

Obstacles on the Road to Palestinian Economic Growth*

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Abstract

This paper quantifies the impact of market access on local GDP in the West Bank, proxied by nighttime lights, using the deployment of road closure obstacles by the Israeli army between 2005 and 2012 as a quasi-natural experiment generating exogenous temporal and spatial variation in accessibility. Minimum travel times between locality pairs are computed using road network and obstacles data supplemented with information on checkpoint traversal times. These are combined with population data to construct a time-varying 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.

*The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank of Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the countries they represent. All errors are our responsibility.

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1 Introduction

How productive is market access? Answering this question is difficult because the infrastructure that connects markets typically 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 (Faber (2014), Allen and Atkin (2017), Alder (2017), Banerjee et al. (2012)), railroads (Donaldson and Hornbeck (2016), Donaldson (2010)), and waterways (Feyrer (2009)), existing studies typically find sizeable returns to improving connectivity. Research addressing this question by examining the impact of changes in borders (Redding and Sturm (2008)) has reached similar conclusions. These studies either examine large accumulated changes in transport infrastructure over extended periods of time or changes in accessibility brought about by large isolated shocks. A notable exception is the study by Storeygard (2016), which uses annual variation in transport costs generated by interacting distances between cities with oil prices, to assess short-run impacts of changes in transport costs on economic performance.

This paper exploits unique variation in travel times within the West Bank resulting from the deployment of road closure obstacles by Israel to identify the impact of market access on local GDP, proxied by nighttime lights (NTL). The obstacles take the form of manned and unmanned physical barriers, including roadblocks, checkpoints, earth mounds, trenches, and a separation barrier wall. According to the Government of Israel, these restrictions are deployed to enhance the security of Israel and Israeli citizens. As the placement of obstacles is not (directly) driven by local economic performance, but rather by security considerations, it is largely exogenous to local economic conditions. Moreover, the number, intensity, and configuration of obstacles are subject to frequent and unanticipated changes, yielding sizeable short-run variation in local market access. This context thus provides a quasi-natural experiment to assess the impact of short-term fluctuations in accessibility on economic performance.

We adopt a market access approach (following Donaldson and Hornbeck (2016)) to quantify how the intermittent re-configuration of road closure obstacles determines each location's connectivity to markets. The resulting measure takes into account both the type and intensity of the obstacles as well as their positioning. 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 is in part determined by obstacles in relatively distant areas, the impact of which simple counts of the number of obstacles would fail to capture.

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

We show that year-to-year changes in market access positively predict changes in nighttime light emissions (NTL), which serves as our measure of local economic performance given the absence of spatially disaggregated GDP measures in the West Bank.¹ According to our preferred estimates, a 10% improvement in market access increases local output by 0.8%, assuming a lights-to-GDP elasticity of 0.3 (cf. Henderson et al. (2012)).² A back-of-the-envelope calculation suggests that in the absence of road blocks, GDP per capita in the West Bank would have been 7.5% to 10.5% higher each year over our sample period. These *ceteris paribus* estimates must be interpreted with caution as they depend on the assumed GDP-to-lights elasticity as well as the choice of distance decay parameters, which govern how much weight is attached to destinations that take more time to reach. Moreover, they abstract away from other distortions and uncertainty that may have attenuated the economy's output response to changes in market access.

The main threat to identification is the potential endogeneity of market access, which could result from omitted variables bias. To address this concern we use geo-referenced data on fatalities to control for local conflict intensity, arguably the most likely confounder of a relationship between local economic performance and mobility restrictions. In addition, 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 plausibly orthogonal to local conditions yet an important determinant of local market access. While 10 to 25 km might seem a small radius, one has to

¹NTL are by now widely accepted as a credible proxy for local GDP/economic performance (Chen and Nordhaus (2011), Henderson et al. (2012), Pinkovskiy (2013), Alesina et al. (2016), and Storeygard (2016)). Henderson et al. (2011) furthermore confirms that log differences in NTL is a suitable proxy for growth in GDP.

²A 10% improvement in market access yields a 2.6% increase in lights emissions.

bear in mind that the West Bank is very small; it is roughly twice the size of the average American county, 56 km at its widest and 133 km at its lengthiest, and the median distance to the nearest governorate capital is just 9 km. Our IV estimates are substantially larger than our simple OLS estimates, suggesting the latter are downwards-biased, possibly reflecting measurement error in our market access measure.

The positive relationship between market access and lights is also obtained when we estimate a difference-in-differences specification in which we relate 4-year growth rates in lights to changes in market accessibility over the same period. It is furthermore robust to using alternative market access measures that hold the population fixed, such that variation in market access is purely driven by obstacle deployment, as well as to using market access measures that account for access to foreign markets. Results also remain when we use different distance decay parameters. Finally, our results are robust to using bottom-coded instead of top-coded lights data, which capture light emissions from economically more vibrant localities better.

Our paper builds on and contributes to different strands of literature. To start with, it complements existing studies on the returns to investing in transportation infrastructure that have exploited large network expansions often materializing over many years, if not decades, in countries with large internal markets. Donaldson and Hornbeck (2016), for example, estimate the effect of changes in market access brought about by a major expansion of US railroads on the value of agricultural land. Faber (2014) and Allen and Atkin (2017) estimate the gains from trade that are made possible by unprecedented expansions of the highway network in respectively China and India.³ See also Alder (2017) for a recent study on the impact of Chinese roads in India. Our study is unique in quantifying the impact of comparatively modest changes in market access on economic performance in a country with a small internal market, where the scope for specialization and exploitation of economies of scale might be limited. For comparison, the market access elasticity estimated for the West Bank is notably smaller than the elasticity estimated for the United States (Donaldson and Hornbeck (2016)) and India (Alder (2017)).

Moreover, our paper is the first to adopt a market access approach to quantify the

³Changes in transportation infrastructure have been shown to impact the structure of economic activity more broadly. Baum-Snow (2007), Duranton and Turner (2012), and Gonzalez-Navarro and Quintana-Domeque (2016) study the impact of transportation infrastructure on sub-urbanization, growth of cities, and property values respectively. Allen and Arkolakis (2014) assess how it shapes the spatial organization of the economy, while Adukia et al. (2017) and Asher and Novosad (2017) investigate the impact of rural road expansion on investments in education and the structural transformation of the labor market. Blankespoor et al. (2017) estimate the impact of road improvements on local employment and specialization. Jedwab and Moradi (2016) and Jedwab et al. (2017) examine how the collapse of railroad network impacted on road network investments as well as on the spatial distribution of economic activity.

productivity impacts of transitory shocks to road connectivity. The only other paper we are aware of that examines annual changes is Storeygard (2016). He cleverly exploits variation in oil prices (interacted with distances between cities) to identify the impact of transportation costs on economic development across Sub-Saharan Africa, taking routes as given. We endogenize the choice of optimal routes by adopting a market access approach that builds on the seminal work of Donaldson and Hornbeck (2016). In a robustness analysis we consider access to both domestic and foreign markets (cf. Jedwab and Storeygard, 2017).

Several other studies exploit obstacles to mobility as a source of identifying variation in the West Bank and Gaza. Abrahams (2018a), in a closely related study to ours, focuses on how Israeli obstacles disrupted Palestinian commuting, causing employment rates to decline in labor-supplying locations but to increase in labor-demanding locations. Calì and Miaari (2018) document a negative association between local employment rates and mobility restrictions in the short-run. Amodio and Di Maio (2017) study the impact of trade restrictions between the West Bank and the outside world on the efficiency of input allocation among Palestinian firms. Finally, Etkes and Zimring (2015) use the blockade of Gaza as a natural experiment to quantify the gains from trade by using the West Bank as the counterfactual.

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. 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 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 2.7 million Palestinians live there, while approximately 330,000 Israeli civilians live in over 160 separate, segregated settlements and outposts throughout the West Bank.⁴ Palestinian workers in settlements account for less than 3% of the West Bank labor force. International trade as a share of GDP was 83% over our sample period, which is lower than the average for small states (111%) but above the average for low and middle income countries (57%). Road transport is critical to market access

⁴See Niksic et al. (2014). Since our study does not concern East Jerusalem, we count Palestinians and Israelis inside the West Bank only.

in the West Bank as there are no railways, no airports, and no ports.

Since 1967, a major part of the West Bank has been controlled by the Israeli army. The army maintains a constant troop presence of bases, garrisons, patrols, and watch-towers throughout the West Bank's interior, while all borders of the West Bank (including 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. The Israeli army responds to ongoing Israeli-Palestinian conflict by both offensive retaliations (Jaeger and Paserman, 2008) and defensive efforts aimed at intercepting militants before they reach Israel or its settlements. This latter policy intensified under the auspices of 'Operation Defensive Shield', and involved the deployment of hundreds of physical obstacles (Calì and Miaari, 2018) inside the West Bank, along the internal road network, and the construction of a 500km wall that separates Israel from the West Bank.⁵ These mobility restrictions serve to safeguard Israeli civilians who have settled beyond the wall inside the West Bank:

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 ethos behind obstacle employment reduces concerns about endogeneity: mobility restrictions served security objectives and did not target market access nor economic performance. We worry that Israeli security objectives accidentally and indirectly related to Palestinian economic conditions, but we do not worry that they are deliberately or directly related.⁶

⁵According to UNOCHA, decisions regarding the placement of obstacles in the West Bank are made by the brigade commander of the Israeli Defense Forces assigned to the location or governorate of interest, often in consultation with the Israeli security forces. The decision to introduce or replace an obstacle is motivated by safety concerns, not by economic considerations.

