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

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Abstract

Land acquisition costs can undermine the net returns of public infrastructure projects in developing cities, hindering the implementation of high-benefit projects. I investigate this issue in Kampala, Uganda, using new survey data with real estate brokers and landowners to evaluate the benefits and costs of 140 km of road improvements since 2017. By exploiting variation in the timing of upgrades, I estimate local benefits and develop a quantitative spatial model that accounts for spillovers and the fiscal cost of land acquisition. I find that, due to the high fiscal wedge, acquiring land through eminent domain could have resulted in negative net returns. However, the government's voluntary land acquisition approach reduced costs, generating net welfare gains equivalent to 99 USD per resident. I also show how the city's three property rights regimes influenced land costs, with weaker property rights functioning as a Pigouvian subsidy. Finally, I solve for the optimal road improvements under different institutional settings and funding restrictions, offering insights for policy design to enhance allocative efficiency and welfare outcomes.

1 Introduction

In African cities, only one-third of roads are paved (Kumar and Barrett 2008). Given the link between urban mobility and economic development (Akbar et al. 2023), road improvements have significant potential benefits. Consequently, transportation infrastructure upgrades have become a priority for both domestic governments and international agencies. However, for African governments attempting to improve these roads, such projects also entail substantial costs. For example, in addition to construction expenditures, the underlying land on which the roads are built must be acquired from private landowners.

Despite the importance of these costs, they have often been overlooked by the literature and by policy makers designing these projects. This oversight has had major consequences. Governments' inability to raise the funds needed to acquire this underlying land has led to costly delays, project revisions, and diminished net returns (World-Bank 1996). Better understanding the drivers of land acquisition costs in African cities is crucial to explaining the lack or suboptimal location of high-benefit infrastructure projects.

In this paper, I address this gap by examining a series of road improvement projects in Kampala, Uganda. I analyze how local government land acquisition practices affect the net returns to these improvements. With less than 45% of its major roads paved, Kampala resembles many other African cities. To enhance the quality of the road network, 140 km of road upgrades have been rolled out since 2017. Construction is primarily funded by the World Bank and the African Development Bank, while the domestic government is responsible for acquiring the underlying land. Citing concerns that compensating landowners at market value, as required by the eminent domain legal framework, would jeopardize the project's full implementation (World-Bank 2023), the government asked owners to voluntarily give up small portions of their land without compensation. However, the success of this *"voluntary land take approach"* varied across the city, with owners in areas with stronger property rights less likely to participate and more inclined to seek the financial compensation to which they are legally entitled.

To study the impacts of the road improvement projects and the associated land acquisitions in this data-scarce environment, I begin by integrating several data sources. I collect new data on the property-level benefits and land costs of road improvements throughout the city, including two novel surveys conducted with real estate brokers and landowners. I then add data on network-level effects of the road improvements, including commuting pattern data from a local ride sharing company and traffic data from Google Maps. Using this data, I estimate the reduced-form benefits of road improvements initiated in 2017, exploiting variation in the timing of the policy. I leverage the coexistence of three property right regimes in the city (Bird and Venables 2020) to characterize how land costs are influenced by land institutions. Next, I build and estimate a quantitative spatial model that accounts for changes in traffic flows and adjustments in the locations where residents live and work to measure the city-level returns of road improvements. Finally, I solve the model for the optimal road improvements under different institutional frameworks and in the absence of restrictions on the use of external funds for land acquisition, to evaluate how these institutional differences affect the location of road improvements.

I find that the road improvement projects in Kampala yielded large, positive net returns only because the government was able to acquire most of the underlying land without compensating landowners, instead relying on weak property rights to facilitate cheaper and easier land acquisition. In the presence of a large fiscal wedge, weak property rights can act as a Pigouvian subsidy by enabling the government to construct more roads with large positive externalities on city-level welfare. Moreover, in Kampala, the areas hosting road improvements with the largest benefits tend to correspond with those that have the strongest property rights regimes. Consequently, the local structure of property rights also has important distributional and allocative implications.

To show how weak property rights can increase the net returns to road improvements, I start by collecting novel datasets. I first conduct a survey with 377 real estate brokers, which includes a retrospective panel of transactions. I show that if road builders were to pay the market value of residential properties under an eminent domain regime, these costs would constitute 80% of overall project costs. Next, I interview 548 landowners whose properties border the upgraded roads in Kampala. I find that under the existing "voluntary land take approach", 80% of landowners consented to forfeit their land without compensation, averaging 73 square meters of land per property. These interviews also show that the decision of landowners to forfeit their land is partly motivated by the high cost of negotiating with the government and by the difficulties of obtaining official copies of ownership documents. These challenges are heterogeneous along the lines of Kampala's three main property right regimes: leasehold, freehold and mailo. *Leasehold* land features limited term ownership with a strong record of property titles. *Freehold* land features perpetual ownership but land titles are poorly tracked. *Mailo* land is characterized by double legal rights - landowner and legal occupant - over a single plot of land (Bird and Venables 2020). I find that leasehold landowners, who report the lowest cost of getting a copy of their ownership documents, are 55% more likely to negotiate than mailo owners, and 75% more likely to negotiate than freehold owners. Consequently, this approach ties land costs, and therefore the likelihood of road improvements, to the different property right regimes in the city.

I then estimate the local benefits of the road improvement projects in Kampala. I start by calculating the impact of road improvements on traffic speed by leveraging information from the Google Maps queries. I use variation in the timing of the policy and compare traffic speeds on the roads upgraded at the start and end of the policy to isolate the effects of the improvements. I estimate that the intervention increased uncongested local traffic speeds by 4.1 km/h (16% faster than baseline speed). Consistent with this change in local speed, I also show that trips across pairs of neighborhoods became more likely to take upgraded roads over time.

Road improvements also increased local property values. Using the appraisal of a standardized hypothetical property from the broker survey, I find that the assessed sales price of a residential property increases by 25% if the road in its immediate vicinity is improved. Extrapolating this estimated increase in sales price to all properties that border upgraded roads implies a total increase in local property values of 76 million USD, less than the 80 million USD it costs to construct the roads. I also estimate this effect using a retrospective panel of transactions from the same survey and I find that improving roads in a parish (neighborhood) leads to a 19% increase in the sales price of local properties.

While informative, these reduced-form estimates do not capture the full net returns of the implemented policy. Indeed, road improvements also have benefits in distant locations through the rerouting of traffic patterns, and the location choices of residents and firms in equilibrium. In addition, using residential land for roads has an opportunity cost. To capture these effects, I build a static general equilibrium quantitative spatial model of a closed city. This model 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). In addition, I explicitly model the competition for land between residential and road uses and assume that residential land is owned by immobile private landowners.

Through the lens of the model, I formalize the benefits and costs of road improvements. On the one hand, commuting costs decrease, inducing workers to relocate, their welfare to increase, and property values to change all over the city. On the other hand, residential land supply decreases, decreasing the welfare of some landowners. If land is acquired under eminent domain, owners are compensated at market value. If land is acquired under the existing voluntary approach, owners are only compensated if they incur a fixed cost to negotiate with the government. Property rights are associated with distinct distributions of negotiation costs, so that not all owners are compensated in equilibrium. Road construction expenditures can be covered by external funds from international donors, but owner compensation is funded through a local property tax. A fiscal wedge captures the high costs of levying funds domestically in this context and implies that owner compensation is costly.

The model described above has a number of parameters that need to be estimated in order to compute the benefits and land costs of road improvements. To estimate the elasticity of commuting flows on commuting times, I partnered with a local prominent ride hailing company with more than $160,000$ monthly users. Using the universe of rides (flows) by users of the app for a random sample of weeks from 2019 to 2024, I estimate that the number of commuters between two locations decreases by 0.33 to 0.45 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 the first such estimate in a LIC city. I use my reduced-form estimates to recover the elasticity of road speed on road infrastructure and owners' negotiation costs.[1] I calibrate the rest of the parameters using public data for Kampala or from the literature.

Equipped with this model and the parameters described above, I compute the benefits of road improvements implemented in Kampala since 2017. I solve for workers' new equilibrium residential and workplace locations to estimate that workers' average commuting time decreased by 7%, and that total property values in the city increased by 1.48% as compared to the period before road improvements. Using the model, I solve for the compensating differential transfer that would need to be made to each resident (lump sum) to reach the same level of welfare gains realized by the road upgrades. Abstracting from land payments, I estimate that this one time transfer is equal to 120 USD, or 164% of the median monthly wage of a worker in Kampala. Summing over all residents, this implies 108 million USD net welfare gains in the absence of land payments (but accounting for construction costs). Comparing this number to the 66 million USD increase in local property values from the brokers' appraisal exercise highlights the importance of accounting for city-level benefits and general equilibrium effects when assessing the impacts of road improvements on property values.

Payments for land may decrease the net returns to road improvements in the presence of large costs of

[1] I estimate that increasing road width by 10% 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).

levying taxes to raise domestic funds. I solve for the fiscal wedge rationalizing the government's claim that acquiring land at market value would threaten the viability of the project (World-Bank 2023). I find that acquiring all land at market value would lead to negative net welfare gains of the realized road upgrades if the fiscal wedge was above 0.7. This number is consistent with Regan and Manwaring (2024), who find that for every 1 dollar due in property taxes, the Kampala capital city government recovers only 39 cents, or a fiscal wedge of 0.61. Given this high fiscal wedge, the net welfare gains of the policy under the existing voluntary land take approach are equivalent to a one time 99 USD lump-sum transfer to all Kampala residents. Importantly, I find a positive correlation between the realized upgrades and the corresponding net welfare gains from specific link-level improvements predicted by my model, consistent with the realized improvements being relatively well allocated given the existing costs and benefits. I also find a negative correlation between the land costs and predicted share of owners negotiating, consistent with the model capturing property right regimes as a relevant feature of the city government's decision.

I then use the model to study how the land institutions impact the allocation and welfare gains of road improvements by conducting counterfactual exercises with alternative land cost structures. I fix the maximum total kilometers of roads improved to match the policy and I solve for the welfare-maximizing (optimal) road improvements. Under compensation at market value, I estimate net welfare gains equivalent to a one-time transfer to each resident of 114 USD, or 1.6 times the median monthly wage. Under the voluntary land take approach, net welfare gains of the optimal policy would instead by equivalent to a 397 USD transfer by resident. Because of the large fiscal wedge, weak property rights act as a Pigouvian subsidy, enabling the government to improve more high benefit roads and reach higher welfare gains than under market value compensation. Yet, this voluntary land take approach also ties land payments to spatially heterogeneous property rights, affecting the spatial distribution of optimal investments. If these property rights were homogeneous (fixing the fiscal cost as under the voluntary land take approach), net welfare gains would be 419 USD per resident as improvements would be allocated towards the highest benefit locations, leading to a larger decrease in commuting times and larger increase in property values.

Finally, given the key role played by the fiscal wedge in driving these results, I investigate the impact of a policy removing existing restrictions on the use of external funds. Currently, the city government can only use funds from the World Bank and the African Development Bank for road construction, not for land acquisition. I solve for the optimal improvements removing this restriction. I find that under the voluntary land take approach in place, the net welfare gains would be 6% larger in the absence of fund use restrictions than under the existing restrictions. Under compensation at market value, the net welfare gains would be 125% larger in the absence of fund use restrictions than under the existing ones. Both results hold despite less roads being improved, as some external funds are instead being used for land acquisition. The existing restrictions are likely driven by corruption concerns, which are outside the scope of this paper. Yet, given the World Bank's stated objective to ensure that owners are *"provided prompt and effective compensation [...] for losses of assets attributable directly to the project."* (World Bank OP 4.12), these numbers should be used to benchmark whether the anticorruption benefits outweigh the potential benefits in terms of better compensating affected owners, and allocating improvements towards higher benefit locations.

Related Literature

My work contributes to a growing literature at the intersection of development and urban economics.[2]

First, my paper is the first measure the net returns to road improvements in a LIC city, accounting for both benefits and land costs. On the benefits side, existing evidence on the impact of road quality on speed is either in the US (Duranton and Turner 2011,Currier et al. 2023) or across cities worldwide (Akbar et al. 2023). One of the few within-city studies on the benefits of road paving in low or middle income country cities comes from Gonzalez-Navarro and Quintana-Domeque (2016), who randomize the rollout of road paving in Acayucan, Mexico and study the impact on local property values, but do not account for the city-level impacts. Instead, I build on a literature that has developed quantitative spatial models (Ahlfeldt et al. 2015, Allen and Li 2015, Redding and Rossi-Hansberg 2017, Monte et al. 2018, Heblich et al. 2020, Severen 2023, Almagro et al. 2024) to study the benefits of improved transportation infrastructures, and add competition between private and public land use while papers usually model competition between residential and business land uses (Lucas and Rossi-Hansberg 2002). Within-city studies using quantitative spatial models in low and middle income countries have focused on the impacts of Bus Rapid Transit (BRTs) (Majid et al. 2018, Balboni et al. 2020, Tsivanidis 2023, Zarate 2024, Kreindler et al. 2023). In Kampala, as in the majority of LIC cities, road is the only transportation mode, so that the improvements will be experienced by all commuters.[3] On the costs, high land costs have been shown to have increased the costs of transportation infrastructure since 1960s in the US (Brooks and Liscow 2023), and a few policy reports have discussed their role in LICs (World-Bank 1996). Collier and Venables (2016) discuss the cost of land use for LIC infrastructures but I am the first to formalize and quantify this mechanism through my quantitative spatial model of optimal road improvements, building on the recent methodologies developed by Allen and Arkolakis (2022), Fajgelbaum and Schaal (2020) and Bordeu (2024). I micro-found land cost heterogeneity in Kampala's historical property right regimes under the voluntary land take approach, and show how they affect the optimal location of road investments by shifting the distribution of relative costs.

