The Effects of Transport Infrastructure on India's Urban and Rural Development*

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Abstract

This paper uses a two-sector domestic trade model to study urban and rural development in India over the past decade. Based on a version of the market access approach proposed by Donaldson and Hornbeck (2016), we derive general equilibrium relationships between a sector's income and it's access to markets in both the urban and rural sectors. While the one-sector model that is often used in the literature predicts a constant elasticity of income with respect to market access, the two-sector version allows for heterogeneous effects. We use satellite data to measure urban and rural growth in 5,900 sub-districts where we assign areas to either urban or rural sectors based on a threshold for urban light intensity. In order to estimate the relationship between income and market access, we exploit changes in transportation infrastructure that have led to reductions in travel times on the computed shortest path. The implied reduction in trade costs generates variation in the market access measures. This time variation allows us to estimate the elasticity of income in each sector with respect to market access in the own and the other sector. The results suggest that both urban and rural market access are each individually strongly correlated with income, but they are empirically difficult to disentangle when estimating jointly. We then study the role of various complementary factors that potentially play different roles for urban and rural production and could imply heterogeneous effects of transport infrastructure. We consider natural resources like ground water, rainfall, temperature, and the availability of crop land, as well as measures for human capital. The evidence on interaction effects is mixed and mostly suggests that the effect of market access is relatively stable.

Keywords: India, spatial development, urbanization, infrastructure, market access environment

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1 Introduction

India is urbanising and the economy is undergoing a structural transformation. The spatial dimension of this development patterns is crucial because the degree and form of urbanisation will have long-lasting implications for how the economy is organized and how efficiently resources can be used now and in the future. The availability of infrastructure and the provision of public services in general are important determinants of these development patterns. Therefore, the public sector and development banks have a great interest in research that provides a sound understanding of the development patterns and that sheds light on the effectiveness of public investments.[1]

One challenge for such studies is that large investments such as a transport infrastructure network, can lead to relocation of economic activity. Their effects therefore often need to be considered in a spatial equilibrium context that takes into account spillovers across locations. Furthermore, the effect of an investment may depend not only on its magnitude, but also on the location and on the availability of complementary factors affecting firms' production and households' living conditions.

We address these challenges by analysing India's spatial development with the aid of a two-sector trade model based on Donaldson and Hornbeck (2016), henceforth DH, and Eaton and Kortum (2002), henceforth EK.[2] We model urban and rural production as taking place in two different sectors that use factor inputs, such as natural resources, human capital, and physical capital with different intensities. This implies that an investment that improves transport infrastructure can have heterogeneous effects that depend on the type of production in that location. The general equilibrium nature of the model allows us to take

[1]For example, the World Bank's World Development Report states that "spatially connective infrastructure" is crucial for market integration and plays a key role in shaping economic geography (World Bank, 2009).

[2]DH discuss this two-sector extension of their baseline model in their appendix. We simplify their model by not allowing for intermediate inputs. See also Roberts et al. (2012) and Bosker et al. (2015) for two-sector new economic geography models.

into account how mobile production factors relocate across locations and how trade flows change as a consequence of public investments. There can therefore be spillover effects of location-specific investments.

We follow the "market access approach" proposed by DH, which captures the effect of improvements in transport infrastructure through the channel of market access. While market access is a general equilibrium object, it intuitively captures how well one location is connected to all other domestic locations. We allow for two different sectors in the economy. Locations that belong to the urban sector only produce goods in that sector, while rural locations only produce rural goods. Within each sector, there is a continuum of varieties of good as in EK. Similar to Alder (2017), for the case of one sector, we solve the model for real income. We obtain that real income in a location with a given sector depends on its consumer market access to each sector (consumers' ability to buy goods from each sector) as well as firm market access (firms' ability to sell to locations with any sector). Hence, while urban market access captures the access to urban locations and rural market access captures the access to rural locations, firm market access includes both sectors. From the perspective of each sector, all types of market access matter because consumers demand goods from both the urban and rural sectors and firms can sell to both markets. But since the two sectors use production factors with different intensities and consumers may value the two types of goods differently, the effect of market access can vary across urban and rural locations. For example, urban production makes greater use of mobile production factors and can thus adjust more to new economic conditions after a change in the transportation network, implying that the effect of firm market access depends on the sector's type of production. The effect of urban and rural market access depends on the importance of these two types of goods for consumers.

The model suggests a straightforward way to quantify the effect of investments in transport infrastructure when taking into account general equilibrium effects and heterogeneity across locations. Furthermore, the model also delivers testable predictions regarding the relative importance of production factors and market access in the two sectors. In order to take the model to the data, we use satellite images of night-time lights, transportation networks, environmental variables, and census data. First, we construct measures of urban and rural income for 5,990 Indian sub-districts between 2001 and 2011.[3] The classification of income (as measured by light) into urban and rural is based on a threshold for the light intensity, above which a light pixel is likely to be urban.[4] Second, we digitise scanned images of historical road atlases and compute shortest paths, as in Allen and Atkin (2016) and Allen and Arkolakis (2014), for each version of the road network.[5] This allows us to calculate changes in transportation costs and thus changes in market access over time. Third, we use environmental variables at the sub-district level from the World Bank's South Asia Database, which includes information on terrain, irrigation, and pollution. Fourth, we use data on literacy rates from the same database in order to approximate human capital.

The elegant structure of the DH framework allows us to estimate the relationship between income of a location (with a given sector) and the three different market access measures. Once the general equilibrium measures for market access are computed, the equations can be estimated in reduced form. In order to account for time-invariant unobserved heterogeneity, we estimate the equations in log differences and exploit time variation in income, market access, and production factors to estimate the constant elasticities of income with respect to each of these variables. As an alternative approach, we also estimate the one-sector version of the model as in Alder (2017), and use interaction effects between the market access measures and various location characteristics in order to test for potential heterogeneous effects.

Our findings suggest that a measure of overall market access is positively as-

[3]The administrative boundaries for districts and sub-districts were obtained from the South Asia Database of the World Bank. We are grateful to Yue Li and her team for making these data available.

[4]Alternatively, we also use the official classification of urban and rural areas based on the census. See Harari (2016) and our companion paper Tewari et al. (2017) for a more detailed discussion of the use of light thresholds.

[5]We are grateful to Treb Allen and David Atkin for sharing the historical road atlas data and the code with us.

sociated with income (as proxied by light). Urban and rural market access play different roles, with the one of rural market access typically being stronger. But the two types of market access are empirically difficult to disentangle. The evidence on interaction effects between market access and local characteristics is mixed and in most cases the effect of market access appears to be relatively stable.

The rest of this paper is structured as follows. Section 2 discusses the related literature, section 3 presents the model, section 4 describes the data, section 5 presents the results, and section 6 concludes.

2 Related literature

We contribute to the following strands in the literature

India's spatial development The spatial development of emerging economies like India has received increasing attention in the literature during recent years. One reason is that there is an awareness that the form of spatial development may have important long-run consequences on growth and living conditions. In our companion paper, Tewari et al. (2017), we map India's spatial development across states, districts, and cities, and document growth and convergence patterns. Using light data, we find that there was overall convergence during the period from 2001 to 2011, but there are substantial differences across regions. We also identify a number of variables that are correlated with growth, such as urban form and environmental factors. In this paper, we complement that descriptive evidence by using the structure of a general equilibrium model to identify the economy-wide effects of infrastructure investments and to analyse the role of complementary factors, such as the environmental variables or human capital. Desmet et al. (2015) study India's spatial development using employment data and find that there is less convergence than, for example, in China and in the USA, especially in the service sector. Furthermore, medium-sized cities appear to grow less and they point to the possibility that there may be constraints that prevent these cities from growing more. Das et al. (2014) use GDP data for Indian districts from 2001 to 2008 to study convergence. They find significant convergence when conditioning on district characteristics like initial urbanisation, electrification, land irrigation, etc. However, they find that without conditioning on these characteristics, there is no significant convergence or even divergence. Our work differs from theirs by using night-time light data from satellites and by building on a general equilibrium model in order to identify the contribution of infrastructure investments across locations that may be driving part of the spatial development patterns. Harari (2016) focuses on Indian cities and how wages and rents are affected by the shape of the city. She uses exogenous determinants of city shape based on geography, and finds that measures of urban form such as compactness play an important role. She also considers the contribution of roads within cities, as these mitigate costs due to a lack of compactness. Unlike Harari (2016), we focus on how roads improve connections among urban and rural sub-districts, rather than within cities and we consider how this effect may depend on location characteristics.

Transportation and development in India A number of recent papers have studied the effects of transport infrastructure in India. Several of these papers have focused on specific highway networks. For example, Datta (2012) and Ghani et al. (2016) estimate the effect of the Golden Quadrilateral, a network of modern highways that connect India's four largest economic centres, on several firm-level outcomes in the proximity of the new or upgraded highways. Khanna (2016) uses light data at the level of Indian sub-districts to estimate the effects of the Golden Quadrilateral. Our work differs from these studies by using a spatial general equilibrium framework, considering highway investments more broadly, and focusing on heterogeneous impacts.

Alder (2017) also studies the Golden Quadrilateral and uses a general equilibrium trade framework combined with satellite data to quantify the effects on aggregate growth and inequality across Indian districts. He uses a one-sector model based on DH in order to analyse the Golden Quadrilateral and perform counterfactual analysis. Our work builds closely on Alder (2017), but uses a two-sector version of the model, considers the evolution of the transport network more broadly instead of focusing on the Golden Quadrilateral, and allows for interaction effects between transportation infrastructure and local factors. Asturias et al. (2016) also consider the general equilibrium effects of the Golden Quadrilateral, but they use a model with variable markups, focus on the manufacturing sector at the state-level, and don't consider interaction effects with local production factors such as land quality and human capital as we do.

A number of related papers look at other changes in transportation infrastructure. We rely on the road atlas images used in and provided by Allen and Atkin (2016), which allows us to consider the broad changes in the network over time, while Allen and Atkin (2016) use these changes to estimate effects on volatility and crop choices based on agricultural micro-data. Van Leemput (2015) compares the effects from domestic and international market integration in India using state-level data. Donaldson (forthcoming) uses the expansion of the colonial railway network in India to estimate the effect of market integration in a historical context. Asher and Novosad (2016) consider a programme that improved rural villages' market access with paved roads and they find that the programme affects sectoral allocation.

Transportation and development in other countries Our model and estimation approach is based on a two-sector version of DH. DH focus on the effect of the American railway network on land prices in the late 19th century. Their baseline framework is a one-sector model but they also present the two two-sector model in order to highlight the similarity in the key relationship between income and various measures of market access. We instead measure market access in the two sectors separately and furthermore consider interaction effects between market access and local factors in both the one- and two-sector version.

Our work is also related to Jedwab and Storeyguard (2016) who study the heterogeneous effects of transport infrastructure in Africa. They focus on the period 1960 to 2012 using data on city population and transportation networks. Their units of observation are cells of about 120 square kilometres. Like us, they use the market access approach in DH to estimate the impact of road investments. Our work differs from theirs by building explicitly on a two-sector model with urban and rural regions, which provides a theoretical foundation for heterogeneous effects of roads. Furthermore, we use light data as a measure of economic activity and can differentiate between urban and rural growth. We also consider a different set of location characteristics, such as natural resources and human capital.

We also relate to Roberts et al. (2012) and Bosker et al. (2015). Both of studies use a two-sector new economic geography model to estimate the impact of the Chinese National Expressway Network. Our study differs from their work by using an EK type model and by using time variation in both transportation costs and income in order to estimate the effect. Furthermore, we consider a large set of location characteristics, such as natural resources and human capital, that allow us to test for heterogeneous effects in addition to different spatial effects across regions and sectors.

3 A two-sector trade model with urban and rural locations

We build our analysis on a two-sector trade model that allows us to consider the role of urban and rural production separately. The model is based on DH and EK.[6] Because of its convenient structure, this model leads to an intuitive relationship between income and market access and it highlights a channel through which transport infrastructure investments can affect income. We present a version of the model with two sectors, a rural sector and an urban sector. Because the two sectors use production factors such as local resources with different intensities, the model predicts that these factors are of different importance in the

[6] We build on DH who present such a two-sector model in their appendix. The difference from the extension presented in DH is that we consider a version without intermediate inputs.

two sectors, allowing for the possibility of interaction effects. Furthermore, urban and rural market access may have different effects on income in each sector. We present different versions with mobile and immobile labor in order to consider the role of labour mobility. In our baseline model, the rural and urban economies interact through the final goods market. Because consumers in urban and rural regions each want to consume goods from both sectors, they are affected by the access to both types of markets.

In a similar way to Alder (2017), we adapt the DH framework to a version that can be estimated with satellite data on night-lights and with digitised geographic data. We assume that Indian sub-districts produce locally using physical capital, human capital (labour), and resources (land, water, etc.) as inputs. Each location (sub-district) produces either rural varieties or urban varieties of goods. Capital is assumed to be mobile across locations, while in the baseline both labour and resources are assumed to be immobile.[7] As in EK, each location has a productivity distribution over a continuum of varieties of goods and the distribution depends on the sector. The locations can then trade with each other and we denote the origin of a trade by o and the destination by d.

3.1 Preferences

Consumers have constant elasticity of substitution (CES) preferences over goods varieties indexed by j and they weigh rural goods with μ and urban goods with $1-\mu$,

$$U_o = \left[\left(\int_j x_o^R(j)^{\frac{\sigma_R - 1}{\sigma_R}} dj \right)^{\frac{\sigma_R}{\sigma_R - 1}} \right]^{\mu} \left[\left(\int_j x_o^U(j)^{\frac{\sigma_U - 1}{\sigma_U}} dj \right)^{\frac{\sigma_U}{\sigma_U - 1}} \right]^{1-\mu},$$

where $x_o(j)$ is the quantity consumed of variety j by a consumer in location o. $\sigma_i > 0$ is the elasticity of substitution between varieties and can differ for the rural sector and urban sector. Indirect utility is

$$V(\mathbf{P_o}, Y_o) = \frac{Y_o}{(P_o^R)^{\mu}(P_o^U)^{1-\mu}},$$

[7]The version with mobile labour is presented in the appendix.

where $\mathbf{P_o}$ is a vector of the price indices in the two sectors, P_o^R and P_o^U, and Y_o is nominal income. The CES price indices are given by

$$\begin{aligned} P_o^U &= \left(\int_0^{\eta_U} p_o^U(j)^{1-\sigma_U} dj \right)^{\frac{1}{1-\sigma_U}} \\ P_o^R &= \left(\int_0^{\eta_R} p_o^R(j)^{1-\sigma_R} dj \right)^{\frac{1}{1-\sigma_R}}, \end{aligned}$$

where η denotes the measure of varieties produced in each sector and $p_o(j)$ is the price of each variety.

3.2 Production technology

The production technology is the same in the two sectors except for parameter values that determine factor shares. We denote the type of a location (i.e. the sector) as i and write $i = r$ for rural locations (producing rural varieties) and $i = u$ for urban locations (producing urban varieties). We denote by S^i the set of locations in sector i. When we specifically refer to the set of the urban sector, then we denote it by $\mathcal{U}$ and analogously for the rural sector by $\mathcal{R}$.

Each location produces varieties with a Cobb–Douglas technology using local resources (R), human capital (H), and physical capital (K),

$$x_o^i(j) = z_o^i(j) \big(R_o(j)\big)^{\alpha_i} \big(H_o(j)\big)^{\gamma_i} \big(K_o(j)\big)^{1-\alpha_i-\gamma_i}.$$

Note that the factor shares are sector-specific, which will be important for the different roles of urban and rural market access and for the heterogeneity in the effects. The amounts of resources in o are fixed and we use the term resources in a general way to denote the effective inputs of a fixed factor that varies in supply across locations. This could, for example, be (quality-adjusted) land, availability of water, or other infrastructure such as electricity.

The production function implies marginal costs

$$MC_o^i(j) = \frac{q_o^{\alpha_i} w_o^{\gamma_i} r_o^{1-\alpha_i-\gamma_i}}{z_o^i(j)},$$

where q_o is the rental rate of the local resource, w_o is the wage rate, and r_o is the interest rate. As in EK, each location draws its productivity $z_o^i(j)$ from a Fréchet distribution with a cumulative distribution function (CDF)

$$F_o(z) = Pr[Z_o \leq z] = \exp(-T_o^i z^{-\theta_i}),$$

where $\theta > 1$ determines the variation of productivity within locations (comparative advantage). θ could potentially differ for rural and urban locations, but for the analysis below it is set equal for both sectors, for simplicity. T_o^i is a location's overall productivity (absolute advantage).

3.3 Transport costs and prices

Trade costs between locations o and d are modelled according to the "iceberg" assumption, i.e. for one unit of a good to arrive at its destination d, $\tau_{od} \geq 1$ units must be shipped from origin o. Therefore, if a good is produced in location o and sold there at the price $p_{oo}(j)$, then it will be sold in location d at the price $p_{od}(j) = \tau_{od} p_{oo}(j)$. To simplify the analysis, we assume that trade costs for a given type of road are equal in the urban sector and rural sectors.[8]

Since we assume perfect competition, prices equal the marginal costs of producing each variety:

$$\begin{aligned} p_{oo}^i(j) &= MC_o^i(j) = \frac{q_o^{\alpha_i} w_o^{\gamma_i} r_o^{1-\alpha_i-\gamma_i}}{z_o^i(j)} \\ p_{od}^i(j) &= \tau_{od} MC_o^i(j) = \tau_{od} \frac{q_o^{\alpha_i} w_o^{\gamma_i} r_o^{1-\alpha_i-\gamma_i}}{z_o^i(j)} \\ z_o^i(j) &= \tau_{od} \frac{q_o^{\alpha_i} w_o^{\gamma_i} r_o^{1-\alpha_i-\gamma_i}}{p_{od}^i(j)} \end{aligned} \tag{1}$$

Consumers find the cheapest price of each variety in each sector and the distribution of prices is governed by the productivity distribution. As in EK, the price index then takes the form

$$P_d^i = \lambda_i (\Phi_d^i)^{-\frac{1}{\theta}} \tag{2}$$

[8]The average trade costs in the two sectors can still differ because the roads that connect urban and rural locations can be of different type or quality.

with

$$\lambda_i \;=\; \left[\Gamma\left(\frac{\theta+1-\sigma_i}{\theta}\right)\right]^{\frac{1}{1-\sigma_i}},$$

where Γ is the Gamma function. With perfect capital mobility, the rental rate for capital is equalised everywhere to $r_o = r$. Note that the destination-specific parameter $\Phi_d^i = \sum_o \left[T_o^i \big(\tau_{od} q_o^{\alpha_i} w_o^{\gamma_i} r_o^{1-\alpha_i-\gamma_i}\big)^{-\theta}\right]$ captures the exposure of destination d to other locations' technology, factor costs, and trade costs.

