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The impact of infrastructure shocks on agricultural markets

Evidence from the Zambezi river in Mozambique

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Abstract: Prior to 2009, there was no direct road connection between the southern regions of Mozambique—where the capital city is located—and the more agriculturally-productive central and northern regions. In this paper, we leverage the opening of a major road bridge to identify the impact of enhanced domestic transport infrastructure on agricultural market performance. We apply a generalized difference-in-difference estimator within a dyadic regression context. While we find no reduction in the market price differential around the time the bridge opened for all treated market pairs, there is a significant and persistent price impact only among previously disconnected markets located close to the new bridge. This suggests that new infrastructure can enhance market performance, but such benefits are spatially limited.

Keywords: infrastructure, agricultural market performance, prices, natural experiment

JEL classification: O13, Q13, R42, C99

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1 Introduction

Sub-Saharan Africa's infrastructure deficit is widely considered to be large (Foster and Bricenno-Garmendia, 2009). Median transport costs for trade within Africa are estimated to be three times as high as in the Middle East and North Africa; and twice that of East and South Asia (Limao and Venables, 2001). While this partly may be explained by natural geographical disadvantages—including low population densities—inexistent and poorly managed infrastructure significantly increases costs to firms, and represents a proximate determinant of the slower rate of economic growth achieved in the region over the long-term relative to many other developing countries (Ndulu and O'Connell, 1999; O'Connell and Ndulu, 2000). In light of this, public action through investments in infrastructure is widely seen as necessary to enhance market integration and growth prospects.

The contribution of large-scale infrastructure projects to aggregate economic performance has been shown in a range of studies from different contexts (e.g., Fernald, 1999; Chandra and Tompson, 2000; Duflo and Pande, 2007; Michaels, 2008; also see Section 2). Literature examining the effect of domestic infrastructure on firm- and market-specific outcomes is more recent (see Datta et al, 2012; Banerjee et al, 2012; Martincus and Blyde, 2013, Donaldson, 2014; Duranton et al,, 2014; Donaldson and Hornbeck, 2016, Ghani et al, 2016; Coşar and Demir, 2016). At the same time, and despite infrastructure shortages in sub-Saharan Africa (SSA), there is little high-quality evidence regarding the magnitude and nature of their developmental contribution in this region. One exception is Jedwab and Moradi (2016) who find positive and persistent effects from transportation investments that took place during the colonial era. Whether investments in infrastructure projects carried out more recently in SSA have had the same positive effects remains an open question.

In this paper we address these gaps and look at the impacts of a new major bridge over the Zambezi river in Mozambique, which opened in August 2009. This was a major project that significantly enhanced connections between markets located in the north (and center) of the country with others located in south (and south-central) regions. We consider the bridge construction as a kind of quasi-natural experiment or positive infrastructure shock. This is in line with both Chandra and Tompson (2000) and Datta et al. (2012), who use interstate highway construction programs as exogenous shocks to the connectedness of different markets. In our case, routes that need to cross the river to communicate, get better infrastructure after the bridge —not as a consequence of a particular economic or other characteristic they have, but simply because of their location. That is, markets were not either included or excluded from benefiting from the bridge on account of existing performance or potential gains from trade.

We quantify the impact of the new bridge on agricultural market performance, comparing outcomes for market pairs that depend on the new bridge to communicate against outcomes for markets pairs that are unaffected by the bridge. Following Barret and Liu (2002), markets can be said to be in a competitive equilibrium if there is zero marginal profit to arbitrage. Thus, and in keeping with Aker (2010a, 2010b) among others, we use changes in the degree of absolute price dispersion across market pairs to evaluate the effects of the bridge on spatial market efficiency (integration). We apply a difference-in-difference design, controlling for market pair–specific fixed effects and market pair–specific time trends. Overall, we find no impact of the bridge on price dispersion. However, treatment effects do vary with distance between markets. Markets within 500 km of each other, that use the bridge to trade, experienced a significant reduction in price dispersion – e.g., around 10 per cent reduction for markets located 250 km apart.

The remainder of this study is organized as follows: section 2 briefly reviews existing literature. Section 3 describes key characteristics of the agriculture sector, trade and infrastructure in Mozambique. Section 4 presents the data. Section 5 describes our econometric model. Section 6 presents the main results, section 7 examines the robustness, and section 8 concludes.

2 Existing literature

Transportation infrastructure is often mentioned as a crucial determinant of economic growth and development. Literature assessing the contribution of infrastructure to economic outcomes can be divided in three strands. A first strand looks at aggregate impacts on long-term economic outcomes. By estimating reduced-form or structural models using cross-country data, various studies find that growth is positively associated with the stock of infrastructure assets (Binswanger et *a.l*, 1987; Aschauer, 1989; Easterly and Rebelo, 1993; Sachs and Warner, 1997; Esfahani and Ramirez, 2003; Calderon and Serven, 2004). A second strand of literature focuses on the impact of infrastructure on social outcomes that can potentially be affected through better access, availability, and quality of key services. These studies tend to find that better infrastructure increases primary school enrolment, reduces child mortality and inequality, thereby having a relatively larger improvement on the welfare of the poor (Calderon and Serven, 2004, Michel Wormser; 2004; World Bank, 2004).

The third strand of literature focuses on trade effects. Studies in this line point out that a main impediment to trade relates to high transaction costs, which comprise a combination of transport costs, communication costs, trade charges and delays due to roadblocks, as well as inefficiencies in administrative procedures at ports and borders (Amjadi and Yeats, 1995). Transport costs represent a substantial fraction of total transaction costs and depend on the overall quality or level of transport infrastructure. In order to evaluate the contribution of transport infrastructure to trade-related outcomes, studies generally use changes in direct measures of infrastructure such as road density and stock values, controlling for differences in predetermined geographical characteristics across countries and/or regions. Limao and Venables (2001), for instance, build an infrastructure index from data on road, rail and telecom density. They find that infrastructure accounts for 40-60 per cent of predicted transport costs and that the condition of being landlocked reduces trade volumes by 70 per cent compared to the median trade volume of coastal countries. Similarly, Elbadawi et al. (2002) use firm-level data from Africa to investigate the impact of infrastructure on export volumes. They proxy infrastructure by the inverse of transport costs and the degree of openness, finding that both measures are positively related to firm exports and productivity.

