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Do Distributional Consequences Affect Public Goods Provision? Insights from 5G antenna placement in Switzerland*

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Abstract

Distributional implications of public goods provision may affect the ability of societies to provide these. Particularly, localized provision costs may result in opposition in the vicinity of provision sites, reducing provision levels and/or efficiency ("not-in-my-backyard" (NIMBY) challenge). We examine mass public support on policy provision in this regard, focusing on 5G, the latest technology standard for mobile data transmission, and the placement of 5G antennas in particular. Based on survey experiments with a geo-coded representative sample of over 5'000 residents of Switzerland, revealing real-world antenna locations to respondents, we find that NIMBYism plays a role for individual attitudes/policy preference formation towards 5G expansion. NIMBYism also affects the (stated) propensity to engage in political action against 5G antennas, irrespective of monetary costs. Finally, NIMBYism can be mitigated when citizens decide under a veil of ignorance on a feasible distribution of siting locations, leaving actual site choice to be a technical process.

Keywords: public goods, technology, mobile data, survey, experiment, public opinion

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1 Introduction

Public goods, by definition, are meant to provide benefits to a large share of the population, perhaps even all members of a given society. Examples include monetary stability and low inflation, low levels of crime, clean water and air, and access to communication infrastructure, such as the Internet. However, societal preferences on the production of such public goods come with various distortions that regularly prevent their efficient provision.

One such distortion derives from so called NIMBY ("not in my backyard") effects (Dear 1992). Many public goods require some sort of site placement, and such placement normally results in provision costs that also depend on geographic proximity to sites. Prominent examples include wind turbines (Stokes 2016) (where proximate people may dislike noise, shade case or scenery change or fear property value losses), public housing projects (Hankinson 2018) (where proximate citizens may worry about changes in their quality of life or real estate values), or nuclear waste disposal (Kraft and Clary 1991) (where proximate citizens may fear radiation). A large literature assumes that in these cases geographic proximity alters the cost-benefit calculus across individuals. In extreme cases, public goods can turn into private bads for proximate citizens, inducing these citizen to oppose public goods provision. As this opposition is localized at intended or actual provision sites, it is presumably concentrated on relatively small groups of highly-affected individuals. And given it is difficult to compensate affected individuals (Foster and Warren 2022), this may then lead to an undersupply of public goods for the whole population (Stokes (2016), see also Sanford (2021)).

In this paper we study two interrelated questions that arise from these presumptions concerning NIMBYism undermining public goods provision: First, how relevant are these NIMBY-effects for majority support on public good provision? This question is important, as majority decision-making and subsequent state enforcement of rules on usage and cost allocations is often the principal means for overcoming problems with public good provision, such as free-rider problems (Aklin and Mildenberger 2020; Ostrom 1990; Hamman, Weber and Woon 2011). However, counter to conventional wisdom, it is a priori not clear how relevant NIMBY attitudes are because: i) general cost-benefit perceptions may be dominating population preferences irrespective of NIMBY effects; ii) it may be those individuals who are ex-ante opposed to public goods provision anyway who then adopt NIMBY attitudes and behavior; and iii) it is unclear how NIMBY-induced preference shifts relate to changes in actual political behavior.

Second, if such NIMBY-effects are relevant, and could distort public good provision, how to address them? We focus on a procedural argument that highlights the relevance of timing for majority decision-making on public good provision. If decisions on public good provision are taken at the planning stage, when *potential*, but not *actual* siting locations are known, general attitudes towards a policy should dominate, while NIMBY considerations should be less relevant for citizens' considerations, and a societal consensus, undistorted from localized site-based opposition, should potentially be achieved more easily.

In addressing these questions, we need to deal with a major empirical challenge: NIMBY attitudes are by definition spatially clustered; at the same time, site placement for public goods provision may be endogenous to the spatial distribution of preferences in the population (Konisky 2007; Trounstine 2016).[1] Hence, the observation that ex-post the preferences of a population with respect to public goods correlate with site placement (e.g. Di Nucci and Brunnengräber (2017) for nuclear waste storage) cannot be interpreted as causal evidence for NIMBY effects without strong assumptions. While field experiments that could address this endogeneity challenge directly are, to our knowledge, non-existent for ethical and practical reasons, we improve on current quasi-experimental (Stokes 2016) or survey experimental (Hankinson 2018) research with a survey experiment that (randomly) reveals actual information about real-world siting choices for a public good, previously largely unknown to the population.

We add new insights on NIMBY challenges along these lines in the context of a technological innovation issue that has, to our knowledge, not yet been studied from this perspective: mobile data networks and the physical infrastructure required for them. In particular, we focus on the expansion of the 5G network and the new antennas required for this. This empirical setting has three advantages: first, the roll-out of the 5G network in Switzerland was undertaken quickly, and a large part of the country had coverage of 5G antennas without citizens being aware of how close they actually are to antennas. Hence, we can study this issue based on a visual and textual survey experiment in which we experimentally reveal information on actual or prospective antenna placement, exploiting geo-referenced information we have on i) respondent's household location and ii) actual (prospective) antenna locations. Second, all study participants are or could, in

[1] E.g., when preferences on public good provision are geographically clustered, but not necessarily in relation to spatial proximity to sites (Uji, Prakash and Song 2021).

principle, be located in proximity to 5G antennas. Hence, based on a large, address-based population-representative sample (N=5'035) of Swiss residents, we can study (NIMBY) attitudes for the general population. Third, because the Swiss political system provides ample opportunities for political action aimed at accelerating or slowing down 5G network expansion, and for legal appeals against specific 5G antenna projects, we can realistically examine not only NIMBY effects on policy preferences, but also (stated) support and willingness to pay for campaigns against 5G antennas. Our research design builds on an extensive pre-registration plan[2].

Concerning our first question, we find that treating respondents with information on the *de facto* location of 5G antennas in their vicinity substantially increases their knowledge and worry over such antennas. When respondents are made aware of 5G antennas in close to medium proximity, this induces stronger NIMBY attitudes and preferences, i.e. they become less supportive of local 5G expansion. Substantially, this effect is relevant for individuals who (before treatment) perceived larger benefits of 5G and expressed more support for 5G expansion. When close or medium proximity to 5G antennas is revealed to them, their approval to 5G network expansion drops strongly and turns average preferences for this group against public good provision. Results of an additional vignette experiment suggest that NIMBY effects matter for respondents' political behavior as well. (Hypothetical) proximity to 5G antennas makes respondents more willing to sign a legal appeal against 5G expansion; additionally, willingness to pay for such an appeal is higher for respondents in closer proximity to antennas.

Concerning our second question, we find that treating respondents with information on the *potential* location of 5G antennas in their vicinity is related to increased knowledge, but not worry over such antennas. Consequently, deciding under a veil of ignorance on actual antenna placement does not lead to increased NIMBY reactions by those who would potentially be close to a site.

With the research presented here, we link to current work that investigates mass public preferences towards public good provision. Recent research has highlighted that public goods provision is closely linked to public support, and that such support depends on individuals' perceived costs and benefits from the produced good – some citizens will like, some will dislike particular forms or degrees of public goods provision in general terms, as for example, is apparent in the context of support for or opposition to climate change

[2] The pre-registration is available at *blinded for peer-review*

mitigation and adaptation policy. Cost heterogeneity may result from various antecedent conditions, e.g. individual occupational interests (sector of employment) (Bechtel, Genovese and Scheve 2019) or time preferences (Milfont et al. 2012). Here, we provide evidence that cost heterogeneity that derives from siting decisions is relevant, and that it is particularly relevant for individuals expecting to benefit from the public good.

This highlights the policy relevance of our findings, as NIMBY effects may prevent efficient levels of public good provision. Switzerland has been a global front runner in 5G network expansion (inCITES 2020; DPA 2020; ITU 2020), but after an initial phase of quick roll-out, public opposition to this expansion picked up rapidly, both nationally in the form of popular initiatives calling for a moratorium on new antennas (e.g., Schutz vor Strahlung 2021*b*; 5G Moratorium 2021) and locally with hundreds of appeals against specific antenna projects (e.g., Lainez 2021; Mathis 2020). Our research indicates that such anecdotal evidence of NIMBY effects is likely a relevant part of this opposition, and points to potential advantages of ascertaining popular support *before* policy roll-out as a strategy that could have mitigated opposition.

2 Theoretical Arguments

We propose, for a start, that citizen-level support for public goods provision depends on expected personal costs, including risk perceptions, and expected personal benefits, i.e. expected usage, of this public good. Inefficiency in public good provision then can come about if citizens' decision making is based on an individual-level cost-benefit calculus that does not reflect the societal cost-benefit calculus.

Importantly, distributional consequences of provision are part of this individual-level cost-benefit calculus. Asymmetric distributional consequences can arise in particular from siting choices in public goods production. People in closer proximity to such sites are, presumably, more likely to oppose them if these sites are regarded as imposing costs on their vicinity, e.g. in terms of pollution, health and environmental risks, noise, or visual inconveniences.

Thus we first focus on assessing the extent to which NIMBYism plays a role for public goods provision – does local support for or opposition to public good provision depend on geographical proximity to (expected) production site placements? Here, we expect that with closer proximity to production sites, support for public good provision decreases.

Again, inefficiency in public good provision will result if siting costs distort the political decision process such that an otherwise beneficial public good is not provided.

However, it is worth noting that even if policy preferences concerning public goods provision are driven by perceived individual utility from provision, behavioral consequences of preferences for or against public goods provision will also depend on the costs of particular forms of behavior. We investigate whether NIMBY attitudes lead to actual behavioral consequences, even if these consequences are costly. We expect that the "appetite" for opposition (i.e. for following through on preferences) declines with increasing costs of such action, but it is worthwhile to investigate to what extent.

Given that NIMBYism or expected NIMBYism can distort both the efficiency of site choices and the efficiency of public good provision overall (Been 1992), this motivates our second research question: How to reduce such distortions?

Here, we explore decision making under a 'veil of ignorance'.[3] We investigate whether NIMBY opposition can be reduced by ensuring policy support for the feasible distribution of siting locations, leaving actual site choice to be a technical process. To this end, we investigate how individuals decide when they only get informed about potential, but not realized site locations. Then, they are fairly informed about the presence of potential local costs and where they fall into the distribution of societal costs and benefits (Rawls 1971). However, attitudes are not yet compromised by revealed actual siting costs – hence, citizens decide on the level of public goods provision while being in principle "on par". Such processes have been adopted for radioactive waste disposal, e.g. in Germany, on a large scale (Brunnengräber and Mez 2016), and are recommended for just city planning on a normative basis (Fainstein 2009). We investigate how such a siting procedure would affect citizen's preference formation compared to non-revealed (in this case, citizens should base their policy support on general attitudes only) or fully revealed sites (in this case NIMBY attitudes should play out fully). We would expect that when citizens decide ex-ante on public good provision, while being informed of relevant siting choices, the decision-making process can avoid substantial NIMBY opposition and support for public good provision is less distorted.

[3] We borrow this principle idea from Rawls (1971), while not directly developing expectations on siting choices from Rawls's 1971 theory (such as has been done e.g. based on the difference principle (Been 1992)).

3 Expected empirical implications for mass public preferenes concerning 5G expansion in Switzerland

To develop case-specific expectations, we focus on 5G expansion in Switzerland. 5G stands for 5^{th} generation technology standard for broadband cellular networks. This technology is being deployed globally in various countries since 2019. 5G wireless technology provides higher data transmission speed, lower latency, and greater network reliability and capacity. This serves conventional mobile telephones, but also other wireless data transmission purposes. 5G relies on higher-frequency radio waves than prior standards (e.g. 4G or 3G), which in turn requires smaller geographic cells and new antennas (Delb et al. 2019).

As of June 2021, 5G is operating - at least partly - in at least 65 countries globally (Viavi 2021). In 2023, it is estimated that 11% of all mobile connections will run via 5G, with North America and Western Europe at the forefront of expansion (Raconteur 2020). While the economic and social advantages of a new 5G network[4] have led to this policy adoption, 5G roll-out has been also been connected to potential risks.

In Switzerland, the debate around 5G roll-out has centered quite strongly on timing, with Switzerland being one of the first countries in the world to hand out 5G concessions (Miserez 2019). This early technology adoption led to much discussion on potential health impacts of 5G.[5] While scientific assessments of potential health risks from 5G have been largely supportive of the technology and there is insufficient evidence to conclude that 5G-exposure causes adverse health effects (Delb et al. 2019), a rather vocal political opposition has emerged. In Switzerland, opponents of 5G even launched initiatives aimed at a national referendum on 5G roll-out.[6]

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4 Furthering automation, enabling fast and seamless communication both for private communication and the Internet of Things, increasing data security due to the availability of computing and storage technology at home, flexibility of networks and the ability to create highly available network sections - so-called "network slicing" - for certain actors such as fire departments, first aid and railway companies (OECD 2019; Delb et al. 2019).