Similar to DH, we define

$$\kappa_1^i = \lambda_i^{-\theta} r^{-(1-\alpha-\gamma_i)\theta}$$

and obtain

$$\begin{aligned}(P_d^i)^{-\theta} &= \kappa_1^i \sum_{o\in S^i} \left[T_o^i \big(\tau_{od} q_o^{\alpha_i} w_o^{\gamma_i}\big)^{-\theta}\right] \\ &= \kappa_1^i \sum_{o\in S^i} \left[T_o^i \big(q_o^{\alpha_i} w_o^{\gamma_i}\big)^{-\theta} \tau_{od}^{-\theta}\right] \equiv CMA_d^i. \end{aligned} \tag{3}$$

DH refer to CMA_d as "consumer market access" (CMA) since it measures location d's access to low-cost goods (i.e. low production costs in supplying location that can be reached with low trade costs). In our case, CMA_d^i denotes location d's consumer market access to varieties from sector i.

3.4 Trade Flows and Gravity

Similar to EK, the fraction of expenditure of location d on goods from location o is

$$\begin{aligned}\frac{X_{od}^i}{X_d^i} &= \frac{T_o^i \big(q_o^{\alpha_i} w_o^{\gamma_i} r^{1-\alpha_i-\gamma_i}\big)^{-\theta} \tau_{od}^{-\theta}}{\Phi_d^i} \\ &= \frac{T_o^i \big(q_o^{\alpha_i} w_o^{\gamma_i} r^{1-\alpha_i-\gamma_i}\big)^{-\theta} \tau_{od}^{-\theta}}{\sum_{k\in S^i} \left[T_k^i \big(q_k^{\alpha_i} w_k^{\gamma_i} r^{1-\alpha_i-\gamma_i}\big)^{-\theta} \tau_{kd}^{-\theta}\right]}. \end{aligned} \tag{4}$$

In this two-sector version of the model, the share is specific to each sector i. The trade flow of sector i goods from o to d is then given by

$$\begin{aligned} X_{od}^i &= \underbrace{T_o^i \left(q_o^{\alpha_i} w_o^{\gamma_i}\right)^{-\theta}}_{\text{Origin's productivity and factor costs}} \\ &\times \underbrace{X_d^i}_{\text{Destination's demand for sector } i \text{ goods}} \\ &\times \underbrace{\left(\sum_{o \in S^i} \left[T_o^i \left(q_o^{\alpha_i} w_o^{\gamma_i}\right)^{-\theta} \tau_{od}^{-\theta} \right] \right)^{-1}}_{\text{Destination's CMA}} \underbrace{\tau_{od}^{-\theta}}_{\text{Trade costs}}, \end{aligned}$$

where the interest rate cancels out because it is equalised across locations.

Using the price index in equation (3), a destination's competitiveness can be written as

$$\sum_{o \in S^i} \left[T_o^i \left(q_o^{\alpha_i} w_o^{\gamma_i}\right)^{-\theta} \tau_{od}^{-\theta} \right] = \frac{CMA_d^i}{\kappa_1^i}.$$

Using this in the trade equation yields

$$\begin{aligned} X_{od}^i &= \underbrace{T_o^i \left(q_o^{\alpha_i} w_o^{\gamma_i}\right)^{-\theta}}_{\text{Origin's productivity and factor costs}} \\ &\times \underbrace{X_d^i}_{\text{Destination's demand for sector i goods}} \\ &\times \underbrace{\kappa_1^i (CMA_d^i)^{-1}}_{\text{Destination's CMA}} \underbrace{\tau_{od}^{-\theta}}_{\text{Trade costs}}. \end{aligned} \tag{5}$$

3.5 Income and market access

As discussed by DH and Alder (2017), equation (5) is a gravity equation with standard features. In particular, trade increases in income of the destination and in productivity of the origin. Furthermore, trade decreases in production costs, trade costs, and in consumer market access of the destination (because it implies more competition in the export market).

Sector i producers in location o can export to both urban and rural destinations. Assuming that goods markets clear, production and income in a location is equal to its total exports (including to itself).[9] Thus, summing over all exports to destinations d leads to total exports of origin o,

$$Y_o^i = \sum_{d \in \mathcal{U},\mathcal{R}} X_{od}^i \quad = \quad \kappa_1^i T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} \sum_{d \in \mathcal{U},\mathcal{R}} \left[\tau_{od}^{-\theta} (CMA_d^i)^{-1} X_d^i \right]. \tag{6}$$

Similar to DH, we define "firm market access" (FMA) of location o as

$$FMA_o^i \equiv \sum_{d \in \mathcal{U},\mathcal{R}} \tau_{od}^{-\theta} (CMA_d^i)^{-1} X_d^i. \tag{7}$$

The income equation is then given by

$$Y_o^i \quad = \quad \kappa_1^i T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} FMA_o^i. \tag{8}$$

FMA_o^i depends positively on all other destinations' demand for that sector's goods, X_d^i, and negatively on their CMA_d^i. The reason for the latter is that a higher consumer market access in d implies that location o faces more competition when exporting to d. Solving equation (8) for productivity and factor costs yields

$$T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} \quad = \quad \frac{Y_o^i}{\kappa_1^i FMA_o^i}.$$

Substituting this into the definition of CMA_d^i allows us to write consumer market access as

$$\begin{aligned} CMA_d^i &= \kappa_1^i \sum_{o \in S^i} T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} \tau_{od}^{-\theta} \\ &= \sum_{o \in S^i} \tau_{od}^{-\theta} (FMA_o^i)^{-1} Y_o^i \\ CMA_o^i &= \sum_{d \in S^i} \tau_{od}^{-\theta} (FMA_d^i)^{-1} Y_d^i. \end{aligned} \tag{9}$$

[9] Note that total total exports are for one sector because a location only produces in one sector. Total imports consist of expenditures on goods from both sectors.

As discussed in DH, in the one-sector model, if trade costs are symmetric, then a solution to equations (7) and (9) must satisfy $FMA_o = \rho CMA_o = MA_o$ for $\rho > 0$. This is not the case in the two-sector model, because consumer market access and firm market access are defined over different sets of locations. In particular, firm market access is defined over *all* locations $\{\mathcal{U}, \mathcal{R}\}$, while consumer market access is defined separately over the locations belonging to each sector $\{S^i\}$.

3.6 Factor mobility

We assume that capital is fully mobile such that the capital rental rate is equalised across locations and sectors. Land is naturally immobile, although we can consider certain changes in land quality due to rainfall and temperature. Labour is likely to be an intermediate case, as it is neither fully mobile over the period 1996-2011 considered here, nor fully immobile. We start by considering the case of immobile labour and the appendix discusses a version of the model where labour is mobile.

Equation (8) shows that income is a function of productivity, factor prices, and firm market access:

$$Y_o^i = \kappa_1^i T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} FMA_o^i.$$

Due to the Cobb–Douglas production function, the rental rates for the immobile factors land and labour are related to their income shares.[10] Hence, we use

$$\begin{aligned} q_o R_o &= \alpha_i Y_o^i \\ w_o H_o &= \gamma_i Y_o^i. \end{aligned}$$

Plugging this in above yields

$$Y_o^i = \kappa_1^i T_o^i \left(\left(\frac{\alpha_i Y_o^i}{R_o} \right)^{\alpha_i} \left(\frac{\gamma_i Y_o^i}{H_o} \right)^{\gamma_i} \right)^{-\theta} FMA_o^i$$

[10] Note that since each location o is either rural or urban sector, the superscript i on income is redundant (as on q_o and R_o) but we keep it for the sake of clarity.

and solving for (nominal) income then leads to

$$Y_o^i = \left(\kappa_1^i T_o^i\right)^{\frac{1}{1+\theta\alpha_i+\theta\gamma_i}} \left(\frac{\alpha_i}{R_o}\right)^{\frac{-\theta\alpha_i}{1+\theta\alpha_i+\theta\gamma_i}} \left(\frac{\gamma_i}{H_o}\right)^{\frac{-\theta\gamma_i}{1+\theta\alpha_i+\theta\gamma_i}} \left(FMA_o^i\right)^{\frac{1}{1+\theta\alpha_i+\theta\gamma_i}}.$$

Luminosity is a measure of real economic activity. We can again use the relationship between the price index and market access from equation (3) ($P_o = (P_o^R)^\mu (P_o^U)^{1-\mu}, P_o^i = (CMA_o^i)^{-\frac{1}{\theta}}$) to get

$$\begin{aligned}
\tilde{Y}_o^i &\equiv \frac{Y_o^i}{(P_o^R)^\mu (P_o^U)^{1-\mu}} \\
&= \left(\kappa_1 T_o^i\right)^{\frac{1}{1+\theta\alpha_i+\theta\gamma_i}} \left(\frac{\alpha_i}{R_o}\right)^{\frac{-\theta\alpha_i}{1+\theta\alpha_i+\theta\gamma_i}} \left(\frac{\gamma_i}{H_o}\right)^{\frac{-\theta\gamma_i}{1+\theta\alpha_i+\theta\gamma_i}} \\
&\quad \left(FMA_o^i\right)^{\frac{1}{1+\theta\alpha_i+\theta\gamma_i}} ((CMA_d^R)^{-\frac{1}{\theta}})^{-\mu} ((CMA_d^U)^{-\frac{1}{\theta}})^{-(1-\mu)}.
\end{aligned}$$

Taking logs yields

$$\begin{aligned}
\ln(\tilde{Y}_o^i) &= \frac{1}{1+\theta(\alpha_i+\gamma_i)} \ln\left(\kappa_1 T_o^i\right) \\
&+ \frac{\theta\alpha_i}{1+\theta(\alpha_i+\gamma_i)} \ln\left(\frac{R_o}{\alpha_i}\right) + \frac{\theta\gamma_i}{1+\theta(\alpha_i+\gamma_i)} \ln\left(\frac{H_o}{\gamma_i}\right) \\
&+ \frac{1}{1+\theta(\alpha_i+\gamma_i)} \ln\left(FMA_o^i\right) \\
&+ \frac{\mu}{\theta} \ln(CMA_d^R) + \frac{(1-\mu)}{\theta} \ln(CMA_d^U). \qquad (10)
\end{aligned}$$

Equation (10) shows that income depends on three types of market access:

1. firm market access captures how well firms producing in location o (with sector i) can sell to consumers in any other location $d \in \mathcal{U}, \mathcal{R}$ (with either of the two sectors);

2. rural consumer market access captures how well consumers in location o can access rural locations $d \in \mathcal{R}$; and

3. urban market access captures how well consumers in location o can access urban locations $d \in \mathcal{U}$.

The market access measures are general equilibrium objects that satisfy the following equations:[11]

$$\begin{aligned}
CMA_o^R &= \sum_{d\in\mathcal{R}} \tau_{od}^{-\theta}(FMA_d^R)^{-1}Y_d, o\in\mathcal{U},\mathcal{R} \\
CMA_o^U &= \sum_{d\in\mathcal{U}} \tau_{od}^{-\theta}(FMA_d^U)^{-1}Y_d, o\in\mathcal{U},\mathcal{R} \\
FMA_o^R &= \sum_{d\in\mathcal{U},\mathcal{R}} \tau_{od}^{-\theta}(CMA_d^R)^{-1}X_d^R, o\in\mathcal{R} \\
FMA_o^U &= \sum_{d\in\mathcal{U},\mathcal{R}} \tau_{od}^{-\theta}(CMA_d^U)^{-1}X_d^U, o\in\mathcal{U}
\end{aligned}$$

Since consumption is a Cobb–Douglas aggregate in rural and urban goods, the share of nominal income spent on each type of good is determined by μ. Hence, we have

$$\begin{aligned}
X_d^R &= \mu Y_d \\
X_d^U &= (1-\mu)Y_d.
\end{aligned}$$

Finally, nominal income equals real income times the price index:

$$Y_d = \tilde{Y}_d \times P_o = \tilde{Y}_d \times (P_o^R)^{\mu}(P_o^U)^{1-\mu} = \tilde{Y}_d \times (CMA_d^R)^{-\frac{\mu}{\theta}}(CMA_d^U)^{-\frac{1-\mu}{\theta}}.$$

Substituting for nominal income and expenditures in the market access equations, we obtain

$$CMA_o^R = \sum_{d\in\mathcal{R}} \tau_{od}^{-\theta}(FMA_d^R)^{-1}(CMA_d^R)^{-\frac{\mu}{\theta}}(CMA_d^U)^{-\frac{1-\mu}{\theta}}\tilde{Y}_d, o\in\mathcal{U},\mathcal{R} \tag{11}$$

$$CMA_o^U = \sum_{d\in\mathcal{U}} \tau_{od}^{-\theta}(FMA_d^U)^{-1}(CMA_d^R)^{-\frac{\mu}{\theta}}(CMA_d^U)^{-\frac{1-\mu}{\theta}}\tilde{Y}_d, o\in\mathcal{U},\mathcal{R} \tag{12}$$

$$FMA_o^R = \sum_{d\in\mathcal{U},\mathcal{R}} \tau_{od}^{-\theta}(CMA_d^R)^{-\frac{\theta+\mu}{\theta}}(CMA_d^U)^{-\frac{1-\mu}{\theta}}\mu\tilde{Y}_d, o\in\mathcal{R} \tag{13}$$

$$FMA_o^U = \sum_{d\in\mathcal{U},\mathcal{R}} \tau_{od}^{-\theta}(CMA_d^U)^{-\frac{\theta+1-\mu}{\theta}}(CMA_d^R)^{-\frac{\mu}{\theta}}(1-\mu)\tilde{Y}_d, o\in\mathcal{U} \tag{14}$$

[11] Note that we now drop the superscript i on income because we have a separate equation for each sector; and each location produces in only one sector. Since consumers in each location demand goods from both sectors, we distinguish demand for the two sectors by X^U and X^R.

General equilibrium market access measures The total number of locations is $N = N^R + N^U$, where N^R and N^U are the number of urban and rural locations, respectively. We take from the data a vector of size N for real income (proxied by light), and the $N \times N$ matrix on bilateral iceberg trade costs, τ_{od}. We have N unknowns for each of CMA^R and CMA^U, N^R unknowns for FMA^R, and N^U unknowns for FMA^U. We solve for the equilibrium market access measures using the $3N$ equations from (11), (12), (13), and (14). Note that this solves the market access equations for given incomes. Following the market access approach, one can then predict income based on market access. However, the implied changes in income also feed back into the market access measures. Although one can solve the equations for income, market access, and a price index for capital jointly, we follow here the market access approach and predict changes in income based on changes in market access.[12]

Approximation of urban and rural market access While these market access measures differ in their exact form and in the sets over which they are defined,[13] they all share the feature that they sum over trade partners' real income, $\tilde{Y}_d^i$, discounted by the bilateral trade cost, τ_{od}. Similar to DH for the one-sector model, we can therefore approximate urban and rural market access by summing over the incomes in the two sectors. This captures in an intuitive way the relationship between income and market access in each sector and thus allows us to study the effect of changes in transport infrastructure through these channels. We therefore write the approximated rural and urban consumer market access measures as

$$MA_o^R \approx \sum_{d \neq o \in \mathcal{R}} \frac{Y_d^i}{\tau_{od}^{\theta}} \tag{15}$$

$$MA_o^U \approx \sum_{d \neq o \in \mathcal{U}} \frac{Y_d^i}{\tau_{od}^{\theta}}. \tag{16}$$

[12]See DH and Alder (2017) for a comparison of results when using the market access approach and when solving the market access, income, and price equations jointly.

[13]See also DH for the case of the two-sector model with intermediate inputs.

Note that urban and rural market access sum to an approximation of firm market access,

$$MA_o \approx \sum_{d \in \mathcal{R},\mathcal{U}} \frac{Y_d^i}{\tau_{od}^{\theta}}, \tag{17}$$

and we will not include this measure in the regressions based on approximations because of collinearity.

Nested one-sector model In the one-sector version of this model (which is a special case), these four equations simplify to just one equation (see Alder, 2017),

$$MA_o = \kappa \sum_d \tau_{od}^{-\theta} MA_d^{\frac{-(1+\theta)}{\theta}} \tilde{Y}_d,$$

where κ is a constant. This one-sector version of the model predicts a constant elasticity of income with respect to market access. We would in this case not expect that the effect of a reduction in trade costs depends on local production factors.[14] One could capture the differences across sectors as predicted by the model also in a reduced form by interacting the one-sector market access measures with indicators for the sectors. However, the advantage of the two-sector model is that it highlights where these differences are coming from, such that they are consistent with the market access framework. The following section will discuss the predictions that can be derived from the model.

3.6.1 Predictions

As discussed above, the different market access measures share the feature that they depend on trade partners' incomes and the bilateral trade costs. The elasticities of income with respect to each market access term depend on the parameters of the utility function and the production function.

[14] For example, the lack of a local production factor would already be reflected in a lower income and the model predicts that a change in market access due to trade costs affects income with a constant elasticity.

Firm market access Firm market access features a higher elasticity when the share of capital in the production function is high, i.e. when the combined share of land and labour, $\alpha_i + \gamma_i$, is low. The capital share is likely to be higher in the urban sector than in the rural sector, and the shares of land and labour are lower. Hence, we expect that $\alpha_R + \gamma_R > \alpha_U + \gamma_U$, which implies that the elasticity of real income with respect to firm market access is higher in the urban sector. This is intuitive, since a higher share of the mobile production factor (capital) implies that these locations can adjust more to increases in their firm market access.

Consumer market access The elasticity of income with respect to each type of consumer market access depends on the share of each type of good in the utility function. When rural goods have a higher weight (i.e. $\mu > 0.5$), then rural consumer market access will have a larger effect on real income. The reason is that a higher rural consumer market access means lower prices for rural goods, and this increases real income more if rural goods have a higher weight in consumption. However, it is empirically not clear whether the weight of urban or rural goods is higher, since the share of expenditures devoted to food is approximately 50% in the Indian national average. The share is higher in rural areas that are also poorer, but this would imply non-homothetic preferences and is beyond the scope of this model.[15]

3.6.2 Empirical implementation

The elasticity of income in each sector with respect to the market access measures can be estimated using data on income and transportation costs. Furthermore, data on production factors such as human capital allow for the testing of the hypothesis that they have distinct roles in determining income in the two sectors.

