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Transport Policies and Development

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Abstract

This survey reviews the current state of the economic literature, assessing the impact of transport policies on growth, inclusion, and sustainability in a developing country context. The findings are summarized and methodologies are critically assessed, especially those dealing with endogeneity issues in empirical studies. The specific implementation challenges of transport policies in developing countries are discussed.

Transport Policies and Development[1]

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Transport Policies and Development

1. Introduction

In developed economies, transport investments and improved transport technology over the last century have resulted in a continuous decline in transport costs, which in turn stimulated growth and economic development. In low- and middle-income countries, the current potential for transport investments and policies to boost sustainable and inclusive growth through declining transport costs also appears to be large. This is especially the case given significant backlogs of transport infrastructure investment in both rural and urban areas, weak governance and inadequate regulations in the transport sector, and rising social costs in terms of congestion, pollution and accidents, especially in emerging large cities. Transport investments can be very large and transformative in their nature, and their success depends on a variety of factors. Because these factors are not well understood and may not be taken into account by policy makers, there is often a risk that transport investments are not cost-effective and do not produce the range of expected outcomes. Thus, understanding and assessing how transport policies can produce growth-inducing effects and reduce social costs will be important for setting priorities in the strategic use of scarce resources.

The objective of this paper is to review the broader direct and indirect benefits and costs of transport investments and policies in developing countries. The literature on transport impacts is large and covers a variety of issues, each study shedding light on a specific aspect. The largest share of papers looks at road and, to a lesser extent, at rail transport. Air and sea transport tends to be much less studied and this review reflects this bias in the literature. Recent surveys on this topic focus on the impact of transport infrastructure on the spatial distribution of economic activity, productivity and economic growth (see Redding and Turner, 2014, and Deng, 2013) but do not systematically review the existing evidence from developing countries. They also tend to overlook issues relevant to developing countries which have implications for transport policies. Policy makers may, for instance, wish to guide or accompany the ongoing process of structural transformation (i.e. the movement out of agriculture into industries and services) with interventions in the transport sector. Another such issue is the fast pace of urban growth currently occurring in

Africa and Asia, which requires massive transport infrastructure investments. Developing countries are also characterized by a low state of development of transport networks, potentially involving high returns on investment given decreasing returns to scale. The transport sector also often faces issues of weak governance and non-competitive practices that affect the construction of networks and the provision of transport services. Finally, the low density of public services in many developing countries also makes reliance on transport especially crucial.

To account for the variety of mechanisms through which transport policies matter from a development perspective, we start in Section 2 by presenting a simple conceptual framework that details the potential links between the various interventions and impacts. In Section 3, we then present an econometric framework that discusses the identification challenges raised in the recent empirical literature. The following section summarizes the lessons learned from the literature, by distinguishing effects on growth, inclusion and sustainability, focusing to the extent possible but not exclusively on papers published on developing countries. Finally, Section 5 concludes by discussing the implementation challenges faced by policy makers.

2. Conceptual Framework

There are three broad types of policies: direct transport infrastructure investments, price instruments and regulations. Investments may entail building new transport infrastructure (whether roads, rail, or airports), upgrading of existing links or of technology, or improvements of transport services. Price incentives may include subsidies or taxes to influence mode choice and transport behavior more generally (e.g. student fare reductions, tolls, parking fares, fossil fuel taxes, subsidies to clean transport). As for regulations, they may apply to a variety of approaches including rules to directly reduce emissions (e.g. fuel emission standards, driving restrictions) or to govern the organization of the transport sector (e.g. organization of freight, taxis, buses) or construction of infrastructure. Some policy interventions may affect supply, e.g. infrastructure investments, whereas others target demand, e.g. transport subsidies.

A useful categorization of the broader objectives of policies can be (i) to facilitate growth (e.g. through lower transport costs, which facilitates agglomeration effects, trade and structural change, and leads to higher productivity), (ii) to improve social inclusion (e.g. through better access to transport services, which can improve economic opportunities for the poor), and (iii) to promote sustainability (e.g. through reduced health and environmental externalities). The extent to which these broad objectives can be reached depends on the behavioral responses of firms and households to the particular policy interventions in terms of trade, location and mode choices.

This framework is represented in Figure 1 below.

Figure 1: Impacts of transport policies: the mechanisms

Policy instruments	Focus of Intervention	Outputs	Responses	Outcomes
Investments Price instruments Regulations	Physical infrastructure (new, upgrading, Operations & Maintenance) Transport services Technology	Δ Transport costs (incl. time costs) Δ Access to transport services / connectivity Δ Environmental externalities	Trade Location Transport use	**Growth** (Δ Production and productivity) **Inclusion** (Δ Opportunity) **Sustainability** (Δ Environment & quality of life)

The literature on the impact of transport policies covers a variety of interventions and outcomes at different geographic levels. Studies have analyzed many aspects from rural tracks and feeder roads all the way to global trade related transport. Given the variety of interventions, mechanisms and outcomes, a simple way to formalize the impact of transport policies is to consider how policies affect the welfare of individuals or groups, or profits of firms, through all possible channels. If we denote by i ($=1…I$) an individual/household (respectively a firm), and by j a location ($=1….J$), the indirect utility

of individual i in location j (respectively the profit function of firm i in location j) can be written as:

$$V_{ij}\left(f^1(\boldsymbol{T},\boldsymbol{X^1}),f^2(\boldsymbol{T},\boldsymbol{X^2}),\dots,f^E(\boldsymbol{T},\boldsymbol{X^E})\right) \tag{1}$$

where f^e (for $e=1\dots E$) are outcome functions which depend on the state of the transport system denoted by vector $\boldsymbol{T}$, and on a vector of contextual variables that matter for outcome e denoted $\boldsymbol{X^e}$. Outcome functions may represent any argument entering the utility function of individuals or the profit function of firms. For individuals, outcome functions would include all relevant variables affected by transport such as employment status and wage (determined by productivity), access to amenities, prices of consumption goods, residential land rents, pollution externalities, health and education status, exposure to crime, etc.[3] For firms, the outcome functions would include, in particular, the Marshallian externalities of learning, sharing and matching (see Fujita and Thisse, 2002) facilitated by the transport system. In this context, a transport policy can be written formally as a change in the transport system $\Delta\boldsymbol{T}$ which induces a change in the indirect utility function of profit as given by:[4]

$$\Delta V_{ij} \equiv V_{ij}\left(f^1(\boldsymbol{T}+\Delta\boldsymbol{T},\boldsymbol{X^1}),f^2(\boldsymbol{T}+\Delta\boldsymbol{T},\boldsymbol{X^2}),\dots,f^E(\boldsymbol{T}+\Delta\boldsymbol{T},\boldsymbol{X^E})\right) -$$
$$V_{ij}\left(f^1(\boldsymbol{T},\boldsymbol{X^1}),f^2(\boldsymbol{T},\boldsymbol{X^2}),\dots,f^E(\boldsymbol{T},\boldsymbol{X^E})\right) \tag{2}$$

It can be seen from (2) that, in general, several outcomes may happen simultaneously following a transport policy intervention. Many empirical studies are partial, usually focusing only on one of these outcomes (e.g. focusing on whether road investments increase wages) without considering the full set of effects. In addition, one should worry about the permanence of the effect and whether short-run effects hold in the long run. Another comment on (2) is that some effects can be desirable (e.g. an increase in wages from the perspective of worker) and others unwanted (e.g. pollution), with possible tradeoffs between different outcomes and agents affected by a given policy

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[3] Individual indirect utilities mays be aggregated using a Social Welfare Function to characterize the welfare of a group.