5 This health focus is different from other OECD countries in which discussion focused much more on the politics of 5G expansion: In the United Kingdom, Germany and the US for example, there has been much concern about the role of the Chinese company Huawei and its connection to the Chinese government, leading to a discussion about security vulnerabilities and fear of foreign influence (Sweney 2019; NZZ 2021).

6 There is a growing literature on risk perceptions concerning 5G, which builds on the large literature on technology risk perceptions (Slovic 1987; Siegrist 2021; Pachur, Hertwig and Steinmann 2012; Frey et al. 2021; Fischhoff et al. 1978; Cousin and Siegrist 2010). We draw on this literature, but are ultimately not interested in explaining 5G risk perceptions. Rather, we regard perceived risks and benefits of 5G as drivers of policy preferences concerning 5G roll-out.

While narrowly missing the signature requirements for a national vote under the Swiss system of direct democracy (only 92,000 of the required 100,000 Swiss citizens signed the initiative in time), residents, with significant support of civil society organizations, organized a large amount of local legal action against 5G antenna projects. At its peak, around one thousand local 5G antenna construction projects were being slowed down, or even stopped in courts, meaning that by the end of 2019, at least every third building application was hindered by an objection (e.g., Schutz vor Strahlung 2021*a*; Brupbacher 2020; Graf 2021; Gyr 2019).[7]

Public opinion regarding 5G is divided. Survey data from the Swiss Environmental Panel (Quoss et al. 2021) indicates that around one in ten citizens voices strong support or strong opposition, while about four in ten citizens are rather supportive or rather opposed to a nation-wide and/or local 5G roll-out. This distribution might explain the puzzling situation that there is, on the one hand, not enough support for a national initiative for a direct democratic vote demanding a 5G moratorium, and on the other hand a large amount of legal action against specific 5G antenna projects. This suggests that 5G might not sufficiently mobilize citizens nationally, but might lead to severe NIMBY-based opposition locally.

Overall, this country context provides a very interesting setting for our study, notably because the issue was publicly salient when we fielded the survey in mid-2020, citizens have a direct say in policy-making, but we do not know how relevant NIMBY effects are, alongside and relative to general attitudes and concerns about 5G that are also likely to affect citizens' policy preferences and behavior in this area.

3.1 Hypotheses

Hence, for our case, the first empirical implication of the theoretical discussion above relates to general perceived costs and benefits. We hypothesize:

Hypothesis 1 *Support for public good provision decreases on average with higher expected personal costs (e.g. health concerns) and increases on average with higher expected personal benefits (e.g. network usage).*

[7] However, during 2019 and early 2020, the Swiss telecommunication companies changed their strategy and implemented a more covert expansion strategy that has relied mainly on the upgrading of existing 3G/4G antennas, rather than constructing new antennas. This approach has lower administrative hurdles and fewer options for objections by citizens. This has effectively led to an expansion of 5G networks through the back door.

Given our specific setting, we also expect that NIMBY effects should have some relevance for 5G expansion in Switzerland. The large amount of local opposition to 5G antenna projects (manifesting in the form of legal objections) indicates that a relevant share of the population is against 5G, at least in their vicinity, though many individuals may not object to a 5G roll-out in general. We also investigate whether such NIMBY effects are moderated by pre-existing attitudes towards the policy, and expect that they are particularly pronounced for individuals who are *ex-ante* skeptical of this new technology (e.g. indicating health concerns).

Hence, we hypothesize:

Hypothesis 2 *If a citizen becomes aware that (s)he is in close proximity to an actual 5G antenna, (s)he is more likely to perceive site specific provision costs, which decreases her/his perceived utility from 5G expansion and leads to less support for 5G roll-out (NIMBY effect).*

Hypothesis 3 *The above mentioned NIMBY-effect should be more pronounced if individuals already perceive high personal costs from public good provision (e.g. health concerns).*

Notably, we also expect that NIMBY effects can be diminished when citizens decide ex-ante on policy provisions, i.e. when *potential*, but not *realized* sites become known.

Hypothesis 4 *If a citizen becomes aware that (s)he is in close proximity to a potential 5G antenna (i.e. a current 3/4G antenna that could be upgraded to 5G with a 20% probability), (s)he is less likely to show NIMBY preferences compared to citizens that are made aware of close proximity to actual 5G antennas.*

Last, we propose that preferences against public good provision translate into political behavior:

Hypothesis 5 *Citizens in closer proximity to 5G antennas are more likely to support legal action against antenna projects, with such support declining with increasing costs of participating in legal action.*

These empirical expectations imply that we expect geographic proximity to 5G antennas to have a negative effect on support for 5G roll-out. Empirical identification of NIMBY effects, separate from general perceptions of 5G risk and benefits, is very challenging, however, because both are intertwined. That is, observational measurement of an individual's geographic proximity to an existing or planned 5G antenna and analysis of whether such proximity relates to 5G support would not allow for any robust identification of NIMBY effects. The reason is that such an observational study design would not allow us to assess whether geographic proximity changes the risk-benefit calculus of individuals, and thus reduces support for 5G expansion, or whether prior risk and benefit perceptions relate to residency decisions, and hence proximity to antennas. As discussed in the next section of the paper, we deal with this analytical challenge via experiments in which we treat study participants with real-world information on actual or potential 5G antenna locations (which are not known to most respondents) and then study the effects this has for preferences as well as political behavior concerning 5G expansion.

4 Study Design

The subsequent Section 4.1 starts by presenting the survey in which the items were fielded, the Swiss Environmental Panel. We then continue in Section 4.2 by describing the survey items and experiments in detail, including evidence of the map treatments' effectiveness in the form of comprehension and manipulation checks.

4.1 Data

We build our study on data from the Swiss Environmental Panel. It is a panel study conceived by ETH Zurich in cooperation with the Swiss Federal Office for the Environment (FOEN) focusing on the attitudes and preferences of the Swiss resident population regarding environmental issues. Fieldwork for the Swiss Environmental Panel was conducted by ETH Zurich and the Decision Science Laboratory of the Department of Humanities, Social and Political Sciences, ETH Zurich. The survey was approved by the Ethics Commission of ETH Zurich (decision EK 2019-N-43).

The data for this paper comes from the fifth wave of this panel which focused on beliefs, attitudes and policy preferences concerning 5G mobile network expansion in Switzerland. An online questionnaire (administered with Qualtrics, invitation with three letters and two e-mails) was prepared by the authors. We invited a total of 10,866 respondents who had all taken part in at least one prior wave of the panel. 7,340 participants responded to the survey, of which 6,828 (93.02%) completed the survey. Including incomplete answers, the response rate was 67.55%. All respondents saw several standard survey items first.

Subsequently, 70% of the sample (n = 5035) were exposed to the treatment arm with the survey experiments that we focus on in this paper. Median response duration was 15.20 minutes. Due to Switzerland's multilingualism, we fielded the survey in the three major languages of the country (German, French, and Italian) as well as in English.

Respondents of the panel survey were recruited either in wave 1 or during a first panel refreshment in wave 4. Out of the 10,866 contacted respondents, 3,296 come from the original sample and 7,570 from the refreshment. The respondents were drawn from the population register of the Federal Statistical Office (BFS/SRPH) comprising Swiss residents. Sampling was conducted as a simple random sample on the level of NUTS-2 regions including an oversampling of the canton of Ticino for which we control using weights during the analyses. The BFS sample mirrors, besides random error and uneven response rates, the Swiss resident population. As discussed in Rudolph, Quoß and Bernauer (2020), there is no evidence that take-up of the survey is particularly biased on socio-demographic respondent and population characteristics. As the sample is based on a random draw of the resident population, we do not have to worry about the oftentimes discussed match of online-access quota-samples to the general population (Cornesse et al. 2020; Baker et al. 2013). We hence conduct our experiment with a high-quality address-based representative sample of the Swiss population, and are confident that our survey speaks to the preference formation of Swiss citizens at large.

Data will be made available to the scientific public via `https://dx.doi.org/10.23662/FORS-DS-1220-1`. The preregistration for this project can be accessed at *blinded for peer-review* Upon publication, replication code to reproduce the analyses presented in this study will be published via Harvard Dataverse.

4.2 Survey design

Wave 5 of the SEP, which we draw on here, includes standard survey items as well as a visual vignette treatment in the form of maps that depict the antennas close to respondents' homes and two text-based vignettes.

The survey flow in the experimental part was as follows:

First was the visual vignette experiment that is at the center of this study. There, a third of respondents was randomly assigned to a control group receiving a placebo statement. Another third was randomly assigned to the display of the "5G-treatment", i.e., an explanation and display of existing 5G mobile antennas in the respondents' vicinity.

A last third was randomly assigned to the display of the "3/4G-treatment", i.e., an explanation and display of existing 3/4G mobile antennas in the respondents' vicinity.

Second, respondents answered several questions on their awareness and perception of mobile antennas in their vicinity, before we elicited respondents preferences towards the rollout of 5G in their municipality. The former questions serve as comprehension and manipulation check, and the latter as one of our central dependent variables.

Third, respondents saw a vignette that presented a hypothetical scenario of a local construction project of an antenna. We present them with different distances of the antenna, varying costs of signing an appeal, and ask how likely they would be to support an appeal against this antenna.

Figure 1 gives an overview of the survey flow. In the following, we present the detailed design of the two survey experiments in the order in which we present the results. The full wording of the items can be found in Appendix Section A.1.

4.2.1 Mobile antenna placement - visual vignette experiment on existing real-world antennas

This survey experimental component, which serves as our main treatment, builds on real locations of existing 3G/4G- and 5G antennas. As we have an address-based sample of Swiss residents, we were able to show them the direct vicinity of their home location and revealed real, existing antennas in their direct neighborhood. We hence go beyond the hypothetical scenarios most survey-experimental work relies on. This set-up increases the external validity of our experiment while also allowing for causal inference.

For the visual treatment, we randomly split the sample into three groups of similar size which only received a placebo text (control group) or saw existing 3G and 4G or existing 5G antennas respectively. Figure 2 shows two examples of treatments from the latter two treatment groups. The 3G/4G treatment group was shown an explanatory text where we highlighted that in 20% of cases, existing 3G/4G masts will be upgraded to 5G antennas. Respondents could therefore develop expectations how likely 5G-masts will be in their vicinity based on the existing number of 3G/4G masts. We thereby capture policy preferences in a scenario where respondents are informed about the likelihood that they will incur local costs through the 5G roll-out. For the 5G treatment, we emphasized that the existing 5G masts that they see will be equipped with high transmitting power and are part of the core of the Swiss 5G network if roll-out continues. We thereby directly