When changes over time in firm market access, as well as urban and rural market access, can be measured separately, then the respective elasticities can be

[15]By imposing CES utility, we assumed homothetic preferences, such that the income spent on rural goods is the same for rich and poor households. Homothetic preferences is clearly a limitation of the current framework and the assumption is only made for tractability.

estimated using panel data that allow controlling for unobserved time-invariant heterogeneity. The approach in DH and Alder (2017) is to exploit changes in the transportation network as a source of variation in transport costs and market access. In this framework, the effect of transportation infrastructure on income goes through market access. The difficulty in the present context is that it is challenging to measure changes in transportation costs separately for the two sectors. However, for given rural and urban sector incomes across sub-districts, changes in each type of market access can still arise from infrastructure improvements that provide better connections to each type of location. For example, if a new highway connects two cities, then that would mainly be an increase in urban market access and firm market access.[16] The distinction between firm market access and consumer market access is based on the different sets over which they are defined: urban consumer market access is only defined over urban trade partners and rural consumer market access is only defined over rural trade partners, while firm market access includes both sectors.

We can therefore estimate the following two simple fixed effects panel regressions, which generalise the equation in Alder (2017) to two sectors:

$$\begin{aligned}\ln(\tilde{Y}^R_{o,t}) &= \phi^R_o + \delta^R_{s,t} + \beta^R \ln\left(FMA_{o,t}\right) + \xi \ln\left(CMA^R_{o,t}\right) + \omega \ln\left(CMA^U_{o,t}\right) \\ &+ \chi^R \ln\left(R_{o,t}\right) + \eta^R \ln\left(H_{o,t}\right) + \Psi X_{o,t} + \varepsilon^R_{o,t} \qquad (18)\\ \ln(\tilde{Y}^U_{o,t}) &= \phi^U_o + \delta^U_{s,t} + \beta^U \ln\left(FMA_{o,t}\right) + \xi \ln\left(CMA^R_{o,t}\right) + \omega \ln\left(CMA^U_{o,t}\right) \\ &+ \chi^U \ln\left(R_{o,t}\right) + \eta^U \ln\left(H_{o,t}\right) + \Psi X_{o,t} + \varepsilon^U_{o,t}. \qquad (19)\end{aligned}$$

ϕ is a location fixed effect that absorbs time-invariant location characteristics. We will let this fixed effect also absorb the production factor natural resource as their time variation may be small. We will show results where we hold human capital fixed and also when we allow it to vary according to changes in education. $\delta_{s,t}$ is a fixed effect that absorbs unobserved time-varying heterogeneity at a higher level

[16]Due to the general equilibrium nature, a change in trade cost can affect any other location to some extent. For this reason, we emphasise in the example above that it affects *mainly* (but not exclusively) urban market access and firm market access; rural consumer market access can be affected to some extent as well.

of aggregation (state or district). X is a vector of initial location characteristics interacted with time fixed effects. This allows for control of, example, convergence patterns, since less developed sectors tend to have higher growth rates. ε is a normal error term.

When we approximate market access using equation (15) and (16), then we do not separately include firm market access and each type of consumer market access in the regression equation, since the three are collinear as is clear from equation (17).

4 Data

We use various types of geocoded data that we obtained from satellites (night lights) and the World Bank geospatial database for South Asia (population, education, and environmental variables). Furthermore, we use scanned historical road atlases from Allen and Atkin (2016).[17] Our main unit of analysis is at the level of sub-districts. There are 5,990 sub-districts in the 2011 census and we use the mapping of administrative units over time provided by the World Bank South Asia database.

4.1 Outcome variables

As suggested by the model, our main outcome variable is real income in the urban and rural sectors. We use data on lights at night as a local measure of economic activity (see Henderson et al., 2012). In order to approximate urban and rural real income using the light data, we apply a threshold to the light data and classify all light above a light density value of 33 as urban. To obtain this threshold, we used maps of urban extent, create a buffer around this urban–rural

[17] Treb Allen and David Atkin have kindly shared the scanned atlas, the code for the colour recognition, and the code for the fast marching algorithm to compute the shortest paths. The underlying source of the transport data is the various editions of the Road Map of India.

boundary and calculated the average light intensity at this boundary.[18] This allows us to identify urban areas within each sub-district and we then compute light in each year and sub-district separately for urban and rural regions. Alternatively, we use the definitions of urban and rural populations of each sub-district from the census in 2001 and 2011 as provided in the World Bank South Asia Database. Based on these two approaches, we can classify districts into being either urban or rural, depending on the share of each sector. When we are using the threshold, then we classify sub-districts with zero urban light as rural and all other sub-districts as urban. When we rely on the classification in the World Bank South Asia Database, then we classify sub-districts as urban if they have an above-median share of urban light and those below the median are classified as rural.

4.2 Explanatory variables

Our main explanatory variables are market access measures and various determinants of urban and rural economic activity, such as environmental variables that affect sectors differently.

4.2.1 Travel times and market access

The model suggests that market access depends on the income of each destination and on the trade costs with each destination.[19] The market access measures are

[18]The approach is explained in more detail in Tewari et al. (2017). See also Harari (2016) for the use of a threshold in the light data. The threshold 33 is for the case of the Defense Meteorological Satellite Program (DMSP) light data (average visible - stable lights product). An alternative version of the light images is the radiance-calibrated data. The advantage of these data is that there is no problem of top-coding, which arises when a pixel reaches the maximum light intensity in the conventional light data, which his 63. We apply the same approach to find the threshold when using the radiance-calibrated data. Furthermore, we also use the inter-annual calibration which makes the light intensities comparable across the years.

[19]Since the dependent variable, real income, also determines the market access measures, there is a possible endogeneity problem and we discuss how this is addressed in the next paragraph.

therefore calculated for each version of the transportation network, which allows us to exploit time variation in market access due to transport costs. The network changes over time when existing roads are improved or new roads are built, both allowing for potentially lower travel times. We capture changes in the transport network by relying on digitised road atlases for 1996 and 2011 from Allen and Atkin (2016).[20] To derive the travel times, we compute shortest paths using the fast marching algorithm from Allen and Arkolakis (2014) and Allen and Atkin (2016). The resulting travel times are mapped to iceberg trade costs using the function $\tau_{od} = 1 + (\rho Time)^{\psi}$.[21] We use a value for ψ that maximises the fit of a cross-sectional regression of income on market access in 1996. The resulting value of 0.6 is in line with other findings, for example Roberts et al. (2012). We choose ρ such that the median iceberg trade cost is about 1.25, which is consistent with evidence on the overall magnitude of transport costs.[22]

With the iceberg trade costs derived from the transportation networks, we can compute general equilibrium measures of market access based on equations (11), (12), (13), and (14). We do so for the iceberg trade costs implied by the 1996 and 2011 road atlases. In order to address the endogeneity problem that arises from using income to construct the explanatory variable, we hold income fixed in the initial year when we compute the market access measures and therefore only allow them to change due to the road network, and not due to income growth in other districts.

There are some limitations of the approach used here. First, we focus on trade costs implied by the road network and don't take into account other transport, for example rail and water. While this is a limitation, it should also be noted

[20]Note that it may also be the case that roads deteriorate over time because of a lack of maintenance. To the extent that the road atlases reflect it correctly, this would be accounted for in our travel times.

[21]See Roberts et al. (2012), Alder (2017), and Baum-Snow et al. (2016) for similar approaches.

[22]According to Limao and Venables (2001), the cost of transporting one ton per truck for 1000 kilometres is US$ 1380. The average distance in our 1996 network is about 1564 kilometres, implying a cost of 2158 on the average route. About 75% of trucks in India are 2-axle 9-tonne trucks. Using an average ton value from the Commodity Flow Survey yields a value of US$ 8546 per truck, such that the transport costs are about 25%.

that road transport accounts for the largest share of the trade in goods. Second, we assume the trade costs on a given route are the same for each type of good, while in practice there may be differences; for example, between agricultural and industrial goods.[23] Third, the iceberg assumption implies that trade costs are a fraction of the value of the goods rather than being based, for example, on weight, but this is a standard assumption in the literature. Finally, there may be other frictions besides driving time that affect trade, such as tolls, waiting times at state borders, corruption, or a lack of competition. While these are difficult to measure, we do capture state borders in the calculation of the driving times by assuming an average waiting time of three hours to cross a state border, which is consistent with survey evidence.[24]

4.2.2 Economic, social, and environmental characteristics of sub-districts

In order to test whether the effects of transport infrastructure depend on local characteristics, we measure a number of environmental characteristics such as ground water, rainfall, and land type using the World Bank's South Asia Spatial Database. We consider these variables as potentially relevant for production at the local level and they are readily available from the database. Furthermore, we also use the census population and education data that are available from the same database and allow us to capture human capital.[25] Finally, we use measures of initial urbanisation, which we either compute by using the threshold in the

[23] However, and as noted earlier, the actual trade costs may differ across sector because they are connected by different types of roads.

[24] According to the World Bank (2002), about a quarter of the travel time across India is spent at state borders. The longest travel time in India is about 80 hours while crossing seven state borders, implying about three hours per state border. Ideally we would use the actual waiting times at borders, because they could be heterogeneous. But in the absence of this evidence, an average of three hours provides a reasonable approximation for the importance of state border frictions. Also note that our algorithm finds the shortest paths given the road network *and* state borders, such that the resulting travel times are optimal given both types of frictions.

[25] An important advantage of this database is that it allows us to match administrative units over time.

light data, or we use the official classification in the census data, again available from the South Asia Spatial Database.

4.3 Descriptive statistics

Table 1 shows the summary statistics for the levels and growth rates of light and population over the periods 2001 to 2011 and 1999 to 2012 (depending on the data source), separately for urban and rural locations. We have approximately 5,990 observations from mainland sub-districts in India.[26] With our classification of urban and rural locations based on a threshold in light intensity, we find that growth in urban light is larger than growth in rural light. This may reflect higher income growth per capita, or changes in urban areas over time. We also see substantially higher growth rates in urban population than in rural population, which reflects the classification of population in the census. The World Bank data uses the census classification for urban and rural locations also to compute light statistics, using radiance-calibrated light data. Based on these data, we find that the growth rate in light is higher in rural areas. These differences suggest that it is important how urban and rural is defined and we will therefore show regression results for both versions.[27]

5 Estimation and results

The model presented in section 3 suggests that market access affects local income. The two-sector version of the model shows that income depends on access to both sectors. The two sectors may differ in their roles depending on consumers' preferences and the weights of local factors in the production function, but they share

[26]The sample is reduced when calculating urban growth rates because some sub-districts have zero urban light.

[27]The World Bank data are based on the radiance-calibrated light data and therefore do not have the top-coding problem. However, this is unlikely to explain the differences in growth rates because we would expect top coding to underestimate urban growth when using the uncalibrated data, yet here we find higher urban growth with the uncalibrated data.

the characteristics that they depend on trade partners' income and the bilateral trade costs. In this section we use panel data from 2001 to 2011 that allow us to exploit changes in the transportation network over time to estimate the effect of market access on income.

We start by discussing the identification strategy in section 5.1. In section 5.2, we consider a one-sector version as in Alder (2017) and estimate the regression equations in the full sample and separately for urban and rural locations. This allows us to consider differences between locations in a reduced form way. However, the two-sector version of the model makes predictions separately for the urban and rural sector. In section 5.3 we therefore consider the outcomes in each sector and relate them to the different measures of market access. This part of the analysis ties closely to the model presented in section 3, which provides a direct way of interpreting the results.

5.1 Identification strategy

The relationship that the model suggests between income of a district o and its access to other districts d as measured by market access implies a spatial dependence that poses a challenge for empirical work. The reason is that the market access of these other districts themselves depends on income or population in district o. Estimating the causal effect of market access therefore requires an identification strategy that can isolate exogenous variation in market access. An important advantage of our panel data is that we can exploit changes over time and absorb some of the spatial dependence by including fixed effects. In particular, we can use the construction of new transport infrastructure as a shock that reduces transportation costs and thus increases market access. By only using time variation in market access, which comes from the change in transportation costs, and by holding income that enters the market access equation fixed in the initial year, we can isolate the effect that is due to the transport infrastructure and not due to growth in trade partners' income. Hence, the approximation of market access in year $t + 1$ can be written as follows:

$$MA^i_{o,t+1} \approx \sum_{d \neq o} \frac{Y^i_{d,t}}{\tau^{\theta}_{od,t+1}}.$$

The log change in market access over time is then computed as

$$\Delta \ln MA^i_{o,t,t+1} \approx \ln\left(\sum_{d \neq o} \frac{Y^i_{d,t}}{\tau^{\theta}_{od,t+1}}\right) - \ln\left(\sum_{d \neq o} \frac{Y^i_{d,t}}{\tau^{\theta}_{od,t}}\right).$$

This is similar to DH who compute market access based on initial population. The same approach of holding income fixed can be applied to the market access measures that are derived from solving the general equilibrium equations.

Besides the spatial dependence, a second source of endogeneity is that transportation infrastructure and thus trade costs generally don't change at random. We may be concerned that highways are built in areas where high growth is expected. But the opposite may also be true, namely that infrastructure is built in lagging regions in order to support economic development. A number of strategies have been proposed in order to address this problem (see Redding and Turner (2014) for an overview of these strategies). We cannot use some of these strategies in our context because we don't isolate individual road projects and instead use the overall change in the network as given by the road atlas. But our data allows us to address the question of whether regions were targeted that had different growth rates already before the construction of the road. An important advantage of the light data is that the data span a substantial number of years before the treatment and allows us to control for pre-trends. Our results will show that these trends are often negatively associated with subsequent growth, even when conditioning on initial development. This could suggest that the location of new roads may have been negatively selected during the period that we consider, i.e. roads were targeted at regions that grew more slowly in previous years.

5.2 The effect of market access and local factors in a one-sector model

Here, we focus on the overall relationship between real income and market access as it would be suggested by a one-sector model (Alder, 2017). The corresponding regression equation is

$$\ln(Y_{o,t}) \;=\; \phi_o + \delta_{s,t} + \beta \ln\left(MA_{o,t}\right) + \omega X_{o,t} + \varepsilon_{o,t}. \tag{20}$$

We estimate the above equation in long differences, such that our dependent variable is the log difference in light and the independent variable is the log difference in market access from 2001 to 2011 and from 1999 to 2012. In the discussion of the empirical results, we will refer to the log difference as (approximating) the growth rate.

5.2.1 Approximation of market access in a one-sector model

While the market access measures in the model are general equilibrium objects, they intuitively capture access to markets by summing over trade partners' income, discounted by bilateral trade costs. We start our analysis with measures that capture this notation and approximate market access based on equation 17.

Table 2 shows the results of a regression of light on market access while controlling for the logarithms of initial light density[28] and market access, share of urbanisation, as well as sub-district fixed effects and district-year fixed effects. Column 1 shows the effect for the full sample, and columns 2 and 3 show the results for the urban and rural sample, respectively. We find a positive and significant estimate for the full and the rural sample. For the urban sample, the estimate is not statistically significant but of a similar magnitude. The control variable initial market access appears to be positively associated with subsequent growth in most specifications.[29] The negative coefficient on initial mean light is negative,

[28]We control for the initial light density as a proxy for initial development in order to allow for convergence, for which we find evidence in Tewari et al. (2017).

[29]This suggests that an improvement in market access does not only have an effect on current growth, but potentially also on future growth.

which suggests that there is conditional convergence. In columns 4, 5, and 6, we additionally control for a pre-trend, an indicator for top-coded locations, and the initial share of urban light.[30] The estimates are reduced somewhat and in the case of rural locations the estimate becomes insignificant. The reduction in the estimates when controlling for growth trends before the road construction could imply that roads were targeted at sub-districts that were growing more slowly. In columns 7, 8, and 9, we further control for changes in the literacy rate, in order to proxy for varying human capital. The model predicts that changes in human capital affect income and that this effect depends on the share of human capital in the production function. Since the shares may vary across urban and rural locations, one may expect that human capital has different effects in the two samples. Although the signs differ, the estimates on literacy rates are insignificant and don't change the market access result substantially.

5.2.2 Interaction effects in the one-sector model

Tables 3, 4, and 5 show the interaction effects with various local characteristics. The effect of market access is relatively stable. The local characteristics that appear to show a significant interaction with market access are urbanisation (more urbanised locations appear to benefit less from an increase in market access), initial development (locations with higher initial mean light benefit less from an increase in market access), and temperature (higher mean temperatures imply a smaller effect of market access). With the exception of exogenous environmental variables, the interaction effects are with characteristics in 2001 in order to avoid endogeneity with the growth variable. The overall finding that the effect of market access on income is relatively stable and in most cases does not depend on initial characteristics may be somewhat surprising. It should also be noted that the one-sector model does not directly suggest heterogeneous impacts. However, in light of the two-sector model that suggests potentially different effects for urban and rural locations, one may expect to find significant interaction effects along

[30]The share of urban light is the proportion of light within a sub-district that is classified as urban.

this dimension. The result that urban and more developed locations benefit less from market access could be viewed as motivating evidence that a meaningful distinction between urban and rural production could be made. But it should also be noted that the smaller effect of market access for more developed (urban) locations is surprising. Based on the factor shares in urban and rural production, we would have expected market access to be more effective in urban locations because they use the mobile factor more intensively.

5.3 The effect of urban and rural market access in a two-sector model

As mentioned above, the two-sector model allows for potentially different effects of urban and rural consumer market access. The model also suggests that the effect of firm market access may be different in urban and rural locations.

5.3.1 Approximation of market access in a two-sector model

Equations 18 and 19 show the empirical implementation of the model equations with two sectors. When using the approximation of market access, then we cannot separately include both types of consumer market access together with firm market access as they would be collinear.[31] We therefore focus on the distinction between urban and rural market access (consumer market access) and do not also include the approximation of firm market access in this version.

The results are shown in Table 6. We observe in column 1 that urban and rural market access are not significant when we include them together in the regression as suggested by the two-sector model. The point estimates suggest that urban market access is less important than rural market access and urban market access often has a negative sign. Given the stark difference to the result for the overall

[31] Note that consumer market access for urban goods captures how well consumers can access urban goods. The analogous holds true for rural market access. Firm market access captures how well firms can access consumers in *both* sectors, such that an approximation of firm market access is equal to the sum of approximation of urban and rural market access, and hence collinear.

market access measure based on the one-sector model, it may appear surprising that the measures for the two sectors don't appear to play a significant role when included jointly. However, DH also point out that different measures of market access are highly correlated and may therefore be difficult to distinguish empirically. The raw correlation in the log changes of urban and rural market access is 0.87. Furthermore, when we include only one of the two measures individually, then we get coefficients that are very similar to the one for a single market access term in column 1 of Table 2. This can be seen in columns 2 and 3 of Table 6. Columns 4, 5, and 6 show the results for the urban sample and columns 7, 8, and 9 for the rural sample. The remaining columns include further control variables analogous to Table 2.