[4] For simplicity of exposure, we assume here that the contextual variables are not affected by the policy. The framework can easily be generalized by considering that the $\boldsymbol{X^e}$s are functions of $\boldsymbol{T}$.

intervention. For instance, better accessibility may improve access to jobs but can harm a subset of renters in a targeted area due to the capitalization of accessibility in housing values. Formula (2) allows for effects to be heterogeneous. Effects may indeed depend on the context (X^e), for instance the initial state of the network. Policies may also affect heterogeneous households differently, for instance along the income distribution (as the poor, for instance, may respond differently to price incentives). When the policy objective is to reduce poverty, it will be important to be able to assess the impact of transport policies on the poor. Policies may also affect locations differently: an expansion of the transport network may induce relocation of activities from one place to another, with potential gains in one place and losses in the other. Therefore, it may be important to consider general equilibrium effects (including changes in prices) that can provide systemic insights into the effects of a given policy. Formally, policy makers need to consider the vector of changes for all agents in all locations:

$$\Delta V \equiv \Delta V_{ij} \text{ for } i = 1,\dots, I \text{ and } j = 1,\dots, J \tag{3}$$

where ΔV_{ij} is given by equation (2).

Depending on the focus, the literature has adopted various approaches ranging from equilibrium type models (spatial computable general equilibriums, structural estimation of trade and economic geography models[5]) to reduced form analysis, with different geographic scopes and identification strategies. In what follows, we summarize the main findings from the recent empirical literature, in light of relevant elements of theory as needed.

3. Empirical Framework

Empirically estimating the causal impact of transportation is challenging. First, consistently with Figure 1, an assessment of policy impacts requires a clear understanding of the "treatment," the outcomes to be evaluated (including the mechanisms by which the treatment affects each outcome), the impacted agents or areas, and the time horizon to be

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[5] A particularly useful framework to assess the impacts of transport is the Eaton and Kortum (2002) model which yields structural equations for bilateral trade accounting for geographic barriers to trade, including high transport costs (see Burgess and Donaldson, 2012, Donaldson, forthcoming, and Donaldson and Hornbeck, 2013).

considered. Besides issues of data availability regarding outcomes, impacted agents, or time horizon, the choice of treatment and how it is measured deserves careful consideration. This is especially true in the case of infrastructure investment, where various measures are relevant (e.g. total expenditure, size of the network, quality of investments, etc.). Most empirical papers focus on improved accessibility associated with a measure of infrastructure investments. A second challenge is the implementation of an appropriate identification strategy given that the treatment variable of interest is likely to be endogenous. We discuss these two issues in the subsections below.

3.1   Choice of treatment

Within the literature focused on evaluating the impacts of transport infrastructure, there are several treatment variables which are considered. In many instances, these variables can be thought of as indicators of access, ranging from proximity to transportation services to a variety of accessibility indicators accounting for locations of relevant markets and physical connections to those markets. A first approach is to consider the available local supply of transport infrastructure. Some authors use a dummy variable indicating the presence or absence of a road or railway within the geographic unit of observation (e.g. Atack and Margo, 2011; Atack *et al* 2010; Burgess and Donaldson, 2012; Chandra and Thomson, 2000; Datta, 2012; Faber, 2014; Jedwab and Moradi, forthcoming; and Michaels, 2008). Others consider the distance or time to the nearest highway (e.g. Faber, 2014; Emran and Hou, 2013; Ghani *et al,* 2012; Ahlfeldt and Wendland, 2011; Duranton *et al*, 2014, Duranton, 2014; Gibbons and Machin, 2005; and Banerjee *et al*, 2012). Still others take into account the road or rail density within a geographic unit of observation. For example, Duranton and Turner (2011) and Hsu and Zhang (2014) focus on lane-kilometers within metropolitan statistical areas. Baum-Snow (2007a, 2010) and Garcia-Lopez *et al* (2015) focus on the number of "rays" (radial highways) stemming from metropolitan areas.

A second, more elaborate approach accounts for various measures of transport costs to markets. A difficulty with this approach is identifying the relevant market to consider. Dorosh *et al* (2012), for example, take distance to the nearest town in the context of agricultural goods. Ali *et al* (2015a, 2015b, 2015c) attempt to more accurately measure

the actual cost of reaching the market, specifically focusing on the cost of transporting one ton of goods to the least-costly-to-reach market.[6] Several authors have used more sophisticated measures taking into account accessibility to multiple markets, improving upon the measure of market potential (Harris, 1954). For instance, Lall *et al* (2004) and Donaldson and Hornbeck (2013) focus on a "market access index", which they note is superior to local road density measures as it allows one to consider how local accessibility is affected by changes occurring throughout the network. Other similar examples include Emran and Shilpi (2012), Hanson (2005), and Head and Mayer (2011). Sanches-Guarner (2012) and Gibbons *et al* (2012) study the impact of a local index of job accessibility.[7]

3.2 Identification challenges

Considering an outcome function, $Y_i = f^e(\boldsymbol{T}, \boldsymbol{X}^e)$ in equation (1), an econometric model of the impact of transport can be expressed in linear form as:

$$Y_i = \beta_0 + \beta_1 T_i + \boldsymbol{X}'_i \boldsymbol{\gamma} + \varepsilon_i \tag{4}$$

where Y_i is the outcome of interest for observation i (household, firm, area), T_i is a measure of transport, and $\boldsymbol{X}_i$ is a set of relevant exogenous variables. The parameter of interest is β_1, which measures the impact of a change in T_i on Y_i. Its estimation, however, will be biased in the presence of an endogenous T_i.

Sources of endogeneity

In practice, endogeneity of the transport variable is very common. When T_i measures transport infrastructure, a recurrent issue is non-random placement, which occurs when infrastructure is not placed independently of the outcome of interest. In practice, areas that attract transport infrastructure typically differ from those that do not. The bias in the estimates can go in either direction. For instance, in a regression of a measure of economic

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[6] The authors calculated this cost using HDM-4 (Highway Development Management Model), a programming tool which takes into account road surface, condition, slope and distance.

[7] These market access indices generally follow the same basic format, with minor variations: $M_i = \sum_j m_j f(d_{ij})$, where M_i, market access at location i, is a function of m_j, the "size" of market j, and d_{ij} the "distance" between location i and market j, with $f(.)$ a distance decay function. The measure of distance itself can be more or less elaborate, e.g. straight-line, distance through the network, time, or monetary costs.

activity on roads, if roads are built near economic growth centers, an estimation of equation (4) by ordinary least squares would overestimate β_1. If instead, roads are built near disadvantaged areas, then the bias would be downwards.