Second, I show how, in the presence of a high fiscal wedge, weak property rights can act as a Pigouvian subsidy for investments in public infrastructures, increasing city-level welfare and the net returns from road improvements. On the one hand, I estimate that any fiscal wedge above 0.7 would lead to negative net welfare gains from road improvements if land was acquired at market value, in line with estimates for Kampala by Regan and Manwaring (2024) and consistent with a dense literature on the widespread challenges faced by LICs to levy domestic and property taxes (Besley and Persson 2014, Traxler 2010, Knebelmann 2019, Bergeron et al. 2023, Brockmeyer et al. 2023). On the other hand, I provide new evidence on the relationship between property rights structure and efficiency of investments, through the channel of public good provision. Unclear property rights yield higher risks of expropriation, associated

[2] 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 absence of detailed data needed to estimate quantitative spatial models.

[3] 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 across-city 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).

with lower economic development (North 1990, Acemoglu et al. 2001, Besley and Ghatak 2010), including in Kampala (Bird and Venables 2020). However, in the context of public goods provision, weak property rights can act as a Pigouvian subsidy, as strong private property rights conflict with public interests (Acemoglu and Robinson 2012, Posner and Weyl 2017), which in turn justifies eminent domain (Munch 1976, Shavell 2010, Jeong et al. 2016) for public purposes. 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, potentially shift their location away from the highest benefit areas.

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 study the welfare effects of spatially heterogeneous land costs. In Section 5, I estimate the model on Kampala, 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

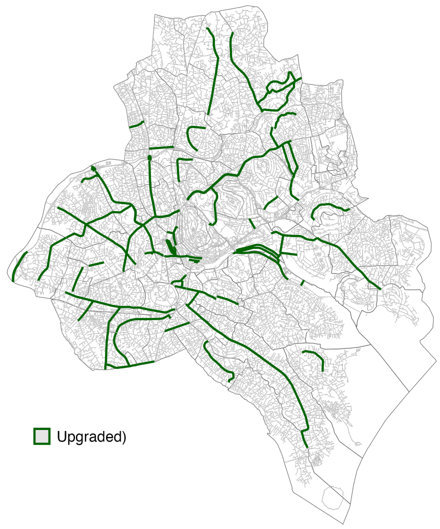
2.1.1 Road Improvements in Kampala

Kampala, Uganda's capital city, 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).[4]

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 USD (572,000 USD per kilometer on average as per the AfDB) and are part of larger investments worth almost 500 million USD. First planned in 2013/2014, road improvements under these two projects started in 2017 and the last roads are expected to be completed by the end of 2026. This time period also includes a few upgrades funded by the Government of Uganda, which are 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

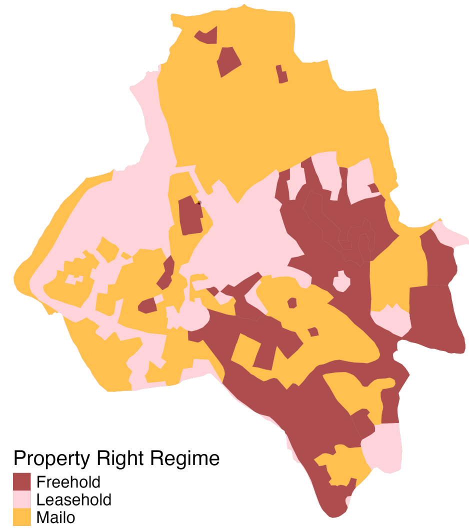
[4] Akbar et al. (2023) define major roads as roads falling under the motorway, primary, secondary or tertiary road classes on OSM. For reference the mean lane km of major urban road in US MSAs in 2008 was $14,000$ km (Couture et al. 2018).

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.

city.[5] Figure 1 displays a map of these upgrades and a timeline of the upgrades can be found on Appendix Figure A1.

2.1.2 Land Acquisition for Infrastructure Projects in Kampala

Widespread Issues to Acquire the Underlying Land

Upgrading road networks commonly requires additional land. 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 WB-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 resettlement activities, and more than 30% of the projects were being 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

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

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 were too high under eminent domain and threatened the project, since most owners were only minimally affected as only one or two meters of land were taken. Thus, it 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 get their consent regarding their affected land. 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.[6] Finally, once all 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 the city's 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 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.[7] 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

[6]Eminent domain is a well studied solution to holdout problems, where private sellers may strategically wait and exert their monopoly power (increasing as they become the last holdout) to seek higher compensations, leading to project delays and inflated costs (Posner and Weyl 2017). In this 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.

[7]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.

landowners and occupants have historically received rights and protections. The history of these property right regimes is described in more details in Appendix A.1.

2.2 Data Sources

To study the benefits and costs of road improvements in Kampala, and later estimate the main model parameters, I gathered 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 B.1. Each query includes information on the trip's time, duration, distance, straight line distance, traffic at the time of query, and average time. In addition, Google Maps Direction API includes a list of coordinates approximately mapping to the path between origin and destination. Trips are sampled 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 parts of 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.[8]

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 B.1.2). 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.

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 B.1.3 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 not 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 traffic speed is thus a first order concern in Kampala.

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

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 that counts more than $30,000$ rides per day.[9] 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. 39% of users take at least 5 trips on the app. The average trip costs 1.47 USD, lasts 21 minutes for a straight line distance of 5 kilometers. In addition, as displayed on Appendix Figure A4, 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 the trip origins seem to over sample commuters coming from the northern part of the city, compared to the universe of Kampala residents (Figure 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 usually not readily available in developing country cities like Kampala, so I collected 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 A7. My respondents are brokers with an average of 14 years of experience, and 76% of them operate in multiple parishes (neighborhoods). The average broker rented 11.3

[9] Safeboda has been operating in Kampala since 2019, and dominates the app-based ride hailing market for motorcycle rides. Since 2023, the company also offers a car option.

properties in the past 3 months, and sold 1.9 properties over the same timeframe. Descriptive statistics on are displayed in Table 2. I designed the survey with two goals in mind.

First, to characterize property values over space and track their changes over time, I asked 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 $59,262$ USD, which corresponds to an average price/m^2 of 142 USD, or about $1/4^{th}$ of the rate / 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 transacted online (Appendix B.3). 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 obtained additional reduced-form and descriptive evidence of the local impacts of road improvement and distance from roads on property values from an appraisal exercise. Brokers were presented with a standardized property (business or residential) and were asked to estimate its sales price varying one characteristic at the time, including whether the road was upgraded or not. In Appendix B.3, I further describe the sample of interviewed brokers.

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 collected data on the land acquisition process by surveying land and property owners (hereafter owners) along segments of 87 road in Kampala. I interviewed a random sample of owners on upgraded roads and roads in the process of being upgraded.[10] More details on the selection of road segments and the sampling strategy are available in Appendix B.4. Descriptive statistics about the data are displayed in Table 3.

A total of 772 respondents were interviewed. 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 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 inherited property, higher for freehold (0.64) and mailo (0.6) than for leasehold (0.5) is consistent with the very high reported cost of getting a copy of ownership documents, which is also higher for freehold an mailo than for leaseholds. This costs indeed often entails getting a lawyer, going to court, get certified copies, recover old land titles that had never been accounted for etc.

The property of 548 of them had been or was being affected by the road upgrade, an 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 owners who consented and who did not) believed that they could get a

[10] 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.

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.

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 were also asked about current and historical road quality, past and ongoing road updates, land acquisition, as well as property and neighborhood characteristics.

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 high, but heterogeneous across locations.

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.

3.1 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 will use in Section 5 to estimate 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 in my sample 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.[11] 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.[12] Standard errors are

[11] 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.

[12] 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

clustered at the road and day of query levels to reflect sampling. To isolate the direct impact of the road improvement, I focus on trips queried outside of traffic rush hours, and I discuss the impact on speed for rush-hour trips in Appendix A4.

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 the comparison of 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 observables. 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.[13] A subset of roads got upgraded between the start and end of my panel, allowing my to 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 ATE, I need to assume that the above assumptions would hold also for the average road in Kampala.

I present regression in Table 4. In columns 1, 2 and 3, I estimate the reduced-form impact of any road improvement (dummy variable) on traffic speed. In column 1, I do not include any road-level control. In column 2, I add road-level controls and in column 3, I replace these controls by road-fixed effects. I estimate a robust impact of road upgrade on free-flow speed of 4.96***, 4.45*** and 4.35** and km/h, respectively, or 18% of the average speed in Kampala. How big is that effect? If average speed in Kampala increased by 4.4 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 4 and 5, I estimate 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 structural and I discuss it in more details in Section 5.1.1.

3.1.2 Impact of Road Improvements on Local Property Values

Property Appraisal: In the 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 B.3). 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.[14] The regression results are displayed in columns 1 and 2 of Table 5, and the distribution of answers is relegated to Appendix Figure A5. Brokers estimate that a road upgrade increases the price of this standardized property by 25% on average for the standardized residential property on the side of the road (column 1) and 27% (column 2).

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.

[13]In Appendix Table A4, 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.

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

Table 4: Impact of Road Improvement on Traffic Speed

	Dependent variable:				
	Traffic Speed (km/h)			Log Traffic Speed (km/h)	
	(1)	(2)	(3)	(4)	(5)
Upgraded (d)	4.964^{***}	4.449^{***}	4.351^{**}		
	(1.156)	(0.859)	(1.598)		
In Progress (d)	1.290	-1.319	-1.112		
	(1.479)	(1.264)	(1.267)		
Log Road Infrastructure (width m)				0.390^{***}	0.313^{***}
				(0.101)	(0.108)
Sample	Non-Rush	Non-Rush	Non-Rush	Non-Rush	Non-Rush
Road Controls		Y		Y	
Road FE			Y		Y
Day + Hour FE		Y	Y	Y	Y
SE Clustered	road+day	road+day	road+day	road+day	road+day
Observations	682	682	682	632	632
R^2	0.165	0.473	0.641	0.280	0.662

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. Columns 2 and 4 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. Columns 2 to 5 include hour and day fixed effects.

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)
Note:						*p<0.1; **p<0.05; ***p<0.01

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.

Focusing on residential properties, evaluated at the median property value in the past transaction database (54,054 USD), and assuming that each property spans an average of 50 meters along these roads,[15] 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 USD.[16]

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 safety from flooding and absence of dust (Appendix Figure A10), 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.

[15] The average width spanned by properties in my owner survey is 48m.

[16] 572,000 USD per km × 140 km

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:

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

where $\mathrm{Q}_{i,b,k,p,t}$ 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 characteristics, potentially including division fixed effects or parish-level controls.[17] 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 $\mathrm{D}_{p,t}$ is both temporal and across locations, β captures both the effect of a road being upgraded in parish p, but also some general equilibrium impact on control locations. These general equilibrium impacts may bias estimates down if the neighboring locations benefit from the road upgrade, or bias estimates up if the neighboring locations become relatively less attractive.

To interpret β as the causal impact 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 specific road improvements were targeting 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 for parish socio-economic characteristics from the 2014 Census to control for selection based on observable characteristics. Further, in column 4, I restrict my sample to parishes who 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 a way that would impact property values, 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

[17] Parish-level controls include pre-policy socio-economic controls {log 2010 population, share of residents with permanent flooring (2014 Census), share of land surface built (2015 GHS)}.

[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.

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.

3.2 High and Heterogeneous Land Costs

While road improvements had benefits, they also had high and spatially heterogeneous land costs. Final land acquisition costs for the government are driven by property values and the probability that owners get paid, which I show depends on both the amount of land affected and owners' property right regimes. I use my data from both the broker and owner surveys to characterize these two components.

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 my broker survey, I estimate that the average sales price per m^2 for residential land properties is 171.7 USD (median 152.3 USD). To recover the total market value of affected land, I recover the average land market rate for each parish and I assume that 3 meters of land were affected on average per owner. The corresponding predicted average affected land market value per owner by parish is displayed on Appendix Map A14. Summing over all upgrades, this corresponds to $140,000 \times 3 = 210,000$m^2 of land, or $64,822,762$ USD. This corresponds to about 2/3 of the construction costs, or $9,600$ USD for the median owner.

3.2.2 Heterogeneous Share of Owners Voluntarily Giving Their Land Without Compensation

Under the "voluntary land take" approach, owners do not get paid if they consent to donate their piece of land without compensation. Among the owners in my survey, 77% of the 548 affected owners 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), summarized on Appendix Figure 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 A11 and A12.