Tables 7, 8, and 9 show the interaction effects. Some of the same initial characteristics that were already identified for the case of the one-sector model appear again as significant interaction effects with urban and rural market access. In particular, initial urbanisation appears to reduce the effect of urban market access, but not rural market access. Groundwater depth shows a negative interaction with rural market access, but a positive interaction with urban market access. The latter effect is somewhat surprising given that we use the initial groundwater depth. But the finding could potentially be explained if locations that have exploited their groundwater more had used this resource to invest in future growth.[32] Literacy shows a positive interaction effect with rural market access. A potential explanation could be that locations with high urban market access can obtain urban goods (which are more likely to require higher education in production) from other locations, such that the own-location literacy plays a smaller role.

5.3.2 Computed general equilibrium measures of market access

In this section, we estimate the two-sector version that was presented in section 3 and use general equilibrium measures of market access instead of the approx-

[32] We have also rerun these regressions separately for urban and rural sub-districts and the results are relatively similar. The results are available on request from the authors.

imations from the previous section. We compute the general equilibrium measures based on equations (11), (12), (13), and (14) and use them in the regression equations 18 and 19. We therefore have separate measures for urban and rural market access, as well as firm market access. Table 10 shows the main results for the effect of the different market access measures on income when using the general equilibrium measures. Focusing on columns 1, 4, and 7, which show the effect in the full sample, we observe that the estimates are generally insignificant but it appears that firm market access has the largest effect. Rural market access tends to have a larger effect on income than urban market access and urban market access is even negative in some cases. As we observed for the case of approximated market access, it may be difficult to disentangle the different types of market access. The estimates are therefore sensitive to the exact specification and we should interpret the results with caution. When we estimate the regressions separately for urban and rural locations, then we find that firm market access has a higher estimate for urban locations than for rural locations once we control for pre-trends. However, the estimates are again not statistically significant. One prediction of the model is that the effect of firm market access is larger in the urban sector based on the reasonable assumption that urban production is more capital intensive. The results suggest that this may be the case, but the estimation is imprecise.

Tables 11, 12, and 13 show the results on the interaction effects between the general equilibrium market access measures and measures of initial urbanisation, distance to main cities, literacy, and initial development. The interaction effects are ambiguous and sensitive to the exact measure, such that it is difficult to interpret the results.[33] However, it is useful to note that the main effect does not change substantially when adding the different interaction effects, suggesting that the effect of market access for the average location does not depend on initial conditions.[34]

[33]The ambiguity also arises from the comparison to the results where we use alternative definitions of urban and rural locations. See also section B.

[34]One exception is column 3 of Table 11 where the interaction effect between initial urbanisation (as measured by light) and market access is strong and the main effect becomes large. However,

6 Conclusion

In this paper, we investigated, the role of transport infrastructure and local production factors for urban and rural development. We used a two-sector trade model based on Donaldson and Hornbeck (2016) that predicts that the effects of transport infrastructure as captured by market access may differ across locations. The model features an urban sector and a rural sector with potentially different roles for market access and local production factors such as natural resources. We use light data as a measure for income in 5,990 Indian sub-districts from 2001 to 2011. Trade costs are derived from computing shortest driving times on digitised road networks from 1996 and 2011. We also use a number of population characteristics from the census as well as environmental variables.

We first use a simple one-sector version of the model and find that a measure that approximates overall market access (combining urban and rural) has a significant effect on sub-districts' growth rates, where we exploit changes in market access that are due to changes in trade costs from the 1996 to the 2011 road network. Second, we find only weak evidence for interaction effects between market access and local factors such as initial urbanisation, education, and environmental variables. The main effect of market access is generally robust when allowing for various heterogeneous effects.

We then consider regressions where we include separate market access measures for the urban and rural sector. We find that while each of the measures individually has a significant effect on income growth, they are difficult to disentangle when included jointly. There is again only weak evidence for interaction effects, but one notable exception is that literacy appears to be more important for rural market access. A possible interpretation could be that when a location has good access to urban goods, then it relies less on having a high local literacy.

Finally, we exploit the structure of the model and compute general equilibrium measures of urban and rural consumer market access as well as firm market access. Similar to the previous results where we used approximations of these

this result seems to depend on the definition of urban and rural sectors, as the results are different when defining urbanisation based on population or the calibrated light data.

measures, we find that it is difficult to disentangle the different versions of market access. However, some of the insights from the approximated measures still hold, for example that literacy features a positive interaction effect with rural market access, although not always significant. The model suggests that the effect of firm market access is larger in the urban sector when we assume that urban production is more capital intensive, and this does appear to be the case, although the estimation is not precise.

We conclude that transport infrastructure seems to have overall an effect on growth across 5,990 sub-districts as predicted by a one-sector model. We also tested for a large set of interaction effects and find that the main effect is relatively stable and most of the interaction effects are insignificant. The two-sector model predicts that the effects of transport infrastructure may differ in urban and rural areas when factor intensities are different, but it appears difficult do distinguish these effects in the data. In future work, it would be interesting to consider alternative ways of identifying urban and rural areas and to use detailed transport cost data that capture additional costs besides travel times.

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Tables

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.
Mean total light in 2000	5807	4.63	7.429
Mean urban light in 2000	5755	8.51	17.221
Mean rural light in 2000	5462	4.24	6.389
Share of top coded sub-districts in 2000	5813	.02	.14
Mean total light in 2011	5807	6.565	9.051
Mean urban light in 2011	5755	12.104	19.848
Mean rural light in 2011	5457	5.872	7.759
Share of top coded sub-districts in 2011	5813	.049	.217
Growth in total light 1999-2012	5506	.596	.764
Growth in urban light 1999-2012	1281	1.005	.928
Growth in rural light 1999-2012	5442	.547	.804
Growth in total population 2001-2011	5808	.147	.178
Growth in rural population 2001-2011	5729	.102	.197
Growth in urban population 2001-2011	2729	.259	.401
Growth in total light 2001-2011 (World Bank data, calibrated)	5280	.757	.782
Growth in urban light 2001-2011 (World Bank data, calibrated)	2689	.358	.405
Growth in rural light 2001-2011 (World Bank data, calibrated)	5209	.778	.806

The table shows the descriptive statistics for the sample of sub-districts. The light data is the non-calibrated OLS-DMSP data, except in the last three rows which are based on calibrated light data as provided in the World Bank South Asia Spatial Database.

Table 2: Main effects for one sector with approximation of market access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Market Access	1.007***	0.696	0.846**	0.619**	0.625	0.334	0.626**	0.630	0.338
	(3.02)	(1.09)	(2.21)	(2.06)	(0.99)	(0.98)	(2.08)	(1.00)	(0.99)
Initial market access	1.587***	0.771	1.625***	1.026***	0.691	0.891***	1.029***	0.695	0.892***
	(3.73)	(1.26)	(3.04)	(3.46)	(1.12)	(2.69)	(3.46)	(1.13)	(2.70)
Log mean light in 1999	-0.129***	-0.135***	-0.147***	-0.105***	-0.0803**	-0.113***	-0.104***	-0.0814**	-0.112***
	(-10.52)	(-5.41)	(-8.93)	(-6.85)	(-2.08)	(-6.46)	(-6.55)	(-2.13)	(-6.20)
Pre-trend				-0.0380**	0.0273	-0.0492**	-0.0386**	0.0294	-0.0494**
				(-2.05)	(0.58)	(-2.49)	(-2.11)	(0.60)	(-2.55)
Top Coded				-0.0494	-0.00623	0	-0.0485	-0.00658	0
				(-1.27)	(-0.15)	(.)	(-1.25)	(-0.15)	(.)
Urban share				0.0315	-0.160*	0	0.0325	-0.165*	0
				(0.52)	(-1.77)	(.)	(0.54)	(-1.77)	(.)
Growth in literacy rate							0.0569	-0.0841	0.0182
							(0.42)	(-0.32)	(0.11)
N	5343	1149	4131	4842	1149	3693	4842	1149	3693
adj. R^2	0.536	0.643	0.556	0.573	0.647	0.594	0.573	0.647	0.594

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). Columns 1, 4, and 7 are for the full sample. Columns 2, 5, and 8, are for the urban sample. Columns 3, 6, and 9 are for the rural sample. The market access measures are based on the approximation in Equation (17). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 3: Interaction effects with urban dummy, literacy, and distance to large city

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market Access	0.619**	0.633**	0.657**	0.651**	0.539*	0.606**	0.586**
	(2.06)	(1.98)	(2.18)	(2.22)	(1.77)	(2.09)	(2.02)
Initial market access	1.026***	1.025***	0.972***	0.968***	0.985***	1.017***	0.874***
	(3.46)	(3.48)	(3.36)	(3.40)	(3.34)	(3.47)	(3.14)
Log mean light in 1999	-0.105***	-0.105***	-0.104***	-0.111***	-0.104***	-0.105***	-0.101***
	(-6.85)	(-6.82)	(-6.81)	(-7.73)	(-6.80)	(-6.81)	(-6.60)
Pre-trend	-0.0380**	-0.0378**	-0.0363*	-0.0351*	-0.0374**	-0.0376**	-0.0356*
	(-2.05)	(-2.02)	(-1.94)	(-1.90)	(-2.01)	(-1.99)	(-1.91)
Top coded	-0.0494	-0.0501	-0.0510	-0.0561	-0.0564	-0.0499	-0.0678*
	(-1.27)	(-1.28)	(-1.32)	(-1.45)	(-1.46)	(-1.28)	(-1.73)
Urban share	0.0315	0.0303	0.0222	0.0425	0.0320	0.0308	0.0376
	(0.52)	(0.50)	(0.37)	(0.73)	(0.53)	(0.50)	(0.62)
Market access * Urban (population)		-0.0387					
		(-0.19)					
Market access * Urban (light)			-0.594***				
			(-2.74)				
Market access * Urban (calib. light)				-0.618***			
				(-3.08)			
Market access * City Distance					0.237		
					(1.12)		
Market access * Literacy (2001)						-0.00222	
						(-0.16)	
Market access * Mean light							-0.383**
							(-2.42)
N	4842	4841	4842	4807	4842	4842	4842
adj. R^2	0.573	0.573	0.574	0.583	0.573	0.573	0.576

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equation (17). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 4: Interaction effects with land characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market Access	0.619**	0.616**	0.624**	0.647**	0.468	0.640**	0.634**	0.507*
	(2.06)	(2.02)	(2.08)	(2.14)	(1.46)	(2.13)	(2.10)	(1.71)
Initial market access	1.026***	1.026***	1.024***	1.024***	0.999***	1.028***	1.030***	0.888***
	(3.46)	(3.46)	(3.47)	(3.43)	(3.43)	(3.51)	(3.47)	(3.03)
Log mean light in 1999	-0.105***	-0.105***	-0.105***	-0.106***	-0.106***	-0.105***	-0.105***	-0.0986***
	(-6.85)	(-6.85)	(-6.85)	(-6.86)	(-6.87)	(-6.86)	(-6.86)	(-6.30)
Pre-trend	-0.0380**	-0.0379**	-0.0382**	-0.0376**	-0.0358*	-0.0378**	-0.0378**	-0.0381**
	(-2.05)	(-2.05)	(-2.07)	(-2.03)	(-1.95)	(-2.05)	(-2.05)	(-2.00)
Top coded	-0.0494	-0.0496	-0.0495	-0.0496	-0.0510	-0.0507	-0.0500	-0.0523
	(-1.27)	(-1.28)	(-1.27)	(-1.27)	(-1.30)	(-1.30)	(-1.28)	(-1.33)
Urban share	0.0315	0.0311	0.0312	0.0329	0.0346	0.0327	0.0327	0.0195
	(0.52)	(0.52)	(0.52)	(0.55)	(0.57)	(0.54)	(0.54)	(0.32)
Market access * Cropland		0.000399						
		(0.09)						
Market access * Forest			0.00489					
			(0.36)					
Market access * Small particles				0.00827				
				(0.71)				
Market access * Particle thickness					-3.923			
					(-1.54)			
Market access * Elevation						0.000838		
						(1.25)		
Market access * Roughness							0.00104	
							(0.79)	
Market access * Groundwater								0.00776
								(0.13)
N	4842	4842	4842	4842	4842	4842	4842	4653
adj. R^2	0.573	0.573	0.573	0.573	0.574	0.574	0.573	0.565

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equation (17). All regressions control for sub-district fixed effects and district-year fixed effects. All variables are at the sub-district level except for groundwater, which is a district-level variables. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 5: Interaction effects with temperature and precipitation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market Access	0.619**	0.647**	0.616**	0.612*	0.964***	0.638**	0.524*
	(2.06)	(2.05)	(2.01)	(1.84)	(2.79)	(2.07)	(1.78)
Initial market access	1.026***	1.028***	1.026***	1.026***	1.077***	1.021***	0.965***
	(3.46)	(3.45)	(3.45)	(3.46)	(3.63)	(3.48)	(3.25)
Log mean light in 1999	-0.105***	-0.105***	-0.105***	-0.105***	-0.106***	-0.105***	-0.105***
	(-6.85)	(-6.85)	(-6.84)	(-6.81)	(-6.90)	(-6.86)	(-6.84)
Pre-trend	-0.0380**	-0.0381**	-0.0379**	-0.0379**	-0.0398**	-0.0386**	-0.0376**
	(-2.05)	(-2.06)	(-2.05)	(-2.05)	(-2.15)	(-2.08)	(-2.03)
Top coded	-0.0494	-0.0495	-0.0494	-0.0494	-0.0501	-0.0505	-0.0495
	(-1.27)	(-1.27)	(-1.27)	(-1.27)	(-1.29)	(-1.30)	(-1.27)
Urban share	0.0315	0.0316	0.0315	0.0314	0.0300	0.0324	0.0298
	(0.52)	(0.52)	(0.52)	(0.52)	(0.50)	(0.54)	(0.49)
Market access * Mean precipitation		0.00163					
		(0.28)					
Market access * Precipitation deviation			-0.000600				
			(-0.04)				
Market access * Precipitation anomaly				-0.00236			
				(-0.07)			
Market access * Mean temperature					-0.254**		
					(-2.48)		
Market access * Temperature deviation						1.095	
						(0.63)	
Market access * Temperature anomaly							2.321
							(1.26)
N	4842	4842	4842	4842	4842	4842	4842
adj. R^2	0.573	0.573	0.573	0.573	0.574	0.573	0.574

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equation (17). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 6: Urban and rural market access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Urban market access	-0.416	1.031***		-1.760	0.695		1.038	0.873**		0.170	-1.988	1.035	0.162	-1.985	1.032
	(-0.19)	(3.03)		(-0.48)	(1.06)		(0.37)	(2.20)		(0.08)	(-0.55)	(0.38)	(0.08)	(-0.55)	(0.38)
Rural market access	1.400		1.006***	2.473		0.743	-0.159		0.817**	0.461	2.643	-0.643	0.477	2.644	-0.637
	(0.67)		(3.09)	(0.72)		(1.19)	(-0.06)		(2.19)	(0.24)	(0.78)	(-0.26)	(0.24)	(0.78)	(-0.26)
Initial urban market access	-0.431	0.203	-0.250	-1.149	0.0194	-0.324	1.157	1.084	0.708	-0.470	-1.746	0.280	-0.489	-1.719	0.275
	(-0.32)	(0.22)	(-0.27)	(-0.59)	(0.01)	(-0.20)	(0.66)	(0.90)	(0.59)	(-0.36)	(-0.86)	(0.16)	(-0.37)	(-0.84)	(0.16)
Initial rural market access	1.991	1.363	1.814**	1.888	0.713	1.071	0.479	0.551	0.918	1.465	2.387	0.598	1.487	2.365	0.604
	(1.51)	(1.63)	(2.11)	(0.94)	(0.45)	(0.67)	(0.28)	(0.51)	(0.83)	(1.15)	(1.14)	(0.36)	(1.17)	(1.13)	(0.37)
Log mean light in 1999	-0.130***	-0.129***	-0.130***	-0.138***	-0.136***	-0.137***	-0.147***	-0.147***	-0.147***	-0.105***	-0.0806**	-0.112***	-0.104***	-0.0816**	-0.112***
	(-10.56)	(-10.52)	(-10.54)	(-5.51)	(-5.42)	(-5.45)	(-8.90)	(-8.90)	(-8.90)	(-6.83)	(-2.03)	(-6.41)	(-6.51)	(-2.07)	(-6.14)
Pre-trend										-0.0383**	0.0284	-0.0498**	-0.0391**	0.0302	-0.0501**
										(-2.07)	(0.60)	(-2.51)	(-2.13)	(0.62)	(-2.57)
Top coded										-0.0504	-0.0102	0	-0.0494	-0.0104	0
										(-1.30)	(-0.24)	(.)	(-1.28)	(-0.24)	(.)
Urban share										0.0216	-0.166*	0	0.0225	-0.170*	0
										(0.35)	(-1.75)	(.)	(0.36)	(-1.76)	(.)
Growth in literacy rate													0.0632	-0.0723	0.0199
													(0.47)	(-0.28)	(0.12)
N	5343	5343	5343	1149	1149	1149	4131	4131	4131	4842	1149	3693	4842	1149	3693
adj. R^2	0.536	0.536	0.536	0.642	0.642	0.643	0.555	0.556	0.556	0.573	0.647	0.594	0.573	0.647	0.594

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). Columns 1–3, 10, and 13 are for the full sample; columns 4–6, 11, and 14 are for the urban sample; columns 7–9, 12, and 15 are for the rural sample. The market access measures are based on the approximation in Equations (15) and (16). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 7: Interaction effects of urban and rural market access with urban dummy, literacy, and distance to large city

