Obstacles on the Road to Palestinian Economic Growth

Roy van der Weide
Bob Rijkers
Brian Blankespoor
Alexei Abrahams

October 16, 2017

Abstract

This paper quantifies the impact of market access on local GDP in the West Bank, proxied by night time lights, using the deployment of road closure obstacles by the Israeli army between 2005 and 2012 as a quasi natural experiment generating temporal and spatial variation in accessibility. Minimum travel times between locality pairs are computed using road network and obstacles data supplemented with information on average traversal times collected in field interviews. These are combined with population data to construct a market access measure for each locality. Market access has a significant and substantial effect on local light emissions. This association is robust to controlling for conflict, and strengthens when market access is instrumented by the number of obstacles located in a radius between 10 and 25km away from the locality. Over our sample period road blocks repressed GDP per capita in the West Bank between 4.1% and 6.1% on average each year.

1 Introduction

How productive is market access? Answering this question is difficult because market access typically only evolves slowly and non-randomly over time which makes it challenging to isolate its impact on economic performance. Exploiting variation in the provision of transportation infrastructure such as roads (Baum-Snow (2007), Faber (2014), Gonzalez-Navarro and Quintana-Domeque (2016), Duranton and Turner (2012), Alder (2017), Banerjee et al. (2012), Allen and Arkolakis (2014)), railroads (Donaldson and Hornbeck (2016), Donaldson (2017), Jedwab et al. (2017), Jedwab and Moradi (2016), and waterways (Feyrer (2009)), existing studies typically find sizeable gains to improving connectivity. Research addressing this question by examining the impact of changes in borders (Redding and Sturm (2008) and transportation costs (Storeygard (2016)) has reached similar conclusions.

This paper exploits unique variation in market access in the West Bank resulting from the deployment of mobility restrictions by Israel to identify its impact on local GDP, proxied by night time lights. Mobility restrictions took the form of manned and unmanned physical road obstacles, including roadblocks, checkpoints, earth mounds, trenches, and a separation barrier wall, and were part of the broader closure regime initially instituted by the Israeli army in response to the Second Palestinian Uprising to safeguard the security of Israeli settlers. The placement of obstacles was not (directly) driven by local economic performance, but rather by security considerations, and thus largely exogenous to local economic conditions. Moreover, the number, intensity, and configuration of obstacles was subject to frequent and unanticipated changes, yielding sizeable short-run variation in local market access. This unique context thus provides a quasi-natural experiment to assess the impact of short-term fluctuations in accessibility on economic performance.

To do so, we first construct a market accessibility index (following Deichmann, (1997), and Donaldson and Hornbeck (2016)), that takes into account both the nature and intensity of the mobility restrictions, their positioning and their configuration. This is important since one strategically placed checkpoint can reduce accessibility more severely than a multitude of roadblocks when alternative connections are available. In addition, restrictions may be mutually reinforcing and market access in a given locality may in part be impacted by obstacles in relatively remote areas, the impact of which conventional proxies for mobility restrictions, such as simple counts of the number of obstacles, would fail to capture.

The index is a comprehensive metric of destination locations' population, with more importance attached to localities that take less time to reach. Estimating travel times between localities requires road network data, detailed information on the the precise geolocations of the obstacles (including the separation barrier wall), road quality, and checkpoint traversal times. To obtain these data we completed obstacle and road maps provided by UNOCHA and conducted repeated interviews with UNOCHA officials, who provided us with estimates of the time cost of traversing each type of obstacle at any given time during our sample period. UNOCHA also provided average travel speeds for all road segments in the West Bank, enabling us to calculate the minimum travel time between any pair of locations in the West Bank via the road network, and to recalculate optimal routes and attendant travel times for any of the configurations of obstacles observed throughout the 2005-2012 period.

We then show that market access predicts night time light emissions, which by now are widely accepted as a credible proxy for GDP (Chen and Nordhaus (), Henderson et al. 2012), and our preferred measure of local economic performance given the absence of spatially disaggregated GDP measures in the West Bank (see e.g. Alesina et al. (2015) or Pinkovskiy (2013) for papers showing how night lights can be used as a proxy for local economic output). According to our preferred estimates, a 10% increase in market access increases local output by 0.6%, assuming a lights to GDP elasticity of 0.3 (cf. Henderson et al. (2012). We conduct counterfactual simulation exercises in which we estimate what GDP per capita in the West Bank would have been had road blocks not been introduced, and estimate that road blocks reduced GDP per capita in the West Bank between 4.1% and 6.1% on average each year over our sample period. These ceteris paribus estimates must be interpreted with caution as they depend on the choice of distance decay parameters and the assumed GDP to lights elasticity.

The main threat to identification is the potential endogeneity of market access, which could result from ommitted variables bias. Detailed data on fatalities enable us to control for local conflict intensity, arguably the most likely confounder of a relationship between local economic performance and mobility restrictions. Although obstacle deployment is plausibly exogenous, we construct an instrument for market access, notably the number of obstacles located in a radius between 10 and 25 km away from the locality. These obstacles are orthogonal to local conditions yet an important determinant of local market access. Our IV estimates are substantially larger than our simple OLS estimates, which are thus downwards biased, perhaps reflecting measurement error in our market access measure.

The positive relationship between market access and night time lights is robust. It is also obtained when we estimate a a difference in difference specification in which we relate 4 year growth rates in night time lights to changes in market accessibility over the same period. It is furthermore robust to using alternative market access measures.

First, we experiment with different distance decay parameters, which govern how much weight is attached to locations that take a longer time to reach in our market access measure. Second, we construct an alternative access measure that holds the population fixed, such that variation in market access is purely driven by obstacle deployment. Results do not change when we use these alternative market access measures. Finally, our results are robust using bottom-coded instead of top-coded night time lights measures, and to correcting either set of lights measures for potential overglow by using Abrahams' (2015) pioneering deblurring methodology.

In documenting how relatively short-run fluctuations in market access impact economic performance, the paper builds on and contributes to different strands of literature. To start with, our context offers us a potential advantage complementing other market access studies which have estimated the benefits of market access via a shock to the transportation network that is generally harder to disentangle from economic objectives. For example, a common shock exploited by previous studies is the expansion or improvement of railroad or highway networks (Donaldson and Hornbeck, 2016; Faber, 2014). Such massive construction projects are costly, so governments prioritize connecting economically vibrant locations, coastal locations, capitals, locations predicted to be economically important, locations that have political leverage to get their part of the network extended or repaired, and so on. Given such selection on the intensive and extensive margins, subsequent estimates of the economic benefits of market access are potentially biased. In our case, by contrast, the army administration ordering obstacle deployment had no particular mandate to affect Palestinian market access. Rather, their task was to ensure security of Israeli civilians. The effect on Palestinian market access was therefore an accidental byproduct, not a deliberate consequence, of the policy.

Second, our focus is on short-term changes in market access. The most prominent empirical studies that investigate the economic benefits of road network expansions often consider changes over decades, not years.[1] The excellent study of Storeygard (2016) is an exception and the only other study we know of that examines changes over one year periods. He cleverly exploits variation in oil prices (interacted with distances between cities) to identify the impact of transportation costs on economic development in Africa, taking routes as given. Our study is similar in analyzing annual changes, and builds on the seminal work of Donaldson and Hornbeck (2016) to assess the impact of shocks not only on given routes, but on a comprehensive market access measure that

[1]For example, Donaldson and Hornbeck (2016) estimate the effect of changes in market access brought about by an expansion of US railroads over a period of 20 years (1870-1890) on the value of agricultural land. In an application to China, Faber (2014) studies the economic impact of being connected to the country's main highway network that was built between 1992 and 2007.

endogenizes the choice of optimal routes.

Third, our findings add to the considerable body of evidence on the (inadvertent economic costs of) the Israeli-Palestine conflict (see e.g. Zussman and Zussman, (2006)), and are particularly closely related to three other studies that exploit obstacles to mobility as a source of identifying variation. Abrahams (2017a), in a closely related study to ours, focuses on how Israeli obstacles disrupted Palestinian commuting, causing employment rates to decline in labor-supply locations but to increase in labor-demanding locations. Cali and Miaari (2012) document a negative association between local employment rates and mobility restrictions in the short-run. Etkes and Zimring (2015) uses the blockade of Gaza as a natural experiment to quantify the gains from trade by using the West Bank as the counterfactual.

Last but not least, our findings also resonate with a sizeable body of literature that demonstrates that reducing trade frictions (Anderson and van Wincoop, 2004, Arkolakolis, 2012) can enhance welfare (Arkolakis et al. (2012), Anderson and Van Wincoop (2004), Head and Mayer (2011)

The remainder of this paper is organized as follows. The next section elaborates on the context. Section 3 discusses the construction of the accessibility index, which is our key independent variable. Night time lights and fatalities data are presented in section 4 . Section 5 presents our empirical strategy. The results are presented in section 6. A final section concludes.

2 Context

The West Bank is an elevated plateau bordered on its north, west, and south by coastal Israel, and to its east by Jordan. It is very small: about 56km (34.8 miles) at its widest and about 133km (82.6 miles) at its lengthiest, roughly 1/4 the area of New Jersey. Approximately 2.4 million Palestinians live there (World Bank, 2007), while more than 300,000 Israeli civilians have settled in over 160 separate, segregated settlements and outposts throughout the West Bank.

Since the rout of the Jordanian army in the Six-Day War of 1967, the West Bank has been under Israeli military occupation. The Israeli army maintains a constant troop presence of bases, garrisons, patrols, and watchtowers throughout the West Bank's interior, while all borders of the West Bank (even its border with Jordan) are controlled by Israeli security fencing, walls, and staffed by Israeli civil administrators and border police at every port of entry and exit. Palestinian aspirations to achieve national sovereignty have remained unrealized for over 50 years now, and frustration has boiled over twice into extended popular uprisings. The first was in 1987-1991 (the First Intifada), which played a role in prompting negotiations at Madrid and Oslo. These talks culminated in the formation of an interim proto-government, the Palestinian Authority (PA), which was intended to take over civil administrative responsibility for Palestinians, and to play an increasingly important role in providing security for Israel from Palestinian militancy. In exchange, the PA was supposed to be rewarded with autonomous control of some to-be-defined portion of West Bank territory, ultimately obtaining a kind of demilitarized protectorate approaching sovereignty (Abrahams, 2017b). This 'two-state solution' quickly accumulated skeptics as Palestinian attacks and expanding Israeli settlements undermined trust on both sides. After the failed talks at Camp David in 2000, a second popular uprising followed from September 2000 to December 2004 (the Second Intifada). The Israel-PA relationship collapsed as the PA itself began funding militant operations, while PA security joined militant groups, most notably the Al-Aqsa Martyrs Brigades. Popular protest was accompanied by an escalation in violence as Palestinian militant groups such as Hamas and Islamic Jihad used conventional and suicide attacks against Israeli military and civilian targets.

The Israeli army responded to militant activity with both offensive retaliations (Jaeger and Paserman, 2008) and defensive efforts aimed at intercepting militants before they could reach Israeli civilian destinations. This latter policy was known as 'Operation Defensive Shield', and involved the deployment of numerous physical obstacles (Cali and Miaari, 2012). A 500km wall was built to separate Israel from the West Bank, yet most Israeli settlers dwelt beyond the wall. To provide protection to these settlers, the army deployed hundreds of obstacles *inside* the West Bank, along the internal road network, in order to intercept militant traffic before it could approach Israeli settlements:

Israel's primary justification for the movement restrictions is that they are necessary to protect Israelis within its jurisdiction and Israelis living in the West Bank or traveling on West Bank roads.

...the settlement enterprise, including the roads built for it, was one of the primary factors in shaping the restrictions regime that Israel has forced on the Palestinians since the beginning of the Second Intifada.
B'Tselem (2007)

The endogeneity concern therefore reduces significantly: we worry that Israeli security objectives accidentally and indirectly related to Palestinian economic conditions, but we do not worry that they deliberately or directly related.

