Wider Economic Benefits of Transport Corridors: A Policy Framework and Illustrative Application to the China-Pakistan Economic Corridor

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Abstract

This paper discusses a new policy framework to appraise proposals of large transport infrastructure investments—transport corridors—and applies it to the China-Pakistan Economic Corridor (CPEC). The framework emphasizes the need to focus the appraisal of transport corridor investments on outcomes that go beyond savings in travel time and reductions in vehicle operating costs, and even beyond intermediate outcomes such as trade and agglomeration. The focus should be on the ultimate benefits that households along a corridor, and, more generally, society, can attain—such as increased consumption, better jobs, and greater equity. It also emphasizes the need to identify and manage trade-offs. For example, household income could increase at the expense of environmental degradation. Or alongside winners, a corridor, may also create many losers. The appraisal framework is applied to Pakistan's portion of the CPEC, using reduced-form econometrics and allowing the impacts of transport corridors to depend on initial market conditions and institutions. The simulations suggest important heterogeneous impacts of CPEC among districts in Pakistan stemming from the variations in restrictions on land use and in secondary education across connected districts.

Keywords: Infrastructure; Transport Corridors; Economic Corridors, Wider Economic Benefits; Consumption; Poverty; Jobs; Gender; Air Pollution; Pakistan; China.

JEL Classification: R40, H54, F15, R12

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1. Introduction

Countries and the international development community invest in transport corridors hoping to create big economic surpluses that can spread throughout the economy, its regions, and society at large.[1] But if the corridors do not generate the expected surpluses in the overall economy, they can become wasteful white elephants—transport infrastructure without much traffic.[2] And when corridors do generate aggregate surpluses, it is often socially desirable that the net benefits be equitably distributed throughout the population.[3,4] Only when transport corridors create more winners than losers, and do not leave some households behind, can they spur equitable growth and help reduce poverty.

Many corridor initiatives are under way or proposed in Asia and around the world. One ambitious proposal is to revive the Grand Trunk Road from Kabul, Afghanistan, to Chittagong, Bangladesh, connecting areas that are home to a significant share of the world's poor. Even more ambitious could be the plan for the New Silk Road Economic Belt. If realized, it would extend from Beijing all the way to Brussels while branching out into some South Asian countries, such as Pakistan via the China-Pakistan Economic Corridor (CPEC) Initiative.

These and other proposed initiatives, and the investments associated with them, could demand trillions of dollars. Such demand exceeds the financial resources available in the

[1] In Vietnam, for instance, developing National Highway No. 5 on the back of complementary reforms in education and trade openness helped reduce the absolute number of people living in poverty in the populous Red River Delta region by an impressive 35 percent between 1995 and 2000. This poverty reduction outpaced the national average reduction of 27 percent (ADB et al. forthcoming).

[2] For example, several studies find that the traffic volume has been low on the multi-country, Greater Mekong Subregion (GMS) corridor (ADB 2008; Srivastava and Kumar 2012).

[3] This is assuming that the social welfare function does not take an extreme utilitarian or Benthamite form in which social welfare is maximized when the sum of individual utilities is maximized.

[4] In China, for instance, the construction of the National Expressway Network (NEN) increased real income across its prefectures by nearly 4 percent, on average, but decreased real wages in either the urban or rural sector in many prefectures (Roberts et al. 2012).

foreseeable future to support corridors. Moreover, large investments in corridors risk crowding out other public investment in critical areas such as education, water and sanitation, or health.[5] Given the huge resources and high stakes, national governments and the international community need to think clearly about how to prioritize investment proposals for corridors, and specifically, how to select the more promising ones over the less promising or potentially wasteful ones.

Policy decisions on corridors, however, have often been influenced by political economy and geopolitics at the expense of sound economics.[6] The geopolitical ambitions drive new transport corridor initiatives in various directions. At the same time, risks are increasing that some proposed corridors could become either white elephant investments or inequitable public investments that benefit a few corporations engaged in foreign trade at the expense of many small businesses and people living near the corridor alignments and of the national taxpayers at large. Indeed, for Asia, the biggest risk is missing the "right" corridors with the greatest welfare enhancing potential.

This paper aims to provide a policy framework for more rigorous ex ante appraisals to empower stakeholders (politicians, technocrats, civil society organizations, and business associations) in scrutinizing and ascertaining socioeconomic benefits when massive investments in a transport corridor are proposed.[7] If adopted, the framework could help discipline stakeholders

[5] Between 2014 and 2020, South Asia will need to invest at least $1.7 trillion to $2.5 trillion in infrastructure (in current prices), most of which is in transport, to close the existing infrastructure gap in the region. This is a conservative estimate by Andrés, Biller, and Herrera Dappe (2013), who benchmarked South Asian countries against their peers, which could also be below the "optimal" infrastructure investment.
[6] For example, Chatterjee and Singh (2015) report that India's Foreign Trade Policy for 2015–20 has highlighted the importance of the International North-South Transport Corridor in expanding India's trade and investment links with Central Asia. Ordabayev (2015, 2016) points out the competing geopolitical interests of India, China, Russia, Europe, the United States, Turkey, and Iran in Central Asia concerning transport corridor connectivity, trade, and energy. In turn, Palit (2017) discusses India's uneasy economic and strategic perceptions of China's Maritime Silk Road Initiative. And Shephard (2017) reports that India and Japan have joined forces to counter China and build their own New Silk Road, in another geopolitical move.
[7] This framework was first set out in the forthcoming joint ADB, DFID, JICA, and World Bank report, *The WEB of Transport Corridors in South Asia*, of which the authors of this paper are among the lead authors.

and policy makers in their appraisal of corridors and help build consensus on the appropriate design of transport corridor programs in specific locations.[8] The framework extends beyond the immediate effects of transport corridors—such as savings in travel time and reductions in vehicle operating costs—which are the focus of traditional cost-benefit analysis (CBA) and focuses on the ultimate goals of boosting local economic activity, jobs, poverty reduction, and economic opportunities for women, among other potentially positive outcomes. It can help stakeholders and policy makers think about possible negative impacts such as congestion, negative redistribution effects, social exclusion, environmental degradation, and other risks or unintended consequences. The framework also considers how well different supporting markets—that is, capital, labor, land, and product markets—and institutions function. It asks which complementary interventions could improve those functions, aid efficient reallocation of resources as well as delivery of public goods, and maximize the potential for wider economic benefits from transport corridors.