⁶One conceivable endogeneity concern, for example, is that in addition to obstacle deployment, the Israeli army performed other security measures such as raids, arrests or curfews, which could be correlated with both obstacle placement and local economic prospects. Though we attempt to assuage these and other endogeneity concerns later by using an instrumental variable approach, an important argument against this concern is that obstacles were essentially a defense security measure, 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. We

Due to a lack of local GDP data, we use nighttime lights as a proxy for local economic output. In theory, Israel could control lights in the West Bank by regulating the supply of electricity to Palestinian localities. If cutting of electricity were used as a punishment device, then this “unobserved variable” could correlate both with NTL and the deployment of road closure obstacles. There is no documented (or anecdotal) evidence however that Israel is manipulating electricity supply as a penalty device in the West Bank. Israel has on occasion halted the supply of electricity but in all cases this has been for commercial reasons, i.e. in response to overdue electricity bills. Thus, there is no reason to believe that this will bias our results.

Another potential cause for concern is that Palestinian firms may have relocated in response to loss of market access caused by obstacle deployment. We expect firm relocation to be limited for several reasons, however. To start with, property rights have been very insecure during this period. Palestinians have tended to rely on their family and patriarchal clan (*hammouleh*) to protect their property. Such protection however only applies when one lives near relatives, which helps explain low voluntary migration rates. Indeed, using census data Abrahams (2018a) 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.

In interpreting our results 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, Area C restrictions, and limited control of public utilities and communications infrastructure (for further discussion, see Niksic et al. (2014) or AIX Group (2013)). While mobility restrictions have gradually been eased over time, these other restrictions have remained, so our estimates of the benefits of market access may be unduly conservative.

3 Measuring market access in the West Bank

3.1 Defining market access

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

do not expect defensive and proactive measures to correlate spatially. For a more in-depth contextual overview we refer the interested reader to Abrahams (2018b).

cheaper access to markets and labor. Donaldson and Hornbeck (2016) derive a measure of market access that 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:⁷

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

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).⁸ We use $h(T) = T^{-\theta}$, where the parameter θ governs the rate at which markets located further away are being discounted. Donaldson and Hornbeck (2016) provide a micro-foundation for this choice that has given economic meaning to the corresponding market access elasticity and has made exponential distance decay the standard choice in the economic literature on market access. The latter also helps us make comparisons between our estimates and those obtained in the existing empirical literature. An alternative choice is Gaussian distance decay, i.e. $h(T) = \exp(-\frac{1}{2}T^2/\theta^2)$, which has been widely used in the geography literature on market access.⁹ We have implemented this choice in van der Weide et al. (2018), which shows qualitatively similar results.

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 that take more time to reach 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

⁷Donaldson 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.

⁸This measure resonates 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).

⁹See e.g. Ingram (1971), Guy (1983), Song (1996), Deichmann (1997), and Kwan (1998).

j changes, it will obviously affect market access for localities i and j , but it will also have an effect on market access of localities connected to i and j , and the localities connected to these localities etc.

We compute market access for a balanced panel of grouped (aggregated) 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). The set of destinations consists of the governorate capitals, excluding Jerusalem (which is located at the other side of the barrier) and using nearby Al Ram instead. In a robustness check in which we attempt to account for access to foreign markets we add Tel Aviv as an additional destination (see section 5.2). The governorate capitals are 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 plausibly 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.¹⁰ We will present additional robustness checks that address this concern in section 6.2.

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 disaggregated localities in the West Bank (green dots), including the 11 governorate capitals (red squares with name labels), and the road network that connects them.¹¹

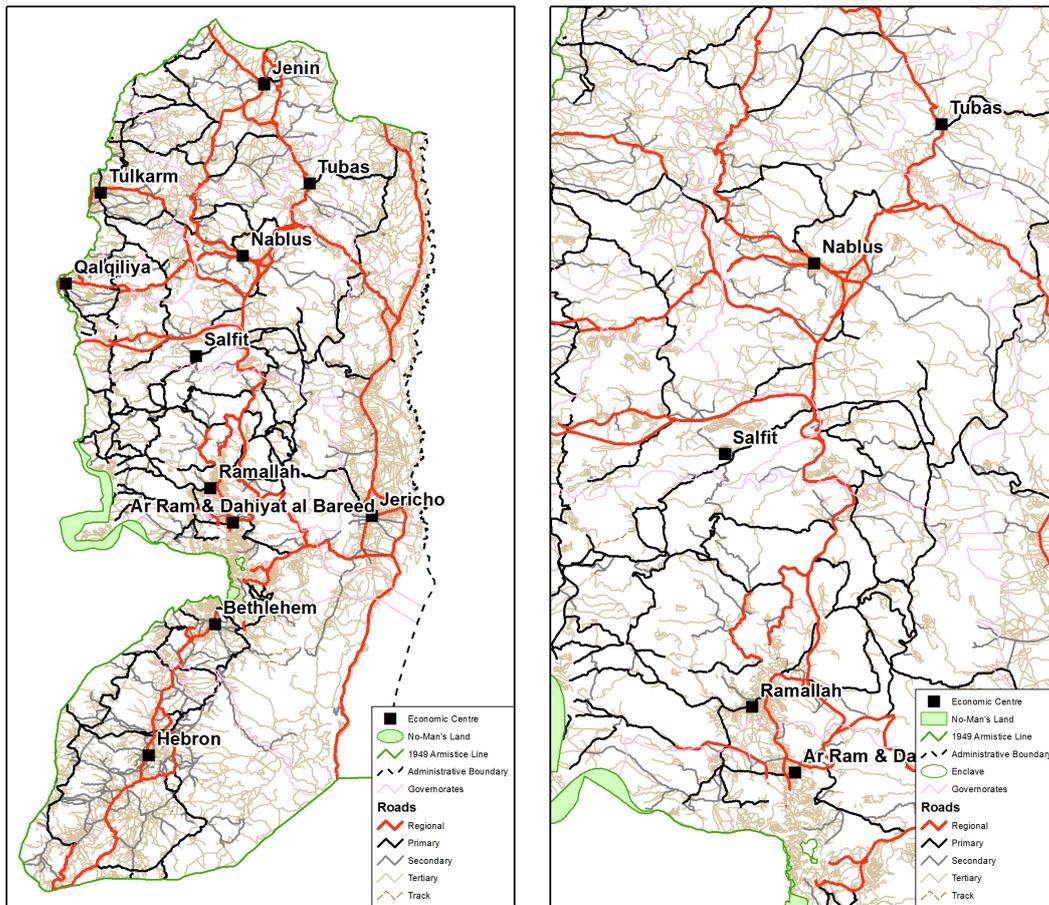
Locality locations and population counts

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 of 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 disaggregated 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 Jerusalem localities that lie outside of the West Bank and localities with a 2007

¹⁰Our results are found to be robust to the decision to include or exclude the governorate capitals themselves from our regression analysis.

¹¹The 11 destination cities include: Jenin, Tubas, Tulkarm, Nablus, Qalqiliya, Salfit, Ramallah, Jericho, Ar Ram, Bethlehem, and Hebron.

Figure 1: The road network and governorate capitals in the West Bank



population count below 1000. This reduces the number of stable localities that will be used in the regression analysis to 241. 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 were kindly provided to us by UNOCHA (who further developed the road network data produced by the European Commission’s Joint Research Center (JRC)). UNOCHA’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 record different categories of restrictiveness for each road segment concerning use by Palestinians: No Restriction, Restricted Use, Partially Prohibited, and Totally Prohibited. We 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 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 our best judgment.

Travel times

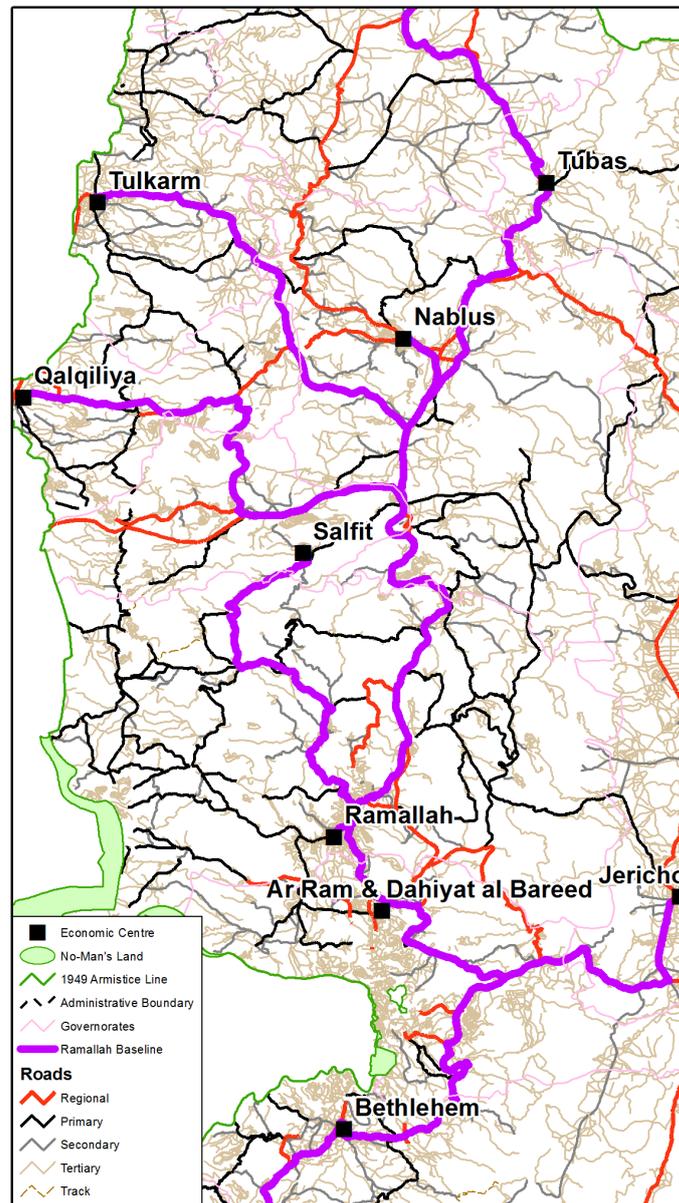
The computation of market access as defined in eq. (1) requires data on travel times T_{ijt} . We used ArcGIS 10.3’s Network Analyst software package to solve for the optimal route that minimizes travel time between all origin and destination pairs of interest. Selected examples of these optimal routes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