One conceivable endogeneity concern, for example, is that the army took extra security precautions for settlements in the vicinity of Palestinian locations from which a greater share of violence tended to emanate (what we might call 'confrontational locations' for short). In that case, the road network in the vicinity of confrontational locations would tend to be more blockaded. Endogeneity then arises by the fact that limited economic opportunity is a potential pathway to violence (see Miaari et al. 2014), so economic levels and trends predict violence and subsequent blockadedness. Our panel framework allows us to net out economic levels and trends per Palestinian location, and we also show results are robust to controlling for indicators of violence, as well as to instrumenting market acces. But the more compelling dismissal of this type of endogeneity concern is that the army was not defending against random, unplanned attacks by enraged Palestinian civilians, but rather against organized, veteran militant groups such as Hamas and Islamic Jihad. These organizations were not mobility-constrained to attack only settlements near to operatives' hometowns. A pre-uprising example demonstrates this point: when Hamas operative Yahya Ayyash was killed in Gaza in early 1996 by Israel's Shin Bet, Hamas dispatched a suicide cell from Gaza to the West Bank to stage retaliatory attacks from the Hebronite town of Al-Fawwar. The ensuing operations were carried out in Tel Aviv and Jerusalem, though both cities are far from Al-Fawwar. Moreover Hamas operatives accomplished these attacks in spite of an Israel-PA cooperative security net active throughout the latter 1990s (Abrahams, 2017b). Not only did this cooperative net collapse at the start of the uprising, but PA security forces actually collaborated with and joined militant groups during the uprising, notably the Al-Aqsa Martyrs' Brigades (see Frisch (2010), for example). For all these reasons, predicting the origin of attacks would have been a dubious task for the army. Defending Israeli locations with barriers and blockades made more sense.

Another potential endogeneity concern arises from the fact that in addition to obstacle deployment, the Israeli army performed other security measures such as raids, arrests or curfews. Though we attempt to assuage concerns later by using an instrumental variable approach, the strongest argument against this concern is once more that obstacles were deployed to defend settlements, and affected Palestinian market access only as an afterthought. By contrast, raids, arrests, and curfews were all offensive (proactive) security measures taken deliberately against specific Palestinian locations. For aforementioned reasons, one should not expect defensive and proactive measures to correlate spatially. On the other hand it is important to keep in mind that road obstacles represent only one class of mobility restrictions limiting the economic success of the West Bank. Other restrictions include international trade restrictions, denial of access to develop Area C, and limited control of public utilities and communications infrastructure (for further discussion, see World Bank (2007) or AIX Group (2013)). While mobility restrictions have gradually been eased over time, these other restrictions remained, so our estimates of the benefits of market access may be unduly conservative.

By lack of local GDP data, we will be using Night Time Lights (NTL) as a proxy for local economic output. One way Israel could in theory control NTL in the West Bank is by regulating the supply of electricity to Palestinian localities. If this is used as a punishment device, then this "unobserved variable" may correlate both with NTL and the deployment of road closure obstacles. There is no documented (or anecdotal) evidence however that Israel is indeed using the regulation of electricity supply as a penalty device. There are rare instances where Israel has halted the supply of electricity but in all cases this has been for commercial reasons, i.e. in response to Palestine not being able to pay their electricity bills. Thus, there is no reason to believe that this may bias our results.

Another potential cause for concern is that firms may have relocated in response to loss of market access. There is indeed some anecdotal evidence that businesses relocated from Nablus (which was almost fully disconnected from the rest of the West Bank in 2002-2008) to Ramallah. We expect firm relocation to be limited for several reasons, however. Firstly, property rights were very insecure during the uprising since PA security joined militant groups or went into hiding after the Israeli crackdown commenced in April 2002. In the absence of police, Palestinians have always tended to rely on their family and patriarchal clan (*hammouleh*) to protect their property and person. But such protection only applies when one lives near relatives, and so that has likely been an important factor in low voluntary migration rates. Indeed, using census data Abrahams (2017a) finds negligible evidence of firm relocation. With regard to market access specifically, lack of relocation has an even more obvious explanation: obstacles were plainly a temporary phenomenon, so it made sense only for the firms fleetest of foot to pay the fixed costs of relocating during a time of such uncertainty and change.

3 Measuring market access in the West Bank

3.1 Defining market access: Ability of roads to connect people

Market access as we will define it evaluates the ability of roads to connect people and firms. Being better connected to populated localities means being better connected to potential consumers as well as workers. The productivity of a locality is enhanced by cheaper access to markets and labor. Donaldson and Hornbeck (2016) derive a measure of market access under a set of assumptions that is standard in modern trade models. Their measure emerges as the solution to a set of implicit equations where market access for a given locality equals a weighted sum over other localities' access to markets, with the weights being a function of the cost of interacting with these other localities and their population counts (see eq. (9) in Donaldson and Hornbeck (2016)). Donaldson and Hornbeck (2016) also derive a first-order approximation to this solution which yields a measure of market access for locality i that is of the following form:[2]

$$MA_{it} = \sum_j h(T_{ijt}) P_{jt}, \tag{1}$$

where P_{jt} denotes destination locality j's population count in year t, T_{ijt} is the minimum travel time between localities i and j in year t, and $h(T)$ denotes the distance decay function (i.e. a positive and monotonically declining function of T). This measure sits well with the accessibility measures put forward in the regional sciences and transportation literature that dates back to the 1950s, see e.g. Harris (1954), Hansen (1959), Ingram (1971), Wachs and Kumagai (1973), Dalvi and Martin (1976), Black and Conroy (1977), Koenig (1980), Guy (1983), Heikkila and Peiser (1992), Allen et al. (1993), Geertman and Van Eck (1995), Song (1996), Deichmann (1997), Kwan (1998), and Geurs and Van Wee (2004), and serves as our measure of choice. For the distance decay function $h(T)$ we will use: $h(T) = \exp\left(-\frac{1}{2}T^2/\theta^2\right)$, where the parameter θ governs the rate at which markets located further away are being discounted.[3]

From the perspective of a producer at some origin location, not all possible destinations are equally important: their size and distance help determine their relevance. Ceteris paribus, destinations farther away are less relevant, since the price of the exported good will be higher there (assuming transport costs increase with distance), and therefore less competitive with local substitutes. Destinations with smaller populations are less relevant, since they contain fewer consumers (and workers). Moreover, market access at a given origin i may respond to changes in road connectivity well beyond the direct neighborhood of locality i; if connectivity between i and j changes, it will obviously affect market access for localities i and j, but it will also have an effect on

[2]Donaldson and Hornbeck (2016) confirm that the approximation is highly correlated with the exact measure of market access, and that their empirical results are not sensitive to switching between the approximate- and exact measure.

[3]There are a handful of commonly used choices for the distance decay function, of which Gaussian decay is one, see e.g. Ingram (1971), Guy (1983), Song (1996), Deichmann (1997), Kwan (1998). $h(T) = T^{-\theta}$ denotes another popular choice, which is adopted by Donaldson and Hornbeck (2016). Results not reported here confirm that using the latter choice of distance decay does not alter our findings. Our results are similarly robust to the choice of distance decay parameter, which is shown in Sections 5.2 and 6.2.

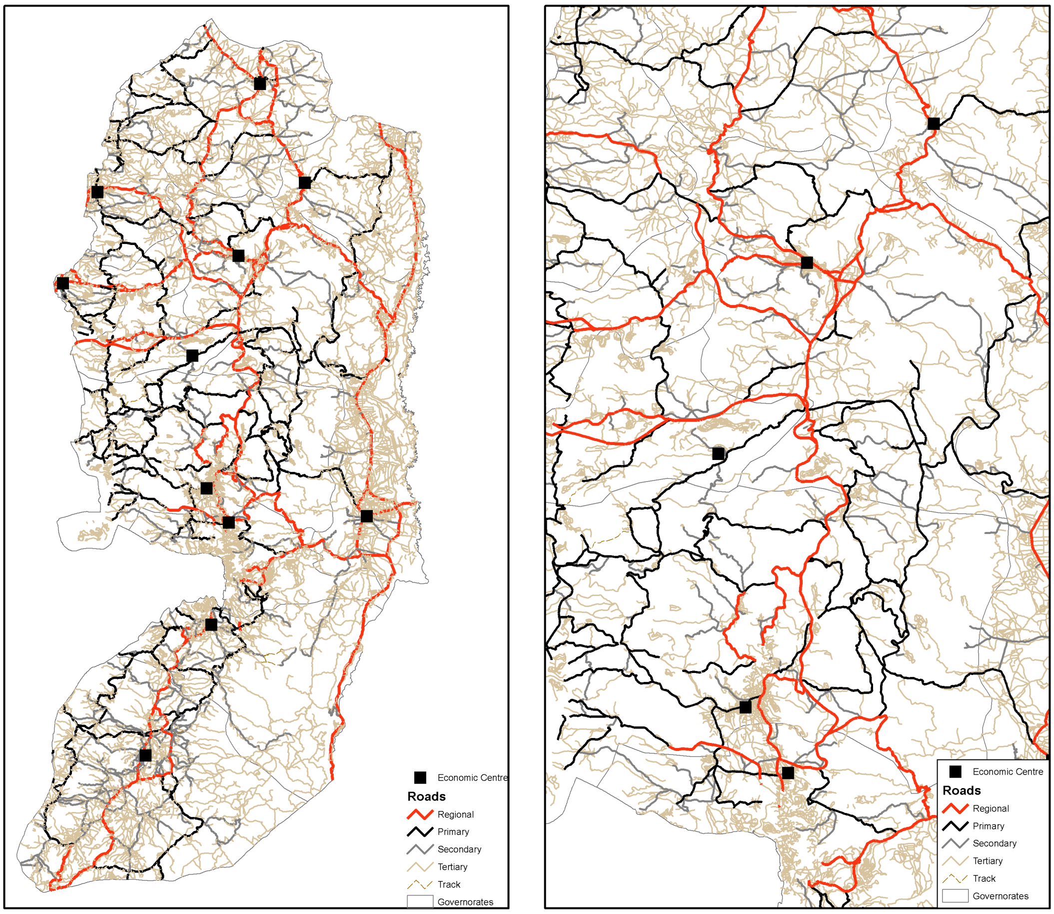

Figure 1: West Bank roads and localities

market access of localities connected to i and j, and the localities connected to these localities etc.

We compute market access for roughly 241 localities in the West Bank at an annual frequency covering the period 2005-2012 (the source of time-variation will be discussed in the next subsection). For computational convenience, we restrict the set of destinations to the governorate capitals (excluding Jerusalem). These governorate capitals will be excluded as origin localities for the same reason Donaldson and Hornbeck (2016) exclude origin locations from their set of destinations, notably concerns of endogeneity bias. A household's decision to reside in a given locality is arguably in part determined by the economic prospects for that location, such that the population count will be co-determined with economic success. Excluding a locality's own population count should alleviate this concern to an important extent.[4] We will elaborate on this further and present additional robustness checks to address this concern in Sections 5.2 and 6.2.

[4]Our results are found to be robust to the decision to include or exclude the governorate capitals themselves from our regression analysis.

Figure 1 shows the geography of the West Bank along with key data inputs that will feature in the computation of market access: the locations of 483 localities in the West Bank (green dots), including the 11 governorate capitals (red squares with name labels), and the road network that connects them.

Locality locations and population counts

The Palestinian Central Bureau of Statistics (PCBS) conducted a population census in 1997 and 2007. In addition to collecting population statistics, the PCBS also records the geographic coordinates of the localities (centroids in 1997 and "urban footprint" stored as polygons in 2007), which they kindly shared with us. We count 687 localities in 1997 and 545 localities in 2007; a number localities were merged or split between the two census periods. In order to build a balanced panel of localities, we created a new locality identifier that equals the 1997 identifier in case of splits and equals the 2007 identifier in case of a merge (i.e. the most dis-aggregated identifier that can be tracked over time). This new identifier counts 533 unique "stable localities" that can be tracked over time. A number of localities are dropped from the analysis, including Jersualem localities that lie outside of the West Bank [need to double check this] and localities with a 2007 population count below 1000. This reduces the number of stable localities (and 1997 and 2007 localities) to $xxxx$ (and aaa and bbb), respectively. Annual population counts P_{jt} are obtained by interpolating (and extrapolating) the log of the 1997 and 2007 counts for each locality separately. For the geographical coordinates of the localities we work with centroids, which were "snapped" to our road network.