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban market Access	0.170	0.0206	0.340	0.554	0.111	-0.104	0.408
	(0.08)	(0.01)	(0.16)	(0.27)	(0.05)	(-0.05)	(0.20)
Rural market Access	0.461	0.606	0.337	0.122	0.440	0.768	0.175
	(0.24)	(0.31)	(0.17)	(0.06)	(0.22)	(0.39)	(0.09)
Initial urban market access	-0.470	-0.439	-0.308	0.00621	-0.514	-0.734	-0.252
	(-0.36)	(-0.33)	(-0.23)	(0.00)	(-0.39)	(-0.56)	(-0.20)
Initial rural market access	1.465	1.445	1.247	0.941	1.467	1.685	1.100
	(1.15)	(1.13)	(0.98)	(0.75)	(1.15)	(1.31)	(0.88)
Log mean light in 1999	-0.105***	-0.105***	-0.104***	-0.111***	-0.104***	-0.104***	-0.102***
	(-6.83)	(-6.80)	(-6.80)	(-7.71)	(-6.76)	(-6.74)	(-6.69)
Pre-trend	-0.0383**	-0.0376**	-0.0371**	-0.0357*	-0.0380**	-0.0399**	-0.0347*
	(-2.07)	(-2.00)	(-1.99)	(-1.93)	(-2.03)	(-2.11)	(-1.86)
Top coded	-0.0504	-0.0464	-0.0550	-0.0598	-0.0591	-0.0684*	-0.0624
	(-1.30)	(-1.17)	(-1.41)	(-1.53)	(-1.52)	(-1.68)	(-1.49)
Urban share	0.0216	0.0139	0.0158	0.0368	0.0218	0.0267	0.0289
	(0.35)	(0.22)	(0.26)	(0.63)	(0.35)	(0.43)	(0.46)
Urban market access * Urban (population)		0.414					
		(1.18)					
Rural market access * Urban (population)		-0.421					
		(-1.42)					
Urban market access * Urban (light)			-0.574**				
			(-2.18)				
Rural market access * Urban (light)			-0.0511				
			(-0.22)				
Urban market access * Urban (calib. light)				-0.540**			
				(-2.14)			
Rural market access * Urban (calib. light)				-0.111			
				(-0.49)			
Urban market access * City Distance					0.245		
					(0.74)		
Rural market access * City Distance					0.0151		
					(0.05)		
Urban market access * Literacy (2001)						-0.0434	
						(-1.65)	
Rural market access * Literacy (2001)						0.0351*	
						(1.71)	
Urban market access * Mean light							0.0309
							(0.08)
Rural market access * Mean light							-0.406
							(-1.19)
N	4842	4841	4842	4807	4842	4842	4842
adj. R^2	0.573	0.573	0.574	0.583	0.573	0.574	0.576

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equations (15) and (16). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 8: Interaction effects of urban and rural market access with land characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urban market access	0.170	0.157	0.163	0.396	0.732	0.192	0.205	-1.069
	(0.08)	(0.08)	(0.08)	(0.19)	(0.34)	(0.09)	(0.10)	(-0.51)
Rural market access	0.461	0.477	0.470	0.331	-0.182	0.444	0.441	1.497
	(0.24)	(0.25)	(0.24)	(0.17)	(-0.09)	(0.23)	(0.23)	(0.78)
Initial urban market access	-0.470	-0.500	-0.454	-0.556	-0.301	-0.279	-0.431	-0.951
	(-0.36)	(-0.38)	(-0.35)	(-0.43)	(-0.23)	(-0.21)	(-0.33)	(-0.76)
Initial rural market access	1.465	1.490	1.445	1.537	1.228	1.298	1.432	1.785
	(1.15)	(1.18)	(1.13)	(1.22)	(0.95)	(1.03)	(1.12)	(1.46)
Log mean light in 1999	-0.105***	-0.105***	-0.105***	-0.104***	-0.105***	-0.105***	-0.105***	-0.0985***
	(-6.83)	(-6.83)	(-6.76)	(-6.80)	(-6.79)	(-6.84)	(-6.83)	(-6.30)
Pre-trend	-0.0383**	-0.0383**	-0.0385**	-0.0387**	-0.0372**	-0.0381**	-0.0382**	-0.0385**
	(-2.07)	(-2.06)	(-2.08)	(-2.08)	(-2.00)	(-2.06)	(-2.06)	(-2.03)
Top coded	-0.0504	-0.0494	-0.0503	-0.0513	-0.0536	-0.0516	-0.0510	-0.0539
	(-1.30)	(-1.24)	(-1.30)	(-1.33)	(-1.38)	(-1.33)	(-1.32)	(-1.38)
Urban share	0.0216	0.0206	0.0220	0.0210	0.0223	0.0245	0.0231	0.00615
	(0.35)	(0.33)	(0.35)	(0.34)	(0.36)	(0.40)	(0.37)	(0.10)
Urban market access * Cropland		-0.00215						
		(-0.21)						
Rural market access * Cropland		0.00187						
		(0.24)						
Urban market access * Forest			-0.0149					
			(-0.21)					
Rural market access * Forest			0.0187					
			(0.31)					
Urban market access * Small particles				0.0443				
				(1.57)				
Rural market access * Small particles				-0.0278				
				(-1.36)				
Urban market access * Particle thickness					-6.286			
					(-1.63)			
Rural market access * Particle thickness					1.830			
					(0.59)			
Urban market access * Elevation						-0.000357		
						(-0.27)		
Rural market access * Elevation						0.00107		
						(0.87)		
Urban market access * Roughness							0.000373	
							(0.15)	
Rural market access * Roughness							0.000625	
							(0.28)	
Urban market access * Groundwater								0.496*
								(1.90)
Rural market access * Groundwater								-0.501*
								(-1.96)
N	4842	4842	4842	4842	4842	4842	4842	4653
adj. R^2	0.573	0.573	0.573	0.574	0.574	0.574	0.573	0.566

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equations (15) and (16). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 9: Interaction effects of urban and rural market access with temperature

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban market Access	0.170	0.328	-0.290	0.317	-0.471	-0.187	-0.201
	(0.08)	(0.15)	(-0.14)	(0.15)	(-0.22)	(-0.09)	(-0.10)
Rural market Access	0.461	0.331	0.924	0.305	1.407	0.818	0.742
	(0.24)	(0.16)	(0.47)	(0.15)	(0.70)	(0.41)	(0.38)
Initial urban market access	-0.470	-0.449	-0.604	-0.491	-0.505	-0.609	-0.432
	(-0.36)	(-0.34)	(-0.46)	(-0.38)	(-0.39)	(-0.46)	(-0.33)
Initial rural market access	1.465	1.457	1.571	1.484	1.560	1.595	1.398
	(1.15)	(1.15)	(1.24)	(1.18)	(1.23)	(1.24)	(1.10)
Log mean light in 1999	-0.105***	-0.105***	-0.105***	-0.105***	-0.106***	-0.105***	-0.104***
	(-6.83)	(-6.82)	(-6.82)	(-6.78)	(-6.89)	(-6.84)	(-6.79)
Pre-trend	-0.0383**	-0.0383**	-0.0394**	-0.0386**	-0.0399**	-0.0389**	-0.0388**
	(-2.07)	(-2.06)	(-2.12)	(-2.08)	(-2.16)	(-2.09)	(-2.08)
Top coded	-0.0504	-0.0504	-0.0507	-0.0505	-0.0507	-0.0517	-0.0510
	(-1.30)	(-1.30)	(-1.31)	(-1.31)	(-1.31)	(-1.34)	(-1.32)
Urban share	0.0216	0.0219	0.0196	0.0205	0.0227	0.0226	0.0199
	(0.35)	(0.35)	(0.32)	(0.33)	(0.37)	(0.36)	(0.32)
Urban market access * Mean precipitation		0.00584					
		(0.25)					
Rural market access * Mean precipitation		-0.00416					
		(-0.20)					
Urban market access * Precipitation deviation			-0.0388				
			(-0.89)				
Rural market access * Precipitation deviation			0.0354				
			(0.93)				
Urban market access * Precipitation anomaly				0.0614			
				(0.64)			
Rural market access * Precipitation anomaly				-0.0617			
				(-0.65)			
Urban market access * Mean temperature					-0.0771		
					(-0.35)		
Rural market access * Mean temperature					-0.173		
					(-0.84)		
Urban market access * Temperature deviation						1.567	
						(0.30)	
Rural market access * Temperature deviation						-0.324	
						(-0.07)	
Urban market access * Temperature anomaly							4.056
							(1.45)
Rural market access * Temperature anomaly							-1.667
							(-0.70)
N	4842	4842	4842	4842	4842	4842	4842
adj. R^2	0.573	0.573	0.573	0.573	0.574	0.573	0.574

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The market access measures are based on the approximation in Equations (15) and (16). All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 10: Growth of total mean light between 2001-2011, general equilibrium market access measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Urban CMA	-3.774	-28.26	-49.83	-2.995	-28.18	-26.64	-2.987	-28.16	-26.10
	(-1.25)	(-0.57)	(-1.51)	(-1.05)	(-0.57)	(-0.88)	(-1.05)	(-0.56)	(-0.86)
Rural CMA	4.553	-27.64	-22.37	3.147	-27.45	-11.71	3.127	-27.42	-11.47
	(1.59)	(-0.55)	(-1.10)	(1.20)	(-0.55)	(-0.60)	(1.19)	(-0.55)	(-0.59)
Firm market access	0.513	56.28	73.40	0.697	56.00	38.93	0.690	55.95	38.12
	(1.01)	(0.57)	(1.39)	(1.43)	(0.57)	(0.79)	(1.41)	(0.57)	(0.77)
Initial urban CMA	-1.066	-48.09	-24.61	-1.432	-47.85	-11.81	-1.385	-47.83	-11.06
	(-0.58)	(-1.62)	(-1.12)	(-0.84)	(-1.62)	(-0.63)	(-0.81)	(-1.62)	(-0.59)
Initial rural CMA	3.110*	-51.58*	-11.57	2.879*	-51.30*	-3.574	2.829*	-51.30*	-3.240
	(1.77)	(-1.77)	(-0.85)	(1.73)	(-1.77)	(-0.29)	(1.70)	(-1.77)	(-0.26)
Initial FMA	0.0913***	100.3*	38.55	-0.0320	99.78*	16.78	-0.0303	99.76*	15.68
	(6.86)	(1.72)	(1.09)	(-1.19)	(1.72)	(0.55)	(-1.12)	(1.72)	(0.51)
Log mean light in 2001	-0.193***	-0.108***	-0.202***	-0.157***	-0.121***	-0.150***	-0.160***	-0.121***	-0.153***
	(-11.28)	(-4.70)	(-9.61)	(-9.31)	(-4.07)	(-7.32)	(-8.93)	(-4.19)	(-7.21)
Pre-trend				-0.0492***	-0.00224	-0.0658***	-0.0481***	-0.00209	-0.0646***
				(-2.93)	(-0.05)	(-3.58)	(-2.88)	(-0.05)	(-3.54)
Urban share				0.0205***	0.00652	0	0.0200***	0.00649	0
				(3.04)	(0.78)	(.)	(2.96)	(0.74)	(.)
Growth in literacy rate							-0.116	-0.00614	-0.133
							(-0.86)	(-0.02)	(-0.81)
N	5324	1149	4175	4836	1149	3687	4836	1149	3687
adj. R^2	0.493	0.588	0.504	0.523	0.587	0.546	0.523	0.586	0.546

The dependent variable is growth in light at the sub-district level from 2001 to 2011. Columns 1, 4, and 7 are for the full sample; columns 2, 5, and 8 are for the urban sample; columns 3, 6, and 9 are for the rural sample. The market access measures are solutions of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 11: Growth of total mean light between 2001 and 2011, general equilibrium market access measures with urban, literacy, and distance interactions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	-2.995	-3.204	6.635	-3.379	-2.949	-3.302	-3.826
	(-1.05)	(-1.08)	(1.64)	(-1.18)	(-1.04)	(-1.16)	(-1.36)
Rural CMA	3.147	3.549	9.306***	2.579	2.887	2.903	2.869
	(1.20)	(1.30)	(2.82)	(0.98)	(1.10)	(1.11)	(1.14)
Firm Market Access	0.697	0.483	-14.98***	1.643**	0.784	1.238**	1.694**
	(1.43)	(0.31)	(-3.06)	(2.09)	(1.58)	(2.17)	(2.17)
Initial Urban CMA	-1.432	-1.416	-1.589	-1.091	-1.331	-1.392	-1.361
	(-0.84)	(-0.82)	(-0.94)	(-0.64)	(-0.79)	(-0.81)	(-0.84)
Initial Rural CMA	2.879*	2.885*	3.165*	2.488	2.727*	2.848*	2.607*
	(1.73)	(1.72)	(1.91)	(1.51)	(1.66)	(1.70)	(1.66)
Initial FMA	-0.0320	-0.0362	-0.198***	-0.0403	-0.0322	-0.0494*	-0.0484
	(-1.19)	(-1.27)	(-4.35)	(-1.45)	(-1.17)	(-1.74)	(-1.58)
Log mean light in 2001	-0.157***	-0.157***	-0.156***	-0.149***	-0.156***	-0.158***	-0.152***
	(-9.31)	(-9.20)	(-9.22)	(-9.03)	(-9.31)	(-9.23)	(-9.15)
Pre-trend	-0.0492***	-0.0488***	-0.0502***	-0.0427***	-0.0483***	-0.0511***	-0.0429**
	(-2.93)	(-2.89)	(-3.00)	(-2.60)	(-2.84)	(-2.95)	(-2.54)
Urban share	0.0205***	0.0205***	0.0222***	0.0157**	0.0205***	0.0243***	0.0230***
	(3.04)	(2.93)	(3.33)	(2.18)	(2.99)	(3.47)	(3.05)
Urban CMA * Urban (population)		0.227					
		(0.18)					
Rural CMA * Urban (population)		-0.841					
		(-1.55)					
FMA * Urban (population)		0.623					
		(0.39)					
Urban CMA * Urban (light)			-22.25***				
			(-3.62)				
Rural CMA * Urban (light)			-22.08***				
			(-4.09)				
FMA* Urban (light)			43.29***				
			(3.84)				
Urban CMA * Urban (calib. light)				-0.541			
				(-0.60)			
Rural CMA * Urban (calib. light)				-2.779*			
				(-1.92)			
FMA * Urban (calib. light)				2.458			
				(1.13)			
Urban CMA * City Distance					-0.0758		
					(-0.17)		
Rural CMA * City Distance					0.333		
					(0.66)		
FMA* City Distance					0.132		
					(0.19)		
Urban CMA * Literacy (2001)						0.0723*	
						(1.95)	
Rural CMA * Literacy (2001)						0.0354	
						(1.15)	
FMA * Literacy (2001)						-0.109**	
						(-2.53)	
Urban CMA * Mean light							0.518
							(1.08)
Rural CMA * Mean light							-0.387
							(-0.85)
FMA * Mean light							-0.638
							(-0.99)
N	4836	4835	4836	4803	4836	4836	4821
adj. R^2	0.523	0.523	0.526	0.527	0.523	0.523	0.525

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated).Column 1 represents the base line regression without interaction effects. The market access measures are solutions of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 12: General equilibrium market access measures interacted with land variables.

	(1)	(2)	(3)	(4)	(5)	(6)
Urban CMA	-28.18	-21.26	-29.45	-34.43	-24.33	-33.93
	(-0.57)	(-0.43)	(-0.59)	(-0.69)	(-0.49)	(-0.65)
Rural CMA	-27.45	-21.05	-27.68	-33.06	-24.28	-31.56
	(-0.55)	(-0.42)	(-0.56)	(-0.67)	(-0.49)	(-0.61)
Firm Market Access	56.00	42.89	57.23	67.80	49.13	65.61
	(0.57)	(0.44)	(0.58)	(0.69)	(0.50)	(0.64)
Initial Urban CMA	-47.85	-45.07	-46.92	-51.51*	-45.23	-48.08
	(-1.62)	(-1.54)	(-1.58)	(-1.72)	(-1.56)	(-1.55)
Initial Rural CMA	-51.30*	-48.82*	-50.24*	-54.58*	-48.88*	-50.66*
	(-1.77)	(-1.69)	(-1.71)	(-1.85)	(-1.72)	(-1.66)
Initial FMA	99.78*	94.58	97.82*	106.7*	94.68*	99.32
	(1.72)	(1.64)	(1.67)	(1.81)	(1.66)	(1.63)
Log mean light in 2001	-0.121***	-0.127***	-0.117***	-0.124***	-0.131***	-0.119***
	(-4.07)	(-4.25)	(-3.49)	(-4.06)	(-3.94)	(-3.69)
Pre-trend	-0.00224	-0.00695	-0.0000113	-0.00227	-0.00333	-0.00481
	(-0.05)	(-0.15)	(-0.00)	(-0.05)	(-0.07)	(-0.10)
Urban share	0.00652	0.00862	0.00521	0.00700	0.00911	0.00555
	(0.78)	(1.00)	(0.58)	(0.82)	(1.00)	(0.63)
Urban CMA * Cropland		-0.0146				
		(-0.48)				
Rural CMA * Cropland		0.000741				
		(0.01)				
FMA * Cropland		-0.00344				
		(-0.04)				
Urban CMA * Forest			-0.476			
			(-1.11)			
Rural CMA * Forest			-0.153			
			(-0.39)			
FMA * Forest			0.552			
			(0.73)			
Urban CMA * Elevation				0.00480		
				(0.74)		
Rural CMA * Elevation				0.00984		
				(0.74)		
FMA * Elevation				-0.0136		
				(-0.72)		
Urban CMA * Roughness					0.00994	
					(0.97)	
Rural CMA * Roughness					0.0162	
					(0.66)	
FMA * Roughness					-0.0169	
					(-0.51)	
Urban CMA * Groundwater						1.037
						(0.25)
Rural CMA * Groundwater						0.817
						(0.16)
FMA * Groundwater						-1.741
						(-0.19)
N	1149	1149	1149	1149	1149	1085
adj. R^2	0.587	0.588	0.587	0.586	0.589	0.577

