYism that may emerge from the anticipated local costs and benefits anticipated by voters, we separately estimate models for the turnout and the proportions of "no" and "yes" votes in the total electorate. This approach accounts for the possibility that amenity and tenure interaction effects not only affect the voting decisions of those participating in the referendum but also influence whether a particular individual votes.

Tab. A3. Airport (dis)amenities and turnout

	(1) Turnout (x100)		(2) "No" votes in the total electorate (x100) (support new concept)		(3) "Yes" votes in the total electorate (x100) (oppose new concept)	
Tempelhof noise (db)	0.491***	(0.084)	0.507***	(0.073)	-0.017	(0.086)
Tegel noise (db)	0.004	(0.028)	0.085***	(0.017)	-0.081***	(0.022)
Schoenefeld noise zone (dummy)	-5.939**	(2.531)	-1.708	(3.570)	-4.196	(3.189)
Distance to Tempelhof (km)	-0.119	(0.085)	-0.081	(0.052)	-0.040	(0.064)
Distance to Tegel (km)	-0.216***	(0.078)	-0.203***	(0.049)	-0.011	(0.059)
Distance to Schoenefeld (km)	-0.332***	(0.069)	-0.202***	(0.044)	-0.128***	(0.048)
Tempelhof noise (db) x H	0.026*	(0.015)	0.007	(0.009)	0.020*	(0.011)
Tegel noise (db) x H	-0.001	(0.001)	0.002**	(0.001)	-0.003**	(0.001)
Schoenefeld noise zone x H	0.134***	(0.043)	-0.056	(0.044)	0.189***	(0.059)
Dist. to Tempelhof (km) x H	0.013***	(0.002)	-0.002	(0.002)	0.015***	(0.002)
Dist. to Tegel (km) x H	-0.005***	(0.002)	0.003***	(0.001)	-0.008***	(0.002)
Dist. to Schoenefeld (km) x H	-0.004**	(0.002)	0.003***	(0.001)	-0.007***	(0.001)
Controls	YES		YES		YES	
Observations	1201		1201		1201	
R^2	0.792		0.725		0.897	
AIC	6498.1		5451.3		6015.0	

Notes: Controls include all covariates used in Table 1, column (1), plus homeownership rate. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results presented in Table A3 are generally consistent with our expectations and the previous results but are somewhat difficult to interpret because noise, access, and homeowner effects, as well as the effects on "yes" and "no" votes, must be considered in tandem for us to understand the resulting local effects.

The airport effects become easier to capture when the contribution to total votes (in thousands of votes) is aggregated by airport (see section 2.2 in this appendix for the method). Table A4 separates the localized effects into a baseline (environmental and renter NIMBY) effect and a homeowner (NIMBY) effect by airport. There are no *a priori* expectations regarding the net effect of countervailing externalities related to noise and accessibility. Additionally, for the homevoter effect, the direction of the net effect is an empirical question because the neighborhoods surrounding the airports may be differently affected by noise. As a result, airports may have either positive or negative net effects on utility, prices, or both.

For Tempelhof, the local baseline effect is clearly negative (33,000 vs. 15,000), which implies that a clear local majority of the residents are in favor of relocating the airport activity to the new site. The relatively large number of local voters (15,000 individuals) who wish to keep the airport in operation could be potential users of the airport or—in light of the limited airport activity prior to its closure—renter NIMBYs who wish to avoid anticipated real estate appreciation (gentrification). The local homeowner NIMBY effect also works in this direction and increases the local support for the new airport by approximately 6,000 votes.

The baseline effect is even more striking in the case of the more frequented Tegel; the net homeowner effect is that 109,000 voters perceive the airport as a local net disamenity, whereas only 2,000 perceive it as an amenity. The homeowner effect moves in the opposite direction but remains small relative to the baseline effect. For Schoenefeld, the pattern is reversed. The baseline local effect works in favor of the new airport, though the population is somewhat split (80 vs. 51). The homeowner effect, however, increases local opposition by approximately 5,000 votes and reduces local support by 1,000, indicating that the (negative) noise effect dominates homeowner voting (NIMBY) behavior. However, it is notable that the homeowner effect is again small compared to the baseline effect.

Tab. A4. NIMBYism by airport

	Baseline contribution				Homeowner contribution			
	Tempelhof	Tegel	Schoenefeld	Total	Tempelhof	Tegel	Schoenefeld	Total
Yes (opposing new concept)	15	2	51	68	-5	3	5	3
No (supporting new concept)	33	109	80	222	1	-2	-1	-2
No – Yes (net support)	18	107	30	154	6	-5	-6	5

Notes: The absolute numbers are in thousands of votes.