Another source of endogeneity relates to the issue of sorting across space which is inherent in spatial analyses. For instance, if equation (4) represents the impact of job accessibility (T_i) on individual i's employment status (Y_i), the fact that employed workers may decide to locate close to their jobs introduces endogeneity. Or if equation (4) represents the impact of market accessibility (T_i) on rural incomes (Y_i), then the emergence of a market near areas of high productivity will also introduce a bias.

Robust estimation of equation (4) requires a source of exogenous variation. We present below the most common identification strategies.

Identification strategies

Contexts where road placement is exogenous are scarce. A few authors restrict the sample to "inconsequential areas" (Redding and Turner, 2014) where they can defend that the infrastructure placement is exogenous. This is the approach adopted by authors who focus on rural places along roads that connect cities, excluding those endogenous nodes (Chandra and Thompson, 2000; Michaels, 2008). Restricting the analysis to specific areas, however, diminishes the external validity of findings. Alternatively, other authors have used quasi- or natural experiments as a source of exogenous variation for identification (such as a strike in public transport, Anderson, 2014, the opening of a metro system, Chen and Whalley, 2012, or the opening of metro stations, Gibbons and Machin, 2005). Other papers achieve identification by resorting to matching and difference-in-differences estimation strategy (Datta, 2012; Ghani *et al*, 2012).

A number of papers correct for endogeneity by instrumenting the transport variable. In a two-stage least squares setting, which is most appropriate for presenting these issues, equation (4) is replaced by the following model:

$$\begin{cases} Y_i = \beta_0 + \beta_1 T_i + \boldsymbol{X}_i'\boldsymbol{\gamma} + \varepsilon_i & (4) \\ T_i = \alpha_0 + \alpha_1 Z_i + \boldsymbol{X}_i'\boldsymbol{\theta} + v_i & (5) \end{cases}$$

where Y_i is the outcome of interest for observation (individual, household, firm, location) i; T_i is a measure of connectivity; $\boldsymbol{X}_i$ is a set of relevant exogenous variables; and Z_i is an exogenous instrumental variable. Because T_i can be endogenous to the outcome of interest (e.g. due to reverse causality from Y_i to T_i or unobserved variables in the residual, ε_i, correlated with both T_i and Y_i), the above identification strategy removes the source of bias in the estimation of the impact of T_i on Y_i (second stage equation, 4) by instrumenting for T_i with Z_i (first stage equation, 5). Since the instrument is by definition not correlated with the outcome, then only the exogenous sources of variations in T_i are considered to identify the impact on the outcome of interest, Y_i.

Choosing an appropriate instrument is key for a robust assessment of transport impacts. Several papers instrument existing transport networks with digitized old transportation networks or historical maps which are likely to be exogenous to the outcome of interest (see e.g. Baum-Snow, 2007a; Hymel, 2009; Donaldson, forthcoming; Duranton and Turner, 2012; Volpe Martincus, 2014; Duranton, *et al*, 2014; Baum-Snow *et al*, 2015; Garcia-Lopez *et al,* 2015; Ali *et al*, 2015c). Alternatively, some authors resort to the construction of an exogenous network based on straight lines between nodes (Ahlfeldt, 2011; Ahlfeldt and Wendland, 2011) and use it as an instrument. This addresses the endogeneity on the path between two nodes. Further refined approaches to address this issue of on-the-way endogeneity consider hypothetical networks that would best conform with geographic features that constrain existing networks (as in Faber, 2014; Emran and Hou, 2013; Ali *et al,* 2015a, 2015b). This is valid under the assumption that those geographic features are not correlated with the outcome of interest. Lastly, a few papers resort to the estimation of structural models (Roberts *et al* 2012), which reduces concerns about endogeneity issues. Table 1 in the appendix details a list of select empirical papers related to transport and their various identification strategies.

4. Lessons from the Literature

In line with our conceptual framework (Section 2) and reviewing mainly studies that apply a robust identification strategy as presented in our empirical framework (Section 3), this section sequentially summarizes the links between transport policies and growth, inclusion, and sustainability.

4.1   Growth

Investing in transport will reduce costs leading to an increase in productivity and shifting the economy to a higher growth equilibrium (see the Big Push Theory of Rosenstein-Rodan, 1943, further developed by Murphy *et al,* 1989, and Agenor, 2010).

Empirical tests at the macroeconomic level confirm transport investments can have a significant impact on growth. Calderón *et al* (2015) estimate that the elasticity of output with respect to a synthetic infrastructure index—which includes transport along with electricity and telecommunications—ranges between 0.07 and 0.10. Similar impacts are found in the case of Sub-Saharan African countries.[8]

Other papers have looked at the different channels through which transport investments influence growth focusing on the impacts on firms' decisions to trade and locate, on income generation and employment, as well as on the structural transformation of economies more generally.

Trade

A reduction in transport costs may stimulate the volume of trade, open up new markets, induce new industries to form, and thereby influence the patterns of trade.

Trade costs are actually very high in much of the developing world. In Ethiopia and Nigeria, Atkin and Donaldson (2014) estimate that trade costs are four to five times larger than in the United States. A significant portion of trade costs is non-physical (e.g. costs and delays associated with border crossing, price markups of non-competitive transport firms, bribes), especially in African countries (Raballand *et al*, 2010). National borders have been estimated to reduce trade by 44 percent between the United States and Canada, and by 30 percent on average among other industrialized countries (Anderson and van Wincoop, 2003). Delays at borders and ports can last between 10 and 30 hours in Africa (Foster and Briceño-Garmendia, 2010). Reducing these costs will thus induce more intra- and inter-regional trade. Hummels (2007) shows that the decrease in transport costs over 50 years was a major driver of increase in international trade. At the regional level, Freund and Rocha (2011) find that a one day decrease in over-land travel time leads to a 7

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[8] See Calderón and Serven, 2010, for the impact of a similar synthetic infrastructure index and Boopen, 2006, for an analysis of the impact of transport capital

percent increase in Africa's exports. Simulations by Buys *et al* (2010) show that upgrading the primary road network connecting major cities would increase trade within Sub-Saharan Africa by $250 billion over 5 years (costing $20 billion for the initial upgrade plus $1 billion per year in maintenance).

Reduction in trade costs also implies improved access to markets. Therefore, some papers directly measure the impact of better market access (proxying for better opportunities to trade) on various economic outcomes. In Sub-Saharan Africa, Dorosh *et al* (2012) find that reduced travel time to the nearest market (proxied by a city with at least 100,000 people) leads to an increase in agricultural production. Along the same vein, Bosker and Garretsen (2012) estimate that a 1 percent increase in a Sub-Saharan African country's market access is associated with a 0.03 percent increase in its GDP per capita. Volpe Martincus *et al* (2014) find that Peru's road improvement program led to a significant increase in firms' average annual growth rate of exports (6.4 percent) and subsequently employment (5.1 percent). Emran and Hou (2013) show that both domestic and international market access stimulate per capita consumption in China.

Reductions in transport costs may also reflect improvements in inter-city transport, which are likely to affect the diversification or specialization of cities. Anas and Xiong's (2003) model predicts that low-cost transport infrastructure (e.g. railways and highways) should lead to more specialized cities. In an empirical paper, Duranton *et al* (2014) find that cities in the US that have more highways specialize in the export of heavy goods without seeing an impact on the value of goods traded. Duranton (2014) applies the same analysis in Colombia and finds, in contrast, that the effect of city roads is moderately stronger on the value of trade than it is on the weight of the goods traded, which is interpreted as roads shifting economic activities within cities towards somewhat lighter, tradable goods.