Inspired by this framework and making use of rich spatial data for India and Pakistan, the paper conducts an illustrative ex ante appraisal of the proposed CPEC highways system using India's completed Golden Quadrilateral (GQ) highway system in India as a benchmark (comparable) investment. Hence, the paper estimates an empirical model that captures the impacts of India's GQ and then applies this model to spatial data for Pakistan to "simulate" the potential impacts of the CPEC highway system. Importantly, this model allows for the impacts of highways to vary across locations along a corridor in accordance with initial and other conditions in those locations. Hence, although the model is initially estimated ("calibrated") based on the Indian

[8] In a sense, the framework could act as a "commitment technology" similar to, for example, the adoption of rules in monetary policy, fiscal policy, or financial policy designed to overcome problems of dynamic inconsistency.

experience with the GQ, the "simulated" impacts it generates for the CPEC system depend on the conditions that prevail in the locations through which it will pass. The model allows for potentially heterogeneous impacts on household expenditure, equity, social inclusion, and environmental quality at the district level due to varied initial conditions in product and factor markets, as well as institutions.

We find that the spatial variation in impacts of the proposed CPEC on household expenditure will be influenced the most by the variation in the share of cropland—that is, by the variation in land market constraints. For example, districts close to Karachi could experience the biggest impacts on household expenditure because they have more land available for industrial uses. Probably because of data limitations, we find no major predicted impacts on poverty reduction.

The simulated CPEC impacts on the share of regular-wage jobs in female employment—a measure of women's inclusion in the labor market—vary markedly across districts. The variation again depends on the share of cropland in the total land area. Land constraints could restrict women's ability to benefit proportionately from improved market access. The range in simulated impacts is on the order of 7 percentage points. Along the CPEC, the land market constraint could reduce the benefits in districts that are closer to the northern leg of the corridor.

The simulated impact of the CPEC corridor on air pollution (as measured by the aerosol optical thickness indicator) is, on average, negative (i.e., air pollution becomes, on average, worse), but spatial variation is, again, substantial across the corridor districts. The spatial variation is driven by differing levels of higher education; air pollution could increase less in districts with higher rates of secondary school completion. Highly educated populations might tend to switch to cleaner vehicles, even if they are relatively more expensive. Also, areas with more secondary schooling can experience a larger structural transformation toward non-farm jobs, and farms might burn less straw—a major contributor to air pollution in South Asia (Singh and Kaskaoutis, 2014).

Several studies have reviewed the literature on the impacts of transport infrastructure investments, informing the ongoing policy dialog and appraisals of proposed corridor investments (Roberts et al. 2018; Berg et al. 2017; Redding and Turner 2014; Melo, Graham, and Brage-Ardao 2013; Straub 2011). Other studies take the more practical perspective of project appraisals (Bakker, Koopmans, and Nijkamp 2010; Laird and Venables 2017). For example, Laird and Venables propose a disciplining structure to encourage more rigorous CBA—a policy framework similar in spirit to ours. However, their framework mostly stops at intermediate development outcomes (such as productivity)—apart from employment—rather than focusing on the ultimate economic benefits or costs experienced by households and society. This paper thus contributes to the literature by proposing an appraisal framework for transport corridors that emphasizes households as the ultimate beneficiary and financier (taxpayer) of corridors. It also disciplines decision makers to identify and address possible policy trade-offs.

Section 2 discusses the proposed appraisal framework and its individual components. Section 3 applies the framework in an illustrative ex ante appraisal of the CPEC in Pakistan in two steps. First, it summarizes the estimation results of a study by Melecky, Sharma, and Subhash (2018) on a benchmark corridor investment in India. Second, using these estimation results, it performs appraisal simulations for CPEC using district-level (spatial) data for Pakistan. Section 4 concludes.

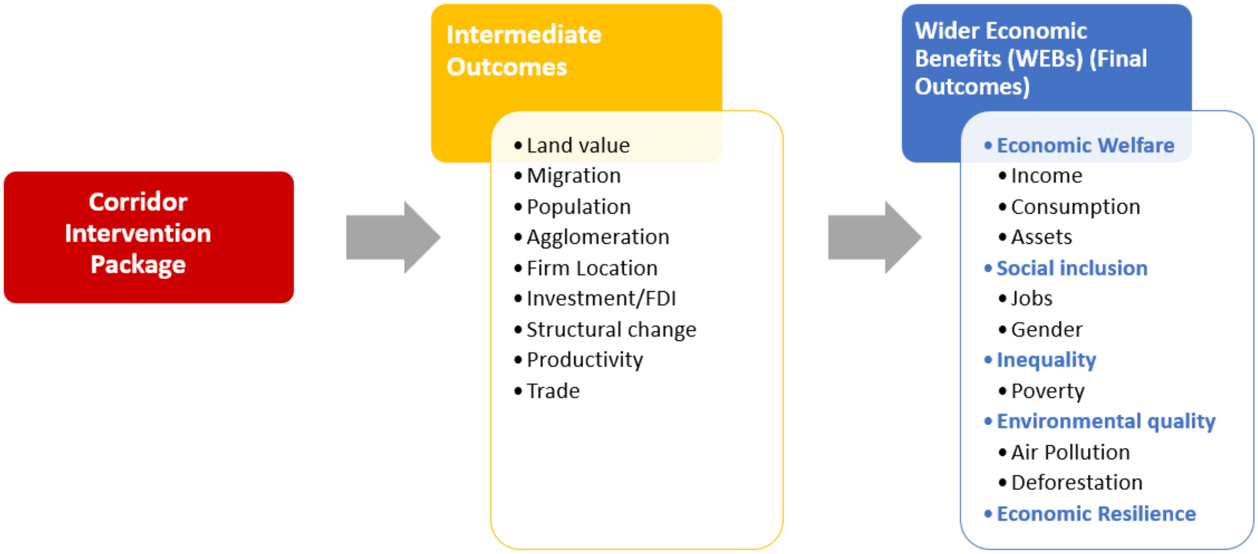
2. A Policy Framework for Achieving Wider Economic Benefits: FIT-2-Deeds

We assume that the policymaker tries to maximize the wider economic benefits (WEBs) of a proposed transport corridor investment, considering benefits net of costs. This *policy maker's* *problem* can play out at different levels of aggregation: local (subnational units such as districts), national, and international. To help think through this problem and guide holistic appraisals of proposed projects on transport corridors, we develop a framework that builds on six elements: namely, the Flow of expected results, the Intervention design, and the Typology of impacts; two sorts of public intervention (policies and institutions); and the twin Deeds of financing and implementing the corridor. These elements are summarized in the acronym "FIT-2-Deeds."