The use of broad proxies for infrastructure—such road distance, travel time, regional transport infrastructure density or the presence of transport infrastructure—has been questioned due to potential endogeneity problems. While road improvements might be thought to drive economic outcomes, it is also possible that higher economic growth stimulates investment to reduce transport costs and enhance competitiveness. To overcome this problem, recent empirical studies take advantage of quasi-natural experiments. Datta (2012) exploits a highway construction program in India to explore the microeconomic channels through which transport infrastructure affects economic outcomes. He argues that the construction program can be treated as a quasi-natural experiment as long as the highway location was not manipulated to include or exclude specific intermediate areas. Thus, construction can be treated as exogenous to areas that the highway passes through. Results from a difference-in-difference estimator indicate that firms in cities affected by the project (i) reduced their average stock of input inventories, (ii) were more likely to switch their supplier, and (iii) reported decreased transportation barriers to production.

In a similar vein, Donaldson (2014) investigates the effects of the construction of India's railroad network during the colonial period. He contends that placement of this infrastructure was driven by largely non-economic factors—a view which is supported by insignificant effects of unfinished or planned-but-unbuilt railroad lines, used as a placebo test. He finds that railroad infrastructure reduced trade costs, narrowed interregional price gaps, and increased trade volumes. The study also shows that most of the benefits in terms of welfare came through enhanced trade. Ghani et al. (2016) also evaluated the effects of a large-scale highway construction carried out in India (the Golden Quadrilateral (GQ) project) on the organization of manufacturing activity. They found that districts along the highway system experienced substantial manufacturing output growth and a shift towards industries intensive in land and buildings, improving allocative efficiency.

Cosar and Demir (2016) investigate the effect of a large-scale public investment in roads on the level and composition of international trade in Turkey. The investment project they analyse consisted of the expansion of existing two-lane roads into divided four-lane expressways, generating a significant improvement in the quality and capacity of key transport arteries. Their results show that these investments significantly reduced the cost of shipments by about 70 per cent on average, thereby increasing regional exports and imports. Martincus and Blyde (2013) address the potential endogeneity problem between domestic transport infrastructure and trade by exploiting the random variation in infrastructure arising from an earthquake in Chile. Using a difference-in-difference estimator, they find a significant negative effect on exports following the shock to domestic infrastructure.

Turning to the USA, Duranton et al. (2014) investigate the effect of highways on the weight and value of bilateral trade between large cities. The authors rely on route maps of major exploration expeditions, major railroad routes, and a preliminary plan of the interstate highway to build instruments and attempt to solve the possible endogeneity of highways to trade flows. Results suggest a significant effect of road on trade volume but a less clear effect on the value of trade. The paper also found that cities with more highway connections employ more people in heavy goods sectors, suggesting an effect of road infrastructure on the degree of productive specialization. Also focusing on the USA, Donaldson and Hornbeck (2016) investigate the historical impact of the national railroad network expanded from 1870 to 1890. The authors estimate variations in counties' market access by simulating the removal of all the railroads in 1890 (at the end of a period of expansion). They find this reduction would lower the value of US agricultural land by 60.2 per cent, indicating that railroads in the US played a crucial role in enhancing market integration.

Comparatively little empirical work on the effects of infrastructure investment has considered the SSA region, which has substantially higher transport costs and poorer transport infrastructure compared with other developing regions. As noted above, the main exception is Jedwab and Moradi (2016) who exploited the construction and demise of colonial railroads in Ghana, and in a sub-sample of African countries to study the impact of transportation investment. They show that colonial railroads had large positive effects on city growth and that effects persisted because the railroads promoted the emergence of cities that eased the coordination of spatial investments for each subsequent period. Related work in the context of SSA, but which considers the intensive margin of infrastructure, is due to Storeygard (2016). The author investigates changes in trade and urban growth driven by plausibly-exogenous variation in transport costs induced by world oil price fluctuations. By focusing on city distance to ports, he finds that a positive oil price shock induces an increase in the income of cities near that port relative to identical cities farther away.

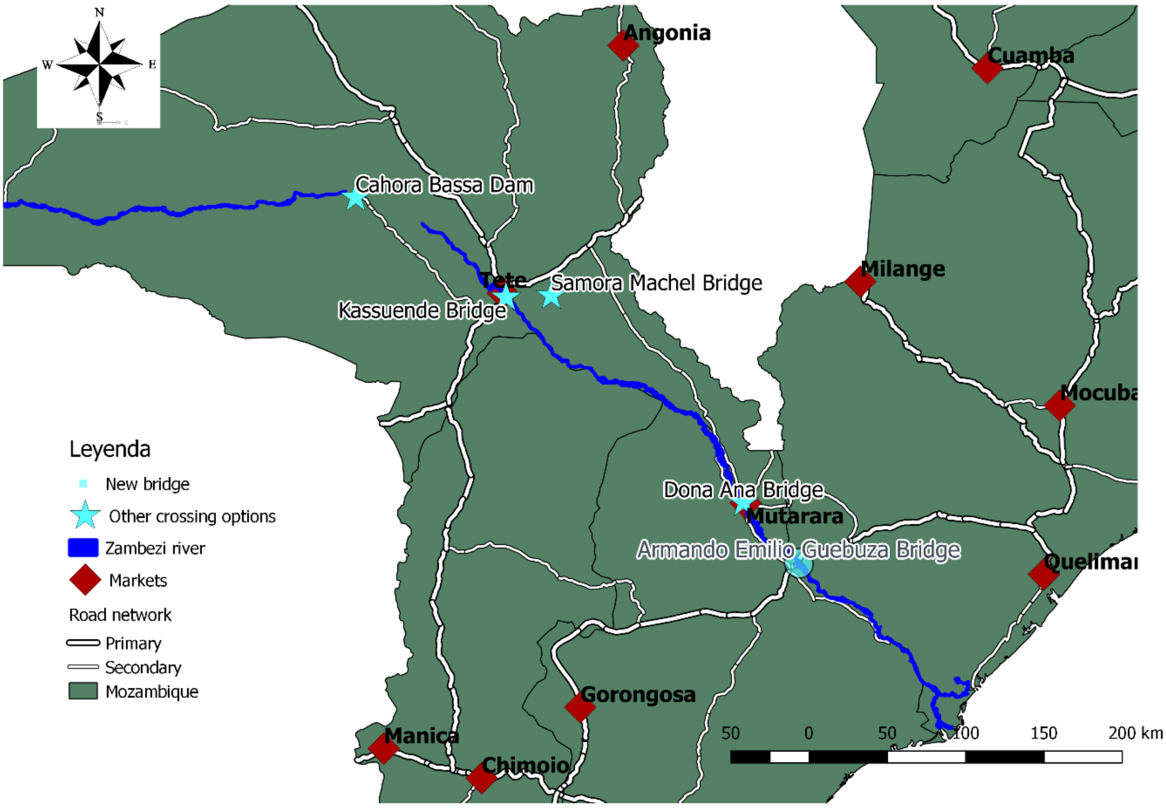
3 Agriculture, trade and road infrastructure in Mozambique

The previous section suggested that improvements at both the extensive and intensive margin of transport infrastructure can have a decisive impact on economic performance. These issues are relevant to Mozambique, which is a low-income country located in southern Africa. Geographically, the country spans a large territory but population density is low, at around 30 people per square kilometer. Agriculture plays a fundamental role in the economy, accounting for around 30 per cent of GDP and employing around 80 per cent of the workforce (Jones and Tarp, 2013). The vast majority of rural households are smallholders, producing extensively at a low level of productivity (World Bank, 2012).