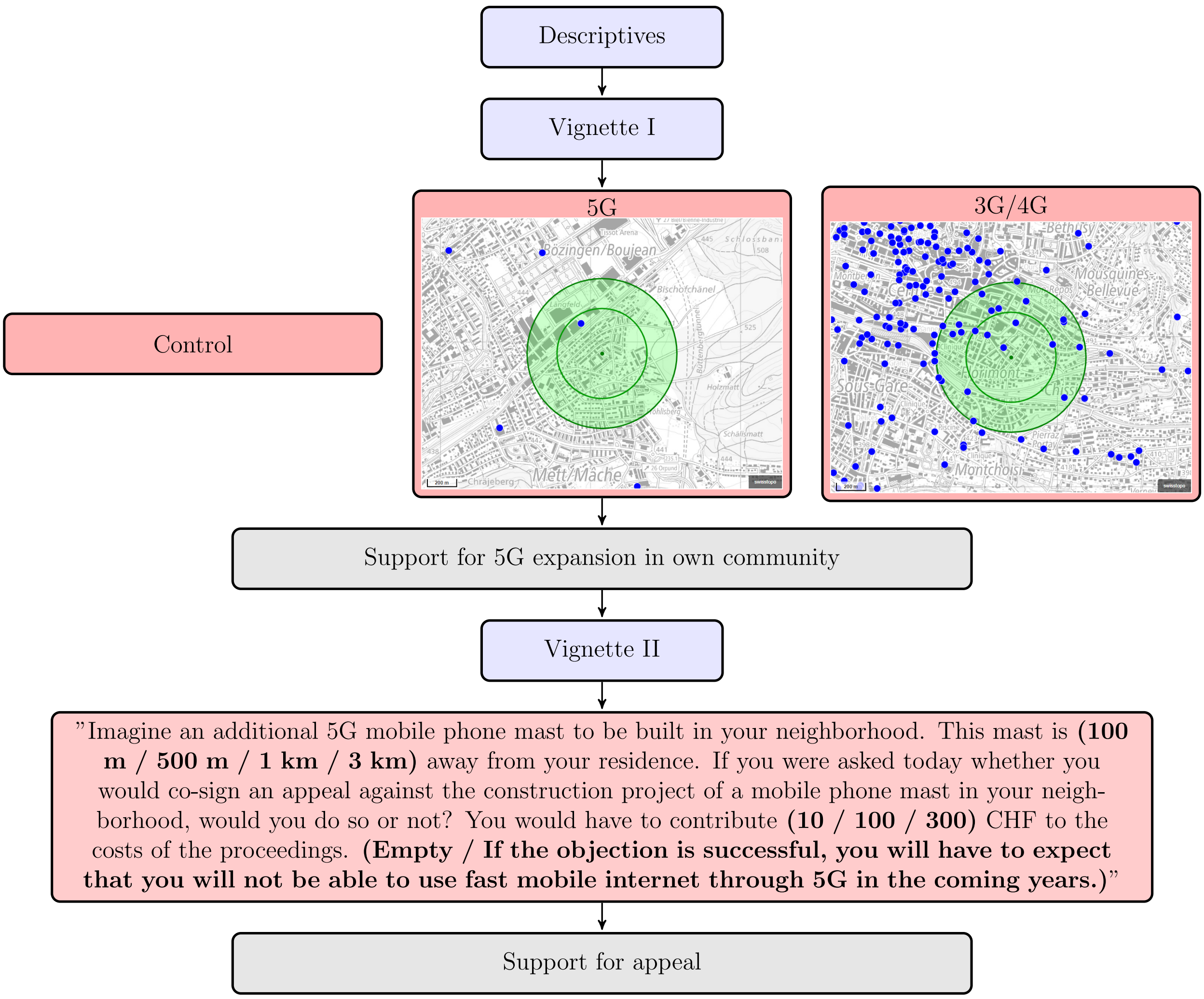

Figure 1: Overview of surveyflow (blue = survey block, red = survey experiment, grey = dependent variable)

reveal the local costs of 5G network expansion to respondents in this treatment group.

Figure A.1 in the appendix shows how many antennas were shown to respondents in the two different treatment groups and for three different distances (within the 300m and 500m circles drawn around their home and on the complete map visible to them). Overall, the number of 3G/4G antennas is much larger than the number of 5G antennas. For the inner circle of 300m, 58% of respondents actually did not see a single 3/4G antenna and 84% did not see a 5G antenna. Looking at the whole map, this percentage is much lower: only 10% of respondents saw no 3G/4G antenna and 33% of respondents did not see a 5G antenna. At the same time, respondents saw up to 204 3G/4G and up to 17 5G antennas on their map.

((a)) 3G/4G treatment **((b))** 5G treatment

Figure 2: Examples of visual vignette treatments

To control whether and to what extent our vignette treatment had an effect on respondents' attitudes towards mobile antennas, we first fielded two items that served as comprehension checks and asked respondents whether they knew the exact location of the mast closest to them and to estimate the distance of the closest antenna to their home.

Then, we followed up with two items that serve as manipulation check to investigate whether the experimental vignettes affected whether respondents perceive the number and distance of antennas in their neighborhood as reasonable or too low/too close or too high/too far.

Appendix Section A.3.1 and Appendix Section A.3.2 report on the results of the comprehension and manipulation checks. Overall, we can show that respondents both comprehended the treatment – with the visual treatment, they correctly and substantially increase their knowledge of how close mobile antennas are placed to their home compared to the control group. Additionally, we can show that the 5G treatment (but not the 3/4G treatment) substantially increases their worry over the proximity of 5G masts to their home – this is even more the case when antennas are actually proximate or if many antennas are shown on the map.

Subsequently, we fielded an item on preferences towards 5G network expansion in respondents' municipality. We expect that compared to the control group, the display of a mobile antenna map increases knowledge over antenna placement on the one hand, and worry over the proximity and amount of mobile antennas in the vicinity on the other hand (and even more so for the display of a 5G map in the latter case). These manipulations should lead respondents to policy preferences that disfavor the 5G rollout in their municipality.

4.2.2 Willingness to sign objection - hypothetical vignette experiment

Lastly, we fielded a survey vignette that presented respondents with the hypothetical scenario of a new 5G mobile phone mast being built in their neighborhood. Depending on the treatment group, the mast in the scenario is 100m, 500m, 1km, or 3km from the respondent's residence. The vignette further varied whether respondents would have to contribute 10, 100, or 300CHF to the costs of the proceedings and whether a successful objection would lead to lacking fast mobile Internet in the coming years. We then asked whether respondents were willing to co-sign an objection against the construction project of a mobile phone mast in their neighborhood. This objection is a local measure to prevent a building application that can delay or prevent construction projects and is regularly used by 5G opponents to voice opposition against antenna projects in Switzerland.

We field this experiment to find out to what extent NIMBYism matters for political mobilization against 5G.

4.2.3 Covariates of 5G-Support

We create a measure of costs versus benefits faced by respondents due to 5G. This measure is based on a principal component analysis with five survey items capturing respondents' extent to which they feel burdened by electromagnetic radiation, whether they identify as electrosensitive, and whether they regularly use a smartphone, a tablet, or streaming services (e.g. Spotify or Netflix). Based on the ordinal nature of the underlying five variables, we run the polychoric PCA proposed by Kolenikov and Angeles (2004). The first dimension explains around 40% of the variance, while the second dimension explains another 24% of variance. The cost-benefit variable derived from the PCA helps us to capture whether respondents are more likely to face relatively higher overall benefits or costs due to 5G expansion.

4.3 Estimation strategy

Before running the analyses, we add survey weights based on the seven big regions of Switzerland to control for the oversampling of the region of Ticino in the contact sample. We further exclude respondents if they do not match with the person we actually wanted to contact, namely if someone else from the household answered. Based on the official year of birth and gender known to us from the original sample provided by the Federal Statistical Office, we exclude a total of 96 respondents from the raw data.

As we have a relatively large sample and full control over the randomization, we do not expect that imbalance across the different treatment groups creates a risk risk of biased estimates. As Appendix Table A.1 shows, balance is indeed given for a wide range of socio-demographic variables.

All analyses use both the first and the second dimension of the above mentioned PCA as control variables. This stratification increases the efficiency of our analyses (Mutz 2011), as general costs and benefits explain most variation in our dependent variable. For the analyses focusing on covariates of 5G-support, we conduct a median split of the first dimension of the PCA results and use the resulting dummy variable as an indicator of respondents who are in the half of the population with comparably higher or lower benefits associated with 5G.

5 Results

5.1 Perceived costs and benefits and respondents' attitudes towards 5G

We first give an overview of the overall sentiment of respondents towards 5G in Switzerland. Asked about their support for rapid 5G expansion in their own community, one of our key dependent variables, we see that respondents in the control group are split on the issue. While 32% answer with one of the three lowest categories, 32% answer with one of the three highest categories of support. The remaining 36% chose one of the two categories in the middle. This shows that the Swiss resident population is fairly divided on the issue. This distribution varies markedly by overall utility: as Figure 3 illustrates, respondents who are in the upper half of perceived benefits (orange) show much more support for local 5G expansion than respondents in the lower half (blue).

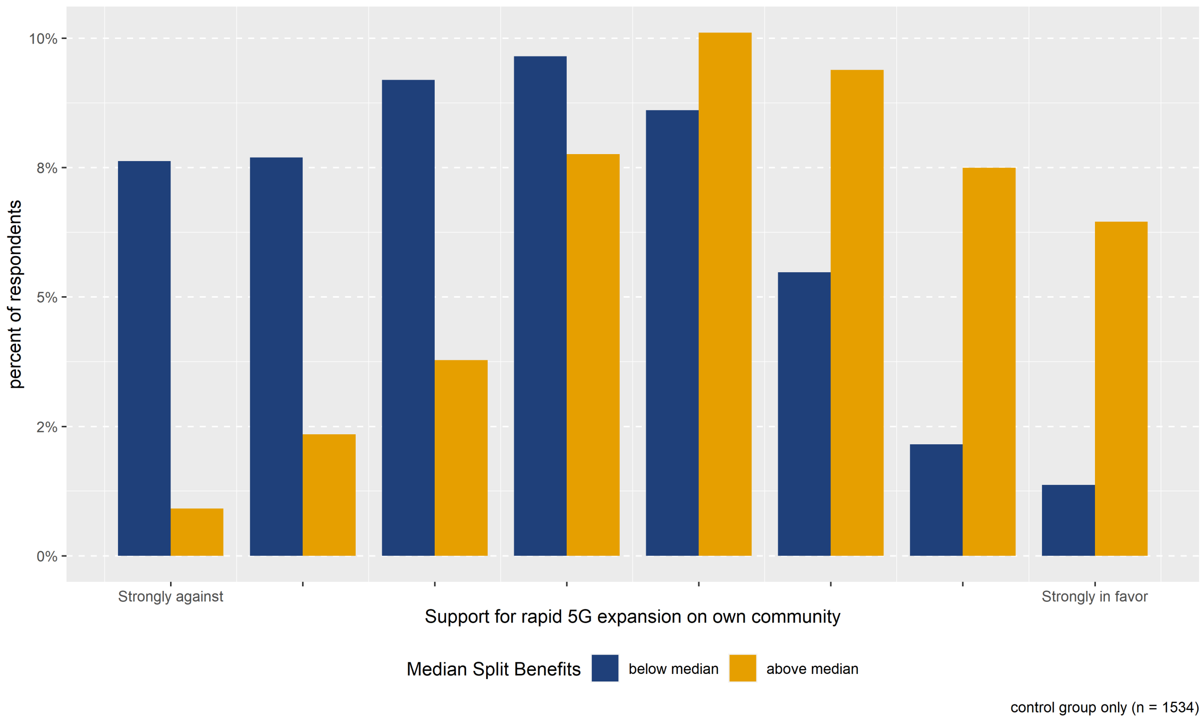

Figure 3: Distribution of support for 5G provision (8-point scale) by whether respondent scores above-median or below-median benefits from 5G expansion (median split based on first factor of PCA on device and streaming service usage, perceived electrosensivity and perceived radiation burden).

As can be seen from Table 1, an increase in perceived costs significantly and substantially relates to increased worry over antenna proximity, and decreased preferences for 5G roll-out in respondents' own municipality (and vice versa for perceived benefits). This is in line with what we expected in H1[8].

[8] Full results including the treatment variables can be found in Appendix tables A.4 and A.5.

	(1) Antennas too far (1)/close (5)	(2) Antennas (much) too close (0-1)	(3) Approve 5G exp. in mun. (0-7)	(4) Approve 5G exp. in mun. (0-1)
Benefits of 5G expansion (PCA)	-0.233***	-0.146***	0.945***	0.195***
	(0.0177)	(0.0104)	(0.0442)	(0.0107)
Costs of 5G expansion (PCA)	0.179***	0.122***	-0.427***	-0.0945***
	(0.0206)	(0.0118)	(0.0507)	(0.0136)
Constant	3.292***	0.276***	3.480***	0.507***
	(0.0162)	(0.0103)	(0.0429)	(0.0115)
N	1534	1534	1534	1534
r2	0.204	0.209	0.306	0.212

Table 1: Relationship between expected benefits and costs of 5G expansion to respondents and their evaluation of distance of the closest antenna (5-point and dichotomous scale) and approval of 5G expansion in own municipality (5-point and dichotomous scale). Control group only.

5.2 Mobile antenna placement - Visual vignette experiment

5.2.1 5G support and distance to mobile antennas

Next, we turn to whether revealing the proximity of existing 5G antennas in the vicinity changes respondents' preferences on whether 5G technology should be rolled out in their municipality.

As can be seen from Appendix Table A.5, models 1 and 4, the 5G treatment significantly (on the 5%-level) reduces the probability that a respondent agrees to a local 5G rollout (by 0.16 scale points on an 8-point scale, or by 3.4 percentage points on a binarized yes/no scale). The population is almost perfectly divided on the issue, as control group approval is at 50.9% for the binary outcome measure.