"F": The "Flow" of expected results—The causal link from the corridor to economic benefits

Several potential transmission mechanisms and associated intermediate outcomes help determine the ultimate impact of a corridor intervention on a relevant set of final outcomes (the wider economic benefits net of costs). The maximization of these WEBs should be policy makers' ultimate objective. We consider five categories of WEBs: economic welfare; social inclusion; equity; environmental quality; and economic resilience to negative shocks. The potential transmission mechanisms from a corridor intervention package through intermediate outcomes to WEBs can be summarized in a Flow (chain) of expected results (figure 1), where a corridor intervention package consists of not just the investment in the trunk transport infrastructure, but also other potential policies and institutional reforms that are intended to complement/enhance the impacts of the transport infrastructure.

Figure 1. The final outcomes of a corridor intervention are realized through many transmission channels and various intermediate outcomes



Note: FDI = foreign direct investment.

A corridor intervention can *directly* affect the final outcomes (wider economic benefits net of costs) depending on other *complementary factors* that affect many aspects of the economy at the same time. These complementary factors could comprise initial conditions in local product markets (such as the level of competition) and factor markets for land, labor, and capital (such as land use restrictions, availability of skilled labor, and access to credit). This direct impact can vary from beneficial to detrimental across the five different types of final outcome (or WEBs). For a given type of outcome, it can also vary considerably across locales and population groups.

A corridor intervention can also affect the complementary factors themselves. Thus, the corridor intervention can affect the final outcomes *indirectly*. For instance, if the corridor reduces commuting and migration costs, it also reduces frictions in the labor market, which, in turn, can increase the local availability of skilled labor, overall employment, and household income. We refer to these indirect changes of complementary (structural) factors as *intermediate outcomes*.

The impact of the corridor on intermediate outcomes can also vary from beneficial to detrimental across the five types of outcome.

Knowledge of the direct and indirect impacts, the trade-offs they could produce, and the complementary policies that could help manage these trade-offs can all improve the design of a corridor intervention.

"I": The "Intervention" design—The program design to support fair distribution of greater and wider benefits

Policy makers deliberate about corridor features such as location, length, and mode of transport infrastructure for the transport corridor project. They may also consider complementary policies and institutions that can help amplify the targeted WEBs. These complementary interventions consider the constraints imposed by initial conditions (such as terrain, population density, market imperfections, and/or inequality of opportunity). They then chose a specific set of interventions. These interventions can occur at three different levels, from the most basic to the most comprehensive (figure 2):

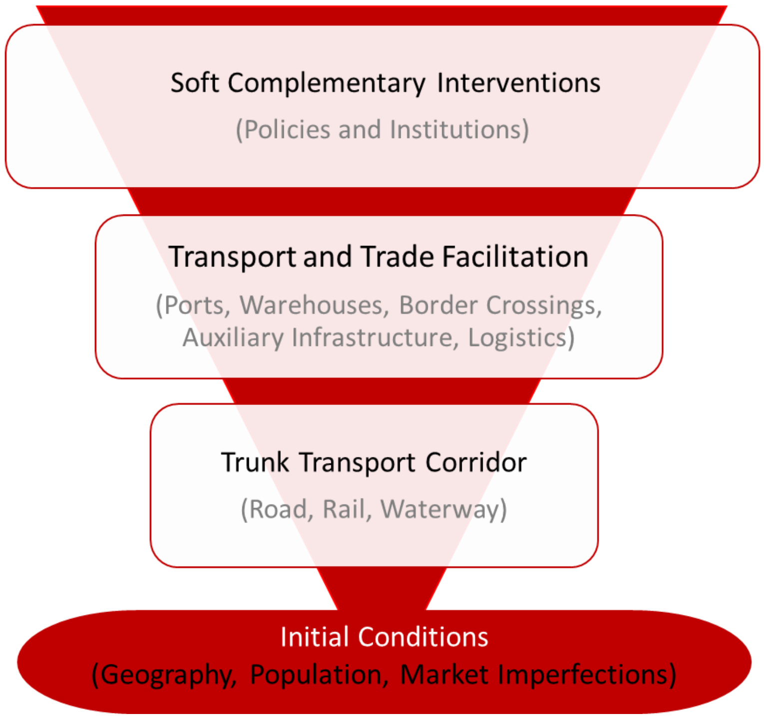
1. *Investments in trunk transport corridors*. This entails building entirely new transport infrastructure (roads, rail, or inland waterways) or upgrading existing ones (entire systems or individual links).

2. *Transport and trade facilitation services*. Benefits from narrow investments in a trunk transport corridor can be enhanced by simultaneous investments and reforms in enabling transport services and policies (including trucking, rail, and/or port services) and trade facilitation services and policies (such as warehouses and border crossings, and/or lowering of trade barriers).

3. *"Soft" complementary interventions*. Benefits from improved regional connectivity can be further enhanced if the project design also addresses the market imperfections (in both final product and factor markets) and missing public goods (institutions) most binding for realizing WEBs. Policy interventions could target improvements in the functioning of capital, labor, land and product markets, and/or improvements in institutions such as enhanced public sector governance or contract enforcement.

Policy makers and other stakeholders would like to know which particular features of corridors (mode of transportation, length, location, nodal connections, and so on) and which complementary policies and institutions (land market reforms, improved access to finance, regulatory improvements in product markets, and so on) need to receive greater weight under different sets of initial conditions (such as unclear land titles, labor market frictions, financial market imperfections, and the extent and state of any pre-existing transport infrastructure).