3.2 Road closure obstacles as a determinant of market access

Road closure obstacles

The Israeli army deployed physical obstacles along roads and borders to defend Israelis

Figure 2: Optimal routes between Ramallah and selected cities in the absence of obstacles

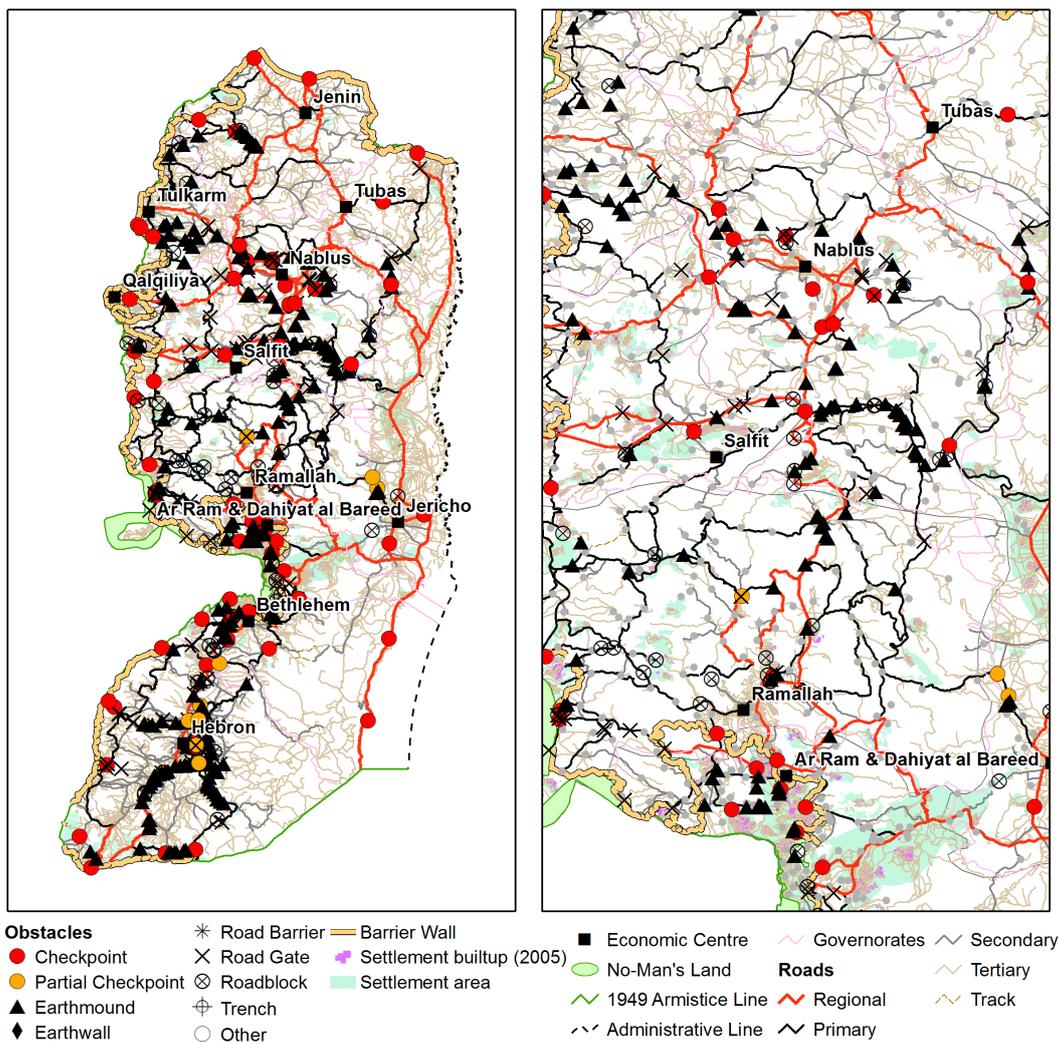


against violence originating in the West Bank. A 500 km wall or separation barrier was built along (and sometimes beyond) the Armistice Line of the West Bank to prevent the entry of threats from the Palestinian side into Israel. Henceforth, all cross-border traffic was forced to pass through any one of nine green-line checkpoint border crossings, guarded by the Israeli army (see B'Tselem (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 Palestinian traffic passing along roads in the vicinity of Israeli settlements. Most of these obstacles constitute a "full stop", meaning that vehicles cannot pass through 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 Israeli army and potential traffic congestion.

The UNOCHA Map Center did an excellent job of recording the progress of the wall's construction, and keeping track of road obstacles' geolocations, frequently updating their maps throughout and after the uprising as obstacles were moved and removed. Over this period, UNOCHA 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. We obtained 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 (d) 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 January 2006. 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) variation in the degree to which each Pales-

Figure 3: West Bank roads with road closure obstacles (January, 2006)



tinian 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, 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 UNOCHA has published over the years, and by manually: (1) dating each segment of the separation barrier, and (2) adding the geolocations and attributes of any obstacles appearing on published UNOCHA maps prior to 2008 into our shapefile. Moreover, obstacles whose locations did not perfectly align with the road network were snapped to the most plausible road segment based on available documentation on these obstacles and consultation with UN-OCHA officials.

Since checkpoints play a critical role in controlling Palestinian traffic in the West Bank, accounting for the time it takes to traverse active checkpoints improves our estimates of optimal travel times over the road network. Working in coordination with UNOCHA, we conducted repeated retrospective interviews between 2009 and 2013 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 checkpoint traversal times.

Updating optimal routes as obstacles are relocated or removed

Between 2005 and 2012 obstacles are frequently relocated, replaced by other types of obstacles, or removed altogether. As the spatial configuration and intensity of obstacles changes, we recalculate the optimal routes between 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 is 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 Huwwara and Awarta checkpoints, located to the south of the city, significantly prolonging travel times. 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 4.¹²

Optimal routes also evolved with the construction of the separation barrier wall. Construction of the barrier wall started during the Second Intifada and it continued throughout the period of analysis.¹³ Figure 5 provides two examples of optimal route changes between 2006 and 2012: Qalqiliya to Hebron (left panel map) and Qalqiliya to Ramallah (right panel maps).

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 6 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 demonstrate that obstacles have greatly increased the travel times between origins and destinations in the West Bank, and that these travel times are subject to sizeable fluctuations 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. In 2009 travel times declined to “just” 4 hours and 40 minutes, and to less than 4 hours in 2010.

3.3 Market access over time and across 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 $\theta = 3$, which is just below the value used in Jedwab and Storeygard (2017). Other values for θ ranging from 1 to 6 are considered as part of the sensitivity analysis (see Sections 5.2 and 6.2).

¹²The figures show that in 2006 and 2007 the obstacles in place forced traffic to take a longer route compared to later years when these obstacles were removed. In 2006-2007, commercial traffic traveled via the Huwwara or Awarta commercial checkpoints south of Nablus. In 2009, the Beit Iba checkpoint was dismantled which opened up the North-West route out of Nablus towards Tulkarm. This eliminated the need to travel via the Jit checkpoint.

¹³As of July 2011, approximately 437 kilometers of the barrier wall was completed, 58 kilometers was under construction, and 213 kilometers was planned and not yet under construction (UNOCHA, 2011). As a result, 71 of 150 settlements are on the Israeli side of the separation barrier. Upon completion of the planned separation barrier, part of the total barrier (15%) is near the 1949 Armistice Line (Green Line) or within Israel, while the remainder of the total barrier (85%) is within the West Bank.