Transport investments may have heterogeneous impacts across space through the stimulation of trade and specialization of industries. Chandra and Thompson (2000) find that industrial output in US counties benefited from connection to highways, but at the detriment of neighboring counties. In India, Donaldson (forthcoming) finds that colonial railways built in the 19th century lowered interregional trade costs and price gaps, increased trade flows, and increased real income per unit of land area. This in turn, increased incomes

within regions with railroads, but not necessarily in areas without railroads. In China, Faber (2014) finds that reducing transport costs can led to a reduction in industrial growth among connected peripheral regions relative to non-connected areas, as opposed to diffusing production from the metropolitan regions to the periphery.

Firm location decision and agglomeration effects

Lower transportation costs can lead to a re-allocation of manufacturing along the transport network. In this respect, Mayer and Trevien (2015) find that the initial construction of the regional express rail stations (RER) in the Paris area attracted manufacturing, business, and household service firms (especially foreign ones) in the municipalities where the stations were built. In Indonesia, Rothenberg (2013) finds that massive upgrades to the highway system during the 1990s led to the dispersion of manufacturing activities. The durable goods producers were more likely to disperse around cities while perishable goods producers were more likely to locate closer to their customers. Gutberlet (2013) finds that reduced transport costs led to a geographic concentration of industries in core regions of 19th century Germany, but that this occurred to the detriment of peripheral regions.

Improved transport can also lead firms to be more productive. Better roads increases firm productivity through more intense vehicle use (Fernald, 1999 in the case vehicle-intensive industries) or less absenteeism (van Ommeren and Gutierrez-i-Puigarnau, 2011). The clustering of firms can further lead to increased productivity (due to agglomeration effects) or attract other more productive firms.[9] In the case of India's "Golden Quadrilateral," Ghani *et al* (2012) find that there are higher entry rates of manufacturing firms near improved highways and that these firms have higher labor productivity and higher total factor productivity. Focusing on the same road improvement program, Datta (2012) finds that firms located near highway improvements are actually run more efficiently (as they keep inventories over a shorter period of time).

At the scale of a city, transport investments can influence the location of economic activities within the city and affect residential patterns. In the US, radial highway investments caused suburbanization over the second half of the 20th century (Baum-Snow,

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[9] Lower transportation costs may also lead to agglomeration effects by virtue of eased interactions between firms even if firms do not actually relocate.

2007a, 2007b). The suburbanization of jobs along with that of residences thus changed commuting patterns: instead of traveling to the central city, workers increasingly traveled within the suburbs (Baum-Snow, 2010).[10] In Chinese cities as well, radial highways have led to the decentralization of both population and industries, (Baum-Snow *et al*, 2015). Applying similar methods, Garcia-López *et al* (2015) finds evidence of highways causing decentralization in Barcelona. For Spain as a whole, Garcia-López *et al* (2014) also find that highways caused suburbanization, but to a lesser extent than in the US.

Economic Activity, Income, and Employment

Increased trade and productivity results in greater production, improved labor market outcomes, and higher incomes. In the context of China, Banerjee *et al* (2012) find that infrastructure (roads and highways) have a positive effect on per capita GDP at the county level. Also in China, Roberts *et al* (2012) estimates a New Economic Geography model and finds that highways increased real incomes. In the case of Nigeria, Ali *et al* (2015a) find that reducing transport costs significantly increases local GDP but note that the full impact of transport costs on incomes may only emerge slowly over time. Jedwab and Moradi (forthcoming) measure the impact of railway access in Ghana (constructed around 1901) on economic development (as measured by nightlights) and on cocoa production. They show that railway access positively affects economic activity, both in the short and long run (path dependency).[11] At the scale of Sub-Saharan Africa, Storeygard (2014) finds that cities close to a main port grow faster. In terms of employment, Duranton and Turner (2012) find that the initial stock of highways in the US caused higher city-level employment growth. The result is somewhat nuanced in a study on the UK in which Gibbons *et al* (2012) find that although roads affect firm entry and exit, they do not affect employment in existing firms.

Regarding wages, Sanchis-Guarner (2012) highlights ambiguous possible effects from road construction resulting from two opposite forces: improved accessibility of firms that may result in higher productivity and thus higher wages, and increased competition among workers which can exert downward pressure on wages. As wages are found to

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[10] Baum-Snow (2014) finds that radial highways caused more decentralization of population than jobs (and a heterogeneous response across sectors as some have strong incentives to remain spatially clustered).
[11] A similar study for Kenya (Jedwab *et al,* 2014) finds further supportive evidence of those effects.

increase, the first effect seems to dominate the second. Gibbons *et al* (2012) using the same data and methodology find that accessibility changes induced by road improvements affects firm entry and exit but not the employment of existing firms.

Structural transformation

Improved transport networks may lead to the structural transformation of local economies. In rural communities, improved transportation may result in a shift from subsistence to commercial agriculture. In this respect, Ali *et al* (2015b) find that falling transportation costs lead to an increase in the production of high-input crops while crop production under a low-input regime is either unaffected or sees a decline in output. Further, the authors find that the likelihood that farmers use more modern techniques (e.g. mechanized agriculture) in their agricultural production increases with the fall in transport costs.

Reduced transportation costs can also lead to a shift of production and labor away from the agriculture sector. Chandra and Thomson (2000) note that falling transportation costs led to a reallocation of labor from agriculture to manufacturing in the US. Van de Walle (2009) finds that the construction of a new road in Vietnam was followed by the emergence of new non-farm activities. Similarly, Gertler *et al* (2014) find that improved road quality in Indonesia increases job creation in the manufacturing sector and triggers an occupational shift of workers from agriculture to manufacturing. In Nigeria, Ali *et al* (2015a) find that falling transportation costs both decrease the probability of agricultural employment by households, and increase the likelihood of them being fully employed. This is indicative of a shift of workers from agricultural to non-agricultural jobs.

When transport costs remain high, however, as in the rural areas of Sub-Saharan Africa, Gollin and Rogerson's (2014) model shows that people remain located near the spatially diffused sources of food production, thus preventing structural transformation by hindering the movement of people out of subsistence into the modern sector.

4.2   Inclusion

High transport costs may also have direct effects on various dimensions of poverty. The literature has focused on how poor transport can affect vulnerable groups through reduced trade, adverse labor market outcomes, poor education and health, as well as crime.