There is a significant heterogeneity in where these negotiations are happening. One dimension of heterogeneity is the plot's property right regime. Indeed, to to get compensated, owners must be able to 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 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 regime from other factors like the amount of land being affected, I model the probability that owners negotiate γ_{oi}^N in order to get compensated, 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.q_i is recovered from the broker survey. As discussed above, this cost may depend on their property right regime Z_{oi} and some idiosyncratic cost ϵ_{oi}

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

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 were asked how likely they beliefs the road would

[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.

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 A13.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 are going to 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, accepting respondents do not systematically over or under estimate 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 am going to use both across-road and within-road variation. In the former, both ΔH_{oi} and q_i will vary, while in the latter, all the variation will come 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 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 low property value q_i^{baseline} parishes 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 negotiation. As the different regimes are pre-determined to the policy, the estimated coefficient captures their overall effect on owners' decision. This does not imply that the regimes are uncorrelated with other observables likely to affect owners' negotiation, including owners' wealth and their social integration in the community, as highlighted in qualitative interviews. To address this concern and isolate the impact of property right regimes on negotiation probability, I control for owners' wealth and social integration in some specifications. Overall, to interpret this coefficient as the causal effect of different levels of property right clarity, 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,[20] 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^{baseline} is fixed within parish) and, while I am less powered statistically, the estimate does not appear to be statistically different.

[20]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 compute, 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.

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 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.[21]

With these estimates, I can predict the share of negotiating owners in each parish, and subsequently the average payment for owners. The distribution of owner-level payment plotted on Figure 3 highlights the shift in land payments to the left (orange), compared to payment at market value (green). Consequently, total land costs are estimated at $18,256,071$ USD.

Taking stock, I estimated that the benefits of road improvements in terms of property values by the side of improved roads was $66,594,000$ USD (broker appraisal). The market value of affected land acquired from private owners is around $64,822,762$ USD. Even if land was acquired under voluntary land take for $18,256,071$ USD, the construction costs of $80,080,000$ USD would make such investments make negative net returns if the benefits were only local. However, road improvements have benefits 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, I build a quantitative spatial model of optimal road improvement with land acquisition.

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.

[21] 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.

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$\bar{R}_{kl}$ (meters).

Land

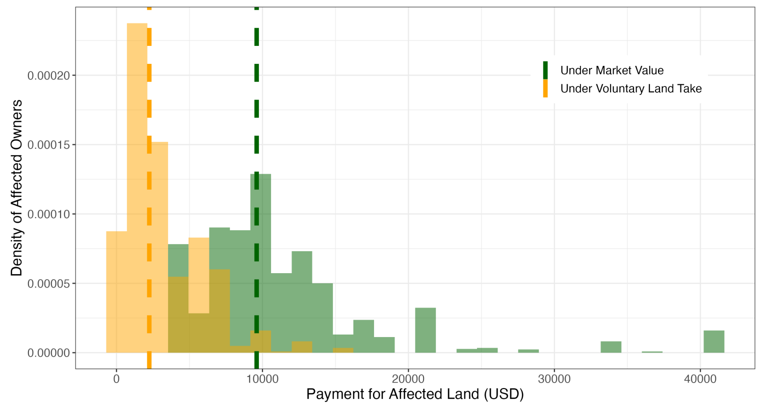
At baseline, in each location i, total land $\bar{H}_i$ is divided between private residential land H_i^{r} and public road land H_i^{p}, such that:

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

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

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

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 (col 2, Table 7).

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 $\frac{T_i}{N_i^o}$, such that owners' 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}^{res} to solve their budget constraint:

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

where 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 decreases 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, such that 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 to local economic conditions given by $\frac{B_i w_j}{{q_i}^{1-\beta} \tau_{ij}}$ are workers, as their idiosyncratic preferences are less dispersed. Consequently, the larger θ, the more workers will relocate in response to a change in commuting costs τ_{ij}.

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

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

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 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, the commuting between the two locations. 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 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 $\tau_{ij,r}$ 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 $\tau_{ij,r}$. At the extreme, $\rho \to \infty$, all commuters use the least cost path.

The total commuting 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 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 writethis 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 will 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 will also impact q_i indirectly, through equilibrium changes in L_{ij}.

Land Payments

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

$$p^l_k = q^0_k \times \gamma^l_k, \tag{17}$$

where I assume that the fraction of owners who negotiate, γ^l_k, get paid.[22]

In my context, 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, $\frac{\Delta H^r_k}{N^o_k}$, evaluated at the pre-road upgrade market rate q^o_k. The 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

$$\gamma^l_k = P\left(\alpha q^o_k \frac{\Delta H^r_k}{N^o_k} \geq Z_k \mu_z + \epsilon_k\right). \tag{18}$$

The fraction of owners negotiating γ^l_k is an equilibrium object which depends on the residential market rate before the policy q^o_k, so with road widths $\left\{R^0_{kl}\right\}$, as well as the change in residential land in location k, ΔH^r_k, which itself is increasing in the new road area in that location, as $\Delta H^r_k = \sum_l \frac{l_{kl}\left(R_{kl} - R^0_{kl}\right)}{2} \geq 0$.

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

$$T_k = p^l_k \times \Delta H^r_k. \tag{19}$$

Government's Optimal Road Improvement Problem

Conditional on the road infrastructure at baseline $\left\{R^0_{kl}\right\}$, the government chooses the new road infrastructure $R_{kl} \geq R^0_{kl}$ $\forall kl$ 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 used exclusively for road construction alone, 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^l_k defined by equation , the government must levy property taxes at rate ϕ, given a fiscal 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 correspond 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

[22] 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^l_k. However, negotiation also brings up other costs not modeled here (e.g. delays, processing times and court fees), which would increase the final cost..

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, and which both 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:

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

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 $\{q_i\}, \{p_i^{\mathrm{l}}\}, \phi$ and quantities $\{L_{ij}\}$, $\{\gamma_i^N\}$, $\{H_{ij}\}$, $\{C_{ij}\}$, $\{R_{kl}\}$ 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).

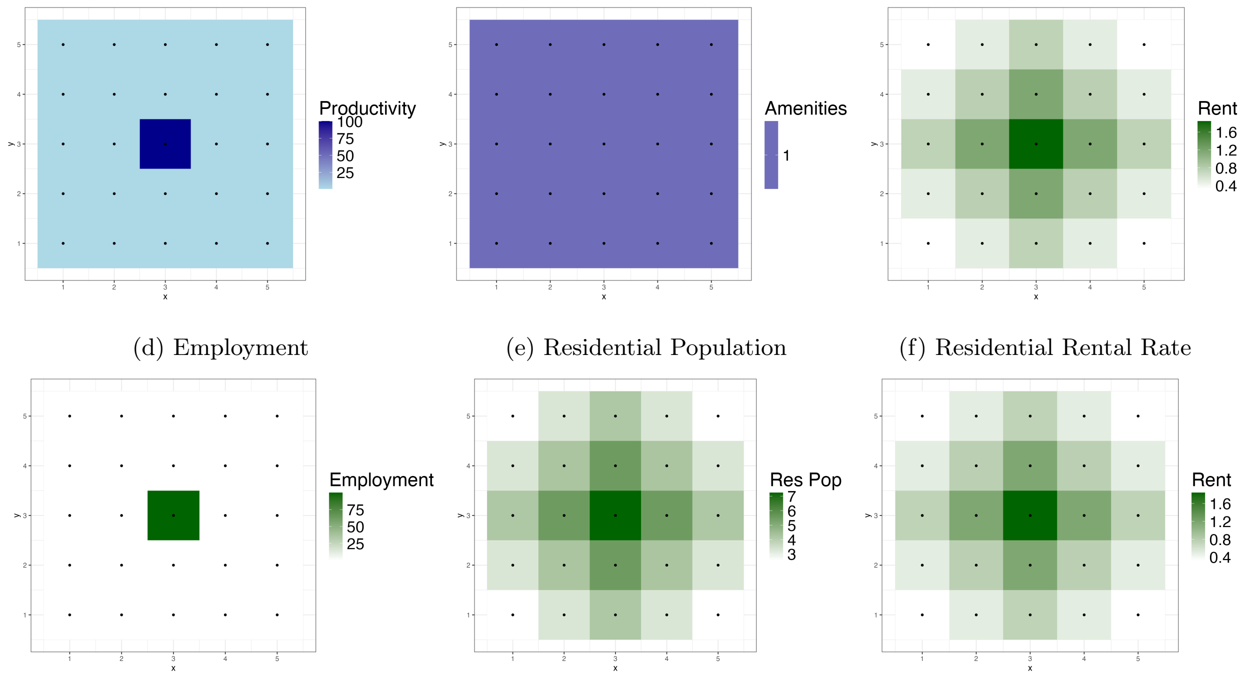
Road improvements have benefits and costs and I illustrate how their joint distribution affects the optimal location of road road improvements and their net returns. In practice, I fix the total amount of road upgrades and solve for the optimal improvements under several model specifications.

Optimal 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. The larger the supply of residential land, the less impactful is this channel.

Optimal road improvements when land is acquired at market value: 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 fiscal wedge $\eta = 0$, this transfer is welfare neutral for a utilitarian planner, as owners are assumed to have linear utility in consumption. However, the larger the fiscal wedge η, the larger the welfare costs of high land payments, and the lower the amount of optimal improvements at the city center, where market values are the highest. Therefore, in the absence of a fiscal wedge (panel c), the optimal road improvements and corresponding welfare at the same than in the absence of land payments. Under a large fiscal wedge (panel d), the optimal road improvements are shifted away from the center of the city, and welfare decreases because of both the fiscal loss and the lower benefit roads being improved. 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 fiscal wedge would still shift optimal improvements away from the high benefit central locations.

Optimal road improvements when land is acquired under voluntary land take: Under the voluntary land take approach, adopted by the government, land acquisition prices p^l_k in location k are tied to owners' property right Z_k, so that for a given amount of land being taken, the stronger Z_k, the larger p^l_k. 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. While the levels of land costs are lower under the voluntary land take approach than under market value compensation (not all owners get compensated), 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, optimal road improvements are displaced from the city center to peripheral locations, as displayed on panel e.

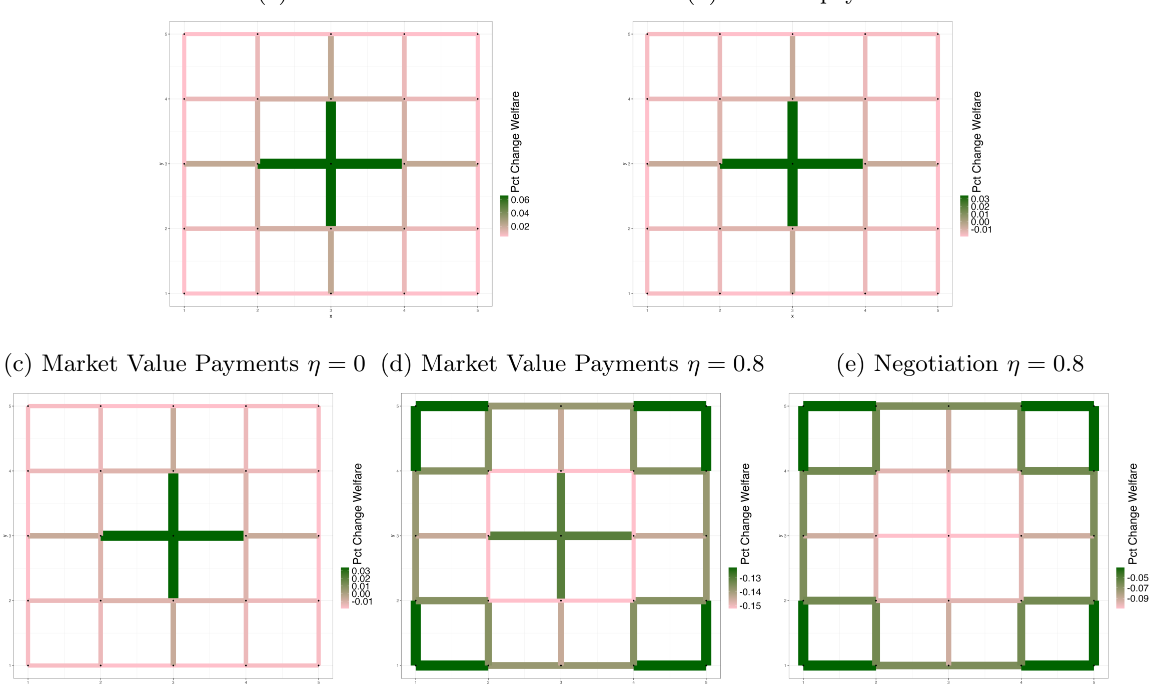
Figure 4: Simulated Economy - Baseline Equilibrium



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

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

Figure 5: Optimal Road Improvements in a Simple Economy



(a) No land use (b) No land payments

(c) Market Value Payments $\eta = 0$ (d) Market Value Payments $\eta = 0.8$ (e) Negotiation $\eta = 0.8$

Notes: These figures display the city-wide 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.