Existing literature for Mozambique recognizes the key role of road infrastructure in linking agricultural markets. Indeed, a number of studies suggest that agricultural market performance in the country is constrained by high transport costs associated with poor road infrastructure (Penzhorn and Arndt, 2002; Tostao and Brorsen, 2005). Cirera and Arndt (2008) specifically exploit the variation in infrastructure quality associated with a series of road rehabilitation programs in Mozambique. They find that overall market performance responds positively with improvement in road quality. However, the concern that road rehabilitation varies in scope and is not exogenous, means the precision of their estimates may be questioned.

Interregional trade from north to south is potentially crucial for Mozambique's economy, especially given the largest city is located in the far south. While maize is the staple crop and production occurs across the country, better soil and rainfall mean that northern and central regions are surplus producers, accounting for 90 per cent of national production. Drier southern provinces have a maize deficit, and import both from other regions and neighboring countries (Tschirley et al., 2006). Reflecting historical legacies and dynamics within the Southern African region, internal transport connections remain poor (Tostao and Brorsen, 2005; Cirera and Arndt, 2008; Abdula et al., 2006). There is no railway, no functional commercial coastal shipping, and just a single tarmac north-south highway. This highway is broken by the Zambezi River, which divides the country at the town of Caia in roughly the middle of the country (see Figure 1), forming a natural barrier to direct north-south trade. Historically, a ferry over the Zambezi allowed cars and trucks to use the highway. However, this service was extremely inefficient. Despite only taking 15 minutes, the ferry ran only between 7am and 5pm, was notorious for breaking down, and was often suspended during the rainy season due to rapid changes in the water level and dangerous currents on the river (Tumbare, 2010). Lengthy queues of trucks lasting hours and even days were common, and perishable goods were in danger of rotting.

Figure 1: Crossing options over the Zambezi river



Source: Authors' own elaboration using information from the Africa infrastructure country diagnostic

As a result of the unpredictable and costly nature of the ferry crossing, road users often sought alternatives. But, these were limited. The nearest option was the Dona Ana bridge that connects the towns of Vila de Sena and Mutarara, around 60 kilometers upstream from the highway. This was originally constructed as a railway bridge to link Malawi and the Moatize coal fields to the port of Beira. In the 1980s it was converted to a single-lane bridge for vehicle traffic and was operative until October 2006 when it was re-converted to a rail bridge. In any case, the Dona Ana bridge is not located on a tarmac highway, meaning vehicles would have to deviate from their original route via degraded dirt roads, significantly increasing time and transport costs. The other domestic option was the Samora Machel Bridge that links Tete—the capital of Tete Province—to Moatize, much further upstream (see Figure 1). This route was reasonable for vehicles transporting goods between the port of Beira to hinterland countries, such as Malawi, Zambia, Zimbabwe, South Africa, and Botswana; but it was extremely inconvenient and costly for those travelling north-south within Mozambique.

During the last decade, substantial investments in road transportation infrastructure have been made in Mozambique, in large part supported by foreign aid. In 2007, the European Development Fund committed €131 million to Mozambique's transport infrastructure sector and regional integration projects for the period 2008-2013 (European Commission, 2007). One of the main projects funded by this program was the construction of a major new bridge over the Zambezi river, named the 'Armando Emilio Guebuza Bridge' (after the then President), connecting the provinces of Sofala and Zambezia, which opened in August of 2009.[1] The new 2376 m long bridge cost around €66 million (before tax), including design and construction project costs. It was built on behalf of the National Road Administration of Mozambique (ANE), and co-financed by the European Commission and the Governments of Italy and Sweden (Reis et al., 2013).

4 Data

As noted previously, we assess spatial market efficiency by quantifying price dispersion between agricultural markets. Data on prices and transport costs are taken from the *Sistema De Informação de Mercados Agrícolas de Moçambique* (SIMA, 2011). The SIMA collects weekly information on prices, transport costs, opportunities and market perspectives of selected agricultural markets. We use data on white maize prices for 25 markets over the period 2005:01-2012:06. We focus on white maize because it is a highly homogenous good that is produced and sold across Mozambique throughout the year, allowing consistent comparison across markets in the country over time.

Descriptive statistics of the variables used in the estimations are summarized in Table 1, where maize prices and transport cost values are deflated by the national consumer price index. Looking across markets, the data constitutes a strongly balanced panel of 300 market pairs, observed over 90 months, yielding a total of 27.000 observations. Notably, maize prices fluctuate substantially among the markets in our sample. Prices per kilo in constant 2005 prices range from around 1,500 to 14,000 MZN, with a mean of 4,800 MZN. Price differences between market pairs are also considerable, as shown in the second row of the table.

Table 1. Descriptive Statistics

Variables	Observations	Mean	St. dev.	Min	Max
Maize price per kilo (000 MZN)	27,000	4.80	1.89	1.42	13.85
Absolute price difference per kilo (000 MZM)	27,000	1.13	0.97	0.00	8.80
Transport cost per kilo (000 MZN)	27,000	0.87	0.16	0.55	1.33
Diesel price per liter (000 MZN)	27,000	22.98	4.21	14.07	30.24
Distance (kilometers)	27,000	629.14	364.07	4.01	1660.93
1 if road connecting *i* and *j* is paved	27,000	0.57	0.50	0.00	1.00
1 if one market hit by a drought (SPEI6)	27,000	0.27	0.44	0.00	1.00
1 if both markets hit by a drought (SPEI6)	27,000	0.06	0.24	0.00	1.00
1 if one market hit by a flood	27,000	0.03	0.17	0.00	1.00
1 if both markets hit by a flood	27,000	0.01	0.10	0.00	1.00
1 if the road was blocked	27,000	0.05	0.22	0.00	1.00

Note: Values are deflated by the consumer price index (base year 2005).