Figure 2. The intervention package for a transport corridor project can include priority transport and trade facilitation measures, as well as soft complementary policies



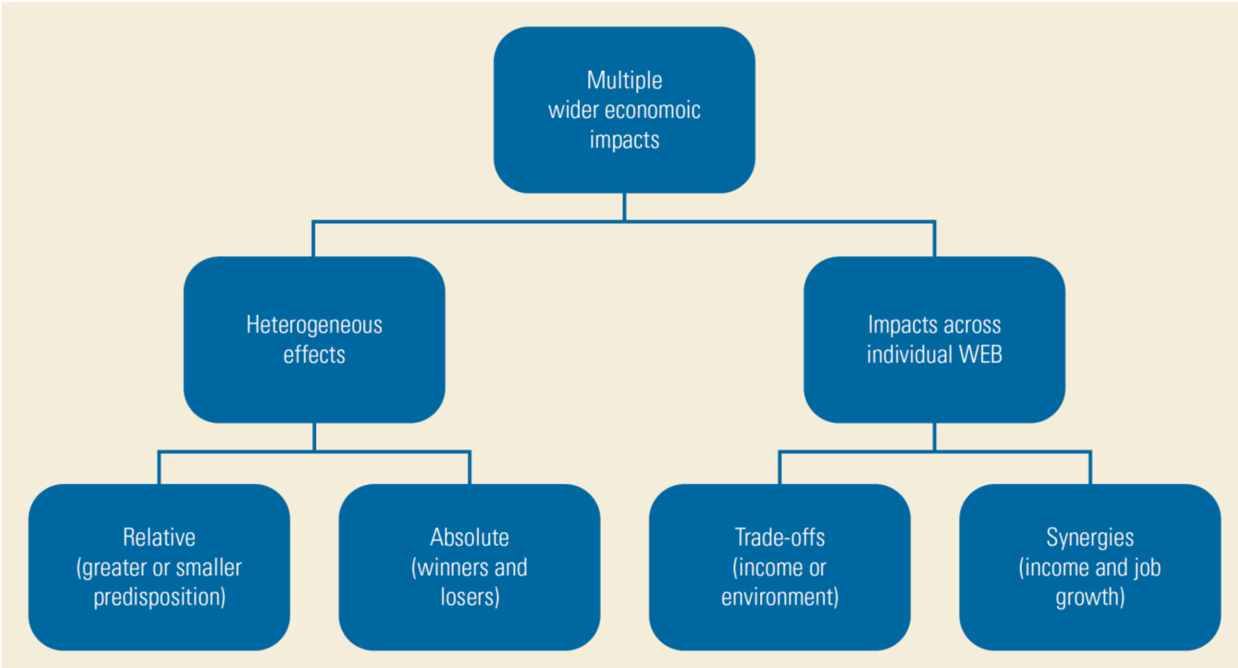
"T": The "Typology" of impacts—Organizing the multiple economic impacts into a hierarchy

A transport corridor intervention has the potential to affect multiple WEBs. In some cases, these impacts may be positively correlated. For instance, the corridor could boost both incomes and job creation. In other words, the corridor intervention could create *synergies* in development impacts, producing beneficial effects for both economic welfare and social inclusion. However, in other cases, the impacts may be negatively correlated. For instance, economic welfare impacts may be beneficial, but environmental impacts may be detrimental. This leads to *trade-offs* between different outcomes.

Impacts may also be *heterogeneous*. That is, for a given outcome, they could vary significantly across different geographic areas, segments of the population, economic sectors, and the like. These varied impacts may benefit all, but vary in size depending on the beneficiaries' greater or smaller predispositions to benefit. For instance, more educated and skilled population groups could benefit more from economic restructuring (in a shift from agriculture to manufacturing, for example), get better jobs, and enjoy more rapid gains in income than those with less education and a lower level of skills. Thus, impacts can be *relative.* But alongside winners, corridor interventions could also produce losers in *absolute* terms. For instance, by increasing efficiency, better transport connectivity could induce structural transformation that exploits a new comparative advantage of the country. But this transformation could require massive shifts in professions. People with more fungible skills and human capital could take advantage and shift easily, but those with lower skills and rigid professional backgrounds could enter the pool of structural unemployment.

Figure 3 summarizes the hierarchy of multiple impacts across different dimensions. Policy makers have three overarching policy objectives: to achieve multiple WEBs, to manage trade-offs in corridor impacts, and to support (compensate) possible losers.

Figure 3. The overall balance between beneficial or detrimental impacts of a corridor intervention package depends on a hierarchy of impacts



Note: WEB = wider economic benefit.

"2": The "2" sorts of complementary interventions—The policies and institutions to reinforce WEBs

Merging the layers of project design (figure 2) and the hierarchy of multiple impacts from transport corridor interventions (figure 3) could produce a useful tool to screen for the quality of project design. An example of such a merger is presented in the matrix in table 1. The different layers of intervention design are arrayed in the rows, while the columns present the overarching policy objectives.

This simple screening tool could help ensure that the designs of corridor programs stay focused on the fair distribution of economic benefits as a priority. Applying the matrix could discipline policy makers by having them answer how each design layer addresses the three policy objectives. For instance, cell (1,1)—that is row 1, column 1—of the matrix asks: What are the expected (projected) impacts of the design of the trunk infrastructure on the multiple WEBs that are priorities for the policy maker? Cell (2,2) asks: Is the design of transport and trade facilitating interventions likely to generate trade-offs across individual WEBs? Cell (3,3) asks: Are there likely losers (relative and absolute), can they be identified, and what are the most effective complementary market policies and/or institutional reforms to support or compensate them? Which are the priority markets that these policies/reforms should target? Which institutions could help in curbing the number of losers by providing them with adequate support and/or compensation?

Table 1. A useful tool to screen for comprehensive project design

Layers of project design	Hierarchy of multiple impacts: Achieve multiple WEB	Manage trade-off impacts	Support possible losers
Trunk infrastructure	?	?	?
Transport and trade facilitation	?	?	?
Complementary market policies and institutions	?	?	?

Note: WEBs = wider economic benefits.

The first "Deed": Devising a viable financing strategy for the corridor program

Ultimately, the costs of corridor investments are paid by taxpayers, ratepayers,[9] and/or future users. The sharing of funding costs among these parties is influenced by social and policy preferences.

Developing a viable and efficient financing strategy starts by assessing how much of the expected returns from the corridor investment could be monetized directly (and so be recovered

[9] In the case of grant or concessional financing from international development banks, the taxpayers may ultimately be located in other countries.

by tariffs) or indirectly (and so financed by taxes), and how much could be nonmonetary (in the form of social returns). Next, policymakers must tackle the potential funding mismatch that stems from the fact that project costs must be paid at the initial preparation and construction stages, while tax and tariff revenues generated either directly or indirectly from corridor investments accrue only over time. The domestic or international financial systems could help tackle this mismatch by providing financing through appropriate instruments, and intermediating available resources elsewhere, either from the domestic or the international economy.