Road network data

The geo-referenced road network data was kindly provided to us by UN-OCHA (who further developed the road network data produced by the European Commission's Joint Research Center (JRC)). UN-OCHA's road network data counts approximately 26,000 geographic features for the West Bank (compared to approximately 20,000 geographic features for JRC's data). Each road segment is classified into one of 6 road types with corresponding estimates of the average amount of time required for a typical civilian/commercial vehicle to traverse the segment: Regional (60kph), Primary (50kph), Secondary (40kph), Tertiary (30kph), Residential (20kph) and Track (10kph). The data also records different categories of restrictiveness for each road segment concerning use by Palestinians: No Restriction, Restricted Use, Partially Prohibited, and Totally Prohibited. We will drop road segments classified as "Totally Prohibited", and assume that the necessary permits have been acquired to permit use of all remaining roads. The analysis requires road segments to be perfectly connected (and origin and destination

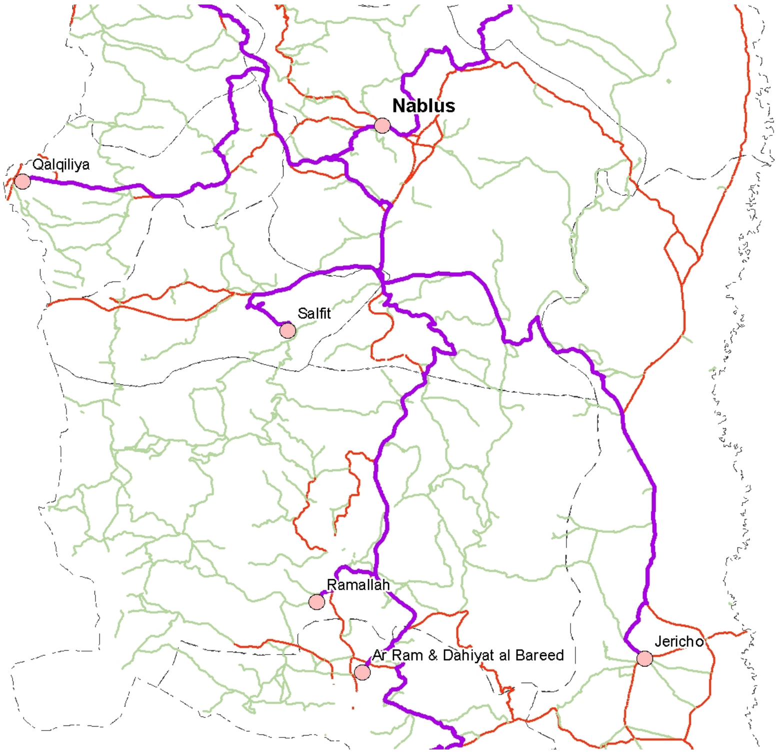

Figure 2: West Bank optimal routes in absence of obstacles

localities to be perfectly connected to the road network) for the the network analyst algorithm to traverse the road network. Road segments that did not exactly connect were modified to connect based on best judgment.

Travel times

The computation of market access as defined in eq. (1) requires data on travel times T_{ijt}. We used ArcGIS 10.3's Network Analyst software package to solve for the optimal route that minimizes travel time between all origin and destination pairs of interest. Selected examples of these optimal routes are plotted in Figure 2 (bold blue lines).

3.2 Road closure obstacles as a driver of market access

Road closure obstacles

Responding to Palestinian militant attacks originating from within the West Bank in the uprising's early years, the Israeli army moved to defend Israeli civilians by deploying physical obstacles along roads and borders. In an effort to prevent Palestinian suicide attackers from entering Israel, a 500km wall or 'separation barrier' was built along (and oftentimes beyond) the 1967 Armistice Line of the West Bank. Henceforth, all cross-border traffic was forced to pass through any one of a dozen 'green-line checkpoint' border crossings, vigilantly guarded by the Israeli army (see, for example, the report by B'Tselem: "Ground to a Halt" (2007)). Throughout the uprising, however, nearly a quarter million Israeli civilian settlers were dwelling deep inside the West Bank, beyond the protection of the wall. To defend those settlements, the army deployed hundreds of manned checkpoints, roadblocks, boulders, earthmounds, and other physical obstacles along the West Bank's internal road network with the intention of monitoring or otherwise discouraging Palestinian traffic along roads passing in the vicinity of Israeli settlements. Most of these obstacles constitute a "full-stop", meaning that vehicles cannot pass though them, prompting a detour for traffic making their way from origin to destination. Checkpoints denote an exception. While these do not constitute a "full-stop", passing through a checkpoint consumes a certain amount of time due to the screening of passengers and vehicles by the IDF and the resulting traffic congestion.

The UN-OCHA Map Center did an excellent job of recording the progress of the wall's construction, and keeping track of road obstacles' geolocations, updating their maps many times throughout and after the uprising as obstacles were moved and removed in response to shifting strategic considerations and political tensions. Over this period, UN-OCHA frequently published Closure Update reports, which include detailed maps (in PDF format) showing the locations of obstacles that were deployed at the given points in time. During our collaboration, we were fortunate to receive a copy of their database in ArcGIS shapefile format which contained: (a) the geolocation of the separation barrier in its completed form, and for each road closure obstacle, (b) start-date, (c) end-date (if no longer active), and (c) type of obstacle. The left panel of Figure 3 displays a map constructed from our data depicting a snapshot of the different types of obstacles along the major arteries of the West Bank's internal road network as of [insert date]. For reference, the map also includes the Palestinian Authority's 11 West Bank governorate capitals. The right panel zooms in on a northwestern section of the West Bank, depicting locations of Israeli army obstacles lying along roads connecting the governorate capitals of Tulkarm, Nablus, and Ramallah. Various types of obstacles are visible, including checkpoints, less vigorously enforced checkpoints dubbed 'partial checkpoints', roadgates, and unmanned obstacles such as earthmounds. The fact that obstacles were deployed on some roads and not others provides cross-sectional (spatial)

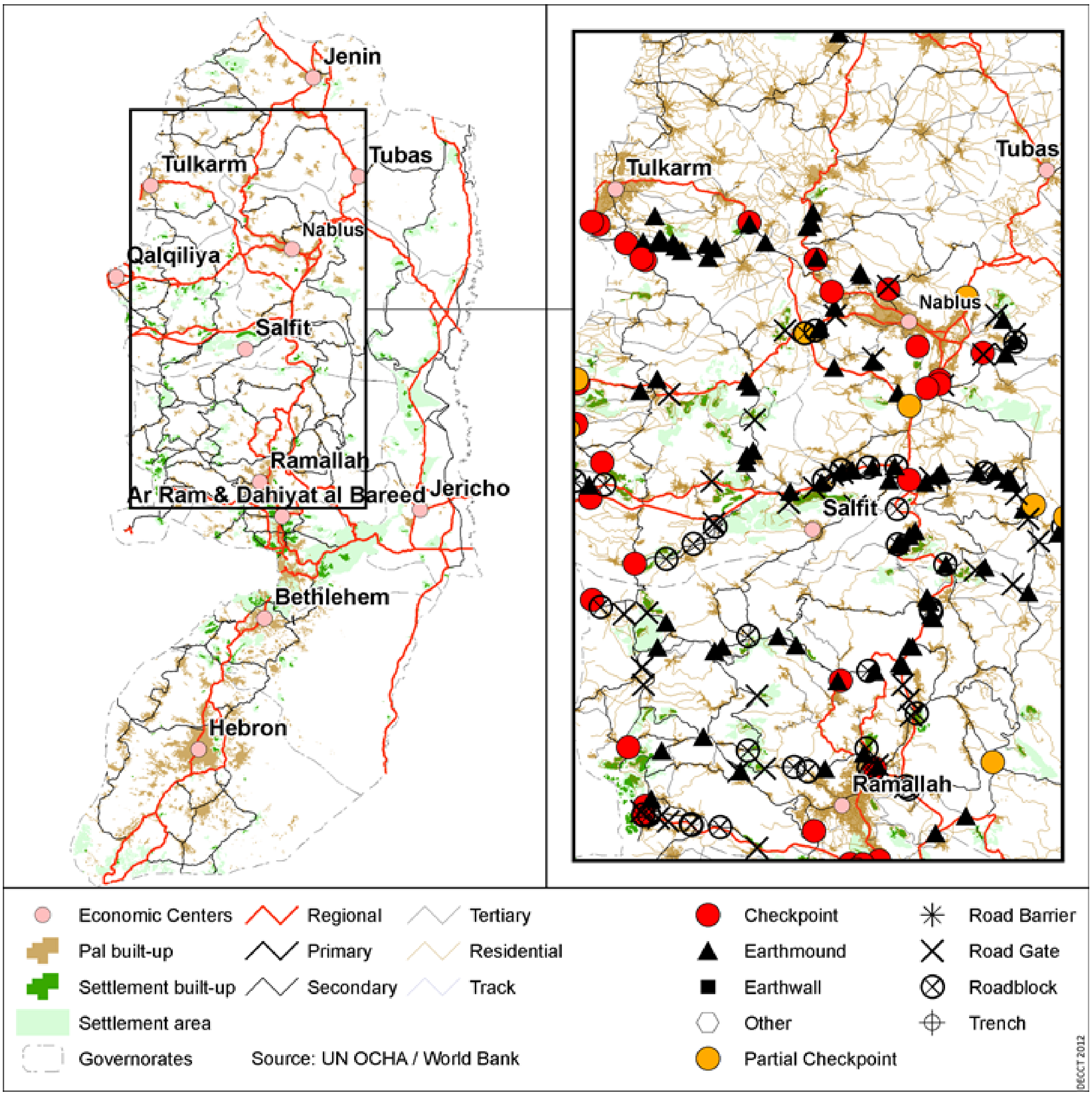

Figure 3: West Bank roads with road closure obstacles

variation in the degree to which each Palestinian location was obstructed by obstacles.

Completing the road closure obstacles database

The original database we received did not include: (a) construction dates for each segment of the separation barrier (needed to account for changes in optimal routes as segments are added to the wall over time), (b) obstacles prior to 2008 [check date], and (c) estimates of the "crossing times" associated with crossing any given checkpoint (which vary over time). We completed (a) and (b) by inspecting the obstacle maps UN-OCHA has published over the years, and manually: (1) dating each segment of the separation barrier, and (2) adding the geolocations and attributes of any obstacles appearing on published UN-OCHA maps prior to 2008 into our shapefile.

Since checkpoints play a critical role in controlling Palestinian traffic in the West Bank, accounting for the time it takes to traverse active checkpoints will improve our estimates of optimal travel times over the road network. Working in coordination with UN-OCHA, we conducted repeated retrospective interviews of their field workers in an effort to estimate average "crossing times" for each checkpoint and for each year between 2005 and 2012. For selected checkpoints the reported crossing times are found to range between 15 minutes and 240 minutes depending on the time period, highlighting the importance of accounting for fluctuations in traversal times.

Updating optimal routes as obstacles are relocated or removed

Between 2005 and 2012 obstacles are frequently relocated, substituted by other types of obstacles, or removed altogether. As the spatial configuration and intensity of obstacles changes, we recalculate the optimal routes between all origin-destination pairs (by minimizing travel times). Figure 4 provides an example, plotting the optimal route between Tulkarm and Nablus as it evolves over time. Nablus denotes Palestine's historical economic capital and the West Bank's second largest city after Hebron. It was surrounded by a large number of obstacles in the years following the uprising that made it difficult for commercial (and civilian) traffic to travel to and from Nablus; all traffic was forced to travel through the XXX checkpoints, located to the south of the city, which added significantly to the travel time.[5] As some of these obstacles were being removed during the 2009-2010 period, more direct routes to/from Nablus were being permitted as can be observed in the bottom panel of Figure 4.