Source: Authors' own estimates

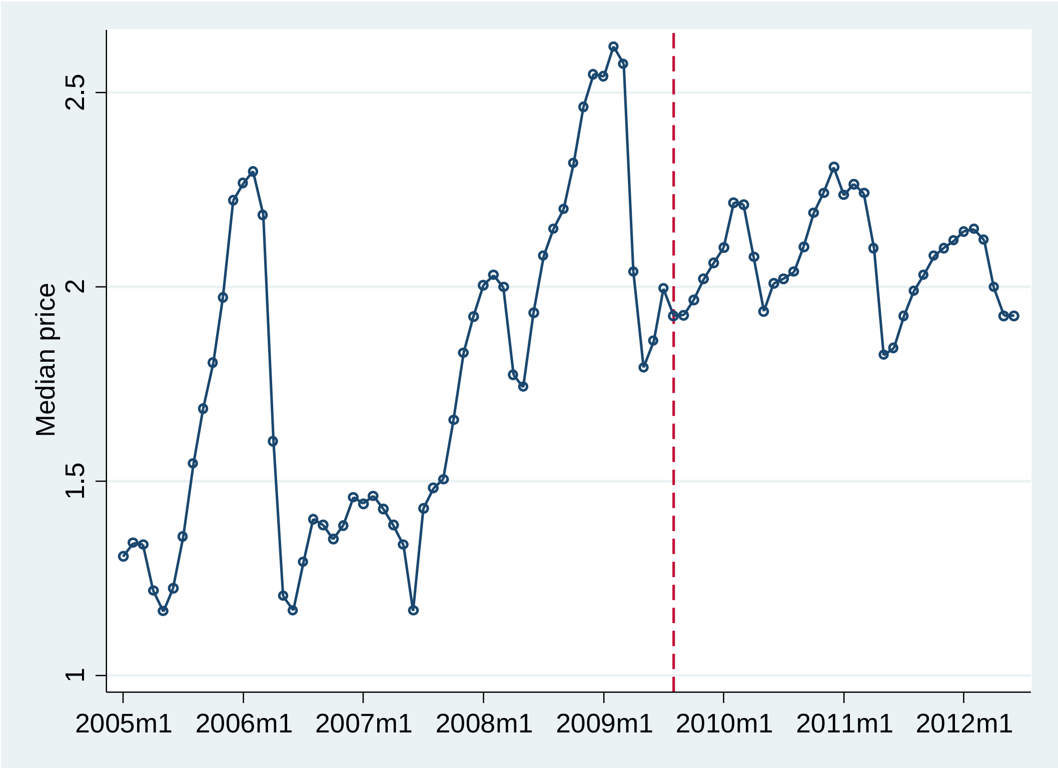
The markets covered by the SIMA data are distributed across the entire territory of Mozambique, from north to south. Inter-market distances are greater than 1,000 km in many cases. Notably, paved roads in Mozambique represent only 57 per cent of the total, and the north region is poorly

[1] Recently in 2014, another bridge was built over the Zambezi river named Kassuende Bridge (see Figure 1). It is located downstream from the Samora Machel Bridge. This reduced traffic on the current bridge since vehicles can bypass Tete and save some time.

connected compared to than the central and southern regions. A limitation of the data is that transport cost information is only available for a few market pairs at a relatively low frequency. The latter is usual in developing countries. To overcome this, we follow Salazar et al. (2016), and use predicted transport costs as a proxy for transaction costs.[2] Transport costs range from 550 to 1,130 MZN per kilo, with an average of 870 MZN. In spite of lower volatility relative to maize prices, transport costs account for around 20 per cent of the total maize value. On average, the absolute maize price difference between a given market pair surpasses the mean of transport costs, thus indicating some room for market arbitrage.

Figure 2 presents a graphical inspection of median monthly maize prices. We notice substantial price variation before the bridge opening and more stable prices after that, although prices still remain high. While lower price variation might be the result of the project construction, other variables may have influence on market performance, adding unwanted noise to price dispersion metrics. We control for the occurrence of drought in our estimations. To identify a drought, we use the Standardized Precipitation-Evapotranspiration Index (SPEI; see Vicente-Serrano et al., 2010). In particular, we use a 6- month time scale index with a 0.5 degrees spatial resolution from the Climatic Research Unit of the University of East Anglia. Following Doesken et al. (1993; 1995), we define a drought event any time the SPEI value reaches an intensity of -1.0. We also control for the occurrence of floods using data recorded in the Global Active Archive of Large Flood Events (Brakenridge, 2013) from the Dartmouth Flood Observatory.

Figure 2: Median maize price across time.



Source: Authors' own estimates

[2] The authors use the existing information of transport cost, distance, road quality and diesel prices to predict transport cost values for each market pair in the study period (see Table 1).

5 Empirical strategy

We follow Aker (2010a; 2010b) and estimate the Average Treatment Effect (ATE) of the bridge opening on maize market efficiency via a dyadic regression analysis. This approach allows us to exploit both temporal and spatial variation in the price data. We define treatment and control groups at the market pair level. The treated group consists of market pairs whose most direct trade route on primary roads involves crossing the Zambezi river at the new bridge. Note that the location of the bridge directly replaced the ferry service and was built as part of the *existing* north-south highway. Thus, there is no endogenous placement of the bridge to alter trading distances between markets. Moreover, the toll for crossing the bridge was fixed at the same price as motorists previously had to pay for using the ferry (4 USD for cars and 30 USD for trucks). Thus, direct transport costs should remain the same.

Despite these similarities, the bridge was built in order to improve the quality and reliability of the connection over the Zambezi river. Thus, we expect that treated markets have the potential to become more integrated after the bridge opened. The control group consists of market pairs that do not depend on the bridge to trade. For these, we expect no significant changes after opening of the new bridge. The ATE is the expected effect of the new bridge, defined as $\alpha = E[y^1_{ij,t} - y^0_{ij,t}]$, where $y^1_{ij,t}$ and $y^0_{ij,t}$ are the potential outcomes for market pair *ij* at time *t*, calculated for all market pairs that need to cross the river at the bridge to trade (Wooldridge, 2010, Blundell and Costa, 2009).