It is also indicative for NIMBY-effects that approval varies by revealed distance to the antennas, as can be seen from the left panel of Figure 4: Respondents who are very proximate to antennas reduce their approval by 0.24 scale points (p=0.103), those at medium distance by 0.24 scale points (p=0.077), those up to 1000 meters away by 0.15 scale points (p=0.15) and those with empty maps by 0.09 scale points (p=0.38). Hence, the 5G treatment lowers support for local 5G expansion for respondents from all distances, but particularly so for respondents at close distance. Effects are substantially relevant with a quarter of a scale point for proximate respondents. Particularly, note that proximate citizens decrease average support below the midpoint of the scale (3.5), hence, they turn from on average in favor to on average opposed to 5G expansion. While effects are only

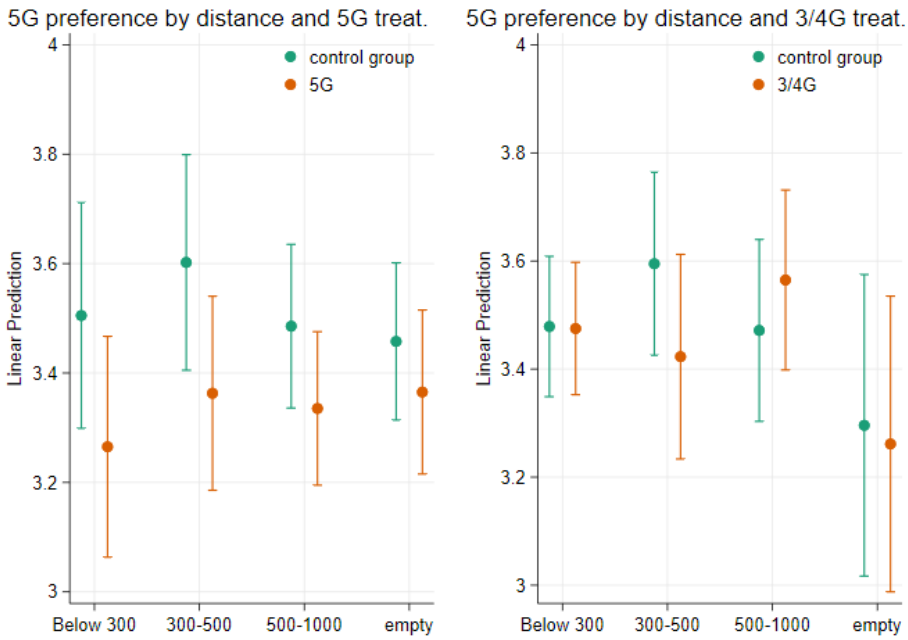

Figure 4: Predictions for models 2 (N=3136) and 3 (N=3141) of Table A.5 using an 8-point measurement (0-7) of 5G preference as dependent variable. 95% confidence intervals shown.

significant at the 10%-level, sample sizes are small for the subgroups of citizens proximate to 5G antennas (around 250 respondents in treatment and control group). Overall, we hence interpret this as an indication of NIMBY-effects for the 5G treatment in line with Hypothesis H2.

5.2.2 Cost-benefit perceptions of 5G-roll-out as moderators

We next investigate whether NIMBY effects are particularly strong for respondents who are ex-ante positively vs. negatively inclined towards 5G expansion. As can be seen in the left panel of Figure 5, baseline preferences for 5G expansion differ starkly by whether respondents have ex-ante above- or below-median benefits from 5G expansion. While the former are on average above 4 on the 8-point preference scale, the latter are on average substantially below 3, and hence much less in favor of the policy. However, when antennas are revealed, the preferences of respondents with below-median benefits remain rather stable. However, respondents with above-median benefits are susceptible to strong

NIMBY effects: With close or medium proximity to antennas and the revelation of 5G-antennas, their approval ratings are starkly lower than the control group's (by 0.44, so almost half a scale point, with p=0.031).[9] With far distance, ratings still drop by 0.25 scale points (p=0.087), and with empty maps displayed policy preferences are even more in favor of 5G-expansion (by 0.25 scale points, p=0.24). Contrary to our expectations in H3, it is the respondents with high expected benefits from 5G expansion who show stronger NIMBY effects while the respondents with below-median benefits do not show any NIMBY effects.

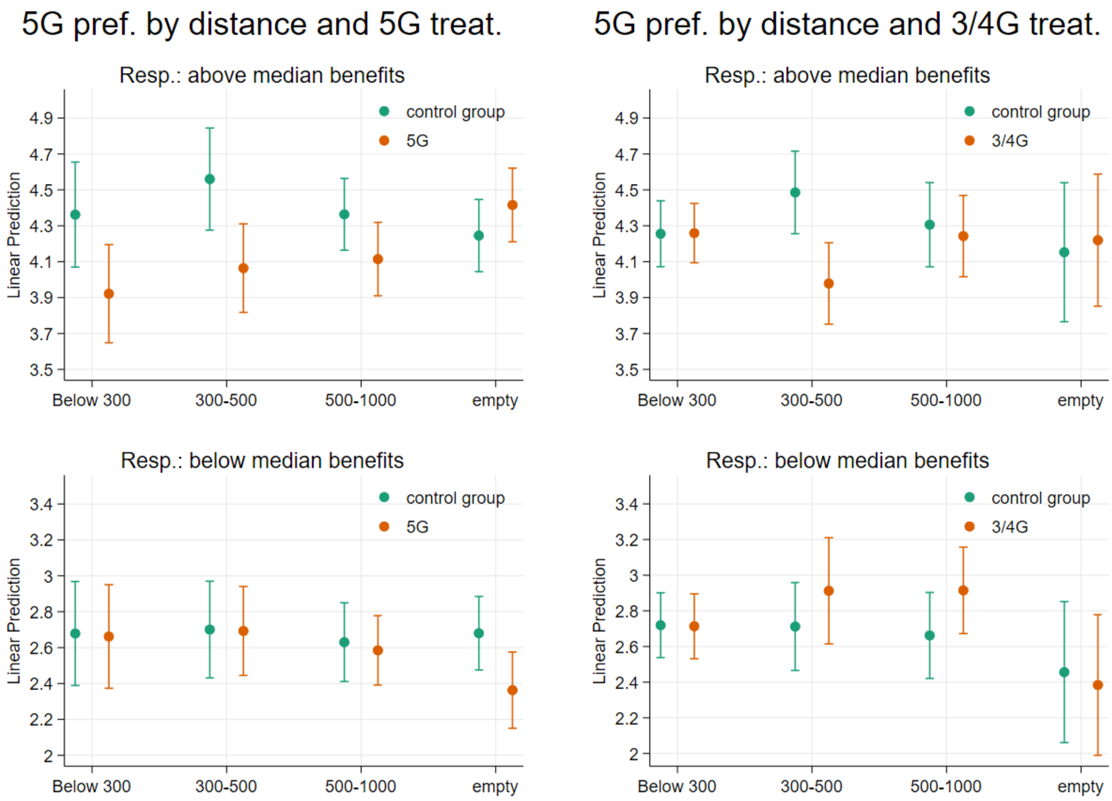

Figure 5: Predictions as in models 2 and 3 of Table A.5, estimated for subgroups of respondents with above/below-median benefits from 5G expansion. 95% confidence intervals shown.

9 The stark heterogeneity in the display of NIMBY effects by whether respondents have above- or below-median benefits also contributes to the large standard errors observed in Figure 4.

5.2.3 Effects of potential (current 3G/4G antennas) versus actual 5G antenna sites

In the next step, we are interested in whether these effects depend on antennas being potential or existing (real) 5G antennas. Appendix Table A.5 models 1 and 4 show that the 3G/4G treatment has only a very marginal and statistically non-significant effect on respondents' agreement to local 5G rollout (effect of -0.02 scale points on an 8-point scale, or by -0.00 percentage points on a binarized yes/no scale).

The right panel in Figure 4 shows the effect of different distances to the next 3G/4G antenna on support for local 5G expansion on an 8-point scale. Compared with the treatment effect for the 5G group, we again find weaker NIMBY effects for the 3G/4G antennas: When existing antennas are revealed in close to medium proximity, respondents become aware of negative personal costs of 5G-network expansion, but the treatment effect is smaller than for the 5G treatment. Respondents at medium distance react most strongly to revealed antenna placement, though not significantly so (p=0.183).

When looking in more detail at the two groups of respondents with either below- or above-median benefits from 5G, the same pattern emerges (Figure 5, right panel): again we find that it is respondents with above-median benefits who react more strongly to the treatment, but the treatment effect is much weaker with the 3G/4G treatment compared to the 5G treatment. For some of the subgroups and distances, we even find a marginally positive treatment effect. These results are in line with our Hypothesis H4.

If citizens show lower NIMBY effects when faced with potential sites in contrast to already implemented sites, this kind of decision under a veil of ignorance could be a promising strategy for public goods distribution.

5.3 Willingness to appeal antenna construction projects - Vignette experiment

In a last step, we examine whether citizens are also willing to take individual action in the form of objections against this new technology. To this end, we fielded a vignette experiment on hypothetical antenna placement – the experimental vignettes asked respondents whether they would agree to sign an objection against a new mobile antenna in their municipality. As reported in Figure 6, without additional information, around 39% of respondents would agree to such an objection. Notably, when the experimental vignette

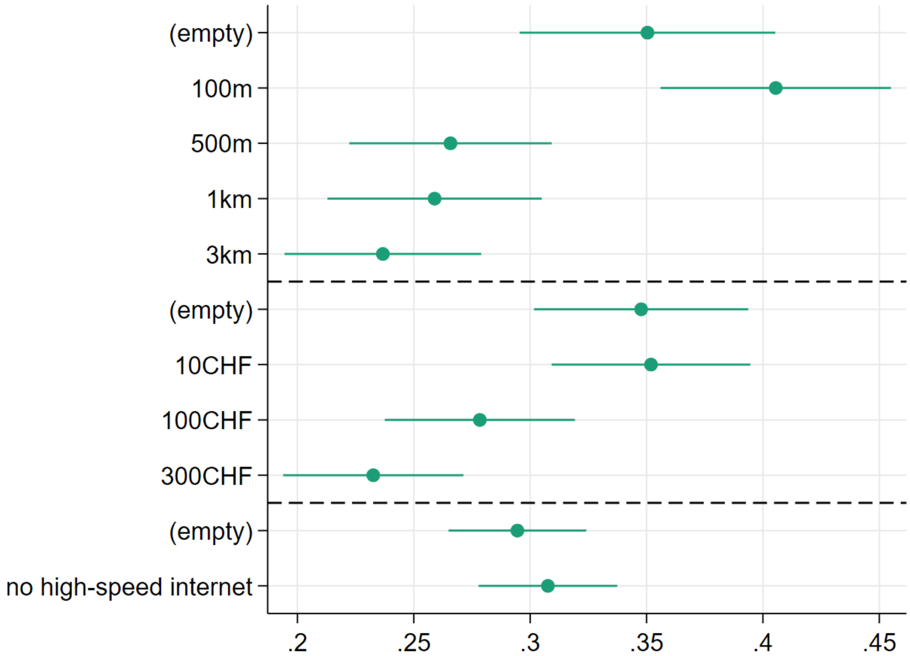

Figure 6: Effects of vignette varying distance to antenna and compensation as well as information on consequences for fast internet on probability that a respondents agrees to sign a petition against a new mobile antenna mast (marginal means for full sample). 95% confidence intervals from robust standard errors shown. Linear regression with control for cost/benefit PCA. Estimates for map treatment control group.

conveys a distance of up to 100 meters for the new antenna, the objection probability increases by around 6 percentage points (p=0.14), and when it communicates a distance of 500 meters or above, it decreases substantially (by up to 11 percentage points with a 3km distance, p=0.001. Also, monetary costs for the objection decrease the objection likelihood remarkably (by up to 12 percentage points with 300 CHF, p=0.000). A communication of potential non-monetary negative side-effects ("no fast internet") has no effect on responses.[10]

Notably, we can also test whether willingness to pay for an appeal differs by distance of antennas. Figure 7 indicates that willingness to appeal decreases with the communicated cost of appealing, but not for the experimental group that has an antenna in immediate proximity (100m) to their home. This indicates that while respondents are cost-sensitive,

[10] These effects are reported for the map control group. The experimental vignettes on actual mast placement do not affect responses significantly – see Appendix Figure A.6.

concern over antennas overrides this cost-sensitivity with close proximity. Note that the effect of costs is substantial at higher or no communicated distance: At higher distances, predicted objection rates half from around 40 percent (with costs of 10 CHF) to around 20 percent (with costs of 300 CHF).