Rural Poverty

In rural areas of developing countries, especially in Africa, there is a general lack of infrastructure investment given the major costs required, lack of available funds and political will (see, for instance, Blimpo *et al*, 2013 who show that there is underinvestment in roads in politically marginalized areas in four West African countries). This is all the more problematic as poor accessibility can be especially harmful for the rural poor. In Uganda, Kyeyamwa *et al* (2008) find that road high transport costs deter farmers from participating in local markets to sell their cattle, relying instead on farm gate sales. Similarly, in rural Kenya, land devoted to cash crops is only located close to markets (Omamo, 1998). There is therefore a large potential for transport infrastructure investments to improve the living standards of the rural poor through stimulation of economic activities. Different dimensions of poverty may be impacted. Jacoby and Minten (2009) find that lower transport costs increase remote household income in Madagascar. In rural China, Emran and Hou (2013) find that better access to domestic and international markets improve *per capita* consumption and the livelihoods of the poor. Focusing on Bangladesh, Khandker *et al* (2009) find that rural road investments reduce poverty, including through higher agricultural production, higher wages, and lower input costs, and higher output prices. They conclude that road investments are pro-poor, with gains that are proportionately higher for the poor than for the non-poor. This is consistent with the finding that benefits from rural road improvements are greater in poor communities, where levels of initial market development are lower (see Mu and van de Walle, 2011, on Vietnam). Impacts on inequality are more nuanced, as Jacoby (2000) finds that although roads improve welfare of poor rural households in Nepal, they do not reduce inequality.

Urban Labor Markets

Regarding the labor market impacts of transport costs, a large urban literature has focused on how poor physical connections between jobs and residences resulted in exacerbating the unemployment and low wages of unskilled workers. This so-called spatial mismatch literature originated in the US context, where jobs suburbanized over the past 70 years, whereas unskilled workers, especially among minorities, remained in inner cities

(Kain, 1968).[12] However, this literature has much broader applicability, especially to sprawling cities in the developing world where the disconnection from jobs could be an important contributor to poverty (see, for example, Rospabé and Selod, 2006, in the case of Cape Town, South Africa). The mechanism of spatial mismatch (see Gobillon *et al*, 2007 and Gobillon and Selod, 2012, 2014 for reviews of this literature) revolves around the role of high transport costs in deterring the unemployed from accepting distant jobs, the harmful effects of long commutes on productivity or decreasing productivity, or high search costs that make the matching between unemployed workers and jobs less efficient. This is most relevant for unskilled workers who are disadvantaged on the labor market and for whom spatial connection to jobs matters a lot (see Selod and Zenou, 2006). Robust empirical studies have shown a causal effect of job decentralization on the unemployment of the less mobile inner city poor (see Zax and Kain 1996 and Weinberg 2000). In this context, there is an important role for transport policies to better connect people to jobs.[13] Other vulnerable groups affected by spatial mismatch include women who have fewer transport choices than men (Blumenberg, 2004) and pay a large share of their income on transport, as compared to men (Babinard and Scott, 2011). Having fewer transport choices also induces women entrepreneurs to locate their business closer to their residences, thus missing out on the benefits of agglomeration in business districts (Rosenthal and Strange, 2012).

In this context, improving access to transportation may have a significant impact on reducing unemployment of the targeted population. Sanchis-Guarner (2012) for instance finds that improved accessibility to work from road constructions in the UK increases wages and hours worked. In the US context, raising the car ownership rates of minorities would considerably narrow the differences in the unemployment rates between groups (Raphael and Stoll, 2001). Transport subsidies to unemployed workers have also been shown to reduce unemployment spells by facilitating search (see Philips, 2014, for a randomized control trial in the Washington, D.C. metro area).

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[12] Although the original framing of the spatial mismatch hypothesis insisted on the role of barriers to residential mobility (mainly housing discrimination), the disconnection of the poor from job locations may also be the result of freely functioning markets in the context of spatial sorting.
[13] In combination with other policies, either facilitating the residential mobility of workers (see Katz *et al,* 2001) or providing incentives to firms to locate in disadvantaged areas (Gobillon *et al*, 2011).

Education

Upstream to the labor market, transport costs also have an impact on educational opportunities and choices. In the rural areas of Bangladesh, Khandker *et al* (2009) find that improving rural roads leads to higher rates of both boys' and girls' enrollment in school. Similarly, Jacoby and Minten (2009) finds a positive impact of road investments on higher secondary school enrollment in Madagascar.

Health

There are also potential food security and health benefits from better transportation. Blimpo *et al* (2013) find that areas with less transport access suffer from food security problems, as evidenced by stunting in West Africa. Food prices are indeed correlated with transport costs (related to road quality) as evidenced by Minten and Kyle (1999) in the case of the Democratic Republic of Congo. There is also evidence that penetration of rural areas by railroad helps poor communities be more resilient to negative agricultural productivity shocks threatening the food supply (see Burgess and Donaldson, 2012, on 19th and early 20th century India).

More generally, lowering transportation costs significantly reduces the probability that a household is multi-dimensionally poor through improvements in health, education, and standard of living (see Ali *et al*, 2015a, who correlate the multi-dimensionally poverty index[14] to transportation cost in the case of Nigeria).

Crime

Finally, as the poor are disproportionately exposed to crime, a trend of the literature has also focused on the relation between crime and transport.

Crime in transport is a serious issue in poor developing countries. This is illustrated by the case of South African urban public transport which has high incidences of murder, rape, and assault (see Kruger and Landman, 2007). Women are especially vulnerable to security issues while traveling especially because they are more dependent on public transport (Babinard and Scott, 2011). Beyond crime repression, investment in physical infrastructure has an impact on reducing crime. In the case of Bogotá, Colombia, Marcelo (2013) finds that crime around *Transmilenio* (bus rapid transit) stations decreases, an effect the author attributes to better lighting at night. The construction of the cable cars in

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[14] See Alkire and Foster (2011) and Alkire and Santos (2011).

Medellín, Colombia (*Metrocable*) was accompanied by neighborhood upgrading (new social housing, schools, and other infrastructure improvements) which resulted in a decline in violence (Brand and Dávila, 2011).

The relation between transport availability and crime location is controversial and not well researched. In well-off US suburban areas, for instance, there is a perception that public transport would bring crime to the residential suburbs by making travel easier for potential criminals living in inner cities. This perception has been at the origin of political opposition to public infrastructure extension. Interestingly, Ihlandfeldt (2003) finds, on the contrary, that the construction of stations in Atlanta, Georgia decreased crime in the suburbs. The author argues that while rail access may have made neighborhoods more accessible to outside criminals, they may also have increased the opportunity cost of crime (as access to legitimate employment becomes easier).[15] It should not be concluded, however, that improved transport will necessarily decrease crime. In the specific context of conflict areas in the Democratic Republic of Congo, Ali *et al* (2015c) have found that more accessible areas are more exposed to violent events, causing a decrease in population welfare.

4.3   Sustainability

Transport may have important social costs, which need to be balanced against potential positive economic impacts. These costs involve negative externalities, ranging from congestion, accidents, impact on health caused through air pollution and the easier spread of epidemics, as well as direct costs to the environment such as deforestation, biodiversity loss, and more generally degradation of ecosystems. In the long run, some of these negative effects may even be harmful to growth. Transport policies thus have a role to play to minimize and mitigate negative impacts. We first describe the problems and then discuss the role of policies to address these issues.

Negative Socio-Economic Impacts

Congestion in transport is a major problem faced by economies—both developed and developing alike given its high opportunity cost (time spent in traffic could be spent in

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[15] Criminals do not travel far (Chainey and Ratcliffe, 2013).

leisure or more productive pursuits). Long commuting times may also be detrimental to employment growth, as demonstrated by Hymel (2009) who estimates the causal impact of traffic congestion on aggregate employment growth in US metropolitan areas.