[Same for Hebron-Nablus/Ramallah; focusing on impact of separation barrier as it evolved over time]

[5]Prior to 2009, commercial cargo traveled through the XXX checkpoints on a "back-to-back" basis, which meant that as a truck approached the checkpoint from one side, another truck would be waiting

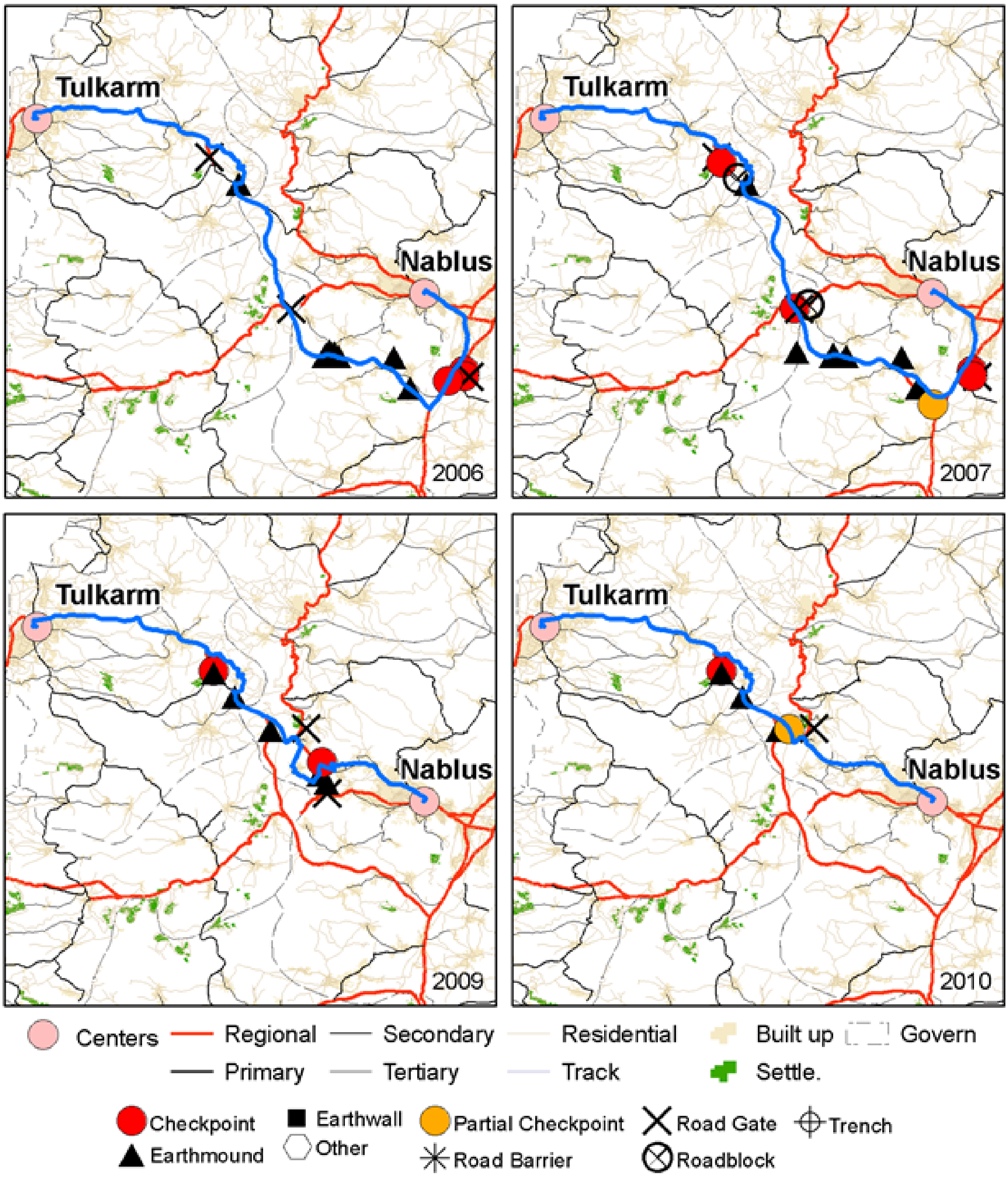

Figure 4: Nablus: before and after the lifting of the blockade

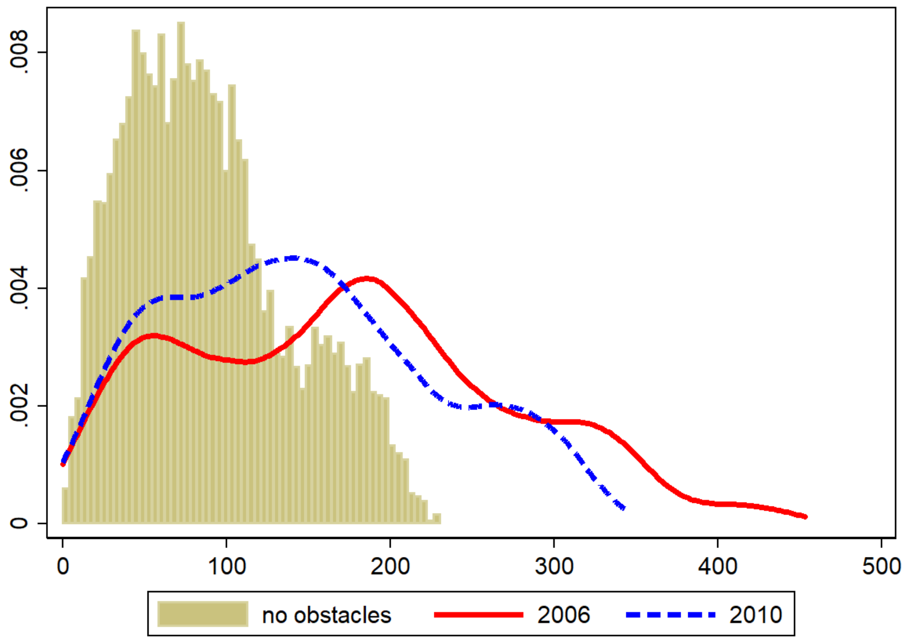

Figure 5: Kernel density plots of travel times (in minutes)

Temporal variation in travel times

Changes in optimal routes generally yield changes in travel times. But travel times may also change when optimal routes have not, namely when the time it takes to traverse the checkpoints located along the optimal routes have changed (without in fact altering the optimal routes). In Figure 5 we plot the kernel density of optimal travel times between all origin-destination pairs for two points in time (2006 and 2010). The third density, depicted in bars, corresponds to a hypothetical world where all road closure obstacles have been removed. Our calculations suggest that obstacles have greatly increased the travel times between origins and destinations in the West Bank, and that these travel times are subject to notable variation over time as obstacles are intermittently reconfigured. For example, traveling from Hebron in the southern West Bank, we calculate that an obstacle-free journey to Nablus would have taken 2 hours and 17 minutes. In 2005-2008, however, the same journey would have taken around 7 hours. Later in 2009, travel times declined to 'just' 4 hours and 40 minutes, and to less than 4 hours in 2010.

on the other side onto which the cargo was then transferred.

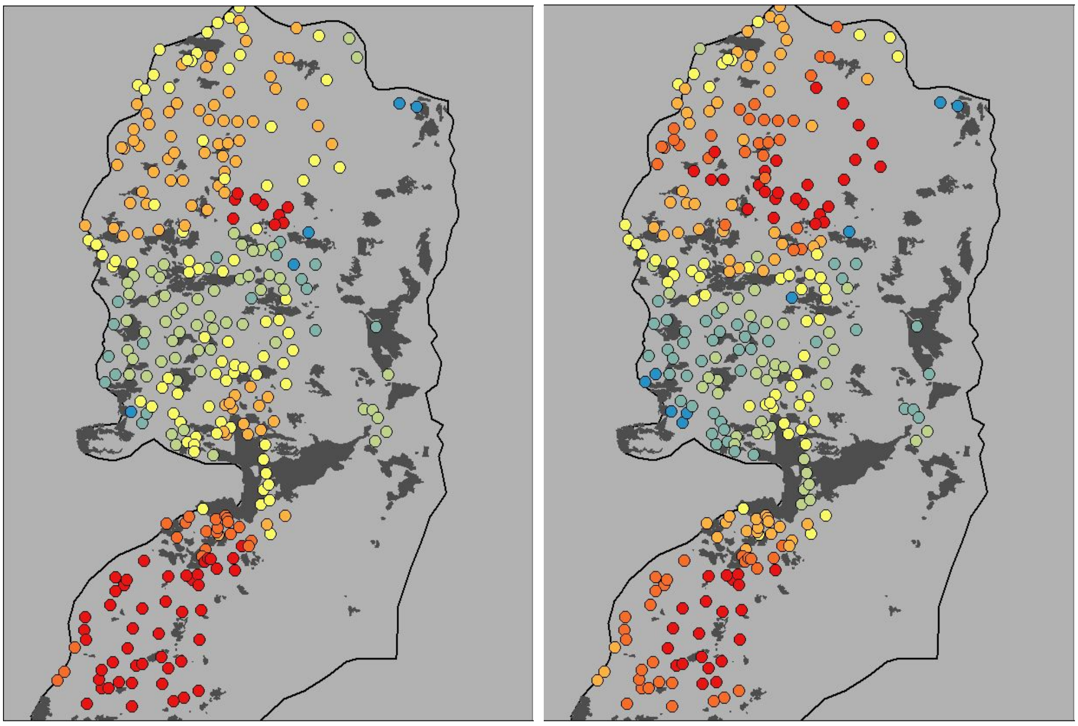

Figure 6: Map of market access (with $\theta = 40$): 2006 (left) versus 2010 (right)

3.3 Market access over time and space

Estimates of travel times T_{ijt} are combined with population count data P_{jt} to obtain estimates of market access MA_{it}, following eq. (1), for all localities i and times t. The distance decay parameter for our main specification is set at $\theta = 40$. Other values for θ will be considered as part of the sensitivity analysis (see Sections 5.2 and 6.2).

Time t will be measured in years. This matches the frequency with which the Night Time Lights data (our outcome variable which will be introduced in the next section) is observed. Note however that our obstacles data is not updated on an annual schedule. For the years after 2008, our database includes exact dates on which obstacles were being deployed or removed. Prior to 2008, the precision with which we can track obstacles over time is determined by the frequency with which UN-OCHA updated its Closure Update reports and maps, which varies with the intensity with which obstacles were being reconfigured (the time between updates ranges roughly between 3 and 12 months). First, we compute market access for the irregularly spaced time periods dictated by data availability (every month prior to 2008, and the times of the OCHA updates after that). Second, we collapse this data to obtain annual estimates of market access by simply averaging the intra-year data.[6]

Figure 6 shows the landscape of market access in the West Bank, and how it has

[6]Note to self: Do we collapse the travel times or the market access data? CHECK!

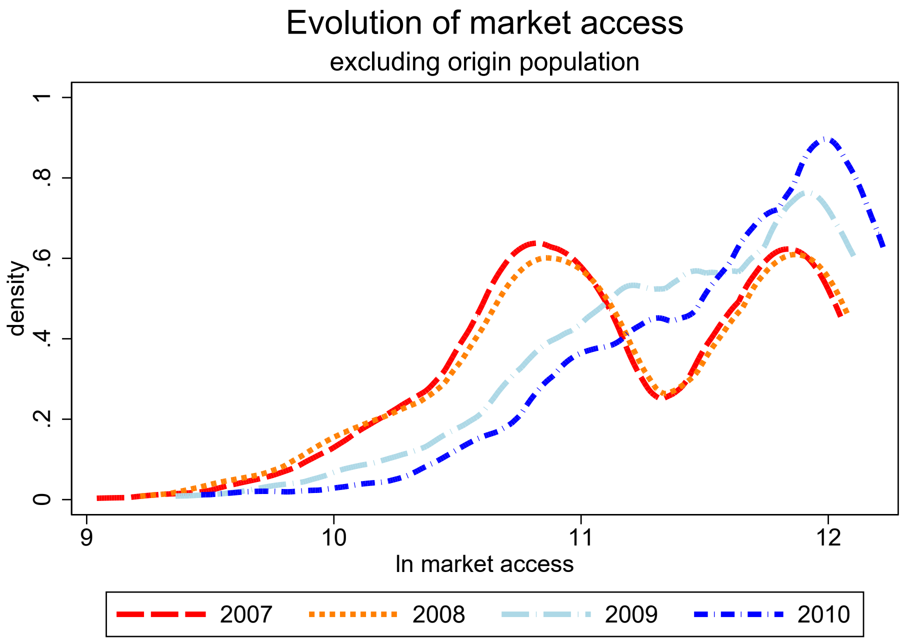

Figure 7: Kernel density plots of market access (with $\theta = 40$)

evolved from 2006 to 2010. Darker colors are associated with higher values of market access. [Will update/revise this paragraph when proper figure is ready.]

Figure 7 presents the same data but in the form of kernel density plots. The reconfiguration of obstacles has reshaped the distribution of market access over the years. The evolution from a bi-modal to a uni-model distribution reflects a number of significant changes between 2006 and 2010 that have improved market access (transferring density at lower levels of market access to higher levels of market access). Lifting key restrictions around Nablus in late 2009 arguably denotes the most prominent change. Not only because Nablus was surrounded by some of the most obstructive obstacles, effectively amounting to a blockade, but also because the city is central to the West Bank, both geographically and economically.[7] Another notable change is the gradual improvement in connectivity between the north and the south of the West Bank (from late 2007 to 2010). The most southern city is Hebron, which is also by far the largest city in the West Bank. As some of the restrictions to north-south traffic are lifted, more centrally located localities are able to re-connect to the south's large market/population. The improvements in market access brought about by the above mentioned changes are also apparent in Figure 8 which shows a time-series of log market access by means of a box plot. The width of the boxes show the cross-sectional variation in (log) market

[7] It is the second largest city, home to the Palestinian Stock Exchange (albeit small by international standards), and enjoys close geographic proximity (in the absence of obstacles) to all but the two most southern governorate capitals (which are Hebron and Bethlehem).