Our baseline model assumes treatment effects are homogeneous across all treated market pairs. These are estimated via a difference-in-difference estimator, including dyad-specific linear time trends, given as follows:

$$y_{ij,t} = \alpha P_t + \beta(B_{ij} \times P_t) + X'_{ij,t}\gamma + \theta_t + v_{ij} + \lambda_{ij}t + \varepsilon_{ij,t} \quad (1)$$

The outcome of interest is the absolute difference in the natural logarithm of prices between markets *i* and *j* at time *t*: $y_{ij,t} = 100 \times |\ln(p_{it}) - \ln(p_{jt})|$. Use of the log transform removes trends in prices induced by a common factor (e.g., general consumer prices) and are naturally interpreted as the percentage price gap. P_t is a post-treatment indicator, equal to 1 from August 2009 onward, and 0 before then; B_{ij} is a treatment status indicator, equal to 1 if the market pair trades via the new bridge and 0 otherwise; $X'_{ij,t}$ is a vector of control variables that affect spatial price dispersion, such as (time-varying) transport costs, and the occurrence of drought and floods; θ_t denotes time-fixed effects; v_{ij} are market pair–fixed effects, which account for all time invariant market pair characteristics (e.g., their distance) and absorbs the treatment dummy (B_{ij}); λ_{ij} is a market pair–specific linear time trend, which controls for differential trends in prices that are unrelated to construction of the bridge (e.g., differential productivity growth); and ε_{ijt} is residual error. The direct effect of the new bridge on absolute price dispersion, conditional on other factors, is represented by β. This can be interpreted as capturing an average structural break in the price dispersion series due to the new bridge that is specific to treated market pairs only.

We hypothesize that not all treated market pairs are equally likely to be affected by the bridge. Also, treatment effects may vary over time as trading patterns shift and other factors impact on optimal arbitrage routes and price differences. Thus, we evaluate whether time and distance to the bridge modify the magnitude of the treatment effect. To address these factors, we augment equation (1) as follows:

$$y_{ij,t} = \alpha P_t + (\beta + \delta M_t + \kappa D_{ij} + \rho M_t \times D_{ij})(B_{ij} \times P_t) + X'_{ij,t}\gamma + \theta_t + v_{ij} + \lambda_{ij}t + \varepsilon_{ij,t} \quad (2)$$

where M_t is the number of months since the bridge opened and D_{ij} is the log. distance in km between market pair *i* and *j*. Heterogeneous treatment effects are captured by parameters δ and κ, which measure the extent to which the new bridge affects price dispersion conditional on time and distance, respectively. With these terms included, the β coefficient alters interpretation and gives the impact of the bridge opening on maize price dispersion for (hypothetical) markets either side of the bridge as at the month of opening.

We estimate equations (1) and (2) via a flexible high-dimensional fixed effects estimator.[3] Because our specification is a dyadic linear regression, the standard errors must be corrected for spatial dependence. Standard errors are calculated via the two-way cluster robust estimator suggested by Cameron et al. (2011), accounting for spatial dependence within each market pair (the clusters). For robustness and comparison, alternative corrections for clustering are presented in the Appendix, including the dyadic standard errors proposed by Fafchamps and Gubert (2007). Reflecting our inclusion of high-dimensional fixed effects, these appear less conservative than the two-way procedure and do not alter our main findings.

6 Results

Table 2 presents our results for the baseline specification (homogeneous treatment effects; equation 1). Moving left to right in the table we build up to the full specification given in equation (1). Columns 1-2 only include controls for market pair–fixed effects. Columns 3-4 add month-year dummies (period-fixed effects); and columns 5-6 include time trend market pair fixed effects. Columns 2, 4 and 6 include the vector of time-varying controls. Across all specifications we find no effect on price dispersion after the new bridge was opened. This suggests there were no clear, generic benefits from the infrastructure shock in terms of spatial market efficiency.

[3] To estimate models with more than one high-dimensional fixed effect we use the Stata command "reg2hdfe" developed by Guimaraes and Portugal (2010).

Table 2. Estimated effects of bridge construction on the absolute difference of log maize prices

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment × bridge open	3.66	3,30	3.66	3.31	3.66	3.28	0.87	1.02
	(2,43)	(2,46)	(2.43)	(2.42)	(2.43)	(2.25)	(2.43)	(2.38)
Bridge open[4]	1.11	0.47	0.60	2.22				
	(1.65)	(2.34)	(2.08)	(2.02				
Drought one market		-2.85***		-1.02		-0.83		-0.62
		(0.90)		(0.68)		(0.60)		(0.63)
Drought both markets		-4.75***		-2.61**		-2.31**		-1.69
		(1.38)		(1.10)		(1.10)		(1.00)
Flood blocks road		-3.54**		-5.70***		-13.77***		-8.97**
		(0.83)		(2.05)		(2.46)		(3.49)
Flood one market		-0.26		-3.59		-11.14***		-6.53
		(2.10)		(2.59)		(3.44)		(4.05)
Flood both markets		0.71		2.02		3.21		2.47
		(1.38)		(1.97)		(2.31)		(2.79)
Transport cost (est.)		10.87		9.54		1.68		-6.23
		(20.03)		(19.58)		(19.39)		(21.72)
Transport cost (est.) × distance		-1.85		3.18		14.62***		9.38
		(3.18)		(4,65)		(6.98)		(6.98)
Market pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	No	No	Yes	Yes	No	No	No	No
Month dummies	No	No	Yes	Yes	No	No	No	No
Year & month dummies	No	No	No	No	Yes	Yes	Yes	Yes
Market pair time trend	No	No	No	No	No	No	Yes	Yes
R-squared	0.19	0.19	0.27	0.27	0.30	0.31	0.35	0.35
Observations	27.000	27.000	27.000	27.000	27.000	27.000	27.000	27.000
Number of market pairs	300	300	300	300	300	300	300	300

*** p<0.01, ** p<0.05, * p<0.1

Note: Two-way clustered standard errors are in parentheses.

Source: Authors' own estimates

In Section 5 we noted that the impact of the bridge may be stronger in the short run and/or larger among proximate market pairs. Results from our augmented specification (equation 2) are shown in Table 3. Again, we build up the specification across columns. Columns 1-2 include an interaction term between the treatment indicator and months since opening (only). Columns 3-4 include an interaction between the treatment status (i.e., treated pair × bridge open) and distance between markets; and columns 5-6 incorporate both the distance and months interaction terms. The table shows no significant results for the interaction terms including months, indicating no average effect even in the short run. However, the coefficient for treatment status and distance is material and significant across specifications. Moreover, interaction of treatment status with both months and distance is not significant, suggesting that the latter effect persists over time.