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[23] 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 columns 3 and 4 of Table 4. I estimate an elasticity ξ between 0.31^{***} and 0.390^{***}. 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.

5.1.2 The elasticity of commuting flows on commuting costs

Now, turning 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 B.1.3, 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 changes, 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

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

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.[24] 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 A7). 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.[25] Nevertheless, my estimate $\hat{\theta\kappa}$ is in line with estimates 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.

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

[24] 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).

[25] Going forward, I will investigate how to address these issues by relying a travel habit survey conducted in 2016/2017 in Kampala. which includes approximately 600 respondents.

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.

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 (48m average in the owner survey), so that the total amount of affected land is equal to $50m$ times $\frac{1}{2}$ the additional road width $\left(R_{kl} - R_{kl}^0\right)$,so that land is taken equally on both sides of the road, belonging to two different owners.

5.1.4 Additional public data and calibrated parameters on Kampala

Data on residential population $\{L_i^r\}$ and employment $\left\{L_i^F\right\}$: 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 location level, where one location corresponds either to one parish, or to a group of small neighboring parishes.

Residential Land H_i^r: 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.

Share of workers' expenditure on housing $1-\beta$: 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 ρ: 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 I assume that 20.15% of them are owners, as per the 2019 Uganda National Panel Survey, which asks detailed characteristics to a subset of households, restricting the sample to Kampala. ω^w is the total welfare weight on all workers in the city. To compare workers' utility to owners' utility, and be able to interpret these utilities as dollars, 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. This scaling factor is not constant given workers' non-linear expected utility in income, so I estimate it so that if the realized road construction expenditures were instead transferred lump sum to workers, the net welfare gains would be 0. Owners' utility is linear in income, no such scaling is needed and ω_i^o is the number of owners in location i.

$\{\tau_{ij}\}$ 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 A1.I recover the average uncongested 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 A2, 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, 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 $\bar{t}_{kl} = t_{kl} \times \left(R_{kl}^0\right)^{\xi}$ from equation (13), where R_{kl}^0 is the average width of roads in locations k and l at baseline. Given $\{\bar{t}_{kl}\}, \{R_{kl}^0\}$, ξ, κ and ρ I can compute $\{\tau_{ij}\}$.

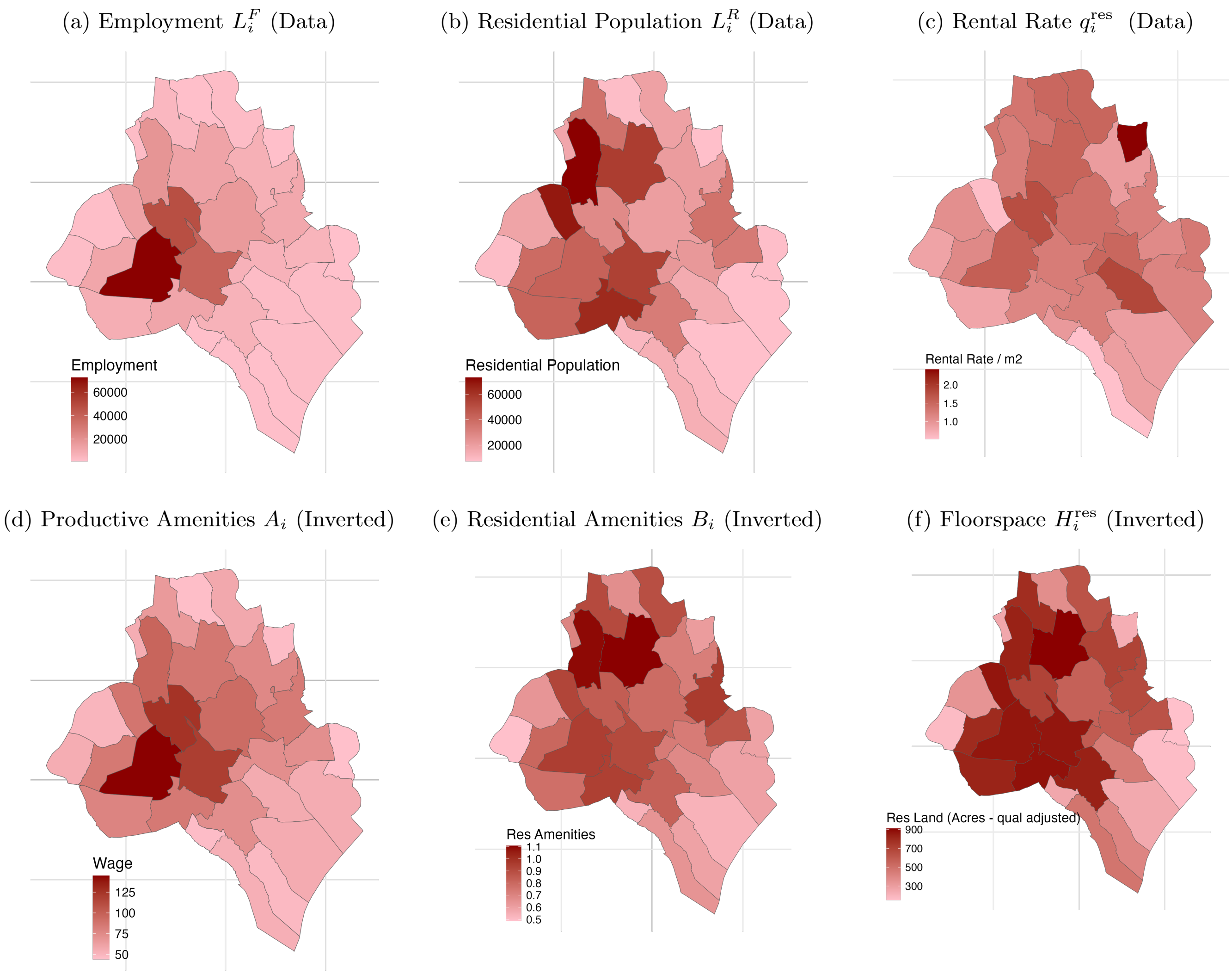
I then map the improvements into the model's aggregated road network by summing over all improvements in a location. Assuming that the average road improvements increased road width by 3.2 meters (one additional lane, as discussed in Section), I compute the total amount of new road infrastructure by location and split it equally across all links connecting this location to its neighbors. The resulting map of road improvements is displayed on Figure 7.

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 median 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 (16).[26]

The data on $L_i^R, L_j^F, q_i$and the recovered $A_i, B_i, H_i^{\mathrm{r}}$ 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.

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)

[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.

Fiscal 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* 0.39% *of the potential revenue from property taxes.*"

5.2 Net Returns to Road Improvements in Kampala

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

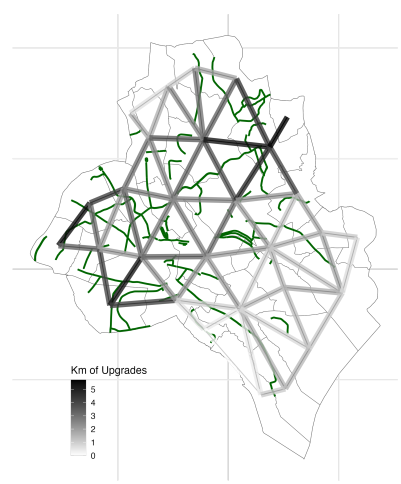
Impacts Commuting Time and Property Values: First, I fix workers' locations at baseline and compute changes in commuting times across any pair of location and rental rates coming from the road upgrades ΔR_{kl}. I find that the realized road upgrades led to a decrease in workers' average commuting time by 8.0% (1min 49 sec), and an increase in total property values by 1.44%.[27] Second, I allow workers to relocate, leading to new equilibrium location and 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 6.75% compared to baseline. In turn, the average increase in property values is 1.45%.

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:

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

I find that under a 3% 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 improvements is 181 USD 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 83 USD per resident, I recover net welfare gains equivalent to a one time transfer of 98 USD per resident, or 11% 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

[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.

[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.

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 A10) including a decrease in traffic accidents, my estimate is likely a lower bound on total net benefits.

Welfare Impacts Under Alternative Land Acquisition Rules: I estimate that the net welfare gains would have been 16% larger in the absence of land payments, but would have been 59% lower if land had been acquired at market value, as mandated under eminent domain, which is consistent with about 25% of owners only getting compensated at market value. This result is driven by the large fiscal wedge, implying that land payments decrease the net welfare gains of the policy.

The 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 0.74, the net welfare gains of the realized road improvements would be negative if land was acquired at market value. This threshold goes up to 0.78 if I do not subtract the construction expenditures. The welfare gains for $\eta \in [0.0, 0.9]$ is displayed on Appendix Figure A15. These estimates are consistent with the $\eta = 0.61$ calibrated from Regan and Manwaring (2024). The larger

Sensitivity to Alternative Parameters: Two key forces in the model are driving these results: the welfare impacts of land payments, governed by the fiscal wedge $\eta^{\phi}$and workers' benefits from the road improvements, governed by workers' response to changes in local speed $\theta\kappa$ and the impact of road improvements on local speed ξ. In Table 10, I investigate the sensitivity of the results with respect to each of these parameters.

5.3 Positive Correlation Between Link-Level Upgrades and Model-Predicted Net Gains

To understand whether these benefits come from upgrading any road, or upgrading the right 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. I unveil a positive correlation between realized upgrades and both link-level net welfare gains and commuting time gains, as well as a negative correlation between realized upgrades and both predicted land costs and predicted share of owners negotiating, consistent with the model capturing relevant features of the city government's decision.

5.3.1 Link-level Costs, Benefits and Welfare Gains

I start by computing the marginal costs, benefits and net returns of upgrading each parish-to-parish link one by one.[29] In practice, for each link, I increase road width by 3.2 meters (1 additional lane) and solve for the equilibrium spatial distribution and share of owners negotiating. I compute the total change in commuting times, total land costs and NPDV of the welfare gains (net of costs), displayed on Figure 8. The color of each link indicates the impact of upgrading this specific link on city-level outcomes of interest.

Starting with a direct measure of benefits, the decrease in commuting times (panel a), I show that the highest marginal benefit links 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 (dark red), as 21.6% of owners would negotiate for roads at the 25^{th} percentile of marginal costs, against 31.7% on roads at the 75^{th} percentile (for 1.5 meters of land being taken on each side the road). Using the model to govern the relative weight of land costs and commuting time savings, 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

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

Did the government upgrade the highest net return (benefits - cost) 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 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 A16, 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 both.

the picture is a little more nuanced when looking at the scatter plot of road upgrades (in km) on predicted net welfare gains (Figure 9, panel (b)).

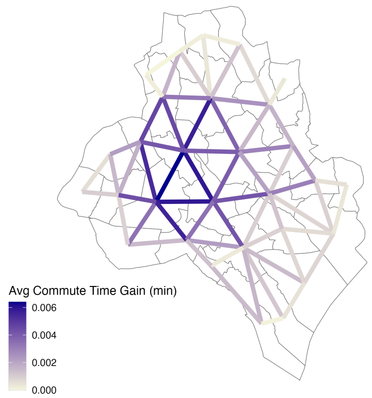
Second, to unpack this relationship, I regress the length of upgraded roads along each link kl, D_{kl}, on these predicted link-level impacts, controlling for the length of link kl, l_{kl}:

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

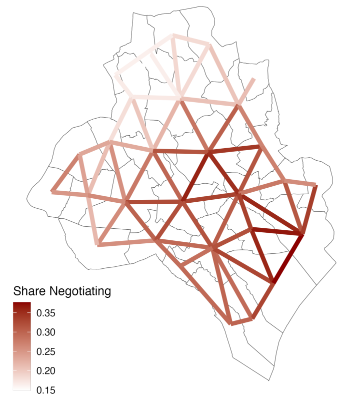
[29] I thus abstract from complementarities across road improvements and land costs, discussed in the next section.