Based on these estimated contributions to the absolute number of "yes" and "no" votes, we can compute counterfactual scenarios for the election outcome in the absence of NIMBYism by subtracting the baseline and homevoter contributions from the actual outcome of the poll. Table A5 compares the actual voting results to three counterfactual scenarios in which we exclude the effects of (dis)amenity and renter NIMBYism (Column I), homeowner NIMBYism (Column II) and both (Column III).

Counterfactual I shows that local effects played an important role in the election outcome, although these effects were not strong enough to alter the majority vote. Without NIMBYism based on local noise and accessibility effects, a larger share of voters would have preferred the continued operation of Tempelhof (and Tegel), at 14.3% to 2% (vs. 17.3% to 12.1% in the official referendum results). Counterfactual II shows that the homevoter effect worked in the opposite direction but played a limited role overall because the already small contributions cancel each other out at the different airport locations. The limited role of the homevoter effect, however, may be specific to the public activity in question and to the Berlin region, its local population densities, and its tenure composition. Even in the present setting, a somewhat tighter vote could have led non-homeowner NIMBYs to influence the majority vote because the silent majority individually faced lower incentives to participate in the referendum. However, this potentially influential vote by a NIMBY minority is partially due to the generally low turnout. If the participation rate had been higher, the absolute contribution would have limited the opportunity for NIMBYism to play a decisive role. Although the 25% participation quorum ironically worked in favor of the NIMBYs at Tempelhof and Tegel, it would have prevented them from playing a decisive role in the scenario in which they were most likely to influence the outcome: under very low general turnout.

Tab. A5. Counterfactual analysis

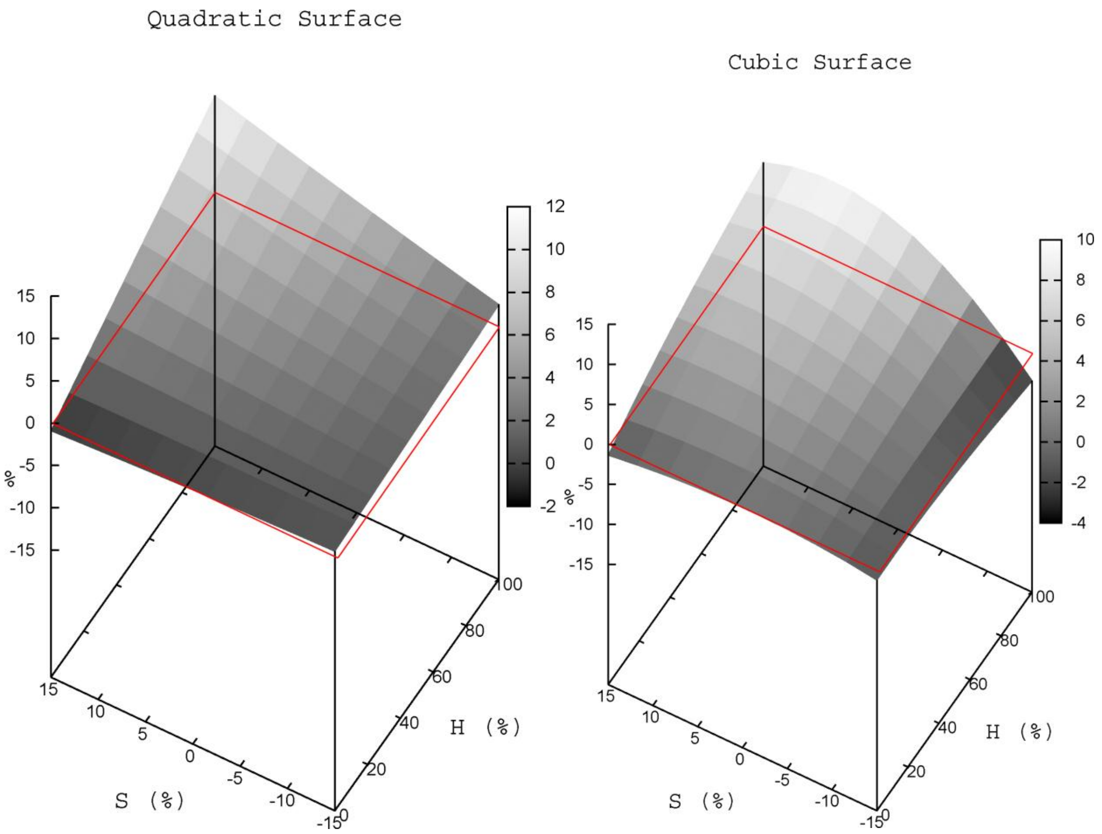
	Official referendum results		Counterfactual (I) Net of baseline NIMBYism		Counterfactual (II) Net of homevoter NIMBYism		Counterfactual (III) Net of total NIMBYism	
	Votes	%	Votes	%	Votes	%	Votes	%
Yes (opposition to the new airport concept)	383	17.3	315	14.3	380	17.2	312	14.1
No (support)	267	12.1	44	2.0	269	12.2	47	2.1
No – Yes (net support)	-116		-270		-111		-266	
Abstention	1558	70.6	1848	83.7	1559	70.6	1849	83.8
Electorate	2207	100.0	2207	100.0	2207	100.0	2207	100.0

Notes: The absolute numbers are in thousands of votes. Mail-in votes were excluded from the analysis.