Figure 3 takes the estimates from columns 4 and 2 of Table 3 and illustrates the treatment effect estimates conditioned on distance (panel a) and time (panel b) after the new bridge opening. The graph shows no effect in maize price dispersion across markets over the period of interest (see Figure 3, panel b). Panel (a) indicates that the reduction in price dispersion is largest among closer markets, but the effect is only significant when markets are located within around 500 km of each other. In practice, this corresponds to 21 market pairs using the bridge for connection. This is plausible. Since it is expected that the new bridge impacts price dispersion mainly through a reduction in transport costs, the *proportional* reduction in transport costs due to the bridge logically is largest for more proximate markets.

[4] The post treatment variable drops when controlling for yearly monthly dummies.

Table 3. Estimated effects of bridge construction on the absolute difference of log of prices by time and distance.

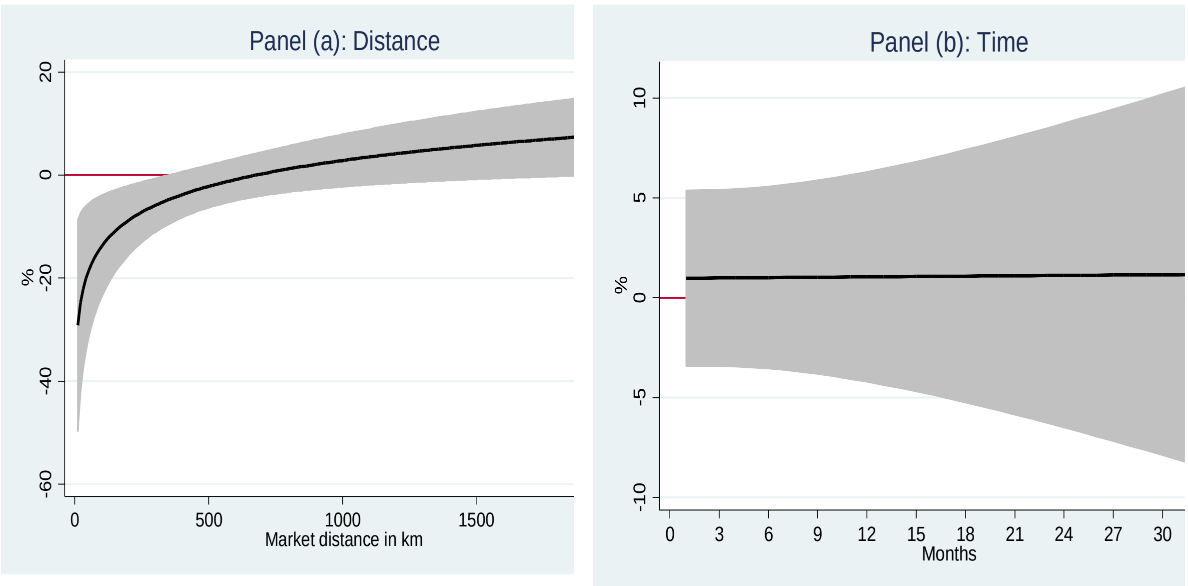
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Treatment × bridge open	0.85	0.98	-49.31***	-47.18**	-51.21**	-50.05**
	(2.25)	(2.25)	(17.12)	(17.00)	(15.17)	(15.46)
Treatment × open × months	0.00	0.01			0.24	0.37
	(0.14)	(0.14)			(1.15)	(1.15)
Treatment × open × distance			7.52**	7.24**	7.08***	7.66**
			(2.68)	(2.66)	(2.29)	(2.34)
Treatment × open × distance × months					-0.04	-0.05
					(0.17)	(0.17)
Drought one market		-0.62		-0.54		-0.54
		(0.63)		(0.63)		(0.63)
Drought both markets		-1.68*		-1.65*		-1.67*
		(0.99)		(1.00)		(1.00)
Flood blocks road		-8.97**		-8.25**		-8.33**
		(3.49)		(3.53)		(3.58)
Flood one market		-6.50		-5.66		-5.76
		(4.07)		(4.05)		(4.14)
Flood both markets		2.46		1.74		1.77
		(2.77)		(2.81)		(2.75)
Transport cost (est.)		-6.38		-11.72		-11.52
		(20.73)		(21.39)		(19.82)
Transport cost (est.) × distance		9.39		9.01		9.07
		(6.88)		(7.11)		(7.07)
Market pair fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Yearly monthly dummies	Yes	Yes	Yes	Yes	Yes	Yes
Market pair time trend	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.36	0.36	0.37	0.37	0.37	0.37
Observations	27.000	27.000	27,000	27,000	27,000	27,000
Number of market pairs	300	300	300	300	300	300

*** p<0.01, ** p<0.05, * p<0.1

Note: Two-way clustered standard errors are in parentheses.

Source: Authors' own estimates

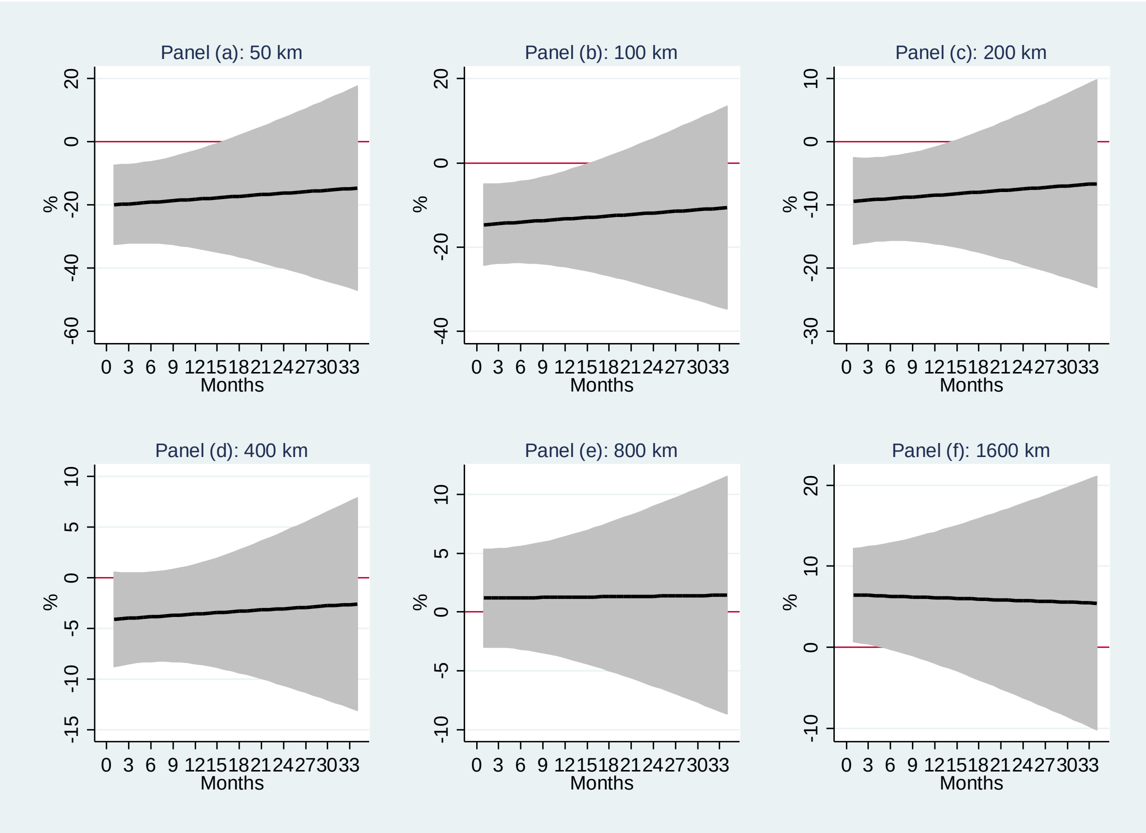
Figure 3. Changes in price dispersion post-bridge opening by time and distance



