Public Roads on Private Lands: Land Costs and Optimal Road Improvements in Urban Uganda

Jeanne Sorin*

Draft Updated Regularly - Latest Version Here

January 15, 2025

Abstract

Despite the need for transportation infrastructure investments in developing cities, empirical evidence on their net returns is lacking due to data constraints and the common oversight of land acquisition costs. In this paper, I collect novel data to estimate the net returns of 140 km of road improvements in Kampala, Uganda, since 2017, accounting for both benefits and land acquisition costs. I conduct two surveys with real estate brokers and landowners and I exploit variation in the timing of improvements to estimate the local benefits. I then develop a quantitative spatial model to capture the city-level impacts of the policy, accounting for general equilibrium effects and heterogeneous land acquisition costs. Leveraging the coexistence of three property rights regimes in the city, I show that weak property rights are associated with lower land acquisition costs. I find that the net welfare gains from the realized road improvements were equivalent to a $119 transfer per resident, but would have been negative if land had been acquired at market value, as legally mandated under eminent domain, due to the high cost of raising domestic funds. Finally, I solve for the optimal road improvements under different institutional settings and demonstrate the importance of accounting for land costs when designing, funding, and evaluating transportation infrastructure projects, particularly in low- and middle-income countries where land acquisition relies on fragile land and financial institutions.

*The University of Chicago; email: jsorin@uchicago.edu. I am thankful to my advisors, Milena Almagro, Fiona Burlig, and especially Michael Greenstone and Esteban Rossi-Hansberg. Special thanks to Vittorio Bassi, Olivia Bordeu, Tom Hierons, Tarren Peterson, Sasha Petrov, Tommaso Porzio, Tanya Rajan, Jordan Rosenthal-Kay, and Oscar Volpe for their constant feedback and encouragements. In addition, this project benefits from conversations with participants of the Trade Working Group, Development and Public-Labor seminars at the University of Chicago, and of 2024 IGC Uganda Climate Change Workshop. I am also grateful to Julia Villenas and the entire team at Dyadic Research Impact for their help with data collection; Robert Kyukyu, Gerald Ahabwe and all those at KCCA who patiently answered my questions and supported the project; as well as Caesar Oweitu for generously sharing data. I gratefully acknowledge financial support from IGC, STEG-CEPR and the University of Chicago. The IRB approvals for this project were provided by the University of Chicago and HAUREC Uganda. All errors are my own.

1 Introduction

Infrastructure is crucial for economic development, and African cities face a severe deficit in transportation infrastructure, with only one third of roads paved (Kumar and Barrett 2008). Despite research linking road quality and urban mobility with economic development, investments to tackle this infrastructure deficit are still insufficient (World Bank 2019). These low investments suggest that for African countries, where raising domestic funds is particularly challenging (Besley and Persson 2014), the high costs of such projects may outweigh the perceived benefits.

Empirical estimates of the net returns to road improvements in low-income cities are scarce. Data constraints limit empirical evidence on the local benefits, while citywide impacts—driven by the rerouting of traffic patterns and the location decisions of residents and firms in equilibrium—are challenging to measure. Moreover, important costs beyond construction are often overlooked by the literature. For example, upgrading road networks commonly requires additional land that must be acquired from private landowners (Collier and Venables 2016). Governments' struggles to secure funding for these substantial additional expenses often hinder projects' implementation (World Bank 1996) or shift investments to locations where land can be acquired at a discount.

In this paper, I estimate the net returns to road improvements in a typical Sub-Saharan African city and study how optimal transportation infrastructure investments are affected by land acquisition, especially in settings with weak fiscal and land institutions. I focus on Kampala, Uganda, a typical Sub-Saharan African city at the 25^{th} percentile of the world traffic speed distribution (Akbar et al. 2023). Between 2017 and 2024, 140 km of roads were upgraded in the city. Landowners whose land was required for the new infrastructure were entitled to market-value compensation under the eminent domain legal framework. However, unlike construction costs, land acquisition costs were not covered by funds from the World Bank and the African Development Bank. The government argued that acquiring land at market value would jeopardize the project's viability and instead encouraged owners to cede small portions of their land without compensation. This approach had mixed success across the city, and concerns were raised about owners' ability to exert their free will (World Bank 2023).

To address this gap in the literature, I collect the most comprehensive data on the net returns to road improvements in a Sub-Saharan African city, accounting for costs and benefits. I conduct two surveys: one with 377 real estate brokers to recover land market values and another with 548 landowners on the side of upgraded roads to examine actual land acquisition costs. I leverage the coexistence of three property rights regimes in the city (Bird and Venables 2020) to characterize the relationship between land costs and local property rights. Using variation in the timing of road improvements, I estimate their local impacts on traffic from Google Maps data and on property values. Finally, with additional data from a local ride-hailing company, I build and estimate a quantitative spatial model of optimal road improvements to measure citywide net returns and formalize the trade-off between land costs and infrastructure benefits.

I find that despite large benefits, implemented road improvements would have led to negative net welfare gains if land had been acquired at market value, because of a high marginal cost of funds. Instead, I show how weak property rights reduced land acquisition costs, enabling substantial net welfare gains, consistent with theoretical work on the tension between private property rights and public goods provision

(Acemoglu and Robinson 2012, Posner and Weyl 2017). However, areas with the highest potential benefits often coincided with those where stronger property rights made land acquisition costlier, shifting welfare-maximizing investments away from these locations. These findings, which underscore the importance of considering both land costs and citywide benefits when designing transportation infrastructure policies in low-income settings, draw on four key results that I discuss next.

First, I use my novel surveys with real estate brokers and landowners to estimate land acquisition costs and uncover a positive relationship between landowners' property rights and land costs. In Kampala, land acquisition costs depend on the market value of land, required under eminent domain, and the likelihood that owners claim this compensation. To address the lack of existing data on property values, I construct a retrospective panel of transactions from the broker survey. My findings show that compensating all landowners at market value for their affected land would result in acquisition costs amounting to 45% of total project costs. However, 80% of surveyed landowners agreed to forfeit an average of 786 square feet of land without compensation, reducing total land costs by an estimated 72%.

I find that this consent was partly driven by significant barriers to entering negotiations with the government to be compensated, including the cost of obtaining official copies of ownership documents. These costs are heterogeneous along the lines of Kampala's three main property right regimes: *leasehold*, *freehold,* as well as *mailo*. Leasehold land, characterized by limited term ownership with a strong record of property titles, had the lowest costs of obtaining documents. Consequently, surveyed leasehold owners were 55% more likely to negotiate than mailo owners, who often face double legal claims—landowner and legal occupant—over a single plot of land (Bird and Venables 2020). Leasehold owners were also 75% more likely to negotiate than freehold owners, whose perpetual ownership often lacks well-tracked titles. As a result, actual land costs in Kampala are lower than those required under the legal framework of eminent domain, but are tied to the different property right regimes in the city.

Second, I estimate the local benefits of road improvements in terms of traffic speed and local property values. I calculate the impact of road improvements on traffic speed by leveraging information from Google Maps queries and I exploit variation in the timing of the policy and compare traffic speeds on the roads upgraded at the start and end of the policy. I estimate that the intervention increased uncongested local traffic speeds by 4.1 km/h (16% faster than baseline speed) and that trips between pairs of neighborhoods became more likely to take upgraded roads over time. Using the appraisal of a standardized hypothetical property from the broker survey, I show that road improvements also increased the value of properties in the road's immediate vicinity by an estimated 25%. Extrapolating these gains to all properties bordering upgraded roads implies a total increase in local property values of $76 million, slightly below the $78 million in road construction costs, implying that the project would not have positive net returns if benefits were only local. Using a retrospective panel of transactions from the same survey, I corroborate these results, showing a 19% increase in property sale prices in parishes (neighborhoods) receiving a road improvement.

Third, I develop and estimate a quantitative spatial model to capture the citywide net returns from road improvements. Beyond their local benefits, these upgrades impact distant locations by altering traffic patterns and influencing the location decisions of residents and firms in equilibrium. In addition, using residential land for roads has an opportunity cost, as it strains the stock of valuable residential land

and increases prices. I build a static quantitative spatial model of a closed city that includes standard elements as workers freely choose residential and workplace locations trading off between high commuting costs and high rents (Redding and Rossi-Hansberg 2017, Allen and Arkolakis 2022). Additionally, I model the competition between residential and road land use, with residential land owned by immobile private landowners under heterogeneous property rights regimes. Road construction may be funded by external funds, but land payments to affected owners are funded through property taxes. However, this transfer is not costless, as raising taxes incurs a wedge, reflecting the high cost of raising domestic funds in low- and middle-income countries.

I estimate key model parameters required to quantify the net returns of road improvements. Partnering with a prominent local ride hailing company, I estimate the elasticity of commuting flows on commuting times on the universe of rides (flows) for a random sample of weeks from 2019 to 2024. I estimate that the number of commuters between two locations decreases by 0.33 percent for every one percent increase in commuting times. This elasticity is in the bottom half of existing estimates in middle- and high-income country settings and consistent with the few existing estimates in low-income country (LIC) cities (Balboni et al. 2020, Kreindler and Miyauchi 2023). Additionally, I use my reduced-form estimates to calculate the elasticity of road speed with respect to road infrastructure and the elasticity of owners' negotiation costs across different property rights regimes. I calibrate the rest of the parameters using public data for Kampala or from the literature.[1] Land payments reduce the net welfare gains of road improvements because the property tax funding these transfers is subject to a high wedge, consistent with the large cost of raising domestic funds.[2] I calibrate the wedge on property taxes from a randomized controlled trial by Regan and Manwaring (2024), which shows that for every dollar due in property taxes, the Kampala city government recovers only 39 cents—a wedge of 0.61. To build confidence in this number, I solve for the wedge that aligns with the government's claim that acquiring land at market value would jeopardize the project (World Bank 2023). I find that compensating all landowners at market value would result in negative net welfare gains if the tax revenue wedge exceeds 0.51.

Equipped with these parameters, I compute the city-level net returns of road improvements by solving the model for workers' new equilibrium residential and workplace locations. The analysis accounts for the opportunity cost of land use and reveals substantial citywide benefits: average commuting time decreased by 6.6%, and total property values in the city increased by 1.36%. The present discounted value of the compensating differential transfer for the gross benefits is \$343 million—\$277 million more than the increase in local property values estimated from the brokers' appraisal exercise. This finding underscores the importance of incorporating citywide benefits and general equilibrium effects in the evaluation of road improvements. Land payments reduce the policy's net welfare gains due to the large wedge on property taxes. Accounting for land and construction costs, I estimate that the policy's net welfare gains amount to \$104 million, equivalent to a one-time transfer of \$119 per resident (80% of the average monthly wage). However, these gains would have turned negative if all landowners had been compensated at market value,

[1] I estimate that increasing road width by 1% decreases average trip time by 0.39%. This estimated elasticity of travel time on road infrastructure is on the upper end of existing estimates, all of them in high or middle income countries (Couture et al. 2018, Fajgelbaum and Schaal 2020, Bordeu 2024).

[2] In the absence of a wedge on property taxes, land payments are welfare neutral as they are transfers across owners through property taxes. In the main specification, owners' utilities are linear in income. The opportunity cost of land is already accounted for in the net returns.

as required by eminent domain.

Notably, the realized road improvements align relatively well with the model's predictions. I find a positive correlation between the location of implemented upgrades and the corresponding model-predicted net welfare gains from specific link-level improvements. Conversely, I observe a negative correlation between predicted local land costs and road upgrades, consistent with the realized improvements being relatively well allocated given the existing costs and benefits.

Fourth, I use the model to study how land institutions impact the allocation and welfare gains of optimal road improvements by conducting counterfactual analyses. Fixing the maximum total kilometers of roads improved to match the policy, I solve for the optimal allocation chosen by a utilitarian central planner maximizing residents' welfare. The planner accounts for the benefits of road improvements—decrease in commuting costs—as well as the costs—the opportunity cost of land and the fiscal loss associated with the wedge on land payments. Under the existing land payment structure, where not all owners are compensated at market value, the net welfare gains are equivalent to a \$500 transfer per resident, compared to \$153 if all owners were compensated at market value. Weak property rights reduce the probability that owners get compensated, reducing fiscal losses from payments, and allowing the government to improve more high-benefit roads and achieve larger welfare gains than under full compensation. However, this approach ties land payments to spatially heterogeneous property rights, impacting the spatial distribution of optimal investments. In turn, I find that if all owners were compensated with the same probability as those with the weakest property rights, the optimal policy would yield net welfare gains of \$563 per resident. Of this increase, 30% comes from a lower fiscal burden and 70% from better allocation towards high-benefit locations, leading to a larger decrease in commuting times and larger increase in property values.

Given the key role played by the tax revenue wedge in driving these results, I then analyze the impact of removing restrictions on the use of external funds from the World Bank and the African Development Bank, which currently limit their application to construction costs rather than land acquisition. Removing these restrictions would eliminate the tax revenue wedge on land payments. Solving for the optimal improvements, I find that under the current approach, where not all owners are compensated at market value, relaxing these restrictions would increase net welfare gains by 12%. If all owners were compensated at market value, the net welfare gains would be 56% larger in the absence of fund use restrictions than under the existing ones. Both results hold despite fewer roads being improved, as some external funds are instead being used for land acquisition. While these restrictions may stem from corruption concerns—beyond the scope of this paper—they conflict with the World Bank's goal of ensuring fair and effective compensation for affected landowners (World Bank OP 4.12). These findings provide a benchmark for weighing anticorruption efforts against the potential benefits of better compensating landowners and allocating improvements toward higher-benefit locations.

With these four results, I make two main contributions to a growing literature at the intersection of development and urban economics.[3] First, thanks to my novel data, I measure the net returns to road

[3] Collier and Venables (2016) and Glaeser and Henderson (2017) highlight that this intersection has historically been overlooked by both development and urban economists, partly to the lack of detailed data needed to estimate quantitative spatial models.

improvements in a LIC city, accounting for benefits and land costs. I characterize benefits in terms of local traffic speed, commuting time, local and city-level property values, while existing evidence on speed is in either in the US (Duranton and Turner 2011, Currier et al. 2023) or across cities worldwide (Akbar et al. 2023) and estimates of the impact on property values in LMIC cities have been local (Gonzalez-Navarro and Quintana-Domeque 2016). Instead, I estimate a quantitative spatial model, used widely in high-income cities to study the benefits of improved transportation (see Redding and Rossi-Hansberg (2017) for a review),[4] but whose key elasticities are rarely estimated in low-income cities (Kreindler and Miyauchi 2023). Within-city studies using quantitative spatial models in low and middle income countries have focused on the impact of Bus Rapid Transit (BRTs) (Majid et al. 2018, Balboni et al. 2020, Tsivanidis 2023, Zarate 2024, Kreindler et al. 2023), but in Kampala, as in most LIC cities, roads are the only transportation mode, ensuring that the improvements are experienced by all commuters.[5] On the costs side, I use my quantitative spatial model of optimal road improvements, that builds on Allen and Arkolakis (2022), Fajgelbaum and Schaal (2020) and Bordeu (2024), to formalize and quantify the opportunity cost of land use, and how land payments affect both the net returns and the optimal location, briefly mentioned by Collier and Venables (2016) for LIC infrastructure, and discussed by Brooks and Liscow (2023) for the US.

My second contribution is to provide new evidence on the relationship between land acquisition, property rights, and efficiency of investments, through the channel of public good provision. As in Holland (2023), who studies the role of strong property rights in shaping opportunistic behavior by private owners in Colombia, I find that payments are increasing with the strength of owners' property rights. My contribution is to show how this relationship can affect the optimal amount of high benefit infrastructure improvements, and, in the presence of spatially heterogeneous property rights, shift them away from the highest benefit areas. Unclear property rights yield higher risks of expropriation, associated with lower economic development (North 1990, Acemoglu et al. 2001, Besley and Ghatak 2010), including in Kampala (Bird and Venables 2020), but the literature acknowledges a tension between strong private property rights and public interests (Acemoglu and Robinson 2012, Posner and Weyl 2017), which is traditionally used to justify eminent domain (Munch 1976, Shavell 2010, Jeong et al. 2016) for public purposes. I show how, however, in LICs, eminent domain may lead to suboptimal investments, given the high costs of raising public funds, a consequence of LICs' widespread challenges to levy domestic and property (Traxler 2010, Besley and Persson 2014, Knebelmann 2019, Bergeron et al. 2023, Brockmeyer et al. 2023) that has been overlooked.

The rest of the paper is organized as follows. Section 2 describes the context and the data I collected. Section 3 details how I estimate the reduced-form benefits and land costs of road improvements. In Section 4, I build a quantitative spatial model to study the city-level impacts of these improvements and

[4]Notable examples include Ahlfeldt et al. (2015), Allen and Li (2015), Monte et al. (2018), Heblich et al. (2020), Severen (2023) and Almagro et al. (2024), among others. Lucas and Rossi-Hansberg (2002) includes competition between residential and business land uses, but not between private and public land uses.

[5]Most existing studies on road improvements in LIC countries focus on rural or cross-city infrastructure (Baum-Snow et al. 2017, Asher and Novosad 2020, Alder et al. 2022, Balboni 2023, Gertler et al. 2024, Morten and Oliveira 2024, Herzog et al. 2024). There are also several studies on the impact of railroad development on intercity transportation costs and migration, including Gollin and Rogerson (2010), Faber (2014), Ghani et al. (2016), Jedwab and Moradi (2016), Donaldson (2018) and Bryan and Morten (2019).

the welfare effects of spatially heterogeneous land costs. In Section 5, I estimate the model on Kampala and characterize the net returns of the road improvements. In Section 6, I solve for the optimal road improvements to quantify the welfare consequences of the existing property right regime, land acquisition rule and fund use restrictions. Section 7 concludes.

2 Context and Data

2.1 Context

2.1.1 Road Improvements in Kampala

Kampala, Uganda's capital, is a fast growing city, with approximately 1.9 million inhabitants in 2024. While Kampala hosts an increasing share of Uganda's population and GDP, its road infrastructure is of low quality: out of 4,622 km of roads and paths recorded by Open Street Map (OSM), only 742 km (16%) are major roads, and less than 43% of these major roads are paved (7% of all roads).[6]

In the past decade, relatively large amounts have been invested to improve the quality of the existing road network. In addition to some domestic investments, most funds come from the World Bank (WB) and the African Development Bank (AfDB), under the umbrella of two projects, the Second Kampala Institutional and Infrastructure Development Project and the Kampala City Road Rehabilitation Project. Estimated construction costs, excluding land costs, sum to $80 million ($572,000 per kilometer on average as per the AfDB) and are part of larger investments worth almost $500 million. First planned in 2013, road improvements under these two projects started in 2017 and the last roads are expected to be completed by the end of 2026. The few upgrades funded by the Government of Uganda during that period are also included in the analysis. Not all roads mentioned in the initial plan got upgraded. In total, major road improvements targeted about 140 km of roads since 2017, including the upgrades to be completed by the end of 2026, equivalent to almost 20% of the major roads in the city.[7] Figure 1 displays a map of these upgrades and a timeline of the upgrades can be found on Appendix Figure A3.

2.1.2 Land Acquisition for Infrastructure Projects in Kampala

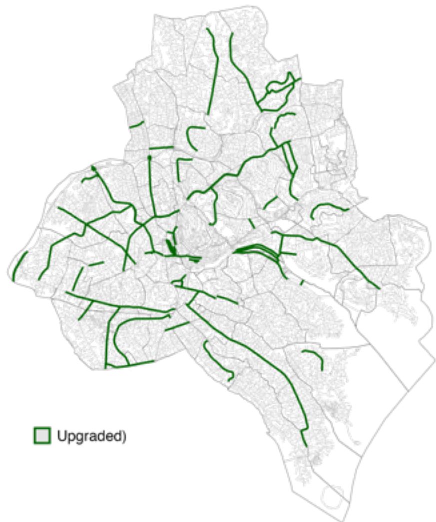
Widespread Issues to Acquire the Underlying Land

Upgrading road networks commonly requires additional land, and widespread challenges to acquire that land have been documented. In Kampala, while the studied road network upgrades have mostly involved improving the existing roads, additional land is still needed as these roads must be widened to either add traffic lanes or build sidewalks and drainage channels. The latter are necessary to absorb the frequent and important volumes of water during the rainy seasons, so as not to damage road pavement. Analogous land acquisition has been challenging worldwide, including for the U.S. Interstate highway system (Brooks and Liscow 2023). In World Bank-funded projects, these challenges are further fueled by domestic governments' inability to use these international funds for land acquisition. A 1996 report estimates that while the WB's legal framework requires compensation, less than 15% of the projects reviewed included funds for

[6] Akbar et al. (2023) define major roads as roads falling under the motorway, primary, secondary or tertiary road classes on OSM. For reference the mean lane km of major urban road in US MSAs in 2008 was 14,000 km (Couture et al. 2018).

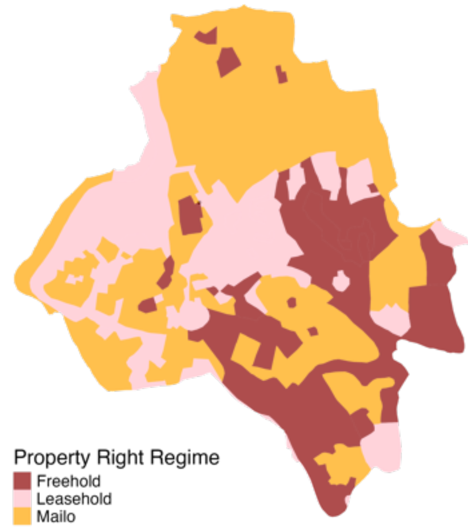
[7] This number is in addition to regular maintenance, which is out of the scope of this paper.

Figure 1: Road Improvements in Kampala



Notes: Road improvements in Kampala since 2017, including domestically-funded improvements, as well as improvements parts of the projects funded by the WB and the AfDB. Sources: KCCA, WB, AfDB.

Figure 2: Property Right Regimes in Kampala



Notes: This map displays the three dominant land tenure systems in Kampala, together with the parish administrative boundaries. Source: GIS Unit at KCCA.

resettlement activities, and more than 30% of the projects had been delayed by an average of two years as a result. In Kampala, the completion of the WB project was delayed by 3.5 years due in part *"to delays in acquisition of rights of way"* (World Bank 2023)

Legal and Practical Land Acquisition Frameworks

The legal framework for land acquisition in Uganda—governed by article 26 of the Constitution of the Republic of Uganda (1995), section 42 of the Land Act (1998), as well as the WB's OP 4.12—is eminent domain with compensation at market value. Yet, in practice, shortly after the start of the WB-funded project, the city government argued that the project's land costs under eminent domain were too high and threatened the project. Since most owners were only minimally affected as only one or two meters of land were taken, the government adopted a "*voluntary land take approach*", where owners were asked to forfeit a small piece of land for the road to be upgraded, without receiving compensation.

A typical land acquisition timeline goes as follows: First, the government decides which roads will be upgraded based on a collection of factors, including potentially overall land availability. Once the road has been chosen, an engineering study is conducted to assess the optimal road design and affected land, under the supervision of the chief government valuer. The government then reaches out to local leaders and affected owners to inform them about the road project, and to obtain their consent. These owners decide whether to accept to give the required amount of land, or to negotiate over the compensation. In this context, negotiations can take the form of discussions with city council members and local leaders, involvement of lawyers, grievances, and court proceedings. The eminent domain legal framework de facto imposes an upper bound on the compensation that can be claimed by affected owners.[8] Finally, once all

[8]Eminent domain is a well-studied solution to holdout problems, where private sellers strategically wait and exert their

land parcels have been secured, the road construction can start.

Thus, the final price of land depends on both the market value of this land, to be paid under eminent domain, and the share of owners who get compensated. While the voluntary land take approach is a more cost effective strategy from the perspective of the government, concerns have been raised that owners may not be informed and able to negotiate effectively (World Bank 2023), potentially because of unclear property rights as land disputes and issues of multiple land claimants per plot would have to be sorted out prior to compensation.

2.1.3 Coexistence of Multiple Property Right Regimes in Kampala

The strength of property rights is heterogeneous within Kampala because land falls under three main types of property right regimes, inherited from the 1900 Buganda Agreement between the British Protectorate and the Buganda Kingdom. Bird and Venables (2020) showed that this distribution of land ownership systems in the city, depicted in Figure 2 and which has not changed much in the past 50 years, has influenced patterns of land use.

Leasehold is dominant at the center and west part of the city and it is the clearest property right regime, as the registry of active leases is maintained by local land boards. Property right clarity is weaker under freehold and mailo regimes. Freehold land is mostly concentrated on the South-East part of the city, less central and closer to Lake Victoria. Freehold land titles are the least restrictive (single ownership and unlimited term), but the accountability of land titles is poor.[9] On mailo land, predominant on the North and South-West parts of the city, issues of multiple land claimants per plots are common, as both landowners and occupants have historically received rights and protections. The history of these property right regimes is described in more details in Appendix A.

2.2 Data Sources

To study the benefits and costs of road improvements in Kampala, and later estimate the main model parameters, I gather detailed information on traffic speed and flows, property values, and the land acquisition process via google maps queries, a partnership with a local ride-hailing company, a survey with real estate brokers, and a survey with landowners.

2.2.1 Google Maps API Data

To study changes in traffic speed following road improvements in the absence of good traffic-related administrative data, I query Google Maps Direction API almost every month between March 2023 and September 2024 to constitute a panel of about $180,000$ Google Maps trips. More details on these queries can be found in Appendix F. Each query includes information on the trip's time, distance, straight line distance, traffic at the time of query, and average duration. In addition, Google Maps Direction API

monopoly power (increasing as they become the last holdout) to seek higher compensation, leading to project delays and inflated costs (Posner and Weyl 2017). In the Kampala context, owners may still holdout until they get the eminent domain payment, but they would not be able to extract more than the ex-ante market value of their property. I abstract from the time dimension in this analysis.

[9] The Uganda government started to digitize the national land registry to decrease the number of land fraud cases in 2013, but, as of 2023, this process had not been finalized yet.

includes a list of coordinates approximately mapping the path between origin and destination. I sample trips with three distinct goals:

1. Impact of road upgrades on local speed (road level): 248 roads ($248 \times 2 = 596$ unique trips, both ways) were selected to compare car speed on upgraded and to be upgraded roads. These roads include 46 roads targeted by the policy and used in the main analysis, as well as as a subset of roads mentioned in earlier road improvement plans but not ultimately upgraded.[10]

2. Average speed by road category across the city: trips between neighboring 1000×1000 meter grid cells in Kampala were mapped to the underlying OSM road network to recover the average speed by road category (results presented in Table A3). The short distance of these trips between neighboring locations limits optimization through route choice and ensures that my trip sample covers all road types in Kampala. The location of the grid cells is displayed on Appendix Figure A4.