Figure 4: Optimal routes between Tulkarm and Nablus over time

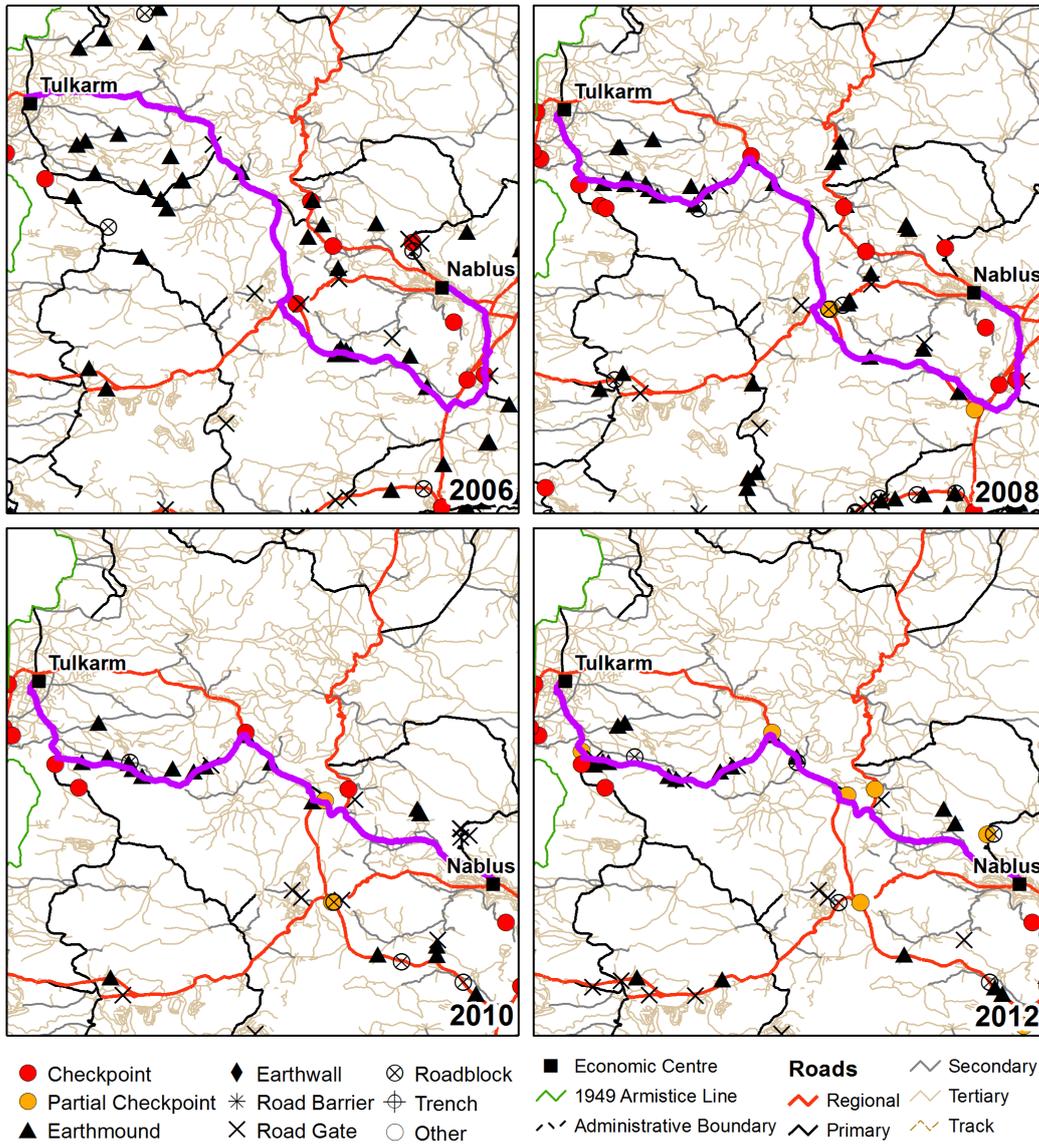
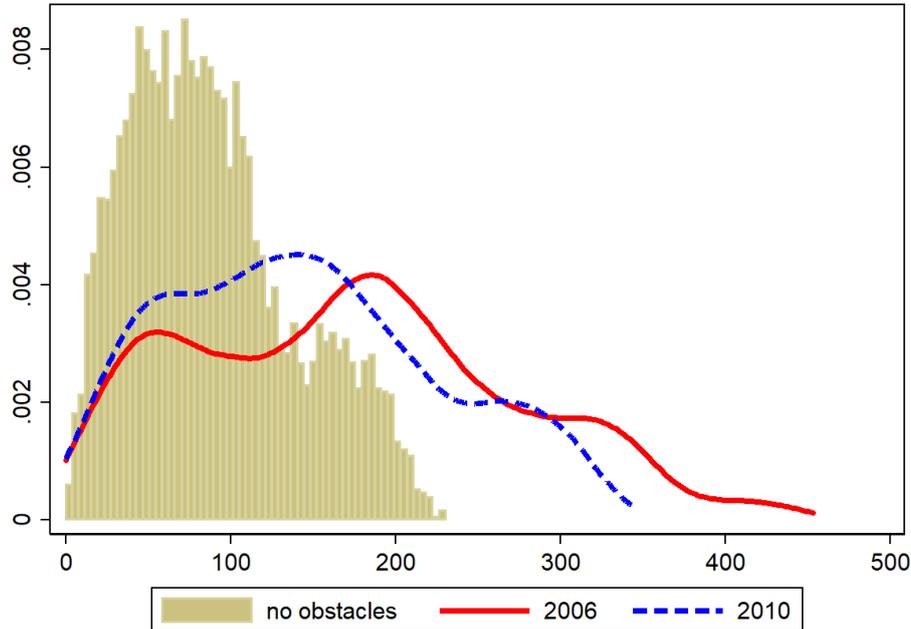


Figure 6: Kernel density plots of travel times (in minutes)



We compute market access on an annual basis. This matches the frequency with which the lights data (our outcome variable which will be introduced in the next section) are observed. Note that our obstacles data are 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 UNOCHA 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 UNOCHA updates after that). Second, we collapse these data to obtain annual estimates of market access by simply averaging the intra-year data.

Figure 7 shows the landscape of market access in the West Bank, and how it has evolved from 2006 to 2010. Darker colors are associated with higher values of market access. It can be seen that localities surrounding Nablus and Ramallah experienced a marked increase in market access over this period.

Figure 8 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 shift in density from lower levels of market access to higher levels of market access reflects a number of significant changes between 2006 and 2010. Lifting key restrictions

Figure 7: Market access ($\theta = 40$): 2006 (left) versus 2010 (right)

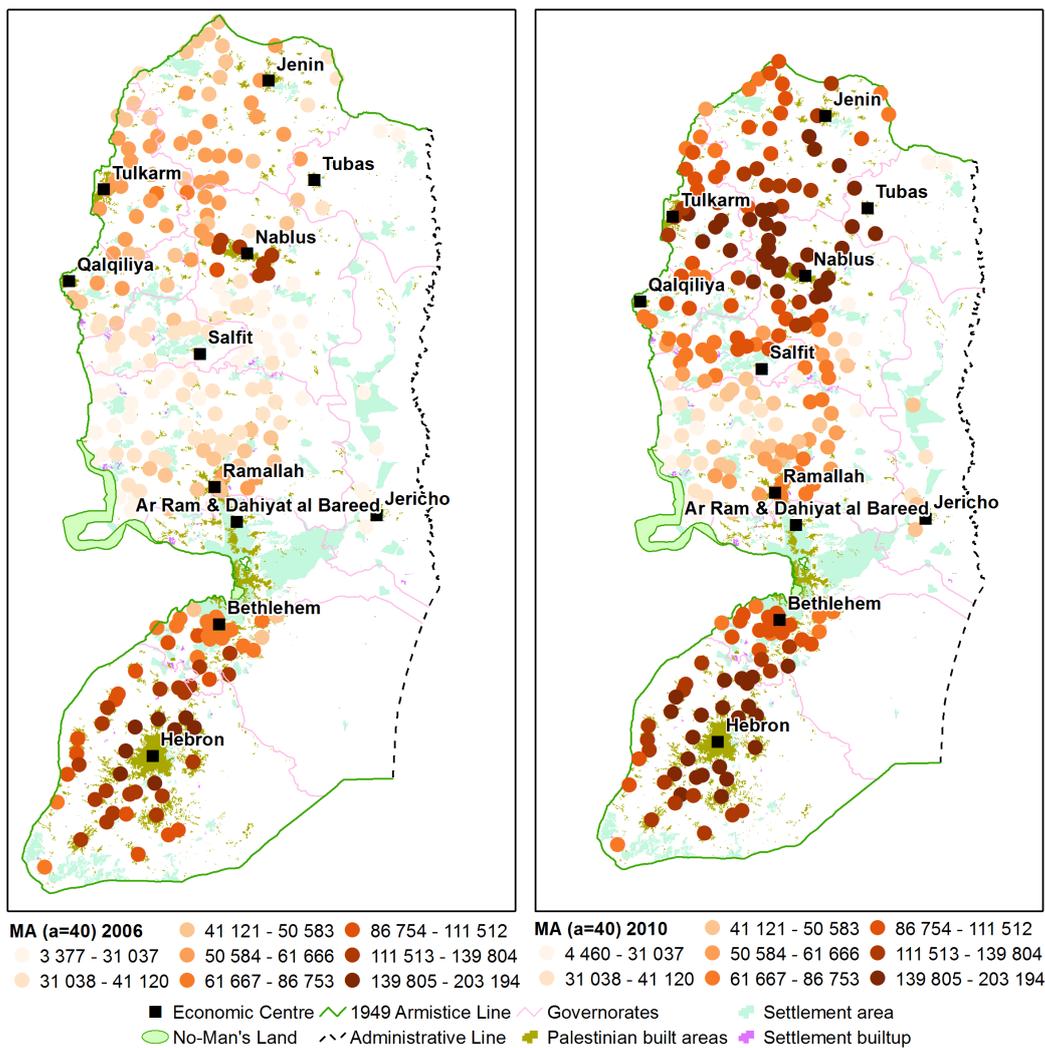
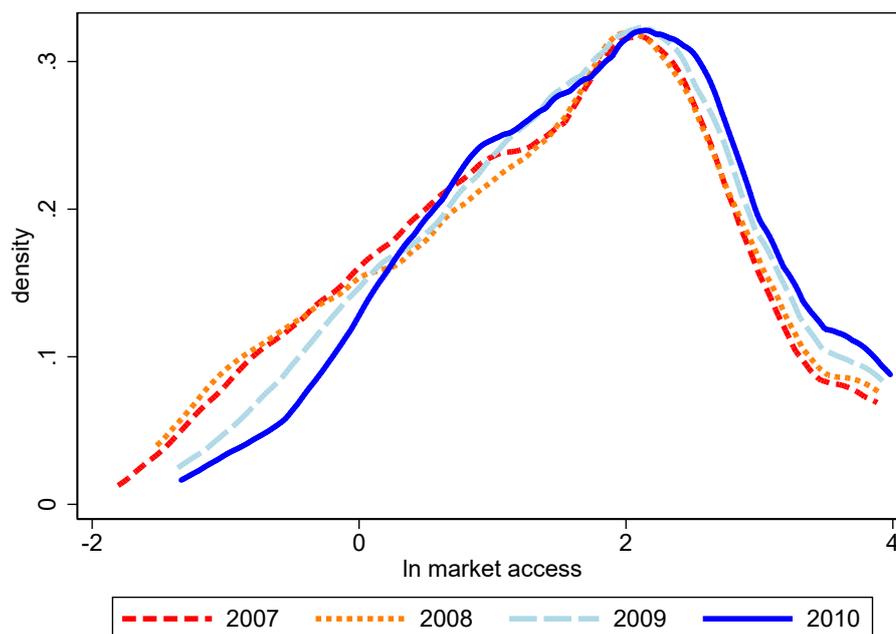