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The market access measures are solutions of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table 13: General equilibrium market access measures interacted with climate variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	-2.995	-2.691	-3.137	-2.552	-3.863	-2.937	-3.707
	(-1.05)	(-0.92)	(-1.10)	(-0.89)	(-1.33)	(-1.03)	(-1.29)
Rural CMA	3.147	2.587	2.881	2.890	3.878	3.071	3.341
	(1.20)	(0.96)	(1.10)	(1.07)	(1.40)	(1.13)	(1.27)
Firm Market Access	0.697	0.874	1.075*	0.505	1.081**	0.696	1.065*
	(1.43)	(0.92)	(1.79)	(1.07)	(2.22)	(0.97)	(1.91)
Initial Urban CMA	-1.432	-1.381	-1.405	-1.381	-1.603	-1.330	-1.416
	(-0.84)	(-0.81)	(-0.83)	(-0.81)	(-0.94)	(-0.77)	(-0.84)
Initial Rural CMA	2.879*	2.859*	2.862*	2.834*	3.084*	2.783	2.765*
	(1.73)	(1.73)	(1.74)	(1.71)	(1.85)	(1.64)	(1.68)
Initial FMA	-0.0320	-0.0323	-0.0311	-0.0344	-0.0230	-0.0324	-0.0342
	(-1.19)	(-1.20)	(-1.16)	(-1.29)	(-0.85)	(-1.20)	(-1.28)
Log mean light in 2001	-0.157***	-0.157***	-0.158***	-0.157***	-0.157***	-0.157***	-0.158***
	(-9.31)	(-9.19)	(-9.29)	(-9.25)	(-9.39)	(-9.21)	(-9.36)
Pre-trend	-0.0492***	-0.0485***	-0.0483***	-0.0503***	-0.0516***	-0.0488***	-0.0497***
	(-2.93)	(-2.89)	(-2.86)	(-3.00)	(-3.08)	(-2.88)	(-2.95)
Urban share	0.0205***	0.0208***	0.0207***	0.0206***	0.0185***	0.0205***	0.0207***
	(3.04)	(3.06)	(3.07)	(3.06)	(2.76)	(3.01)	(3.06)
Urban CMA * Mean precipitation		0.0103					
		(0.34)					
Rural CMA * Mean precipitation		-0.0210					
		(-1.02)					
FMA * Mean precipitation		0.00584					
		(0.27)					
Urban CMA * Precipitation deviation			-0.0398				
			(-0.64)				
Rural CMA * Precipitation deviation			-0.0284				
			(-0.65)				
FMA * Precipitation deviation			0.0557				
			(1.23)				
Urban CMA * Precipitation anomaly				0.0389			
				(0.30)			
Rural CMA * Precipitation anomaly				-0.109			
				(-0.92)			
FMA * Precipitation anomaly				0.0670			
				(1.35)			
Urban CMA * Mean temperature					-0.596*		
					(-1.94)		
Rural CMA * Mean temperature					-0.280		
					(-1.07)		
FMA * Mean temperature					0.646***		
					(3.69)		
Urban CMA * Temperature deviation						3.350	
						(0.45)	
Rural CMA* Temperature deviation						-3.780	
						(-0.56)	
FMA * Temperature deviation						0.197	
						(0.06)	
Urban CMA* Temperature anomaly							6.902**
							(1.98)
Rural CMA * Temperature anomaly							3.274
							(1.09)
FMA * Temperature anomaly							-6.100**
							(-2.14)
N	4836	4836	4836	4836	4836	4836	4836
adj. R^2	0.523	0.523	0.523	0.523	0.525	0.523	0.524

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The market access measures are solutions of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

ONLINE APPENDIX

The Effect of Transport Infrastructure on India's Urban and Rural Development

Simon Alder, Mark Roberts, Meenu Tewari

This appendix discusses an alternative version of the model with mobile labor and additional results for other data sources and alternative definitions of urban and rural areas.

A Model with mobile labour

In Section 3.6 we considered a version of the model where labour is immobile. While there is indeed a low mobility across districts in India, it may be expected that workers do move, at least to some extent, in response to a changing economic environment. In this section, we therefore present a version of the model where labour is fully mobile. The reality is likely to lie in between the two extremes of total immobility and perfect mobility and it is therefore interesting to consider both cases.[35]

The starting point is the income equation (8)

$$Y_o^i = \kappa_1^i T_o^i (q_o^{\alpha_i} w_o^{\gamma_i})^{-\theta} FMA_o^i.$$

We can substitute for the price of the fixed resource using the income share,

$$q_o = \frac{\alpha_i Y_o^i}{R_o}.$$

Furthermore, the assumption of mobile labour implies that utility and hence real wages must be equalised to $\bar{U}$, such that

$$w_o = \bar{U}(P_o^R)^{\mu}(P_o^U)^{1-\mu}.$$

[35]There are also frameworks that allow for *partial* mobility based on idiosyncratic location preferences. See for example Redding and Turner (2014).

The income equation can therefore be written as

$$\begin{aligned} Y_o^i &= \kappa_1^i T_o^i \left(\left(\frac{\alpha_i Y_o^i}{R_o} \right)^{\alpha_i} (\bar{U}(P_o^R)^{\mu}(P_o^U)^{1-\mu})^{\gamma_i} \right)^{-\theta} FMA_o^i \\ &= \kappa_2^i \bar{U}^{-\theta\gamma_i} T_o^i \left(\frac{\alpha_i Y_o^i}{R_o} \right)^{-\theta\alpha_i} (MA_o^R)^{\mu\gamma_i}(MA_o^U)^{(1-\mu)\gamma_i} FMA_o^i \end{aligned}$$

with $\kappa_2^i = \kappa_1^i \rho^{\gamma_i}$.

Solving for income yields

$$Y_o^i = \left(\kappa_2^i \bar{U}^{-\theta\gamma_i} T_o^i\right)^{\frac{1}{1+\theta\alpha_i}} \left(\frac{\alpha_i}{R_o} \right)^{\frac{-\theta\alpha_i}{1+\theta\alpha_i}} (MA_o^R)^{\frac{\mu\gamma_i}{1+\theta\alpha_i}} (MA_o^U)^{\frac{(1-\mu)\gamma_i}{1+\theta\alpha_i}} (FMA_o^i)^{\frac{1}{1+\theta\alpha_i}}.$$

In order to obtain real income, we again divide by the price index

$$P_o = (P_o^R)^{\mu}(P_o^U)^{1-\mu} = (MA_o^R)^{-\frac{\mu}{\theta}}(MA_o^U)^{-\frac{1-\mu}{\theta}}$$

to get

$$\tilde{Y}_o^i = \left(\kappa_2^i \bar{U}^{-\theta\gamma_i} T_o^i\right)^{\frac{1}{1+\theta\alpha_i}} \left(\frac{\alpha_i}{R_o} \right)^{\frac{-\theta\alpha_i}{1+\theta\alpha_i}} (MA_o^R)^{\frac{\mu(\theta\gamma_i+(1+\theta\alpha_i))}{(1+\theta\alpha_i)\theta}} (MA_o^U)^{\frac{(1-\mu)(\theta\gamma_i+(1+\theta\alpha_i))}{(1+\theta\alpha_i)\theta}} (FMA_o^i)^{\frac{1}{1+\theta\alpha_i}}$$

B Alternative definitions of urban and rural areas

For the baseline analysis we have categorised urban and rural sub-districts based on their initial share of urban light. Urban light was derived by applying a threshold light intensity above which a pixel is coded as urban. To be consistent with the model, we classified a sub-district as either urban or rural and assigned the entire economic activity of the location to that sector. An alternative way of distinguishing urban from rural areas is to rely on the official classification in the census.[36] The World Bank South Asia Spatial Database reports urban and rural light within each sub-district based on the official classification in the census. Using this classification in this section is the first difference to our baseline data. The second difference is that the light data in the World Bank South Asia Spatial Database are radiance-calibrated, which also addresses the problem of top-coding.

[36] It should be noted that the official classification might understate urbanization due to political factors.

B.1 Approximations of market access in the one-sector model

We start by showing results for the one sector model, where we approximate market access and use the calibrated World Bank data. The results based on this alternative approach are shown in Table A1 in Appendix C.1. The magnitudes of the coefficients are larger than with the baseline data and highly significant (see column 1). In the following two columns, we then estimate the regression equation separately for two samples, namely for more urban sub-districts that have an above-median share of initial urban light (column 2), and for less urban districts that have a below-median share of urban light (column 3). We observe that the estimate is particularly large for the rural sample in column 3, which is qualitatively consistent with the earlier results. In columns 4, 5, and 6, we then control for pre-trends and initial urban share.[37] The coefficient estimates fall somewhat and in the case of the urban sample become insignificant. But the overall effects and the rural sample continue to show a significant effect of market access on growth. In columns 7, 8, and 9, we then control for the growth in the literacy rate but this is not significant and does not change the estimates on market access substantially. Tables A2, A3, and A4 in Appendix C.2 then show the interaction effects between market access and the various local characteristics. With the exception of the share of forest land and temperature anomaly, there are no significant interactions. A large share of forest land may potentially limit the scope of the geographical and economic expansion but we have no direct evidence for this. The temperature anomaly remains difficult to explain and only appears in this one case.

B.2 Approximation of market access in the two-sector model

Table A5 in Appendix C.3 shows the results when approximating urban and rural market access using the calibrated light data. We find that rural market access

[37] Note that the World Bank South Asia Spatial Database does not allow us to consider pre-trends as the data only goes to 2001. We therefore use the pre-trend based on the conventional DMSP data.

appears to have a stronger effect on growth, although it should be noted again that it appears difficult to disentangle urban and rural market access empirically. Tables A6, A7, and A8 in Appendices C.4.1 show the interaction effects. While many of the interaction effects are again ambiguous and results differ from the earlier ones with different data, it is interesting to note that literacy appears to matter less for urban locations. A potential explanation could be that having good urban market access serves as a substitute for having high literacy in the own location, since, the types of goods that are produced using more educated workers can also be obtained from urban locations instead of from home.

B.3 General equilibrium measures of urban, rural, and firm market access

Tables A9 and A10 in Appendices C.4.2 and C.4.3 show the results on the main effects when using different data sources and different ways to classify urban and rural locations. A key difference in the results for these two versions is that urban consumer market access shows a stronger effect than rural consumer market access when using the version in the World Bank South Asia database, but a smaller effect when we use a radiance-calibrated version that we construct based on the data from National Oceanic and Atmospheric Administration (NOAA).[38] Tables A11, A12, A13, A14, A15, and A16 in Appendices C.4.4 and C.4.5 show the results for the interaction effects with the general equilibrium measures based on the calibrated data. We again observe, for example, that literacy appears less important for urban market access, but we now also see that it seems to matter for firm market access. A possible explanation is that firms benefit more from access to other markets if they can rely on a more educated workforce for their production.

[38] We label this third version of the data 'non-World Bank calibrated data' in order to distinguish these data from the data that we obtain from the World Bank that are also radiance-calibrated. However, there are different ways of implementing the radiance-calibration, which may explain part of the difference in the results.

C Additional Tables

C.1 Main effects for single market access (calibrated light)

Table A1: Main effects for one sector

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Market Access	1.551***	1.019**	1.644***	0.929**	0.744	0.853*	0.920**	0.742	0.883*
	(3.75)	(2.04)	(3.08)	(2.39)	(1.56)	(1.85)	(2.39)	(1.55)	(1.95)
Initial market access	2.430***	1.366***	2.796***	1.566***	1.169***	1.387**	1.562***	1.166***	1.402**
	(3.95)	(2.81)	(2.91)	(4.04)	(2.72)	(2.53)	(4.04)	(2.72)	(2.56)
Log mean light in 1999	-0.257***	-0.202***	-0.323***	-0.247***	-0.212***	-0.296***	-0.249***	-0.209***	-0.295***
	(-17.22)	(-10.40)	(-13.78)	(-15.15)	(-10.59)	(-10.10)	(-14.40)	(-9.74)	(-9.90)
Pre-trend				-0.106***	-0.182***	-0.0692***	-0.105***	-0.184***	-0.0697***
				(-5.03)	(-4.77)	(-3.02)	(-5.05)	(-4.82)	(-3.04)
Urban share				0.0307*	0.0122	-14.93**	0.0302*	0.0128	-14.94**
				(1.71)	(0.62)	(-2.20)	(1.68)	(0.64)	(-2.20)
Growth in literacy rate							-0.0609	0.102	0.0860
							(-0.44)	(0.48)	(0.46)
N	5273	2666	2607	4859	2608	2251	4859	2608	2251
adj. R^2	0.591	0.672	0.572	0.610	0.681	0.590	0.610	0.681	0.590

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.2 Interaction effects of market access with local characteristics (calibrated light)

Table A2: Interaction effects with urban dummy, literacy, and distance to large city

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market Access	0.929**	0.933**	0.963**	0.926**	0.973**	0.865**	0.904**
	(2.39)	(2.21)	(2.46)	(2.38)	(2.57)	(2.46)	(2.38)
Initial market access	1.566***	1.566***	1.521***	1.530***	1.589***	1.520***	1.490***
	(4.04)	(4.07)	(3.98)	(4.00)	(4.12)	(4.13)	(4.00)
Log mean light in 1999	-0.247***	-0.247***	-0.248***	-0.252***	-0.247***	-0.246***	-0.245***
	(-15.15)	(-15.12)	(-15.10)	(-15.45)	(-15.14)	(-15.15)	(-14.77)
Pre-trend	-0.106***	-0.106***	-0.105***	-0.104***	-0.106***	-0.104***	-0.105***
	(-5.03)	(-5.05)	(-5.01)	(-4.97)	(-5.07)	(-5.04)	(-4.98)
Urban share	0.0307*	0.0308*	0.0307*	0.0296*	0.0306*	0.0308*	0.0298*
	(1.71)	(1.71)	(1.70)	(1.66)	(1.70)	(1.71)	(1.68)
Market access * Urban (population)		-0.0100					
		(-0.05)					
Market access * Urban (light)			-0.330				
			(-1.38)				
Market access * Urban (calib. light)				-0.401			
				(-1.50)			
Market access * City Distance					-0.136		
					(-0.54)		
Market access * Literacy (2001)						-0.0108	
						(-0.65)	
Market access * Mean light							-0.198
							(-1.26)
N	4859	4859	4825	4796	4859	4859	4859
adj. R^2	0.610	0.610	0.610	0.620	0.610	0.610	0.610

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A3: Interaction effects with land characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Market Access	0.929**	0.898**	0.899**	0.862**	0.924**	0.954**	0.915**	0.869**
	(2.39)	(2.32)	(2.32)	(2.27)	(2.37)	(2.47)	(2.33)	(2.22)
Initial market access	1.566***	1.565***	1.575***	1.568***	1.565***	1.567***	1.563***	1.458***
	(4.04)	(4.06)	(4.06)	(4.07)	(4.05)	(4.08)	(4.02)	(3.71)
Log mean light in 1999	-0.247***	-0.246***	-0.248***	-0.247***	-0.247***	-0.246***	-0.247***	-0.245***
	(-15.15)	(-15.14)	(-15.15)	(-15.16)	(-15.15)	(-15.13)	(-15.10)	(-14.45)
Pre-trend	-0.106***	-0.105***	-0.104***	-0.106***	-0.106***	-0.106***	-0.106***	-0.109***
	(-5.03)	(-5.02)	(-4.98)	(-5.07)	(-5.05)	(-5.06)	(-5.03)	(-5.00)
Urban share	0.0307*	0.0302*	0.0297*	0.0311*	0.0307*	0.0293*	0.0315*	0.0325
	(1.71)	(1.67)	(1.68)	(1.66)	(1.71)	(1.68)	(1.71)	(1.11)
Market access * Cropland		0.00435						
		(0.71)						
Market access * Forest			-0.0222**					
			(-2.39)					
Market access * Small particles				-0.0178				
				(-1.60)				
Market access * Particle thickness					-0.158			
					(-0.08)			
Market access * Elevation						0.00106		
						(1.37)		
Market access * Roughness							-0.000998	
							(-0.86)	
Market access * Groundwater								0.0178
								(0.32)
N	4859	4859	4859	4859	4859	4859	4859	4671
adj. R^2	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.603

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. All variables are at the sub-district level except for groundwater, which is a district-level variables. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A4: Interaction effects with temperature and precipitation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Market Access	0.929**	0.957**	0.929**	0.960**	1.157***	0.977**	0.663*
	(2.39)	(2.44)	(2.39)	(2.31)	(2.85)	(2.52)	(1.86)
Initial market access	1.566***	1.569***	1.566***	1.566***	1.600***	1.557***	1.402***
	(4.04)	(4.04)	(4.05)	(4.04)	(4.10)	(4.05)	(3.70)
Log mean light in 1999	-0.247***	-0.247***	-0.247***	-0.247***	-0.247***	-0.247***	-0.247***
	(-15.15)	(-15.16)	(-15.17)	(-15.10)	(-15.16)	(-15.18)	(-15.18)
Pre-trend	-0.106***	-0.106***	-0.106***	-0.106***	-0.107***	-0.108***	-0.105***
	(-5.03)	(-5.05)	(-5.06)	(-5.05)	(-5.13)	(-5.16)	(-4.98)
Urban share	0.0307*	0.0308*	0.0307*	0.0307*	0.0296*	0.0309*	0.0319*
	(1.71)	(1.71)	(1.71)	(1.71)	(1.65)	(1.72)	(1.82)
Market access * Mean precipitation		0.00158					
		(0.24)					
Market access * Precipitation deviation			-0.000102				
			(-0.01)				
Market access * Precipitation anomaly				0.0105			
				(0.26)			
Market access * Mean temperature					-0.171		
					(-1.50)		
Market access * Temperature deviation						3.281	
						(1.60)	
Market access * Temperature anomaly							6.750***
							(3.24)
N	4859	4859	4859	4859	4859	4859	4859
adj. R^2	0.610	0.610	0.610	0.610	0.610	0.610	0.612

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.3 Main effects for urban and rural market access (calibrated light)

Table A5: Urban and rural market access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Urban market access	-0.380	-10.03***	21.26***	0.131	-9.748***	18.46***	0.143	-9.779***	18.47***
	(-0.10)	(-2.69)	(3.71)	(0.04)	(-2.65)	(3.67)	(0.04)	(-2.66)	(3.68)
Rural market access	1.864	11.04***	-19.64***	0.754	10.49***	-17.49***	0.732	10.52***	-17.47***
	(0.49)	(2.99)	(-3.51)	(0.22)	(2.89)	(-3.54)	(0.22)	(2.90)	(-3.53)
Initial urban market access	2.756	-2.341	16.11***	2.408	-2.362	12.30***	2.412	-2.382	12.33***
	(1.20)	(-1.35)	(4.02)	(1.28)	(-1.38)	(3.80)	(1.28)	(-1.40)	(3.83)
Initial rural market access	-0.383	3.700**	-13.32***	-0.863	3.525**	-10.73***	-0.870	3.543**	-10.74***
	(-0.18)	(2.03)	(-3.59)	(-0.45)	(1.98)	(-3.35)	(-0.46)	(1.99)	(-3.36)
Log mean light in 1999	-0.256***	-0.204***	-0.324***	-0.246***	-0.215***	-0.295***	-0.247***	-0.212***	-0.294***
	(-17.23)	(-10.49)	(-14.27)	(-15.21)	(-10.78)	(-10.50)	(-14.44)	(-9.89)	(-10.28)
Pre-trend				-0.103***	-0.180***	-0.0685***	-0.102***	-0.182***	-0.0691***
				(-4.85)	(-4.72)	(-2.86)	(-4.86)	(-4.78)	(-2.89)
Urban share				0.0347*	0.0134	-17.23**	0.0342*	0.0140	-17.25**
				(1.88)	(0.66)	(-2.41)	(1.85)	(0.68)	(-2.42)
Growth in literacy rate							-0.0589	0.109	0.0971
							(-0.43)	(0.51)	(0.53)
N	5273	2666	2607	4859	2608	2251	4859	2608	2251
adj. R^2	0.591	0.674	0.577	0.610	0.683	0.595	0.610	0.683	0.594