In line with Hypothesis H5, we conclude that NIMBY effects are a relevant feature of citizens' policy positions on 5G expansion at the local level. Citizens perceive distance to new antennas as an important feature of their utility. This utility decreases (increases) with proximate (distant) antennas – the turning point of how distance affects utility is in-between 100 and 500 meters. At close distance, citizens also seem to be highly willing to take action against antenna projects, accepting costs that many citizens are unwilling to take at higher distances.

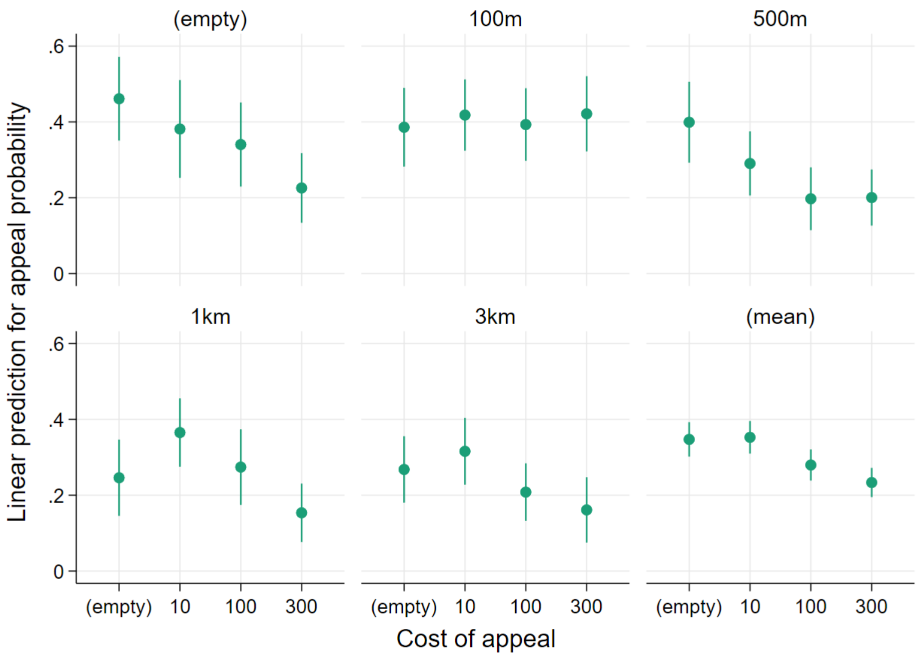

Figure 7: Predicted probabilities of cost attribute on respondent indicating appeal for the different levels of communicated distance of antenna projects. 95% confidence intervals from robust standard errors shown. Linear regression with control for cost/benefit PCA. Estimates for map treatment control group.

6 Conclusion

5G network expansion is politically contested in Switzerland and elsewhere. When our survey was fielded in mid-2020, 40 to 50% of construction projects were contested locally, leading to a near-halt of network development in some parts of the country (Heule 2020) – even though mobile internet capacities are at times at their limits (SWI 2020) due to high demand by the vast majority of the population.

In this paper, we investigate this seeming mismatch between high demand for mobile internet capacity and high levels of contestation of 5G expansion. We propose that NIMBYism of residents who feel that they face localized negative consequences of 5G antennas can explain opposition; and we provide evidence for a procedural argument to reduce this opposition – decision-making of citizens under a 'veil of ignorance' (Rawls 1971).

Using geo-coded information of survey respondents' household location, and real-world 5G network antenna locations, where almost every citizen is at a realistic risk of local exposure, we can experimentally manipulate citizens' knowledge of antenna locations in their neighborhood. We show that citizens proximate to antennas increase their worry over the 5G network and increase their opposition to 5G network expansion when exposed to information on antenna locations. This is particularly the case for individuals who ex-ante expect to benefit from this expansion. We also show that citizens more proximate to antennas exhibit a higher willingness to support judicial appeals against antenna projects – and while willingness to pay for such an appeal decreases (as expected) with higher distance to an antenna, it is invariant to costs at close proximity.

Given that our survey indicates that public opinion on 5G roll-out is divided in Switzerland, with around equal shares of respondents favoring and opposing this roll-out, respectively, NIMBYism is potentially consequential. In a second step, we therefore investigate whether decision making before antenna locations are known would affect support levels – a mode of decision making recommended for just site choices on a normative basis (Fainstein 2009). To this end, we communicate to citizens the potential spatial distribution of antennas (i.e. their probability of being affected) but not their actual affectedness (i.e. citizens remain under a veil of ignorance). Our results indicate that such a procedure would help to avoid NIMBYism when deciding about policy roll-out.

Our research also speaks to two broad types of policy questions: How to ensure public support for public goods provision with localized siting costs, e.g. in areas such as waste storage, green energy production, infrastructure construction, or low-income housing.

Moreover, it links to concerns about and public opposition to new technology associated with perceived or real uncertainty about risks. Future research could take our study design as a template to inform respondents about their local exposure to such new technology to study its perception, notably with a view to how we combine survey experimental evidence with high ecological validity (as our survey experiment reveals real-world information) and high generalizability (as we draw upon a population representative sample where every citizens has a positive probability of being exposed to the private bads — hence, we can meaningfully report on average citizen preferences).

Theoretically, our findings contribute to a large literature in political economy and related fields that seeks to account for whether and when public goods are provided. A large research stream focuses on the conditions under which social groups can resolve collective action problems associated with the production of public goods[11]. This literature predominantly focuses on how free-rider problems can be overcome, e.g. by majority decision-making and subsequent state enforcement of rules on usage and cost allocations (Aklin and Mildenberger 2020; Ostrom 1990). What is less often noted in this literature is that the formation of a majority decision, i.e. of citizen's aggregate preferences on public goods, can also be affected by distortions and inefficiencies. These are much less understood than free-riding problems, but similarly relevant as our paper shows. While other research in this field is based on hypothetical survey experiments (Hankinson 2018) or aggregate-level voting behavior (Stokes 2016), we focus on individual-level perceptions and preferences, including (stated) behavioral outcomes when citizens are asked to trade-off voicing opposition with monetary costs – revealing relevant NIMBY attitudes.

Moreover, we contribute to recent research investigating how non-material interests shape the preferences of individuals on public goods provision. Recent research has focused on other-regarding concerns/preferences (Rudolph, Kolcava and Bernauer 2022; Rudolph et al. 2022; Bechtel, Genovese and Scheve 2019). Our paper indicates that perceived costs can have important non-material elements as well, in our case perceptions of health risks (in addition to material costs (Rho and Tomz 2017)). Future research could study how these components of citizens' utility function are interrelated – our research indicates that NIMBY attitudes are particularly relevant for citizens who ex-ante expect to benefit from public goods provision. Why this is the case, and why this is not the case with *potential* as opposed to *actual* costs remains to be studied in greater depth.

[11] See e.g. the works of Olson (1989, 1965); Marwell and Oliver (1993); Melucci (1996); Gamson (1992); Ostrom (2010); Hardin (1982); Sandler (1992, 2004)

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Online Appendix for 'Do Distributional Consequences Affect Public Goods Provision? Insights from 5G antenna placement in Switzerland'

A.1 Wording of survey questions

Vignette I

Control Group

The mobile operators are currently considering where and how they can upgrade 3G/4G mobile networks from today's 3G/4G networks to 5G mobile networks. These considerations include the question of how many and what types of masts would have to be built.

There are also frequent media reports on the question of whether a 5G network should be available for which purposes. If so, a second question is where and how this should be expanded, and whether there should be new mast sites.

Treatment Group 3G/4G

The mobile operators are currently considering where and how they can expand their 5G networks. In an area of 300 m around your house/flat there is/are (XXX) "old" 3G/4G mobile phone mast(s). Within a range of 500 m around your house/flat there is/are (XXX) "old" 3G/4G mobile phone mast(s). The closest 3G/4G mobile phone mast is (XXX) m from your house/flat.

You will now see a map showing your residence and the 3G/4G mobile phone masts in the area. (Map inserted here)

One consideration is that some of the 3G/4G mobile phone masts you have seen on the map are being upgraded to the 5G standard and will be equipped with high transmitting power. Across Switzerland, about every fifth 3G/4G mast is to be converted to 5G. These upgraded masts form the core of the 5G network in your community. Additional mast sites are then not necessary in your community for the time being.

Treatment Group 5G

The mobile operators are currently considering where and how they can expand their

5G networks. There is/are (XXX) 5G mobile phone masts in an area of 300 m around your house/flat. There is/are (XXX) 5G mobile phone mast(s) within 500 m of your house/flat. The closest 5G mobile phone mast is (XXX) m from your house/flat.

You will now see a map that shows your residence and the 5G mobile phone masts in the area. (Map inserted here)

One consideration is that the 5G mobile phone masts that you have seen on the map will be equipped with high transmitting power. These form the core of the 5G network in your community. Additional mobile phone masts are then not necessary in your community for the time being.

Comprehension checks for all Treatment Groups

The exact location of the closest (empty / 3G/4G / 5G) mobile phone mast to my house/flat is...

Response options: not known to me, approximately known to me, known to me

What do you estimate? The closest (empty / 3G/4G / 5G) mobile phone mast from my house/flat is...

Response options: less than 100 m away, 100 - 300 m away, 300 - 500 m away, 500m - 1 km away, more than 1 km away

Manipulation checks for all Treatment Groups

In my opinion, the distance of the closest mobile phone mast to my house/flat is...

Response options: way too close, too close, just the right amount of distance, too far, way too far

In my opinion, the number of mobile phone masts in my area is...

Response options: way too high, too high, just right, too low, far too little

Support for 5G expansion in own community

To what extent are you (in favor of / against) a rapid 5G expansion in your community?

Response options: 0 (strongly against) - 7 (strongly in favor)

Vignette II

Treatment text

Imagine an additional 5G mobile phone mast to be built in your neighborhood. (This mast is (100 m / 500 m / 1 km / 3 km) away from your residence).

Support for appeal

If you were asked today whether you would co-sign an appeal against the construction project of a mobile phone mast in your neighborhood, would you do so or not? (You would have to contribute (10 / 100 / 300) CHF to the costs of the proceedings) (Empty / If the objection is successful, you will have to expect that you will not be able to use fast mobile internet through 5G in the coming years).

Response options: Yes, I would sign, No, I would not sign, Do not know if I would sign, Have no opinion on this.

Covariates of 5G support

To what extent do you feel burdened or not burdened by electromagnetic radiation from mobile phones, tablets and computers in your place of residence?
Response options: Not burdened at all, lightly burdened, medium burdened, strongly burdened, very strongly burdened

Would you describe yourself as electro-sensitive? This means that you feel that your health or well-being is impaired, and you attribute this to electromagnetic fields.
Response options: yes, not sure, no.

Which of the following technologies do you use regularly?
Response options: I do use ... regularly, I do not use ... regularly
items: Smartphone, Tablet, Streaming services (e.g. Spotify, Netflix)