3. Change in shortest path in response to road upgrades: I mapped trips between all pairs of Kampala parish centroids ($9,216$ unique trips) to the underlying OSM road network to provide evidence that a road is more likely to be used for a given trip after being upgraded. In Appendix D.2, I show how the share of a trip's length happening on roads in the later wave of the policy, which start to get upgraded over the course of the Google Maps sample, increases over time, while no such relationship exists for roads upgraded before the start of the sample.

I recover that the average speed in Kampala across all pairs of parishes (unweighted) is 24.4 km/h (26.8 km/h at non-rush hour and 22.0 km/h at rush hour). This corresponds to cities at the 25^{th} percentile of the world speed city distribution (Akbar et al. 2023). Improving road speed is thus a first order concern in Kampala.

2.2.2 Ride-Sharing Data

To study how workers will adjust their location choice in response to a change in commuting time, I partner with a local ride hailing company running a popular app with more than $30,000$ rides per day.[11] I have access to the universe of motorcycle trips for a random sample of weeks between 2019 and 2024. As described in Table 1, my sample covers 95 days (5% of the period) and includes 2.3 million trips and more than $330,000$ unique users (about 38% of the adult population in Kampala's 2014 Population Census). These users take an average of 6.9 trips on the app, but the standard deviation is very large (104), indicative of a subset of riders using the app daily, and consistent with 39% of users taking at least 5 trips on the app in my sample. The average trip costs $1.47, lasts 21 minutes for a straight line distance of 5 kilometers. In addition, as displayed on Appendix Figure A7, most trips at morning commuting hours (6 am - 10 am) originate from the outskirts of the city to end at the city center. This commuting pattern towards the city center is consistent with the location of jobs from the Uganda Census of Business of Establishments displayed on Figure 6 Panel (b), but residents originating the northern part of the city are overrepresented among morning commuters, compared to the universe of Kampala residents (Figure

[10] These roads were selected based on information available as of March 2023, and thus may not include roads whose upgrade was decided later.

[11] Safeboda has been operating in Kampala since 2019, and dominates the app-based ride hailing market for motorcycle rides.

6, Panel a).

Table 1: Ride-Hailing Descriptive Statistics

	Total		Per Month	
	Count / Mean	sd	Count / Mean	sd
Sample				
Number of Days Covered	95			
Share of Days Covered	0.05			
Trips				
Number of Trips	2,284,986		163,213	57,747
Length of Trip (min)	20.66	12.6	20.79	0.72
Straight Line distance (km)	5.01	2.89	5.15	0.47
Price (USD)	1.47	1.63	1.59	0.37
Users				
Number of Users	330,426		163,213	57,747
Avg Nb Trips per User	6.9	104.2	2.7	31.3
Share of users w/ more than 5 trips	0.39		0.15	

Notes: Descriptive statistics from the ride hailing data. The sample covers a random sample of weeks between 2019 and 2024. Motorcycle rides only are included in the sample.

2.2.3 New Broker Survey

Data on property values is not usually readily available in developing country cities like Kampala, so I collect my own data by interviewing 377 real estate brokers in 89 of Kampala's 96 parishes in March-April 2024, as described in Appendix Figure A10. Descriptive statistics are displayed in Table 2. My respondents are brokers with an average of 14 years of experience, and 76% of them operate in multiple parishes (neighborhoods). In the 3 months preceding the interview, the average broker rented 11.3 properties and sold 1.9 properties. The survey is designed with two goals in mind.

First, to characterize property values over space and track their changes over time, I ask brokers about retrospective transactions (sales and rentals). The final database includes about $3,250$ properties, transacted between 2018 and 2024 all over Kampala. For each property, available information includes the transaction date (month, year), location (parish, village, closest road, distance to closest road) and a comprehensive set of property characteristics. The average bare land property in my sample is sold for $\$59,262$, which corresponds to an average price/m^2 of $142, or about $1/4^{th}$ of the rate per m^2 for land in Delhi (Statista). There is a lot of variation in the sales prices and monthly rents of properties across parishes. To build confidence in my data, I also compare these past transactions to scrapped online data of high-end properties. In appendix F,. I show that my novel survey data is positively correlated with data from the online platform, but has a better spatial coverage and is more representative.

Second, I obtain additional reduced-form evidence of the local impacts of road improvement and distance from roads on property values from an appraisal exercise. Brokers are presented with a standardized property (business or residential) and asked to estimate its sales price varying one characteristic at the time, including whether the road by the property is upgraded or not. In Appendix F, I further describe the sampling strategy and sample characteristics.

Table 2: Broker Survey's Descriptive Statistics

	Mean	Sd	Median
Number of brokers	377		
Number of brokers per parish	3.92	1.79	4
Panel A: Broker characteristics			
Age	42	8.9	
Years operating as brokers	14	10.1	
Share of brokers operating in multiple parishes	0.76		
Panel B: Activity			
Number of properties rented in the past 3 months in Kampala	11.32	18.09	
Number of properties sold in the past 3 months in Kampala	1.89	2.68	
Past Transactions (USD)			
Price - rented residential	206	335	108
Price - rented business	218	337	
Price - sold residential	70472	60550	54054
Price - sold business	78019	72479	
Price - sold land	59262	55035	40541
Price / m2 - sold residential	203	384	131
Price / m2 - sold business	330	554	184
Price / m2 - sold land	142	206	97
Appraisal Exercise - Standardized res property near road			
Relative sales price post upgrade	1.318	0.58	1.25

Notes: The descriptive statistics in this table come from the real estate broker survey. Panels A and B describe the characteristics of the respondents. Panel C describes the properties transacted by the respondents and panel D includes information about the impact of road upgrade on the hypothetical price of the standardized property.

2.2.4 New Owner Survey

The second component of land costs is the share of owners getting compensated. As I do not have access to the comprehensive land acquisition data from the Kampala Capital City Authority, I collect data on the land acquisition process by surveying land and property owners (hereafter owners) along segments of 87 road in Kampala. I interview a random sample of owners on upgraded roads and roads in the process of being upgraded.[12] More details on the selection of road segments and the sampling strategy are available in Appendix C, and descriptive statistics about the data are displayed in Table 3.

A total of 772 respondents were interviewed on roads targeted by upgrades since 2017. Among them, 612 were on the sides of roads upgraded in the past and 160 were on the sides of roads to be upgraded in the

[12] Because of the different land tenure systems in Kampala, not all house owners own the underlying land. Yet, under the legal regime, these owners must be compensated (or consent) if their property is affected by public work, and are thus valid respondents for our study.

near future, and owners with plots under each of the three property right regimes (leasehold, freehold, mailo) were interviewed. The average respondent had owned that property for 36 years, and 41% of them had purchased the property, as opposed to inherited it. The large share of owners having inherited their property, higher for freehold (0.64) and mailo (0.6) than for leasehold (0.5) is consistent with the very high reported cost of obtaining a copy of ownership documents, which is also higher for freehold an mailo than for leaseholds. This cost indeed often entails hiring a lawyer, going to court, obtaining certified copies, recovering old land titles that had never been accounted for, etc. As further discussed in Appendix Section C.3, the average owner in my survey is wealthier than the average Kampala resident (2014 Population Census and 2019 Uganda National Panel Survey), which is consistent with landowners being wealthier than non-landowners.

The property of 548 of these owners had been or was being affected by the road upgrade, on average by 73 m^2. 80% of respondents consented to give this land without getting compensated, and this probability is higher for freehold and mailo owners than for leasehold, who were more likely to negotiate to get compensated. The average owner (including both owners who consented, and those who did not) believed that they could get a higher compensation by not consenting for at least six months with probability 0.31 and this probability is the highest for leasehold owners.

In the survey, respondents are also asked about current and historical road quality, past and ongoing road updates, land acquisition, as well as property and neighborhood characteristics.

Table 3: Owner Survey's Descriptive Statistics

	Overall	Leasehold	Freehold	Mailo
Panel A: Sample Characteristics				
Number of owners	548	127	112	293
Share on already upgraded roads	0.78	0.68	0.63	0.87
Car ownership (share)	0.4	0.25	0.48	0.42
Panel B: Property Characteristics				
Purchased property (share)	0.41	0.5	0.36	0.4
Tenure (years)	35.5	35.2	38.9	34
Cost Copy of Ownership Documents (USD)	1750	1111	2651	1653
Panel C: Land Acquisition				
Land Affected (m2)	72.7	50.33	79.68	80.62
Negotiated Over Initial Compensation Offer (share)	0.2	0.28	0.16	0.18
Perceived Probability to Increase Compensation if Negotiation	0.31	0.38	0.24	0.3

Notes: Descriptive statistics are from the owner survey, restricted to the 548 respondents (out of 772) whose property or land was affected by the road upgrade.

3 Empirical Evidence on the Benefits and Costs of Road Improvements

Equipped with this new data and using variation in the timing of road upgrades and heterogeneity in property right regimes in the city, I estimate the local benefits and land costs of road improvements in Kampala. I show that road upgrades increased local speed and local property values. The associated land costs were heterogeneous across locations.

3.1 Local Benefits of Road Improvements

3.1.1 Impact of Road Improvements on Local Road Speed

The impact of road improvement on local speed is an important outcome of interest for two reasons. First, it is a reduced-form measure of the most direct impact of the intervention, which may be very different than in the U.S. given the prevalence of unpaved roads at baseline in African cities. Second, it is a key input into the model that I estimate in Section 5 to recover the full returns of the policy.

To recover the impact of road improvements on local speed, I compare speed on upgraded and non-upgraded roads. I restrict my sample to roads being upgraded as part of the policy, which includes roads upgraded before the start of my data in March 2023, roads upgraded between the start and end of my data in August 2024, and roads whose upgrade hasn't started yet.[13] I run the following regression:

$$\mathrm{s}_{h,d,r} = \alpha + \beta \times \mathrm{D}_{d,r} + \beta \times \mathrm{l}_{h,d,r} + \mathbf{X_r}'\psi^{\mathbf{x}} + \gamma_h + \gamma_d + \epsilon_{h,d,r} \tag{1}$$

where the dependent variable $s_{h,d,r}$ is the GoogleMap estimated traffic speed on road r, day d at hour h in km/h, $\mathrm{D}_{d,r}$ is a dummy variable equal to 1 if road r was upgraded by day d, $\mathrm{l}_{h,d,r}$ is the length of the trip (in km), $\mathbf{X}_r$ is a vector of road-level characteristics, including road origin and destination coordinates or road fixed effect. I also control for whether the road was under construction on day d. I include hour and day fixed-effects to control for traffic patterns being highly variable over time.[14] Standard errors are clustered at the road and day of query levels to reflect sampling. I further split the sample between rush hour trips and non-rush hour trips to isolate the direct impact of the road improvement. I further discuss alternative specifications in Appendix A8.

Because my Google Maps data covers the period between March 2023 and August 2024 and many roads were already upgraded by March 2023, most of the variation used to identify β is cross-sectional and comes from comparing roads that were upgraded early (before the start of the Google Maps sample), and roads upgraded late (during or after the Google Maps sample). Thus, in the main specification, to interpret β as the average treatment effect on the treated (ATT), I need to assume that roads were not selected into early or late upgrade based on the predicted increase in free flow speed, conditional on observable

[13] I do not have road-level trips for a representative sample of all roads in Kampala, and I cannot control well for road quality beyond its OSM category and a dummy for whether that road is paved. Thus, to isolate the impact of the policy on speed, rather than confounding the effect of selection into the policy, I only include roads part of the policy.

[14] In addition, my panel is unbalanced at the hour-day level, as I could not query trips for all roads for each hour-day due to restrictions on the frequency of Google Maps API queries. Thus, including hour and day fixed-effects controls for potential sample bias across hours and days.

characteristics. Note that this assumption does not require that the selection of roads into early vs late wave is orthogonal to the predicted impact of the upgrade on economic activity or overall traffic flows, but instead that the timing was not based on the predicted impact on local speed in non-rush hour.[15] A subset of roads got upgraded between the start and end of my panel, allowing me to also run a specification with road fixed-effects. Standard errors increase because the identifying variation comes only from a subset of roads, but the ATT identification assumption is weaker than in the absence of road fixed-effects and only relies on the exact timing of the specific road upgrade (e.g. segment) being conditionally random. To further interpret β as the Average Treatment Effect (ATE), I further need to assume that the above assumptions would hold for the average road in Kampala.

I present regression results in Table 4. I estimate the reduced-form impact of any road improvement (dummy variable) on traffic speed, including road-level controls. In column 1, where the sample includes all the GoogleMaps trips on these policy roads, I estimate that road upgrade increases speed by an average of 3.8***km/h, or 18% of the average speed in Kampala. This effect is large: if average speed in Kampala increased by 3.8 km/h, this would take Kampala from the 25^{th} percentile of the speed distribution among cities worldwide, to the 50^{th} percentile (Akbar et al. 2023). In columns 2 and 3, I split this effect by non-rush hour and rush hour trips, respectively. The effect of road upgrade on traffic speed is larger at non-rush hour (4.4***km/h) than at rush hour (2.6***km/h), consistent with road upgrades increasing traffic flows at rush hour, mitigating the speed increase. Road upgrades improving rush hour speed is consistent with Akbar et al. (2023) who find a positive relationship between city-level road quality and both congested (rush hour) and uncongested (non-rush hour) traffic speed. In Appendix Table A9, I estimate the elasticity of speed on road width using analogous specifications as in columns 1 to 3. This elasticity is a key input in my structural model and I discuss it in more details in Section 5.1.1. In Appendix A8, I show that these results are robust to alternative sets of controls, and to including road fixed effects.

Table 4: Impact of Road Improvement on Traffic Speed

	Dependent variable:		
	Traffic Speed (km/h)		
	(1)	(2)	(3)
Upgraded (d)	3.817***	4.449***	2.616***
	(0.673)	(0.859)	(0.612)
In Progress (d)	−1.299	−1.319	−1.283
	(1.105)	(1.264)	(0.907)
Sample	All	Non-Rush	Rush
Day + Hour FE	Y	Y	Y
SE Clustered	road+day	road+day	road+day
Observations	1,108	682	426
R^2	0.446	0.473	0.407

Notes: Standard errors are displayed in parentheses and clustered at the road and day levels, with significance levels $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Observations are at the road level (trips covering a single road) from Google Maps API queried between 2023/03/17 and 2024/06/30. All columns include flexible geographic controls: longitude, longitude^2, latitude, latitude^2 of the trip's origin and trip length. Rush hour is defined as 6 to 9am and 4 to 7pm.

[15] In Appendix Table A8, where I also discuss the impact on speed for rush-hour trips, the assumption is stronger, as it now accounts for existing and predicted traffic flows (which may affect rush hour speed). In that case, if timing was based on existing flows—with the busiest roads upgraded first—the bias may go both ways, depending on the congestion technology.

3.1.2 Impact of Road Improvements on Local Property Values

Property Appraisal: Real estate broker survey respondents were asked to assess the contemporary market value of a standardized property (residential or business) where the property's characteristics were varied one at the time (full description in Appendix F). I compare the assessed sales price of that property in the immediate vicinity of a road if that road is not upgraded (e.g. unpaved), and if that road gets upgraded.[16] The regression results are displayed in columns 1 and 2 of Table 5, and the distribution of answers is relegated to Appendix Figure A8. Brokers estimate that a road upgrade increases the price of this standardized property by 25% on average for the standardized residential property (column 1) and 27% for the standardized business property (column 2).

Focusing on residential properties, evaluated at the median property value in the past transaction database ($\$54,000$), and assuming that each property spans an average of 50 meters along these roads, 140 km of road upgrades would have increased the total value of properties by the side of the road by about $76 million (broker appraisal), which is slightly below the corresponding construction costs of $80 million.[17]

Table 5: Broker Appraisal: Impact of Road Improvement on Local Property Values

	Dependent variable:					
	Log Price					
	(1)	(2)	(3)	(4)	(5)	(6)
Post road upgrade	0.224***	0.224***	0.224***	0.237*	0.237***	0.237***
	(0.028)	(0.032)	(0.028)	(0.129)	(0.042)	(0.036)
Property Type	Res	Res	Res	Bus	Bus	Bus
FE		Parish	Respondent		Parish	Respondent
Observations	354	354	354	304	304	304
R^2	0.008	0.693	0.978	0.011	0.770	0.962
Adjusted R^2	0.005	0.606	0.955	0.008	0.693	0.923
Residual Std. Error	1.235 (df = 352)	0.778 (df = 275)	0.262 (df = 176)	1.125 (df = 302)	0.626 (df = 227)	0.313 (df = 151)

Notes: Standard errors are displayed in parentheses, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Columns 1 and 2 include broker fixed-effects. Brokers were randomly asked about either the standard residential or the standard business property.

Importantly, this increase in local property values captures two potential impacts of road improvements: the change in the property's accessibility and the change in local amenities. Indeed, interviewed owners on the side of upgraded roads confirm that these improvements had positive impacts on road quality, but also decreases flooding and dust (Appendix Figure A11), all of these amenities being local. Therefore, while this is a helpful sufficient statistic to measure the local benefits of road upgrades, fixing property characteristics, it does not capture the impact of the road upgrade on farther away properties through spatial spillovers and general equilibrium effects. I estimate this full effect in Section 5.2 leveraging a quantitative spatial model.

Transacted Properties: Next, I leverage the database of past transactions from the broker survey to shed additional light on the impact of road improvements on property values. More specifically, I run the following regression:

$$\log \mathrm{Q}_{i,b,p,t} = \alpha + \beta \times \mathrm{D}_{p,t} + \mathbf{X_i'} \cdot \eta^{\mathbf{X}} + \mathbf{Z_p} \cdot \eta^{\mathbf{Z}} + \gamma_t + e_{i,b,p,t} \tag{2}$$

[16]Brokers are asked to think of that property in a typical location of their parish, so the road upgrade is hypothetical.

[17]The average width spanned by properties in my owner survey is 48m. $\$572,000$ per km $\times$ 140 km.

where $Q_{i,b,k,p,t}$ is the sales price of property i, transacted by broker b in parish p at time t, X_i is a vector of property i's characteristics and Z_p is a vector of location p's characteristics, potentially including division fixed-effects or parish-level controls. Parish-level controls include log 2010 population, share of residents with permanent flooring (2014 Census), and the share of land surface built (2015 Global Human Settlement Layer). γ_t is a vector of time (month and year) fixed-effects. Property characteristics X_i include {floor type, number of bathrooms, distance to the closest main road, log(land dimensions), formal (dummy), building type, presence of buildings in addition to the main one (dummy)}, as well as missing dummies for these controls. Standard errors are clustered as in Conley (1999).[18] $D_{p,t}$ is a dummy variable equal to 1 if parish p had received a road improvement by time t. As variation in $D_{p,t}$ is both temporal and spatial, β captures both the effect of a road being upgraded in parish p, as well as some general equilibrium impact on control locations. These general equilibrium effects may bias estimates down if the neighboring locations benefit from the road upgrade, or bias estimates up if the neighboring locations become less attractive.

To interpret β as the causal effect of a road improvement in parish p on property values in that parish, I need to assume that road improvements did not target parishes with differential trends in property values (no selection) and did not come with other place-based policies. This condition would be violated if the road improvements targeted specific locations based on returns, but, reassuringly, policy-documents emphasize the goal of improving traffic flows and connectedness in the city, rather than road upgrades being used as place-based policy. Still, I include parish socio-economic characteristics from the 2014 Census to control for selection based on observable characteristics. In an alternative specification, I instead restrict my sample to parishes that received a road improvement at some point (ever-treated), so as to leverage the exact timing of these road improvements rather than their location and address concerns that parishes receiving road upgrades would be different along unobservable characteristics. Ideally, I would want to run an event study at the parish level, including parish fixed-effects. However, I am not powered to do so, as I have too few properties transacted by parish in my database.

I present the results in Table 6. In column 1, I do not include any parish or location control and I estimate that properties sold after a road upgrade in the parish (dummy) commanded a 17% premium (0.157***). This estimate is relatively robust to adding socio-economic controls at the parish level (column 2) and division fixed-effects (column 3). To address the concern that locations targeted by road upgrades were fundamentally different than locations that did not receive road upgrades, in column 4 I restrict my sample to parishes that received a road upgrade since 2017 (*ever-treated*), de facto comparing properties sold in parishes with early vs late upgrades. The identification assumption in column 4 is thus that there is no selection on the timing of road upgrades. This parish-level estimate is about 60% of the estimate from the broker appraisal exercise on properties on the side of upgraded, which is consistent with some of these local benefits being local and only affecting properties in the immediate vicinity of the road, rather than properties all over the parish.

[18] Each observation's location is defined at the centroid of its parish. I define a 3000 meter threshold, so that on average, one parish has 18% of the other parishes within that cutoff

Table 6: Past Transactions: Impact of Road Improvements on Property Values

	Dependent variable:			
	Log Sales Price (USD)			
	(1)	(2)	(3)	(4)
Post Road Upgrade (dummy)	0.157***	0.142***	0.156***	0.188***
	(0.006)	(0.007)	(0.003)	(0.019)
Division FE			Y	Y
Parish controls		Y	Y	Y
Sample	All	All	All	Ever-treated
Mean Sales Price (USD)	77,500	77,500	77,500	75,884
Observations	1184	988	952	234
R2	0.43	0.44	0.49	0.58

Notes: Conley SHAC Standard errors are displayed in parentheses, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. I use 3000 meters as the cutoff distance for spatial correlation so that on average, one parish has 18% of the other parishes within that cutoff. All specifications include controls for property characteristics {floor type, number of bathrooms, distance to the closest main road, log(land dimensions), formal (dummy), building type, presence of buildings in addition to the main one (dummy)}, as well as missing dummies for these controls. Parish-level controls in columns 2 to 4 include flexible geographical controls {longitude, latitude, longitude^2, latitude^2} and pre-policy socio-economic controls {log 2010 population, share of residents with permanent flooring (2014 Census), share of land surface built (2015 Global Human Settlement Layer)}. There are 5 divisions in Kampala and 96 parishes. The sample of transacted properties span 86 parishes.

3.2 High and Heterogeneous Land Costs

While road improvements had benefits, they also had high and spatially heterogeneous land acquisition costs, driven by property values and by the probability that owners get paid. The latter depends on both the amount of land affected and owners' property right regimes. I characterize these two components using data from both the broker and owner surveys.

3.2.1 High and Heterogeneous Market Value of Affected Land

Under eminent domain, owners would be compensated at market value. In my survey, road improvements claimed a portion of the land or property of 548 owners. These owners report an average of 73m^2 of their land being taken up by the road upgrade (Table 3). Given that the average property in the survey spans 48 meters along the road, this is equivalent to about 1.5 meter of land being taken on each side of the road, about one additional lane of average width 3.2 meters (KCCA), and a total of approximately $5,600$ owners affected in total.

The market value of that land is substantial. From the broker survey, I estimate that the average sales price per m^2 for residential land properties is \$171.7 (median \$152.3). To recover the total market value of affected land, I take the average land market rate for each parish and I assume that 1.6 meters were affected on average per owner. The corresponding parish-level predicted affected land market value per owner is displayed on Appendix Figure A16. Summing over all upgrades, this corresponds to $210,000$ m^2 of land, \$65 million, or about 2/3 of the construction costs and \$$9,600$ for the median owner.

3.2.2 Heterogeneous Share of Owners Giving Their Land Without Compensation

Under the *voluntary land take* approach, however, owners do not get paid if they consent to donate their piece of land without compensation. Among the 548 affected owners in my survey, 77% reported not being initially offered a financial compensation, and yet, 79% of them consented to forfeit their land within less than 6 months (hereafter "*accepted*" as opposed to "*negotiated*").[19] There are two types of reasons given by respondents for accepting to forfeit a piece of their land (on average 73m^2). First, are genuine benefits from the road improvements, either for the community (69%) or in terms of improved local amenities (44%). Second, however, $1/3^{rd}$ of owners report not negotiating because they were powerless, which is consistent with only 31% of owners believing that they would be able to get a compensation by negotiating (Table 3). Respondents' emphasis on their low ability to get compensated is consistent with property rights being weak on average, as highlighted in multiple policy reports. On the other hand, the top three reasons given by owners negotiating are: being entitled by law (55%), wanting to get a "piece of the pie" (34%), and being asked to give too much land without compensation (27%). The full distributions of reasons given by owners to negotiate or consent are displayed in Appendix Figures A12 and A13.

There is a significant heterogeneity in where these negotiations are happening, and one dimension of heterogeneity is the plot's property right regime. Indeed, to get compensated, owners must prove their ownership rights, but doing so is costly and this cost differs across the different property right regimes in Kampala. As summarized in Table 3, owners on leasehold land report a cost of getting a copy of ownership documents 33% lower than mailo and 58% lower than freehold owners. In turn, leasehold owners are 55% and 75% more likely to negotiate than mailo and freehold owners, respectively.

To isolate the impact of each property right from other factors like the amount of land being affected, I model the probability that owner o in location i negotiates in order to get compensated γ_{oi}^{N}, as opposed to consenting to donate their piece of land without compensation. I model this decision as the probability that the potential gains from negotiating—the market rate q_i times the amount of land being taken ΔH_{oi}, as per the eminent domain legal framework—is greater than the costs of negotiating. The average residential property rate per m^2, q_i, is recovered from the broker survey. This cost depends on owners' property right regime Z_{oi}, and some idiosyncratic cost ϵ_{oi}, such that

$$\gamma_{oi}^{N} = \mathbf{P}\left(\alpha_1 \times q_i \times \Delta H_{oi} - \alpha_0 T_{oi}^{0} \geq Z_{oi}^{'}\mu_Z + \epsilon_{oi}\right), \tag{3}$$

where I control for whether owners were initially offered some financial compensation T_{oi}^{0}. I assume that ϵ_{ok} is logistic distributed (0,1) and I estimate the parameters of the model $\{\alpha_1, \alpha_0, \mu_Z\}$ through maximum likelihood. The eminent domain imposes an upper bound on compensation, ruling out owner holdout. This is consistent with evidence from the survey where owners were asked how likely they believed the road would be upgraded on a scale of 0 to 5. 96% and 89% of owners stated that the road had more than 80% (4 out of 5) changes to be upgraded if they accepted the government's offer right away, or negotiated, respectively. The full distribution of answers is displayed in Appendix Figure A14.

[19]These numbers are consistent with administrative data I have access to on a subset of roads. Matching the universe of affected owners to dated consents, I find that 22% (33%) of affected owners had consented within 30 (90) days (from the day the first owner on that road consented).This number is likely biased downwards as not all consents in the database could be matched to the universe of affected owners.