Policy makers devising a financing strategy for a given design of corridor intervention could consider the following options:

- Increasing current taxes or reallocating public spending funded by existing tax revenues
- Sovereign borrowing from concessional lender(s) (multilateral, bilateral, or other providers of concessional finance and grants)
- Sovereign borrowing from private financial institutions or through the capital markets
- Leveraging public capital to mobilize private equity and debt at the project level, or at the level of an investment fund (special purpose vehicle), among others.

Several of these options could include public guarantees and other explicit or implicit potential liabilities—including within public-private partnerships (PPPs). PPPs must be devised and managed realistically and carefully (ADB et al. forthcoming, spotlight 3; Macário, Ribeiro, and Costa 2015; Makovšek 2013; Koppenjan 2005).

The public sector (usually at the level of the central government) needs adequate capacity to assess which risks can be passed onto the private sector, which need to be retained, and how the retained and passed risks are interconnected. This risk management capacity is especially important in cases of corridor investments that cross borders. If risk management capacity is low, contingent liabilities from shifted risks may ultimately shrink the fiscal space – i.e. the space for the fiscal authority to borrow and spend. For instance, poorly assessing risks surrounding large PPP programs could leave the country with incomplete transport infrastructure projects, a large stock of bad loans in the domestic banking system, and additional contingent (potential) liabilities resulting from the need to recapitalize troubled systemically important or state-owned banks.[10]

Complementary policies and institutions to strengthen institutional and legal frameworks, as well as public sector capacity to transfer risk using complex legal and corporate entities—that is, through structured finance—could be pursued as part of the corridor intervention package or as stand-alone broader reforms of public financial management and governance.

The second "Deed": Managing the implementation of the corridor program and its projects

Successfully managing the implementation process presents its own set of challenges. For large cross-border corridors, four challenges are paramount.

- *Managing cross-border complexity.* This challenge could be tackled by establishing effective standing or temporary bodies, such as supranational committees, that could decide how to partition the overall corridor program into "implementable" projects, considering regional and national financing constraints as well as agency responsibilities for implementation; plan appropriate sequencing of subprojects; devise effective tracking of the overall program delivery; and enforce accountability for performance. However, if not adequately empowered, these supranational coordination bodies could fail. Alternatively, international organizations

[10] In India, which has more PPPs than the other countries, it appears that the insolvencies of many highway PPPs are challenging the banking sector and impeding physical progress on construction. These problems have not yet been addressed, which affects both infrastructure assets and their WEBs. The issues with the PPP highways are linked to a heavy reliance on public sector banks for PPP lending, combined with speculative behavior in contracts for short-term gains while the projects were being constructed. Similarly, in Nepal, PPP models have failed to deliver on major corridor projects such as the Fast Track highway, despite six attempts since 1996 (ADB et al. forthcoming, spotlight 3).

could take the lead as an "honest broker" toward all countries involved and provide them with technical counsel and assistance.

- *Boosting local delivery.* Effective collaboration between local and central governments is needed to optimize administrative capacity and the legitimacy of some interventions, including of complementary policies specific to locales, such as property price taxes, delivery of vocational education, development of economic zones, or zoning for environmental protection. This collaboration may require temporary increases in budget and staff transfers from the central to the local government. Possible tensions involving local governments that do not directly benefit from the corridor intervention must be anticipated and managed early on.
- *Integrating expertise across sectors.* Because corridor interventions, to be efficient and fair, must ultimately maximize WEBs, the expertise that needs to be mobilized for project design and implementation must extend beyond transport infrastructure and its financing, tapping such areas as industrial organization, trade, urban development, financial and private sector development, cross-sectoral institutions, environmental management, public financial management, and macroeconomics. Mobilizing such expertise and effectively integrating it could be a challenge for both the country governments and any international organization(s) that support corridor projects at their different stages. Building on the experience of other institutions that need to quickly mobilize and integrate diverse expertise (such as the U.S. space agency, NASA), governments and international organizations could consider identifying potential members of "Corridor Tiger Teams" to deploy well-integrated cross-sectoral expertise rapidly.[11]

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[11] The concept of Tiger Teams originally came out of early NASA innovations for solving technical or systemic problems. For example, the NASA Engineering and Safety Center (NESC), when requested by a project or program, puts together "tiger teams" of engineers and scientists from multiple NASA centers to assist solving a difficult or

- *Leveraging the private sector in delivery.* Successfully engaging the private sector during implementation requires strong governance arrangements, sufficient administration capacity, and clear knowledge of private sector preferences. Tenders must be transparent and efficient without conflicts of interests; administrators must stick to announced timelines; sequencing of implementation phases must be carefully planned; and expectations and uncertainty must be managed through effective communication and guidance, among other requirements. Credible and regular communication with businesses at the grassroots level (industry associations, business leaders, and financiers) must be established rapidly to encourage businesses investments early. Without these foundations and under greater uncertainty, businesses will hold back their investments to see how the uncertainty that they face will play out, which could restrain the spillover of WEBs for some time.[12]

3. An Illustrative Appraisal of CPEC's impacts

As an illustration, this section first shows how to estimate the impacts of India's Golden Quadrilateral (GQ) and North-South-East-West (NSEW) highway systems[13] on WEBs. To that end, it summarizes the study by Melecky, Sharma, and Subhash (2018), who apply the "difference-in-difference" (DiD) method to India's district-level data from 1994 to 2011. They also discuss

complex problem. Tiger teams have been used extensively in governmental organizations. They are often used to assess compliance with, as well as the efficacy of, existing policies, as well as to generate proposals or recommendations for future policies. In the United States, governmental tiger team recommendations have directly influenced laws and policies in the national government (see, for example, Evans, 2016).

[12] Bloom, Bond, and Van Reenen (2007) study the effects of uncertainty on short-term investment dynamics using models with partial irreversibility, testing the theoretical predictions by estimating the investment model on the panel of UK firms. Demir (2009) analyzes the effects of macroeconomic uncertainty and volatility on firms' decision to undertake fixed investment. Fuss and Vermuellen (2008) test the implication of demand and price uncertainty on investment decisions surveying a panel of manufacturing firms. They find that demand uncertainty at the planning stage could reduce planned and later realized investments.

[13] The Golden Quadrilateral (GQ) highway, together with the North-South-East-West (NSEW) Corridor and port connectivity highways, connect many of India's major manufacturing, commercial, and cultural centers. Both roadways are four-lane highways.

how to examine the dependence of these impacts on initial conditions in input (capital, labor, and land) markets, product markets, and governance by using interaction terms in the DiD regressions.