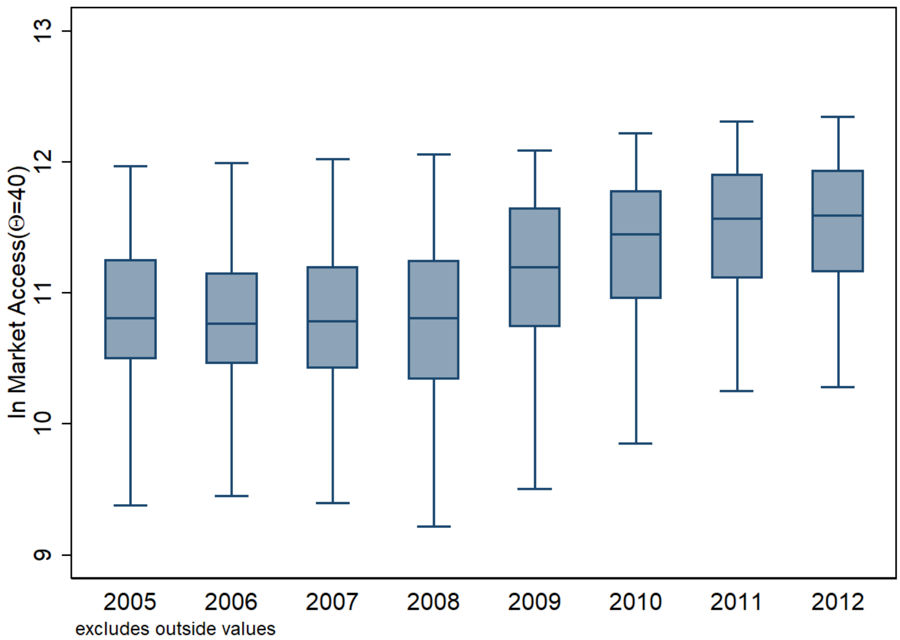

Figure 8: Box plot time-series of market access (with $\theta = 40$)

access (across locations), which is largely stable over the years.

4 Other data

4.1 Nigth Time Lights as a proxy for economic output

In this section we argue that nighttime lights (NTL) are a useful proxy for West Bank Palestinian economic activity in the absence of spatially and temporally disaggregated GDP data. We make an effort to improve upon previous economic studies that used NTL by carefully applying several corrections to the data that enhance their spatial resolution and temporal comparability.

Since the 1970s the Defense Meteorological Satellite Program (DMSP) has been recording the intensities of nighttime light emissions from the Earth's surface. For all satellites and all years since 1992, the National Oceanic and Atmospheric Administration (NOAA) has generated freely accessible annual composite images that average the intensities of light recorded on cloud-free nights at each pixel. Apart from their obvious usefulness for tracking electrification rates (Min, 2015), year-to-year changes in nighttime lights have also been shown to track year-to-year GDP changes (Henderson et al., 2012). This fact has popularized nighttime lights as a proxy for GDP in underdeveloped or conflict-prone contexts where spatially disaggregated GDP data are often

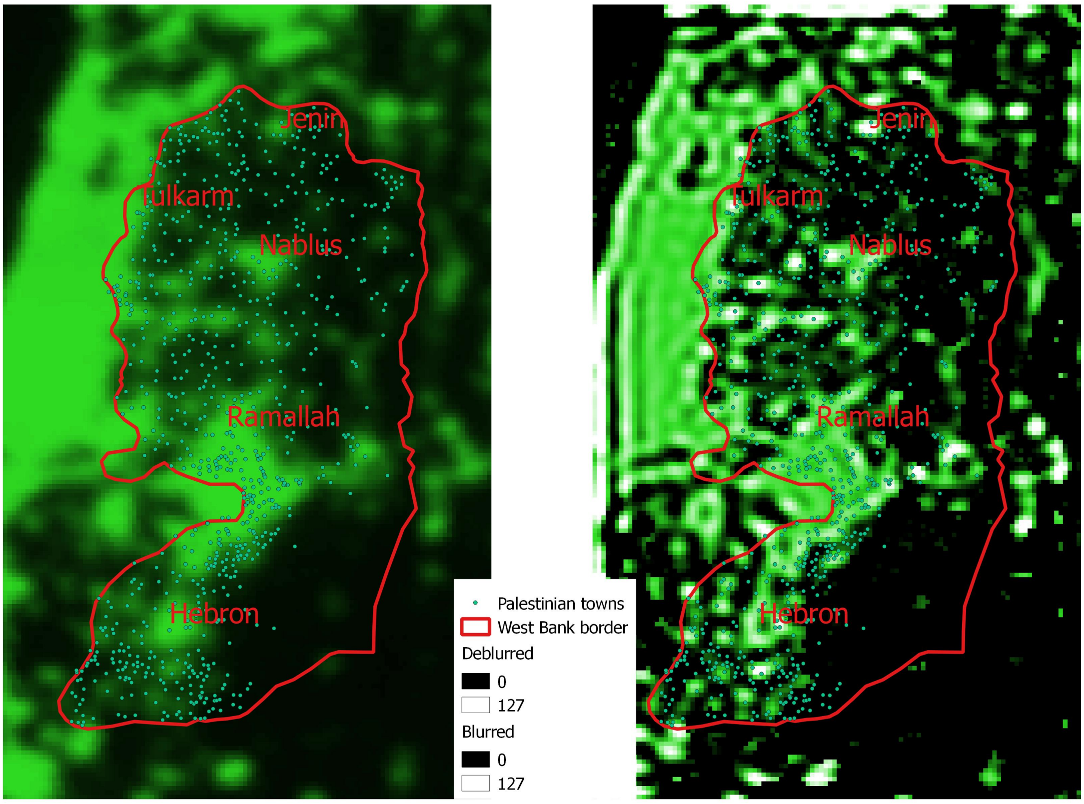

Figure 9: F16-2008 blurred image (left) and deblurred image (right)

unavailable or unreliable (see, for example, Alesina et al. (2015) or Pinkovskiy (2013)).

On the left of Figure 9 is an annual composite (avg_vis) image of the West Bank recorded by the DMSP's F16 satellite in the year 2008. We can see brighter and larger concentrations of light around the major West Bank cities of Nablus, Ramallah, and Hebron, among others. To decide whether or not to assign a pixel's light intensity (digital number or DN) to a Palestinian location, we obtain urban footprint polygon data for all Palestinian census locations through the UN-OCHA Map Center. Polygons were finely drawn to circumscribe built-up areas and are highly accurate for the time period of interest. Throughout our analysis we assign a pixel's value to a Palestinian location if the pixel's centroid lies within 500 meters of the location's polygon. This "generous" assignment rule allows for potential geolocation errors in both ArcGIS' under-the-hood projection of NTL data from WGS-1984 coordinates to UTM-36N, and for shifting error in the NTL data themselves (Tuttle et al., 2013). [8] Summing up the DNs of all assigned pixels per location, we find that the brightest three towns in 2008

[8]In a robustness check that we do not present to conserve space but is available upon request we experimented with using a more conservative assignment rule, where a pixel's value is assigned to a location only if its centroid lies inside the polygon. The results obtained using this alternative assignment rule are very similar to the ones presented in the main text.

were Hebron (3528 counts), Nablus (2355), and Ramallah (1785).

DMSP-NTL imagery are known to suffer from blurring, with light spreading out horizontally far beyond source locations, in some instances exaggerating urban areas up to 10 or 11 times their true size (Croft, 1979; Imhoff et al., 1997; Henderson et al., 2003; Small et al., 2005; Pinkovskiy, 2013). The blurring problem, often dubbed 'overglow' or 'blooming', complicates the application of DMSP-NTL to contexts like the West Bank where locations lie in close proximity to each other. Israeli settlements or major Palestinian towns like Ramallah, for example, enjoy superior street lighting and generally wealthier residents, causing them to glow brightly at night. Nearby Palestinian villages are poorer and glow dimly. But with blurring, these inequalities are partially washed away: wealthier locations lose part of their light as it spreads out symmetrically, enveloping poorer location and causing them to appear too bright.

To mitigate blurring we consider a deblurring method recently developed in Abrahams et al. (2017). In that paper, empirical inspection of isolated light sources and a review of DMSP satellites' onboard data handling reveal that blurring occurs according to a symmetric Gaussian pattern, whose dimensions expand with the brightness of sources. They then define a method to mitigate blurring, applying three filters on the imagery in succession. Firstly, a Wiener Deconvolution is performed to invert symmetric Gaussian blurring. The presence of noise somewhat limits the success of this filter, so a second filter is then applied. The second filter relies on each avg_vis image's complementary pct image, which records the percentage of cloud-free nights on which light was observed at each pixel. Because of the way DMSP satellites operate, light sources are all local maxima in the pct image. Contrapositively, this implies that pixels that are not local maxima in the pct image cannot be light sources in the avg_vis image. The second filter is therefore simply to turn off any pixels that cannot be light sources. Finally, to filter out the light of passing cars, fires, or moonlight reflected off desert sand, a hard threshold is applied that turns off all pixels lit less than 20% of cloud-free nights per year.

The resulting deblurred image is depicted in the right panel of Figure 9. Like in the blurred image, the brightest Palestinian town in the deblurred image is Hebron, but its DN count is up 20% to 4224, indicating that blurring error had caused as much as 20% of the town's light to spread out beyond its borders. The second brightest town is once again Nablus, with an increased DN count of 3037. But unlike the blurred image, the third brightest town is not Ramallah but instead Tulkarm, with a DN count of 2069 (up from 1662 in the blurred image). Ramallah instead ranks fourth with a DN count of 2053 (up from 1785 in the blurred image). The fact that Tulkarm overtakes Ramallah in the rankings suggests that Ramallah's blurred DN count of 1785 was partially inflated by spillage of light from surrounding commercial and governmental locations like Al-Bireh and Beitunya. In the deblurred image, we discover that Tulkarm is in fact a brighter location (albeit marginally). It should also be noted however that this deblurring approach is novel and will benefit from further empirical validation studies, which may for example verify whether the geographical scale of the area being deblurred impacts on its precision.

Blurring is not the only type of error to afflict DMSP-NTL imagery. In an experimental study, Tuttle at al. (2013) discover that DMSP satellites can miscalculate the geolocation of a light source by several pixel widths. NOAA scientists do apply corrections to reduce 'shifting error' globally, but are unsure to what degree the error persists regionally. A danger arises that if the geolocation of light shifts from year to year, a location's light may fall sufficiently close to its polygon to be counted in one year, but too far to be counted in another. Since location DN counts are our left-hand-side variable, this back-and-forth shifting from year to year generates classical measurement error, raising variance without necessarily biasing regression results. In the blurred imagery, light is spread around horizontally, so even if shifting occurs, part of the light is still counted. In deblurred imagery, however, light is more concentrated, so shifting error could notably increase the variance of the LHS variable. In robustness checks, we do indeed find that regressions with deblurred data generate statistically weaker results.

Perhaps the best known error with DMSP-NTL imagery is topcoding. Based on 1970s technology, DMSP satellites were only equipped to record up to 6 bits of information per pixel, rendering DNs of 0 to 63. Moreover, the gain setting was typically quite high in order to detect faint light sources. When the satellite viewed bright urban sources, it often topcoded. Most West Bank Palestinian locations were too dim to suffer from this problem, but Jerusalem and its immediate demesnes are topcoded for most years. This is problematic since we largely cannot tell for most Jerusalem locations if they grew brighter or dimmer; they report 63 for most or all of their pixels. As described below, we perform several robustness checks to guard against the influence of these topcoded locations on our results. Specifically, parallel to the topcoded DMSP-NTL series, NOAA also generated a non-topcoded 'radiance-calibrated' series for select years, including 2004, 2005 [2006?], and 2010. We show that main results survive when we use these non-topcoded data.