A.2 Descriptives and experimental balance

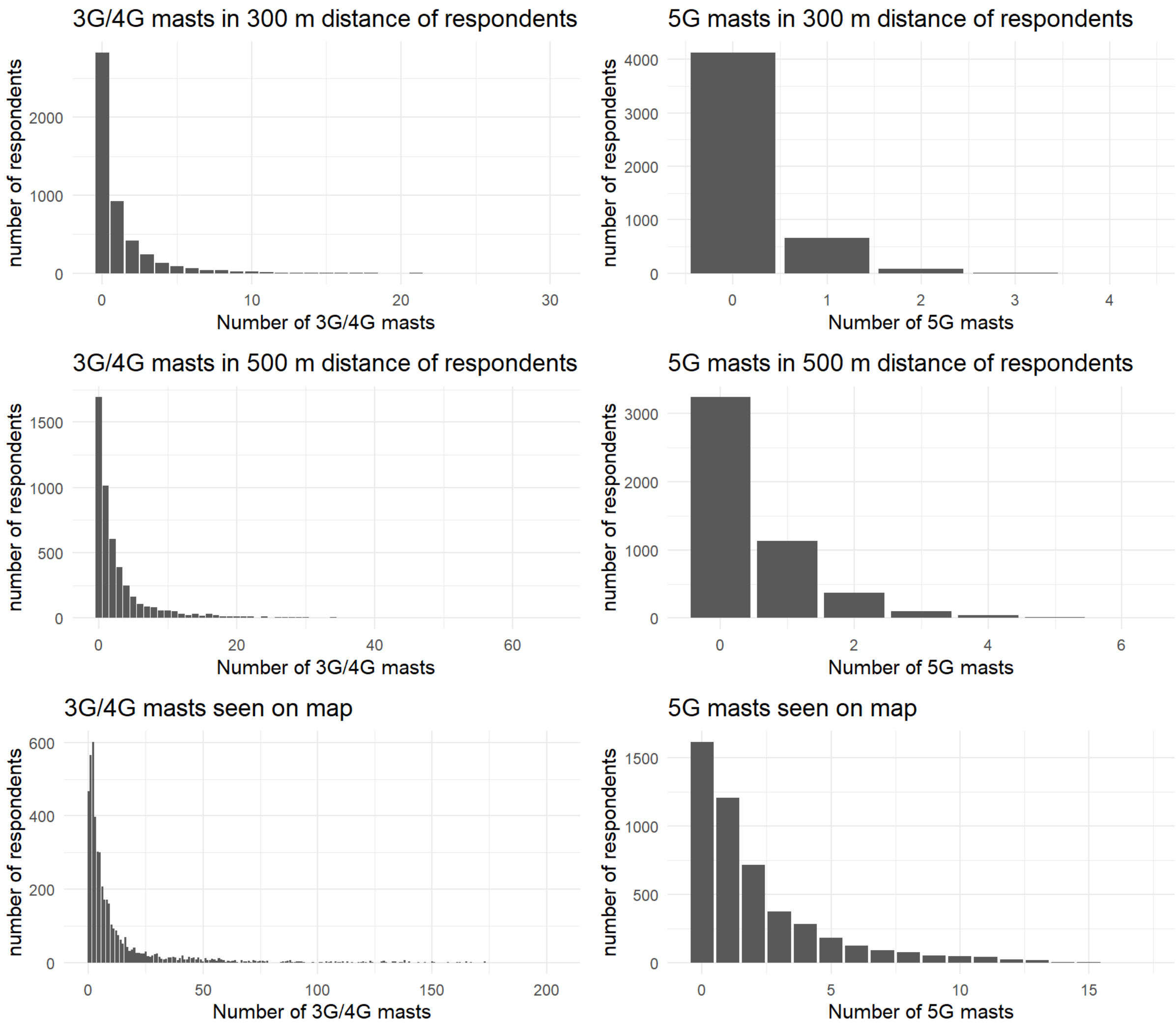

Figure A.1: Overview of number of antennas shown to respondents in visual vignette treatment

	(1)					(2)				
	C/mean	T/mean	Diff-In-Means/se	N C	N T	C/mean	T/mean	Diff-In-Means/se	N C	N T
Benefits of 5G expansion (PCA)	0.00	0.03	-0.03	1534	1602	0.00	-0.00	0.01	1534	1607
			(0.03)					(0.03)		
Costs of 5G expansion (PCA)	-0.04	-0.03	-0.01	1534	1602	-0.04	-0.03	-0.01	1534	1607
			(0.03)					(0.03)		
treat2_300m	1.23	1.16	0.07	1553	1619	1.23	1.19	0.04	1553	1622
			(0.09)					(0.09)		
treat1_300m	0.18	0.17	0.02	1553	1619	0.18	0.19	-0.00	1553	1622
			(0.02)					(0.02)		
treat2_500m	3.28	3.16	0.12	1553	1619	3.28	3.19	0.09	1553	1622
			(0.21)					(0.21)		
treat1_500m	0.49	0.50	-0.00	1553	1619	0.49	0.49	0.00	1553	1622
			(0.03)					(0.03)		
closest_antenna_treat2	489.86	480.55	9.31	1553	1619	489.86	495.76	-5.90	1553	1622
			(15.91)					(16.45)		
closest_antenna_treat1	1131.65	1109.29	22.36	1553	1619	1131.65	1160.24	-28.59	1553	1622
			(41.83)					(42.75)		
treat2_rect	13.95	14.43	-0.47	1553	1619	13.95	14.39	-0.44	1553	1622
			(0.92)					(0.94)		
treat1_rect	2.05	2.11	-0.05	1553	1619	2.05	2.08	-0.02	1553	1622
			(0.10)					(0.10)		
RECODE of srph_gender	0.53	0.51	0.02	1553	1619	0.53	0.51	0.01	1553	1622
			(0.02)					(0.02)		
srph_rpermit	33.17	33.24	-0.08	1553	1619	33.17	32.55	0.62	1553	1622
			(3.32)					(3.31)		
srph_hsize	2.76	2.73	0.03	1553	1619	2.76	2.70	0.06	1553	1622
			(0.05)					(0.05)		
srph_nationality_Swiss	0.87	0.87	0.00	1553	1619	0.87	0.88	-0.00	1553	1622
			(0.01)					(0.01)		
srph_marital_3cat== 1.0000	0.29	0.30	-0.02	1553	1619	0.29	0.30	-0.02	1553	1622
			(0.02)					(0.02)		
srph_marital_3cat== 2.0000	0.59	0.58	0.01	1553	1619	0.59	0.58	0.01	1553	1622
			(0.02)					(0.02)		
srph_marital_3cat== 3.0000	0.12	0.11	0.01	1553	1619	0.12	0.11	0.01	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 1.0000	0.16	0.14	0.01	1553	1619	0.16	0.15	0.01	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 2.0000	0.20	0.22	-0.02	1553	1619	0.20	0.22	-0.02*	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 3.0000	0.14	0.14	-0.00	1553	1619	0.14	0.14	-0.00	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 4.0000	0.16	0.19	-0.02*	1553	1619	0.16	0.16	-0.00	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 5.0000	0.15	0.12	0.03**	1553	1619	0.15	0.14	0.00	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 6.0000	0.11	0.09	0.02	1553	1619	0.11	0.10	0.01	1553	1622
			(0.01)					(0.01)		
srph_bigreg== 7.0000	0.09	0.10	-0.01	1553	1619	0.09	0.09	0.00	1553	1622
			(0.01)					(0.01)		
srph_lang==de	0.71	0.70	0.02	1553	1619	0.71	0.70	0.01	1553	1622
			(0.02)					(0.02)		
srph_lang==fr	0.19	0.20	-0.01	1553	1619	0.19	0.21	-0.01	1553	1622
			(0.01)					(0.01)		
srph_lang==it	0.09	0.10	-0.01	1553	1619	0.09	0.09	0.00	1553	1622
			(0.01)					(0.01)		
rural	0.27	0.24	0.03*	1553	1619	0.27	0.26	0.01	1553	1622
			(0.02)					(0.02)		
Observations	3172					3175				

Table A.1: Balance tests for various pre-treatment covariates and socio-demographics by experimental groups

A.3 Comprehension and manipulation checks

A.3.1 Comprehension check for visual map vignette treatment

In this section, we analyze how respondents react when treated with the existing 3/4G or 5G antenna map dispersion in their immediate vicinity.

We assume that ex-ante knowledge is low and improves with our treatments. Hence, we first turn to the question whether the display of mobile antenna maps was correctly perceived by respondents and whether they thereby updated their knowledge of how proximate their household is to the next 5G or 3/4G antenna mast.

As seen from Appendix Table A.2, respondents have some baseline knowledge over the proximity between their household and the next mobile antenna. Both for 5G and 3/4G antennas, around 30% are able to correctly indicate their distance on a 5-point scale (below 100m; 100-300m; 300-500m; 500m-1km; above 1km), and around 70% do so in a roughly correct way with +-1 category (see constant in models 1, 3, 5, 7 of Appendix Table A.2). When revealing antenna placement, we are able to shift respondents perceptions to be more accurate, however. Correct placement increases by about 27 percentage points with both the 5G and 3/4G treatment (see models 1, 5), and roughly correct placement increases by around 15 percentage points (see models 3, 7). As shown in Figure A.2, the improvement of placement does not strongly depend on distance to mobile antennas ex-ante. While there are some differences in ex-ante distance to antennas and the baseline probability of correct placement, the displayed 5G and 3/4G maps improve perceptions for all experimental groups. The improvement of perceptions is strongest in the group with moderate distance (300-500 meters) and there is no improvement of perceptions for empty 3/4G maps (likely because these respondents have no network service at their home, which is easily known to them).

All in all, this indicates that respondents understood our treatment and were able to improve, on average, the accuracy of the closest (5G or 3/4G) antenna mast placed to their household under treatment.

	5G				3/4G			
	(1) match of placement	(2) match of placement	(3) rough match of placement	(4) rough match of placement	(5) match of placement	(6) match of placement	(7) rough match of placement	(8) rough match of placement
5G	0.274***	0.266***	0.159***	0.161***				
	(0.0172)	(0.0299)	(0.0149)	(0.0246)				
5G × Below 300		-0.0101		0.00700				
		(0.0535)		(0.0435)				
5G × 300-500		0.0870+		-0.0815*				
		(0.0488)		(0.0393)				
5G × empty		-0.0173		0.0357				
		(0.0426)		(0.0375)				
3/4G					0.267***	0.238***	0.150***	0.0716**
					(0.0173)	(0.0356)	(0.0138)	(0.0241)
3/4G × Below 300						0.0291		0.154***
						(0.0444)		(0.0331)
3/4G × 300-500						0.146**		0.104**
						(0.0495)		(0.0349)
3/4G × empty						-0.167*		-0.0931+
						(0.0666)		(0.0526)
Below 300		0.0651+		-0.00709				
		(0.0368)		(0.0351)				
300-500		-0.0294		0.0762*				
		(0.0344)		(0.0317)				
empty		0.00802		-0.115***				
		(0.0293)		(0.0299)				
Below 300						-0.0433		-0.188***
						(0.0312)		(0.0271)
300-500						-0.0801*		-0.0739*
						(0.0344)		(0.0292)
empty						0.0732		-0.0511
						(0.0475)		(0.0383)
Benefits of 5G expansion (PCA)	0.0350***	0.0346***	0.0147+	0.0128	0.00806	0.00857	-0.00261	-0.00339
	(0.00929)	(0.00928)	(0.00827)	(0.00817)	(0.00940)	(0.00940)	(0.00746)	(0.00737)
Costs of 5G expansion (PCA)	0.00627	0.00516	-0.00677	-0.00836	0.0130	0.0131	-0.00617	-0.00282
	(0.0103)	(0.0103)	(0.00885)	(0.00877)	(0.0103)	(0.0104)	(0.00846)	(0.00845)
Constant	0.309***	0.301***	0.697***	0.722***	0.323***	0.352***	0.741***	0.842***
	(0.0119)	(0.0206)	(0.0119)	(0.0202)	(0.0121)	(0.0250)	(0.0113)	(0.0192)
N	3136	3136	3136	3136	3141	3141	3141	3141
r2	0.0810	0.0844	0.0385	0.0559	0.0722	0.0801	0.0379	0.0656

Table A.2: Effect of mobile antenna map display on correct perception of distance household to nearest antenna on 5-point scale (below 100m; 100-300m; 300-500m; 500m-1km; above 1km). Results displayed by 5G treatment vs. control group (models 1-4) and 3/4G treatment vs. control group (models 5-8), also taking into account baseline distance between respondent and nearest antenna (models 2, 4, 6, 8). Models 1, 2, 5, 6 code an exact match of distance to response scale, models 3, 4, 7, 8 an rough match (+-1 category). Reference category: Control group; Reference category for distance: 500-1000 meters

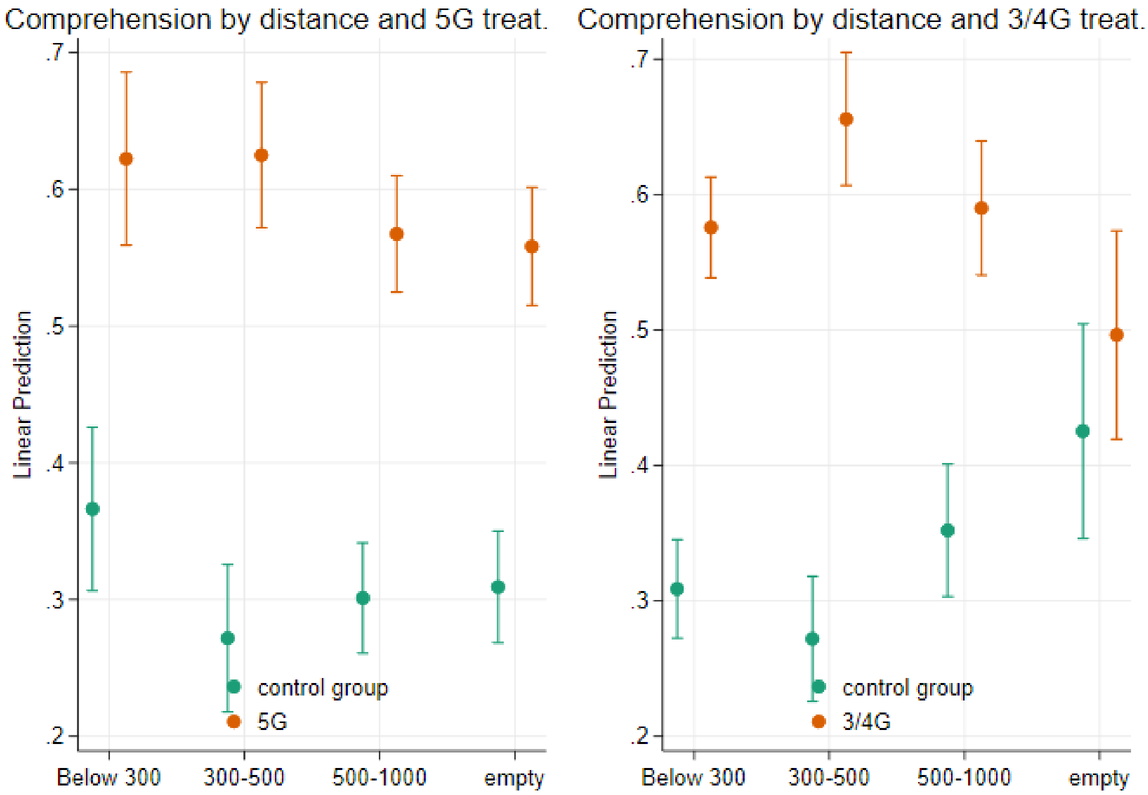

Figure A.2: Predictions for models 2 and 6 of Table A.2. 95% confidence intervals shown.