Second, using the estimation result of Melecky, Sharma, and Subhash, this section illustrates how to use the estimated DiD model to simulate an appraisal of the proposed highway systems for the CPEC transport corridor in Pakistan, focusing on the issues of multiple impacts, trade-offs, and complementary policies and institutions emphasized by our general policy framework.

3.1. Summarizing the estimations by Melecky, Sharma, and Subhash (2018)

The study by Melecky, Sharma, and Subhash (2018) uses a DiD methodology to estimate the impact of India's GQ highways on district-level outcomes of interest. This method compares the change in the outcome of interest after the highway was constructed in districts located close to the new highways (the "treatment districts") to those located far away from them (the "control districts"). The computed differences capture the change in the outcome before and after the highways were built. The identification assumption behind this approach is that unobserved time-varying factors had the same impact across control and treatment districts.

Following Ghani, Goswami, and Kerr (2016), districts were assigned into two sets of distance bands—one set by proximity of the district centroid to the GQ and one set by proximity of the district centroid to the NSEW. In both cases, four designations were used: more than 100 km from the nearest GQ/NSEW point; 40−100 km from the GQ/NSEW; 0−40 km from the GQ/NSEW; and nodal districts.[14] Using these distance bands, the specification estimated by Melecky, Sharma, and Subhash is as follows:

[14] As in Ghani, Goswami, and Kerr (2016), the estimation assigns nodal districts to a separate category, and does not classify them as treated districts. Nodal districts correspond to major metropolitan areas and their peripheries, and thus are distinct from the average Indian district.

$$Y_{i,t} = \beta^{GQ} \times GQ_i \times Post_t^{GQ} + \beta^{NSEW} \times NSEW_i \times Post_t^{NSEW} + \emptyset_i + \varphi_t + \varepsilon_{i,t} . \quad (1)$$

Here, GQ_i (or $NSEW_i$) is a vector of dummies indicating the distance band from the GQ (or NSEW) to the centroid of district i, while $Post_t^{GQ}$ (or $Post_t^{NSEW}$) is a dummy equal to one in the years after the GQ (or NSEW) is completed. The omitted distance band dummy corresponds to districts more than 100 kilometers from the highway (GQ or NSEW). $\emptyset_i$ is a set of district fixed effects, and φ_t is a set of year dummies (or state-year dummies).

Depending on the availability of data for the outcome variable, the panel dataset covers either four of the data spells (1994−95, 2000−01, 2004−05, and 2010−11) or just two spells (2000−01 and 2010−11). Because the GQ network was largely complete by 2005, the indicator $Post_t^{GQ}$ is set equal to one in the years 2004−05 and 2010−11, and zero otherwise. Work on NSEW started after 2005. Thus $Post_t^{NSEW}$ is set equal to one only in 2010−11.[15]

The outcomes variables correspond to four WEB categories highlighted in figure 1: economic welfare, inequality, social inclusion, and environmental quality. The measures of economic welfare are GDP per capita and mean household per capita expenditure for each district, while inequality is measured by rural and urban poverty headcount rates. The measures of social inclusion are the percentage of the working-age population that is working and the percentage of regular-wage ("good") jobs to total employment, both disaggregated by gender. The second measure is the preferred measure of social inclusion. The measures of environmental quality include measures of particulate matter (smog) in the air, as well as measures of air pollution (carbon dioxide and nitrogen dioxide levels).

[15] Certain segments for the NSEW were not complete by 2011. The analysis takes this into account when assigning districts to distance bands around the NSEW.

The impact of the GQ is measured by β^{GQ} , corresponding to the 0−40 distance band from the GQ, to be denoted by $\beta^{GQ,0-40}$ hereafter. Because the estimation is controlling for $NSEW_i \times Post_t^{NSEW}$, $\beta^{GQ,0-40}$ in effect measures how the post-GQ change in the outcome differed between districts 0−40 km from the GQ highway (the GQ treatment group) and districts more than 100 km from both the GQ and NSEW highways (the control group). Similarly, the impact of NSEW is measured by β^{NSEW} , corresponding to the 0−40 distance band from the NSEW, denoted by $\beta^{NSEW,0-40}$. The preferred specification replaces the year fixed effects with more flexible state-year fixed effects. In summarizing the results of Melecky, Sharma and Subhash, we focus only on their results for the GQ highways given that these are the results that we subsequently use, for reasons explained below, to simulate the impacts of the CPEC.

Average Impacts of the GQ Highways

The estimation results suggest that the GQ highways had a statistically significant positive impact on district output per capita. For GDP per capita variable, the point estimate of $\beta^{GQ,0-40}$ implies that the highway increased GDP per capita growth over 2001−11 by 4 percentage points. The regressions do not find statistically significant impacts of the GQ on other measures of welfare such as mean household per capita consumption expenditure. Nor do the regressions detect significant impacts on poverty headcount rates and the main measure of labor market inclusion, the share of regular-wage ("good") jobs.[16]

Finally, the regressions examine the GQ's impacts on measures of environmental quality. While they do not detect a significant impact on carbon dioxide and nitrogen dioxide levels in the air, it appears that the GQ led to an increase in air pollution (smog) related to particulate matter.

[16] Night lights intensity, a commonly used proxy for economic activity, also was not affected significantly.

Specifically, the GQ is estimated to have increased particulate pollution (as measured by "aerosol optical thickness") by 0.02 points relative to a baseline increase of 0.06 points. This signals a significant trade-off between economic benefits (increases in GDP per capita) and pollution.

Varied impacts of the GQ based on initial market conditions

Next, the study assesses the possibility that investments in highways generate WEBs only when certain ("complementary") market conditions are present that allow people to exploit opportunities opened-up by improved market access. For example, highways could have a bigger impact on firms in areas with better access to finance or to skills, or in areas with better functioning land markets.

The study undertakes this assessment by extending the regression framework to a triple-difference (DDD) approach that involves interacting the treatment ($Highway_i \times Post_t^{Highway}$) with variables capturing initial conditions in input (labor, land, and capital) and product markets in districts. Within this framework, the impact of complementary factors (i.e. favorable initial conditions in markets) is the difference of the impact of highways in districts with low levels of complementary factors and the impact of highways in districts with high levels of complementary factors.[17]

The main labor market variables are measures of human capital as of 2001: the literacy rate and the percentage of those with a secondary school or higher educational qualification. The land market variables measure the extent of land that is suitable/available for agriculture, as well as the capacity of the district for mineral production. Thus, they are measures of the nature of land endowments in districts. The capital market variables measure household access to bank services

[17] See Melecky, Sharma, and Subhash (2018) for the formal regression specification.