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). Columns 1, 4, and 7 are for the full sample; columns 2, 5, and 8 are for the urban sample; columns 3, 6, and 9 are for the rural sample. The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.4 Interaction effects of urban and rural market access with local characteristics (calibrated light)

C.4.1 Outcomes in urban and rural locations (calibrated light)

Table A6: Interaction effects of urban and rural market access with urban dummy, literacy, and distance to large city

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban market Access	0.131	0.347	0.623	0.299	-0.533	-0.610	-0.380
	(0.04)	(0.10)	(0.18)	(0.09)	(-0.15)	(-0.19)	(-0.12)
Rural market Access	0.754	0.579	0.350	0.621	1.488	1.579	1.321
	(0.22)	(0.17)	(0.10)	(0.19)	(0.43)	(0.48)	(0.42)
Initial urban market access	2.408	2.361	2.656	2.841	1.940	1.656	1.722
	(1.28)	(1.26)	(1.36)	(1.47)	(1.00)	(0.90)	(0.96)
Initial rural market access	-0.863	-0.813	-1.147	-1.335	-0.358	-0.140	-0.202
	(-0.45)	(-0.43)	(-0.58)	(-0.68)	(-0.18)	(-0.07)	(-0.11)
Log mean light in 1999	-0.246***	-0.246***	-0.248***	-0.252***	-0.247***	-0.249***	-0.250***
	(-15.21)	(-15.34)	(-15.39)	(-15.74)	(-15.28)	(-15.48)	(-14.52)
Pre-trend	-0.103***	-0.103***	-0.104***	-0.103***	-0.105***	-0.111***	-0.108***
	(-4.85)	(-4.87)	(-4.89)	(-4.85)	(-4.96)	(-5.21)	(-4.91)
Urban share	0.0347*	0.0348*	0.0351*	0.0343*	0.0343*	0.0352*	0.0326*
	(1.88)	(1.88)	(1.90)	(1.88)	(1.84)	(1.88)	(1.82)
Urban market access * Urban (population)		-0.405					
		(-0.64)					
Rural market access * Urban (population)		0.332					
		(0.57)					
Urban market access * Urban (light)			-1.256**				
			(-2.19)				
Rural market access * Urban (light)			0.776				
			(1.36)				
Urban market access * Urban (calib. light)				-1.455**			
				(-2.45)			
Rural market access * Urban (calib. light)				0.880			
				(1.43)			
Urban market access * City Distance					0.926		
					(1.33)		
Rural market access * City Distance					-0.975		
					(-1.34)		
Urban market access * Literacy (2001)						-0.140***	
						(-3.28)	
Rural market access * Literacy (2001)						0.112***	
						(2.76)	
Urban market access * Mean light							-0.866
							(-1.37)
Rural market access * Mean light							0.587
							(0.92)
N	4859	4859	4825	4796	4859	4859	4859
adj. R^2	0.610	0.610	0.611	0.621	0.610	0.612	0.611

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A7: Interaction effects of urban and rural market access with land characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urban market access	0.131	0.0745	-0.231	-0.144	0.300	-0.0345	0.0864	0.238
	(0.04)	(0.02)	(-0.07)	(-0.04)	(0.09)	(-0.01)	(0.03)	(0.07)
Rural market access	0.754	0.767	1.042	0.992	0.670	0.903	0.784	0.586
	(0.22)	(0.23)	(0.30)	(0.30)	(0.20)	(0.27)	(0.23)	(0.17)
Initial urban market access	2.408	2.430	2.472	2.264	2.297	2.408	2.384	2.960
	(1.28)	(1.29)	(1.31)	(1.22)	(1.27)	(1.26)	(1.27)	(1.44)
Initial rural market access	-0.863	-0.890	-0.929	-0.713	-0.830	-0.829	-0.842	-1.488
	(-0.45)	(-0.46)	(-0.48)	(-0.38)	(-0.45)	(-0.43)	(-0.44)	(-0.72)
Log mean light in 1999	-0.246***	-0.246***	-0.248***	-0.245***	-0.245***	-0.246***	-0.246***	-0.244***
	(-15.21)	(-15.39)	(-15.30)	(-15.22)	(-15.24)	(-15.20)	(-15.12)	(-14.54)
Pre-trend	-0.103***	-0.103***	-0.101***	-0.104***	-0.104***	-0.102***	-0.103***	-0.106***
	(-4.85)	(-4.87)	(-4.83)	(-4.89)	(-4.87)	(-4.84)	(-4.83)	(-4.82)
Urban share	0.0347*	0.0344*	0.0345*	0.0347*	0.0338*	0.0337*	0.0355*	0.0387
	(1.88)	(1.85)	(1.86)	(1.83)	(1.83)	(1.89)	(1.88)	(1.27)
Urban market access * Cropland		0.0140						
		(0.67)						
Rural market access * Cropland		-0.00772						
		(-0.41)						
Urban market access * Forest			-0.146***					
			(-3.48)					
Rural market access * Forest			0.113***					
			(2.95)					
Urban market access * Small particles				0.0246				
				(0.74)				
Rural market access * Small particles				-0.0378				
				(-1.36)				
Urban market access * Particle thickness					-12.24**			
					(-2.00)			
Rural market access * Particle thickness					11.10*			
					(1.91)			
Urban market access * Elevation						-0.00240		
						(-1.10)		
Rural market access * Elevation						0.00322		
						(1.57)		
Urban market access * Roughness							-0.000319	
							(-0.06)	
Rural market access * Roughness							-0.000691	
							(-0.12)	
Urban market access * Groundwater								0.633**
								(2.43)
Rural market access * Groundwater								-0.605**
								(-2.28)
N	4859	4859	4859	4859	4859	4859	4859	4671
adj. R^2	0.610	0.610	0.611	0.611	0.611	0.611	0.610	0.604

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A8: Interaction effects of urban and rural market access with temperature

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban market Access	0.131	0.0209	-0.0905	0.0717	-0.624	-0.909	-1.755
	(0.04)	(0.01)	(-0.03)	(0.02)	(-0.18)	(-0.27)	(-0.56)
Rural market Access	0.754	0.903	0.986	0.868	1.748	1.858	2.419
	(0.22)	(0.26)	(0.29)	(0.25)	(0.51)	(0.55)	(0.77)
Initial urban market access	2.408	2.382	2.382	2.459	2.303	2.244	1.903
	(1.28)	(1.26)	(1.27)	(1.32)	(1.23)	(1.21)	(1.07)
Initial rural market access	-0.863	-0.834	-0.861	-0.907	-0.720	-0.719	-0.516
	(-0.45)	(-0.43)	(-0.45)	(-0.48)	(-0.38)	(-0.38)	(-0.28)
Log mean light in 1999	-0.246***	-0.246***	-0.246***	-0.246***	-0.246***	-0.246***	-0.245***
	(-15.21)	(-15.22)	(-15.23)	(-15.13)	(-15.24)	(-15.26)	(-15.31)
Pre-trend	-0.103***	-0.103***	-0.103***	-0.102***	-0.104***	-0.105***	-0.105***
	(-4.85)	(-4.86)	(-4.89)	(-4.82)	(-4.96)	(-4.99)	(-4.91)
Urban share	0.0347*	0.0348*	0.0349*	0.0350*	0.0337*	0.0353*	0.0349*
	(1.88)	(1.88)	(1.88)	(1.88)	(1.83)	(1.91)	(1.91)
Urban market access * Mean precipitation		-0.0000469					
		(-0.00)					
Rural market access * Mean precipitation		0.00232					
		(0.13)					
Urban market access * Precipitation deviation			-0.0237				
			(-0.49)				
Rural market access * Precipitation deviation			0.0231				
			(0.54)				
Urban market access * Precipitation anomaly				-0.154			
				(-1.10)			
Rural market access * Precipitation anomaly				0.164			
				(1.14)			
Urban market access * Mean temperature					0.140		
					(0.39)		
Rural market access * Mean temperature					-0.326		
					(-1.02)		
Urban market access * Temperature deviation						-2.391	
						(-0.32)	
Rural market access * Temperature deviation						6.466	
						(0.87)	
Urban market access * Temperature anomaly							15.38***
							(2.86)
Rural market access * Temperature anomaly							-7.882
							(-1.59)
N	4859	4859	4859	4859	4859	4859	4859
adj. R^2	0.610	0.610	0.610	0.610	0.610	0.611	0.613

The dependent variable is growth in light at the sub-district level from 1999 to 2012 (averaging start and end years). The radiance-calibrated light data is from the World Bank. Market access is based on the approximation. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.4.2 Main effects for general equilibrium market access measures (calibrated light)

Table A9: Main effects for general equilibrium market access measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Urban CMA	8.226**	0.239	171.6**	6.586**	0.719	205.6***	6.614**	0.638	205.1***
	(2.52)	(0.06)	(2.49)	(2.03)	(0.17)	(3.21)	(2.03)	(0.15)	(3.18)
Rural CMA	-5.321*	0.0655	183.1**	-5.672*	-1.188	237.1***	-5.708*	-1.118	236.5***
	(-1.72)	(0.02)	(2.07)	(-1.86)	(-0.31)	(2.87)	(-1.87)	(-0.29)	(2.84)
Firm market access	-0.692	1.068	-351.2**	0.515	1.498*	-440.4***	0.513	1.507*	-439.3***
	(-0.83)	(1.36)	(-2.24)	(0.65)	(1.80)	(-3.01)	(0.65)	(1.81)	(-2.98)
Initial urban CMA	6.543***	-0.663	126.5***	4.578*	-0.487	130.4***	4.600*	-0.528	130.0***
	(2.61)	(-0.25)	(2.92)	(1.89)	(-0.18)	(3.56)	(1.89)	(-0.20)	(3.51)
Initial rural CMA	-3.596	2.144	140.1**	-2.622	1.797	156.4***	-2.645	1.832	155.9***
	(-1.59)	(0.83)	(2.48)	(-1.16)	(0.69)	(3.22)	(-1.16)	(0.70)	(3.18)
Initial FMA	0.115***	0.0640**	-262.1***	0.0557**	0.0429	-284.2***	0.0546**	0.0433	-283.3***
	(4.81)	(2.18)	(-2.64)	(2.48)	(1.45)	(-3.35)	(2.44)	(1.47)	(-3.30)
Initial MeanLight	-0.271***	-0.207***	-0.327***	-0.255***	-0.216***	-0.303***	-0.256***	-0.213***	-0.302***
	(-17.73)	(-10.49)	(-14.23)	(-15.32)	(-10.69)	(-10.57)	(-14.61)	(-9.81)	(-10.35)
Pre-trend				-0.105***	-0.182***	-0.0721***	-0.104***	-0.184***	-0.0725***
				(-4.99)	(-4.78)	(-3.15)	(-4.99)	(-4.83)	(-3.17)
Urban share				0.0220	0.00766	-18.17***	0.0217	0.00820	-18.17***
				(1.29)	(0.43)	(-2.69)	(1.27)	(0.45)	(-2.69)
Growth in literacy rate							-0.0528	0.102	0.0658
							(-0.38)	(0.48)	(0.34)
N	5238	2650	2588	4832	2594	2238	4832	2594	2238
adj. R^2	0.594	0.674	0.577	0.611	0.682	0.596	0.611	0.682	0.596

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Columns 1, 4, and 7 are for the full sample; columns 2, 5, and 8 are for the urban sample; columns 3, 6, and 9 are for the rural sample. The radiance-calibrated light data is from the World Bank. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.4.3 Main effects for general equilibrium market access measures (calibrated light, NOAA)

Table A10: Main effects for general equilibrium market access measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Urban CMA	1.841***	-4.185	11.80*	1.674	-4.962	9.452*	1.663	1.663	1.663
	(3.75)	(-1.31)	(1.94)	(0.63)	(-1.56)	(1.74)	(0.63)	(0.63)	(0.63)
Initial urban CMA	3.193***	1.349	6.996*	3.241*	0.811	4.972*	3.254*	3.254*	3.254*
	(4.34)	(0.67)	(1.72)	(1.88)	(0.41)	(1.73)	(1.88)	(1.88)	(1.88)
Initial mean light	-0.262***	-0.231***	-0.335***	-0.268***	-0.234***	-0.307***	-0.269***	-0.269***	-0.269***
	(-17.38)	(-10.53)	(-13.69)	(-15.10)	(-10.68)	(-9.93)	(-14.49)	(-14.49)	(-14.49)
Rural CMA		5.842*	-5.596	-0.432	5.423*	-6.086	-0.428	-0.428	-0.428
		(1.82)	(-1.04)	(-0.16)	(1.72)	(-1.31)	(-0.16)	(-0.16)	(-0.16)
Firm market access		-0.623	-3.849	-0.171	0.313	-1.941	-0.176	-0.176	-0.176
		(-0.84)	(-1.08)	(-0.21)	(0.43)	(-0.47)	(-0.22)	(-0.22)	(-0.22)
Initial rural CMA		0.296	-3.326	-1.288	0.640	-3.008	-1.304	-1.304	-1.304
		(0.14)	(-0.96)	(-0.73)	(0.30)	(-1.12)	(-0.74)	(-0.74)	(-0.74)
Initial FMA		0.0529***	0.120**	0.0518***	0.0307**	0.0888*	0.0517***	0.0517***	0.0517***
		(3.86)	(2.38)	(3.83)	(2.52)	(1.90)	(3.82)	(3.82)	(3.82)
Pre-trend				-0.101***	-0.173***	-0.0709***	-0.101***	-0.101***	-0.101***
				(-4.93)	(-4.59)	(-3.09)	(-4.93)	(-4.93)	(-4.93)
Urban share				0.0245	0.00696	-15.19**	0.0239	0.0239	0.0239
				(1.47)	(0.40)	(-2.16)	(1.44)	(1.44)	(1.44)
Growth in literacy rate							-0.0621	-0.0621	-0.0621
							(-0.44)	(-0.44)	(-0.44)
N	5238	2650	2588	4832	2594	2238	4832	4832	4832
adj. R^2	0.593	0.677	0.574	0.613	0.684	0.592	0.613	0.613	0.613

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Columns 1, 4, and 7 are for the full sample; columns 2, 5, and 8 are for the urban sample; columns 3, 6, and 9 are for the rural sample. The radiance-calibrated light data is from NOAA. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.4.4 Interaction effects for general equilibrium market access measures (calibrated light)

Table A11: Interactions of market access with urban, literacy and distance variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	6.586**	9.168**	6.599**	6.703**	6.733**	5.789*	6.281*
	(2.03)	(2.26)	(2.03)	(2.08)	(2.11)	(1.85)	(1.95)
Rural CMA	-5.672*	-2.571	-5.142*	-5.264*	-5.634*	-3.332	-4.568
	(-1.86)	(-0.76)	(-1.70)	(-1.78)	(-1.88)	(-1.15)	(-1.56)
Firm Market Access	0.515	-5.196	-0.0308	-0.0421	0.511	-0.926	-0.310
	(0.65)	(-1.31)	(-0.03)	(-0.04)	(0.66)	(-1.08)	(-0.27)
Initial Urban CMA	4.578*	4.634*	4.350*	4.703**	4.567*	3.587	4.157*
	(1.89)	(1.91)	(1.80)	(1.98)	(1.90)	(1.57)	(1.79)
Initial Rural CMA	-2.622	-2.665	-2.423	-2.760	-2.552	-1.741	-2.259
	(-1.16)	(-1.17)	(-1.08)	(-1.25)	(-1.14)	(-0.80)	(-1.06)
Initial FMA	0.0557**	0.0589**	0.0602**	0.0575**	0.0556**	0.0771***	0.0634***
	(2.48)	(2.34)	(2.55)	(2.49)	(2.49)	(3.34)	(2.69)
Log mean light in 2001	-0.255***	-0.254***	-0.256***	-0.260***	-0.256***	-0.258***	-0.255***
	(-15.32)	(-15.11)	(-15.08)	(-15.49)	(-15.28)	(-15.32)	(-14.09)
Pre-trend	-0.105***	-0.106***	-0.106***	-0.105***	-0.106***	-0.109***	-0.106***
	(-4.99)	(-5.02)	(-5.06)	(-5.01)	(-5.05)	(-5.27)	(-4.93)
Urban share	0.0220	0.0225	0.0218	0.0210	0.0215	0.0227	0.0220
	(1.29)	(1.31)	(1.28)	(1.24)	(1.26)	(1.34)	(1.31)
Urban CMA * Urban (population)		-2.863					
		(-1.27)					
Rural CMA * Urban (population)		-3.824*					
		(-1.93)					
FMA * Urban (population)		6.753*					
		(1.69)					
Urban CMA * Urban (light)			-0.668				
			(-0.95)				
Rural CMA * Urban (light)			-0.0248				
			(-0.03)				
FMA * Urban (light)			0.640				
			(0.48)				
Urban CMA * Urban (calib. light)				-0.763			
				(-1.12)			
Rural CMA * Urban (calib. light)				-0.413			
				(-0.39)			
FMA * Urban (calib. light)				1.146			
				(0.81)			
Urban CMA * City Distance					-0.136		
					(-0.18)		
Rural CMA * City Distance					-0.489		
					(-0.55)		
FMA* City Distance					0.129		
					(0.11)		
Urban CMA * Literacy (2001)						-0.157***	
						(-3.15)	
Rural CMA * Literacy (2001)						0.0456	
						(0.78)	
FMA * Literacy (2001)						0.0836	
						(0.96)	
Urban CMA * MeanLight							-0.714
							(-1.13)
Rural CMA * Mean light							-0.344
							(-0.39)
FMA * Mean light							0.866
							(0.78)
N	4832	4832	4825	4796	4832	4832	4832
adj. R^2	0.611	0.611	0.611	0.621	0.611	0.613	0.611