There are two key parameters to estimate. First, α_1 governs the elasticity of owners' negotiation probability γ_{oi}^N on the market value of the affected land, or the extent to which owners respond to different values and amounts of their land being encroached upon. To causally estimate this parameter, I need to assume that there is no selection of ΔH_{oi} or q_i conditional on Z_{oi}, T_{oi}. The amount of affected land ΔH_{oi} is determined by engineering studies before the start of the road construction and to the extent that it is reported with measurement error by survey respondents, I assume that this measurement error is classical. In other words, I assume that consenting respondents do not systematically over- or underestimate ΔH_{oi} compared to negotiating respondents. In addition, I need to assume that there is no omitted variable bias at the parish level, so q_i is orthogonal to ϵ_{oi}. Importantly, to identify α_1, I use both across-road and within-road variation. In the former, both ΔH_{oi} and q_i vary, while in the latter, all the variation comes from ΔH_{oi} (e.g. differences in the amount of land affected across two neighboring owners on the same road) as q_i is defined at the parish level. Differences in the amount of land affected across two neighboring owners on the same road may come from uneven initial or final road width or from some plots encroaching on the existing road, which is common due to the unplanned nature of historical urban development in Kampala. If parishes with low property value q_i were also home of owners less likely to negotiate, conditional on owner and parish characteristics including property right regimes, then my estimate of α_1 would be biased upward.

The second parameter of interest, μ_z, governs the relationship between the different property right regimes and owners' negotiation. As the different regimes are pre-determined to the policy, the estimated coefficient captures their overall effect on owners' decision. As those regimes may be correlated with other observables likely to affect owners' negotiation, including owners' wealth and their social integration in the community, to isolate the impact of property right regimes on negotiation probability, I include controls for owners' wealth and social integration in some specifications. Overall, to interpret this coefficient as the causal effect of different levels of property rights, I need to assume that my controls—which include owner-level and parish-level socio-economic characteristics and geography—are capturing potential owner sorting, as well as all other aspects of the different regimes, including heterogeneous historical economic development (Bird and Venables 2020).

The results are presented in Table 7, with non-dummy regressors standardized for interpretation. In column 1, without any parish level control, I estimate $\hat{\alpha_1} = 0.316^{***}$, which corresponds to a 37% increase in the odds of negotiating for the average owner in response to a one standard deviation in the market value of owners' affected land. This number is robust to including parish-level geographical (latitude, longitude, latitude^2, longitude^2) and socio-economic (wealth index, 2014 population and the share of owner occupied properties) in column 2 and division fixed-effects in columns 3 and 4. In column 5, when including parish fixed effect, all variation comes from within-parish differences in the amount of affected land (as q_i is fixed within parish) and, while I am less powered statistically, the estimate does not appear to be statistically different.

Moving on to the role of property right regimes, I find that compared to owners on leasehold land—the strongest property rights and reference category—owners on Mailo and Freehold land had lower odds of negotiating, with estimated coefficients -0.673^{***} and -0.667^{**} in the absence of parish-level controls in column 1, respectively. The coefficient on mailo is robust to including parish-level controls (column

2), division fixed-effects (column 3) and owner-level controls (column 4), and the coefficient on freehold jumps to -1.253^{***} (column 2) and up to -1.442^{**} (column 4), consistent with freehold neighborhoods having different socio-economic characteristics. Given the limited within-parish variation in property right regimes, I am not powered to estimate these coefficients precisely with parish fixed-effects (column 4). Noticeably, the estimates on mailo and freehold are about 40% and 30% lower than the coefficients in columns 1-3. However, the identifying variation comes only from 42% of the respondents in parishes with at least 2 distinct property rights regimes (29% of the parishes), and the estimated coefficients are not statistically different than when variation from the whole sample is used for identification.[20]

With these estimates, I predict the share of negotiating owners in each parish and the corresponding payment for owners. The distribution of owner-level payment plotted on Figure 3 highlights the shift in land acquisition costs under *voluntary land take* to the left (orange), compared to payment at market value (green). I estimate that under *voluntary land take*, total land costs are equal to $18 million.

Taking stock, I estimate that the benefits of road improvements in terms of property values by the side of improved roads sums to $67 million (broker appraisal). The market value of affected land acquired from private owners is around $65 million, consistent with local owners benefiting only marginally from the road improvements. Even if land was acquired under voluntary land take for $18 million, the construction costs of $80 million would imply negative net returns for these investments if the benefits were only local. However, road improvements have positive externalities throughout the whole city, as roads are used by workers to commute between their residence and workplace. Hence increasing local road infrastructure benefits workers all over the city by decreasing commuting costs. To properly account for spatial spillovers, and study how the costs and benefits of road improvements interact, in Section 4 I build a quantitative spatial model of optimal road improvement with land acquisition.

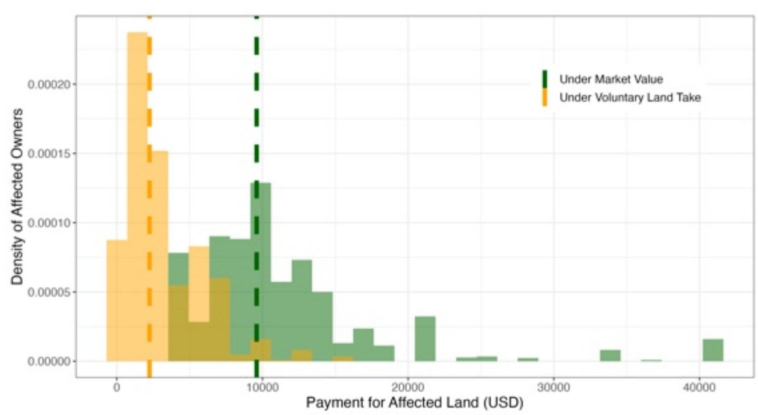
[20] These findings are consistent with estimates from administrative data I have access to for a subset of roads part of the last wave of road upgrading (KCRRP). I find that the more land affected, the less likely owners are to have consented within 90 days (from the day the first owner on that road consented): going from the first to the last quintile in terms of amount of affected land decreases the probability to have consented within 90 days by 6 percentage points. I also find that owners under the "customary" (no land title) property right regimes are 13-19 percentage point more likely to have consented within 90 days than titled owners. Unfortunately, this administrative data does not include the exact location of plots, so I cannot match it to my data on property right regimes.

Table 7: Drivers of Negotiation and Delays - Owner Survey

	Propensity to Negotiate				
	(1)	(2)	(3)	(4)	(5)
Market Value Affected Land	0.316***	0.324***	0.326***	0.367***	0.251*
	(0.106)	(0.107)	(0.108)	(0.121)	(0.134)
Tenure Mailo	-0.673***	-0.689***	-0.684***	-0.681*	-0.395
	(0.249)	(0.255)	(0.257)	(0.365)	(0.516)
Tenure Freehold	-0.667**	-1.253***	-1.285**	-1.442**	-0.874
	(0.327)	(0.4)	(0.516)	(0.62)	(1.266)
Any Compensation Initially Offered	-0.541*	-0.757**	-0.813**	-0.816**	-0.456
	(0.308)	(0.319)	(0.327)	(0.362)	(0.423)
Observations	544	544	544	540	443
Ref Tenure	Leasehold	Leasehold	Leasehold	Leasehold	Leasehold
Geo FE			Division	Division	Parish
Parish Geo Controls		Y	Y	Y	
Parish SocioEcon Controls		Y	Y	Y	
Owner SocioEcon Controls				Y	Y

Notes: The coefficients of equation (3), estimated through maximum likelihood are presented in this table. In column 1, I do not include any other control than the ones presented in the table. In columns 2,3 and 4, I include parish-level geographical (latitude, longitude, latitude^2, longitude^2) and socio-economic (wealth index, 2014 population and the share of owner occupied properties) controls. The parish-level wealth index is a standardized index made of the share of residents (above 18 y.o.) who are literate, the share of housing units with a permanent floor, the share of households owning a computer, the share of households owning a bicycle, the inverse of the share of households within distance of a secondary public school, the share of households who have had a bank account in the past 12 months and the share of households who reporting using any mosquito net. In column 4, I include an owner-level wealth index and an owner-level social-integration index to control for owners' covariates that may be correlated with property right regimes and influencing owners' decision. In column 5, the sample is restricted to respondents with non-missing parishes and in parishes with at least one observation. The market value of affected land is standardized so as to yield mean 0 and standard deviation 1. Source: own survey.

Figure 3: Owner-Level Predicted Land Costs For Realized Road Upgrades



Notes: I plot the distribution of (owner-level) land costs for the realized road upgrades, when payment is made at market value (green) or under the voluntary land take existing system (orange). I assume that each owner is affected by $75m^2$ (50m long over 1.5m wide), and that they are compensated at the median parish-level residential rate as recovered from the broker survey. To build the orange distribution, I further predict the share of owners negotiating in each parish given this amount of affected land and residential rate, as well as the parish coordinates and property right regimes (Table 7, column 2).

4 Model

I propose a static general equilibrium model of a city, populated by a fixed number of households who choose where to live, work, and which route to commute on. Commuting happens on a road network, that connects neighboring locations. The road network takes up land, so that in each location, residential use and road infrastructure compete for land. Residential land is owned by private owners. These owners may be compensated if their land is transformed into roads and they do not give it up for free. A city government determines the optimal road improvement to maximize city residents' welfare, tying together the spatially heterogeneous benefits and land costs of road improvements.

4.1 Quantitative Spatial Model of Optimal Road Improvements with Land Acquisition

Environment

The city is composed of distinct locations, indexed by $i, j \in \mathcal{J}$. Locations are connected through a road network (undirected graph), where each location i is connected to $\mathcal{C}(i)$ other locations. Workers must use this road network to commute. Locations are endowed with fixed amounts of land H_i as well as exogenous residential amenities B_i, productivity A_j, and landowners' property rights Z_i. Each link between neighboring locations kl has a baseline amount of road infrastructure of width R^0_{kl} (meters).

Land

At baseline, in each location i, total land H_i is divided between private residential land H_i^{r} and public road land H_i^{p}, such that:

$$H_i = H_i^{\mathrm{r}} + H_i^{\mathrm{p}} \quad \forall i. \tag{4}$$

Road land H_i^{p} is the sum of the area used by roads of width R_{mi} and length in l_{mi}, connecting i to neighboring locations $m \in \mathcal{C}_i$ and assuming that the road is split equally across the two locations,

$$H_i^p = \sum_{m \in \mathcal{C}_i} R_{mi} \times \frac{\mathrm{l}_{mi}}{2} \quad \forall i. \tag{5}$$

Land Owners

Residential land H_i^{r} is owned by N_i^o local immobile representative landowners who get utility from consuming the freely tradeable good. Owners in location i share rental income $H_i^{\mathrm{r}} \times q_i$, taxed at rate ϕ, plus a transfer from the government T_i, such that each owner's welfare is given by

$$W_i^o = \frac{H_i^{\mathrm{r}} q_i \left(1 - \phi\right) + T_i}{N_i^o}. \tag{6}$$

Workers

The city is inhabited by a fixed mass $\bar{L}$ of mobile workers who choose where to live i, work j, their commuting route r, as well as how much to consume of the tradeable good C_{ij} and housing H_{ij} to solve their budget constraint:

$$\max_{i,j,C_{ij},H_{ij}} U_{ij,r} = B_i \left(\frac{C_{ij}}{\beta}\right)^{\beta} \left(\frac{H_{ij}}{1-\beta}\right)^{1-\beta} \epsilon_{ij}. \tag{7}$$
$$\text{s.t.} \quad \frac{w_j}{\tau_{ij}} = C_{ij} + H_{ij} q_i.$$

q_i is the rental rate in location i, B_i the residential amenity in location i, w_j the wage in location j and τ_{ij} the average iceberg commuting costs between i and j. Commuting costs τ_{ij} between their residence i and workplace j decrease workers' available income $\frac{w_j}{\tau_{ij}}$. ϵ_{ij} is a preference shock over the pair ij drawn from a Frechet distribution with shape parameter θ. In equilibrium, workers' expected welfare W^w is equalized over space, so that

$$W^{\mathrm{w}} \equiv \left(\sum_{ij} \left(\frac{B_i\, w_j}{{q_i}^{1-\beta}\, \tau_{ij}}\right)^{\theta}\right)^{\frac{1}{\theta}}. \tag{8}$$

The larger θ, the more responsive are workers to local economic conditions given by $\frac{B_i\, w_j}{{q_i}^{1-\beta}\, \tau_{ij}}$, as their idiosyncratic preferences are less dispersed.

These preferences imply that the number of workers commuting from i to j in equilibrium is given by

$$L_{ij} = \bar{L} \frac{\left(\frac{B_i\, w_j}{q_i^{1-\beta}\, \tau_{ij}}\right)^{\theta}}{\sum_{mn} \left(\frac{B_m\, w_n}{q_m^{1-\beta}\, \tau_{mn}}\right)^{\theta}} = \bar{L} \frac{\left(\frac{B_i \cdot w_j}{q_i^{1-\beta}\, \tau_{ij}}\right)^{\theta}}{(W^w)^{\theta}}. \tag{9}$$

Local residential count increases in the rent-adjusted amenities $\left(\frac{B_i}{q_i^{1-\beta}}\right)$ with elasticity θ. Similarly, the larger the nominal local wage w_j, the larger local labor supply. On the other hand, the larger the commuting costs τ_{ij}, the less likely are workers to select the ij option. The attractiveness of a pair ij therefore depends on the characteristics of its residential location i, its workplace location j and the commuting between the two locations. In a closed city, the attractiveness of this pair is relative to the attractiveness of all other available pairs in the city, summarized by the endogenous aggregate variable W^w.

The number of residents L_i^R and the number of workers L_j^F in locations i and j can be further defined as

$$L_i^R = \sum_j L_{ij}, \qquad L_j^F = \sum_i L_{ij}. \tag{10}$$

Commuting

τ_{ij} is the average iceberg commuting costs of workers living in i and working in j. It is a function of the route-level commuting costs $\tau_{ij,r}$ on all possible routes $r \in \mathcal{R}_{ij}$ between i and j, such that

$$\tau_{ij} \equiv \left[\sum_{r \in \mathcal{R}_{ij}} \tau_{ij,r}^{-\rho}\right]^{-\frac{1}{\rho}}. \tag{11}$$

Average commuting costs between i and j are decreasing as route-level commuting costs $\tau_{ij,r}$ decrease, with elasticity ρ. The larger ρ, the larger the decrease in average commuting costs τ_{ij} in response to a decrease in the lowest route-level commuting costs $\tau_{ij,r}$. As $\rho \to \infty$, all commuters use the least cost path.

The total costs of traveling through route $r \in \mathcal{R}_{ij}$ is a function of the cost of commuting d_{kl} on all individual edges kl on route r, such that

$$\tau_{ij,r} = \prod_{kl \in r} d_{kl}. \tag{12}$$

Edge-level commuting costs $d_{kl}, kl \in r$ are an exponential function of travel time, as in Ahlfeldt et al. (2015) and are given by

$$d_{kl} = \exp\left(\kappa \cdot \frac{\bar{t}_{kl}}{(R_{kl})^{\xi}}\right), \tag{13}$$

where κ is the elasticity of commuting costs on commuting times, $\bar{t}_{kl}$ is the time it takes to commute on kl under 1 unit of road infrastructure R_{kl}, which depends on the length of link kl. ξ governs the elasticity of commuting time on the level of road infrastructure. The larger ξ, the more speed will increase (and commuting time decrease) in response to an increase in road infrastructure (corresponding to road improvements in this model). There is no congestion in this model and commuting costs are symmetrical, s.t. $d_{kl} = d_{lk}\ \forall kl$. I assume that workers must use roads to commute, which is a reasonable assumption in my setting where there is not subway or commuter train in the city.

Given workers' preferences for specific routes, governed by ρ, the equilibrium expected commuting cost τ_{ij} depends on all edge-level commuting costs, represented by a matrix. Following Allen and Arkolakis (2022), I write this relationship as the matrix τ of dimensions $N \times N$, where the (i, j) elements is τ_{ij},

$$\tau = \left((\mathbf{I} - \mathbf{A})^{-1}\right)^{-\frac{1}{\rho}}, \tag{14}$$

where $\mathbf{A} \equiv \left[d_{kl}^{-\rho}\right]$ is a matrix with (k, l) element $d_{kl}^{-\rho}$.

Production

Perfectly competitive firms produce a freely traded final good using only labor, such that

$$Y_j = A_j \cdot L_j^F \quad \forall j,$$

where L_j^F is the number of workers in j and A_j the productivity in that location. This production function implies that

$$w_j = A_j \quad \forall j. \tag{15}$$

Residential Land Market Clearing

Land markets are competitive so the equilibrium rental rate q_i equates the supply of residential land H_i^r to the demand for residential land pinned down by equation 7. In equilibrium, all workers spend a fraction

$(1-\beta)$ of their income on housing due to their Cobb-Douglas utility function, so that

$$q_i = (1-\beta)\frac{\sum_j L_{ij}\frac{w_j}{\tau_{ij}}}{H_i^{\mathrm{r}}}. \tag{16}$$

Road improvements impact q_i directly through a decrease in commuting costs τ_{ij} increasing workers' available income and thus the total amount spent on housing and, if happening in location i, through a decrease in H_i^{r}. Road improvements also impact q_i indirectly, through equilibrium changes in L_{ij}.

Land Payments

Improving road infrastructure on link kl, from width R_{kl}^0 to width R_{kl}, requires acquiring $\left(R_{kl}-R_{kl}^0\right)\times\frac{\mathrm{l}_{kl}}{2}$ units of land from owners in k, at price p_k^{l}. According to the "*voluntary land take*" framework, the final land price is equal to the market rate under R_{kl}^0, q_k^0, times the probability that owners in k get paid γ_k^{l}:

$$p_k^{\mathrm{l}} = q_k^0 \times \gamma_k^{\mathrm{l}}, \tag{17}$$

where I assume that the fraction of owners who negotiate, γ_k^{l}, get paid.[21]

As described in Section 3.2.2, owners negotiate if the potential benefits are greater than the costs. The potential benefits are the amount of affected land in location k, split across all owners in k, $\frac{\Delta H_k^r}{N_k^o}$, evaluated at the pre-road upgrade market rate q_k^o. Negotiation costs are decreasing owners' property rights Z_k at rate μ_z and have an idiosyncratic component ϵ_k following a logistic distribution of mean 0 and standard deviation 1, such that

$$\gamma_k^{\mathrm{l}} = P\left(\alpha q_k^o \frac{\Delta H_k^r}{N_k^o} \geq Z_k\mu_z + \epsilon_k\right). \tag{18}$$

The fraction of owners negotiating, γ_k^l, is an equilibrium object which depends on the residential market rate before the policy q_k^o, road width $\left\{R_{kl}^0\right\}$, as well as the change in residential land in location k, ΔH_k^r, which is itself increasing in the new road area in that location, as $\Delta H_k^r = \sum_l \frac{l_{kl}\left(R_{kl}-R_{kl}^0\right)}{2} \geq 0$.

These land payments are transferred to the affected owners as a transfer, and so,

$$T_k = p_k^{\mathrm{l}} \times \Delta H_k^r. \tag{19}$$

Government's Optimal Road Improvement Problem

Conditional on the road infrastructure at baseline $\left\{R_{kl}^0\right\}$, the government chooses the new road infrastructure $R_{kl} \geq R_{kl}^0\ \forall kl$ to maximize a weighted average of residents' (workers and owners) expected welfare, subject to two budget constraints. First, the government has access to external funds $\bar{M}$, which can be

[21] I do not observe whether all owners who negotiate actually get paid but focus group discussions with affected owners highlighted the prevalence of formal and informal monetary payments, as well as in kind compensations to replace destroyed fences and gates for example and whose value is likely to be correlated with the local market value. If not all owners get compensated (or at a value below market rate), I would be overestimating p_k^{l}. However, negotiation also brings up other costs not modeled here (e.g. delays, processing times and court fees), which would increase the final cost.

used exclusively for road construction, at fixed marginal construction cost $\bar{p}$. Second, to fund any additional construction expenditures $\hat{C}$, as well as the acquisition of the underlying land from private owners at the equilibrium rate p_k^{l} defined by equation 17, the government must levy property taxes at rate ϕ, given a tax revenue wedge $\eta \geq 0$, corresponding to tax leakage and corruption. Property taxes contributed to 47% of the Kampala Capital City Authority (KCCA)'s own-source revenues in 2021/2022, making it the top source of local revenues (Regan and Manwaring 2024). These two budget constraints match to the empirical setting of Kampala, where the government has access to external funds from the World Bank and the African Development Bank to fund road construction, but cannot use these funds for land acquisition.

The government's objective function is the weighted average of owners' welfare W_k^{o} and workers' expected welfare, W^{w}, defined in equations 6 and 8, respectively, both of which depend on the optimal policy. Owners in location k, and workers are weighted by Pareto weights ω_k^o and ω^w, respectively, so that the problem of the government is as follows:

$$\max_{\{R_{kl}\}\forall kl, \phi} \qquad \mathbf{W} \equiv \sum_k \left[\omega_k^o \, W_k^{\mathrm{o}} \left(\{R_{kl}\}, \phi\right)\right] + \omega^w \, W^{\mathrm{w}} \left(\{R_{kl}\}, \phi\right), \tag{20}$$

s.t.

$$\hat{C} \equiv \min \left\{ 0.0 \, , \, \bar{p} \cdot \sum_{kl} \frac{l_{kl}\left(R_{kl} - R_{kl}^0\right)}{2} - \bar{M} \right\}, \qquad \text{[External Funds BC]}$$

$$\sum_k \underbrace{p_k^{\mathrm{l}} \frac{l_{kl}\left(R_{kl} - R_{kl}^0\right)}{2}}_{\equiv T_k} + \hat{C} \leq \quad (1-\eta)\, \phi \sum_i H_i^r q_i. \qquad \text{[Domestic Funds BC]}$$

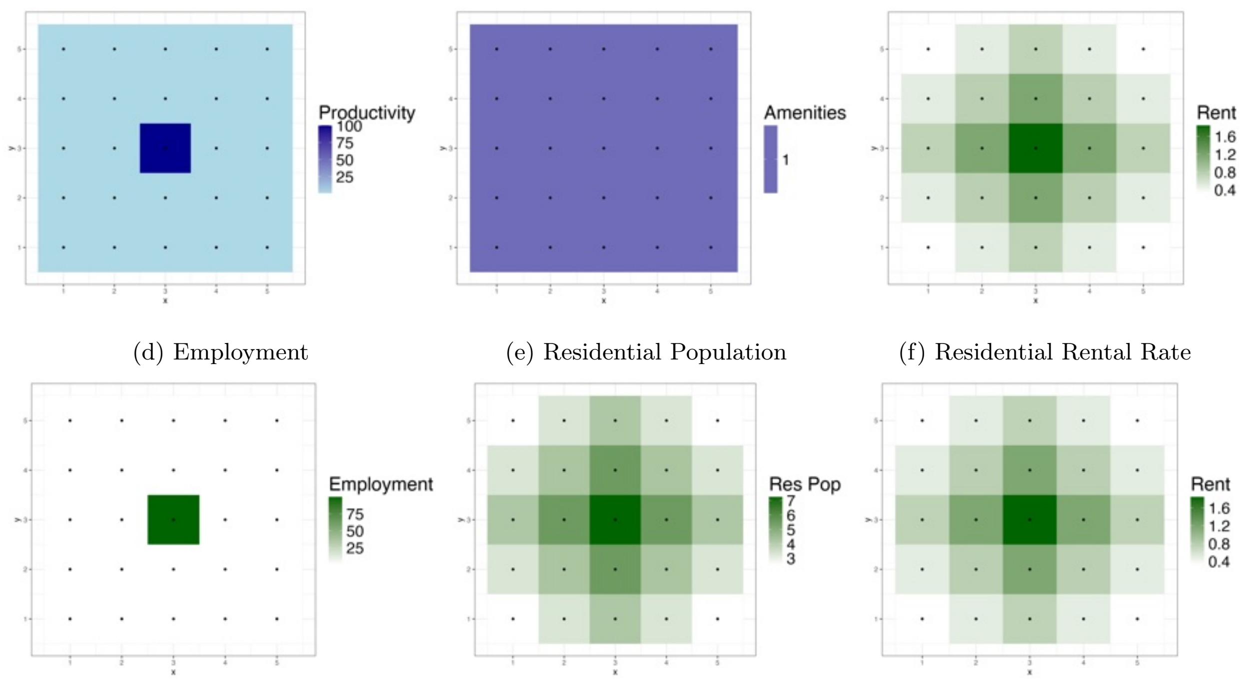
Equilibrium

Given the parameters $\left\{\beta, \theta, \kappa, \xi, a, \eta, \alpha, \mu_z, \bar{M}, \bar{p}, \bar{L}\right\}$, location and link characteristics $\{B_i\}$, $\{A_i\}$, $\{H_i\}$, $\{Z_i\}$, $\{\bar{t}_{kl}\}$, welfare weights $\{\omega_i^o\}$, ω^w and baseline infrastructure $\{R_{kl}^0\}$, the equilibrium of the model is the set of prices $\{q_i\}$, $\{p_i^{\mathrm{l}}\}$, ϕ and quantities $\{L_{ij}\}$, $\left\{\gamma_i^N\right\}$, $\{H_{ij}\}$, $\{C_{ij}\}$, $\{R_{kl}\}$ such that (i) the government chooses $\{R_{kl}\}$ and the corresponding tax rate ϕ to maximize workers and owners' welfare ; (ii) the government's budget constraints are satisfied ; (iii) workers choose $\{i, j, r, C_{ij}, H_{ij}\}$ to maximize their utility ; (iv) owners consume all their income on the tradeable good and choose to negotiate with probability γ_i^N ; (v) residential land markets clear ; (vi) the good market clears, and (vii) labor markets clear.

4.2 Main Model Mechanisms: A Simple Economy on a Grid

To highlight the key forces of the model, I simulate a city of 25 locations, arranged on a 5×5 grid, represented in Figure 4. Productivity is high in the central location and close to zero everywhere else (panel a). All locations have similar residential amenities (panel b), total land supply and road infrastructure at baseline. The distributions of equilibrium residential population (panel d), employment (panel e) and residential rental rate (panel f) are intuitive: most residents want to work in the central location to access the highest productivity and wages, and, as a result, their demand for land is decreasing in distance to the center, as they must incur a longer commute. This geography is a simplification of Kampala's, where most jobs are located at the center (Figure 4). In addition, property right regimes Z_k are highest at the central locations (panel c), to mirror the location of leasehold land, the strongest property right in the city (Figure 2).