Congestion is also problematic given its contribution to air pollution caused by vehicle emissions, especially by cars. In developing countries, although car ownership is only a fraction of that of the US, experience of traffic congestion and air pollution is often far worse (Sperling and Claussen, 2004).

Fatalities and injuries on the road exert a toll, especially on the economies of developing countries. Cubí-Mollá and Herrero (2012) report that in 2004 over 50 percent of road fatalities worldwide were among economically active young adults, aged 15-44. Even when accidents are non-fatal, they can still be economically catastrophic, leaving people too disabled to work.

It has been noted that transport (roads) can also help spread infectious diseases, as evidenced by AIDS following the road network in southern Africa (see Regondi *et al,* 2013). Mobility restrictions imposed during the recent Ebola epidemics onto affected countries, are likely to have had harmful economic impacts by interrupting the flow of trade (World Bank, 2014).

Finally, transport infrastructure may disturb the ecosystem through deforestation, biodiversity loss, pollution, road kill, and blocking of seasonal migration patterns (see Chomitz and Gray, 1996; Laurance *et al*, 2009). [16] The negative impacts of roads may increase over time. In the Brazilian Amazon, for instance, the Belém-Brasília Highway, completed in 1970, today cuts a 400-kilometer-wide path through the rainforest (Laurance and Balmford, 2013).

Designing Sustainable Transport Policies

Policies to address these issues, whether through investment, pricing, or regulation, will influence either the supply of or the demand for transport. There are different policy options available, generally with nuanced impacts.

Addressing congestion and air pollution through an increase in the supply of infrastructure, although intuitive, has been shown to be inefficient in the case of highways in the US. Duranton and Turner (2011) show that additional road investments in the US

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[16] See Damania and Wheeler (2015) for an index measuring biodiversity losses.

actually increases traffic by either drawing traffic from alternative roads, stimulating commercial trucking, or attracting new drivers. Similarly, Hsu and Zhang (2013) replicate the analysis for Japan and find that road construction induces increased traffic. Along the same line, Anas and Timilsina (2009) estimate that although new road construction may reduce emissions of existing cars through increased travel speed, it may ultimately increase overall emissions by attracting additional drivers. Alternatively, a more efficient approach can be to target investments at public transport systems. Investments in rail in US cities was indeed found to draw commuters away from buses and, in some cases, away from cars (Baum-Snow and Khan, 2005). The public transit system in Los Angeles was found to significantly reduce congestion (Anderson, 2014). The opening in 1996 of the Taipei metro reduced carbon monoxide emissions between 5 and 15 percent (Chen and Whalley, 2012).

Infrastructure investments also have a direct impact on the shape of cities, which in turn affects the level of congestion and emissions within cities. In particular, the pace of suburbanization (a historic trend associated with rising incomes) is accelerated by transport infrastructure investment and the subsequent fall in transport costs (Brueckner, 2000). There is indeed ample evidence that highways and railways have caused the decentralization of population at the city level (Baum-Snow, 2007, for the US; Garcia-López *et al*, 2013, for Spain; Ahlfeldt and Wendland, 2011, for Germany; and Baum-Snow, 2013, for China) as well as of jobs (Baum-Snow, 2010, for the US and Baum-Snow, 2013, for China). Gonzalez-Navarro and Turner (2014), using a panel of 138 cities around the world, confirm the role played by subways in decentralization. These evolutions have contributed to urban sprawl (Brueckner, 2000) where extensive car use increased carbon emissions (Glaeser and Kahn, 2003). For developing countries, especially those at early stages of urbanization and experiencing fast spatial expansion and population growth, there appears to be a role for transport policies to influence the evolving shape of the city in a sustainable way (Suzuki *et al,* 2013). Once cities have suburbanized, investment in public transit to mitigate car use is very costly. The impact of transport policies is also dependent on city shape and may have heterogeneous effects throughout a city. Using a core-periphery model calibrated on Beijing, China, Anas and Timilsina (forthcoming) show that more efficient transport in the core area would attract population and thereby reduce carbon

dioxide emissions, whereas lower transport costs in the periphery would encourage suburbanization, thus increasing carbon dioxide emissions.

On the demand side, pricing, through subsidizing "good" behavior or taxing "bad" behavior, can also be a useful tool to alter incentives. Subsidizing public transport may reduce emissions by incentivizing people to switch from driving to using public transit.[17] The price instrument, however, is seldom used in developing countries (see Timilsina and Dulal, 2011 on urban road transportation externalities). Subsidies are costly and taxation is politically difficult to implement. [18]

Taxation (either a toll or fuel tax) can be efficient in reducing emissions by discouraging car use in cities (Anas and Timilsina, 2009). Graham and Glaister (2002) estimate for the US that a 10 percent increase in price, would reduce consumption by 3 percent in the short run and by 6 percent in the long run. These different price elasticities of fuel consumption suggest that there is a gradual adaptation of behavior. Consistently with these results for the US, Anas *et al* (2009), using a calibrated land-use and commuting-choice model for Beijing, China, find that a 10 percent increase in monetary cost of travel would reduce carbon dioxide emissions by 1 percent.[19] In the case of France, Givord *et al* (2014) finds that both carbon and diesel taxes would slightly reduce carbon dioxide emissions in the short-term through fewer car purchases. Tolls should also reduce congestion and emissions by incentivizing drivers to switch to public transport (Anas and Lindsay, 2011).[20]

Rather than relying on price incentives to influence behavior, policy makers can mandate the desired behavior through a variety of regulations (e.g. catalytic converters, fuel efficiency standards, driving restrictions). In theory, fuel efficiency regulations may only have limited, short-term impacts on air pollution when they apply only to new cars and can only be gradually phased in (Anderson *et al*, 2011). Their impact may also be

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[17] Note, however, that the effect may be offset by inducing pedestrians to use public transportation.

[18] See Anas and Lindsay (2001) and Timilsina and Dulal (2011) for a review of externality pricing.

[19] For other examples of calibrated models exploring the effects of externality pricing in developing country cities, including Mexico City (Anas and Timilsina, forthcoming; Anas *et al* 2009); Cairo (Parry and Timilsina, 2010); and Sao Paolo (Anas and Timilsina, 2009). These models are able to compare the efficiency of different taxes (e.g. gasoline tax vs. car tolls).