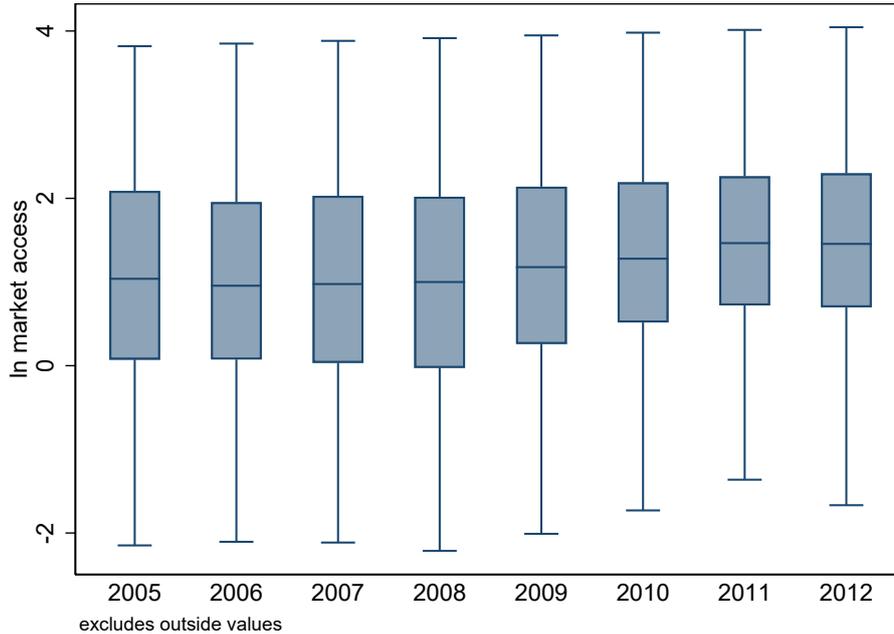
Figure 8: Kernel density of market access (with $\theta = 3$)



around Nablus in late 2009 arguably denotes the most prominent change. Not only because Nablus was surrounded by some of the most restrictive obstacles, effectively amounting to a blockade, but also because the city is central to the West Bank, both geographically and economically.¹⁴ Another notable change is the gradual improvement in connectivity between the north and the south of the West Bank (from late 2007 to 2010) resulting from a reduction in Wadinar checkpoint traversal time (which controls North-South traffic). As some of the restrictions to north-south traffic were eased, more centrally located localities were 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 9 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 access (across locations).

¹⁴It is the second largest city, home to the Palestinian Stock Exchange (which is 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 9: Box plot time-series of market access (with $\theta = 3$)



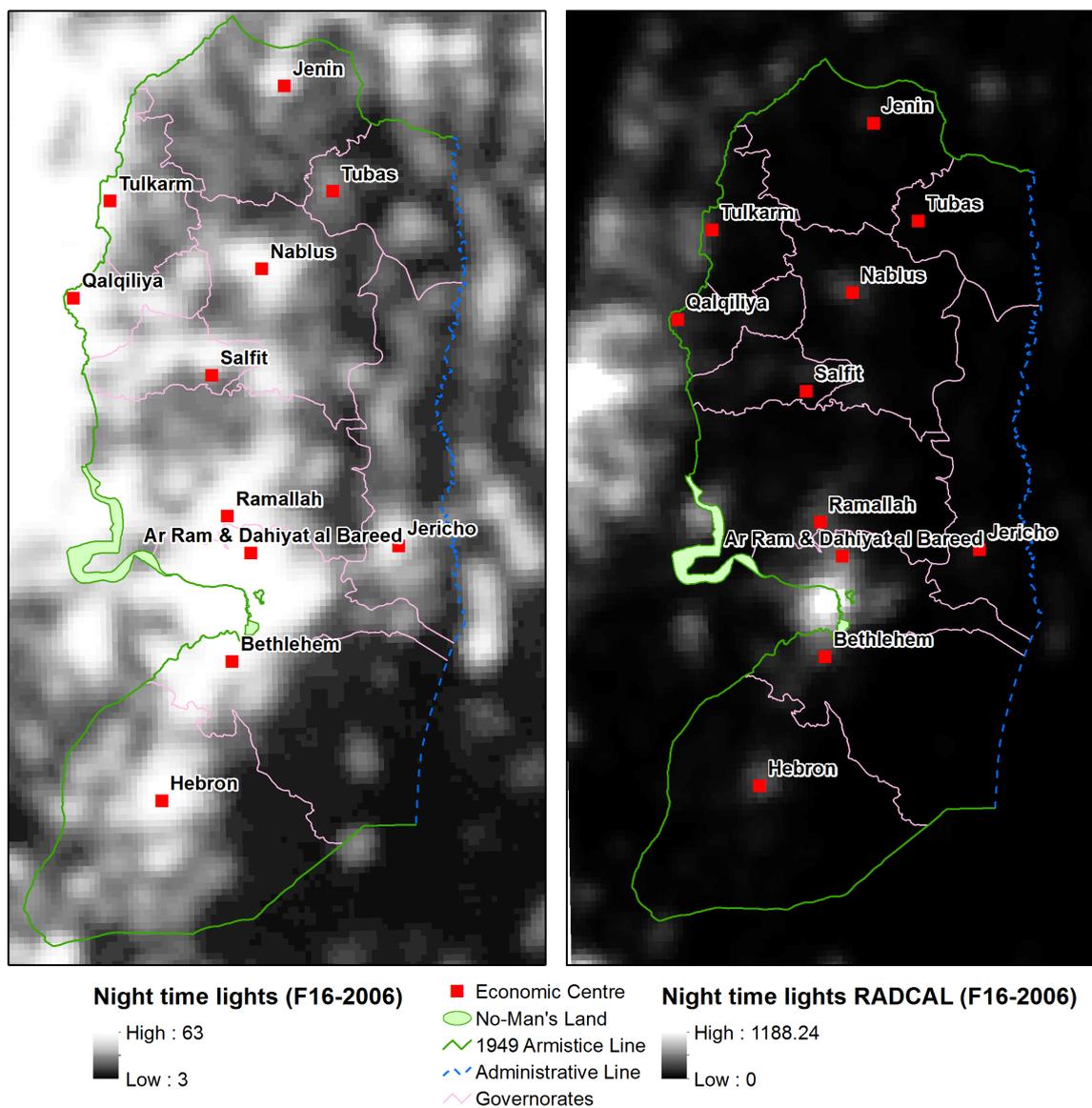
4 Nighttime Lights and local conflict data

4.1 Nighttime Lights as a proxy for economic output

This section introduces the nighttime lights (NTL) data. 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 lights have also been shown to track year-to-year GDP changes (Henderson et al., 2012). This has popularized lights as a proxy for GDP in under-developed or conflict-prone contexts where spatially disaggregated GDP data are often unavailable or unreliable (see, for example, Alesina et al. (2016) or Pinkovskiy (2013)).

The left-hand-side map of Figure 10 shows an annual composite image of the West Bank recorded by the DMSP’s F16 satellite in the year 2006. 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 UNOCHA Map Center. Poly-

Figure 10: Top-coded vs. bottom-coded lights



F16-2006 (top-coded) Lights image (left) and RADCAL (bottom-coded) Lights image (right)

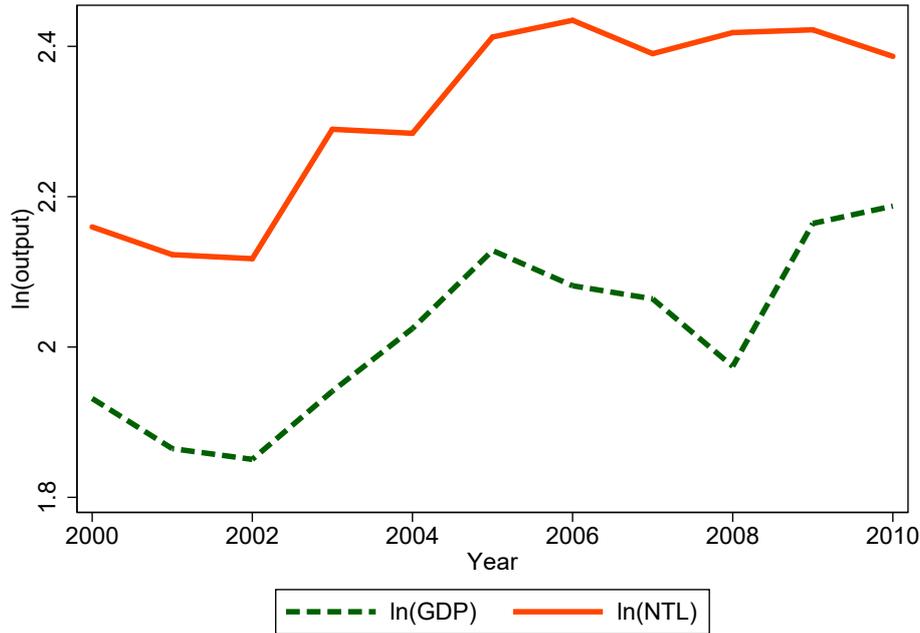
gons were finely drawn to circumscribe built-up areas and are highly accurate for the time period of interest. Throughout our analysis we assign a pixel’s value to a Palestinian location if the pixel’s centroid lies within 500 meters of the location’s polygon. This “generous” assignment rule allows for 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).¹⁵ Summing up the DNs of all assigned pixels per location, we find that the brightest three towns in 2006 were Hebron (3577 counts), Nablus (2309), and Ramallah (1830).