Figure 8: Link-Level Impacts of Road Improvements

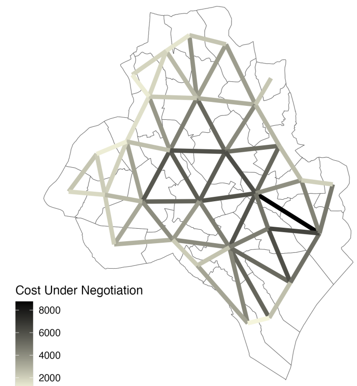
(a) Average Commuting Times (in min)



(b) Predicted Share of Owners Negotiating



(c) Land Costs



(d) NPDV Net Welfare Gain

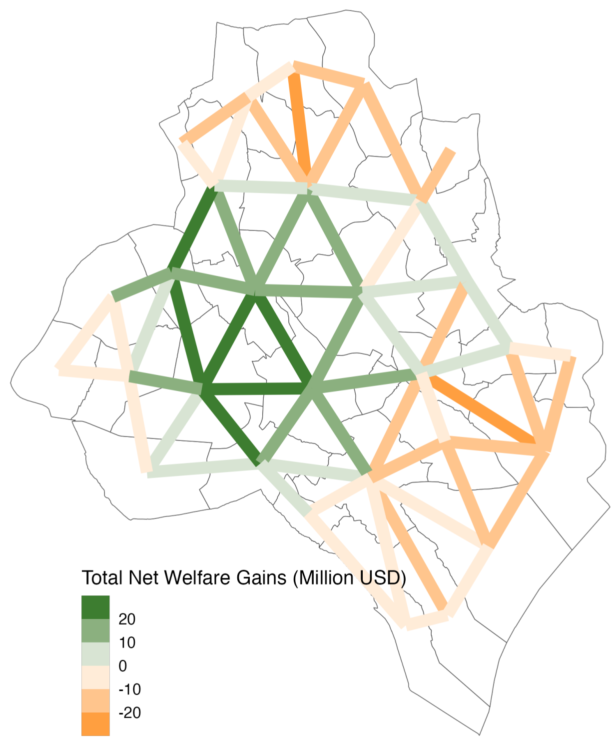
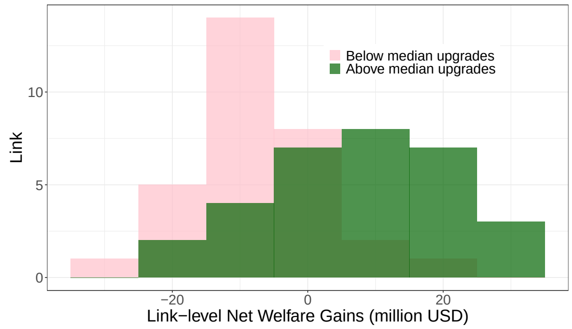


Figure 9: Net Welfare Gains of Link-Level Upgrades and Realized Upgrades



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)

where ΔW_{kl} is the standardized change in city-level welfare from upgrading link kl. The results are displayed in Table 9.[30] 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 unpack the role of land costs and benefits, as measured by gains in commuting time, and I unveil a positive correlation between road upgrades and predicted gain in commuting time, and a negative correlation between road upgrades and land costs. In column 3, I further split these land costs between land market value and the share of owners negotiating, and find that most of the negative correlation between upgrades and land costs seem to come from negotiations. Overall, these findings are consistent with my model capturing relevant features of the city government's decision.

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 are affecting the net welfare gains of road improvements in Kampala. Heterogeneous land payments affect welfare through two channels. First, through an allocative channel, as the heterogeneity in land costs may change the relative net gains of various sets of upgrades. Second, through a level channel because of the welfare costs of compensating owners (fiscal wedge). For exposition, I start by discussing these channels in a simple simulated economy. I then move to Kampala, and compare the welfare maximizing upgrades under alternative land payment structures and funding rules.

6.1 Optimal Road Improvements in Kampala With and Without Land Payments Counterfactuals

How do these forces play in Kampala, where land is acquired under the voluntary land take approach, and owners of land under different property right regimes get compensated at different rates depending on the clarity of their property rights? To answer this question, I start by establishing whether the existing land acquisition costs affect the set of roads being improved and the welfare returns from these improvements,

[30] I Appendix Table **X**, I show that they are robust to replacing Δrank welfare$_{kl}$ by the measure of welfare itself Δwelfare$_{kl}$, but the magnitudes are harder to interpret given that not all variables are in the same unit.

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

	Dependent variable:		
	Length of Upgraded Roads (All upgrades)		
	(1)	(2)	(3)
Net Welfare Gains (std)	0.370^{**}		
	(0.184)		
Gain in Commuting Time (std)		0.360^{**}	0.320^{*}
		(0.177)	(0.174)
Land Costs Under Negotiation (std)		-0.515^{**}	
		(0.222)	
Land Costs at Market Value (std)			-0.018
			(0.248)
Share Owners Negotiating (std)			-0.528^{***}
			(0.175)
Observations	58	60	60
R^2	0.069	0.135	0.188

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).

compared to a scenario where land did not need to be acquired. This counterfactual exercise corresponds not only to cases of expropriation without compensation, but also cases where land is owned by the government (public land), as in the case in Hong-Kong, in urban China, or in federally owned land in the United-States (40 percent of the total surface of the country).

Existing Property Right Regimes and Land Payment Rule (status-quo): In all counterfactuals, I fix the maximum area of roads that can be upgraded at the level of the implemented policy.[31] I start by solving for the welfare maximizing (optimal) road improvement in Kampala under the voluntary land take approach, the status quo. When solving for the optimal road improvement $\{R_{kl}\}$, the government must keep track of several equilibrium objects: land payments depend on $\{R_{kl}\}$ as the more land is taken from them, the more likely owners are to negotiate ; rental rates $\{q_i\}$ depend not only on commuting costs $\tau_{ij}(\{R_{kl}\})$ but also on workers' residence and workplace, which are also determined in equilibrium as a function of $\{R_{kl}\}$. The algorithm I use to solve this problem is described in Appendix X. The map of optimal road improvements is presented in Figure 10, and corresponding welfare gains and other outcomes of interest in Table 11. I estimate that the NPDV of the net welfare gains in this benchmark is about 344 million USD for a 3% annual discount rate. This corresponds to about 400 USD per Kampala resident (Table 11, row 1).[32]

[31] I am working on counterfactuals where I allow the government to levy property taxes also to fund improvements of additional roads.

[32] The 2014 Uganda Population Census counts about 1.6 million inhabitants, but only about 866,000 inhabitants about 18 y.o, which are considered as the "residents" in this paper.

No Land Payments: I then solve for the optimal road improvements in the absence of land payments and display differences in the optimal road improvements on Figure 11. In the absence of land payments, road improvements are reallocated from the periphery (orange) towards the center (purple), compared to the existing land payment rule. Central locations have the highest marginal benefits (Figure 8, panel (a)), but also the highest property values and some of the highest share of owners negotiating (Figure 8, panel (c)). Therefore, in the absence of land payments, these previously high land costs locations are more likely to be upgraded. The net welfare gains of road improvements under this no payment counterfactual sum up to about 492 million USD, or 148 more million USD than under the current regime.

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

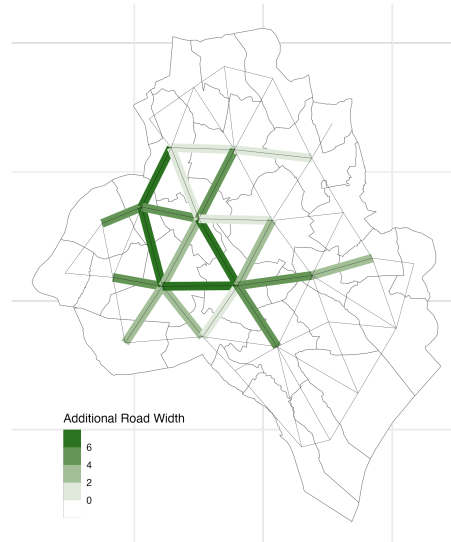
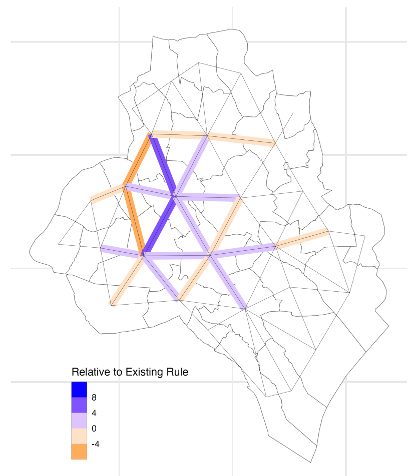


Figure 11: No Land Payment



Notes: I display the difference in optimal road improvements between the existing rule. 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.

Decomposition of the Effect Between the Allocation and Level Channels: These additional welfare gains come from both the allocation of road improvements (*allocative channel*) yielding larger benefits (5% larger decrease in average commuting time, 10% larger increase in property values), as well as lower fiscal burden from land payments (*level channel*).

How much does this first channel contribute to this difference? To answer this question, I solve for the optimal road improvement without land payment, but impose a tax on property values to redistribute the total land payments from the status quo among these owners ex-post. On the one hand, by design, the allocation is analogous as the no land payment counterfactual. On the other hand, despite equal total payments, welfare gains are higher than at the status quo by 20 million USD, which is 6% of the status quo welfare gains and 25% of the construction funds. This result comes from the spatial heterogeneity in land costs drive optimal upgrades away from high benefit locations.

The Opportunity Cost of Land Use: Importantly, even in the absence of land payments, the government is taking into account the opportunity cost of land use. Indeed, decreasing the amount of residential land available in these central locations has welfare costs, as this land is highly demanded by workers and their high rent increases owners' welfare. Consistently, if I also remove the opportunity cost of land use channel and assume that these road upgrades do not take up any residential land, optimal improvements are slightly more concentrated in the central locations (Appendix Figure A17), and the welfare costs of the policy increase, as no owner loses from land being taken from them without compensation.

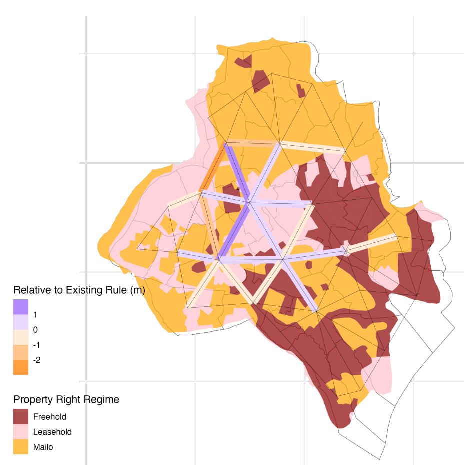
6.2 Optimal Road Improvements in Kampala Under Alternative Property Right Regimes Counterfactuals

In Kampala, the optimal road investments displayed on Figure 10 are driven by both the benefits of these specific improvements, as well as the corresponding land costs. In turns, these land acquisition costs depend on the different property right regimes. In particular, a lower share of owners gets compensated on freehold and mailo land, where property rights are less clear and land disputes are widespread. These issues are well known by the Uganda government, who started to digitize the national land registry to decrease the number of land fraud in an effort to decrease transaction costs and frictions on the land market.[33]

Such initiative may impact the land costs of road improvements through the same two channels as discussed above. First, by reducing heterogeneity across the different property right regimes, it would homogenize the share of owners getting paid across locations, potentially decreasing the relative land costs of some high benefit roads (*allocative* channel). Second, by increasing all owners' ability to claim compensation, it would increase land costs overall, reducing the net returns of road improvements (*level* channel). I estimate the overall impact of homogenize property right regimes in Kampala, before decomposing this effect into each allocative and level channel. I do not model the potential impact of such reform on the market value of residential properties. Yet, as this reform would likely homogenize and increase residential property values, the estimated impact on overall land costs here may be interpreted as a lower bound.

Single Property Right Regime at Freehold: I first compare the optimal road improvements under a counterfactual where all owners negotiate like freehold owners, the property right regimes with the lowest rate of negotiation, to the status quo property right regimes, on Figure 12, where I also display the existing property right regimes, for reference. If owners in all locations become compensated at the freehold (maroon) rate, I find that the quantity of upgrades increase (blue) in existing leasehold areas, as these locations become relatively less expensive than under the existing prop-

Figure 12: All Freehold Property Rights



[33] This digitization effort started in 2013 but is still ongoing.

erty right regimes. In turn, net welfare gains increase (400 million USD against 344 million USD under the existing property right regimes) both because of overall lower land costs, but also because of higher benefit improvements. For the same area of road upgrades, commuting time decreases by 0.2 percentage points more than under the existing property right regimes. Analogously, property values increase by 0.1 percentage point more than under the existing property right regimes, corresponding roughly to an additional increase in the NPDV of total property values by 12 million USD.[34]

This overall effect is the sum of two channels, as the homogenization of property right regimes changes both the *level* and the *allocative* channels. To isolate the latter, I solve for the optimal road improvements under freehold, but fix total land payments as per the existing property right regime, de facto shutting down the level channel.[35] Doing so yields, by construction, the same optimal improvements as on Figure 12, but net welfare gains of 380 million USD. Compared to the 400 million USD gain from the full freehold counterfactual, implying that $3/5^{th}$ of the welfare gain come from the allocative channel, and $2/5^{th}$ from the level channel.

6.3 Compensation at Market Value Counterfactuals

The previous exercises either maintain the voluntary land take rule or remove land payments entirely. Yet, there is evidence that policy makers may be concerned with enforcing land acquisition at market value, as both the Ugandan constitution and the World-Bank guidelines mandate fair compensation against land take.[36]

Given the assumed linear utility of owners, the government objective function (equation 20) is analogous to minimizing commuting costs and maximizing property values while minimizing total land costs, but says nothing about redistribution concerns. More specifically, in the absence of a fiscal wedge, the government would be indifferent about land payments. As owners' utility is assumed to be constant, and each owner has the same utilitarian welfare weight, taking a small amount of money from each owner to transfer to an affected owner otherwise losing land worth a large amount of money, would have no welfare consequence.