Figure 4: Simulated Economy - Baseline Equilibrium



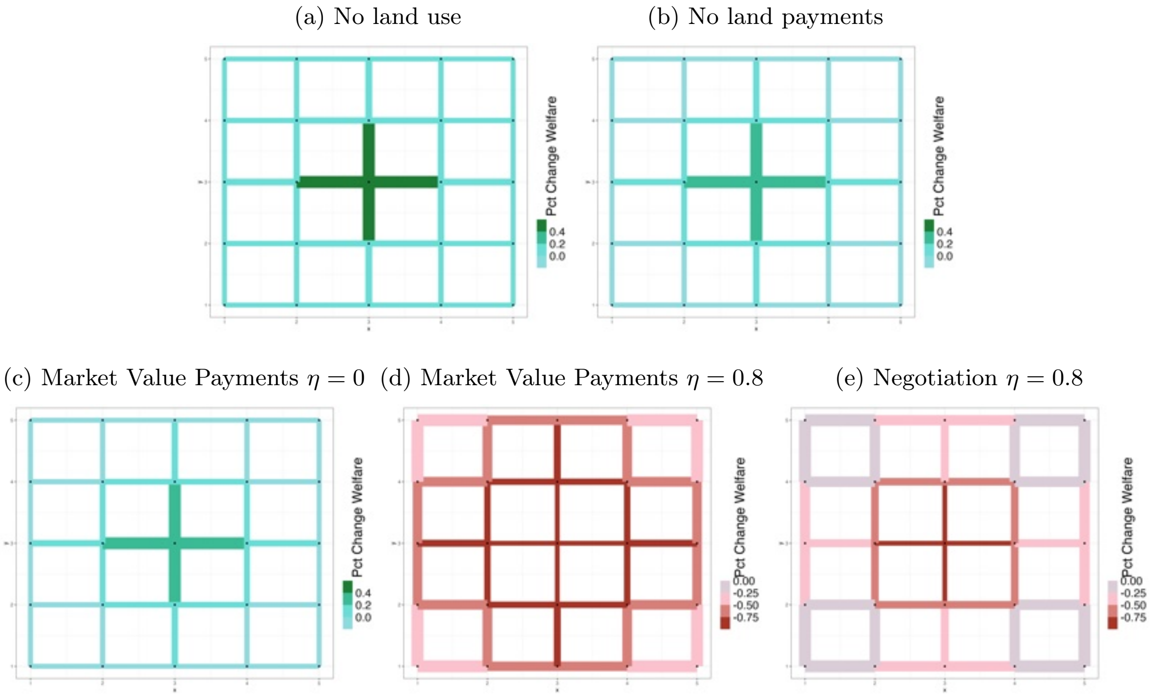
(a) Productivity (b) Residential Amenities (c) Strength of Property Rights

(d) Employment (e) Residential Population (f) Residential Rental Rate

Road improvements have benefits and costs and I illustrate how their joint distribution affects the net welfare gains of different road improvements. In practice, for each road link, I increase width by one unit fixing width at baseline for all other links, solve for the new spatial equilibrium and compute the corresponding welfare change for upgrading this specific link. This exercise highlights how the level and relative welfare gains from different road upgrades vary in response to the different forces of the model and land acquisition rule. By looking at road upgrades one by one, I abstract from complementarity effects across road upgrades.

Net welfare gains of road improvements in the absence of land payments: I first assume that road improvements do not use land and have no other costs than construction costs, which is the dominant approach in the literature. Given the homogeneous distribution of road infrastructure at baseline, the roads connecting the central location host the well paying jobs and thus have the largest marginal benefits (Figure 5, panel *a*). Yet, these central locations also have the largest opportunity cost of land use, as workers would like to live as close as possible to the majority of jobs. The welfare-maximizing planner accounts for this opportunity cost of land use, decreasing the net welfare gains from road improvements in all locations, and especially by the city center (panel b). In Appendix Figure A15, I how that the larger the supply of residential land at baseline, the less impactful is this channel.

Figure 5: Net Welfare Gains of Road Improvements in a Simple Economy



Notes: These figures display the citywide welfare effects of improving each link, solving for equilibrium location choices, routing, and accounting for the fiscal cost of funds. In panels (b) to (e), I account for the opportunity cost of land use by assuming that additional roads compete with residential land.

A large tax revenue wedge decreases net welfare gains of road improvements, especially at the center: Under the eminent domain legal framework, landowners must be compensated at market value for their affected land. This compensation is funded through property taxes ϕ. In the absence of a tax revenue wedge $\eta = 0$, this transfer is welfare neutral for a utilitarian planner, as owners are assumed to have linear utility in consumption. Consequently, as displayed on panel c, the road improvements and corresponding city-level welfare at the same than in the absence of land payments. However, under a large tax revenue wedge (panel d), high land payments at the center of the city have a high welfare costs, both their decreasing their net welfare gains and making these central improvements less attractive than improvements at the periphery, which are lower benefit but also lower cost. Note that if landowners had decreasing marginal utility of income, compensating them at market value would be welfare improving compared to the no payment counterfactual, but the tax revenue wedge would still shift optimal improvements away from the high benefit central locations.

Weak property rights and *voluntary land take* can lead to higher welfare gains but change the hierarchy of returns across locations: Under the voluntary land take approach, adopted by the government, land acquisition prices p_k^l in location k are tied to owners' property right Z_k, so that for a given amount of land being taken and rental rate q_i^0, the stronger Z_k, the larger p_k^l. In Kampala, leasehold land features the strongest property rights and largest negotiation rate (Section 3.2.2), and is also dominant at the city center as displayed on Figure 2. On panel e of figure 5, I show that the net welfare gains of road improvements under voluntary land take are higher than under market value (panel d) because of the lower associated fiscal burden (not all owners get compensated). In addition, the gradient of relative land costs is steeper: central locations do not only have relatively high land market value, but also relatively high rates of owner negotiations, compared to peripheral locations. Consequently, in this simulation, road improvements with the largest net welfare gains under voluntary land take are displaced further from the city center compared to market value.

5 Model Estimation and Net Returns to Realized Road Improvements

5.1 Estimating The Parameters of the Model

To estimate the model parameters, I use the data and variation from the reduced-form analysis. I start by describing my estimation of key elasticities. I then calibrate the remaining parameters using estimates from other studies and public data on Kampala.

5.1.1 The elasticity of local speed on road infrastructure ξ

ξ governs the changes in speed in response to an increase in road infrastructure and thus is a key parameter in my model to determine the benefits of new roads. The larger ξ, the larger the increase in speed for any additional meter of road width. As in Section 3.1.1, I use the Google Maps API queries to study the relationship with road speed and road infrastructure. I compare speed on roads upgraded early in the rollout of the policy, to speed on roads upgraded later or to be upgraded. An important change compared to the results presented in Section 3.1.1 is that in the model, the measure of road upgrades is continuous. Thus, here, I map the road upgrade (dummy) to a change in the amount of road infrastructure, or road width. Non-upgraded road width is defined as per the KCCA road inventory[22] and upgraded roads add 3.2 meters (one lane) to that initial width. Indeed, as most road improvements involved *dualling* and/or *paving,* I assume to this corresponds to adding one lane to the original road. I exclude trips on roads under construction.

The identification assumptions are analogous to the ones in Section 3.1.1, and I present the results in Appendix Table A9. I estimate an elasticity of traffic speed on road infrastructure of 0.386^{***} over the whole sample of GoogleMaps trips. This elasticity is robust to including additional road geographical controls (column 2, 0.344^{***}). This number is 2 to 3 times larger than existing estimates for this parameter, all in middle or high income countries. For example, Fajgelbaum and Schaal (2020) translate estimates by Couture et al. (2018) on U.S. data into $\xi = 0.10$. In Santiago, Chile, Bordeu (2024) estimates $\xi = 0.13$. These papers use either OLS specifications, or instrument for local road infrastructure with institutional features, but do not leverage changes in road infrastructure from a policy, as I do here. In addition, the discrepancies in these coefficients should not be surprising, given the dramatically different levels of road infrastructure at baseline, illustrated by the average speed in Couture et al. (2018) being 38.5 km/h, or 60% higher than in Kampala. In columns 3 and 5 of Appendix Table A9, I further split this elasticity between non-rush hour and rush hour trips, respectively and estimate an elasticity between 0.314^{***} (rush hour) and 0.422^{***} (non-rush hour) for my main specification.

[22]For the 27% of roads with missing width, I assign the average width of roads in their OSM category in that sample.

5.1.2 The elasticity of commuting flows on commuting costs

Then, I turn to the parameters governing how workers' location choice responds to changes in commuting times using data from a local ride-sharing company. This increase in local road speed will induce changes in commuting flows in the city. Taking workers' residence and work locations as given, workers will be more likely to choose a route using these faster roads. I provide evidence that this re-routing is happening in Appendix D.2, by showing that over time, Google Maps trips between parish centroids are increasingly likely to use roads in the second wave of the policy, which are progressively upgraded over the course of the sample. Workers will then reallocate in response to these local speed increases, changing the number of residents and workers in each location, thereby affecting commuting flows L_{ij}. The magnitude of this response is governed by the model parameters θ, the elasticity of commuting flows on commuting costs, and κ, the elasticity of commuting costs on commuting times. These elasticities are important: the larger $\theta\kappa$, the larger the impacts of road improvements on workers' welfare.

To estimate this elasticity, I rely on the ride hailing data discussed in Section 2.2.2. To capture work-related trips, I restrict my sample to morning and evening trips during days of the week.[23] I aggregate the data to the origin-destination $\times$ year level (or $\times$month), where $t_{kl,t} = \frac{1}{N_{o,kl,t}} \sum_o \mathrm{t}_{o,kl,t}$, is the average commuting time for user o on ij in period t. I assume that drivers used the shortest path, so I combine equations (11), (12) and (13) and plug in the observed time $t_{kl,t}$, such that $\tau_{kl,t} = \exp(\kappa \times t_{kl,t})$. I take the log and first difference of the gravity equation (9), so

$$\log L_{ij,ym} = \alpha + \gamma_{i,y} + \gamma_{j,y} - \theta\kappa \mathrm{t}_{ij,ym} + \eta \mathrm{l}_{ij} + \gamma_m + \epsilon_{ij,ym}.$$

where the dependent variable is the log number of trips from parish i to j, in month m year y. Year-origin $\gamma_{i,y}$ and year-destination $\gamma_{j,ty}$ fixed-effects absorb annual changes in location unobservables and month fixed-effects γ_m capture time patterns. I do not have enough power to include pair fixed-effects, but by controlling for the straight-line distance l_{ij}, I effectively use variation in $\mathrm{t}_{ij,ym}$ across trips of the same straight-line distance to identify the parameters $\theta\kappa$. Standard errors are clustered by origin-destination pairs. The identification assumption to causally identify $\theta\kappa$ is that difference in $\mathrm{t}_{ij,ym}$ across pairs and over time are uncorrelated with unobservable differences captured by $\epsilon_{ij,ym}$. This condition would be violated if changes in commute times were correlated with unobserved pair-specific characteristics also affecting trends in commute flows, after conditioning on origin-month and destination-month.

The results are presented in Table 8. In column 1, where observations are defined at the pair $\times$ month level, I estimate $\hat{\theta\kappa} = 0.033^{***}$. This result is robust to restricting the sample to evening commuting alone (column 2, 0.023^{***}) and defining observations at the pair $\times$ year level (Appendix Table A10). It is worth acknowledging two potential issues with these data. First, there is a potential selection issue as users of this motorcycle taxi company may be different than the average commuter in Kampala. Second, using data on actual trips (rather than predicted) prevents me from including an observation (pair $\times$ period) for which no trip was recorded in a given time period.[24] Nevertheless, my estimate $\hat{\theta\kappa}$ is in line with estimates

[23] This includes trips from 6am to 10am, and 4pm to 8pm. Motorcycles (bodas) is one of the most common mode of transportations in urban Uganda, and 90% of the public transportation providers in Kampala are motorcycle taxis (KCCA (2020)).

[24] Going forward, I will investigate how to address these issues by relying a travel habit survey conducted in 2016/2017 in

in other contexts, including Bogota (Tsivanidis 2023, $\hat{\theta\kappa} \in [0.028, 0.046]$). As $\theta\kappa$ governs workers' response to a change in commuting times, a large $\theta\kappa$, as estimated for Santiago (Bordeu 2024, $\hat{\theta\kappa} = 0.0656$) and Berlin (Ahlfeldt et al. 2015, $\hat{\theta\kappa} = 0.0683$), would imply larger benefits from road improvements.

Table 8: Estimated $\theta\kappa$

	Dependent variable:	
	(1)	(2)
Time (in Min)	-0.033^{***}	-0.023^{***}
	(0.001)	(0.001)
Period Def	Month	Month
Sample	All	Evening
Fixed Effects		
- origin x year	Y	Y
- destination x year	Y	Y
- month	Y	Y
SE Clustered	o-d	o-d
Observations	59,300	45,077
R^2	0.437	0.687

Notes: Standard errors are displayed in parentheses and clustered at the o-d pair level, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. All specifications include origin-year, destination-year and month fixed effect. I control for log distance in all specifications. In column 1, I include all trips from 6am to 10am, and from 4pm to 8pm. In column 2, I restrict the sample to the evening rush hour from 4pm to 8pm. Observations are at the pair-month level. Trips are motorcycles (bodas) trips.

Given $\hat{\theta\kappa} = 0.033$, I follow the literature (Ahlfeldt et al. 2015) and I choose κ, the elasticity of commuting costs on commuting times = 0.01, resulting in $\theta = 3.33$.

5.1.3 Parameters Governing Owners' Negotiation

There is a direct mapping between the parameters government owners' decision to negotiate in the model and the empirical specification in Section 3.2. α governs the elasticity of negotiation on the market value of affected land, and μ_z governs the elasticity of negotiation on owners' property right regimes, as well as other observable characteristics. Given the stability of the coefficients across the different specifications presented in Table 7, my preferred specification to take to the model is in column 2, where I include parish coordinates (recentered longitude, longitude^2, latitude, latitude^2), parish-level socio-economic controls, and share of property right regimes per location. When solving the model, I also assume that the length of each owner's property is 50 meters (48 meters on average in the owner survey), so that the total amount of affected land is equal to 50 meters times $\frac{1}{2}$ the additional road width $\left(R_{kl} - R^0_{kl}\right)$, so that land is taken equally on both sides of the road, each belonging to a different owner.

5.1.4 Additional public data and calibrated parameters on Kampala

Data on residential population $\{L^r_i\}$ and employment $\left\{L^F_i\right\}$: I get data on workers' residence and workplace at baseline from the Population and Housing Census (2014) and Census of Business Establishments (2011) from the Uganda Bureau of Statistics (UBOS), respectively. I aggregate this data to the

Kampala. which includes approximately 600 respondents.

location level, where one location corresponds either to one parish, or to a group of small neighboring parishes.

Residential Land: H_i^r, the quality-adjusted quantity of residential land in the model, is pinned down by the land market clearing condition in equation 16, given data on $\{q_i\}$ from the real estate broker survey.[25]

Share of workers' expenditure on housing: I recover the share of workers' expenditure on housing, $1-\beta$, from the Uganda National Panel Survey (2019), restricted to households in the Kampala region. I recover $(1-\beta) = 0.2355$ as the ratio of the monthly rental expenditure (or monthly-equivalent value of housing for owners) and the household's total income, excluding respondents who report 0 income.

Elasticity of commuting route on commuting costs: I set $\rho = 50$, which is significantly larger than in Allen and Arkolakis (2022) ($\rho = 6.83$), corresponding to workers' choice route being closely aligned with the shortest route. Importantly this value of ρ ensures that the commuting cost matrix $I - A$ is invertible.

Weight on owners $\{\omega_i^o\}$ and workers ω^w: I assume a utilitarian planner, putting equal weights on worker and owner households. I recover the total number of residents in age of working residing in each location from the 2014 Uganda Population Census, and set the share of owners to 20.15%, as per the 2019 Uganda National Panel Survey restricted to Kampala, which asks detailed characteristics to a subset of households. The weight on each owner in location i, ω_i^o, is the number of owners in this location. For ω^w, the welfare weight of all workers in the city, I scale the number of workers so that the welfare gains associated with making each worker a lump-sum transfer is equal to the total monetary sum of these transfers. In practice, I solve for this scaling factor such that the welfare benefits from transferring the construction funds to workers in a lump-sum transfer, fixing location at baseline, would be equal to the construction funds themselves.

$\{\tau_{ij}\}$ and Mapping Roads to the Model: To estimate $\{\tau_{ij}\}$, I need to recover link-level commuting times in the absence of road infrastructure $\bar{t}_{kl}$, as well as the road width on each link at baseline R_{kl}^0. To do so, I use data from Open Street Map and from Google Maps. Open Street Map categorizes all roads in Kampala into five categories associated with different speeds as summarized in Appendix Table A7. I recover the average speed of each road type from the Google Maps trips between neighboring grid cells. In practice, I regress a trip's average speed on the share of the trip on each road category, controlling for the trip's distance, its hour, and second degree polynomials for the origin and destination coordinates, to control for local heterogeneity in road speed. The results are presented in Appendix Table A3, along with additional details on the estimation strategy.

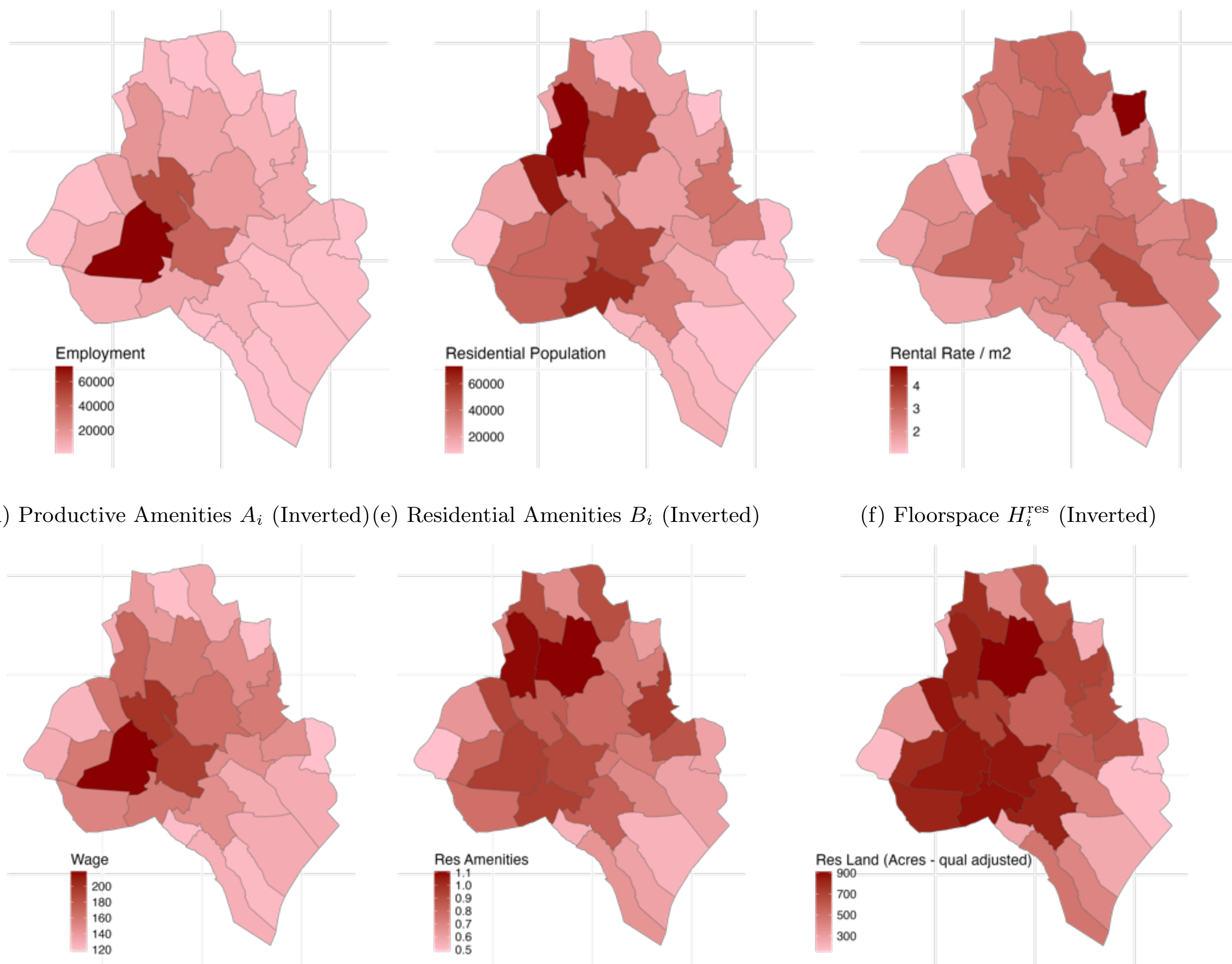
To map these estimates to the model, I then aggregate roads by location, such that the average speed in location k is the weighted average of category-specific free flow speed on all roads in that location,

[25] I estimate the median sales price per square meter for residential properties in each location from the past transaction database from the broker survey. For locations with no transacted property, I predict the median sales rate from a smooth kernel estimator based on distance to the central business district. I convert sales rates into monthly rental rates to match a price-to-annual rent ratio of 20.

weighted by the share of each road category. I recover the time between two neighboring locations t_{kl} as the distance between these locations times this average speed. I further recover $\bar{t}_{kl} = t_{kl} \times \left(R^0_{kl}\right)^{\xi}$ from equation (13), where R^0_{kl} is the average width of roads in locations k and l at baseline. Given $\{\bar{t}_{kl}\}$,$\{R^0_{kl}\}$, ξ, κ, and ρ I can compute $\{\tau_{ij}\}$.

I then map the improvements into the model's aggregated road network by assigning each realized road upgrade to the closest link connecting locations in the model. Assuming that the average road improvements increased road width by 3.2 meters (one additional lane, as discussed in Section 3.1.1), The resulting map of road improvements is displayed on Figure 7.

Figure 6: Kampala at Baseline



(a) Employment L_i^F (Data) (b) Residential Population L_i^R (Data) (c) Rental Rate q_i^{res} (Data)

(d) Productive Amenities A_i (Inverted) (e) Residential Amenities B_i (Inverted) (f) Floorspace H_i^{res} (Inverted)

Fundamental Location Productive $\{A_i\}$ and Residential $\{B_i\}$ Amenities: I follow the standard inversion procedure in the literature to recover the exogenous productivities $\{A_i\}$ and residential amenities $\{B_i\}$. As data on property rates q_i is in USD, I scale $\{A_i\}$ up to the average monthly local wage (KCCA

2019). From the gravity equation (9), I then recover flows L_{ij} given $\left\{\tau_{ij}, w_j, q_i^{\beta-1}B_i, L_i^R, L_j^F\right\}_{\forall i \forall j}$ and θ. Last, I solve for the quality-adjusted supply of land $\{H_i^r\}$ given $\{L_{ij}, w_j, q_i\}$ using the equilibrium condition for the market of residential land (equation 16).[26]

The data on L_i^R, L_j^F, q_i and the recovered A_i, B_i, H_i^r are displayed on Figure 6. Most jobs are concentrated in the city center (panel a), and both residential population (panel b) and residential rental rate (panel c) are high in the areas surrounding the city center. The relatively low population density on the immediate north east of the city center is explained by the prevalence of administrative and official buildings in these locations, rationalized by relatively low residential amenities (panel e) and quantity of quality-adjusted residential land H_i^r (panel f) in the model.

Tax revenue wedge η: I calibrate $\eta = 0.61$ from Regan and Manwaring (2024) who, in an experiment in collaboration with the Kampala city government, estimate that "*over the years 2019-2022, the KCCA has collected* 39% *of the potential revenue from property taxes.*" In addition, in Section 5.2, I solve for the wedge on tax revenues rationalizing the government's claim that acquiring land at market value would threaten the viability of the project (World Bank 2023), which is well aligned with Regan and Manwaring (2024)'s estimate.

5.2 Net Returns to Road Improvements in Kampala

Equipped with the estimated model, I solve for the new spatial equilibrium given the realized road upgrades.

Impacts on Commuting Time and Property Values: First, I fix workers' locations at baseline and compute changes in commuting times across any pair of locations and changes in rental rates coming from the road upgrades ΔR_{kl}. I find that the realized road upgrades led to a decrease in workers' average commuting time by 8.2% (1 min 44 sec), and an increase in total property values by 1.4%.[27] Second, I allow workers to relocate in equilibrium, affecting rental prices. Facing lower commuting costs, workers increase the distance between their residence and workplace, so that the average commuting time decreased by only 6.62% compared to baseline. In turn, the average increase in property values is 1.36%.

Welfare Impacts Under Voluntary Land Take: I compute the compensating differential lump-sum transfer s that the government would have to make to every resident (owners and workers) to reach the same total expected utility as the road improvements policy. In other words, I solve for s such that:

$$\sum_k \left[\omega_k^o \times W_k^o\left(\{R_{kl}\}, \phi, 0\right)\right] + \omega^w \times W^w\left(\{R_{kl}\}, \phi, 0\right) = \sum_k \left[\omega_k^o \times W_k^o\left(\{\bar{R_{kl}}\}, 0, s\right)\right] + \omega^w \times W^{\text{w}}\left(\{\bar{R_{kl}}\}, 0, s\right)$$

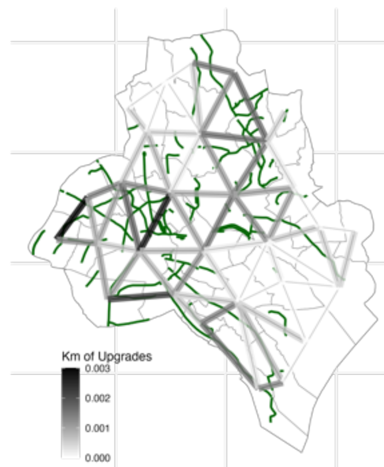
As displayed in Table 10, panel A, I find that under a 5% discount rate, the Net Present Discounted Value (NPDV) of the lump-sum transfer that would have led to the same city-level welfare as the road

[26] Note that as H_i^r is the quality-adjusted supply of residential land, it cannot be directly compared to, or recovered from satellite data on residential land use from the Global Human Settlement Layer. This data further does not differentiate between residential and non-industrial business land use.