Potential truncation of DMSP-NTL imagery can arise because of 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 (maxed out at 63). The overwhelming majority of West Bank Palestinian locations were too dim to suffer from this problem, but few neighborhoods in the greater Jerusalem area (Bethlehem, Ramallah) are topcoded for most years. As a result, we cannot tell for most of these locations if they grew brighter or dimmer; they report 63 for most or all of their pixels. As described below, we perform robustness checks to guard against the influence of these topcoded locations on our results. Most importantly, parallel to the topcoded DMSP-NTL series, NOAA also generated a ‘radiance-calibrated’ series for select years, including 2006 and 2010. The radiance-calibrated (RADCAL) series was constructed from a lower average gain setting, avoiding topcoding at the cost of introducing bottom-coding. We show that our main results survive when we use these non-topcoded data. The right-hand-side map of Figure 10 shows the RADCAL image captured by the F16 satellite for 2006, which illustrates that the bottom-coded setting does not pick up light emissions from dimly lit areas.

Another potential concern is that OLS sensors on DMSP satellites deteriorate over years in orbit, and that their average gain settings vary from year to year and satellite to satellite. As a result, the images of the West Bank in any two given years are not directly comparable. To facilitate interpretation of our graphs, however, we applied intercalibration parameters to make the data as comparable over time as possible. For topcoded imagery, we applied the 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

¹⁵In 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.

Figure 11: GDP of the West Bank & Gaza and Nighttime Lights (NTL), 2000-2010



of natural-logs, to minimize this source of error.

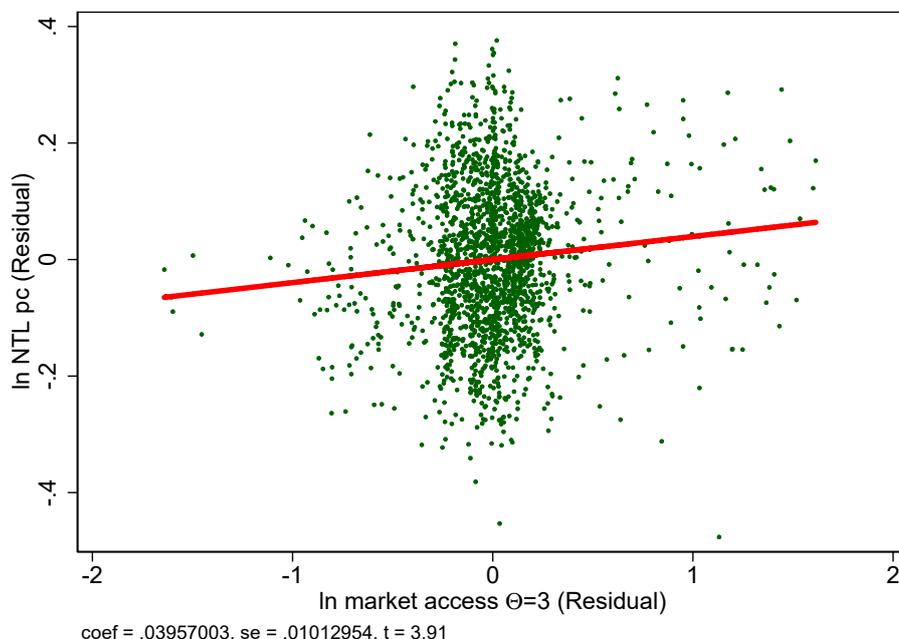
DMSP-NTL appear to track West Bank Palestinian economic growth accurately for the period under study. To construct a NTL series for the West Bank as a whole, we sum the intercalibrated pixel values (i.e. the quantities of light observed) within 500m of West Bank Palestinian polygons. After taking natural logs, we plot the resulting time series for 2000-2010 in Figure 11, along with series of logged Palestinian GDP. The GDP data were obtained from the World Bank, which unfortunately does not disaggregate series separately for the West Bank and Gaza. The NTL series tracks the time-evolution of national GDP well. Note for example the marked decline in light before and during the early years of the Second Intifada, which commenced in late 2000. Note also the slump in both series from 2005 to 2007 resulting from the introduction of sanctions in response to the election of a majority-Hamas legislature. The subsequent recovery coincided with improvements in market access.

Joint evolution of Nighttime Lights and Market Access

Figures 12 and 13 provide a preview of our regression results. Figure 12 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, which will be discussed below. The positive slope suggests that higher market access is associated with more output (proxied by lights). Similarly, Figure 13 plots

the difference in log lights per capita over 2006-2010 against the difference in log 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 12: Nighttime Lights (NTL) vs. market access



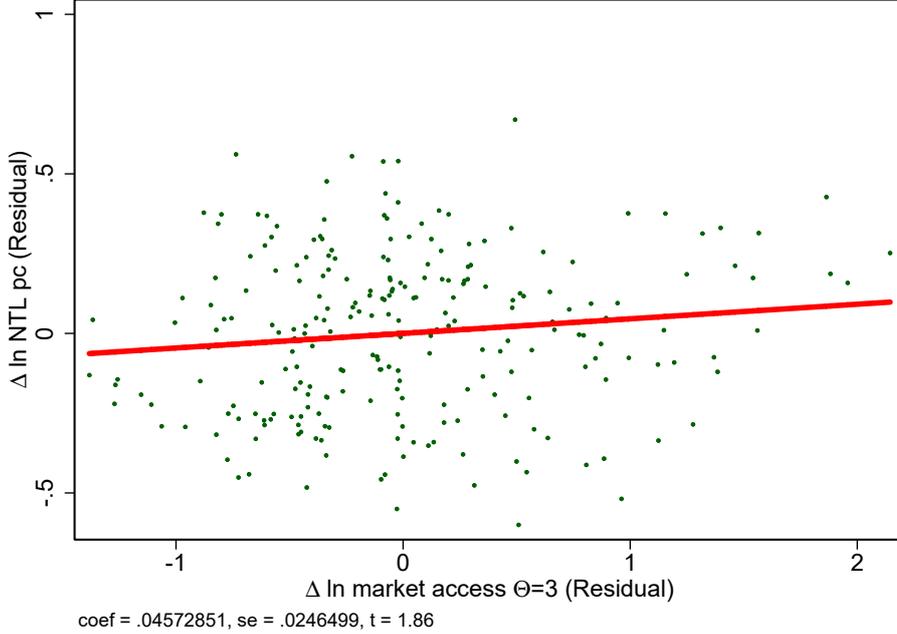
Nighttime Lights (NTL) vs. market access (controlling for locality, year and fatalities)

4.2 Fatalities data

We use geo-referenced data on Israeli and Palestinian fatalities in the West Bank from B'Tselem¹⁶ as our indicators of local conflict. For each violent incident, B'Tselem records the exact date, geolocation, and number of fatalities for Israelis and Palestinians separately. We combine these 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.

¹⁶B'Tselem is an Israeli independent non-profit organization that records a variety of statistics related to the conflict between Israel and Palestine. It refers to itself as an Information Center for Human Rights in the Occupied Territories. The statistics published by B'Tselem we use can be downloaded from: <http://www.btselem.org/statistics>.

Figure 13: Change in Nighttime Lights (NTL) vs. change in market access



Change in Nighttime Lights (NTL) vs. change in market access (controlling for fatalities), 2006-2010

5 Empirical strategy

Taking Palestinian locations as our units of analysis, we attempt to identify the causal effect of market accessibility on annual local nighttime light output per-capita. Our main specification is:

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

where the outcome variable y_{it} is the total lights per-capita observed at location i in year t , MA_{it} is our measure of market access from eq. (1) with $\theta = 3$ (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} are the number of Palestinian and Israeli fatalities that occurred in year t within a 5km radius. β is the (short-run) elasticity of lights with respect to market access, the key parameter of interest.

We drop locations with fewer than 1000 residents (in 2007), so as to ensure that results are not driven by temporary bedouin encampments or small villages. Finally, we only keep localities for which we have data for all 8 years, but drop outlier observations for which the studentized residual in the base specification exceeds 3 in absolute value. This concerns a select number of localities for which market access is zero or near zero

during our sample period. The resulting regression sample is a panel with 239 to 241 locations for the years 2005 to 2012. Standard errors are clustered by locality and are robust to heteroskedasticity.

The year 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 (FE) capture the time-invariant features of location i that affect annual light output, such as initial size of the location, local geographic conditions etc. The locality FE arguably also control for the conflict-proneness of localities to the extent that these do not vary over time. Our motivation for controlling for local violence, by including x_{it} , is to account for remaining variation in proneness to conflict which could conceivably be a driver of both accessibility and changes in lights.

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. The sign of such bias is theoretically ambiguous. 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 reflects complementary penalties imposed on Palestinian localities. These 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 section 2, 10 km is a considerable distance (recall that the West Bank is 56 km at its widest and 133 km at its lengthiest) that would take you beyond the nearest governorate capital for the median locality. 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. Specifically, we compute the number of checkpoints located farther away than 10 km but no farther than 25 km, and will refer to this as the checkpoint “donut count”. This instrument is also orthogonal to possible measurement error to the extent that this error is due to errors in estimated “crossing times” (associated with crossing the checkpoints).

It should be noted however that road blocks and check-points might conceivably be associated with additional trade costs unrelated to travel time, think of risk of having goods confiscated, damage to goods, being arrested, payment of bribes etc. If indeed, then this would inflate our estimates of the market access elasticity, which would measure both the effect of changes in travel times as well as the effect of changes in these additional costs on economic outcomes.

5.2 Addressing additional concerns

This section elaborates on a variety of robustness checks addressing additional concerns.