Empirically, I find that the realized upgrades are consistent with minimizing total land costs, are there is a negative correlation between link-level predicted share of owners getting compensated and realized upgrades, controlling for link-level marginal benefits (Table **??**).[37] Yet, this attachment to compensation at market value is consistent with the international agencies and judicial branches of the government being concerned with redistribution, rather than simply minimizing total land costs.

I now study the welfare costs (as measured by the model), or enforcing compensation at market value, and how relaxing the restriction on the use of international funds may affect this outcome.

[34] On the other hand, if all owners negotiate like leasehold owners, a weak property right regime, net welfare gains are lower (316 million USD), as total land costs increase.

[35] In practice, after solving for the optimal improvement under freehold, I impose an additional lump sum tax on all owners to account equal to the different in fiscal losses from the compensation between the two counterfactuals.

[36] The question of whether market value at baseline is a fair compensation rate is beyond the scope of this paper.

[37] If the government was concerned with redistribution, then we should observe either all owners being compensated at market value, or, under voluntary land take, a positive correlation between the probability owners get compensated and road upgrades, as not compensating owners would have welfare costs internalized by the government.

Under Existing Restriction on the Use of External Funds

I solve for the road improvement if land must be acquired at market value and compare the optimal policy to the voluntary land take status quo on Figure 13. Intuitively, road improvements decrease (orange) in the central, higher market value locations, and instead are allocated towards more peripheral links (blue). Net welfare gains are 100 million USD (30% of the status quo), as the fiscal burden of land costs is high, and the gross benefits (increase in property values, decrease in commuting time) are lower than under voluntary land take because lower benefit roads were upgraded. Interestingly, the total area of roads upgraded decreases by $11,597$ m^2, or about 3.6 km, as the corresponding land acquisition costs are too high. This result should not be surprising: the market value of land is high, up to 2/3 of the construction costs (Section A10), and the government must borrow to international agencies like the World Bank or the African Development Bank to fund the construction expenditures. Thus, she likely is not able to find funds for the complementary land acquisition costs. Anecdotally, this result is also consistent with how voluntary land take came to be the Kampala Capital City Authority's approach to land acquisition: she started under eminent domain with payment at (assessed) market value on the first couple roads, before running out of funds and switching towards voluntary land take.

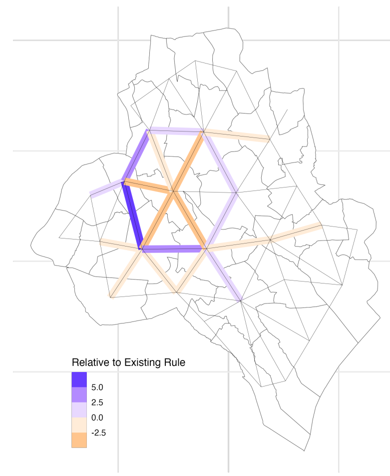


Figure 13: Payment at Market Value

Relaxing Restrictions on the Use of External Funds

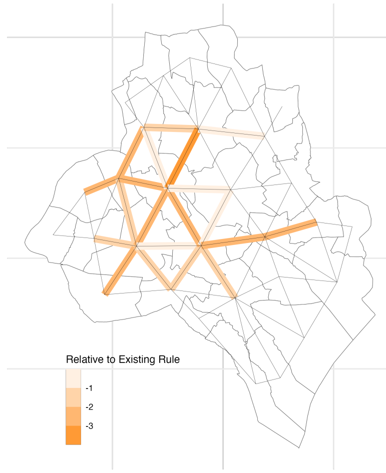
One potential avenue to remove this distortion would be to relax the existing restrictions on the use of external funds. Currently, the city government can only use external funds (from the World Bank and the African Development Bank) for road construction but not for land acquisition. This status quo restriction is likely driven by concerns of corruption that international agencies are wary not to fund (World Bank 2011) but, in the presence of high fiscal leakage on property value taxes used to fund land acquisition, it may conflict with other stated objectives like ensuring that displaced owners are *"provided prompt and effective compensation [...] for losses of assets attributable directly to the project."* (World Bank 4.12 Involuntary Resettlement).

In practice, I consolidate the budget constraints of the government's problem into a single one:

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

I find that under this relaxed restriction and payment at market value (Figure 14), net welfare gains from the road improvements sum up to 252 million USD, which is lower than under the status quo (344 million

Figure 14: Payment at Market Value &
No Restriction of the Use of External Funds



USD) because only 55% of the total area gets upgraded, as funds are used for land acquisition instead.

Compared to land acquisition at market value under the existing restrictions on fund use, however, the net welfare gains are higher (252 million USD against 100 million USD), even though less roads are upgraded, as the marginal value of these funds for land acquisition payments is higher than for an additional marginal road (for which land would have to be acquired too).

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.

Table 10: Welfare Impacts of Realized Road Improvements Under Alternative Model Parameters

	Parameters				Outcomes				
	η^{ϕ}	θ	κ	ξ	avg Δ commuting times (%)	Δ property values (%)	USD per resident-equivalent transfer (NPDV 3%)	USD net welfare gains (NPDV 3%)	USD net welfare gains (NPDV 6%)
Main	0.61	3.3	0.01	0.39	-7.1	$+1.3$	$+99$	$+85,640,225$	$+1,327,000$
Robustness	0.3	-	-	-	-7.1	$+1.3$	$+139$	$+119,973,517$	$+19,520,809$
	-	6.6	-	-	-26.6	$+22.6$	$+8,051$	$+6,972,213,288$	$+3,445,640,694$
	-	-	0.015	-	-14.9	-6.6	$+341$	$+294,983,996$	$+107,026,048$
	-	-	-	0.29	-8.4	-2.6	$+5$	$+4,284,928$	$-3,832,349$

Table 11: Optimal Road Improvements

Counterfactual					Outcomes			Net Welfare Gain (equivalent transfer)		
	Land acquisition Rule	Property Right Regimes	Land Use	Restriction Ext. Funds	total area upgraded (m^2)	Δ commuting time (%)	Δ property values (%)	USD / resident (NPDV 3%)	USD total (NPDV 3%)	USD total (NPDV 6%)
1	"voluntary land take" (VLT)	Existing	Y	Y	$452,765$	-13.2%	$+2.9\%$	$+397$	$343,767,916$	$131,418,009$
2a	no payment	Existing	Y	Y	$452,765$	-13.9%	$+3.2\%$	$+568$	$491,780,377$	$205,424,239$
2b	no payment	Existing	N	Y	$452,765$	-13.9%	$+3.3\%$	$+861$	$737,175,720$	$328,121,911$
3	equally split land payments	-	Y	Y	$452,765$	-13.9%	$+3.2\%$	$+419$	$363,283,998$	$141,176,050$
4a	VLT	All freehold	Y	Y	$452,765$	-13.4%	$+3.0\%$	$+461$	$399,570,320$	$159,319,210$
4b	VLT & fixing total payments at existing	All freehold	Y	Y	$452,765$	-13.4%	$+3.0\%$	$+438$	$379,676,761$	$149,372,431$
5	VLT	All leasehold	Y	Y	$452,765$	-13.1%	$+2.9\%$	$+364$	$315,592,361$	$117,330,231$
6	payment at market value	-	Y	Y	$441,168$	-12.4%	$+2.7\%$	$+115$	$99,865,592$	$9,127,330$
7	"voluntary land take"	Existing	Y	N	359,771	-11.2%	$+2.5\%$	$+425$	$367,852,167$	$151,771,522$
8	payment at market value	-	Y	N	$252,032$	-8.3%	$+1.9\%$	$+261$	$225,827,807$	$90,388,550$

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 less than 50% of the 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). 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 4.12 Involuntary Resettlement), adjustments of the restrictions on the use of external funds for land acquisitions could 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 levying domestic funds for compensation).

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Appendix

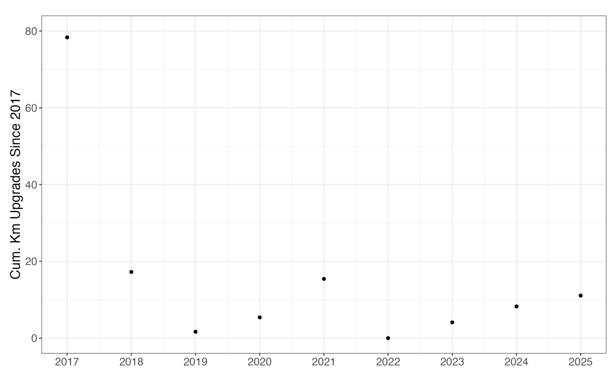
A Context

A.1 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.[38] 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.

A.2 The Policy

Figure A1: 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.

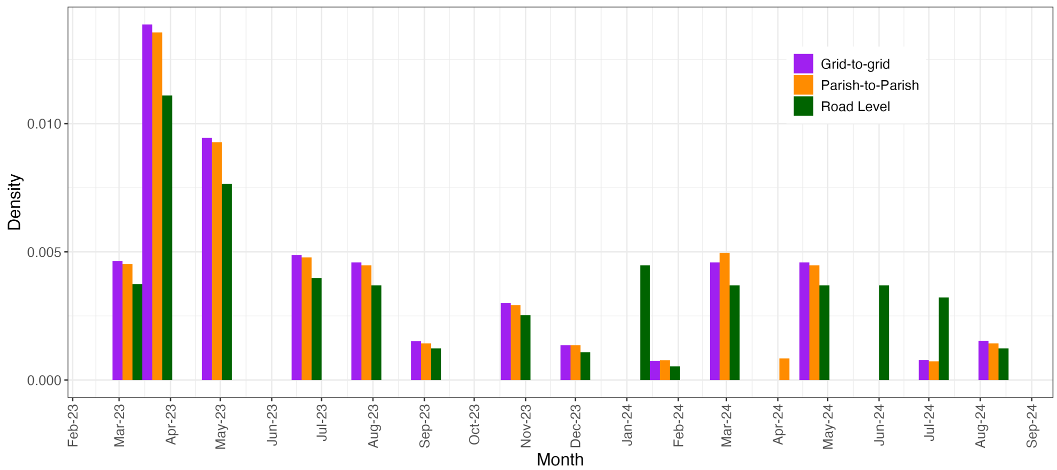
[38]The Uganda government started to digitize the national land registry to decrease the number of land fraud cases in 2013, but, as of 2023, this process had not been finalized yet.

B The Data

B.1 Google Maps API and Open Street Maps

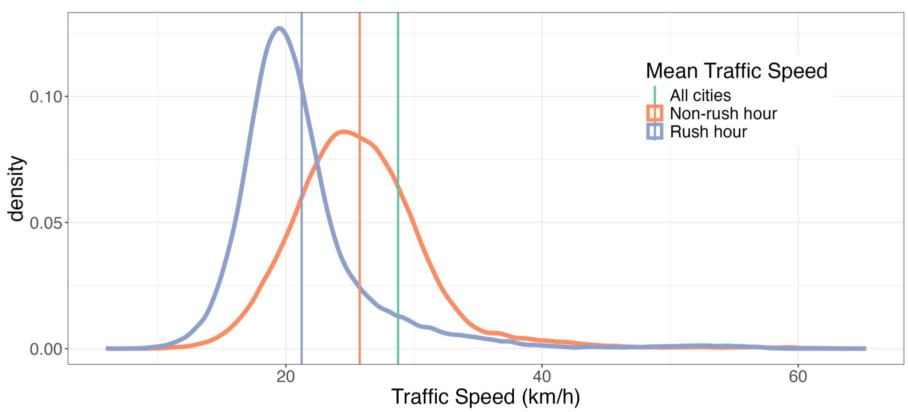
B.1.1 Additional Figures and Tables

Figure A2: 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 $\in$ {between neighboring grid cells, between all pairs of parish centroids, road level}.

Figure A3: 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 A2. 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.

B.1.2 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

Table A1: 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

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 A2. 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.

B.1.3 Evidence of Traffic Reallocation Towards Upgraded Roads

Empirical Approach 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

Table A2: 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 $^{*}p < 0.1; ^{**}p < 0.05; ^{***}p < 0.01$.

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:

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

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.[39]

Results Regression results are presented in Table A3. 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

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

6, I find that indeed, the share of trips on these roads did not increase since the beginning of the Google Maps data.

Table A3: 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.