A.3.2 Manipulation check for visual map vignette treatment

Next, we turn to the question whether respondents increased their worry over the proximity or amount of 5G or 3/4G antennas in the vicinity after having been shown the maps.

We turn to worry over proximity (antennas placed (much) too close) first. As can be seen from Appendix Table A.4, model 1, while on average the 5G treatment increases worry (substantially so, with the probability of a respondent voicing worry increasing from 27% by 9 percentage points), the 3/4G treatment does not do so. In models 2 and 3 we investigate whether this increase in worry depends on ex-ante distance to antennas: Compared to households 500-1000 meters away, worry increases for all other groups with the 5G treatment (notably also for respondents shown empty maps (though differences between groups are significant on the 10% level only). For the 3/4G treatment overall does not increase, though worry in subgroups shifts slightly up for proximate, and down for distant antennas. Figure A.3 provides a visual indication of these effects.

Next, we also checked whether worry increased particularly in the group of respondents that we code ex-ante to be sceptical vs. open towards 5G. This is based on an above/below median score of a polychoric pca on several items (see research design). We observe that levels of worry are substantially lower in the group of respondents with ex-ante high benefits and low costs from 5G-expansion. However, this group also increases worry most substantially with our revelation of 5G-antennas (but not 3/4G-antennas), *if these were geographically proximate to respondents*. Results are presented in Appendix Figure A.5.

Last, we turn to the question whether respondents feel there are (much) too many antennas nearby. As can be seen from Appendix Table A.3, model 1, the 3/4G treatment and even more so the 5G treatment substantially increase worry over the amount of antennas on average. From a baseline probability of voicing worry of around 28%, the 5G treatment increases worry by 9 percentage points and the 3/4G treatment by 4 percentage points. As can be seen from models 2 and 3 (which are presented in Figure A.4, worry over the amount of antennas increases with the number of antennas displayed on the map.

All in all, we conclude that the display of 5G maps increases worry over placement substantially, and mostly so when the closest antenna is (very) proximate to respondents' homes or when many antennas are displayed. The 3/4G maps do only increase worry over amount when many are present, but do not clearly shift worry over proximity with close distance, indicating that respondents are not too much concerned over masts with

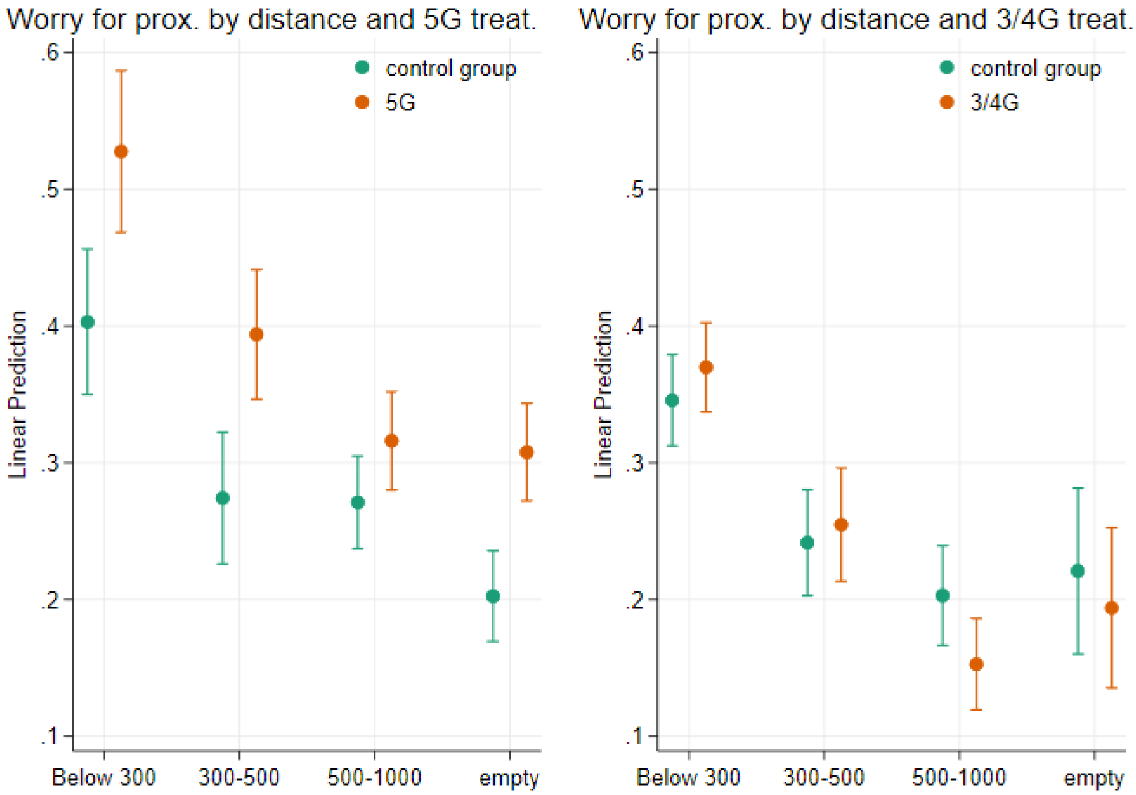

Figure A.3: Predictions for models 3 and 4 of Table A.4. 95% confidence intervals shown.

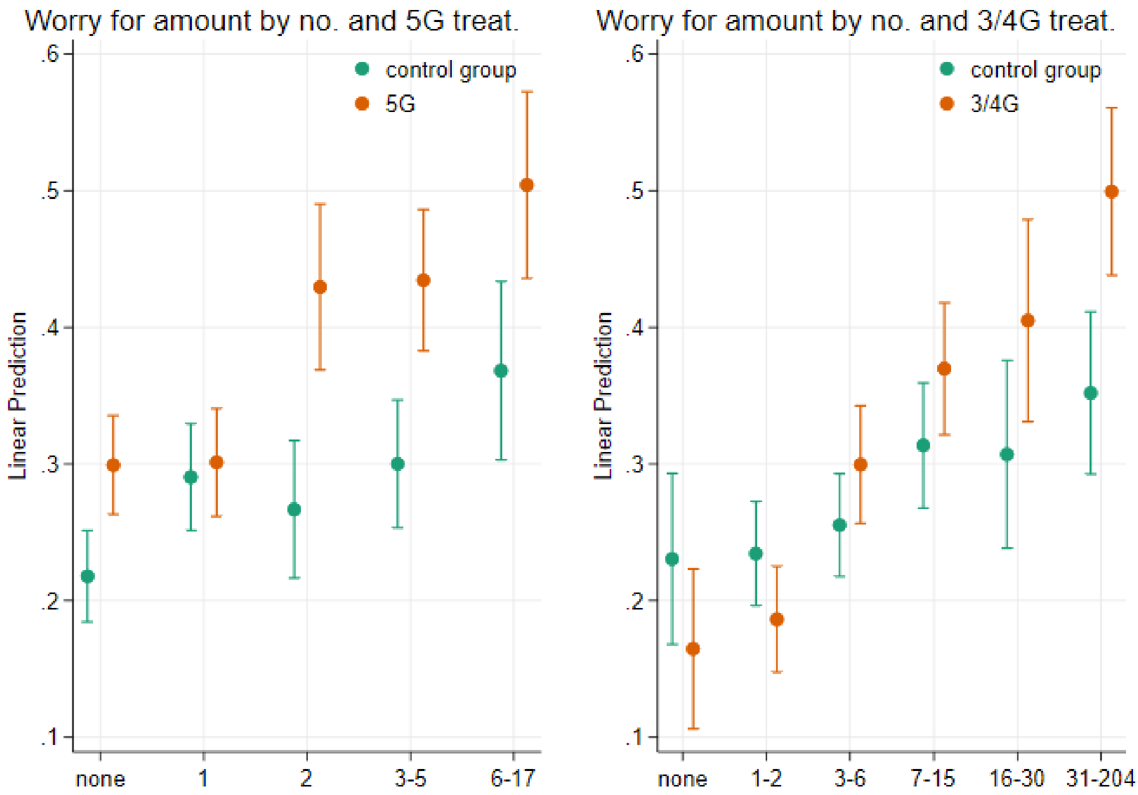

Figure A.4: Predictions for models 2 and 3 of Table A.3. 95% confidence intervals shown.

the current 3/4G technology in their close vicinity.

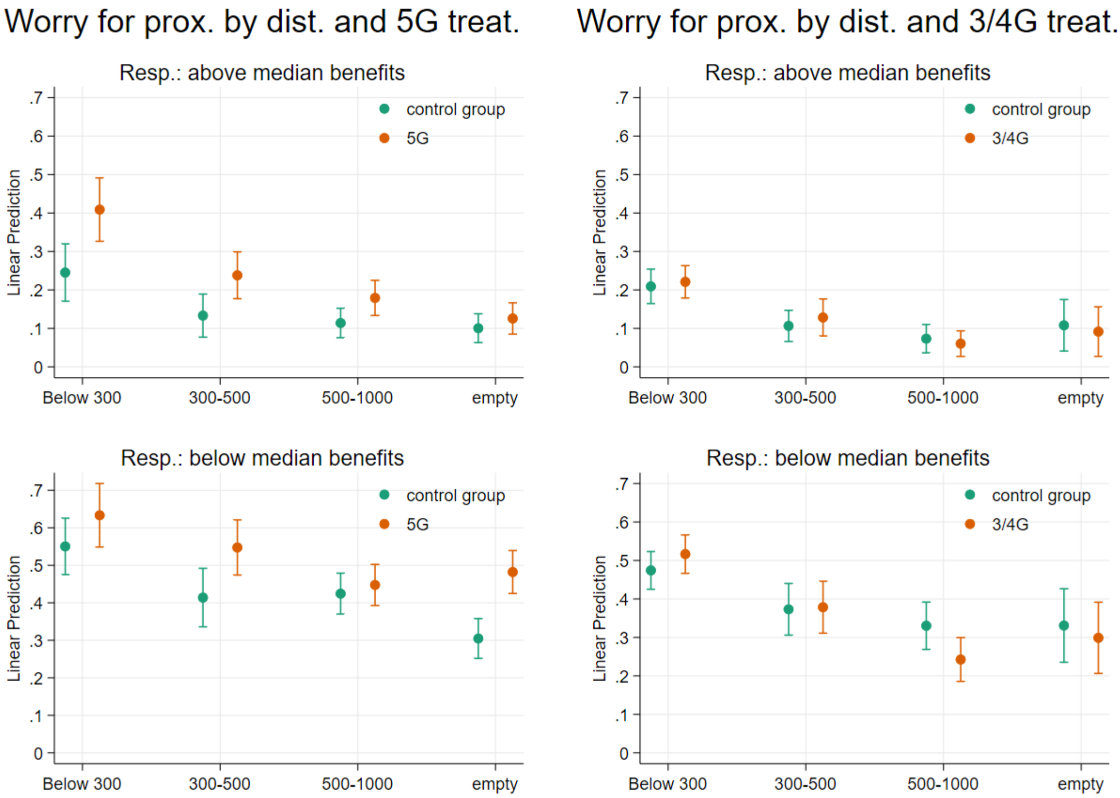

Figure A.5: Predictions for worry by distance to (revealed) antenna placement and subgroups with above/below median benefits from 5G-expansion. 95% confidence intervals shown.