Holding the population constant

Changes in our measure of market access over time are not only 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 (Baum-Snow et al. (2017)). 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 recompute each location’s market access by holding the destination population 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 equal to 3 (in practice this implies that destinations that take about 60 minutes or more to travel to 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). As a robustness check we will consider different values of θ ranging between 1 and 6. 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-envelope exercise are presented in Section 6.3.

Accounting for access to international markets

Economic performance depends both on domestic and foreign market access. To account for potential impacts of changes in road connectivity on external market access we compute an augmented measure of market access in which we proxy external market access by adding Tel Aviv as a 12th destination (in addition to the 11 governorate capitals), considering a range of different population sizes for the external market.¹⁷ We compute the shortest travel time to Tel Aviv allowing travel via three different border crossings, notably Al Jalama, At Tayba, and Tarqumiya.¹⁸

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 variations are obtained by employing different settings on the same satellite, akin to adopting different settings concerning light-sensitivity on a 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

¹⁷In the default measure we assign a population of 10 million to Tel Aviv as it serves to represent all external markets. This number is admittedly arbitrary but serves as a crude approximation to the relative size of the Palestinian external market. Israel, which had approximately 8 million inhabitants in 2012, is the main trading partner of the West Bank and Gaza; Palestinian sales to Israel account for roughly four-fifths of all Palestinian exports while purchases from Israel account for about two thirds of all imports. In robustness checks presented in the Appendix we assess the robustness to increasing the size of the external market to respectively 25 and 50 million people.

¹⁸Our approach to accounting for access to external market is inevitably somewhat crude. We do not take into consideration potential time penalties associated with crossing the border nor do we quantify other transactions costs associated with crossing borders, including tariffs, obtaining travel permits etc. We also do not account for border closure days. Accounting for all of these additional factors would presumably only reduce our external market access measures. Put differently, our external market access proxies might be conservative in the sense that by not accounting for these additional frictions we allow for a maximal impact of external market access.

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 equipped to track lights for large and more developed cities, while the top-coded series may be preferred when tracking smaller less developed locations.

Top-coded data are recorded annually while bottom-coded data are 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 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-differences approach. For completeness, the same difference-in-differences 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 constitutes a valuable robustness check in and of itself.

6 Results

To set the stage, columns 1 and 2 of Table 2 present first stage regressions using the natural log of market access as dependent variable and the checkpoint donut count, the number of checkpoints located in a radius between 10 and 25km from the locality 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 2.8 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.

6.1 Main findings

Turning to the main specifications, Table 2 presents estimates of equation 2. Lights emissions are clearly strongly and significantly correlated with market access. Simple

Table 1: First Stage Regressions

	(1)	(2)	(3)
	ln Market Access	ln Market Access	Checkpoints 10-25km
	OLS	OLS	OLS
Checkpoints 10-25km	-0.0276*** (3.62)	-0.0276*** (3.65)	
ln(1+Pal.Fat.<5km)		0.0147 (0.52)	0.0720 (0.62)
ln(1+Isr.Fat.< 5km)		-0.00446 (0.06)	-0.00354 (0.01)
Year FE	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes
N	1920	1920	1920
R^2	0.375	0.375	0.479

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Heteroscedasticity robust t -statistics clustered by locality in parentheses, *Pal.Fat.<5km* (*Isr.Fat.<5km*) denotes the number of Palestinian (Israeli) fatalities within a 5km radius in a given calendar year (Source: B'Tselem). *Checkpoints 10-25km* is the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA). *Market Access* is calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function with $\theta = 3$ (see Section 3 for details).

OLS estimates presented in column 1 imply that a 10 percentage points increase in market access increases lights by 0.4 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 0.12 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 lights and market access strengthens substantially. According to our preferred IV estimates that control for local violence, presented in column 4, a 10 percentage points increase in market access leads to a 2.6 percentage point increase in lights emissions (or a 0.8 percentage point increase in local GDP). Similar estimates are obtained when local violence is not controlled for.¹⁹ OLS estimates of the relationship between market access and lights are thus downward biased (a finding which is consistent with existing studies, see e.g. Jedwab and Storeygard (2017), Redding and Turner (2015)). We speculate that this in part reflects attenuation bias due to measurement error in our market access measure. Alternatively, it may reflect the effect of trade costs unrelated to travel time (see the discussion in Section 5.1). While our estimates of the market

¹⁹Regressions that do not control for local violence are not reported to conserve space but are available upon request.

access elasticity are significant, both statistically and economically, they are notably smaller than the estimates obtained by Donaldson and Hornbeck (2016) for the United States and by Alder (2017) for India. This may reflect the difference in size of the geographic areas (the West Bank fits almost 600 times in India and over 1700 times in the United States) and/or the difference in frequency (we examine annual changes where other studies examine changes over decades).

Table 2: 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	0.0399** (2.58)	0.0396** (2.56)	0.263** (2.56)	0.264*** (2.61)
ln(1+Pal.Fat.<5km)		0.00955 (1.12)		0.00670 (0.63)
ln(1+Isr.Fat.<5km)		0.0170 (1.01)		0.0180 (0.80)
Year FE	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes
N	1920	1920	1920	1920
R^2	0.467	0.468	0.312	0.311

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Heteroscedasticity robust t -statistics clustered by locality in parentheses. *NTL pc* measures local (top-coded) Lights emissions per capita (Source: NOAA) as described in section 4. *Market Access* is calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function with $\theta = 3$ (see Section 3 for details). *Pal.Fat.<5km* (*Isr.Fat.<5km*) denotes the number of Palestinian (Israeli) fatalities within a 5km radius in a given calendar year (Source: B'Tselem). In columns 3 and 4 *Market Access* is instrumented using *Checkpoints 10-25km*, the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA).

6.2 Robustness checks

Robustness checks for our preferred IV estimates that control for local violence (column 4 of Table 2) are presented in Table 3. Columns 1-4 demonstrate how our estimates change when alternative distance decay parameters are used, notably $\theta = 1$, $\theta = 2$, $\theta = 4$, and $\theta = 6$, respectively.²⁰ While the choice of the distance decay parameter impacts the magnitude of the coefficients, the qualitative pattern of results remains the same; market access is significantly positively correlated with lights, irrespective of the choice of the distance decay parameter. Note that as θ increases the regression coefficient associated with log market access decreases mechanically. The impact of a one standard deviation in log market access on log NTL per capita is arguably less sensitive to the choice of distance decay parameter. Multiplying the regression coefficients reported in Table 3 obtained for different distance decay parameters with one standard deviation of the corresponding log market access measure yields estimates that range between 0.24 and 0.59. A similar degree of stability of this effect with respect to varying the distance decay parameter is obtained by Jedwab and Storeygard (2017), who examine the effect of changes in market access on local population growth.

Second, one may be concerned that the association between market access and lights reflects population movements (which are potentially endogenous to economic prospects as alluded to in section 5.2). To address this concern, column 5 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/or differential population growth.

Third, column 6 presents estimates for an augmented measure of market access in which access to external markets is proxied for by including Tel Aviv as an additional destination. We hold the population fixed (so that we don't have to take a stance on the evolution of the size of the external market over time) and use a distance decay parameter of 3. The resulting coefficient estimate is very similar to the estimate that only considers domestic markets, suggesting that our findings are robust to controlling for changes in external market access. Inflating the size of the external market does not alter this conclusion, as is shown in Appendix Table 6.

Table 4 presents estimates of the change in the log of 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)

²⁰Note that a higher distance decay parameter θ implies that relatively remote locations are given less weight in the market access measure.

Table 3: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
	ln NTL pc IV	ln NTL pc IV	ln NTL pc IV	ln NTL pc IV	ln NTL pc IV	ln NTL pc IV
MA=Market Access		Varying Distance Decay			fixed pop.	External MA
ln MA ($\theta = 1$)	0.657*** (2.73)					
ln MA ($\theta = 2$)		0.332*** (2.71)				
ln MA ($\theta = 4$)			0.243** (2.45)			
ln MA ($\theta = 6$)				0.221** (2.12)		
ln MA ($\theta = 3, p\bar{op}$)					0.266*** (2.59)	
ln MA ($\theta = 3, \text{incl. ext.}$)						0.275** (2.57)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1920	1920	1920	1920	1920	1920
R^2	0.374	0.360	0.235	0.044	0.306	0.300

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Heteroscedasticity robust t -statistics clustered by locality in parentheses. *NTL pc* measures local (top-coded) Nighttime Lights emissions per capita (Source: NOAA) as described in Section 4. *Market Access* is calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function. The choice of the distance decay parameter θ is indicated in the variable names (see Section 3 for details). In columns 1, 2 and 3, population counts are allowed to vary over time, whereas in columns 4, 5 and 6, they are kept constant (as is indicated by $p\bar{op}$), such that all variation in market access is driven by obstacle deployment. The augmented market access measure in column 6 adds Tel Aviv as a 12th destination (in addition to the 11 governorate capitals) and assigns it a population of 1 million in order to proxy for external market access. *Pal.Fat.<5km (Isr.Fat.<5km)* denotes the number of Palestinian (Israeli) fatalities within a 5km radius in a given calendar year (Source: B'Tselem). *Market Access* is instrumented using *Checkpoints 10-25km*, the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA).

top-coded data (columns 1 and 2) and bottom-coded data (columns 3 and 4). Changes in market access are a strong and significant predictor of changes in lights, irrespective of which datasource is used; ceteris paribus, localities with bigger improvements in market access also experienced larger increases in 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 OLS estimates of the market access elasticity are slightly lower when using bottom-coded data, hinting at the possibility that less developed localities (whose natural light emissions are 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 4: Difference-in-Differences Regressions (2006-2010)