[27] Computing expected workers' welfare while fixing locations at baseline is not informative, as expected welfare is defined over workers' idiosyncratic preferences over pairs of locations, leading them to choose their residence and workplace.

improvements is \$209 per resident. This number accounts for the land costs of the policy, funded through a property tax. Once I further subtract the one time construction expenditures, equivalent to \$80 per resident, I recover net welfare gains equivalent to a one time transfer of \$119 per resident, or 6.7% of the median annual wage for Kampala workers.[28]

Figure 7: Realized Road Improvements



To interpret these numbers and compare them to the reduced-form results from Section 3, it is important to keep in mind what elements are captured or not by the model and by the reduced-form results. The model accounts for spatial spillovers through the road network and for the general equilibrium impacts of workers relocating over space in response to a change in commuting costs, increasing overall economic activity in the city. I do not explicitly model firms' land use (captured into the exogenous local productivity), so any increase in the property value of business premises would not be captured by my model. However, more than 71% of Kampala businesses count at most 2 employees (UBOS 2010), implying that most businesses are small and likely ran on the side of residential dwellings, so capitalization of the road improvements into residential property values should capture most of the gains. Last, my model has exogenous residential amenities B_i, but, given the empirical evidence that road upgrades improved local amenities (Appendix Figure A11) including a decrease in traffic accidents, my estimate is likely a lower bound on total net benefits.

Welfare Impacts Under Alternative Land Acquisition Rules: Table 10, panel A, I also show that the net welfare gains would have been 157% larger in the absence of land payments, but would have been negative if land had been acquired at market value, as mandated under eminent domain, which is consistent with less than 25% of owners compensated at market value (Section 3.2). This result is driven by the large tax revenue wedge, implying that land payments decrease the net welfare gains of the policy.

The city government claimed that acquiring land at market value would threaten the viability of the project (World Bank 2023). I assess this claim through the lens of my model. In practice, I do a grid search for the wedge η such that the net welfare gains of the realized policy are equal to 0. I find that for any η greater than 0.44, the net welfare gains of the realized road improvements would be negative if land was acquired at market value. This threshold goes up to 0.51 if I do not subtract the construction expenditures. The welfare gains for $\eta \in [0.0, 0.9]$ is displayed on Appendix Figure A17. These estimates are consistent with the $\eta = 0.61$ calibrated from Regan and Manwaring (2024).

Sensitivity to Alternative Parameters: Two key forces in the model are driving these results: the welfare impacts of land payments, governed by the tax revenue wedge η and workers' benefits from the road improvements, governed by workers' response to changes in local speed $\theta\kappa$ and the impact of road

[28]The 2014 Uganda Population Census counts about 1.6 million inhabitants, but only about 866,000 inhabitants about 18 years old. When talking about the residents in this paper, I focus on those inhabitants about 18 years old, who are of working age and thus agents in my model.

improvements on local speed ξ. In Table A5, I investigate the sensitivity of the results with respect to each of these parameters. I find that if under a larger tax revenue wedge $\eta = 0.7$, even land acquisition under voluntary land take would yield barely positve net returns (C2). I also find that the larger the elasticity of commuting costs on commuting times κ (C5 and C6), and the larger the elasticity of commuting time on road infrastructure (C8 and C9), the larger the net welfare gains to road improvements. It is worth also highlighting that the net welfare gains of the policy in NPDV critically depend on the discount rate applied on residents' utility (Panel B), as construction costs are upfront but flow utility must be discounted. The larger the discount rate, the lower the net returns of the policy. Last, in Panel (D), I relax the assumption that owners' utility is linear in income and instead assume that owners' utility is equal to the log of their income. This concavity allows for compensation at market value to have positive net welfare gains for owners. I find that the gap between the different land acquisition rules decreases, making market value compensation relatively less unattractive than under the constant utility assumption. However, given the high cost on fiscal funds, compensating owners at market value would still lead to negative welfare gains.

5.3 Link-Level Upgrades and Model-Predicted Net Returns

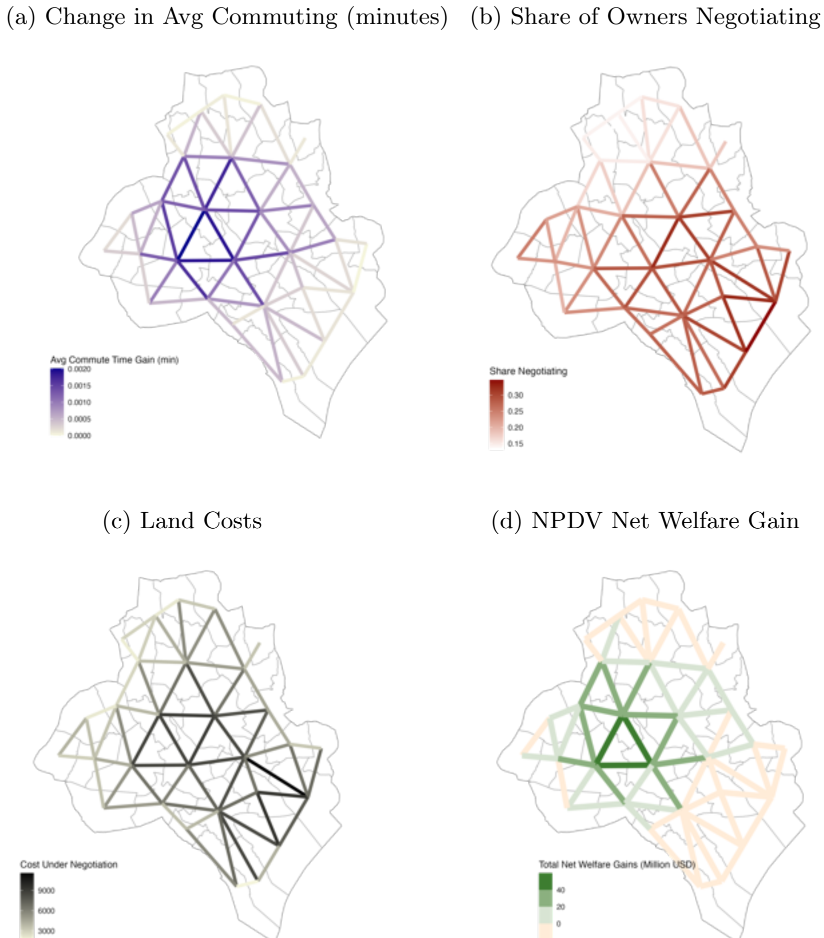
To understand whether these benefits come from upgrading any road, or upgrading the highest return roads, I investigate the spatial distribution of improvements' marginal benefits, costs and net welfare gains. I compare the length of roads upgraded along each link to the model-predicted link-level net welfare gains, benefits and costs.

5.3.1 Link-level Costs, Benefits and Welfare Gains

I start by computing the marginal costs, benefits and net returns of upgrading each location-to-location link, one by one, as in Section 4.2. In practice, for each link, I increase road width by one lane and solve for the resulting equilibrium. I compute the total change in commuting times, total land costs, and NPDV of the welfare gains (net of costs). The results are displayed on Figure 8. The color of each link indicates the impact of upgrading this specific link on city-level outcomes of interest. This exercise abstracts from complementarities across road upgrades, discussed in the next section.

Starting with a direct measure of benefits, the decrease in commuting times (panel a), I show that the highest marginal benefit upgrades are concentrated at the center of the city, and that there is substantial heterogeneity across links. Moving on to land costs (panels b and c), I show that there is heterogeneity in the predicted share of owners bargaining, as 19.8% of owners would negotiate for roads at the 25^{th} percentile of marginal costs, against 28.3% on roads at the 75^{th} percentile. I plot the distribution of net marginal welfare gains on panel (d). The first takeaway is that there is a lot of heterogeneity and that not all roads have positive net marginal welfare gains, as expensive construction and land costs are not always offsets by gains in commuting times and property values. The second takeaway is that the highest marginal net welfare gains are at the center of the city, consistent with these locations being also high marginal benefits (panel a).

Figure 8: Link-Level Impacts of Road Improvements



Notes: These figures display the impact of adding one lane on each link on city-level average commuting time (panel a), predicted share of owners negotiating (panel b), land costs under the existing voluntary land take approach (panel c) and net welfare gains (panel d, NPDV 5%). The color of each link corresponds to this impact of this link's upgrade of the city-level outcome of interest.

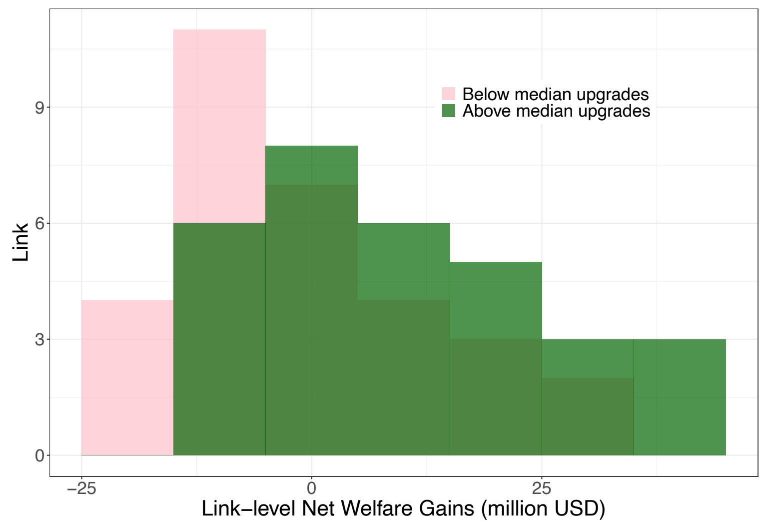
5.3.2 Predicting Realized Road Improvements from Link-Level Net Welfare Changes

Did the government upgrade the highest net return roads, as predicted by the model? I answer this question in two steps. First, I look at the correlation between the length of upgraded roads along each link kl, and predicted link-level net welfare gains. On Figure 9, I plot the distribution of predicted link-level welfare gains, split between above (green) and below (pink) median road upgrades along that link. This exercise highlights two patterns. First, there is a positive relationship between realized road upgrades and link-level welfare gains, as the green distribution is to the right of the pink one. Second, however, there is substantial overlap between the two distributions, suggesting some amount of misallocation. In Appendix Figure A18, I further investigate the relationship between model-predicted link-level net welfare gains (from a 1 lane upgrade) and the length of road upgrades around that link. This figure shows a positive relationship between the two.

Second, to unpack this relationship, I regress the length of upgraded roads along each link kl, D_{kl}, on these predicted link-level impacts, controlling for the length of link kl, l_{kl}:

$$D_{kl} = \alpha + \beta \times \Delta \mathrm{W}_{kl} + \mathrm{l}_{kl} + e_{kl},$$

Figure 9: Net Welfare Gains of Link-Level Upgrades and Realized Upgrades



Notes: I display the relationship between link-level net welfare gains as predicted by the model, and the length of realized road upgrades along that link. I split links according to whether the total length of road upgrades along that link is above median (green) or below median(pink)

Table 9: High Marginal Benefits and Low Land Costs Predict Realized Road Upgrades

	Dependent variable:	
	Length of Upgraded Roads (All upgrades)	
	(1)	(2)
Net Welfare Gains (std)	0.571**	
	(0.254)	
Gain in Commuting Time (std)		0.578**
		(0.267)
Land Costs Under Negotiation (std)		−0.737**
		(0.353)
Observations	62	62
R^2	0.166	0.195

Notes: Standard errors are displayed in parentheses, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Observations are at the link-level. Covariates are standardized (mean 0, sd 1).

where ΔW_{kl} is the standardized change in city-level welfare from upgrading link kl. The results are displayed in Table 9. In column 1, I unveil a positive correlation between the length of roads upgraded along a link between neighboring locations and the road's predicted welfare gains from upgrading that link. In column 2, I split net welfare gains into benefits (gains in commuting time) and land costs. I find a positive correlation between road upgrades and predicted gain in commuting time, and a negative correlation between road upgrades and land costs. Overall, I conclude that the selection process of roads to upgrade in Kampala was relatively good.

5.4 Optimal Road Improvements in Kampala under the Status-Quo Land Costs

The above exercise recovers the net returns of the realized road improvements, but does not allow me to study how land acquisition affects the optimal set of road upgrades. To do that, I solve the model for the road improvements that maximize the government's objective function (equation 20).

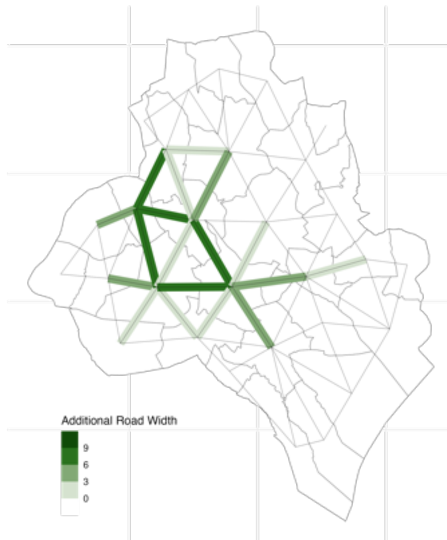
I fix the maximum area of roads that can be upgraded at the level of the implemented policy and I solve for the welfare maximizing (optimal) road improvements in Kampala under the voluntary land take approach, the status quo. When solving for the optimal road improvement $\left\{R_{kl} - R^0_{kl}\right\}$, the government must keep track of several equilibrium objects: land payments $\left\{p^l_k\right\}$ depend on $\{R_{kl}\}$ through the probability owners negotiate, which is increasing in the amount of land taken ; rental rates $\{q_i\}$ depend not only on commuting costs τ_{ij} but also on workers' residence and workplace, both of which are determined in equilibrium as a function of $\{R_{kl}\}$. In addition, unlike in Section 5.3, the set of optimal upgrades account for the complementarities across road upgrades.

I solve for the optimal road improvements as follows. First, I start from an arbitrary policy $\{R_{kl}\}$ and solve for the corresponding spatial equilibrium locations $\mathbf{x}_1 = \{L^R_i, L^F_j\}$. Second, given these location choices $\mathbf{x}_1$, the planner solves for the optimal policy $\mathbf{z}_2 = \{\{R_{kl}\}, \phi\}$ that maximizes residents' expected welfare subject to its budget constraints. In that step, the planner accounts for the impact of the policy on all equilibrium objects $\left\{W^w, W^o_i, q_i, \gamma^l_i, p^l_i\right\}$ but takes workers' equilibrium locations as given from the first step. Third, given the optimal policy from step 2, $\mathbf{z_2} = \{\{R_{kl}\}, \phi\}$, I solve for the new spatial equilibrium $\mathbf{x}_3 = \{L^R_i, L^F_j\}$. I iterate over steps 2 and 3 until convergence.

The map of optimal road improvements is presented in Figure 10, and corresponding welfare gains and other outcomes of interest in Panel B to D of Table 10. I estimate that the NPDV of the net welfare gains in this benchmark is about \$511 million under a 5% annual discount rate, which corresponds to a one time transfer of \$500 per Kampala adult (B2).

This number is 4.2 times larger than the net returns from the realized road improvements, despite the positive correlation between the location of realized upgrades and these link-level marginal returns (Section 5.3.2). The discrepancy between the two numbers has two main explanations. First, when solving for optimal road improvements $\{R_{kl}\}$, I allow for a continuous solution in terms of additional width, rather than a discrete solution in terms of additional lanes. This common simplification (Fajgelbaum and Schaal 2020, Bordeu 2024), motivated by computational considerations as solving for the optimal combination of additional (discrete) lanes is a high dimensionality discrete-choice combinatorial problem (Arkolakis et al. 2023), de-facto ignores this discreteness constraint faced by the government. Second, the government may face other constraints that are beyond the scope of this paper, including corruption (Olken 2007), procurement constraints (Wolfram et al. 2024) and, more generally political economy considerations (Brueckner and Selod 2006, Glaeser and Ponzetto 2018, Bordeu 2024, Fajgelbaum et al. 2024). In Appendix Table A6, I investigate the robustness of this number to alternative parameters and functional form assumptions on owners' utility. As per the realized road improvements, on the one hand, the larger κ and ξ, the larger the NPDV net welfare gains from the road improvements. On the other hand, the larger the discount rate, the lower the NPDV net welfare gains from the road improvements. In Panel E, I also quantify the role of the opportunity cost of land by comparing the optimal road improvements with and without land being taken from residential use.

Figure 10: Optimal Road Improvements Under "Voluntary Land Take"



6 Does the Existing Land Acquisition Framework Lead to Misallocation?

In this final section, I leverage the model to understand how the specific structure of land payments affects the net welfare gains from road improvements in Kampala. The structure of this section mirrors the mechanisms from Section 4.2. In a first part, to study the role of the tax revenue wedge, I compare the welfare gains of the optimal road improvements under the status quo voluntary land take approach (Section 5.4) to a counterfactual where land is acquired at market value. I then investigate a potential solution to this high tax revenue wedge: removing restrictions on the use of external funds. In a second part, I study the allocative impact of property rights heterogeneity in Kampala, by comparing the status quo to a counterfactual scenario with homogeneous property rights.

6.1 Welfare Impacts of a High tax revenue wedge for Optimal Road Improvements in Kampala

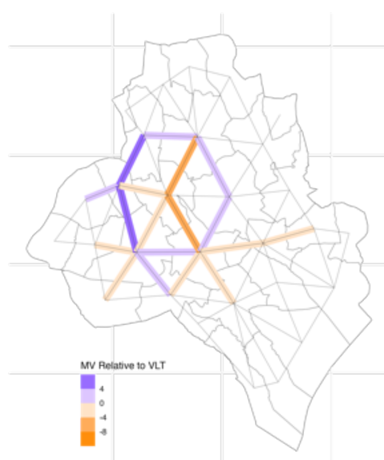
6.1.1 Optimal Road Improvements Under Alternative Compensation Rules

Market Value Compensation: Under both the Ugandan constitution and the World-Bank guidelines, owners should receive a fair compensation against land take. I solve for the corresponding counterfactual, where owners are compensated at market value. The optimal upgrades under market value compensation, compared to the optimal upgrades under voluntary land take, are displayed on Figure 11. Under market value acquisition, less roads are upgraded are the city center (orange) and instead upgrades are displaced towards surrounding locations (blue), with relatively lower land costs. Net welfare gains of the policy are equivalent to a \$153 one-time transfer per resident (Table 10, B3), or 30.6% of the net welfare gains under the status quo voluntary land take approach. Importantly, these differences across payment rules would be lower if landowners' utility was concave in income, as opposed to linear (Appendix Table A6, Panel D). In the case where owners' utility is concave in income (log), compensating owners at market value would indeed yield not only additional fiscal costs, but also additional owner welfare gains, somewhat mitigating decrease in overall welfare gains.

No financial compensation: Consistent with this result, the counterfactual optimal road upgrades where owners would not be compensated for their land (Table 10, B2) yield net welfare gains equivalent to a \$634 per resident, or 27% more than under the existing voluntary land take rule. The difference between the two optimal allocations is displayed on Figure 12. This result is driven both by the optimal upgrades leading to a larger decrease in commuting time (-10.4% against -10.1%) and a larger increase in property values ($+3.1\%$ against $+2.9\%$) compared to the voluntary land take optimal upgrades, and by the absence of a fiscal loss on payments.

Decomposition of the difference between tax revenue wedge and improved allocation: When imposing an analogous fiscal burden as under the voluntary land take optimal upgrades, while removing cost heterogeneity across locations (Table 10, B4), the net welfare gains drop to \$514 per resident, implying that 10% (\$14 million) of the gains come from the improved allocation, and the remaining 90% (\$120 million) from the tax revenue wedge.

Figure 11: Optimal Improvements: Acquisition at Market Value Compared to Voluntary Land Take

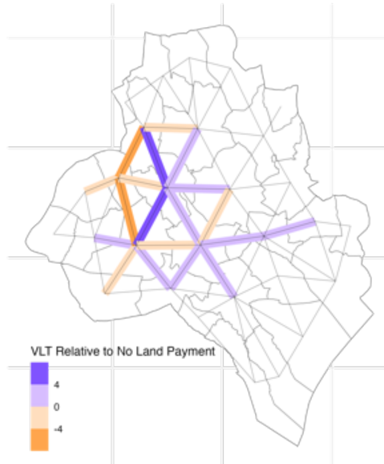


Notes: I display the difference in optimal road improvements between the land acquisition under voluntary land take, compared to land acquisition at market value. Orange links correspond to less improvements under land acquisition at market value than under voluntary land take. Purple links correspond to more improvements under market value than under voluntary land take. These optimal policies are under the existing restrictions on the use of external funds.

6.1.2 Optimal Road Improvements Relaxing Restrictions on the Use of External Funds

One potential avenue to remove distortions imposed by the fiscal cost under market value payments would be to relax the existing restrictions on the use of external funds. Currently, the city government can only use external funds (from the World Bank and the African Development Bank) for road construction but

Figure 12: Optimal Improvements: No Payment for Land Compared to Voluntary Land Take



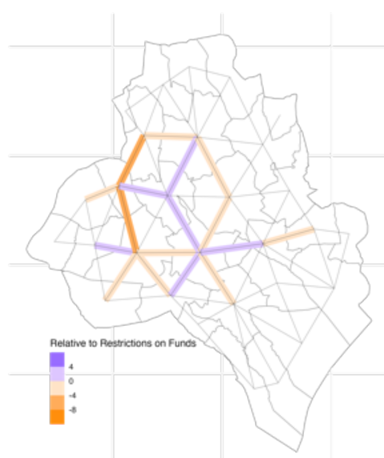
Notes: I display the difference in optimal road improvements between the land acquisition under voluntary land take, compared to land acquisition in the absence of land payments. Orange links correspond to less improvements under land acquisition without land payment than under voluntary land take. Purple links correspond to more improvements under acquisition with no land payment than under voluntary land take. These optimal policies are under the existing restrictions on the use of external funds.

not for land acquisition. This status quo restriction is likely driven by concerns of corruption (World Bank 2011). However, in the presence of high fiscal leakage on property value taxes used to fund land acquisition, this restriction may significantly hinder the net welfare gains of road improvements.

In practice, I calculate the optimal policy when the government faces a consolidated budget constraint given by

$$\sum_k \underbrace{p^{\mathrm{l}}_k \times \left[R_{kl} - R^0_{kl}\right]}_{\text{land payment expenditures}} + \underbrace{\bar{p} \cdot \sum_{kl} \left[R_{kl} - R^0_{kl}\right]}_{\text{construction expenditures}} \leq (1-\eta)\,\phi \cdot \sum_i \underbrace{\left(H_i - H^{\mathrm{r}}_k\left(R_{kl}\right)\right)}_{H_i^{\mathrm{res}}} \cdot q_i + \bar{M}$$

Figure 13: Optimal Improvements: Acquisition at Market Value without Fund Use Restrictions



Notes: I display the difference in optimal road improvements between the land acquisition at market value under eminent domain with the existing restrictions on the use of funds, compared to the absence of restrictions on the use of external funds. Orange links correspond to less improvements in the absence of restrictions than with the status quo restrictions. Purple links correspond to more improvements in the absence of restrictions than with the status quo restrictions.

I find that under this relaxed constraint and voluntary land take approach, the net welfare gains are equivalent to a \$561 transfer per resident, or 12% more than under the existing restrictions (Table 10, panel C), despite less roads being upgraded as some of the funds are instead used for land acquisition (Appendix Figure A20).

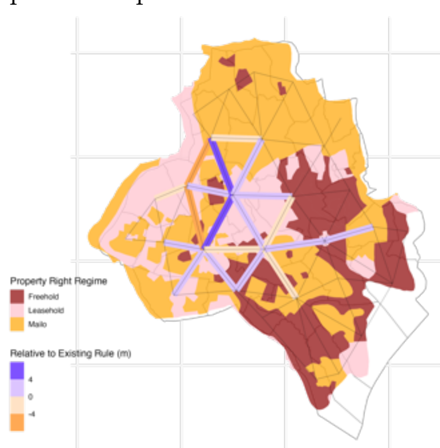
Furthermore, relaxing this restriction may help reach other World Bank's stated objectives, like ensuring that owners are *"provided prompt and effective compensation [...] for losses of assets attributable directly to the project."* (World Bank O.P. 4.12). Under market value compensation, removing the fund use restrictions leads to net welfare gains of the policy equivalent to a \$239 transfer per resident, or 56% more than under the existing restrictions (Table 10, panel C), despite fewer road upgrades. This increase in welfare is larger than under the voluntary land take approach because of the larger fiscal burden with market value acquisition under the existing restrictions. On Figure 13, imposing compensation at market value, I show that relaxing the restriction on the use of external funds leads to more upgrades at the city center (purple) and less in surrounding locations (orange).

While corruption costs are outside the scope of this model, these numbers can be used to benchmark whether the anticorruption benefits outweigh the potential benefits of alternate payment and funding rules.

6.2 Welfare Impacts of a Heterogeneous Property Right Regimes in Kampala

While the resort to voluntary land take leads to higher net welfare gains than under the eminent domain market value compensation rule because of the large tax revenue wedge, this approach also ties land costs and optimal road improvements to the distribution of property right regimes in the city.

Figure 14: Optimal Improvements: All Freehold Property Rights



Notes: I display the difference in optimal road improvements between the land acquisition under voluntary land take with the existing property right regimes, compared to land acquisition under voluntary land take if all land was freehold. Orange links correspond to less improvements with land acquisition under freehold land than under the existing property right regimes. Purple links correspond to more improvements with land acquisition under freehold land than under the existing property right regimes. These optimal policies are under the existing restrictions on the use of external funds.

Under voluntary land take, fewer owners gets compensated on freehold and mailo land, where property rights are less clear and land disputes are widespread.[29] To assess the welfare impact of this heterogeneity,

[29]These issues are well known by the Uganda government, who started to digitize the national land registry to decrease

on Figure 14, I compare the optimal road improvements under the existing property right regimes (Figure 10), to the optimal road improvements if all land was owned under the freehold property right regime, the weakest in the city. Under these hypothetical uniform weak property rights, upgrades would be reallocated towards the central leasehold locations and commuting times would decrease by 0.25 percentage point more than under the existing property right regimes. These higher commuting time benefits, together with the lower fiscal burden from lower total payments, would lead to net welfare gains equivalent to a $563 transfer, or 11% more than under the existing rights (Table 10, D1). To isolate the allocative effect coming from higher benefits, I then enforce a total fiscal cost equal to the one under the existing rights (Table 10, D2). Increasing the fiscal burden up to the status quo, I find that the net welfare gains remain equivalent to a $544 transfer, implying that 69% of the gains come from a better allocation, and 31% from a lower fiscal burden. In rows D3 and D4, I show that, correspondingly, under hypothetical uniform strong property rights (at leasehold level), the optimal road improvements would 6% lower than under the existing property rights.