(that is, to formal bank accounts), and firms' access to bank loans, as of 2001. The product market variables include a measure of product diversification, as well as a measure of the share of private firms in industrial establishments; both are intended to proxy for competition in the product market. A third measure is the share of agro-processing in manufacturing. This proxies for the initial level of opportunity for factory work available to low-skilled workers, who constitute a majority of the workforce, particularly in rural areas. The hypothesis is that a large agro-processing sector also signals better supply chain infrastructure (such as warehouses, cold chains, and other logistical facilities) in rural areas. Appendix table A.1 lists the main interaction (initial market condition) variables and their sources.

Melecky, Sharma, and Subhash use a simple iterative procedure based on maximizing the adjusted R^2 to reduce the number of extraneous interaction variables.[18] Thus, the set of interaction variables in the final specification varies across outcomes. The broad hypothesis is that gaining the full benefits of market access could have depended on certain factor endowments such as skills (which are immobile in the short to medium term), and on the efficiency of product and factor markets. If this hypothesis is correct, then low average levels of factor endowments or market efficiency could explain why the *average* district did not experience widespread benefits from the highway construction. Identifying such complementary factors can point to how the construction of highways could be combined with complementary public investment or policy and institutional reforms to maximize their wider economic benefits.

[18] Similar results are obtained when instead optimizing based on the Bayesian Information Criterion (BIC).

Capital Markets (Households' Access to Bank Accounts and Firms' Access to Credit)

The estimation results for capital markets suggest that the impacts of proximity to the GQ depend on access to formal banking in a potentially complex manner. Consider the impact of the GQ on mean household consumption expenditure per capita. The estimated coefficient on the interaction between the GQ treatment and a measure of households' access to bank accounts is negative and significant (appendix table A.2, panel a).[19] This implies that the impact of the GQ on household expenditure was less positive in districts where households had better access to formal savings accounts. Given that the main use of these formal accounts is to save, one potential explanation is that even though the highways increased household earnings, a larger fraction of that additional income was saved in locations where households had better access to formal channels of saving. This could reflect an unmet demand among households for channels to diversify assets to build resilience to shocks ("save for a rainy day") and/or invest, which may require some equity.

Labor Markets (Skills)

The results indicate a complementarity between highways and skills. For the GQ, the impact of the highways is amplified in districts with a higher share of the population that has completed secondary schooling. Namely, the negative impact of highways (the GQ) on particulate matter air pollution (aerosol optical radius) is mitigated by having a better educated population (as measured by the share of the population that has completed secondary schooling). This could be because more educated individuals buy higher quality, environmentally cleaner vehicles as their income

[19] Moreover, the estimated coefficient on the interaction between the GQ treatment and the banking access measure is negative and significant when the outcome being examined is the reduction in the poverty headcount. Because the headcount measure is derived from the consumption expenditure measure, these interaction results reinforce each other.

rise. Another possible explanation for this interaction is that the way in which economic activity changes after a highway is built is more environmentally friendly in more-educated districts. Notably, districts with higher levels of secondary schooling experience a greater impact of the GQ on the shift from farm to non-farm jobs. This may have reduced pollution from a major contributing factor, the burning of straw in farms.

Land Markets

The results suggest that the impact of the highways also depended significantly on the share of cropland in a district's total land area. This interaction variable can be seen as a proxy for a district's comparative advantage in agriculture. A higher share of cropland also signals a bigger constraint on the availability of land for industrial purposes.

The impacts on household consumption per capita (namely, the coefficient on the interaction of the GQ treatment with the cropland measure) is negative and statistically significant (appendix table A.2, panel a). GQ districts gained less if they had less land available for non-farm usage. This is consistent with the hypothesis that the extent to which improved market access resulting from the GQ shifted people out of farm jobs was negatively related to comparative advantage in agriculture (or it depended positively on the availability of industrial land).[20]

[20] For the share of non-farm jobs among females and the share of regular-wage jobs among both males and females, Melecky, Sharma, and Subhash estimate the interaction of the GQ treatment with the cropland measure to be negative and statistically significant. For example, the estimates of the interaction term imply that moving from the 10^{th} to the 90^{th} percentile of cropland share would reduce the impact of the GQ on non-farm employment among females by 5 percentage points, and the share of regular wage jobs by 0.1 percentage points. This further reinforces the hypothesis presented.

Product Markets

The regressions also tested the hypothesis that the gains from highways depend on efficiency and competition in product markets. This part of the analysis relies on proxies for product market competition at the district level, such as the share of the private sector in formal manufacturing. No statistically significant and consistent interaction was observed between these measures and the impact of the highways; perhaps it reflects the crude quality of the available measures.

There is, however, a positive and statistically significant interaction between the share of agro-processing in local industry and the impact of the GQ in reducing rural poverty (appendix table A.2, panel b). There could be two reasons for this complementarity. First, as discussed, for the structural change wrought by the GQ to have translated into widespread benefits, the availability of suitable jobs for the vast reserves of low-skilled workers leaving the farm could have been critical. Agro-processing could be an important source of suitable jobs for rural workers. Second, the size of the agro-processing sector could be acting a proxy measure for the quality of "soft infrastructure" (such as warehouses and cold chains) in rural areas. This is indicative of a complementarity between "hard" infrastructure like the highway and soft connective infrastructure.[21]

3.2. Simulated Impacts of the CPEC Transport Corridor

The Simulation Method

This section simulates and discusses the expected impacts of a corridor that has not been built yet: the CPEC transport corridor in Pakistan. The simulations are based on the estimated

[21] Melecky, Sharma, and Subhash also estimate the effect of initial governance (institutions) on the conditional impact of the highways. We do not summarize these results here because district or state-level data on governance for Pakistan are not readily available.

regressions describing the impacts of the GQ in India, and are intended to illustrate how spatial data and econometric modelling can be used to better assess the varied impacts of proposed transport investments.

The simulation uses estimates of the GQ instead of the NSEW for two reasons. First, we are more confident of the estimates of the GQ because they are based on data for a longer span of time after the highway were built. Second, there are similarities in the effects of the GQ and the simulated corridors on market access: like the GQ, the CPEC transport corridor will connect places along their paths to major external markets, ports, and/or metropolitan areas.

The estimated regression model for India assumes that the impact of the GQ depends on a set of initial conditions in input and output markets in the places located along the corridor. If the GQ were to be replicated in a different location, like the proposed paths of the CPEC highways network, it would have a different impact because of the initial market conditions in those locations were different.