	5G and 3/4G (1) (Much) too many antennas (0-1)	5G (2) (Much) too many antennas (0-1)	3/4G (3) (Much) too many antennas (0-1)	5G and 3/4G (4) Too few (1)/too many (5) antennas	5G (5) Too few (1)/too many (5) antennas	3/4G (6) Too few (1)/too many (5) antennas
5G	0.0910***	0.0813**		0.104***	0.108**	
	(0.0148)	(0.0251)		(0.0233)	(0.0413)	
3/4G	0.0341*		-0.0658	0.0377^{+}		-0.0809
	(0.0148)		(0.0437)	(0.0215)		(0.0712)
5G × 1		-0.0705^{+}			-0.101^{+}	
		(0.0378)			(0.0607)	
5G × 2		0.0813^{+}			0.0694	
		(0.0474)			(0.0725)	
5G × 3-5		0.0531			0.0305	
		(0.0435)			(0.0687)	
5G × 6-17		0.0546			0.0473	
		(0.0542)			(0.0851)	
3/4G × 1-2			0.0177			0.0350
			(0.0517)			(0.0813)
3/4G × 3-6			0.110*			0.129
			(0.0525)			(0.0832)
3/4G × 7-15			0.122*			0.164^{+}
			(0.0553)			(0.0853)
3/4G × 16-30			0.164*			0.138
			(0.0675)			(0.101)
3/4G × 31-204			0.213***			0.237*
			(0.0617)			(0.0964)
1		0.0725**			0.168***	
		(0.0262)			(0.0400)	
2		0.0489			0.141**	
		(0.0308)			(0.0452)	
3-5		0.0822**			0.186***	
		(0.0292)			(0.0447)	
6-17		0.150***			0.245***	
		(0.0374)			(0.0592)	
1-2			0.00389			0.0641
			(0.0374)			(0.0576)
3-6			0.0247			0.111^{+}
			(0.0371)			(0.0588)
7-15			0.0830*			0.179**
			(0.0395)			(0.0604)
16-30			0.0764			0.195**
			(0.0474)			(0.0665)
31-204			0.121**			0.266***
			(0.0441)			(0.0693)
Benefits of 5G expansion (PCA)	-0.147***	-0.166***	-0.145***	-0.236***	-0.270***	-0.222***
	(0.00651)	(0.00760)	(0.00775)	(0.0104)	(0.0126)	(0.0121)
Costs of 5G expansion (PCA)	0.116***	0.116***	0.111***	0.172***	0.182***	0.153***
	(0.00735)	(0.00879)	(0.00873)	(0.0118)	(0.0146)	(0.0139)
Constant	0.277***	0.222***	0.233***	3.264***	3.145***	3.137***
	(0.0100)	(0.0171)	(0.0319)	(0.0153)	(0.0262)	(0.0498)
N	4743	3136	3141	4743	3136	3141
r2	0.188	0.244	0.213	0.197	0.248	0.217

Table A.3: Effect of mobile antenna map display on increased worry for amount of antennas in vicinity (binary indicator for there being "too many" or "much too many")). Results displayed by 5G treatment vs. control group and 3/4G treatment vs. control group (model 1), also taking into account baseline distance between respondent and nearest antenna (models 2 for 5G, model 3 for 3/4G treatment) and baseline amount in vicinity (model 4 for 5G, model 5 for 3/4G treatment). Reference category: Control group; Reference category for distance: 500-1000 meters. Reference category for amount: None.

A.4 Direct effects of map display

	5G and 3/4G (1) Antennas (much) too close (0-1)	5G (2) Antennas (much) too close (0-1)	3/4G (3) Antennas (much) too close (0-1)	(4) Antennas too close (1)/far (5)	(5) Antennas too close (1)/far (5)	(6) Antennas too close (1)/far (5)
5G	0.0877***	0.0450+		-0.107***	-0.0243	
	(0.0149)	(0.0251)		(0.0240)	(0.0396)	
3/4G	0.000283		-0.0502*	-0.00486		0.0864*
	(0.0145)		(0.0252)	(0.0221)		(0.0383)
5G × Below 300		0.0796+			-0.137*	
		(0.0476)			(0.0699)	
5G × 300-500		0.0746+			-0.146*	
		(0.0426)			(0.0685)	
5G × empty		0.0603+			-0.119*	
		(0.0354)			(0.0584)	
3/4G × Below 300			0.0744*			-0.130*
			(0.0346)			(0.0520)
3/4G × 300-500			0.0634+			-0.122*
			(0.0383)			(0.0579)
3/4G × empty			0.0232			-0.0500
			(0.0498)			(0.0841)
Below 300		0.132***			-0.169***	
		(0.0321)			(0.0467)	
300-500		0.00316			0.0336	
		(0.0300)			(0.0485)	
empty		-0.0686**			0.185***	
		(0.0242)			(0.0378)	
Below 300			0.143***			-0.218***
			(0.0253)			(0.0382)
300-500			0.0387			-0.0360
			(0.0270)			(0.0429)
empty			0.0180			0.0718
			(0.0361)			(0.0617)
Benefits of 5G expansion (PCA)	-0.146***	-0.155***	-0.141***	0.248***	0.267***	0.230***
	(0.00632)	(0.00761)	(0.00744)	(0.0108)	(0.0133)	(0.0123)
Costs of 5G expansion (PCA)	0.120***	0.117***	0.113***	-0.180***	-0.179***	-0.160***
	(0.00715)	(0.00864)	(0.00853)	(0.0120)	(0.0147)	(0.0141)
Constant	0.276***	0.275***	0.205***	2.708***	2.670***	2.801***
	(0.0103)	(0.0173)	(0.0187)	(0.0161)	(0.0258)	(0.0286)
N	4743	3136	3141	4743	3136	3141
r2	0.198	0.234	0.219	0.206	0.243	0.233

Table A.4: Effect of mobile antenna map display on increased worry for distance of household to nearest antenna (binary indicator for antennas being "too close" or "much too close")). Results displayed by 5G treatment vs. control group and 3/4G treatment vs. control group (model 1), also taking into account baseline distance between respondent and nearest antenna (models 2 for 5G, model 3 for 3/4G treatment). Reference category: Control group; Reference category for distance: 500-1000 meters.

	5G and 3/4G (1) Approve 5G exp. in mun. (0-7)	5G (2) Approve 5G exp. in mun. (0-7)	3/4G (3) Approve 5G exp. in mun. (0-7)	5G and 3/4G (4) Approve 5G exp. in mun. (0-1)	5G (5) Approve 5G exp. in mun. (0-1)	3/4G (6) Approve 5G exp. in mun. (0-1)
5G	-0.159^{**}	-0.150		-0.0340^{*}	-0.0408	
	(0.0596)	(0.105)		(0.0161)	(0.0281)	
3/4G	-0.0241		0.0933	-0.0000118		-0.000470
	(0.0604)		(0.121)	(0.0161)		(0.0328)
5G × Below 300		-0.0896			0.0420	
		(0.181)			(0.0488)	
5G × 300-500		-0.0888			-0.0543	
		(0.171)			(0.0473)	
5G × empty		0.0579			0.0317	
		(0.149)			(0.0397)	
3/4G × Below 300			-0.0970			0.0164
			(0.151)			(0.0408)
3/4G × 300-500			-0.265			-0.0283
			(0.177)			(0.0474)
3/4G × empty			-0.128			0.00615
			(0.233)			(0.0601)
Below 300		0.0195			-0.0481	
		(0.130)			(0.0340)	
300-500		0.117			0.0214	
		(0.126)			(0.0344)	
empty		-0.0280			-0.0182	
		(0.106)			(0.0283)	
Below 300			0.00723			-0.0343
			(0.108)			(0.0296)
300-500			0.123			0.00383
			(0.122)			(0.0333)
empty			-0.176			-0.0738^{+}
			(0.166)			(0.0431)
Benefits of 5G expansion (PCA)	0.895^{***}	0.915^{***}	0.895^{***}	0.194^{***}	0.190^{***}	0.197^{***}
	(0.0263)	(0.0315)	(0.0324)	(0.00643)	(0.00788)	(0.00778)
Costs of 5G expansion (PCA)	-0.413^{***}	-0.422^{***}	-0.411^{***}	-0.0871^{***}	-0.0923^{***}	-0.0852^{***}
	(0.0299)	(0.0357)	(0.0375)	(0.00779)	(0.00953)	(0.00965)
Constant	3.481^{***}	3.465^{***}	3.465^{***}	0.507^{***}	0.517^{***}	0.528^{***}
	(0.0428)	(0.0763)	(0.0858)	(0.0115)	(0.0202)	(0.0237)
N	4743	3136	3141	4743	3136	3141
r2	0.279	0.296	0.278	0.199	0.203	0.205

Table A.5: Effect of mobile antenna map display on approval of 5G-rollout in the respondents municipality (binary indicator for approval rating of 4-7 on an 8 point approval scale (8: full approval)). Results displayed by 5G treatment vs. control group and 3/4G treatment vs. control group (model 1), also taking into account baseline distance between respondent and nearest antenna (models 2 for 5G, model 3 for 3/4G treatment). Reference category: Control group; Reference category for distance: 500-1000 meters.

A.5 Appeal probability

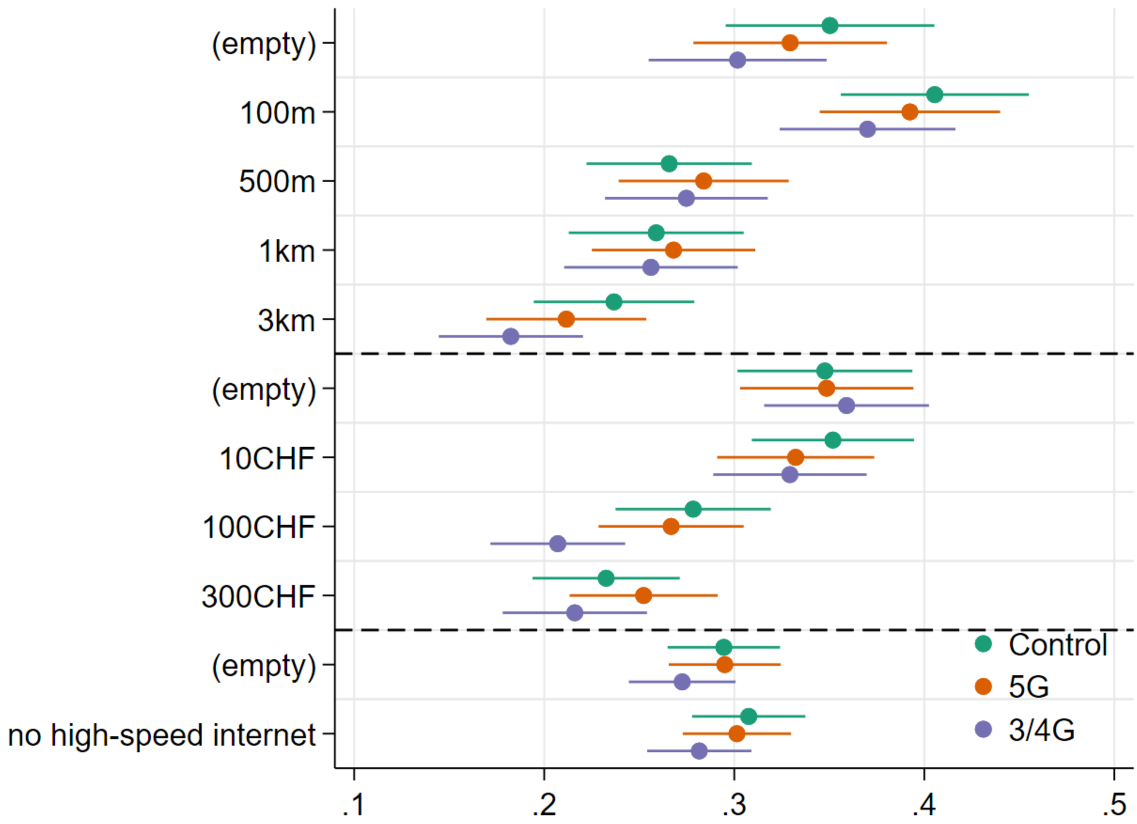

Figure A.6: Appeal probability by vignette attributes and whether respondents also received the map treatment.