Finally, the OLS sensors on DMSP satellites were known to deteriorate over years in orbit, and their average gain settings varied from year to year and satellite to satellite. As a result, the images of the West Bank in any two given years are not comparable. To make sense of our graphs, however, we applied intercalibration parameters to make the data as comparable as possible from year to year. For topcoded imagery, we applied the

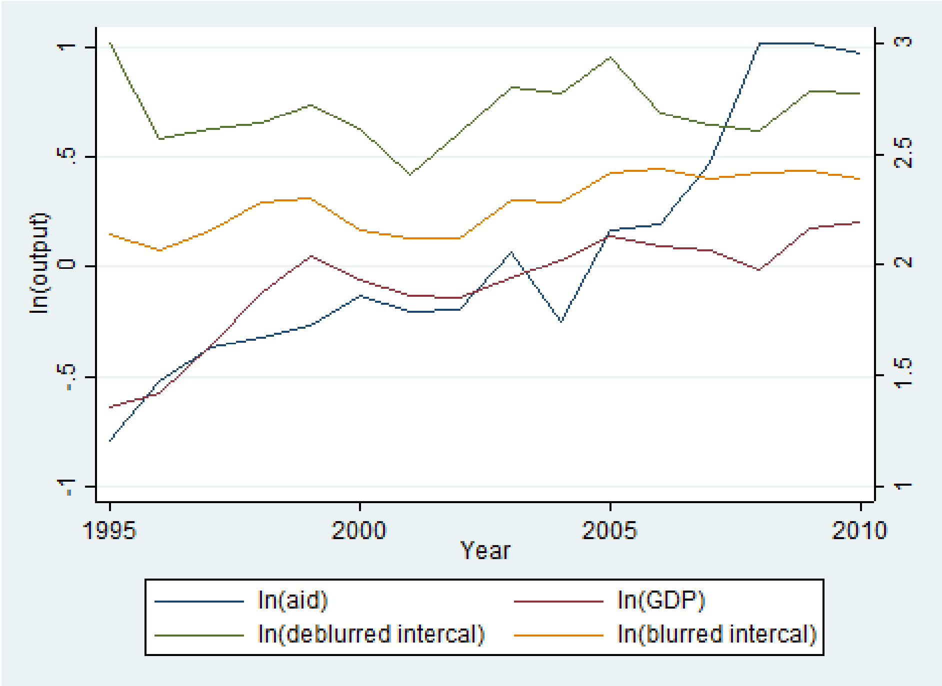

Figure 10: GDP of the West Bank & Gaza, aid to the PA, and lights, 1995-2010

parameters recommended in Wu et al. (2013). For non-topcoded imagery, we applied the parameters recommended in Hsu et al. (2015). In our regressions, we rely on year effects and locality fixed effects, as well as the use of natural-logs, to minimize this source of error.

DMSP-NTL appear to track West Bank Palestinian economic growth accurately for the period under study. For each of the blurred and deblurred images covering the period 1995-2010, we sum the intercalibrated pixel values (i.e. the quantities of light observed) within 500m of West Bank Palestinian polygons. After taking natural logs, we plot the resulting blurred and deblurred time series for 1995-2010 in Figure 10, along with series of logged Palestinian GDP. The GDP data were obtained from the World Bank, which unfortunately does not disaggregate the West Bank and Gaza. Comparing the two light series, we notice firstly that Palestinian locations are brighter for all years in the deblurred series as compared to the blurred. As with the Hebron example above, blurring causes light to spill outside the boundaries of locations' polygons so that they appear dimmer than they truly are. Notice that the deblurred series is also evidently more volatile than the blurred, exhibiting larger peaks and troughs. This is consistent with our expectation that blurring smooths away contrasts, redistributing light across locations. As such, downturns or upturns in the Palestinian economy appear softened by the blurred imagery. It is also consistent with our conjecture that any shifting error may get amplified by the deblurring approach, thereby trading a reduction in bias for an increase in variance.

Importantly, both series track the time-evolution of national GDP remarkably well. Note for example the marked decline in light before and during the early years of the Second Intifada, which commenced in late 2000. The deblurred series achieves an earlier recovery, however, and a more pronounced slump in 2005-2007 as the West Bank was slapped with sanctions after the election of a majority-Hamas legislature. The economic recovery suggested by the deblurred series 2008-2010, which is simultaneous with the increase in market access (see Figure 8), is less observable in the blurred series.

Joint evolution of Night Time Lights and Market Access

Figure 11 and 12 provide a preview of our regression results. Figure 11 plots the residual of the natural log of lights per capita against the residual of the natural log of market access, controlling for locality and year fixed effects, as well as proxies for local conflict. The positive slope suggest that higher market access is associated with more output (proxied by night time lights emission). Similarly, Figure 12 plots the log difference in lights per capita over 2006-2010 against the log difference in night time lights, controlling for local conflict. The slope is again positive, indicating that improvements in market access are associated with output growth. In Sections 5 and 6 we make an effort to establish causality.

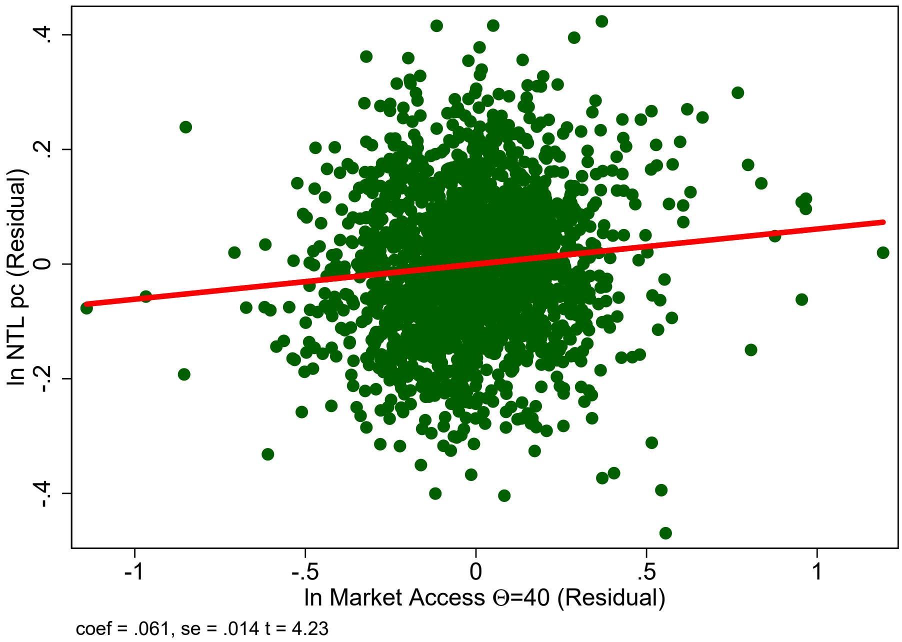

Figure 11: log NTL vs. change in log market access (controlling for locality, year and conflict)

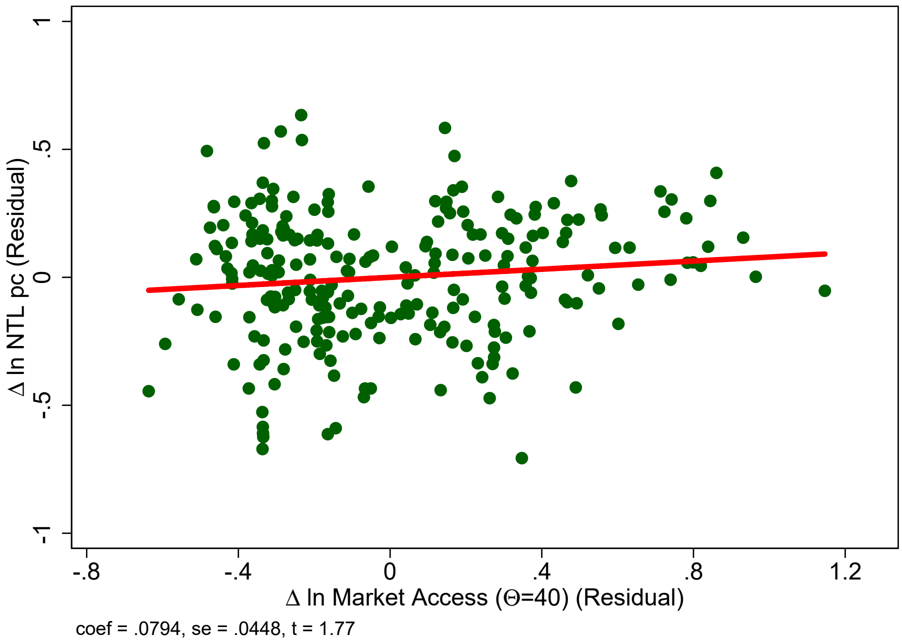

Figure 12: Change in log NTL vs. change in log market access (controlling for conflict), 2006-2010

4.2 Conflict data: Number of fatalities within 10km radius

Indicators of local violent conflict will be included as control variables for reasons that will be discussed in Section 5. The data we use has been obtained from B'Tselem, an Israeli independent non-profit organization that records a variety of statistics related to the conflict between Israel and Palestine.[9] We will focus on (the number of) fatalities as an indicator of local conflict. For each violent incident, B'Tselem records the exact date, geolocation, and the number of fatalities for Israelis and Palestinians separately. We combine this data with our geo-referenced locality data for the West Bank, to obtain the number of Israeli and Palestinian fatalities that have been recorded within a 5km radius of each locality during the course of the year, which we use as a control variable.

5 Empirical strategy

Taking Palestinian locations as our units of analysis, we attempt to identify the causal effect of market accessibility on annual per-capita changes in locations' observed light

[9]B'Tselem refers to itself as an Information Center for Human Rights in the Occupied Territories. The statistics published by B'Tselem, including the data we use, can be downloaded from: http://www.btselem.org/statistics.

output. Our main specification is:

$$\ln y_{it} = \beta \ln MA_{it} + \gamma x_{it} + \lambda_i + \delta_t + \varepsilon_{it}, \tag{2}$$

where the outcome variable y_{it} is the total lights per-capita observed at location i in year t, MA_{it} denotes our measure of market access from eq. (1) with $\theta = 40$ (different values for θ are considered in the sensitivity analysis), x_{it} is a vector of time-varying control variables for location i, λ_i denote location fixed effects, and δ_t denote year fixed effects. Our controls x_{it} includes conflict-related binary variables, namely whether or not Palestinian fatalities occurred in year t within a 10km radius, and similarly for Israeli fatalities. β denotes our parameter of interest.

We drop locations with fewer than 1000 residents (in 2007), so as to ensure that results are not driven by small villages or temporary bedouin encampments. Finally, we only keep localities for which we have data for all 8 years. The resulting regression sample is a balanced panel of 241 locations for the years 2005 to 2012. Standard errors are clustered at the location level and are robust to heteroskedasticity.

The year fixed effects control for West Bank level time-varying conditions, including shifts in public policy, terms of trade, international aid flows etc. They also help us account for the deterioration and changes of the satellites over the years (see Section 4.1). Location fixed effects capture the permanent features of location i that affect annual light output, think of initial size of the location, local geographic conditions etc. Our decision to control for local violence, by including x_{it}, is that it could conceivably be a driver of both accessibility and changes in lights. For example, checkpoints proximate to a location may decrease its access to consumer markets while also contributing to the increase in incidence of violent confrontation, which in turn may harm economic activity and the emission of light.

5.1 Instrumental variables estimation

OLS estimation of β from eq. (2) may be vulnerable to endogeneity bias if other factors not accounted for are correlated with changes in both local obstacle deployment and local lights. It is not immediately clear in what direction such a bias would run. We can think of at least three different scenarios that would predict biases of different signs. A positive bias (i.e. OLS over-estimating β) might emerge when the omitted variable denotes complementary penalties imposed on Palestinian localities. This would be negatively correlated with market access and negatively correlated with local economic success, hence predicting a positive bias.

For a candidate explanation for a negative bias consider the possibility that our measure of market access is subject to measurement error which would introduce classical attenuation bias. Alternatively, consider a scenario where fixed checkpoints are being replaced by "flying" checkpoints, which are temporary and mobile checkpoints that can pop-up anywhere and anytime depending on current circumstances. They can be in place for a couple of hours or a couple of days, but rarely much longer. Because of their fleeting nature it is harder to collect reliable data on them, such that they are currently not captured in our database. This "omitted variable" would be positively correlated with our market access variable (as fixed checkpoints are replaced by flying checkpoints, our measure of market access and the flying checkpoint count go up together) but negatively correlated with local economic success, which would predict a negative bias.

We address this concern by building an instrument for market access that omits obstacles located within 10 kilometers from a given location. Note that given the very compact size of the West Bank discussed in 2 10km is a considerable distance (recall that the West Bank is 56km at its widest and 133 km at its lengthiest). The idea is that this instrument is orthogonal to local "incidents", thereby uncorrelated with the above mentioned omitted variables, but nevertheless correlated with market access since changes in the deployment of obstacles located further away from a given locality will have an impact on how well the locality is connected to the governorate capitals. One option would be to recompute our measure of market access for each location, where any obstacles within 10 kilometers are ignored, and then use this as an instrument. However, this is highly computationally intensive. As a computationally more convenient alternative we compute the number of checkpoints located farther away than 10km but no farther than 25km, and will refer to this as the checkpoint "donut count". Note that this instrument would also be orthogonal to possible measurement error to the extent that this error is driven by guesstimation errors in "crossing times" (associated with crossing the checkpoints). This may serve as an additional argument for using the checkpoint donut count rather than the alternative market access variable as an instrument.

5.2 Addressing additional concerns

This section will elaborate on a variety of robustness checks we will perform in order to address a selection of other concerns.