7 Conclusion

Improving road infrastructure in developing cities is an investment priority, but little is known about the net returns to these investments in practice, neither about their levels nor their drivers. In this paper, I fill this gap by collecting new data and studying the returns to road improvements in Kampala. I show that the benefits of road improvements are large but so are the costs. These costs hinder the net returns of road improvements in two ways. First, for a given set of improved roads, land costs decrease net returns, as there is a high cost for domestic governments to compensate owners. Compensating owners at market value—mandated under eminent domain—would yield negative realized welfare gains. The realized welfare gains are higher because not all owners get compensated, especially if they have weak property rights. In the context of public good provisions, clear property rights can have large negative welfare gains, by preventing budget constrained governments from seizing land that could be used more efficiently for the public good (Acemoglu and Robinson 2012), because there are positive externalities of road improvements on the whole city that owners do not internalize. In counterfactual scenarios, I further explore how land acquisition under more uniform property right regimes could improve welfare outcomes by shifting investments towards higher benefit locations.

Ultimately, my study highlights the need to account for existing property rights and land acquisition conditions when designing infrastructure investments in rapidly growing cities. As international donors weigh in to enforce that owners are compensated at market value are *'provided prompt and effective compensation [...] for losses of assets attributable directly to the project."* (World Bank OP 4.12), adjustments of the restrictions on the use of external funds for land acquisitions should be considered. More generally, land acquisition in Kampala is a textbook example of the theory of the second best where correcting a market imperfection (e.g. enforcing compensation at market value to prevent abusive expropriation) does not necessarily improve overall welfare in the presence of other market imperfections (e.g. cost of raising domestic funds for compensation).

the number of land fraud in an effort to decrease transaction costs and frictions on the land market.

Table 10: Net Returns to Road Improvements Under Alternative Counterfactuals

	Road Area	Avg Change (%)		Costs			Gross Welfare Gains (USD)		Net Welfare Gains (USD)	
	m2 m2	Commuting Time	Property Values	Construction (million USD)	Land	Tax Rate ϕ	Per resident (USD)	Total (million USD)	Per resident (USD)	Total (million USD)
Panel A. Realized Road Improvements with External Funds Restrictions										
A1. Voluntary Land Take (benchmark)	434296	-6.62	1.36	78	15	0.022	209	181.2	119	103.57
A2. No Land Payment	434296	-6.62	1.36	78	0	0	395	342.75	306	265.12
A3. Market Value Acquisition	434296	-6.62	1.36	78	63	0.091	-380	-329.71	-470	-407.34
Panel B. Optimal Road Improvements with External Funds Restrictions										
B1. Voluntary Land Take	434296	-10.14	2.86	78	17	0.024	590	511.33	500	433.7
B2. No Land Payment	434296	-10.38	3.07	78	0	0	724	627.36	634	549.73
B3. Market Value Acquisition	433979	-9.9	2.74	78	62	0.088	242	209.89	153	132.31
B4. Constant Land Costs	434295	-10.38	3.07	78	17	0.023	604	523.67	514	446.04
Panel C. Optimal Road Improvements with External Funds & No Restriction										
C1. Voluntary Land Take	296050	-7.77	2.33	53	12	0	622	539.23	561	486.31
C2. No Land Payment	434296	-10.38	3.07	78	0	0	724	627.36	634	549.73
C3. Market Value Acquisition	359065	-8.7	2.43	64	54	0.067	313	271.31	239	207.13
Panel D. Optimal Road Improvements with Voluntary Land Take & Alternative Property Right Regimes										
D1. All Freehold	434295	-10.39	3.05	78	10	0.014	653	565.8	563	488.17
D2. All Freehold & Fixed Payment	434295	-10.39	3.05	78	17	0.014	633	549.23	544	471.6
D3. All Leasehold	434295	-10.11	2.83	78	21	0.029	559	485.01	470	407.38
D3. All Leasehold & Fixed Payment	434295	-10.11	2.83	78	17	0.029	570	494.58	481	416.95

Notes: In the main specification, $\theta = 3.3$, $\kappa = 0.01$, $\xi = 0.39$ and $\eta = 0.61$. Welfare gains per resident are obtained by solving for the one-time compensating equivalent lump-sum transfer to each resident such that the planner would be indifferent between the road upgrades and the transfer, with residents' flow utility discounted at 5% to get the net present discounted value of the improvements. Gross gains do not account for construction expenditures, while net gains do.

Bibliography

Acemoglu, Daron and James Robinson, *Why Nations Fail: the Origins of Power, Prosperity, and Poverty*, New York: Crown Publishers, 2012.

_ , Simon Johnson, and James A. Robinson, "The Colonial Origins of Comparative Development: An Empirical Investigation," *The American Economic Review*, 2001, *91* (5), 1369–1401.

Ahlfeldt, Gabriel M., Stephen J. Redding, Daniel M. Sturm, and Nikolaus Wolf, "The Economics of Density: Evidence From the Berlin Wall," *Econometrica*, 2015, *83*, 2127–2189. Publisher: Econometric Society.

Akbar, Prottoy A., Victor Couture, Gilles Duranton, and Adam Storeygard, "The Fast, the Slow, and the Congested: Urban Transportation in Rich and Poor Countries," *NBER Working Paper w31642*, 2023.

Alder, Simon, Kevin Croke, Alice Duhaut, Robert Andrew Marty, and Ariana Brynn Vaisey, "The Impact of Ethiopiaâs Road Investment Program on Economic Development and Land Use : Evidence from Satellite Data," Policy Research Working Paper Series 10000, The World Bank April 2022.

Allen, Treb and Costas Arkolakis, "The Welfare Effects of Transportation Infrastructure Improvements," *The Review of Economic Studies*, 02 2022, *89* (6), 2911–2957.

Almagro, Milena, Felipe Barbieri, Juan Camilo Castillo, Nathaniel Hickok, and Tobias Salz, "Optimal Urban Transportation Policy: Evidence from Chicago," *Working Paper*, 2024.

Arkolakis, Costas, Fabian Eckert, and Rowan Shi, "Combinatorial Discrete Choice: A Quantitative Model of Multinational Location Decisions," *Working Paper*, 2023, (31877).

Asher, Sam and Paul Novosad, "Rural Roads and Local Economic Development," *American Economic Review*, March 2020, *110* (3), 797–823.

Balboni, Clare, "In Harm's Way? Infrastructure Investments and the Persistence of Coastal Cities," *Working Paper*, 2023.

_ , Gharad Bryan, Melanie Morten, and Bilal Siddiqi, "Transportation, Gentrification, and Urban Mobility: The Inequality Effects of Place-Based Policies," *Working Paper*, 2020.

Baum-Snow, Nathaniel, Loren Brandt, J Vernon Henderson, Matthew A Turner, and Qinghua Zhang, "Roads, railroads, and decentralization of Chinese cities," *Review of Economics and Statistics*, 2017, *99* (3), 435–448.

Bergeron, Augustin, Gabriel Z. Tourek, and Jonathan L. Weigel, "The State Capacity Ceiling on Tax Rates: Evidence from Randomized Tax Abatements in the DRC," September 2023, (31685).

Besley, Timothy and Maitreesh Ghatak, "Property Rights and Economic Development," in Dani Rodrik and Mark Rosenzweig, eds., *Dani Rodrik and Mark Rosenzweig, eds.*, Vol. 5, Elsevier, 2010, chapter Chapter 68, pp. 4525–4595.

_ **and Torsten Persson**, "Why Do Developing Countries Tax So Little?," *Journal of Economic Perspectives*, November 2014, *28* (4), 99–120.

Bird, Julia and Anthony J. Venables, "Land tenure and land-use in a developing city: A quantitative spatial model applied to Kampala, Uganda," *Journal of Urban Economics*, 2020, *119* (C).

Bordeu, Olivia, "Commuting Infrastructure in Fragmented Cities," *Working Paper*, 2024.

Brockmeyer, Anne, Alejandro Estefan, Karina RamÃrez Arras, and Juan Carlos SuÃ¡rez Serrato, "Taxing Property in Developing Countries: Theory and Evidence from Mexico," *NBER Working Paper W28637*, 2023.

Brooks, Leah and Zachary Liscow, "Infrastructure Costs," *American Economic Journal: Applied Economics*, April 2023, *15* (2), 1–30.

Brueckner, Jan K. and Harris Selod, "The political economy of urban transport-system choice," *Journal of Public Economics*, 2006, *90* (6), 983–1005.

Bryan, Gharad and Melanie Morten, "The Aggregate Productivity Effects of Internal Migration: Evidence from Indonesia," *Journal of Political Economy*, 2019, *127* (5), 2229–2268.

Collier, Paul and Anthony J. Venables, "Urban infrastructure for development," *Oxford Review of Economic Policy*, 2016, *32* (3), 391–409.

Conley, T. G., "GMM estimation with cross sectional dependence," *Journal of Econometrics*, September 1999, *92* (1), 1–45.

Couture, Victor, Gilles Duranton, and Matthew A. Turner, "Speed," *The Review of Economics and Statistics*, 10 2018, *100* (4), 725–739.

Currier, Lindsey, Edward L. Glaeser, and Gabriel Kreindler, "Infrastructure Inequality: Who Pays the Cost of Road Roughness," *NBER Working Paper w31981*, 2023.

Donaldson, Dave, "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*, April 2018, *108* (4-5), 899–934.

Duranton, Gilles and Matthew A. Turner, "The Fundamental Law of Road Congestion: Evidence from US Cities," *American Economic Review*, October 2011, *101* (6), 2616–52.

Faber, Benjamin, "Trade Integration, Market Size, and Industrialization: Evidence from China's National Trunk Highway System," *The Review of Economic Studies*, 03 2014, *81* (3), 1046–1070.

Fajgelbaum, Pablo D. and Edouard Schaal, "Optimal Transport Networks in Spatial Equilibrium," *Econometrica*, 2020, *88* (4), 1411–1452.

_ , Cecile Gaubert, Nicole Gorton, Eduardo Morales, and Edouard Schaal, "Political Preferences and Transport Infrastructure: Evidence from California's High-Speed Rail," *NBER Working Paper w31438*, 2024.

Gertler, Paul J., Marco Gonzalez-Navarro, Tadeja GraÄner, and Alexander D. Rothenberg, "Road maintenance and local economic development: Evidence from Indonesiaâs highways," *Journal of Urban Economics*, 2024, *143*, 103687.

Ghani, Ejaz, Arti Grover Goswami, and William R. Kerr, "Highway to Success: The Impact of the Golden Quadrilateral Project for the Location and Performance of Indian Manufacturing," *The Economic Journal*, 2016, *126* (591), 317–357.

Glaeser, Edward and J. Vernon Henderson, "Urban economics for the developing World: An introduction," *Journal of Urban Economics*, March 2017, *98*, 1–5.

Glaeser, Edward L. and Giacomo A.M. Ponzetto, "The political economy of transportation investment," *Economics of Transportation*, 2018, *13* (C), 4–26.

Gollin, Douglas and Richard Rogerson, "Agriculture, Roads, and Economic Development in Uganda," *NBER Working Papers*, April 2010, (w15863).

Gonzalez-Navarro, Marco and Climent Quintana-Domeque, "Paving Streets for the Poor: Experimental Analysis of Infrastructure Effects," *The Review of Economics and Statistics*, May 2016, *98* (2), 254–267.

Heblich, Stephan, Stephen Redding, and Daniel Sturm, "The Making of the Modern Metropolis: Evidence from London*," *The Quarterly Journal of Economics*, 11 2020, *135*, 2059–2133.

Herzog, Ian, Liu Siyuan, and Yue Yu, "National Road Upgrading and Structural Transformation: Evidence from Ugandan Households," *Working Paper*, 2024.

Holland, Alisha C., "Roadblocks: How Property Rights Undermine Development in Colombia," *American Journal of Political Science*, 2023, *67* (3), 639–655.

Jedwab, Remi and Alexander Moradi, "The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa," *The Review of Economics and Statistics*, 05 2016, *98* (2), 268–284.

Jeong, David, DD Gransberg, Heedae Park, and Nikhil Shelar, "Barriers to right-of-way acquisition and recommendations for change," Technical Report, Minnesota Department of Transportation, Research Services & Library 2016.

KCCA, "Analysis of Boda-Boda Operations Paratransit Modernization and Street Usage Study," Technical Report 2020.

Knebelmann, Justine, "Taxing Property Owners in Dakar," *IGC Policy Brief 50415*, 2019.

Kreindler, Gabriel, Arya Gaduh, Tilman Graff, Rema Hanna, and Benjamin A. Olken, "Optimal Public Transportation Networks: Evidence from the World's Largest Bus Rapid Transit System in Jakarta," NBER Working Papers 31369, National Bureau of Economic Research, Inc June 2023.

Kreindler, Gabriel E. and Yuhei Miyauchi, "Measuring Commuting and Economic Activity inside Cities with Cell Phone Records," *The Review of Economics and Statistics*, 07 2023, *105* (4), 899–909.

Kumar, Ajay and Fanny Barrett, "Stuck in Traffic: Urban Transport in Africa," Technical Report 2008.

Lucas, Robert E. and Esteban Rossi-Hansberg, "On the Internal Structure of Cities," *Econometrica*, July 2002, *70* (4), 1445–1476.

Majid, Hadia, Ammar Malik, and Kate Vyborny, "Infrastructure investments and public transport use: Evidence from Lahore, Pakistan," *Working Paper*, 2018.

Monte, Ferdinando, Stephen J. Redding, and Esteban Rossi-Hansberg, "Commuting, Migration, and Local Employment Elasticities," *American Economic Review*, December 2018, *108* (12), 3855–90.

Morten, Melanie and Jaqueline Oliveira, "The Effects of Roads on Trade and Migration: Evidence from a Planned Capital City," *American Economic Journal: Applied Economics*, April 2024, *16* (2), 389–421.

Munch, Patricia, "An Economic Analysis of Eminent Domain," *Journal of Political Economy*, 1976, *84* (3), 473–497.

North, Douglass C., *Institutions, Institutional Change and Economic Performance* Political Economy of Institutions and Decisions, Cambridge University Press, 1990.

Olken, BenjaminÂ A., "Monitoring Corruption: Evidence from a Field Experiment in Indonesia," *Journal of Political Economy*, 2007, *115* (2), 200–249.

Posner, Eric A. and E. Glen Weyl, "Property Is Only Another Name for Monopoly," *Journal of Legal Analysis*, 04 2017, *9* (1), 51–123.

Redding, Stephen J. and Esteban Rossi-Hansberg, "Quantitative Spatial Economics," *Annual Review of Economics*, 2017, *9* (Volume 9, 2017), 21–58.

Regan, Tanner and Priya Manwaring, "Public Disclosure and Tax Compliance: Evidence from Uganda," Working Papers 2024.

Severen, Christopher, "Commuting, Labor, and Housing Market Effects of Mass Transportation: Welfare and Identification," *The Review of Economics and Statistics*, 09 2023, *105* (5), 1073–1091.

Shavell, Steven, "Eminent Domain versus Government Purchase of Land Given Imperfect Information about Owners' Valuations," *Journal of Law and Economics*, February 2010, *53* (1), 1–27.

T., Arkolakis C. Allen and X. Li, "Optimal city structure," *Mimeo*, 2015.

Traxler, Christian, "Social norms and conditional cooperative taxpayers," *European Journal of Political Economy*, 2010, *26* (1), 89–103.

Tsivanidis, Nick, "Evaluating the Impact of Urban Transit Infrastructure: Evidence from Bogota's TransMilenio," *Working Paper*, 2023.

Wolfram, Catherine D., Edward Miguel, Eric Hsu, and Susanna B. Berkouwer, "Contracting Structures in Public Procurement: Evidence from Donor-Funded Electrification in Kenya," *NBER Working Paper w30948*, 2024.

World Bank, "Resettlement and Development: The Bankwide Review of Projects Involving Involuntary Resettlement 1986-1993," Technical Report, Environment Department, Washington, D.C., SDP 13, p. 142. 1996.

_ , "Beyond the Gap: How Countries Can Afford the Infrastructure They Need while Protecting the Planet," Technical Report 2019.

_ , "Implementation Completion Report (ICR) Review," Technical Report, Independent Evaluation Group (IEG) 2023.

Zarate, Roman David, "Spatial Misallocation, Informality and Transit Improvements: Evidence from Mexico City," *Working Paper*, 2024.

Appendix

A Context: Property Right Regimes in Kampala

The different property right regimes (or *land tenure systems*) are inherited from the 1900 Buganda Agreement between the British Protectorate and the Buganda Kingdom, which split used land into Mailo and Crown land. On the one hand, crown land, owned by the British protectorate, was leased to private owners for 49 or 99 year leases and are still managed by local land boards. These leases can be renewed. On the other hand, Mailo land (square mile plots) was owned by the Kabaka, head of the Kingdom or by local chiefs and notables. Over time, legal protections were put in place to protect the peasant tenants occupying this land (*kibanja*) from being evicted by the landowners, giving them ownership over developments on this land and creating de-facto double ownership claims over mailo land. These land titles and occupancy certificates are managed by the Buganda Land Board, and issues of multiple land claimants per plot are common. In addition, previously unoccupied land was titled over the course of the 20^{th} century and became freehold land. A small number of leases were also replaced by permanent titles. While freehold land titles are the least restrictive (single ownership and unlimited term), the clarity of the owners' property rights is conditional on the titles being correctly accounted for, which is seldom the case.[30] Bird and Venables (2020) compare Mailo land to all other property right regimes in Kampala, using information from the Census to recover the share of Mailo land in each parish. They find that the larger the share of Mailo land in a parish, the higher its population density, the larger the prevalence of informal housing and the lower economic activity.

B Broker survey: Comparison with Scrapped Online Property Ads

To increase confidence in the reliability of the broker survey data, I compare it with data scrapped online from RealEstateDatabase.net, which includes posts of properties to rent or sale in Kampala and other parts of Uganda. This online database includes some geographical information (at the *neighborhood* level, which is less precise than parish and very noisy), as well as property characteristics. In addition, the date at which the property is posted can be recovered from the file name of the photos accompanying the post (but not the transaction date).

On Figure A1, I plot the distributions of property-level prices for sold residential properties in my broker survey data (red) and the online data (blue). The distribution of online property prices is skewed to the right, with an average price list at $332,694 (against $70,261 in the survey data). Given that the average monthly net salary in Kampala is $147 (KCCA 2019 Statistical Abstract) and 18.4% of Kampala households own a laptop (UBOS 2014), property posted online are upscale properties only, not within reach of the average household, and not representative.

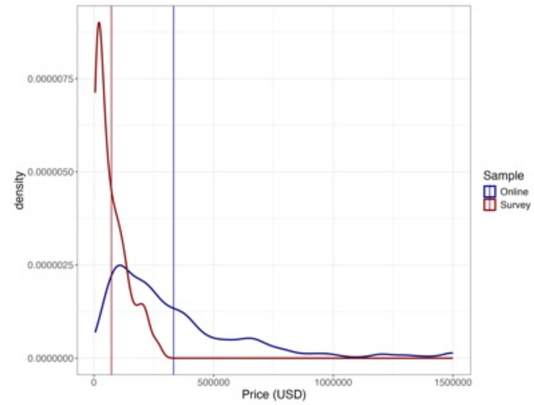
Reassuringly, however, while price levels are different across the databases, they are positively correlated over space. To check this, I run the following regression

$$\ln \mathrm{p}_{pt}^{b} = \alpha + \beta \times \ln \mathrm{p}_{pt}^{o} + \gamma_t + \gamma_p + e_{pt}$$

where p_{pt}^{b} is the average property price in parish p, year t in the broker data, and analogously for the online database $\ln \mathrm{p}_{pt}^{o}$. γ_t and γ_p are year and parish fixed-effects, respectively. The results are displayed on Table A1 are confirm the robust positive correlation between the online and broker survey databases at the parish and parish-year levels.

[30] The Uganda government started to digitize the national land registry to decrease the number of land fraud cases in 2013, but, as of 2023, this process had not been finalized yet.

Figure A1: Comparison of Property Prices in the Broker Survey and the Online Database



Notes: This figure displays property-level log sale prices for residential properties in the real estate broker survey and the online database. The vertical lines correspond to the average prices in each database

Table A1: Comparison of Online Data and Broker Data

	Dependent variable:				
	Log Parish-Level Mean Broker Survey Price (USD)				
	(1)	(2)	(3)	(4)	(5)
Log Parish-Level Mean Online Price (USD)	0.396***	0.400***	0.497**	0.494**	0.272***
	(0.099)	(0.100)	(0.194)	(0.198)	(0.080)
Year FE		Y		Y	
Parish FE			Y	Y	
Level of Observation	Parish-Year	Parish-Year	Parish-Year	Parish-Year	Parish
Observations	181	181	181	181	309
R^2	0.083	0.108	0.644	0.659	0.036
Adjusted R^2	0.078	0.077	0.433	0.431	0.033

Notes: standard errors are displayed in parentheses, s.t. *p< 0.1; **p< 0.05; ***p< 0.01. Price variables are trimmed at the top and bottom 1%. The sample is restricted to residential properties sold out (or posted) in 2018 onwards.

C Owner survey

C.1 Sampling Strategy

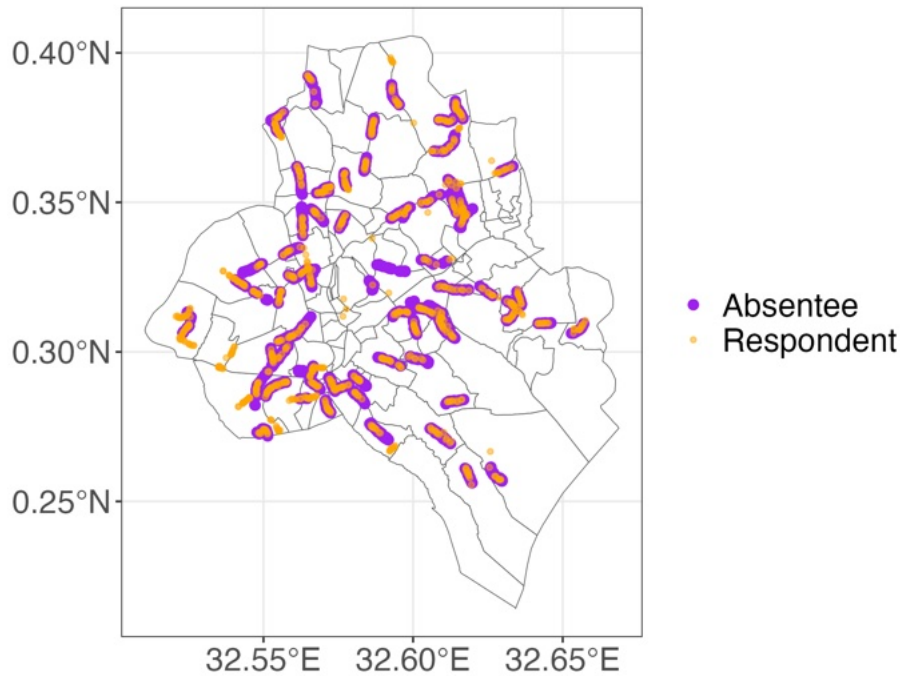
The sampling frame for the owner survey was at the road segment level. More precisely, roads within Kampala were split into categories based on their policy status: road targeted by the policy with completed upgrade (pre-2020 or 2020-2024), road targeted by the policy but upgrade ongoing (2024 onwards), potential road candidate for upgrade (either mentioned by policy documents but not upgraded, or unpaved roads). To ensure coverage of the different property right regimes in the city, the main tenure system within a 50 meters buffer of each road was identified. Then, for each triplet {division, land tenure, road category}, road segments were randomly ordered and the first 97 valid segments were selected.[31]

Enumerators conducted a census of properties over a pre-specified road segment of approximately $\frac{1}{2}$ to 1 mile, between two intersections, starting from a randomly selected point over the road segment. In addition to the property census, enumerators were instructed to interview all available potential respondents, moving from the (randomly selected) starting point to the end of the road segment. Figure A2 shows a

[31]Segments within approximately $1km$ from a previously selected segment were excluded, as well as segments where data collection was impossible (based on on-the-ground observations) or where road characteristics were different than in the database (for example a large paved road vs an unpaved road).

map of the survey areas, displaying both interviewed respondents (in orange) and listed plots (in purple).

Figure A2: Spatial Coverage of the Owner Survey



Notes: This map displays the approximate location of respondents and potential respondents (but not interviewed) of the owner survey. Roads covered include roads targeted by the policy with completed upgrade (pre-2020 or 2020-2024), roads targeted by the policy but upgrade ongoing (2024 onwards) and potential roads candidate for upgrade (either mentioned by policy documents but not upgraded, or unpaved roads). Respondents on the latter roads are not used in the main analysis because their property was not affected by road upgrades.

Eligible respondents were property (land or building) owners above 18 years old, their spouse or an individual with knowledge and decision power over land and property related issues. The targeted property must be on the side of one of the targeted roads. If the respondent was not available at that time, but willing to participate, the survey team offered to make an appointment and come back at a later time.

C.2 Overview of Survey Instruments

1. Eligibility and consent
2. Road quality and road upgrade
    - Name and characteristics of the closest road and road upgrade characteristics.
    - Road quality on a scale of 1 to 10, today and before the road upgrade (conditional on upgrade).
3. Land acquisition (conditional on land or property affected by the road upgrade)[32]
    - What was affected: how much land was affected, whether developments in the road reserve were affected.

[32]In addition, if respondents' road was not part of the policy, or if their property had not been affected by the road upgrade, respondents were asked analogous questions about their decision and reasoning, in the hypothetical case their property had been affected by a road upgrade.

- Compensation, offer and negotiations: timeline and accept / negotiate / court and outcomes, reasons.
- Perceptions: pivotality, potential returns from negotiating, affected neighborhood
- Interactions: with neighbors, family, local leaders
- Knowledge of the legal system
- Suggestions

4. Property value and property characteristics
    - Self-assessed property value if sold and rented today, as well as either before the road upgrade and today if the road had not been upgraded.
    - Ownership status: timeline and characteristics of the acquisition and ownership, ownership documents.
    - Property characteristics, including recent improvements.
5. Household and neighborhood characteristics
    - religion, ethnicity, local leader popularity
    - basic socio-economic characteristics on the model of the Uganda National Panel Survey

C.3 Comparing Survey Respondents to the Average Kampala Resident

In Table A2, I compare owner survey respondents to the average Kampala resident as per the 2014 Population Census and the 2019 Uganda National Panel Survey (UNPS) along the lines of wealth proxies (panel A), education (panel B) and property characteristics (panel C). On average, survey respondents are wealthier and more educated than the average Kampala resident from the 2014 Population Census. Comparing the 2019 UNPS participants that are property owners and those that are renters (columns 2 and 3) reveals that property owners are wealthier than the average Kampala resident. In turn, the respondents to my owner survey tend to be wealthier than the average Kampala owner, which is consistent with property on the side of roads being wealthier than away from roads, which corresponds to the majority of properties in Kampala.