[20] As for infrastructure investments, it is notable that pricing instruments may also have an impact on city shapes by influencing location and travel decisions (see Brueckner, forthcoming, in the case of cordon toll pricing).

offset by an increase in the vehicle-miles driven causing higher induced fuel consumption and emissions (see Small and Van Dender, 2007; Anas and Timilsina, 2009). Other types of regulations include driving restrictions during periods of high pollution generation. Quito, Ecuador implemented a vehicle use restriction program during peak driving (*Pico y Placa*) which was found to efficiently reduce emissions by between 9 to 11 percent during peak hours and by 6 percent during the day (see Carrillo *et al,* forthcoming). In Santiago, Chile, peak-hour vehicle-use restrictions led to a shift to public transport systems as well as a shift in arrival and departure times (De Grange and Troncosa, 2011). These studies, however, tend to focus on the relatively short-term. Bonilla (2012) argues that in the long run, households will respond to such programs by purchasing additional vehicles thus reducing the effectiveness of the program. This argument is consistent with the findings of Eskeland and Feyzioglu (1997) and Davis (2008) who study car use restrictions in Mexico (i.e. the "*Hoy No Circula*" program) and find that it does not improve air quality as it actually induces an increase in the number of vehicles in circulation, with people buying a second—often older and thus less fuel efficient—car. Other examples of regulations include more drastic measures such as those implemented by China in anticipation of the 2008 Olympic Games who combined plant relocation and furnace replacement with new emission standards and traffic controls. Chen *et al* (2013) find that pollution fell during and shortly after the games, but this effect was short lived given the temporary nature of the measures.

Examples of potential regulatory tools aimed at reducing the negative environmental impact caused by road construction in forested areas are found in Damania and Wheeler (2015). They develop a novel index of biodiversity loss to guide the planning of road investments in ecologically rich areas.

5.   Discussion

This literature review presented the diverse mechanisms through which transport policies can induce beneficial outcomes, in terms of sustainable growth and inclusion, as well as the tradeoffs encountered. Transport infrastructure investments play a major role in the process of structural transformation, urbanization and city growth. Price instruments

and regulations can also be useful tools to affect behavior and address environmental externalities. In developing countries, however, transport policies are often poorly designed and implemented. In particular, there remains a large backlog of transport infrastructure investment especially in Africa (see Foster and Briceño-Garmendia, 2010) and price instruments are not widely used (Timilsina and Dulal, 2011).

Implementation of transport policies in developing countries faces a number of challenges. Obtaining funding for transport infrastructure investments is difficult in contexts of scarce resources and limited fiscal capacity (Sperling and Claussen, 2004). This is exacerbated by the fact that construction of infrastructure is particularly costly in developing countries given non-competitive procurement (Estache and Iimi, 2009) or corruption (Collier *et al*, 2015). Today, in addition to using government resources and borrowing, there is an increasing emphasis on leveraging funds through public-private partnerships (see Dintilhac *et al*, 2015). However, this requires the presence of a private operator and appropriate coordination between the public sector (that sets the strategy) and the private sector (that provides funds, construction, and operation). An innovative funding mechanism (although dating back to the 19th century) is the capture of land value increases following an infrastructure investment (see Peterson, 2009).[21] However, for this strategy to work, property rights must be well defined to allow for taxation, which is not the case in much of the developing world.

When the infrastructure is in place, operation may also require scarce funding or be hindered by inefficient management (Bogart and Chaudhary, 2012; Lowe, 2014), non-competitive market structures of service providers (Lall *et al*, 2009) or excessive regulations (Button and Keeler, 1993; Combes and Lafourcade, 2005), which further drives up user costs. These non-physical costs may represent a significant share of total transport cost, in particular in African countries (Teravaninthorn and Raballand, 2008).

Another challenge, although not restricted to developing countries, revolves around the politics that underpin transport investment choices and the resulting allocative inefficiencies. Ethnic favoritism and political clientelism influence the placement of road

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[21] Investments that improve a location accessibility will raise land values. For empirical studies in an urban context, see Baum-Snow and Kahn (2000), Boarnet and Chalermpong (2003), Gibbons and Machin (2005) and Gonzalez-Navarro and Quintana-Domeque (2014). For increased accessibility and land price increases in rural areas, see Atack and Margo (2011) and Donaldson and Hornbeck (2013).

investments (see Burgess *et al*, forthcoming, and Blimpo *et al,* 2014). This occurs at the detriment of investment in other areas where the return of investment could have been greater, or that could have a greater poverty-reduction impact (for example, in light of the "pro-poor" effect of rural feeder roads, see Jacoby, 2000, van de Walle, 2002).

There can be complementarities between transport policies. For instance, the effectiveness of price incentives in shifting people towards greater public transport use also depends on the quality and capacity of that network (Anas and Lindsay, 2011, Sperling and Claussen, 2004). Transport policies may also need to be combined with non-transport policies to produce the intended effects. For instance, better road connections will have an amplified impact on the development of commercial agriculture when combined with expanded cell phone coverage (Casaburi *et al*, 2013), agriculture extension services, or access to credit (Ali *et al* 2015b). Similarly, urban renewal programs may require both transport investments and neighborhood investments (Brand and Dávila, 2011). Connecting unemployed workers to jobs may produce little effect in the absence of training to reduce the skill mismatch. At the macro scale, transport investment will have transformative impacts provided an enabling environment is present that allows for the development of a manufacturing sector and trade.

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Table 1 –Focus and identification strategy in select transport research

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Ahlfeldt and Wendland (2011)	Impact of metro and railways on decentralization (Berlin, Germany, 1890-1936)	Changes in land value gradient	Travel time to CBD	Endogeneity of metro and railway placement	Instrument: distance to straight-line counterfactual transport network between the CBD and neighboring municipalities
Anderson (2014)	Impact of public transit on traffic congestion (Los Angeles, US)	Highway delay	Public transit ridership	Endogeneity of public transit provision	Regression discontinuity using public transit workers' strike
Atack and Margo (2011)	Impact of railroad access on agricultural land use and value (US, 1850-1860)	Cultivated land and land values	Dummy for access to railroad network	Endogenous railway placement	Instrument: Straight-line hypothetical network connecting selected nodal cities (identified for transport investment in the 1820s)
Atack *et al* (2010)	Impact of railroad access on urbanization (US, 1850-1860)	Urbanization rate at the county level	Dummy for access to railroad network	Endogenous railway placement	Instrument: Straight-line hypothetical network connecting selected nodal cities (identified for transport investment in the 1820s)
Banerjee *et al* (2012)	Impact of transport accessibility on economic development (China)	Level and growth of local GPD per capita	Proximity to transport infrastructure	Endogeneity of infrastructure placement	Argue exogeneity of regressor by using distance to straight line network (linking 19th century historical cities and ports)
Baum-Snow (2007a)	Impact of highways on decentralization in cities (US, 1950-1990)	Central city population	Number of radial highway ("rays")	Endogenous highway placement	Instrument: Number of rays in historical highway plan (1947 National System of Interstate Highways plan)
Baum-Snow (2010)	Impact of highways on decentralization in cities (US, 1960-2000)	Commuting patterns	Number of radial highway ("rays")	Endogenous highway placement	Instrument: Number of rays in historical highway plan (1947 National System of Interstate Highways plan)
Burgess and Donaldson (2012)	Impact of railways on famine (India, 1861-1930)	Local prices, total output, and mortality	Dummy for District penetrated by rail	Endogenous railway placement	Claim that network built for military reasons is exogenous
Casaburi *et al* (2013)	Impact of road improvement on trade (Sierra Leone)	Crop prices	Road improvement	Endogeneity of selection of roads for rehabilitation	Regression discontinuity using assignment rule for road improvement