Holding the population constant

Changes in our measure of market access over time are due to changes in the configuration of road closure obstacles but also due to changes in the population size of the destinations (i.e. changes in size of the respective markets). Population growth however is arguably co-determined with economic prospects. Hence, one concern is that growth in lights may in part be driven by unobserved local shocks that also impact on population growth in nearby governorate capitals. For this reason, population at origin is not counted in our market access measure (by dropping the governorate capitals from the sample). To further address this concern, we will re-compute each location's market access by holding the destination's population counts constant.

Varying distance decay
Market access is also a function of the distance decay parameter θ (see eq. (1)). For our main specification we set this parameter at $\theta = 40$ (which means that destinations located about 90 minutes travel time or father will get relatively little weight). While one could in theory estimate θ, it is a difficult parameter to estimate precisely (see e.g. the discussion in Donaldson and Hornbeck, 2016; while they use a slightly different choice of distance decay function, the challenge is conceptually identical). As a robustness check we will consider different values of θ ranging between 30 and 60 [did we not also try 80]. It should be noted that the level (variance) of market access will mechanically increase (decrease) as we increase θ. Therefore, one way of evaluating the impact of the choice of θ is to compare estimates of light emission in a West Bank with and without closure obstacles (the latter denoting a hypothetical West Bank), where in both cases market access is computed using the same choice of θ. The results of this back-of-the-envelop exercise are presented in Section 6.3.

Top-coded versus bottom-coded NTL (+ dif-in-dif estimation)
We use two different variations of original NTL data: top-coded and bottom-coded lights data (see Section 4.1). The latter will also be referred to as radiance-calibrated lights data, or RADCAL in short. These two variatons are obtained by employing different settings on the same satellite, akin to adopting different settings concerning light-sensitivity on your photo camera. When the "top-coded setting" is adopted, the satellite is sensitive to dim sources of light, thus providing accurate readings of the brightness of these relatively dim sources. However, it is unable to distinguish between lights if their brightness exceeds a certain level of intensity. The opposite holds true for bottom-coded (RADCAL) data; it accurately measures bright light but is unable to distinguish between relatively dim sources. This means that the bottom-coded series is better equiped to track lights for large and more developed cities, while the top-coded series may be preffered when tracking smaller less developed locations.

Top-coded data is recorded annually while bottom-coded data is only available for 2006 and 2010 (for our period of study). For this reason we use the top-coded data for our main specification. To verify how sensitive our findings are with respect to this choice, we will present the regression results obtained using bottom-coded data as a robustness check. As we only have two years of bottom-coded data, which are 5 years apart, we will estimate the parameters from eq. (2) using a difference in difference approach. For completeness, the same difference-in-difference regressions are also applied to the top-coded data. Examining how the relationship between changes in market access and changes in lights holds up over this longer term denotes a valuable robsutness check in and of itself.

Original versus deblurred NTL
Our base specification uses NTL (per capita) as published by NOAA for the dependent variable. For reasons discussed in Section 4.1, we will consider deblurred NTL as a robustness check. We anticipate that "deblurring" may yield a less biased but more volatile measure of local lights, which will have implications for the precision with which we estimate β.

6 Empirical results

To set the stage, columns 1 and 2 of Table 2 present first stage regressions using as dependent variable the natural log of market access and the checkpoint donut count, the number of checkpoints located in a radius between 10 and 25km from the localitys center, as the main explanatory variable. Although obstacles captured by this donut count measure are not deployed within the locality but rather in its vicinity, they clearly significantly adversely impact local market access; each additional obstacle reduces market access by approximately 3.81 percentage points according to the estimates presented in column 1. This estimate is not sensitive to controlling for local conflict as is demonstrated in column 2, suggesting that checkpoint deployment outside ones own locality is largely orthogonal to local conflict. Column 3 provides corroborative evidence for this conclusion by demonstrating that our proxies for local economic conflict are not significant predictors of the donut count measure, which now serves as the dependent variable. In summary, the number of obstacles deployed within a 10 to 25 km radius of the locality is a suitable instrument for market access.

First Stage Regressions

	(1)	(2)	(3)
	ln Market Access	ln Market Access	Checkpoints 10-25km
	OLS	OLS	OLS
Checkpoints 10-25km	-0.0381***	-0.0380***	
	(-8.59)	(-8.60)	
ln(1+Pal.Fat.<5km)		-0.0175	0.0639
		(-1.11)	(0.56)
ln(1+Isr.Fat.< 5km)		0.0006	-0.0132
		(0.02)	(-0.04)
Year FE	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes
N	1928	1928	1928
adj. R^2	0.671	0.671	0.478

t statistics clustered by locality in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.1 Main findings

Turning to the main specifications, Table 2 presents estimates of equation 2. Night time lights emissions are clearly strongly and significantly correlated with market access. Simple OLS estimates presented in column 1 imply that a 10 percentage points increase in market access increases night time lights by 0.6 percentage points. If we assume that the GDP to lights elasticity is 0.3 (cf. Henderson et al., 2012), this corresponds to an increase in local output of approximately 0.2 percentage points. This relationship is robust to including proxies for violence, as is done in column 2.

When we instrument market access using our donut count measure of obstacles located in a radius between 10 and 25km of the locality (columns 3 and 4), the association between night time lights and market access strengthens substantially, with the coefficient estimate tripling in size. According to our preferred IV estimates, presented in column 4, a 10 percentage points increase in market access leads to a 1.9 percentage point increase in night time lights emissions (or a 0.6 percentage point increase in local GDP). OLS estimates of the relationship between market access and night time lights are thus downward biased. We speculate that this may reflect attenuation bias due to measurement error in our market access measure. Whatever the reason may be, the IV regressions lend credence to a causal interpretation of the positive association between market access and economic performance.

Main Regressions

	(1)	(2)	(3)	(4)
	ln NTL pc	ln NTL pc	ln NTL pc	ln NTL pc
	OLS	OLS	IV	IV
ln Market Access	0.0610**	0.0624**	0.188***	0.190***
	(2.41)	(2.50)	(2.76)	(2.81)
ln(1+Pal.Fat.<5km)		0.0137		0.0162*
		(1.59)		(1.84)
ln(1+Isr.Fat.<5km)		0.0182		0.0181
		(1.05)		(1.06)
Year FE	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes
N	1928	1928	1928	1928
adj. R^2	0.452	0.453	0.344	0.346

t statistics in parentheses, clustered by locality

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.2 Robustness checks

Robustness checks of our preferred IV estimates that control for local violence (column 4 of table 2) are presented in Table 3. To start with, columns 1-3 demonstrate how our estimates change when alternative distance decay parameters are used, notably $\theta = 30$, $\theta = 60$, and $\theta = 80$, respectively.[10] While the choice of the distance decay parameter impacts the magnitude of the coefficients, the qualitative pattern of results is not impacted; market access is significantly positively correlated with night time lights, irrespective of the choice of the distance decay parameter. Incidentally, note that the adjusted R^2 is highest when choosing $\theta = 40$, which is our benchmark model.

Second, one may be concerned that the association between market access and night time lights reflects population movements (which are potentially endogenous to economic prospects ass alluded to in section 5.2). To address this concern, column 4 estimates a specification in which we hold population fixed in our market access measure such that all variation in market access results from changes in the configuration and severity of obstacles. The resulting coefficient estimate is nearly identical to the one in our preferred specification; variation in market access is thus primarily driven by changes in obstacles rather than migration and differential population growth.

Third, in column 5 a deblurred measure of night time lights is used as the depen-

[10]Note that a higher distance decay parameter theta implies that relatively remote locations are given more weight in the market access measure.

dent variable. The coefficient on market access is now much smaller and statistically insignificant.

Table 4 present estimates of the change in the log of night time lights emissions between 2006 and 2010 on the change in market access between 2006 and 2010 as well as the change in our proxies for political violence, separately using (the more conventional) top-coded data (presented in columns 1 and 2) and bottom-coded data (presented in columns 3 and 4). Changes in market access are a strong and significant predictor of changes in night time lights, irrespective of which datasource is used; ceteris paribus, localities with bigger improvements in market access also experienced larger increases in night time lights per capita. Interestingly, the estimated coefficients are larger than in the specifications that exploit annual variation, perhaps reflecting that longer time lags have a higher signal to noise ratio. The estimated impact of improving market access is slightly lower when using bottom-coded data, hinting at the possibility that less developed localities (whose natural light emissions best captured using top coded data) benefit more from improvements in market access than more prosperous towns (whose light emissions are best captured by bottom coded data).

Table 5 replicates table 5 but uses deblurred night time lights as the dependent variable. Coefficient estimates are considerably higher, though not always statistically significant at conventional levels. As alluded to in section 5.2, the reason presumably is that the deblurring method entails a trade-off between bias and variance. Using deblurred top-coded nigh time lights data, the coefficient on market access is as high as 0.584, suggesting that a 10% increase in market access yields a 5.8% increase in night time lights (or a 1.8% increase in local GDP).

Robustness Checks

	(1)	(2)	(3)	(4)	(5)
	ln NTL pc	ln NTL pc	ln NTL pc	ln NTL pc	ln NTL pc
					Deblurred
	IV($\theta = 30$)	IV($\theta = 60$)	IV($\theta = 80$)	IV($p\bar{o}p$)	IV
ln Market Access	0.184***	0.246***	0.367**	0.189***	0.0262
	(2.86)	(2.66)	(2.56)	(2.81)	(0.11)
ln(1+Pal.Fat.<5km)	0.0165*	0.0165*	0.0201**	0.0166*	0.0654***
	(1.81)	(1.86)	(2.14)	(1.88)	(2.73)
ln(1+Isr.Fat.<5km)	0.0169	0.0176	0.0162	0.0180	-0.0467
	(1.01)	(0.98)	(0.87)	(1.05)	(-0.78)
Year FE	Yes	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes	Yes
N	1928	1928	1928	1928	1928
adj. R^2	0.342	0.310	0.261	0.345	-0.028

t statistics in parentheses, clustered by locality

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Difference-in-Difference Regressions (2006-2010)
Original (Non-Deblurred) Night Time Lights

	(1)	(2)	(3)	(4)
	Top Coded		Bottom Coded	
	Δln NTL pc	Δln NTL pc	Δln NTL pc	Δln NTL pc
	OLS	IV	OLS	IV
Δln Market Access	0.100**	0.225**	0.0773*	0.194**
	(2.19)	(2.37)	(1.73)	(2.10)
Δln(1+Pal.Fat.<5km)	0.0235	0.0277	0.0654***	0.0693***
	(1.28)	(1.46)	(3.65)	(3.77)
Δln(1+Isr.Fat.<5km))	0.0800	0.110**	-0.0193	0.00888
	(1.56)	(1.97)	(-0.39)	(0.16)
N	241	241	241	241
adj. R^2	0.018	-0.012	0.050	0.023

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Difference-in-Difference Regressions (2006-2010)
Deblurred Night Time Lights

	(1)	(2)	(3)	(4)
	Top Coded		Bottom Coded	
	Δln NTL pc Deblurred OLS	Δln NTL pc Deblurred IV	Δln NTL pc Deblurred OLS	Δln NTL pc Deblurred IV
Δln Market Access	0.130	0.584*	0.141	0.248
	(0.84)	(1.82)	(1.42)	(1.23)
Δln(1+Pal.Fat.<5km)	0.0776	0.0929	0.126***	0.130***
	(1.25)	(1.46)	(3.20)	(3.25)
Δln(1+Pal.Isr.<5km)	0.137	0.247	-0.101	-0.0725
	(0.79)	(1.31)	(-0.92)	(-0.60)
N	241	241	230	230
adj. R^2	-0.001	.	0.041	0.036

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.3 Counterfactual output estimates

We end our analysis by conducting a back of the envelope calculation of the costs of mobility restrictions in terms of foregone output. We simulate how much higher night time lights per capita would have been had obstacles not been present in the West Bank. The results are presented in figure 13. Using our preferred distance decay parameter of 40, in 2005, night time lights per capita would have been 15.7 percentage points higher had there not been any mobility restrictions. Put differently, GDP would have been about 4.7% higher in 2005 assuming a GDP to night-time lights elasticity of 0.3. Over time, however, restrictions have been alleviated, such that, by 2012, the cost of mobility restrictions amounted to approximately 2.6% of GDP. The easing of mobility restrictions has thus improved Palestines economic performance.