Source: Authors' own estimates

A follow-up question is whether the stronger and significant effect found among closer markets remain in the long run. The Figure 4 shows the ATE estimates from regressions considering the interaction term with time after the new bridge opening by several market distance categories. Results indicate that the impact of the new bridge on price dispersion is strong and persistent, but only among closer markets. In particular, the figure shows that markets within around 200 km of each other benefit most. For example, price dispersion between markets located within 50 km of each other may fall by up to 20 per cent (see Figure 4, panel a). This point estimate changes little over time, but standard errors mechanically widen over time. These results suggest that the overall insignificant effect shown in Figure 3(b) is driven by distant market pairs. The obvious explanation is that the benefits of the new bridge on total transport costs are relatively small for transport over long distances (see Figure 4, panel d-f).

Figure 4. Changes in price dispersion Post-bridge opening by time and distance.



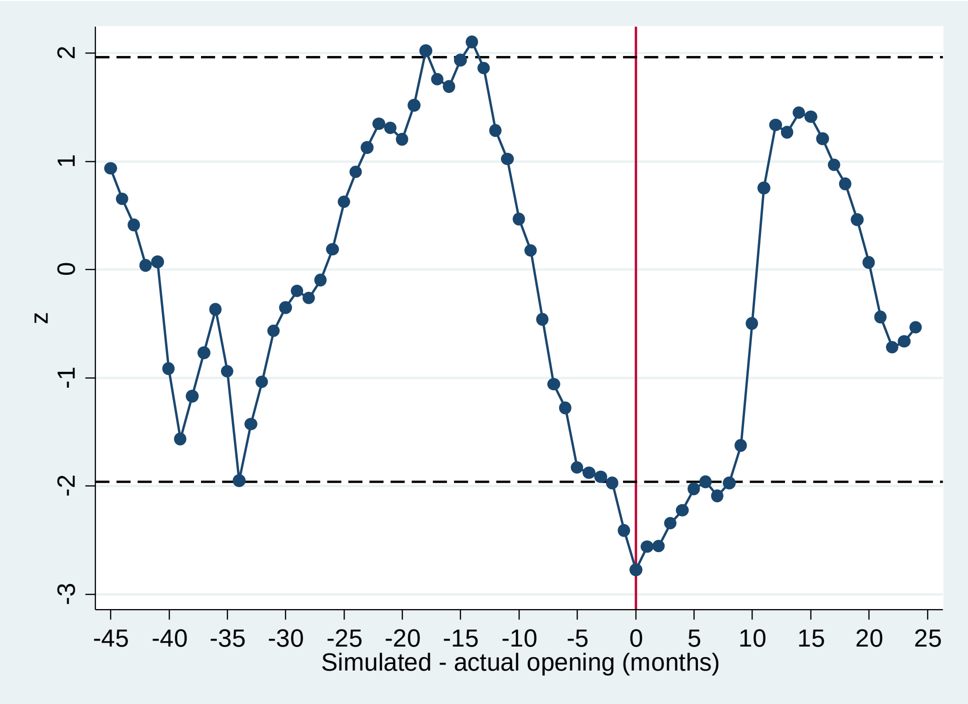
Source: Authors' own estimates

7 Robustness

To examine the robustness of our results, we pursue two strategies. First, we examine whether the specific timing of the opening of the bridge was a genuine event or shock. To do so, we run the distance-interacted model (column 4, Table 3) with multiple different hypothetical bridge opening times. Our expectation is that if the opening of the bridge was a shock, then the series of coefficient estimates for β will converge to a global low at the true opening time period. We would also expect that estimates for β would be insignificant for those hypothetical opening times that are distant in time from August 2009.

Results from this exercise are illustrated in Figure 5. The x-axis gives the difference in months between the simulated and actual opening times; the y-axis reports the z-statistic for the estimated β. In line with expectations, we find significantly negative estimates around one month before and six months after the actual bridge opening month with a low at August 2009. A further finding is a substantial (trend) increase in the z-statistic 12–30 months before the opening of the bridge, suggesting a fall in market efficiency during this period. This may reflect the combination of two effects. First, the nearest alternative to the ferry service was re-purposed as a rail bridge from around October 2006, which corresponds to 33 months before the opening of the new Zambezi bridge. Second, construction of the bridge may have further increased traffic and congestion on the main highway near the river and perhaps even disrupted the ferry service. Either way, these results confirm that the bridge opening was a meaningful event.

Figure 5. Placebo test: z test after random bridge opening



Source: Authors' own estimates

A second concern with our results is that they may be particular to the SIMA data in the sense that heterogeneity among market pairs (e.g., outliers) is driving the results. To investigate this, we explore the impact of the new bridge on price dispersion employing separate maize price data used to construct the Consumer Price Index (CPI), taken from only three selected markets (the three major cities of Maputo, Beira and Nampula). Our control market pair is Maputo-Beira since its does not depend on the bridge to communicate (see Figure 1). Thus, we evaluate the impact on price dispersion between Beira-Nampula and Maputo-Nampula relative to Maputo-Beira. These results are shown in column 1 of Table 4, employing the baseline specification of equation (1) but allowing the treatment effect to vary across specific market pairs. We find a reduction in price dispersion of around 18 per cent for Beira-Nampula after opening of the bridge. In contrast, price differences between Maputo-Nampula remain unchanged. This confirms the pervious results, since Nampula is significantly closer to Beira than Maputo (approximately 1000 km versus 2000 km).