Table A2: Comparison of Owner Survey Respondents and Population Census

	2014 Population Census	2019 UNPS	2019 UNPS (owners only)	Owner Survey
Panel A: Wealth Indicators				
Own TV (share)	0.68			0.97
Own Bicycle (share)	0.07	0.06	0.1	0.2
Own Car (share)		0.18	0.23	0.4
Own Computer (share)	0.18			0.3
Access to Electricity	0.84			0.97
Bank Account (share)	0.57			0.86
At least 2 meals per day (share)	0.14			1
Panel B: Education				
No formal education (share)	0.18			0.03
Some secondary education (share)	0.55			0.75
Panel C: Property				
Inherited Property (share)			0.31	0.58
Year Acquired			1994	1988
Parcel Area (m2)			2075	2218
Floor Tiles (share)		0.13	0.15	0.4
Floor Cement screed (share)		0.78	0.77	0.54

Notes: Census data from the 2014 Population Census and from the 2019 Uganda National Panel Survey restricted to Kampala. The share of population with secondary education in the Census data is for 13-18 y.o. residents, while it is for survey respondents in the survey data.

D Additional Analyses

D.1 Estimating Speed by Road Category

To recover the average free-flow speed on each type of roads as per the Open Street Map (OSM) classification $\in$ {highway, primary, secondary, tertiary and other}, I leverage information from my Google Maps trips. From the Direction API, I recover each trip's approximate path from a list of coordinates roughly corresponding to turns and intersections. I draw a buffer of 50 meters around the straight lines between these points to account for measurement error, and map them to the OSM underlying road network. I compute the share of the total length of OSM intersected roads belonging to each road type, c^{RT}, and regress the trip's average speed $s_{h,d,od}$ on road categories and trip controls:

$$\mathrm{s}_{h,d,od} = \alpha + \sum_{RT} \beta^{RT} \times \mathrm{c}^{RT}_{h,d,od} + \mathbf{X}'_{\mathbf{od}}\beta^{\mathbf{od}} + \gamma_h + \gamma_d + \epsilon_{h,d,od}.$$

$\mathbf{X_{od}}$is a vector of origin and destination characteristics, including longitude, latitude, longitude^2, latitude^2 at origin and destination and γ_h is an hour fixed effect. The sample of trips is restricted to grid-to-grid trips, to ensure a detailed coverage of Kampala as a whole. $\alpha + \beta^{RT}$ can be interpreted as the average speed on a trip where all the trip happens on a road of type RT (the share of the trip on a road of type RT is equal to 1). Standard errors are clustered at the day level to reflect the query sampling strategy. The results are presented in Table A3. In columns 1 to 4, $\mathrm{s}_{h,d,od}$ is defined as the speed at time of query and the sample is restricted to non-rush hour speed to capture free-flow speed. In columns 5 to 8, speed is defined as the average speed reported by Google Maps on each query for that trip. The speed patterns are robust across specifications: compared to a trip exclusively on primary roads (the omitted category), the larger the share of the trip on motorway, the faster the trip. On the other hand, the larger the share of the trip on secondary, tertiary or other roads, the slower. Given the stability of the coefficients across specifications, I pick the third specification to map to OSM, as it is the most comprehensive in terms of road characteristics, but does not include geographical characteristics and I am assuming that local speed is constant over space within a road category.

Table A3: Speed by Road Category

	Dependent variable:							
	Speed at time of Query (km/h)				Average Speed (km/h)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Distance (km)		0.187***	0.177***	0.170***		0.192***	0.188***	0.178***
		(0.006)	(0.004)	(0.005)		(0.004)	(0.004)	(0.004)
Paved (share)			8.843***	9.026***			7.853***	8.128***
			(0.457)	(0.388)			(0.086)	(0.096)
Motorway (share)	10.890***	11.790***	7.501***	7.573***	11.360***	12.510***	8.620***	8.661***
	(0.812)	(0.713)	(0.590)	(0.538)	(0.444)	(0.548)	(0.435)	(0.462)
Secondary (share)	−4.218***	−1.976***	−3.766***	−3.572***	−4.559***	−2.155***	−3.968***	−3.726***
	(0.196)	(0.156)	(0.138)	(0.125)	(0.113)	(0.144)	(0.102)	(0.112)
Tertiary (share)	−4.210***	−1.797***	−2.931***	−2.667***	−4.161***	−1.748***	−2.653***	−2.577***
	(0.203)	(0.212)	(0.154)	(0.212)	(0.172)	(0.145)	(0.135)	(0.137)
Other (share)	−7.198***	−4.961***	−1.094***	−1.162***	−6.378***	−3.983***	−0.445***	−0.547***
	(0.360)	(0.354)	(0.233)	(0.233)	(0.129)	(0.090)	(0.080)	(0.080)
Sample	Grid	Grid	Grid	Grid	Grid	Grid	Grid	Grid
Ref Road Cat: Primary								
Flexible Geo Controls		Y		Y		Y		Y
Time	Non-rush	Non-rush	Non-rush	Non-rush	All	All	All	All
Hour FE	Y	Y	Y	Y	Y	Y	Y	Y
Dep Var Mean (km/h)	20.2	20.2	20.2	20.2	19.1	19.1	19.1	19.1
Observations	36,267	36,267	36,267	36,267	58,783	58,783	58,783	58,783
R^2	0.142	0.269	0.380	0.381	0.087	0.245	0.339	0.344
Note:								*p<0.1; **p<0.05; ***p<0.01

Notes: Standard errors are clustered at the day of query level and displayed in parentheses with significance levels $^{*}p < 0.1; ^{**}p < 0.05; ^{***}p < 0.01$.

D.2 Evidence of Traffic Reallocation Towards Upgraded Roads

A road being improved may also affect the number of commuters using this road, coming from both (i) a change in path for existing trips in both the short and long term and (ii) new trips. The data allows me to study (i) by conducting the following thought experiment: take a trip between the centroids of two parishes o and d. Over time, as a given road r gets improved (late wave), does the probability the trip takes road r increase?

To answer this question, I leverage my Google Maps data between all pairs of parish centroids in Kampala. Over the period covered by the data (March 2023 - September 2024), upgrades of some roads in the late policy wave were finalized, allowing me to study whether trips queried later were more likely to take roads part of the late policy wave, as these roads were increasingly improved over time. Google Maps API itinerary is a series of coordinates, corresponding to turns and intersections. I construct straight lines between these points, calculate a buffer of 50 meters around these straight lines to account for measurement error. I recover the corresponding roads by intersecting (buffered) straight lines between these points and the OSM underlying road network. I run the following regression:

$$\frac{\text{dist policy roads late wave}}{\text{dist total}}_{h,d,ij} \times 100 = \beta \times \text{t}_d + \gamma_h + \gamma_{ij} + e_{h,d,ij}$$

where $\frac{\text{dist policy roads late wave}}{\text{dist total}}_{h,d,ij} \times 100$ is the share of trip between i and j on day d, hour h that is mapped to roads in the late policy waves, t_d corresponds to the month of query, while γ_h and γ_{ij} are hour and origin-destination fixed-effects, respectively. Standard errors are clustered at the day of query level.[33]

Regression results are presented in Table A4. In columns 1 to 4, I show that over time, the share of trips happening on roads upgraded in the late wave of the policy increases, as more and more of these roads get upgraded. This finding is robust to including origin-destination fixed-effects (column 4), so that the identifying variation comes from changes in the path of the same $o - d$ trip over time. I reproduce the analysis but change the dependent variable to be the share of trips happening on roads upgraded in the early wave of the policy. These roads' upgrades were already completed by the beginning of the period covered by my Google Maps data, so they can be used as a placebo test. In columns 5 and 6, I find that indeed, the share of trips on these roads did not increase since the beginning of the Google Maps data.

Table A4: More Likely to Use a Road As It Gets Upgraded

	Dependent variable:					
	Share of Total Trip Length on Late Policy Roads * 100				Share of Total Trip Length on Early Policy Roads * 100	
	(1)	(2)	(3)	(4)	(5)	(6)
Time (months)	0.024**	0.022**	0.022**	0.013*	−0.001	−0.005
	(0.010)	(0.010)	(0.011)	(0.007)	(0.006)	(0.004)
Straight line o-d length controls	Y					
Trip length controls				Y		Y
Spatial FE		o and d	od pair	od pair	od pair	od pair
Observations	104,404	104,404	104,404	104,404	104,404	104,404
R^2	0.247	0.563	0.912	0.914	0.877	0.878
Adjusted R^2	0.247	0.562	0.904	0.906	0.865	0.867
Note:						*p<0.1; **p<0.05; ***p<0.01

Notes: Standard errors are displayed in parentheses and clustered at the day of query level, with significance levels $^{*}p < 0.1; ^{**}p < 0.05; ^{***}p < 0.01$. I do not cluster at the road level as I include the universe of parish-to-parish centroids in the city of Kampala.

[33] We do not cluster at the road level as we include the universe of parish-to-parish centroids in the city of Kampala.

E Robustness to Alternative Model Parameters

Table A5: Net Returns to Realized Road Improvements: Robustness Exercises

	Avg Change (%)		Land Costs	Tax	Welfare Gains (USD)		Net of Construct. Costs	
	Commuting Time	Property Values	(USD) (million)	Rate ϕ	Per Resident	Total (million)	Per Resident	Total (million)
Panel A. Realized Road Improvements - Main								
A1. VLT	-6.62	1.36	15.18	0.022	209	181.2	119	103.57
A2. Market Value	-6.62	1.36	63.1	0.091	-380	-329.71	-470	-407.34
A3. No Payment	-6.62	1.36	0	0	395	342.75	306	265.12
Panel B. Alternative Discount Rates								
B1.1. - A1 & 3%	-6.62	1.36	15.18	0.022	348	302	259	224.37
B1.2. - A1 & 7%	-6.62	1.36	15.18	0.022	149	129.43	60	51.8
B2.1. - A2 & 3%	-6.62	1.36	63.1	0.091	-634	-549.51	-723	-627.14
B2.2. - A2 & 7%	-6.62	1.36	63.1	0.091	-272	-235.51	-361	-313.14
B3.1. - A3 & 3%	-6.62	1.36	0	0	659	571.26	569	493.63
B3.2. - A3 & 7%	-6.62	1.36	0	0	282	244.82	193	167.19
Panel C. Alternative Model Parameters								
C1. - A1 & $\eta = 0.5$	-6.62	1.36	15.18	0.017	250	216.75	160	139.12
C2. - A1 & $\eta = 0.7$	-6.62	1.36	15.18	0.028	153	132.71	64	55.08
C3. - A1 & $\theta = 3.0$	-6.8	1.41	15.18	0.021	240	208.13	151	130.5
C4. - A1 & $\theta = 3.6$	-6.44	1.32	15.18	0.022	182	157.61	92	79.98
C5. - A1 & $\kappa = 0.008$	-7.61	1.22	15.18	0.021	136	118.24	47	40.61
C6. - A1 & $\kappa = 0.012$	-5.99	1.49	15.18	0.023	281	243.99	192	166.36
C7. - A1 & $\xi = 0.34$	-5.5	1.24	15.18	0.022	156	134.9	66	57.27
C8. - A1 & $\xi = 0.44$	-7.85	1.47	15.18	0.021	255	221.23	166	143.6
Panel D. Owner Log Utility								
D1. - A1 & log U	-6.62	1.36	60.71	0.022	158	137.1	69	59.47
D2. - A2 & log U	-6.62	1.36	252.38	0.091	-265	-229.9	-355	-307.53
D3. - A3 & log U	-6.62	1.36	0	0	287	248.51	197	170.88

Notes: In the main specification, $\theta = 3.3$, $\kappa = 0.01$, $\xi = 0.39$ and $\eta = 0.61$. Gross welfare gains per resident is obtained by solving for the one-time compensating equivalent lump-sum transfer to each resident such that the planner would be indifferent between the road upgrades and the transfer, with residents' flow utility discounted at 5% (Panels A, C and D) to get the net present discounted value of the improvements. In panels A to C, owners' utility is linear in income. In panel D, I introduce concavity in owners' utility function by defining owners' utility as $W_i^o = \alpha \cdot \log(\text{income}_i)$ where α is such that if construction funds were distributed lump-sum to all residents, the gross welfare gains would be equal to the construction funds.

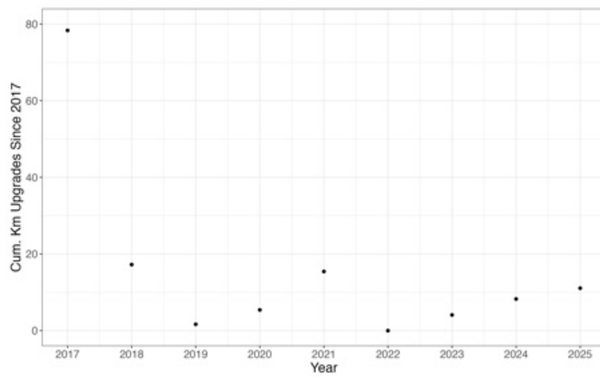
Table A6: Net Returns to Optimal Road Improvements: Robustness Exercises

	Avg Change (%) Commuting Time	Avg Change (%) Property Values	Land Costs (USD) (million)	Tax Rate ϕ	Welfare Gains (USD) Per Resident	Welfare Gains (USD) Total (million)	Net of Construct. Costs Per Resident	Net of Construct. Costs Total (million)
Panel A. Optimal Road Improvements - Main								
A1. VLT	-10.14	2.86	16.61	0.024	590	511.33	500	433.7
A2. Market Value	-9.9	2.74	62.16	0.088	242	209.89	153	132.31
A3. No Payment	-10.38	3.07	0	0	724	627.36	634	549.73
Panel B. Alternative Discount Rates								
B1.1. - A1 & 3%	-10.14	2.86	16.61	0.024	983	852.22	893	774.59
B1.2. - A1 & 7%	-10.14	2.86	16.61	0.024	421	365.24	332	287.61
B2.1. - A2 & 3%	-9.9	2.74	62.16	0.088	403	349.81	314	272.24
B2.2. - A2 & 7%	-9.9	2.74	62.16	0.088	173	149.92	83	72.34
B3.1. - A3 & 3%	-10.38	3.07	0	0	1206	1045.59	1116	967.96
B3.2. - A3 & 7%	-10.38	3.07	0	0	517	448.11	427	370.48
Panel C. Alternative Model Parameters								
C1. - A1 & $\eta = 0.5$	-10.17	2.91	17.04	0.019	635	550.43	545	472.8
C2. - A1 & $\eta = 0.7$	-10.1	2.8	16.03	0.03	529	459.06	440	381.43
C3. - A1 & $\theta = 3.0$	-10.53	2.99	16.91	0.023	636	551.7	547	474.07
C4. - A1 & $\theta = 3.6$	-9.78	2.77	16.44	0.024	549	475.87	459	398.24
C5. - A1 & $\kappa = 0.008$	-11.53	2.4	15.83	0.021	454	393.85	365	316.22
C6. - A1 & $\kappa = 0.012$	-9.23	3.27	17.02	0.025	726	629.42	636	551.79
C7. - A1 & $\xi = 0.34$	-8.34	2.6	16.21	0.023	505	437.53	415	359.9
C8. - A1 & $\xi = 0.44$	-12.14	3.02	16.39	0.023	662	573.81	572	496.18
Panel D. Owner Log Utility								
D1. - A1 & log U	-8.3	5.65	16.88	0.024	1166	1010.71	1076	933.08
D2. - A2 & log U	-6.52	4.61	66.07	0.095	763	661.48	674	583.97
D3. - A3 & log U	-8.64	6	0	0	1211	1049.72	1121	972.09
Panel E. No Opportunity Cost of Land								
E1. VLT	-11.39	3.12	18.34	0.026	966	837.11	876	759.48
E2. Market Value Acquisition	-10.86	2.84	66.89	0.095	557	483.07	468	405.44
E3. No Land Payment	-11.39	3.14	0	0	1098	952.03	1009	874.4

Notes: In the main specification, $\theta = 3.3$, $\kappa = 0.01$, $\xi = 0.39$ and $\eta = 0.61$. Gross welfare gains per resident is obtained by solving for the one-time compensating equivalent lump-sum transfer to each resident such that the planner would be indifferent between the road upgrades and the transfer, with residents' flow utility discounted at 5% (Panels A, C, D and E) to get the net present discounted value of the improvements. In panels A to D, owners' utility is linear in income. In panel E, I introduce concavity in owners' utility function by defining owners' utility as $W_i^o = \alpha \cdot \log(\text{income}_i)$ where α is such that if construction funds were distributed lump-sum to all residents, the gross welfare gains would be equal to the construction funds.

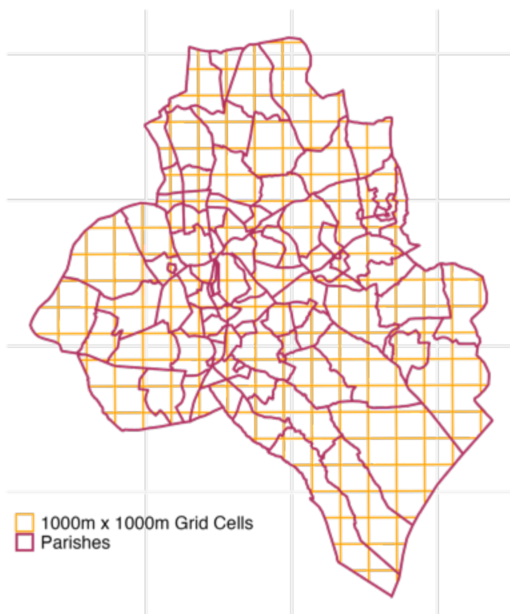
F Additional Figures and Tables

Figure A3: Cumulative Length of Road Upgrades in Kampala since 2017



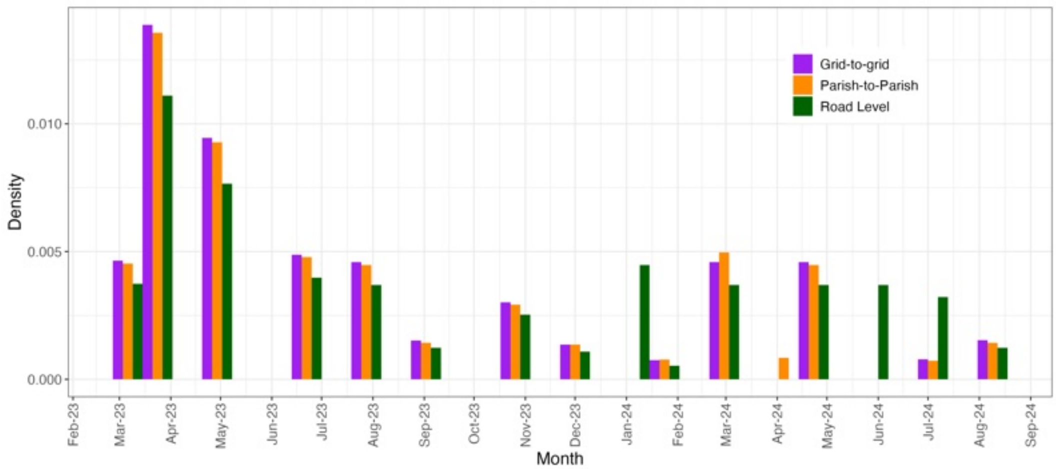
Notes: This figures displays the length of road upgrades between 2017 and 2024 in Kampala, 2017 being the first year KIIDP2 policy roads are upgraded. Source: KCCA, WB, AfDB.

Figure A4: GoogleMaps API queries: Geographic Units



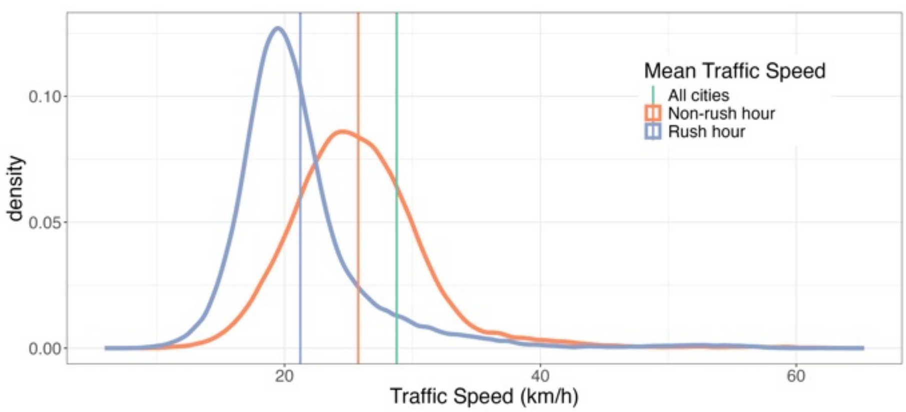
Notes: This figure displays the location of parishes and 1000m × 1000m grid cells used as sampling units for the GoogleMaps API queries.

Figure A5: Timing of Google Maps API Queries By Type of Queries



Notes: This figures plots the distribution of Google Maps Direction API queries over time by type of queries ∈ {between neighboring grid cells, between all pairs of parish centroids, road level}.

Figure A6: Distribution of Traffic Speed



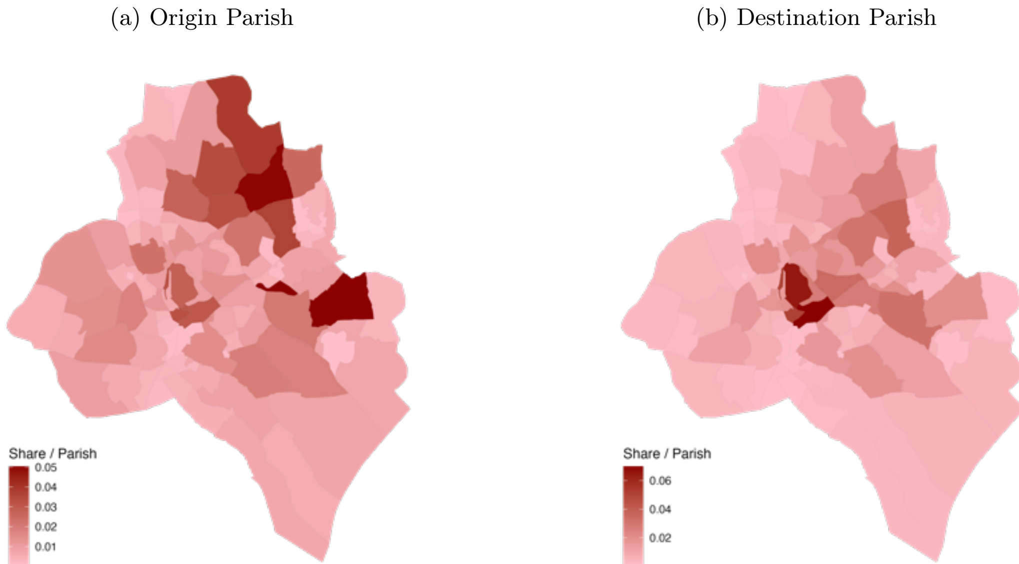
Notes: This figures plots the distribution of traffic speed from Google Maps Direction API queries for parish-to-parish (unweighted) queries. The data spans March 2023 - August 2024, as displayed on Figure A5. The average non-rush hour speed is 25.76 km/h and the average rush-hour speed is 21.23 km/h. There are 57,662 non-rush hour trips and 55,535 rush-hour trips.

Table A7: Length of Roads by Category

Road Class		Length (km)	share
Motorway	1	125	0.03
Primary	3	129	0.03
Secondary	4	186	0.04
Tertiary	5	309	0.07
Other	2	3873	0.84

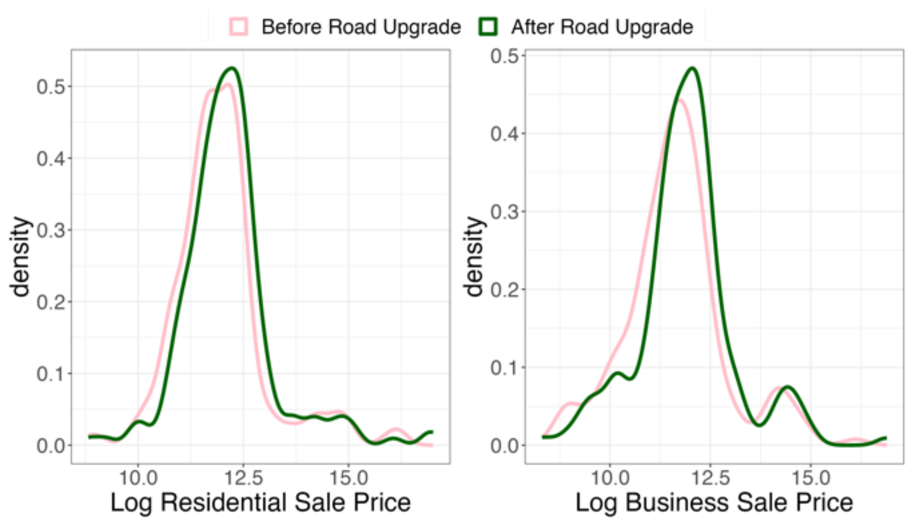
Source: Open Street Maps

Figure A7: Ride-Hailing Trips: Origin and Destination of Morning Rush Hour Trips



Notes: These figures show the share of morning rush-hour trips by parish of origin (panel a) and destination (panel b) from the ride-hailing data.

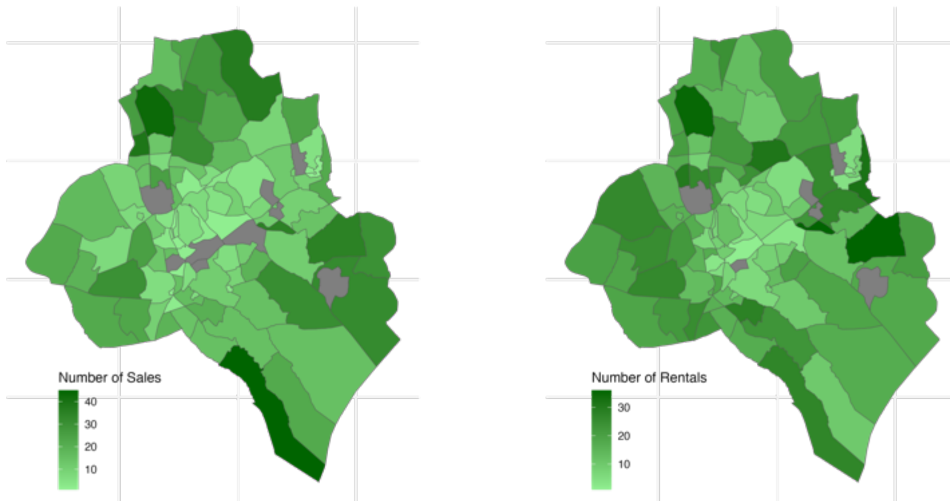
Figure A8: Broker Appraisal: Impact of Road Upgrades on Local Property Values



Notes: I plot the distribution of log sales price for residential (left) and business (right) properties, as assessed by brokers during the appraisal of a standardized property if the road was/wasn't upgraded. Source: own survey.