These estimates must be interpreted with caution, as they are very sensitive to the choice of the distance decay parameter, with more permissive decay parameters yielding considerably higher estimates; for instance, with a distance decay parameter of 80, the estimated GDP per capita loss amounts to 9.2% in 2005 and to 3.6% in 2012. Taking the estimates with $\theta = 40$ as the lower bound and $\theta = 80$ as the upper bound, over the period 2005-2012 Israel's closure policy repressed GDP per capita in the West Bank between 4.1% and 6.1% on average each year. These estimates are of course also very sensitive the assumed elasticity of night-time lights with respect to GDP. Moreover, the

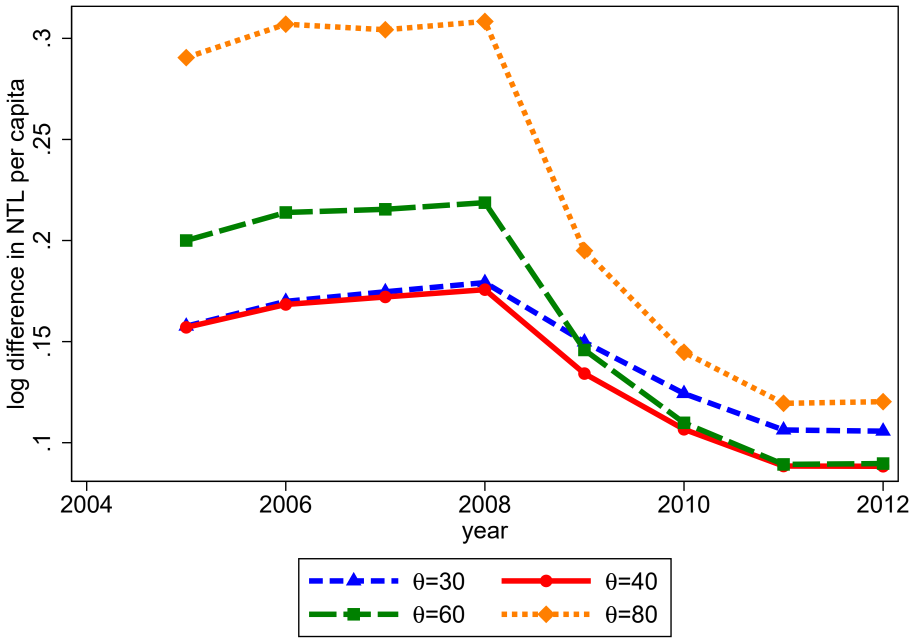

Figure 13: Counterfactual growth rates: West Bank with and with road closure obstacles

alleviation of obstacles is easy to reverse, and the context is marred by uncertainty and distortions (described in section 2), which may have dampened the output response to changes in market access.

7 Concluding remarks

Assessing the impact of market access on economic performance is challenging because it evolves slowly and non-randomly. This paper has exploited the imposition of obstacles by the Israeli army in the West Bank as part of its closure policy as a quasi natural experiment generating variation in local market access tackling both these concerns. The placement of obstacles was largely exogenous to local economic performance since they served to safeguard Israel, and did not (directly) target local economic performance. Moreover, they were subject to frequent and unanticipated changes, yielding substantial short-run variation in market access.

To assess the impact of Israel's closure policy on market access, we have constructed a local market access measure using unique data on the positioning of obstacles and their traversal times, in conjunction with road network and population data. These data allow us to compute minimum travel times between each locality and governorate capitals (and how these were impacted by road closure obstacles), which are a key ingredient of the market access measure.

The resulting local market access measure is shown to strongly predict local GDP, proxied by night time lights. This association is robust to controlling for conflict. Moreover, it strengthens when we instrument market access using the count of obstacles located in a radius between 10 and 25km from the locality. The relationship is furthermore robust to using alternative market access and night time-lights measures, and also obtains when estimating a difference in difference specification using 4 year changes in night time lights and market access. According to our preferred IV estimates, on average, a 10% increase in market access results in a 1.9% percentage point increase in market access, which corresponds to a 0.6% increase in local GDP if we assume a GDP to lights elasticity of 0.3 (cf. Henderson et al. (2012). In interpreting this number, it is important to bear in mind the distortions and uncertainty that characterize the West Bank. It is possible that in the absence of these, the output response of the economy would have been stronger.

Our estimates imply that over the period 2005-2012 Israel's closure policy repressed GDP per capita in the West Bank between 4.1% and 6.1% on average each year. Restrictions have gradually been eased over time. Further relaxation of remaining mobility restrictions will be conducive to Palestinian economic performance.

References

Abrahams, A., Oram, C. and Lozano-Gracia, N. (2017). Deblurring dmsp nighttime lights. *Unpublished manuscript.*

Abrahams, Alexei (2017a). Hard traveling: Distributional impact of travel costs on urban unemployment. *Unpublished manuscript.*

Abrahams, Alexei (2017b). Not dark yet: the israel-pa relationship 1993-2016. *Unpublished manuscript.*

AIX Group (2013). Twenty years after oslo and the paris protocol: Changing course, averting crisis – from dependency to economic sovereignty. Technical Report. AIX Group.

Alder, S. (2017). Chinese roads in india: The effects of transport infrastructure on economic development. *mimeo.*

Alesina, Alberto, Michalopoulos, Stelios and Papaioannou, Elias (2015). Ethnic inequality. *Journal of Political Economy*, **123,** number 3, 547–724.

Allen, T. and Arkolakis, C. (2014). Trade and the topography of the spatial economy. *Quarterly Journal of Economics* 1085–1139.

Allen, W., Liu, D. and Singer, S. (1993). Accessibility measures of u.s. metropolitan areas. *Transportation Research* B, **27,** 439–449.

Anderson, J. and Van Wincoop, E. (2004). Trade costs. *Journal of Economic Literature*, **42,** 691–751.

Arkolakis, C., Costinot, A. and Rodriguez-Clare, A. (2012). New trade models, same old gains? *American Economic Review*, **102,** 94–130.

Banerjee, A., Duflo, E. and Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in china. *mimeo.*

Baum-Snow, N. (2007). Did highways cause suburbanization? *Quarterly Journal of Economics*, **122,** 775–805.

Black, J. and Conroy, M. (1977). Accessibility measures and the social evaluation of urban structure. *Environment and Planning* A, **9,** 1013–1031.

B'Tselem (2007). Ground to a halt. Technical Report. B'Tselem.

Calì, Massimiliano and Miaari, Sami H (2012). The labor market impact of mobility restrictions: Evidence from the west bank. *World Bank Policy Research Working Paper*, number 6457.

Chena, Xi and Nordhaus, William D. Using luminosity data as a proxy for economic statistics. *PNAS*, **108,** number 21.

Croft, T. A. (1979). The brightness of lights on earth at night, digitally recorded by dmsp satellite. *US Geological Survey.*

Dalvi, M. and Martin, K. (1976). The measurement of accessibility: Some preliminary results. *Transportation*, **5,** 17–42.

Deichmann, U. (1997). Accessibility indicators in gis. *United Nations Statistics Division Working Paper.*

Donaldson, D. (2017). Railroads of the raj: Estimating the impact of transportation infrastructure. *American Economic Review, forthcoming.*

Donaldson, Dave and Hornbeck, Richard (2016). Railroads and american economic growth: A market access approach. *The Quarterly Journal of Economics*, qjw002.

Duranton, G. and Turner, M. (2012). Urban growth and transportation. *Review of Economic Studies*, **79,** 1407–1440.

Etkes, H. and Zimring, A. (2015). When trade stops: Lessons from the gaza blockade 2007-2010. *Journal of International Economics*, **95,** 16–27.

Faber, Benjamin (2014). Trade integration, market size, and industrialization: evidence from china's national trunk highway system. *The Review of Economic Studies*, rdu010.

Feyrer, J. (2009). Distance, trade, and income: The 1967 to 1975 closing of the suez canal as a natural experiment. *NBER Working Paper*, **15557**.

Frisch, Hillel (2010). *The Palestinian military: Between militias and armies.* Routledge.

Geertman, S. and Van Eck, J. (1995). Gis and models of accessibility potential: An application in planning. *International Journal of Geographical Information Systems*, **9,** 67–80.

Geurs, K. and Van Wee, B. (2004). accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography*, **12,** 127–140.

Gonzalez-Navarro, M. and Quintana-Domeque, C. (2016). Paving the streets for the poor: Experimental analysis of infrastructure effects. *Review of Economics and Statistics*, **98,** 254–267.

Guy, C. (1983). The assessment of access to local shopping opportunities: A comparison of accessibility measures. *Environment and Planning B: Planning and Design*, **10,** 219–238.

Hansen, W. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners*, **25,** 73–76.

Harris, C. (1954). The market as a factor in the localization of industry in the united states. *Annals of the Association of American Geographers*, **44,** 315–348.

Head, K. and Mayer, T. (2011). Gravity, market potential and economic development. *Journal of Economic Geography*, **11,** 281–294.

Heikkila, E. and Peiser, R. (1992). Urban sprawl, density, and accessibility. *Journal of the Regional Science Association International*, **71,** 127–138.

Henderson, J Vernon, Storeygard, Adam and Weil, David N (2012). Measuring economic growth from outer space. *The American Economic Review*, **102,** number 2, 994–1028.

Henderson, M., Yeh, E. T., Gong, P., Elvidge, C. D. and Baugh, K. (2003). Validation of urban boundaries derived from global night-time satellite imagery. *International Journal of Remote Sensing*, **24,** 595–609.

Hsu, Feng-Chi, Baugh, Kimberly E, Ghosh, Tilottama, Zhizhin, Mikhail and Elvidge, Christopher D (2015). Dmsp-ols radiance calibrated nighttime lights time series with intercalibration. *Remote Sensing*, **7,** number 2, 1855–1876.

Imhoff, M. L., Lawrence, W. T., Stutzer, D. and Elvidge, C. D. (1997). A technique for using composite dmsp/ols 'city lights' satellite data to map urban area. *A Remote Sensing of Environment*, **61,** 361–370.

Ingram, D. (1971). The concept of accessibility: A search for an operational form. *Regional Studies*, **5,** 101–107.

Jaeger, David A and Paserman, M Daniele (2008). The cycle of violence? an empirical analysis of fatalities in the palestinian-israeli conflict. *The American Economic Review*, **98,** number 4, 1591–1604.

Jedwab, R., Kerby, E. and Moradi, A. (2017). History, path dependence and development: Evidence from colonial railroads, settlers and cities in kenya. *Economic Journal, forthcoming.*

Jedwab, R. and Moradi, A. (2016). The permanent effects of transportation revolutions in poor countries: Evidence from africa. *Review of Economics and Statistics*, **98,** 268–284.

Koenig, J. (1980). Indicators of urban accessibility: Theory and application. *Transportation*, **9,** 145–172.

Kwan, M. (1998). Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis*, **30,** 191–216.

Miaari, Sami, Zussman, Asaf and Zussman, Noam (2014). Employment restrictions and political violence in the israeli–palestinian conflict. *Journal of Economic Behavior & Organization*, **101,** 24–44.

Min, Brian (2015). *Power and the Vote: Elections and Electricity in the Developing World*. Cambridge University Press.

Pinkovskiy, Maxim L (2013). Economic discontinuities at borders: Evidence from satellite data on lights at night.

Redding, S. and Sturm, D. (2008). The cost of remoteness: Evidence from german division and reunification. *American Economic Review*, **98,** 1766–1797.

Small, C., Pozzi, F. and Elvidge, C. D. (2005). Spatial analysis of global urban extent from dmsp-ols night lights. *Remote Sensing of Environment*, **96,** 277–291.

Song, S. (1996). some tests of alternative accessibility measures: A population density approach. *Land Economics*, **72,** 474–482.

Storeygard, A. (2016). Farther on down the road: Transport costs, trade and urban growth in sub-saharan africa. *Review of Economic Studies*, **83,** 1263–1295.

Tuttle, B., Anderson, S., Sutton, P. C., Elvidge, C. D. and Baugh, K. (2013). It used to be dark here. *Photogrammetric Engineering & Remote Sensing*, **79,** 287–297.

Wachs, M. and Kumagai, G. (1973). Physical accessibility as a social indicator. *Socio-economic Planning Science*, **7,** 437–456.

World Bank (2007). Movement and access restrictions in the west bank: Uncertainty and inefficiency in the palestinian economy. Technical Report. World Bank.

Wu, Jiansheng, He, Shengbin, Peng, Jian, Li, Weifeng and Zhong, Xiaohong (2013). Intercalibration of dmsp-ols night-time light data by the invariant region method. *International journal of remote sensing*, **34,** number 20, 7356–7368.

Zussman, Asaf and Zussman, Noam (2006). Assassinations: Evaluating the effectiveness of an israeli counterterrorism policy using stock market data. *Journal of Economic Behavior Perspectives*, **20,** number 2, 193–206.