A last concern with our estimations is that it only relies on data for unprocessed maize. It would be interesting to see if similar results are found for other agricultural crops with different perishability and storage requirements. Results for other products based on the same CPI data are presented in columns 2 to 9 of Table 4. Broadly, they support our main findings. Price differentials between treated market pairs are found for maize flour, beans, sweet potatoes and banana; and in these cases both treated pairs show a significant change. Somewhat unexpectedly, price reduction is larger between Maputo and Nampula for maize flour and sweet potatoes, despite being more distant markets. This may reflect differences in demand for these products and scale economies of bulk transport for these products.

Table 4. Estimated effects of bridge construction on the absolute difference of log of prices, various products.

Variables	(1) Maize	(2) Maize flour	(3) Cassava	(4) Bean	(5) White Sugar	(6) Sweet Potato	(7) Banana	(8) Tomato	(9) Eggs
Treat*Post (BE-NA)	-19.57***	-10.01***	-10.87	-9.46*	1.03	-3.10	-17.95**	-8.71	4.87
	(7.07)	(3.74)	(13.04)	(4.84)	(2.16)	(12.70)	(7.28)	(9.43)	(3.64)
Treat*Post (MA-NA)	10.53	-17.12***	-11.35	-10.01**	0.17	-21.97**	-11.74**	-5.49	-1.77
	(7.55)	(4.17)	(10.22)	(4.96)	(2.70)	(9.83)	(5.20)	(7.56)	(3.42)
Drought (one market)	-11.54***	-4.44**	5.42	-2.38	0.57	8.01**	3.93	-2.38	0.55
	(2.76)	(2.04)	(3.92)	(1.61)	(0.77)	(3.05)	(3.04)	(2.95)	(1.60)
Drought (both markets)	-11.38	-3.63	4.56	-17.40*	0.67	4.77	10.78*	8.45	-3.54*
	(15.15)	(3.23)	(11.12)	(9.15)	(1.61)	(13.16)	(5.51)	(7.51)	(2.03)
Ln(Predicted tran. cost)	-55.75	38.81	92.94	168.47**	14.63	241.04***	-213.49**	-47.18	28.44
	(76.55)	(51.12)	(108.62)	(77.36)	(15.97)	(77.27)	(88.27)	(64.47)	(17.33)
Market pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yearly monthly dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Market pair time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.64	0.87	0.77	0.76	0.70	0.88	0.65	0.52	0.62
Observations	270	270	270	270	270	270	270	270	270
Number of market pairs	3	3	3	3	3	3	3	3	3

*** p<0.01, ** p<0.05, * p<0.1

Note: The table uses CPI data for products from three selected markets – Maputo (MA); Beira (BA); and Nampula (NA). Standard errors in parentheses are clustered by year & month.

Source: Authors' own estimates

8 Conclusions

The aim of this paper was to add to the literature on the impact of infrastructure investments on economic performance in developing countries. We noted that poor provision of road infrastructure can significantly increase costs to firms and make potential market opportunities unprofitable. Investment in transport infrastructure is widely seen as crucial to overcoming natural barriers and mitigating connectivity problems, in turn enhancing market integration. For this purpose, we used a quasi-natural experiment based on the construction of a new bridge across the Zambezi river that connected markets in Mozambique.

Using a difference-in-difference approach within a dyadic set up, and including controls for differential linear trends across each market pair, we did not find evidence of a significant average effect on differences in maize price after the bridge was opened for 'treated' market pairs. However, when we differentiate between proximate and distant pairs, we find a persistent impact on price dispersion among proximate markets affected by the new bridge. For instance, treated markets located within 200 km appear to benefit from at least a 10 per cent reduction on price dispersion after the opening of the bridge. These findings are robust to a date placebo test, use of alternative price data, and other products. Overall, these results confirm that infrastructure can provide a significant and persistent contribution to spatial market efficiency, which is likely to be welfare-enhancing. The flipside is that benefits deriving from infrastructure projects in terms of market performance appear to diminish (quite rapidly) with distance. Thus, cost/benefit analysis of such projects needs to pay careful attention to the expected scope of impacts.

Finally, some caveats with respect to our results deserve comment. Given our estimation strategy and our definition of treatment, the estimates reported here mainly capture shorter-run effects from enhanced infrastructure that translate into price effects. Effects on other socio-economic outcomes and longer-run effects on performance—such as changes in production—require accounting for the possibility of changes in the patterns and localization of economic activity and resource flows. These are important dimensions to infrastructure projects, but they go beyond the present exercise.

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Appendix

Estimated effects of bridge construction on the absolute difference of log of prices by distance for several standard error corrections.

Variables	(1) Robust OLS	(2) Robust (HDFE)	(3) Dyadic correction	(4) Two way Clustering
Treatment × bridge open	-31.52***	-47.19***	-47.19***	-47.19**
	(4.59)	(7.45)	(6.78)	(17.00)
Treatment × open × distance	5.09***	7.24***	7.24***	7.24**
	(0.70)	(1.13)	(1.04)	(2.67)
Drought one market	-2.96***	-0.54**	-0.54	-0.54
	(0.27)	(0.27)	(0.49)	(0.63)
Drought both markets	-4.85***	-1.65***	-1.65**	-1.65
	(0.39)	(0.42)	(0.71)	(1.01)
Flood blocks road	-3.99***	-8.25***	-8.25***	-8.25**
	(0.55)	(1.51)	(1.07)	(3.53)
Flood one market	-0.82	-5.67***	-5.67***	-5.67
	(0.64)	(1.61)	(1.21)	(4.06)
Flood both markets	-0.25	1.74	1.74	1.74
	(0.96)	(1.22)	(1.63)	(2.81)
Transport cost (est.)	-45.30***	-11.72	-11.72***	-11.72
	(2.45)	(9.11)	(3.32)	(21.39)
Transport cost (est.) × distance	7.44***	9.02***	9.02***	9.02
	(0.33)	(2.55)	(0.52)	(7.11)
Market pair fixed effects	No	Yes	Yes	Yes
Yearly monthly dummies	No	Yes	Yes	Yes
Market pair time trend	No	Yes	Yes	Yes
R-squared	0.05	0.37		0.37
Observations	27.000	27.000	27,000	27,000
Number of market pairs	300	300	300	300

Note: *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' own estimates.