B.1.4 Impact of Road Improvement on Rush-Hour Speed

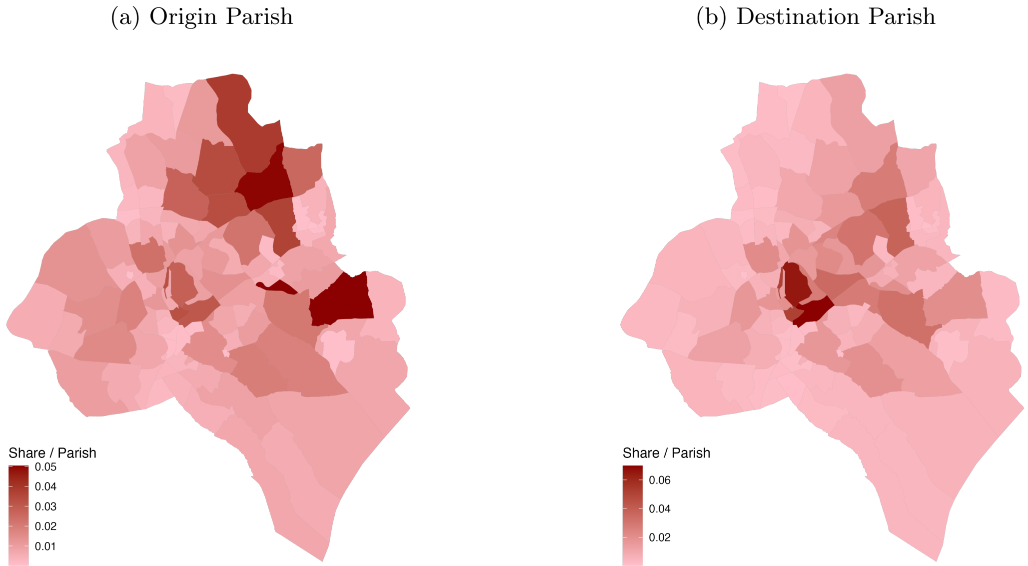
Table A4: Impact of Road Improvement on Rush-Hour Traffic Speed

	Dependent variable:						
	Traffic Speed at time of query in km/h						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Upgraded (dummy)	4.804^{***}	4.504^{***}	4.449^{***}	4.351^{**}	1.735^{**}	2.616^{***}	1.957
	(1.151)	(1.105)	(0.859)	(1.598)	(0.884)	(0.612)	(2.167)
Construction (dummy)	0.771	0.395	-1.319	-1.112	-1.173	-1.283	-1.523^{*}
	(1.368)	(1.585)	(1.264)	(1.267)	(0.888)	(0.907)	(0.751)
Mean dep var (km/h)	22.39	22.39	22.39	22.39	22.85	20.21	20.21
Time of Day	Non-rush	Non-rush	Non-rush	Non-rush	Non-rush	Rush	Rush
Hour + Day FE	Y	Y	Y	Y	Y	Y	Y
Control for road class		Y	Y		Y	Y	
Flexible geo controls			Y		Y	Y	
Road FE				Y			Y
Sample	Policy	Policy	Policy	Policy	Policy + Mentioned	Policy	Policy
Observations	682	682	682	682	1,663	426	426
R^2	0.311	0.323	0.473	0.641	0.331	0.407	0.613
Adjusted R^2	0.267	0.276	0.434	0.592	0.310	0.362	0.544
Note:					*p<0.1; **p<0.05; ***p<0.01		

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.

B.2 Ride sharing data

Figure A4: Ride-Hailing Trips: Origin and Destination of Morning Rush Hour Trips

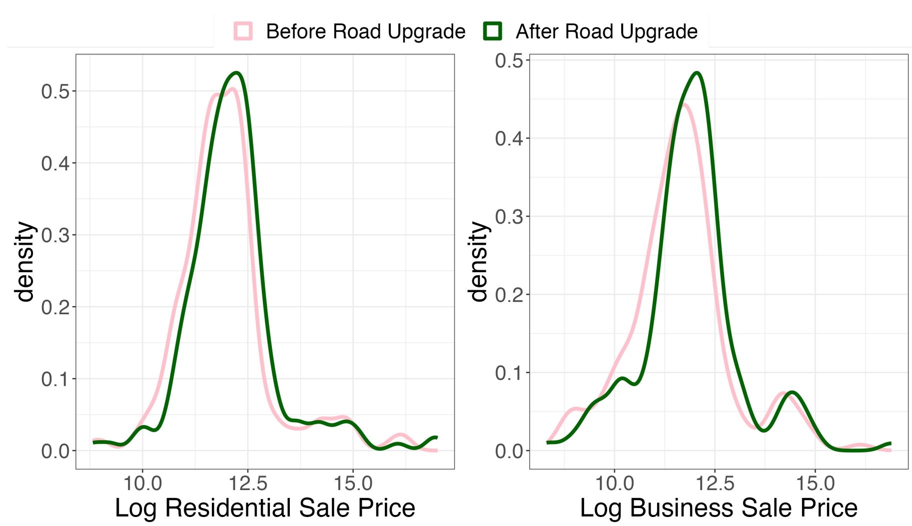


Notes: These figures show the share of morning rush-hour trips by parish of origin (panel a) and destination (panel b) from the ride-hailing data.

B.3 Broker survey

B.3.1 Additional Tables and Figures

Figure A5: 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.

B.3.2 Sampling Strategy

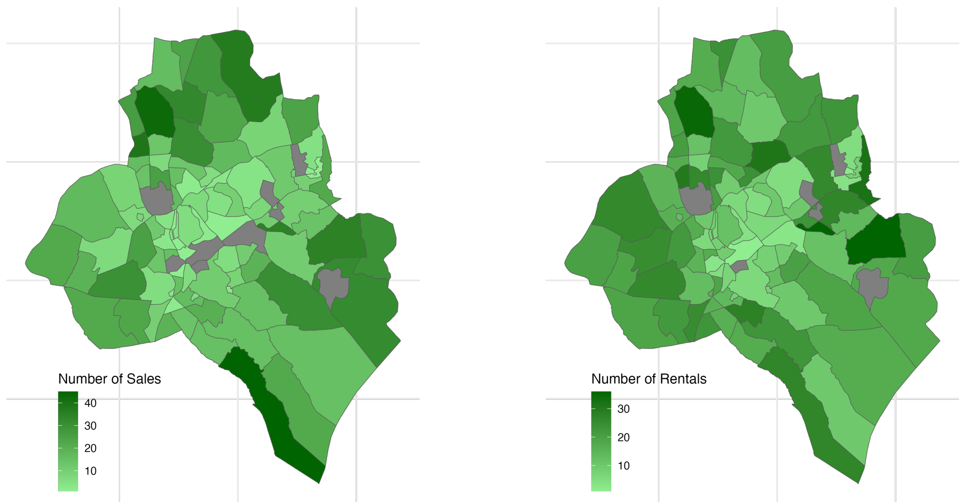
B.3.3 Comparison of the Broker Survey with Scrapped Online Property Ads.

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

Table A5: Property Values and Property Characteristics

Figure A6: Number of Transactions By Parish

(a) Sales (b) Rent



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

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).

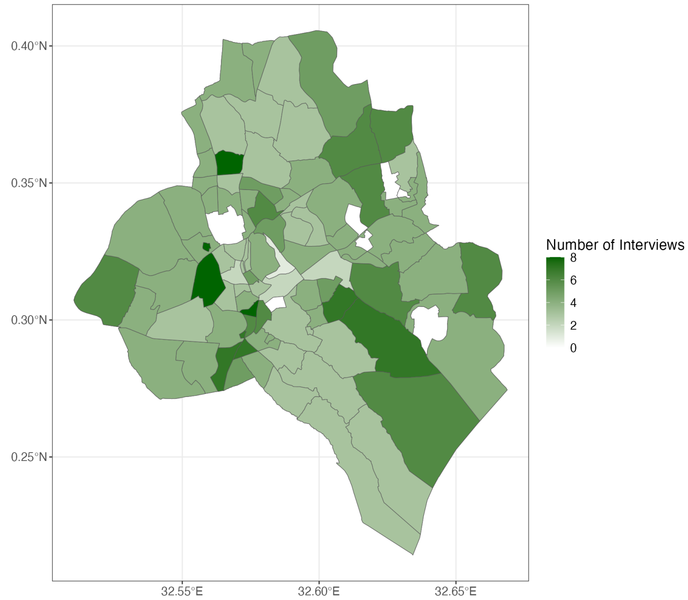
On Figure A8, I plot the distributions of property-level prices for sold residential properties in my broker survey data (red) and the online data (blue). The distribution of online property prices is skewed to the right, with an average price list at $332,694$ USD (against $70,261$ USD in the survey data). Given that the average monthly net salary in Kampala is \$188 USD (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

$$\ln \mathrm{p}^b_{pt} = \alpha + \beta \times \ln \mathrm{p}^o_{pt} + \gamma_t + \gamma_p + e_{pt}$$

where p^b_{pt} is the average property price in parish p, year t in the broker data, and analogously for the online database $\ln \mathrm{p}^o_{pt}$. γ_t and γ_p are year and parish fixed effects, respectively. The results are displayed on Table A6 are confirm the robust positive correlation between the online and broker survey databases at the parish and parish-year levels.

Figure A7: Number of Real Estate Broker Interviews By Parish



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

Table A6: 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.

B.4 Owner survey

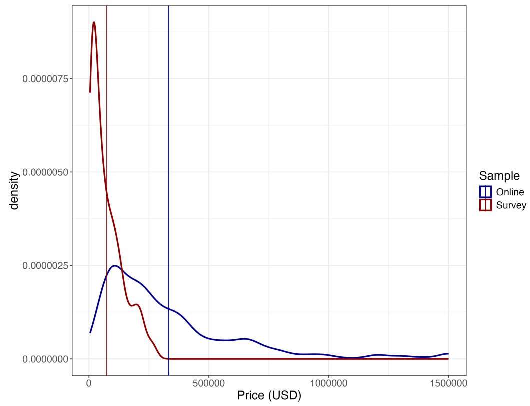
B.4.1 Sampling Strategy

The sampling frame for the owner survey was at the road segment level. More precisely, roads within Kampala were split into five categories based on their policy status: road upgraded in batch 1, road upgraded in batch 2, road upgraded in batch 3, road mentioned but not upgraded and other unpaved roads. To ensure coverage of the different land tenure systems 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 X valid segments were selected.[40]

Enumerators conducted a census of properties over a pre-specified road segment of approximately $\frac{1}{2}$ to 1

[40] 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).

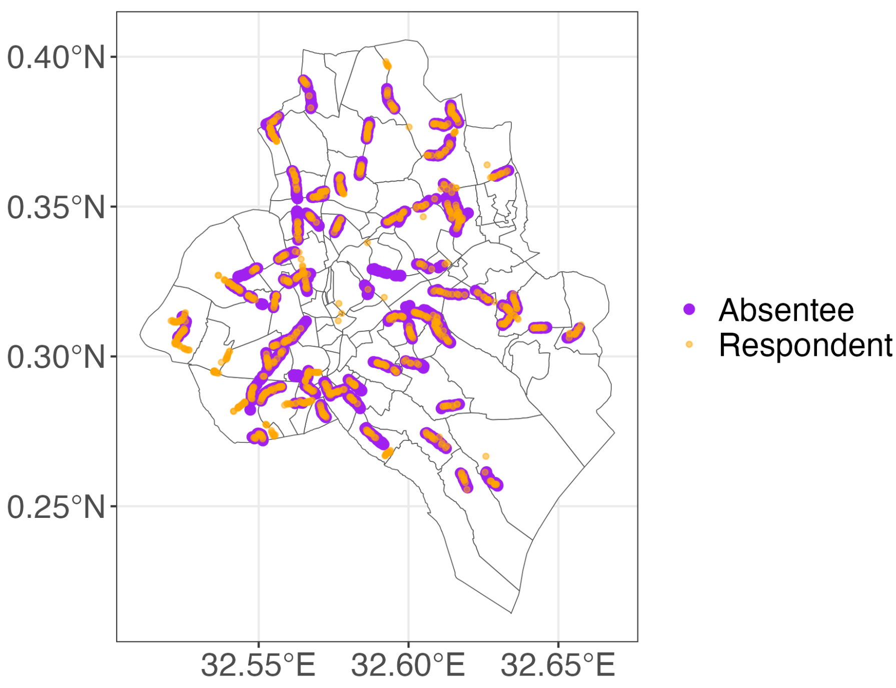
Figure A8: Comparison of Property Prices in the Broker Survey and the Online Database



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

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 A9 shows a map of the survey areas, displaying both interviewed respondents (in orange) and listed plots (in purple).

Figure A9: Spatial Coverage of the Owner Survey



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.

B.4.2 Additional Figures and Tables

C The Model

C.1 Recovering η from the Government's Actions

C.2 Model Parameters Estimation

Table A7: 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

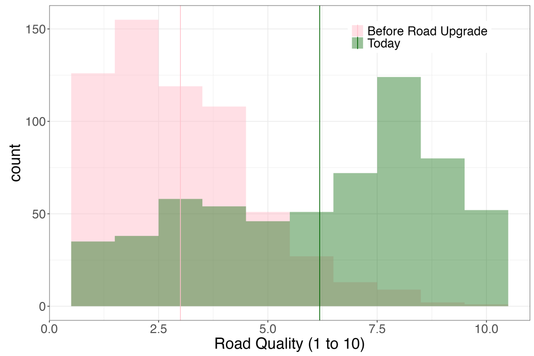
Notes: Standard errors are displayed in parentheses and clustered at the o-d pair level, with significance levels $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. All specifications include origin-year, destination-year and month fixed effect. I control for log distance in all specifications. In column 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.