5 . 2 Capitalization–tenure interaction effects: robustness checks

Table 1 (column) and Figure 5 in the main paper present the parametric results of our empirical test of the capitalization tenure interaction effect. Table A6 complements the evidence by adding several variations to the benchmark specification. Model I in column I begins with an evaluation of whether our results are driven by extreme values in the estimated price signals. Our concern is that the highly flexible functional form of our treatment variable *TREAT* used in the estimation of the price signal could lead to exaggerated estimates in areas with relatively few transactions. We therefore restrict the variation in the price signal to the 1^{st} to 99^{th} percentile interval, i.e., we assign the value at the 1^{st} (99^{th}) percentile to all observations below (above) the respective threshold. The results are qualitatively consistent and quantitatively close to the benchmark model. Models II and III alter the baseline model by estimating a quadratic and cubic version of the price signal–homeownership surface. The 2^{nd}- or 3^{rd}-order polynomials of the homeownership rate H, the price signal S and the interactions HxS are jointly statistically distinguishable from zero according to a Wald test. The resulting surfaces are plotted in Fig. A5. The quadratic surface is highly consistent with the linear version in Fig. 5 in the main paper. The cubic version mainly differs from the benchmark results in that it indicates small but negative capitalization-related effects to renters and owners at locations with negative price signals. The positive homeownership-capitalization interaction effect, however, is clearly evident in both surfaces.

Fig. A5. Quadratic and cubic price signal homeownership surface



Notes: Baseline models are II and III in Table A6.

Models IV–VIII provide robustness checks for the basic linear model. In Model IV, we bootstrap the standard errors in 500 replications to address potential issues that might be generated by the fact that the price signal (*S*) is a generated regressor (Murphy & Topel, 2002). While the homeownership rate–price signal interaction term is no longer significant, all surface variables easily pass a Wald joint significance test. Model V uses weighted regressions in which observations with larger numbers of eligible voters receive proportionally higher weights, to prevent our results from being driven by marginal precincts. In Models VI and VII, we estimate a spatial error model and a lag model (Anselin, 1988) using a maximum likelihood estimator because the spatial Lagrange multiplier test suggests the presence of a significant degree of spatial dependency.[4] We use a row-standardized exponential distance weights matrix to give higher weights to voting precincts that are closer to

[4] The test scores from the baseline specification presented in the main document (Table 3, Column V) are as follows: spatial error: Lagrange multiplier 18.86, robust Lagrange multiplier 13.46; spatial lag: Lagrange multiplier 25.29, robust Lagrange multiplier 19.89.

each other.[5] Model VIII replicates the benchmark specification of Table 1 in the main paper but replaces the straight distance measures with road distance measures to incorporate the effect of the actual road system on accessibility. Column XI presents the results obtained using our benchmark specification and a third-order polynomial distance specification. Based on a comparison across the results, it is evident that the parametric results discussed in the main text exhibit a relatively large degree of stability with respect to technical changes to the specification.

[5] The weight depends on the distance to voting precinct j on $w_{jJ} = e^{-\Phi D_{jJ}} / \sum_J e^{-\Phi D_{jJ}}$ and the decay parameter Φ, to which we assigned a value of 0.1, making the half-life distance slightly less than 7 km.