	(1)	(2)	(3)	(4)
	Top Coded		Bottom Coded	
	$\Delta \ln$ NTL pc	$\Delta \ln$ NTL pc	$\Delta \ln$ NTL pc	$\Delta \ln$ NTL pc
	OLS	IV	OLS	IV
$\Delta \ln$ Market Access	0.0457** (2.04)	0.323** (2.20)	0.0161 (0.71)	0.342** (2.16)
$\Delta \ln(1+Pal.Fat.<5km)$	-0.00884 (-0.42)	-0.0936* (-1.83)	0.0694*** (3.00)	-0.0301 (-0.56)
$\Delta \ln(1+Isr.Fat.<5km)$	0.0740** (2.29)	0.0945** (2.12)	-0.0679* (-1.81)	-0.0438 (-0.71)
Constant	0.0464 (0.49)	-1.096* (-1.82)	-0.324*** (-3.41)	-1.666** (-2.57)
N	239	239	239	239
R^2	0.031	0.207	0.071	0.323

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Heteroscedasticity robust t -statistics in parentheses. $\Delta \ln$ NTL pc measures the change in the natural log of local lights emissions per capita between 2006 and 2010 (Source: NOAA) as described in section 4. Columns 1 and 2 use (conventional) top-coded data, while columns 3 and 4 use bottom-coded data (see section 4). $\Delta \ln$ Market Access is the change in the natural log of market access between 2006 and 2010 calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function with $\theta = 3$ (see Section 3 for details). $\Delta \ln(1+Pal.Fat.<5km)$ ($Isr.Fat.<5km$) measures the change in the number of Palestinian (Israeli) fatalities within a 5km radius (Source: B'Tselem). In columns 2 and 4 $\Delta \ln$ Market Access is instrumented using both the level and the first difference of *Checkpoints 10-25km*, the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA).

6.3 Counterfactual output estimates

We conclude our analysis with a back-of-the-envelope calculation of the costs of mobility restrictions in terms of forgone output. Specifically, we simulate how much higher lights per capita would have been had obstacles not been present in the West Bank holding all else equal. The results are presented in Figure 14. Using our preferred distance decay parameter of 3, in 2005, lights per capita would have been 25 percentage points higher had there not been any mobility restrictions. Put differently, GDP would have been about 7.5% higher in 2005 assuming a GDP to lights elasticity of 0.3. Over time, however, restrictions have been alleviated, such that, by 2012, the cost of mobility restrictions amounted to approximately 6% of GDP. The easing of mobility restrictions has thus catalyzed growth.

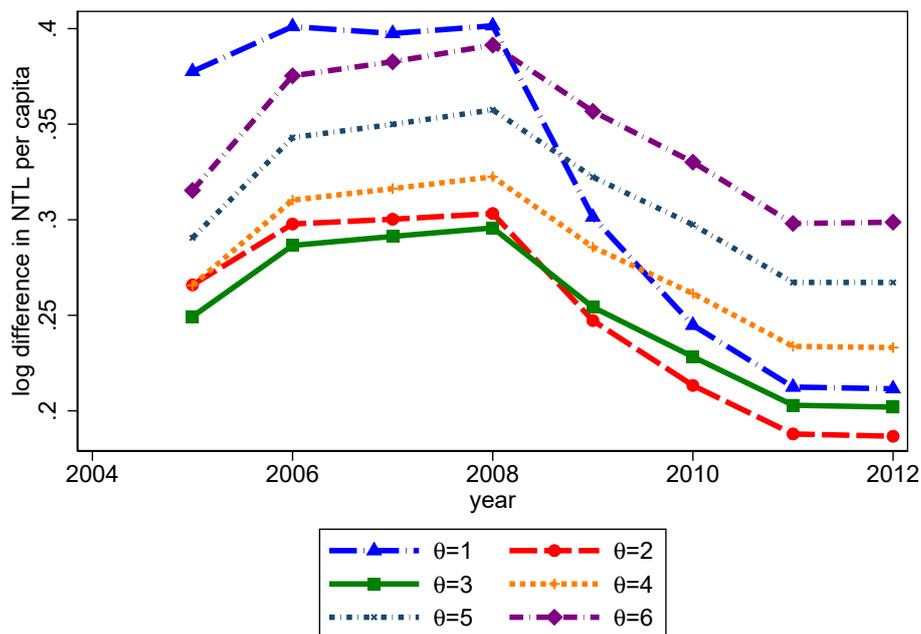
These estimates must be interpreted with caution, as they are sensitive to the choice of the distance decay parameter; for instance, with a distance decay parameter of 6, the estimated GDP per capita loss amounts to 11% in 2006 and to 9% in 2012. On average, over the period 2005-2012 road closure obstacles reduced GDP per capita in the West Bank between 7.5% and 10.5% each year by repressing market access. These estimates are of course also sensitive to the assumed elasticity of lights with respect to GDP. Moreover, the 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 usually evolves slowly and non-randomly. In this paper we exploit the repeated redeployments of Israeli road obstacles along the internal road network of the West Bank as plausibly exogenous spatio-temporally disaggregated shocks to market access of Palestinian towns. Complementary to other studies, which have mostly focused on large long-term shocks to market access resulting from once-in-a-generation transportation network extensions, our study examines the intensive margin, quantifying the economic losses and gains caused by year-to-year enhancements or deteriorations to inter-city transit. More importantly, previous studies have focused on countries with large internal markets, such as China, India, and the United States. We study the West Bank, a territory roughly twice the size of the average American county.

Despite these contextual differences, our findings resonate with this broader literature, confirming the importance of spatial interdependence in the productivity of

Figure 14: Counterfactual output in the West Bank in the absence of restrictions



Counterfactual output in the West Bank in the absence of restrictions (using different distance decay parameters θ)

market economies. We find that the localized, temporary, and reversible shocks to road network connectivity significantly impact economic output (proxied for by nighttime lights). The association between market access and nighttime lights 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 25 km from the locality. The relationship is furthermore robust to using alternative market access and nighttime lights measures, and also obtains when estimating a difference-in-differences specification using 4-year changes in nighttime lights and market access. A back-of-the-envelope calculation suggests that over the period 2005-2012 market access constraints resulting from the deployment of road closure obstacles reduced GDP per capita in the West Bank between 7.5% and 10.5% on average each year.

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8 Appendix

Table 5: Summary statistics

	Mean	Std. Dev.	Min	Max	N
ln NTL pc	-3.115	0.713	-5.405	-0.896	1920
ln NTL pc - deblurred	-3.023	0.937	-7.195	-0.308	1920
ln Market Access ($\theta = 3$)(default)	1.195	1.278	-2.214	4.045	1920
ln Market Access ($\theta = 1$)	8.672	0.359	7.8	9.649	1920
ln Market Access ($\theta = 2$)	4.762	0.805	2.723	6.774	1920
ln Market Access ($\theta = 4$)	-2.229	1.747	-7.06	1.333	1920
ln Market Access ($\theta = 6$)	-8.928	2.66	-16.49	-4.084	1920
ln Market Access ($\theta = 3, p\bar{o}p$)	1.17	1.27	-2.225	3.904	1920
ln Market Access (incl. external) ($\theta = 3, p\bar{o}p$)	1.187	1.254	-2.12	3.904	1920
ln(1+Pal.Fat.<5km)	0.374	0.671	0	3.85	1920
ln(1+Isr.Fat.<5km)	0.067	0.247	0	1.946	1920
Checkpoints 10-25km	17.407	8.592	0.417	41.083	1920

Notes: *NTL pc* measures local (top-coded) Nighttime Lights emissions per capita (Source: NOAA) as described in Section 4. *Market Access* is calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function. The choice of the distance decay parameter θ is indicated in parentheses, $p\bar{o}p$ denotes that the population is held constant such that all variation in market access is driven by obstacle deployment (see Section 3 for details). *Pal.Fat.<5km* (*Isr.Fat.<5km*) denotes the number of Palestinian (Israeli) fatalities within a 5km radius in a given calendar year (Source: B'Tselem). *Checkpoints 10-25km* is the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA).

Table 6: Alternative Measures of External Market Access

	(1)	(2)	(3)	(4)	(5)
	ln NTL pc	ln NTL pc	ln NTL pc	ln NTL pc	ln NTL pc
	IV	IV	IV	IV	IV
External market (millions)	0.5	1	2	5	10
ln MA (ext pop=0.5)	0.271*** (2.58)				
ln MA (ext pop=1)		0.275** (2.57)			
ln MA (ext pop=2)			0.283** (2.56)		
ln MA (ext pop=5)				0.306** (2.51)	
ln MA (ext pop=10)					0.343** (2.44)
Fatality controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Locality FE	Yes	Yes	Yes	Yes	Yes
N	1920	1920	1920	1920	1920
adj. R^2	0.199	0.195	0.189	0.169	0.134

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Heteroscedasticity robust t -statistics clustered by locality in parentheses. *NTL pc* measures local (top-coded) Nighttime Lights emissions per capita (Source: NOAA) as described in Section 4. *Market Access* is calculated using: $MA_{it} = \sum_j h(T_{ijt})P_{jt}$, where P denotes destination population, T denotes travel time, and $h(T) = T^{-\theta}$ is a distance decay function. The set of destinations comprises the 11 governorate capitals and Tel Aviv, which serves to represent external markets. The size of the external market varies depending on the population assigned to Tel Aviv, indicated in the column headings. The choice of the distance decay parameter θ is 3 to allow for maximum impact of external market access (see Section 3 for details). Population counts are kept constant, such that all variation in market access is driven by obstacle deployment. *Pal.Fat.<5km (Isr.Fat.<5km)* denotes the number of Palestinian (Israeli) fatalities within a 5km radius in a given calendar year (Source: B'Tselem). *Market Access* is instrumented using *Checkpoints 10-25km*, the number of checkpoints deployed in a radius between 10 and 25km away from the locality's center (Source: UNOCHA).