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Chandra and Thompson (2000)	Impact of Interstate highways on economic activity in rural areas (US)	Real earnings by industry	Dummy for highway going through rural counties	Endogenous highway placement	Focus on "inconsequential" non-metropolitan areas
Chen and Whalley (2012)	Impact of urban rail transit on air pollution (Taipei, Taiwan, China)	Carbon monoxide emission	Metro ridership	Endogeneity of metro station placement	Regression discontinuity using opening of new metro
Datta (2012)	Impact of highways on firm efficiency (India)	Stock of input inventories	Dummy for area benefitting from highway network improvement (more or better infrastructure) or distance to highway network	Endogeneity of highway network improvement	Focus on inconsequential areas and use of difference-in-difference
Donaldson, forthcoming	Impact of railways on trade (India, 1870-1930)	Trade costs, interregional price gaps, trade flows, income	Distance (speed along least cost path)	Endogenous railway placement	Claim that network built for military reasons is exogenous
Donaldson and Hornbeck (2013)	Economic impact of railways (US)	Agricultural land value	Market access index	Endogenous railway placement	Instruments: - counterfactual market access measure based on fixed initial population figures - waterway only market access
Dorosh et al (2012)	Impact of roads on agriculture (Sub-Saharan Africa)	Crop production	Travel time to nearest city	Endogeneity of road placement	Instrument: Terrain roughness in production area (difference between max and min elevation)
Duranton (2014)	Impact of roads on trade (Colombia)	Weight and value of goods	Road travel time or distance	Endogeneity of roads	Instrument: - colonial route (1938)

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Duranton and Turner (2011)	Impact of road supply on congestion (US)	Traffic (vehicles-kilometers traveled)	Lane-kilometers of roads	Endogeneity of road placement	Instruments: - historical interstate highway plan (1947) - historical railroad routes (1898) - exploration routes (1835-1850)
Duranton *et al* (2014)	Impact of interstate highways on trade between cities (US)	Weight and value of goods	Length of interstate highways between two MSAs	Endogeneity of road placement	Instruments: - historical interstate highway plan (1947) - historical railroad routes (1898) - exploration routes (1835-1850)
Emran and Hou (2013)	Impact of domestic and international market access on rural poverty (China)	Per capita consumption	Travel distance by road or railway to domestic business center or international seaport	Endogenous placement of roads and railways	- Instrument: straight-line distance from village to nearest coastline and navigable river - Identification by heteroskedasticity
Faber (2014)	Impact of highways on trade, market size, and industrialization (China)	Value added in manufacturing and agriculture; local government revenue; GDP; population	Proximity to highway (dummy for less than 10km, or exact distance to nearest highway segment)	Endogenous highway placement	Instruments: Hypothetical road networks between nodes (cost-minimizing or straight line)
Garcia-López (2012)	Impact of changes in transportation on location patterns within cities (Barcelona, Spain, 1991-2006)	Change in population density at census-tract level	Change in distance to nearest highway ramp, and distance to nearest railroad station	Endogenous placement of highways and railways	Instruments: straight-line distance to the nearest network (Roman roads built for military purposes, pre 19th century roads designed to improve communications; and 19th century railroad lines)
Garcia-López *et al* (2015)	Impact of highways on decentralization in cities (Spain)	Change in central city population and suburban population growth	Change in number of highway rays in central cities	Endogenous highway placement	Instruments: Rays or kilometers from historic roads (either Roman roads built for military purposes, or Bourbon roads built for political reasons).

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Ghani, Goswami, and Kerr (2012)	Impact of highways on economic activity (India)	Entry of firms, labor productivity, and TFP	Distance of non-nodal district to highway system	Endogenous highway placement	Focus on "inconsequential" non-nodal districts
Gibbons and Machin (2005)	Impact of transport accessibility on land prices (London, UK)	Change in property values	Change in distance to nearest railway station	Endogeneity of station placement	Diffs in diffs within differentially treated areas: within 2km and further away
Gibbons et al (2012)	Impact of road construction on economic activity (UK)	Number of firms and employment	Local index of job accessibility to jobs	Endogeneity of road construction and of worker location	Comparison of effects at various distances within a narrow band (avoiding selection issues in the comparison) Instrument: counterfactual accessibility index in the absence of relocation
Hsu and Zhang (2013)	Impact of road capacity on traffic (Japan)	Traffic (vehicles-kilometers traveled)	Lane-kilometers of roads	Endogeneity of road placement	Instrument: - historical expressway extension plan (1987)
Hymel (2009)	Effects of congestion on employment growth (US, 1982-2003)	Employment growth in US metropolitan areas	Annual aggregate time lost in traffic at metropolitan level	Endogeneity due to reverse causality (employment growth causing congestion)	Instruments: - Number of radial road-miles per capita in historical highway plan (1947 National System of Interstate Highways plan) - Number of transportation committee members in the House of Representatives (influencing congestion through road construction in their constituencies)
Jedwab and Moradi (forthcoming)	Railroad construction on economic development (Ghana, 1891-2000)	Cocoa production, population, urban growth	Dummy for proximity to railway	Endogeneity of railway placement	Instrument: distance from straight lines between two main seaports Placebo regressions

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Khandker and Koolwal (2011) (Bangladesh)	Impacts of rural roads on household outcomes	Per capita expenditure, school enrollment, non-agricultural employment, consumption prices	Rural road improvement	Endogeneity of road placement and improvement	First differences Instruments: lagged outcome variables
Khandker *et al* (2009) (Bangladesh)	Impacts of rural roads on household outcomes	Per capita expenditure, school enrollment, wages, hours worked, input and output prices	Rural road improvement	Endogeneity of road placement and improvement	First difference controlling for initial conditions
Mayer and Trevien (2003)	Impact of public transport extension on local economic activity (Paris, France)	Local share of firms (out of metropolitan area total)	Construction of suburban express railway station	Endogeneity of station placement	Focus on non-consequential stations between "new towns" and metropolitan core
Michaels (2008)	Impact of interstate highway on labor market/trade (US)	Earnings in the trucking and warehousing industries (indicative of trade activity)	Dummy for highway going through rural counties	Endogenous highway placement	Instruments: - Dummy whether a route was planned for in 1944 - Angle with closest city (correlated with probability of connection to highway grid)
Sanchis-Guarner (2012)	Impact of road construction on labor market outcomes (UK)	Wages and hours worked	Local index of job accessibility to jobs	Endogeneity of road construction and of worker location	Comparison of effects at various distances within a narrow band (avoiding selection issues in the comparison) Instrument: counterfactual accessibility index in the absence of relocation
Storeygard (2014)	Impact of transport cost on trade and urban growth (sub-Saharan Africa)	City light output	Price of oil interacted with distance along road to primate city	Endogenous road placement	Argues exogeneity of oil prices

Study	General Focus	Outcome of Interest	Treatment or Explanatory Variable of Interest	Identification Problem	Source of Exogenous Variation or IV
Van de Walle and Mu (2007)	Fungibility of aid money for road construction and improvement (Vietnam)	Length of road improvements or new roads	Aid money for road improvement	Endogenous assignment of aid money to project areas	Difference-in-difference matching
Volpe Martincus *et al* (2014)	Impact of road expansion on exports and employment (Peru)	Exports and employment	Road infrastructure expansion program	Endogeneity of road placement	Difference-in-difference. Instrument: distance to and along Inca Road