Tab. A6. Capitalization–tenure interaction robustness checks

	I	II	III	IV	V	VI	VII	XIII	IX
	OLS	OLS	WLS	SAR (err)	SAR (lag)	OLS	OLS	OLS	OLS
				“No” votes as a percentage of total votes					
(Former) East Berlin (dummy)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	-0.688
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	(0.473)
Share conservative parties (×100)	0.313^{**}	0.348^{**}	0.536^{***}	0.232	0.248^{**}	0.217^{*}	0.104	0.113^{**}	-1.139^{***}
	(0.143)	(0.145)	(0.118)	(0.158)	(0.111)	(0.115)	(0.111)	(0.046)	(0.412)
Share Green party (×100)	0.423^{***}	0.431^{***}	0.531^{***}	0.337^{***}	0.345^{***}	0.330^{***}	0.279^{***}	0.231^{***}	1.454^{***}
	(0.098)	(0.105)	(0.089)	(0.112)	(0.087)	(0.091)	(0.086)	(0.044)	(0.465)
Share age < 18 (×100)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	-0.688
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	(0.473)
Share age 18–27 (×100)	0.313^{**}	0.348^{**}	0.536^{***}	0.232	0.248^{**}	0.217^{*}	0.104	0.113^{**}	-1.139^{***}
	(0.143)	(0.145)	(0.118)	(0.158)	(0.111)	(0.115)	(0.111)	(0.046)	(0.412)
Share age 45–55 (×100)	0.423^{***}	0.431^{***}	0.531^{***}	0.337^{***}	0.345^{***}	0.330^{***}	0.279^{***}	0.231^{***}	1.454^{***}
	(0.098)	(0.105)	(0.089)	(0.112)	(0.087)	(0.091)	(0.086)	(0.044)	(0.465)
Share age >55 (×100)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	-0.688
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	(0.473)
Purch. power 1000 Euro/capita	0.313^{**}	0.348^{**}	0.536^{***}	0.232	0.248^{**}	0.217^{*}	0.104	0.113^{**}	-1.139^{***}
	(0.143)	(0.145)	(0.118)	(0.158)	(0.111)	(0.115)	(0.111)	(0.046)	(0.412)
Share non-Germans (×100)	0.423^{***}	0.431^{***}	0.531^{***}	0.337^{***}	0.345^{***}	0.330^{***}	0.279^{***}	0.231^{***}	1.454^{***}
	(0.098)	(0.105)	(0.089)	(0.112)	(0.087)	(0.091)	(0.086)	(0.044)	(0.465)
Share unemployed (×100)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	-0.688
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	(0.473)
Tempelhof noise (db)	0.313^{**}	0.348^{**}	0.536^{***}	0.232	0.248^{**}	0.217^{*}	0.104	0.113^{**}	-1.139^{***}
	(0.143)	(0.145)	(0.118)	(0.158)	(0.111)	(0.115)	(0.111)	(0.046)	(0.412)
Tegel noise (db)	0.423^{***}	0.431^{***}	0.531^{***}	0.337^{***}	0.345^{***}	0.330^{***}	0.279^{***}	0.231^{***}	1.454^{***}
	(0.098)	(0.105)	(0.089)	(0.112)	(0.087)	(0.091)	(0.086)	(0.044)	(0.465)
Schoenefeld noise zone (dummy)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	-0.688
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	(0.473)
Distance to Tempelhof (km)	0.313^{**}	0.348^{**}	0.536^{***}	0.232	0.248^{**}	0.217^{*}	0.104	0.113^{**}	
	(0.143)	(0.145)	(0.118)	(0.158)	(0.111)	(0.115)	(0.111)	(0.046)	
Distance to Tegel (km)	0.423^{***}	0.431^{***}	0.531^{***}	0.337^{***}	0.345^{***}	0.330^{***}	0.279^{***}	0.231^{***}	
	(0.098)	(0.105)	(0.089)	(0.112)	(0.087)	(0.091)	(0.086)	(0.044)	
Distance to Schoenefeld (km)	-0.995^{***}	-0.944^{***}	-0.877^{***}	-0.931^{***}	-0.931^{***}	-0.925^{***}	-0.777^{***}	-0.439^{***}	
	(0.130)	(0.122)	(0.118)	(0.121)	(0.119)	(0.126)	(0.121)	(0.076)	

Tab. A6 (continued)

	I	II	III	IV	V	VI	IX	X	XI
Homeownership rate (HR) (×100)	0.072***			0.066***	0.077***	0.063***	0.056***	0.058***	0.042***
	(0.013)			(0.012)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)
Price signal from 1996 announcement	-0.079			-0.153**	-0.165***	-0.149***	-0.167***	-0.154***	-0.030
(×100)	(0.060)			(0.073)	(0.033)	(0.026)	(0.026)	(0.048)	(0.025)
Signal × HR	0.004**			0.003	0.003***	0.003***	0.003***	0.003***	0.001**
	(0.002)			(0.002)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
Lambda							0.890***		
							(0.112)		
Rho								0.432***	
								(0.086)	
Surface variables	Linear	Quadratic	Cubic	Linear	Linear	Linear	Linear	Linear	Linear
Distance measure	Straight line	Straight line	Straight line	Straight line	Straight line	Road distance	Straight line	Straight line	Straight-line Third-order polynomial.
Observations	1,201	1,201	1,201	1,201	1,201	1,201	1,201	1,201	1,201
R^2	0.920	0.917	0.928			0.913	0.737	0.888	0.932
AIC	7675.3	7709.1	7562.0	7702.0	7691.0	7759.4	5394.5	6103.1	7484.1

Robust standard errors are given in parentheses and are bootstrapped within 500 iterations in (2). * p < 0.10, ** p < 0.05, *** p < 0.01. Robust standard errors are given in parentheses and are bootstrapped with 500 iterations in (2). * p < 0.10, ** p < 0.05, *** p < 0.01.

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