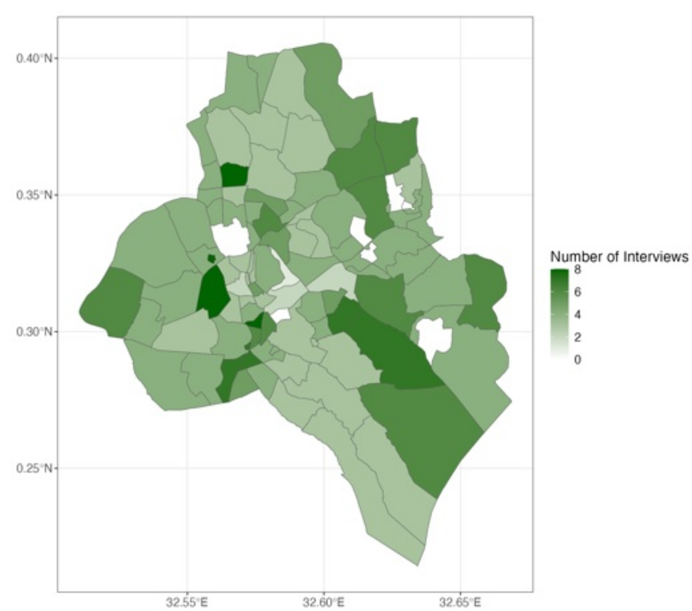
Figure A9: Number of Transactions By Parish

(a) Sales (b) Rent



Notes: These maps display the number of transactions by parish from the broker survey.

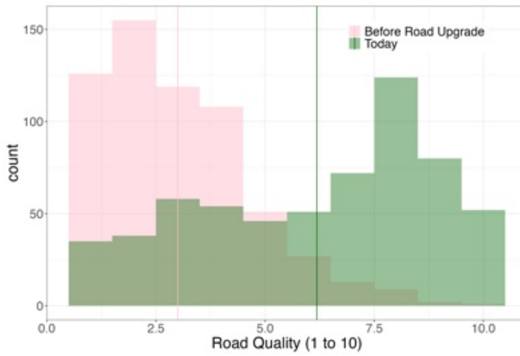
Figure A10: Number of Real Estate Broker Interviews By Parish



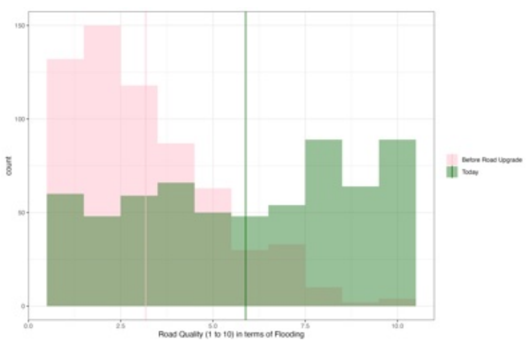
Notes: This map displays the number of real estate brokers interviewed by parish.

Figure A11: Change in Road Quality and Local Amenities Following Road Upgrades

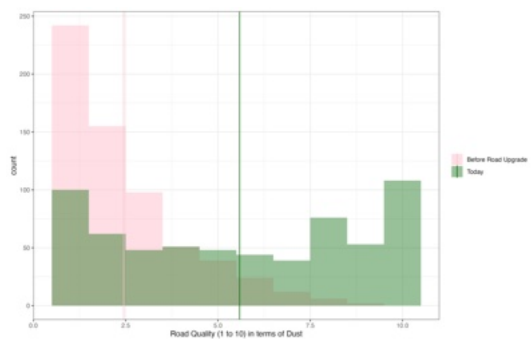
(a) Road Quality



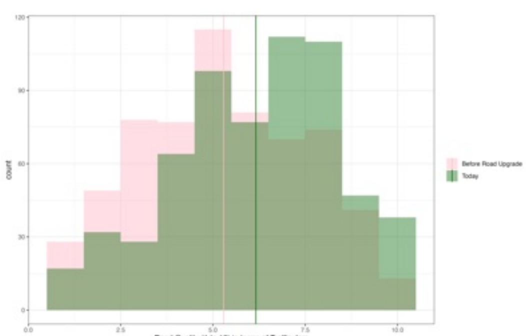
(b) (Absence of) Flooding



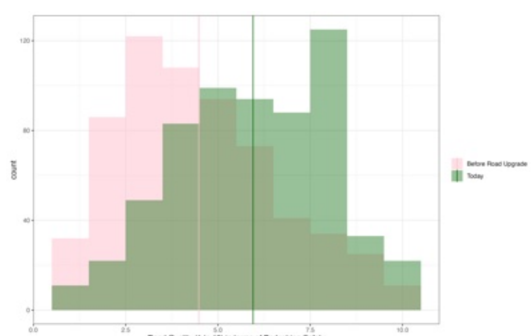
(c) (Absence of) Dust



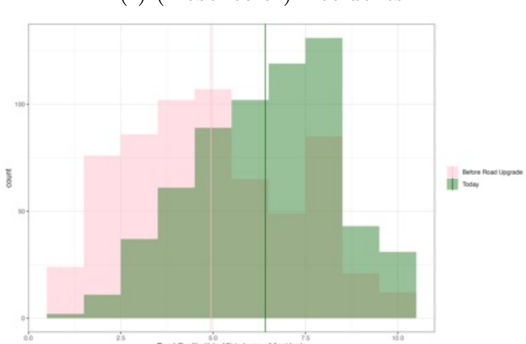
(d) (Absence of) Traffic Jam



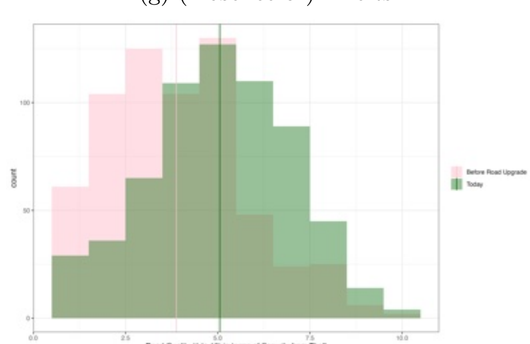
(e) Pedestrian Safety



(f) (Absence of) Accidents



(g) (Absence of) Thefts



Notes: Owners on the side of roads with completed upgrades were asked about the quality of various road-level amenities before and after the road was upgraded, on a scale of 0 to 10, where 0 corresponds to the worst roads in Kampala, while 10 corresponds to the best roads in Kampala. Source: own survey.

Figure A12: Owners' Stated Reasons to Accept Not to Get Compensated

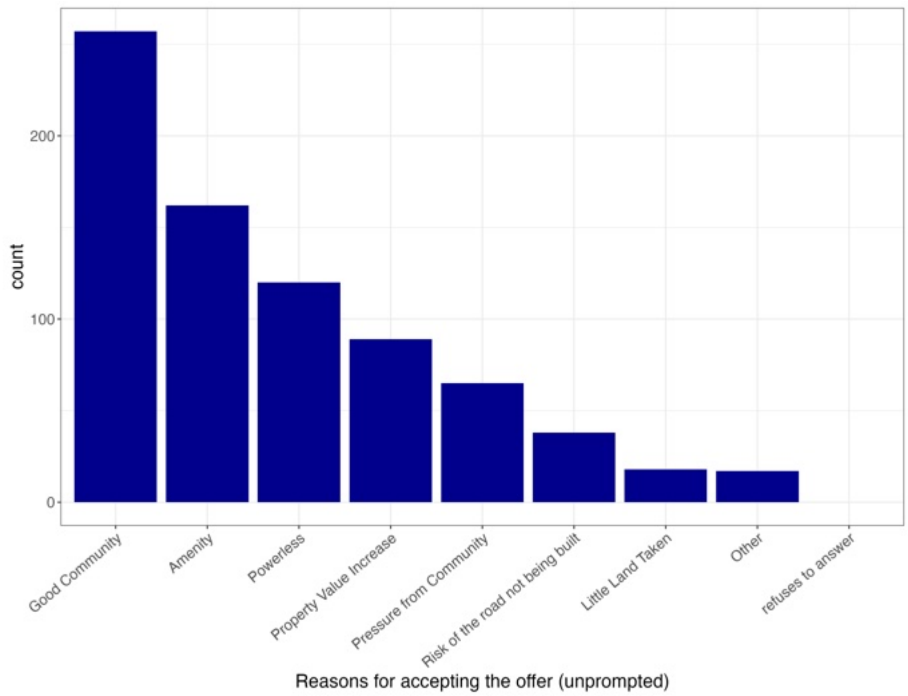


Figure A13: Owners' Stated Reasons to Negotiate to Get Compensated

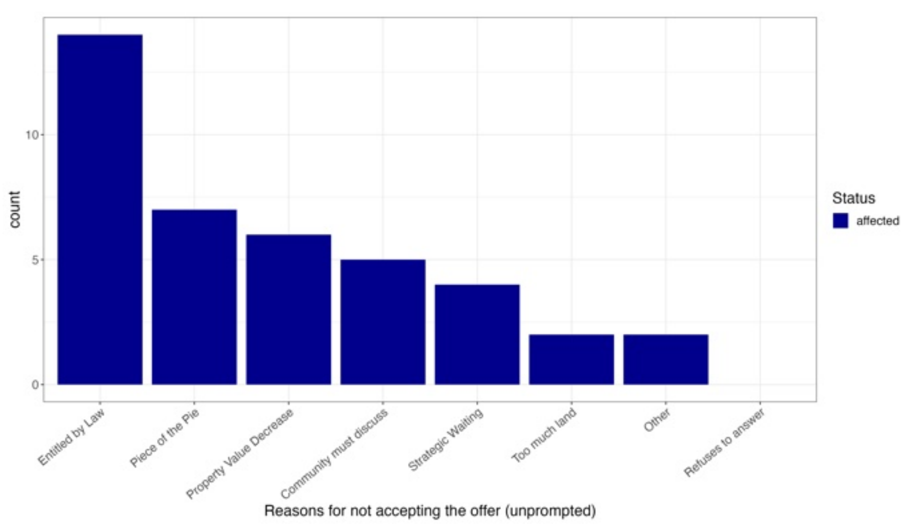


Figure A14: Interviewed Owners Do Not Believe that their Decision has an Impact on The Probability of the Road Being Built

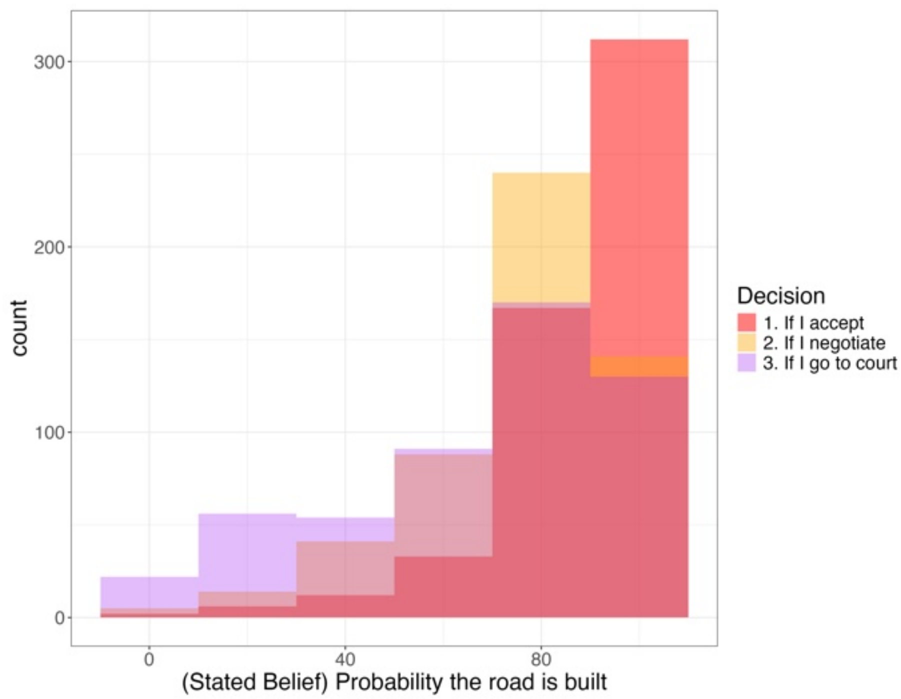
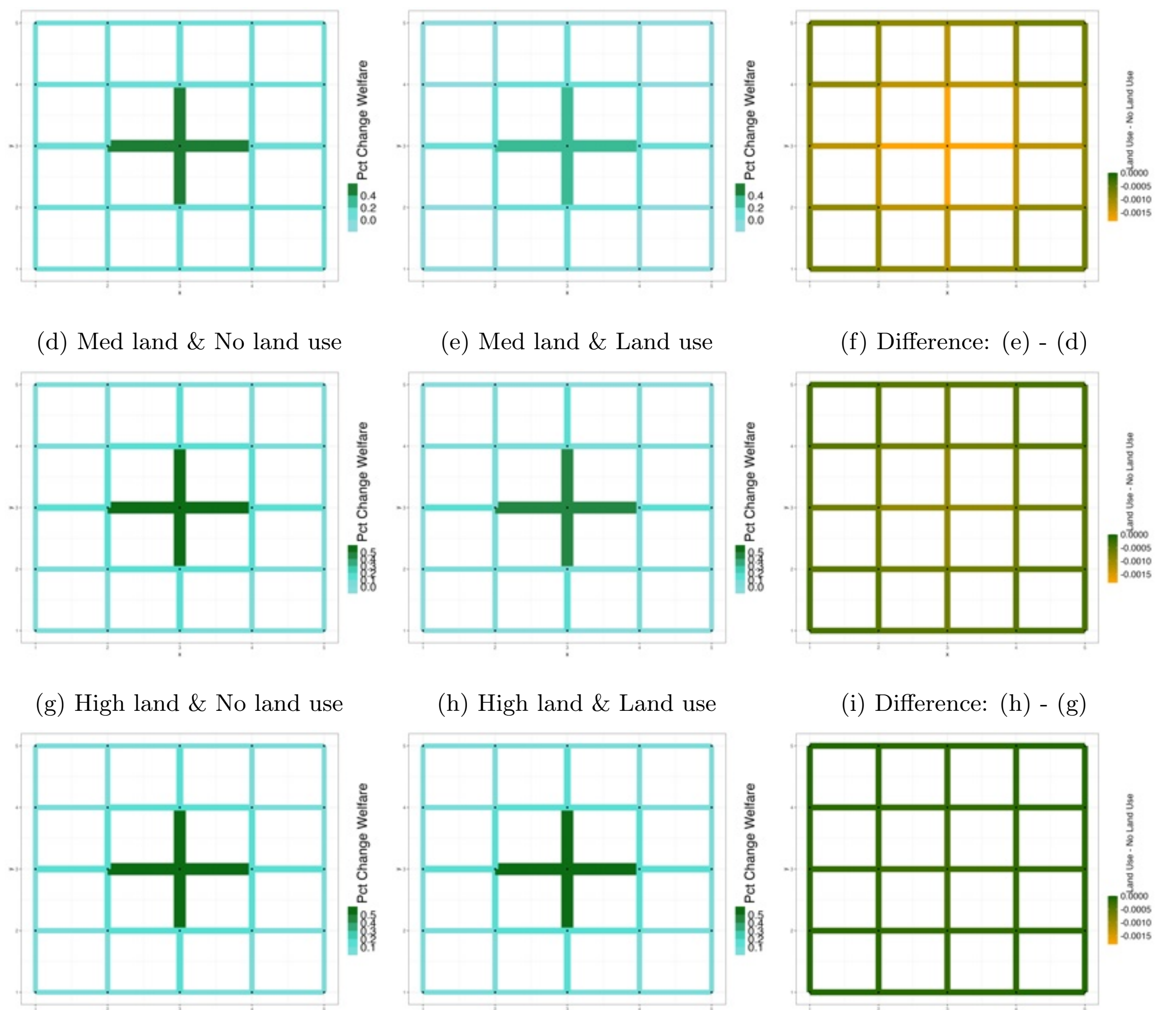


Table A8: Impact of Road Improvements on Traffic Speed - Alternative Specifications

	Dependent variable:					
	Traffic Speed (km/h)					
	(1)	(2)	(3)	(4)	(5)	(6)
Upgraded	3.817***	3.545*	4.449***	4.351**	2.616***	1.957
	(0.673)	(1.812)	(0.859)	(1.598)	(0.612)	(2.167)
In Progress	−1.299	−1.255	−1.319	−1.112	−1.283	−1.523*
	(1.105)	(1.004)	(1.264)	(1.267)	(0.907)	(0.751)
Sample	All	All	Non-Rush	Non-Rush	Rush	Rush
Road Controls	Y		Y		Y	
Road FE		Y		Y		Y
Day + Hour FE	Y	Y	Y	Y	Y	Y
SE Clustered	road+day	road+day	road+day	road+day	road+day	road+day
Observations	1,108	1,108	682	682	426	426
R^2	0.446	0.598	0.473	0.641	0.407	0.613

Notes: Standard errors are displayed in parentheses and clustered at the road and day levels, with significance levels $^*p < 0.1; ^{**}p < 0.05; ^{***}p < 0.01$. Observations are at the road level (trips covering a single road) from Google Maps API queried between 2023/03/17 and 2024/06/30. Rush hour is defined as 6 to 9am and 4 to 7pm.

Figure A15: Net Welfare Gains of Road Improvements in a Simple Economy: Alternative Specifications



(a) Low land & No land use (b) Low land & Land use (c) Difference: (b) - (a)

(d) Med land & No land use (e) Med land & Land use (f) Difference: (e) - (d)

(g) High land & No land use (h) High land & Land use (i) Difference: (h) - (g)

Notes: These figures display the citywide welfare effects of improving each link, solving for equilibrium location choices, routing, and accounting for the fiscal cost of funds. In panels (a), (d) and (g), no land is used for roads, while in panels (b), (e) and (h) land is used for roads. Panels (c), (f) and (i) show the welfare difference between land use and no land use. There is no payment for land. In panels (a) to (c), supply of residential land at baseline is low. In panels (d) to (f), supply of residential land at baseline is medium. In panels (g) to (i)), supply of land at baseline is high.

Figure A16: Predicted Market Value of Affected Land by Parish for 75m^2

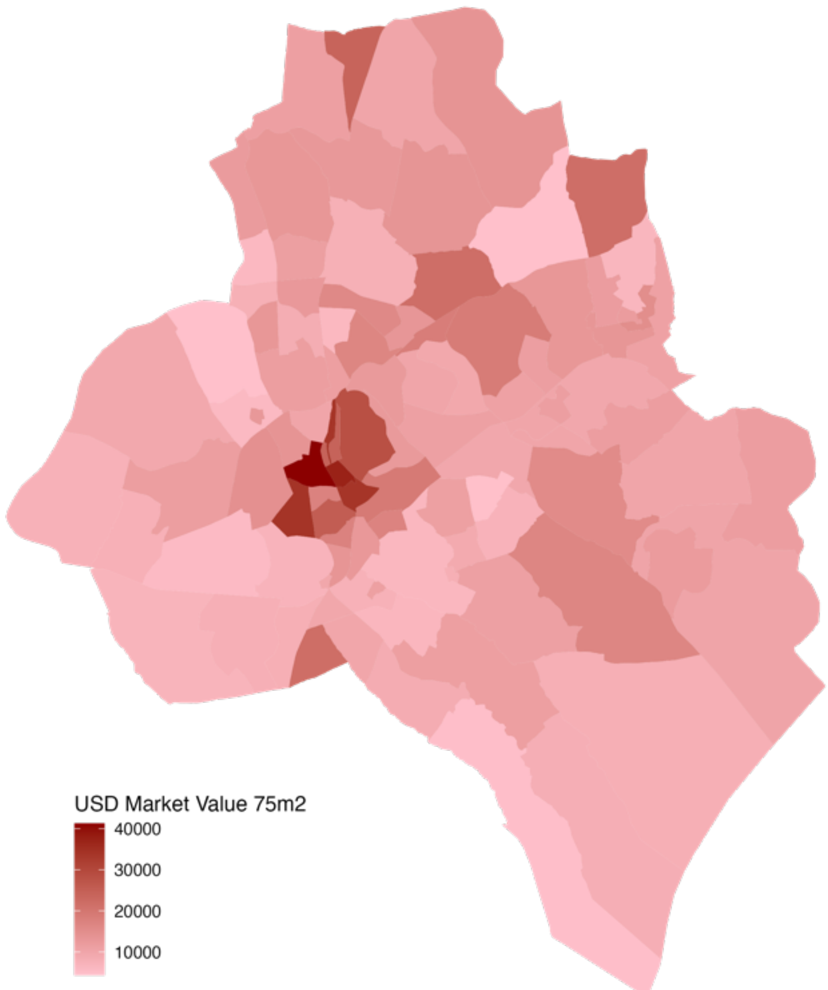


Table A9: Estimated ξ

	Dependent variable:					
	Traffic Speed (km/h)					
	(1)	(2)	(3)	(4)	(5)	(6)
Log Road Infrastructure (width m)	0.386***	0.344***	0.422***	0.390***	0.314***	0.253***
	(0.093)	(0.082)	(0.112)	(0.096)	(0.089)	(0.075)
Sample	All	All	Non-Rush	Non-Rush	Rush	Rush
Road Controls		Y		Y		Y
Day + Hour FE	Y	Y	Y	Y	Y	Y
SE Clustered	road+day	road+day	road+day	road+day	road+day	road+day
Observations	1,021	1,021	632	632	389	389
R^2	0.323	0.417	0.312	0.465	0.318	0.348

Notes: Standard errors are displayed in parentheses and clustered at the road and day levels, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Observations are at the road level (trips covering a single road) from Google Maps API queried between 2023/03/17 and 2024/06/30. Even columns include flexible geographic controls: longitude, longitude^2, latitude, latitude^2 of the trip's origin and trip length. Rush hour is defined as 6 to 9am and 4 to 7pm.

Table A10: Estimated $\theta\kappa$ - Alternative Specifications

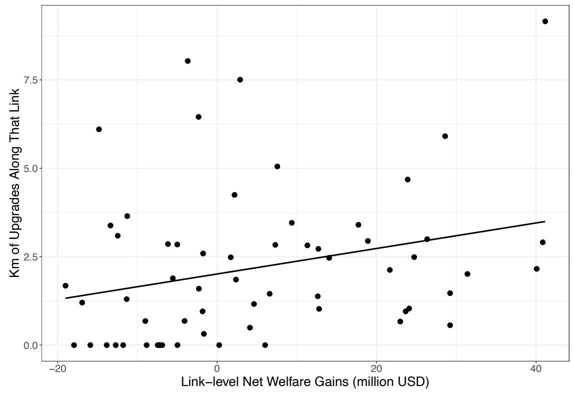
	Dependent variable:			
	(1)	(2)	(3)	(4)
Time (in Min)	-0.033^{***}	-0.023^{***}	-0.045^{***}	-0.035^{***}
	(0.001)	(0.001)	(0.001)	(0.001)
Period Def	Month	Month	Year	Year
Sample	Evening	All	Evening	All
Fixed Effects				
- origin x year	Y	Y	Y	Y
- destination x year	Y	Y	Y	Y
- month			Y	Y
SE Clustered	o-d	o-d	o-d	o-d
Observations	59,300	45,077	17,084	15,009
R^2	0.437	0.687	0.513	0.813

Notes: Standard errors are displayed in parentheses and clustered at the o-d pair level, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. All specifications include origin-year, destination-year and month fixed effect. I control for log distance in all specifications. In column 1, I include all trips from 6am to 10am, and from 4pm to 8pm. In column 2, I restrict the sample to the evening rush hour from 4pm to 8pm. Observations are at the pair-month level. Trips are motorcycles (bodas) trips.

Figure A17: Welfare Gains of the Realized Improvements Under Market Value Acquisition as a Function of the tax revenue wedge η

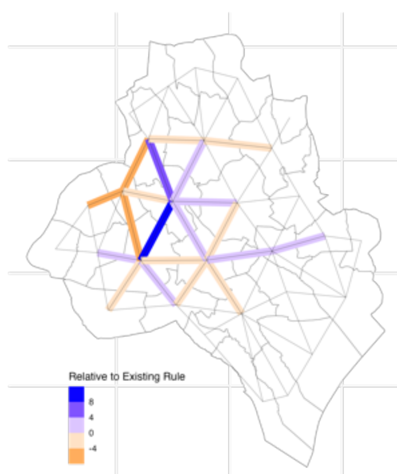
Notes: This figure displays the percentage welfare gains from the realized road improvements if land is acquired at market value, under various values for the tax revenue wedge $\eta \in [0.0, 0.9]$. The red curve accounts for the construction costs to compute the net welfare gains, but assume that the tax revenue wedge on these funds is 0 because they are funded through international agencies. The blue curve takes the construction costs as free.

Figure A18: Net Welfare Gains of Link-Level Upgrades and Realized Upgrades



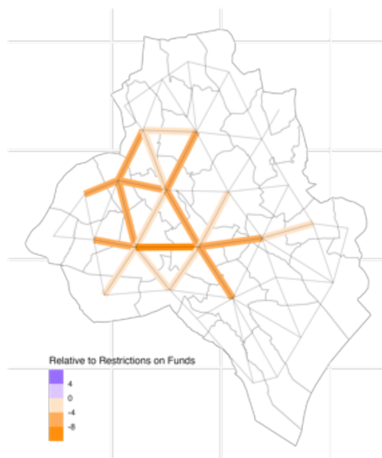
Notes: I display the relationship between link-level net welfare gains as predicted by the model, and the length of realized road upgrades along that link.

Figure A19: No Land Payment & No Land Use



Notes: I display the difference in optimal road improvements between the existing rule in the absence of land payments (Figure 12). Orange links correspond to less improvement under the no land payment counterfactual than under the status quo rule. Purple links correspond to more improvements under the no land payment counterfactual than under the status quo rule. In addition to removing land payments, I remove the opportunity cost of land use, so that road improvements do not take up any residential land, and so their optimal location is only driven by the relative benefits.

Figure A20: Optimal Improvements: Voluntary Land Take in the Absence of Fund Use Restrictions



Notes: I display the difference in optimal road improvements between the land acquisition under voluntary land take with the existing restrictions on the use of funds, compared to the absence of restrictions on the use of external funds. Orange links correspond to less improvements in the absence of restrictions than with the status quo restrictions. Purple links correspond to more improvements in the absence of restrictions than with the status quo restrictions.