D Returns of realized road improvements

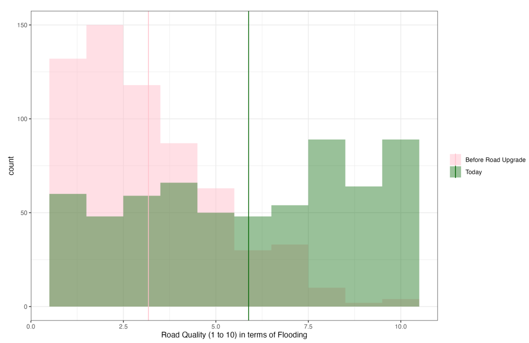
E Optimal Road Improvements

Figure A10: Change in Road Quality and Local Amenities Following Road Upgrades

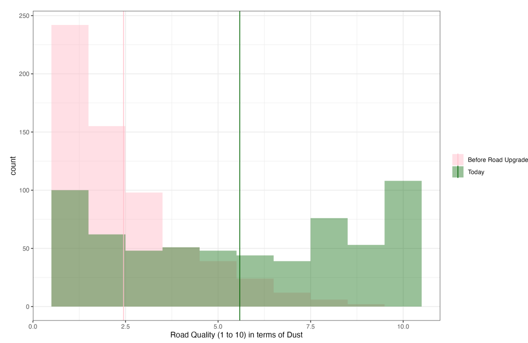
(a) Road Quality



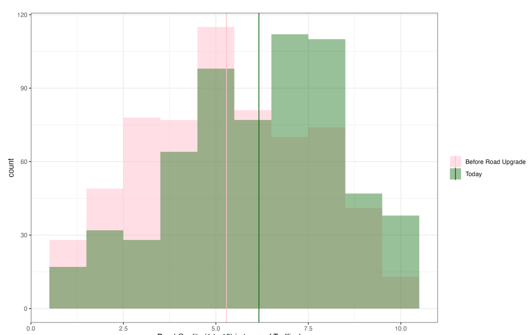
(b) (Absence of) Flooding



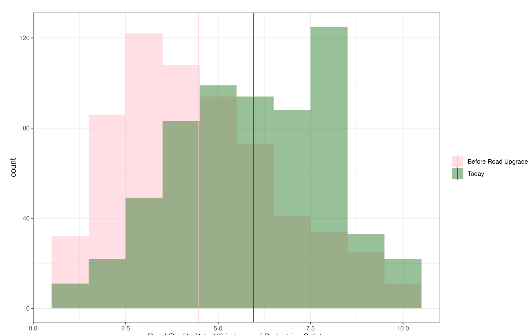
(c) (Absence of) Dust



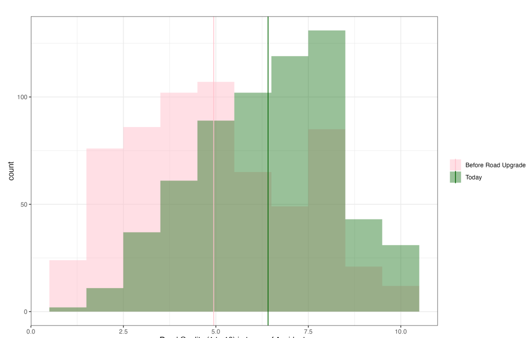
(d) (Absence of) Traffic Jam



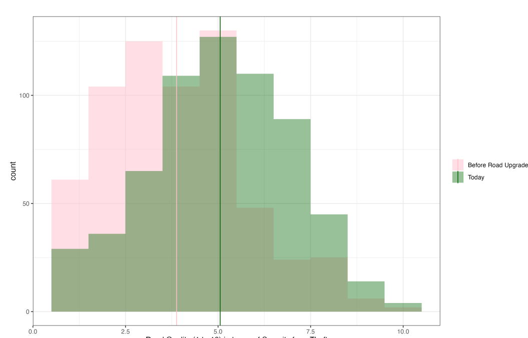
(e) Pedestrian Safety



(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 A11: Owners' Stated Reasons to Accept Not to Get Compensated

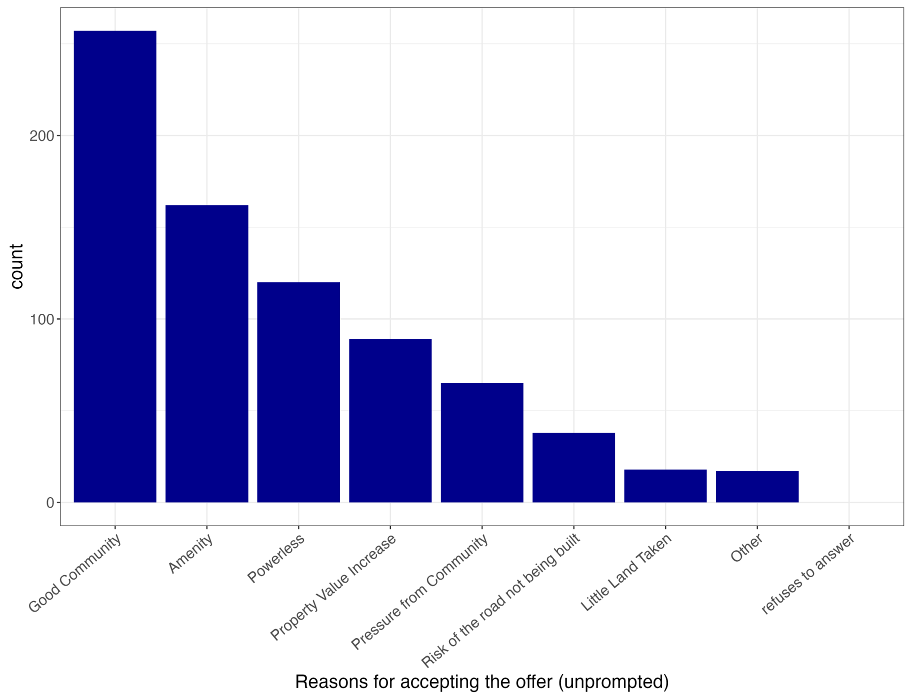


Figure A12: Owners' Stated Reasons to Negotiate to Get Compensated

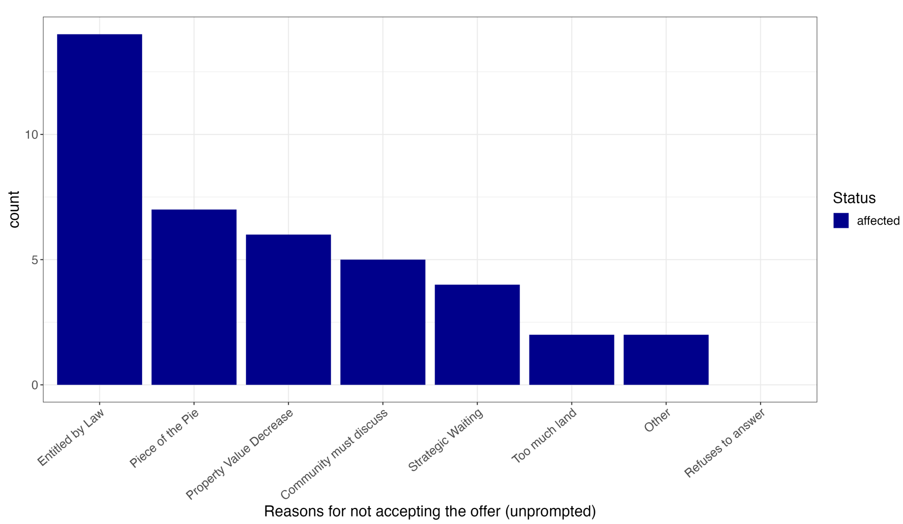


Figure A13: Interviewed Owners Do Not Believe that their Decision has an Impact on The Probability of the Road Being Built

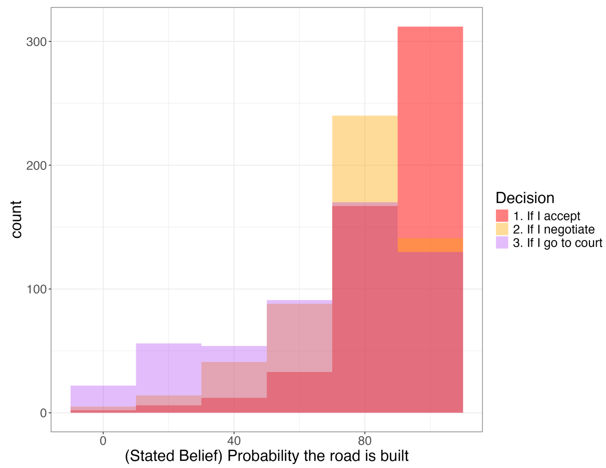


Figure A14: Predicted Market Value of Affected Land by Parish for 75m^2

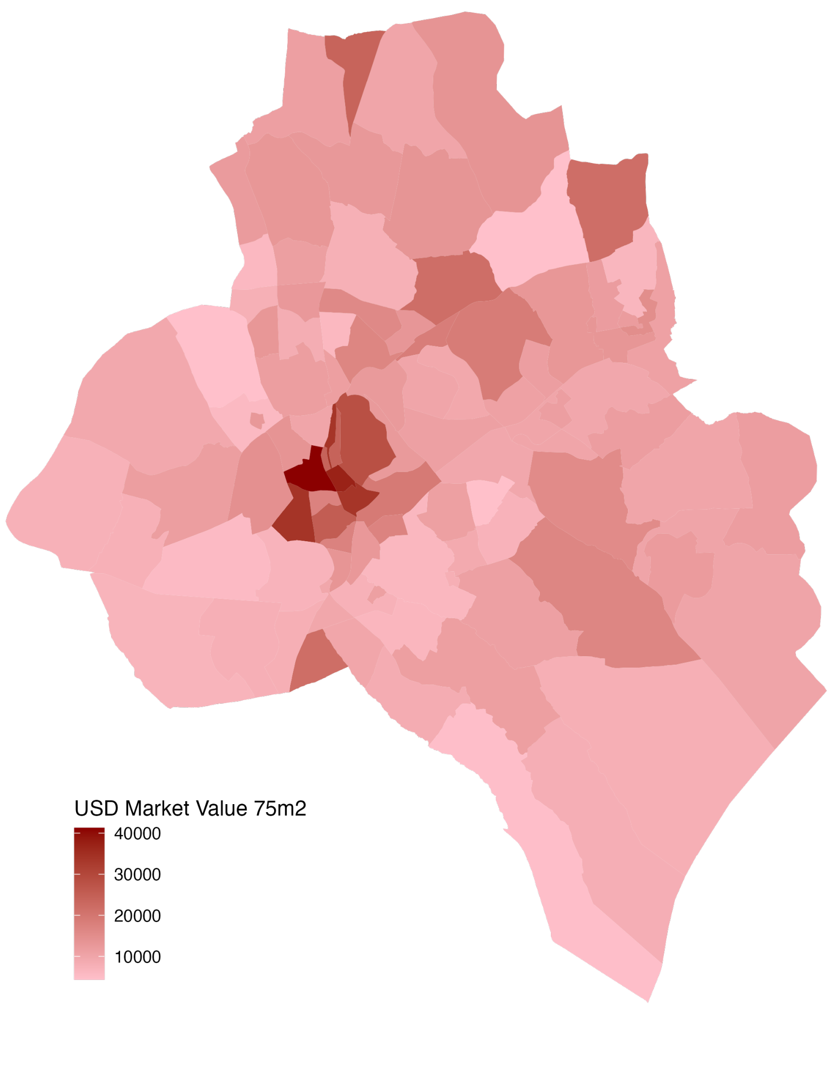
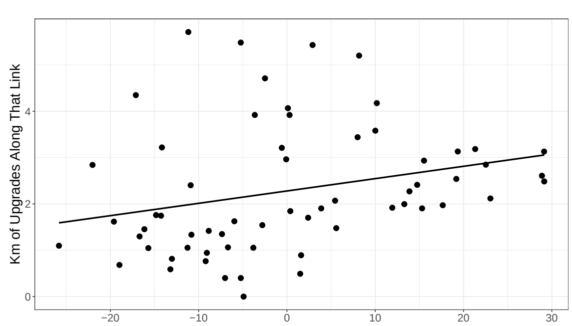


Figure A15: Welfare Gains of the Realized Improvements Under Market Value Acquisition as a Function of the Fiscal Wedge η

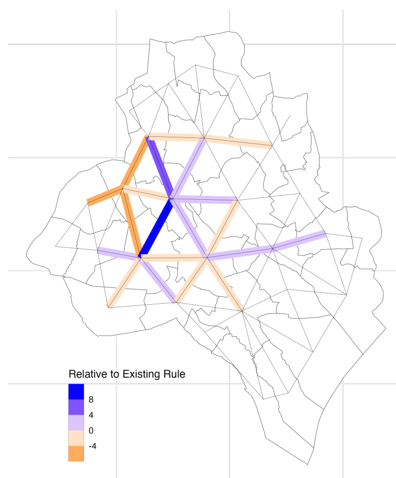
Notes: This figure displays the percentage welfare gains from the realized road improvements if land is acquired at market value, under various values for the fiscal wedge $\eta \in [0.0, 0.9]$. The red curve accounts for the construction costs to compute the net welfare gains, but assume that the fiscal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

Figure A16: 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 A17: 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 **??**). 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.