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated).Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from the World Bank. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A12: Interactions of market access with land variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urban CMA	6.586**	6.390**	6.332*	6.256*	5.751*	6.544**	6.534**	5.261
	(2.03)	(2.00)	(1.95)	(1.94)	(1.76)	(2.07)	(2.03)	(1.62)
Rural CMA	-5.672*	-5.609*	-6.357**	-5.958**	-4.896	-5.640*	-5.579*	-5.151*
	(-1.86)	(-1.86)	(-2.07)	(-1.98)	(-1.59)	(-1.90)	(-1.84)	(-1.67)
Firm Market Access	0.515	0.680	1.431	1.085	0.598	0.580	0.473	1.179
	(0.65)	(0.68)	(1.56)	(1.38)	(0.67)	(0.73)	(0.58)	(1.35)
Initial Urban CMA	4.578*	4.344*	4.807**	4.460*	4.356*	4.753**	4.475*	3.908*
	(1.89)	(1.84)	(1.98)	(1.85)	(1.79)	(1.98)	(1.85)	(1.65)
Initial Rural CMA	-2.622	-2.421	-2.860	-2.523	-2.579	-2.803	-2.536	-2.066
	(-1.16)	(-1.10)	(-1.26)	(-1.13)	(-1.13)	(-1.25)	(-1.13)	(-0.94)
Initial FMA	0.0557**	0.0538**	0.0614***	0.0603***	0.0636**	0.0549**	0.0559**	0.0576**
	(2.48)	(2.37)	(2.67)	(2.64)	(2.55)	(2.48)	(2.48)	(2.47)
Log mean light in 2001	-0.255***	-0.255***	-0.257***	-0.255***	-0.254***	-0.254***	-0.255***	-0.253***
	(-15.32)	(-15.49)	(-15.39)	(-15.41)	(-15.45)	(-15.32)	(-15.32)	(-14.78)
Pre-trend	-0.105***	-0.104***	-0.103***	-0.107***	-0.106***	-0.105***	-0.105***	-0.109***
	(-4.99)	(-4.94)	(-4.97)	(-5.05)	(-4.95)	(-5.03)	(-4.96)	(-5.01)
Urban share	0.0220	0.0221	0.0199	0.0216	0.0213	0.0205	0.0219	0.0188
	(1.29)	(1.31)	(1.21)	(1.25)	(1.29)	(1.26)	(1.29)	(0.83)
Urban market access * Cropland		-0.0267						
		(-1.39)						
Rural market access * Cropland		0.0215						
		(0.97)						
FMA * Cropland		-0.00226						
		(-0.08)						
Urban market access * Forest			-0.224***					
			(-3.24)					
Rural market access * Forest			-0.0828					
			(-0.76)					
FMA * Forest			0.280*					
			(1.92)					
Urban market access * Small particles				-0.0479				
				(-1.08)				
Rural market access * Small particles				-0.109**				
				(-2.29)				
FMA * Small particles				0.141**				
				(2.04)				
Urban market access * Particle thickness					-11.20*			
					(-1.96)			
Rural market access * Particle thickness					13.81**			
					(2.32)			
FMA * Particle thickness					-6.095			
					(-1.02)			
Urban market access * Elevation						0.000903		
						(0.41)		
Rural market access * Elevation						0.000927		
						(0.44)		
FMA * Elevation						0.000638		
						(0.25)		
Urban market access * Roughness							0.00308	
							(0.56)	
Rural market access * Roughness							-0.00230	
							(-0.48)	
FMA * Roughness							-0.00108	
							(-0.16)	
Urban market access * Groundwater								0.538
								(1.44)
Rural market access * Groundwater								-0.490
								(-1.28)
FMA * Groundwater								-0.0968
								(-1.08)
N	4832	4832	4832	4832	4832	4832	4832	4646
adj. R^2	0.611	0.612	0.612	0.612	0.612	0.612	0.611	0.605

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from the World Bank. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A13: Interactions of market access with climate variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	6.586**	5.407*	5.803*	6.261*	5.399	5.465	5.294*
	(2.03)	(1.66)	(1.84)	(1.91)	(1.63)	(1.61)	(1.74)
Rural CMA	-5.672*	-6.502**	-5.779*	-5.274*	-4.161	-5.431*	-4.555
	(-1.86)	(-2.04)	(-1.92)	(-1.69)	(-1.33)	(-1.67)	(-1.60)
Firm Market Access	0.515	2.583*	1.445	0.462	0.546	1.365	0.361
	(0.65)	(1.86)	(1.47)	(0.56)	(0.69)	(1.26)	(0.44)
Initial Urban CMA	4.578*	4.771**	4.631*	4.576*	4.276*	4.244*	4.429*
	(1.89)	(1.97)	(1.94)	(1.92)	(1.77)	(1.77)	(1.89)
Initial Rural CMA	-2.622	-2.838	-2.719	-2.605	-2.299	-2.332	-2.648
	(-1.16)	(-1.25)	(-1.21)	(-1.17)	(-1.02)	(-1.04)	(-1.20)
Initial FMA	0.0557**	0.0577**	0.0619***	0.0539**	0.0607**	0.0724**	0.0531**
	(2.48)	(2.50)	(2.63)	(2.21)	(2.51)	(2.40)	(2.41)
Log mean light in 2001	-0.255***	-0.257***	-0.255***	-0.255***	-0.255***	-0.256***	-0.254***
	(-15.32)	(-15.40)	(-15.37)	(-15.30)	(-15.33)	(-15.55)	(-15.46)
Pre-trend	-0.105***	-0.106***	-0.106***	-0.104***	-0.106***	-0.106***	-0.106***
	(-4.99)	(-5.05)	(-5.06)	(-4.94)	(-5.13)	(-5.09)	(-5.02)
Urban share	0.0220	0.0212	0.0216	0.0221	0.0209	0.0213	0.0234
	(1.29)	(1.26)	(1.27)	(1.29)	(1.23)	(1.25)	(1.42)
Urban CMA * Mean precipitation		-0.0493*					
		(-1.83)					
Rural CMA * Mean precipitation		-0.0182					
		(-0.65)					
FMA * Mean precipitation		0.0683**					
		(2.12)					
Urban CMA * Precipitation deviation			-0.120**				
			(-2.30)				
Rural CMA * Precipitation deviation			-0.0448				
			(-0.74)				
FMA * Precipitation deviation			0.161**				
			(2.10)				
Urban CMA * Precipitation anomaly				-0.149			
				(-1.09)			
Rural CMA * Precipitation anomaly				0.121			
				(0.85)			
FMA * Precipitation anomaly				0.0244			
				(0.27)			
Urban CMA * Mean temperature					-0.206		
					(-0.60)		
Rural CMA * Mean temperature					-0.443		
					(-1.46)		
FMA * Mean temperature					0.335		
					(1.07)		
Urban CMA * Temperature deviation						7.756	
						(1.03)	
Rural CMA* Temperature deviation						2.060	
						(0.26)	
FMA * Temperature deviation						-7.517	
						(-1.30)	
Urban CMA* Temperature anomaly							9.846**
							(2.08)
Rural CMA * Temperature anomaly							-7.175
							(-1.64)
FMA * Temperature anomaly							7.139*
							(1.66)
N	4832	4832	4832	4832	4832	4832	4832
adj. R^2	0.611	0.612	0.611	0.611	0.612	0.611	0.614

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from the World Bank. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

C.4.5 Interaction effects for general equilibrium market access measures (calibrated light, NOAA)

Table A14: Interactions of market access with urban, literacy, and distance variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	3.912	9.492***	9.048**	23.33***	4.047	4.892*	7.303**
	(1.38)	(2.66)	(2.41)	(3.02)	(1.43)	(1.70)	(2.41)
Rural CMA	-3.246	-1.752	-0.632	8.042*	-2.876	-2.308	-0.517
	(-1.11)	(-0.57)	(-0.22)	(1.78)	(-1.00)	(-0.83)	(-0.20)
Firm Market Access	-0.367	-7.367**	-8.060**	-31.09***	-0.862	-2.316***	-6.465***
	(-0.45)	(-2.45)	(-2.54)	(-2.89)	(-1.13)	(-2.73)	(-4.14)
Initial Urban CMA	3.234*	3.192*	2.645	1.959	2.887*	2.330	1.405
	(1.81)	(1.79)	(1.53)	(1.18)	(1.65)	(1.36)	(0.86)
Initial Rural CMA	-2.210	-2.256	-1.718	-0.853	-1.866	-1.536	-0.627
	(-1.20)	(-1.23)	(-0.96)	(-0.50)	(-1.04)	(-0.86)	(-0.38)
Initial FMA	0.00954	0.0156	0.00806	-0.148	0.0169	0.0247**	0.0443***
	(0.81)	(1.28)	(0.55)	(-1.45)	(1.44)	(2.02)	(3.19)
Log mean light in 2001	-0.140***	-0.134***	-0.134***	-0.137***	-0.140***	-0.133***	-0.118***
	(-7.18)	(-6.77)	(-6.80)	(-6.99)	(-7.13)	(-6.87)	(-6.18)
Pre-trend	-0.0957***	-0.0969***	-0.0943***	-0.0958***	-0.0956***	-0.0948***	-0.0931***
	(-4.34)	(-4.39)	(-4.29)	(-4.38)	(-4.34)	(-4.33)	(-4.28)
Urban share	-0.0858	-0.109	-0.0982	-0.0789	-0.131	-0.160*	-0.313***
	(-1.09)	(-1.38)	(-1.27)	(-1.04)	(-1.60)	(-1.93)	(-3.18)
Urban CMA * Urban (population)		-6.325***					
		(-2.65)					
Rural CMA * Urban (population)		-1.087					
		(-1.23)					
FMA * Urban (population)		7.139**					
		(2.38)					
Urban CMA * Urban (light)			-7.531***				
			(-2.69)				
Rural CMA * Urban (light)			-1.329				
			(-1.60)				
FMA* Urban (light)			8.059**				
			(2.40)				
Urban CMA * Urban (calib. light)				-36.67**			
				(-2.42)			
Rural CMA * Urban (calib. light)				-19.34*			
				(-1.75)			
FMA * Urban (calib. light)				54.99**			
				(2.12)			
Urban CMA * City Distance					1.754**		
					(1.99)		
Rural CMA * City Distance					0.0242		
					(0.03)		
FMA* City Distance					-1.648*		
					(-1.71)		
Urban CMA * Literacy (2001)						-0.251***	
						(-4.21)	
Rural CMA * Literacy (2001)						0.0607	
						(1.36)	
FMA * Literacy (2001)						0.148**	
						(2.21)	
Urban CMA * Mean light							-4.730***
							(-4.70)
Rural CMA * Mean light							-0.259
							(-0.30)
FMA * Mean light							4.296***
							(3.64)
N	4796	4796	4795	4796	4796	4796	4796
adj. R^2	0.557	0.558	0.559	0.560	0.558	0.560	0.565

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated).Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from NOAA. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A15: Interactions of market access with land variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urban CMA	3.912	3.605	4.791*	3.992	3.603	4.032	4.152	2.747
	(1.38)	(1.33)	(1.65)	(1.41)	(1.27)	(1.41)	(1.47)	(0.94)
Rural CMA	-3.246	-3.021	-3.060	-2.833	-2.434	-3.411	-3.135	-3.077
	(-1.11)	(-1.05)	(-1.04)	(-0.99)	(-0.86)	(-1.18)	(-1.09)	(-1.03)
Firm Market Access	-0.367	-0.349	-1.469	-0.863	-0.716	-0.240	-0.681	0.514
	(-0.45)	(-0.32)	(-1.43)	(-1.00)	(-0.65)	(-0.29)	(-0.83)	(0.52)
Initial Urban CMA	3.234*	3.157*	3.248*	2.889	2.432	3.559**	3.089*	2.568
	(1.81)	(1.83)	(1.82)	(1.64)	(1.40)	(2.01)	(1.75)	(1.43)
Initial Rural CMA	-2.210	-2.143	-2.233	-1.874	-1.600	-2.524	-2.064	-1.675
	(-1.20)	(-1.20)	(-1.22)	(-1.04)	(-0.89)	(-1.37)	(-1.13)	(-0.91)
Initial FMA	0.00954	0.00901	0.0125	0.0100	0.0118	0.00776	0.00909	0.00618
	(0.81)	(0.74)	(1.05)	(0.84)	(0.99)	(0.66)	(0.77)	(0.53)
Log mean light in 2001	-0.140***	-0.138***	-0.137***	-0.137***	-0.138***	-0.139***	-0.139***	-0.137***
	(-7.18)	(-7.14)	(-6.90)	(-7.19)	(-7.25)	(-7.18)	(-7.17)	(-6.80)
Pre-trend	-0.0957***	-0.0948***	-0.0955***	-0.0966***	-0.0971***	-0.0952***	-0.0965***	-0.0999***
	(-4.34)	(-4.26)	(-4.30)	(-4.38)	(-4.36)	(-4.39)	(-4.35)	(-4.34)
Urban share	-0.0858	-0.0933	-0.0945	-0.0904	-0.0937	-0.0871	-0.0881	-0.0944
	(-1.09)	(-1.23)	(-1.20)	(-1.16)	(-1.20)	(-1.12)	(-1.13)	(-1.18)
Urban market access * Cropland		-0.00120						
		(-0.05)						
Rural market access * Cropland		0.00960						
		(0.44)						
FMA * Cropland		0.00116						
		(0.05)						
Urban market access * Forest			0.279**					
			(2.00)					
Rural market access * Forest			-0.0421					
			(-0.61)					
FMA * Forest			-0.259*					
			(-1.71)					
Urban market access * Small particles				0.130*				
				(1.83)				
Rural market access * Small particles				-0.0667				
				(-1.56)				
FMA * Small particles				-0.0762				
				(-1.22)				
Urban market access * Particle thickness					-19.12***			
					(-2.86)			
Rural market access * Particle thickness					16.51**			
					(2.51)			
FMA * Particle thickness					0.436			
					(0.09)			
Urban market access * Elevation						0.00110		
						(0.36)		
Rural market access * Elevation						0.00107		
						(0.65)		
FMA * Elevation						0.000371		
						(0.14)		
Urban market access * Roughness							0.0127*	
							(1.84)	
Rural market access * Roughness							-0.00184	
							(-0.69)	
FMA * Roughness							-0.00962	
							(-1.56)	
Urban market access * Groundwater								0.309
								(0.90)
Rural market access * Groundwater								-0.138
								(-0.42)
FMA * Groundwater								-0.117
								(-1.53)
N	4796	4796	4796	4796	4796	4796	4796	4612
adj. R^2	0.557	0.557	0.558	0.558	0.559	0.558	0.557	0.552

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from NOAA. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.

Table A16: Interactions of market access with climate variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban CMA	3.912	3.155	2.474	3.487	3.449	2.532	2.112
	(1.38)	(1.11)	(0.90)	(1.20)	(1.19)	(0.88)	(0.78)
Rural CMA	-3.246	-4.491	-3.282	-3.413	-3.117	-3.425	-1.572
	(-1.11)	(-1.50)	(-1.16)	(-1.12)	(-1.02)	(-1.10)	(-0.58)
Firm Market Access	-0.367	1.630	1.176	0.136	0.309	1.262	-0.608
	(-0.45)	(1.04)	(1.09)	(0.15)	(0.33)	(0.59)	(-0.67)
Initial Urban CMA	3.234*	3.262*	2.761	3.276*	3.102*	2.936*	2.963*
	(1.81)	(1.87)	(1.59)	(1.86)	(1.76)	(1.66)	(1.77)
Initial Rural CMA	-2.210	-2.145	-1.748	-2.259	-2.018	-1.921	-2.107
	(-1.20)	(-1.18)	(-0.97)	(-1.24)	(-1.10)	(-1.04)	(-1.20)
Initial FMA	0.00954	0.00499	0.00756	0.00701	0.00345	0.00598	0.00847
	(0.81)	(0.42)	(0.65)	(0.60)	(0.30)	(0.49)	(0.71)
Log mean light in 2001	-0.140***	-0.142***	-0.142***	-0.139***	-0.140***	-0.141***	-0.138***
	(-7.18)	(-7.22)	(-7.27)	(-7.09)	(-7.19)	(-7.23)	(-7.08)
Pre-trend	-0.0957***	-0.0948***	-0.0961***	-0.0942***	-0.0977***	-0.0966***	-0.0968***
	(-4.34)	(-4.30)	(-4.37)	(-4.27)	(-4.46)	(-4.36)	(-4.36)
Urban share	-0.0858	-0.0937	-0.109	-0.0844	-0.0903	-0.0864	-0.0975
	(-1.09)	(-1.19)	(-1.37)	(-1.08)	(-1.15)	(-1.10)	(-1.25)
Urban CMA * Mean precipitation		-0.00315					
		(-0.10)					
Rural CMA * Mean precipitation		-0.0485					
		(-1.65)					
FMA * Mean precipitation		0.0502*					
		(1.92)					
Urban CMA * Precipitation deviation			-0.198***				
			(-2.88)				
Rural CMA * Precipitation deviation			0.0161				
			(0.28)				
FMA * Precipitation deviation			0.174***				
			(2.95)				
Urban CMA * Precipitation anomaly				-0.0402			
				(-0.29)			
Rural CMA * Precipitation anomaly				0.0921			
				(0.64)			
FMA * Precipitation anomaly				-0.0820			
				(-1.23)			
Urban CMA * Mean temperature					-0.928**		
					(-2.29)		
Rural CMA * Mean temperature					-0.0972		
					(-0.33)		
FMA * Mean temperature					0.751***		
					(2.79)		
Urban CMA * Temperature deviation						-0.373	
						(-0.04)	
Rural CMA* Temperature deviation						9.773	
						(1.15)	
FMA * Temperature deviation						-7.453	
						(-1.03)	
Urban CMA* Temperature anomaly							9.352*
							(1.95)
Rural CMA * Temperature anomaly							-5.841
							(-1.33)
FMA * Temperature anomaly							6.357*
							(1.88)
N	4796	4796	4796	4796	4796	4796	4796
adj. R^2	0.557	0.558	0.558	0.557	0.558	0.557	0.560

The dependent variable is growth in light at the sub-district level from 2001 to 2011 (calibrated). Column 1 represents the base line regression without interaction effects. The radiance-calibrated light data is from NOAA. Market access measures are the solution of the general equilibrium model. All regressions control for sub-district fixed effects and district-year fixed effects. Standard errors are clustered at the district level. t values reported in parenthesis. Significance levels are: * 0.10, ** 0.05, *** 0.01.