Based on the estimated regression model for the GQ, the expected impact of a proposed corridor in country c is simulated using data on initial market conditions of districts d that lie along the path of that corridor:

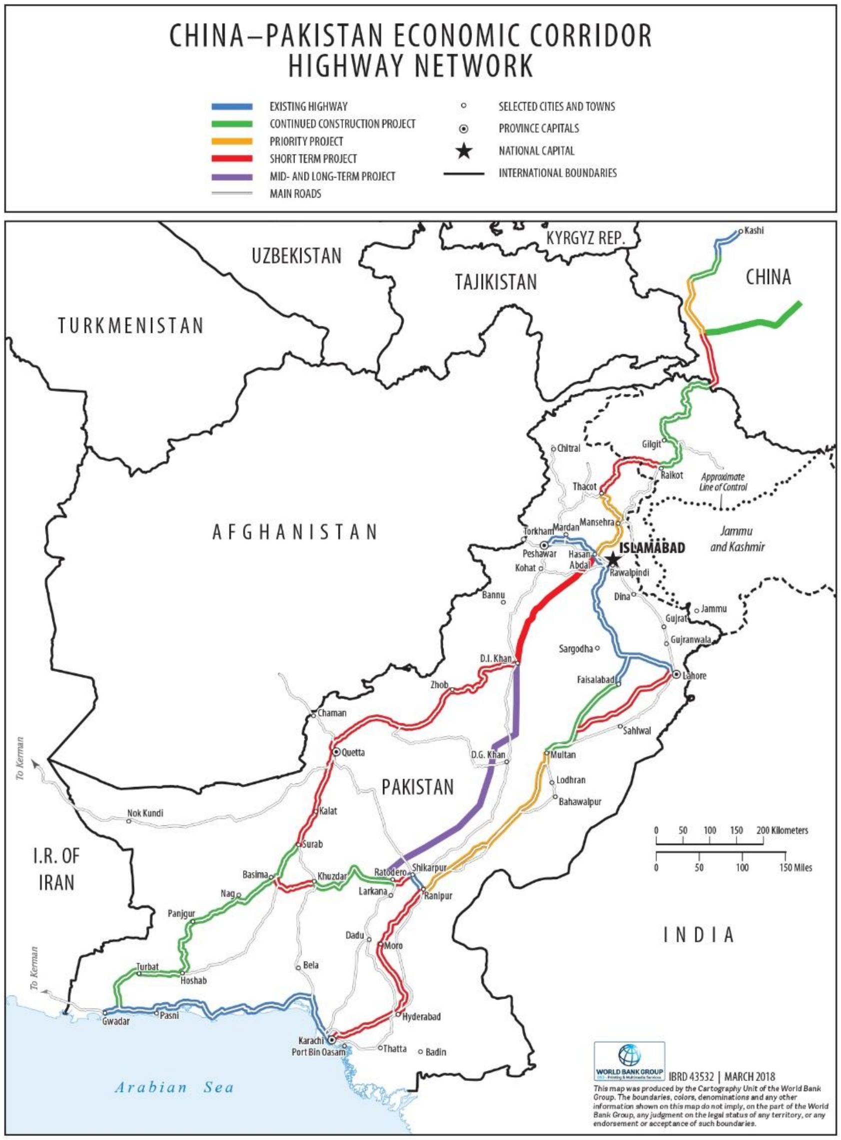
$$\Delta Y_{d,c} = \beta^{Y} + \boldsymbol{\delta}^{Y}.\left(\boldsymbol{Z}_{d,c} - \boldsymbol{Z}_{India}\right), \tag{3}$$

where $\Delta Y_{d,c}$ is the expected impact of the corridor on outcome Y in location d of country c. β^{Y} is the estimate of the average impact of the GQ on outcome Y in India. The vector $\boldsymbol{\delta}^{Y}$ consists of estimates of how the impact of the GQ on Y depends on initial market conditions $\boldsymbol{Z}$ in a district with upgraded connectivity. The vector $\boldsymbol{Z}_{d,c} - \boldsymbol{Z}_{India}$ measures how initial conditions in location d in country c differ from their average values in locations in India along the GQ.

This formula expresses the basic idea behind the simulation: the impact of a GQ-like corridor on location *d* in country *c* will differ from the average impact of the GQ in India to the extent that initial market conditions in location *d* are different from their averages along the path of the GQ.

CPEC consists of three proposed arteries (map 1). For our simulation exercise, the eastern-most one was chosen because it most resembles the GQ, passing through well-populated areas and several cities and towns, and connecting major metropolitan nodes and ports (international gateways).

Map 1. Proposed arteries of the China-Pakistan Economic Corridor



Source: http://cpec.gov.pk/map-single/1.

The simulation exercise focused on assessing the *spatial variation* in the expected impacts of the proposed corridors along their prospective paths, and not on assessing their average impact. The simulated corridors are only roughly comparable to the GQ, and their average impact could differ from that of GQ for several reasons. However, if the mechanisms of impact are the same, the way in which they depend on initial conditions is expected to be similar.

The simulation for the CPEC corridor used district-level data from Pakistan on the distance to the proposed corridor and relevant market conditions. The exercise measured the distance of district centroids to the nearest point on the proposed highway, and identified districts within 40 kilometers of the proposed highway. Following the estimated model for India, these districts were considered the "treatment" districts; that is, the districts that would be affected by the proposed corridor. The impacts were simulated only for these districts.[22] Also following the Indian estimation, major metropolitan districts that lie on the proposed corridor path, like Karachi in Pakistan, were treated as "nodal" districts and excluded from the simulation.

Data on market conditions were estimated from household- or firm-level surveys or sourced from satellite data. Because the highways have not been built yet, the exercise used the most recent values of the variables to simulate "initial" market conditions. As much as available data allow, the simulations used sources and definitions of indicators equivalent to those used in India. For example, the share of cropland in land area was based on MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data, the same source as in India. In some cases, it was not possible to avoid minor differences in the source type or variable definition. For example, variables on educational attainment were based on Census data for India and household survey data for Pakistan. Appendix tables A.3, A.4, and A.5 present the summary statistics and data sources for Pakistan.[23]

[22] The treatment group also includes all districts through which the proposed corridor would pass, regardless of how close it would come to the district centroid. Overall, the exercise identified 41 districts for the CPEC in Pakistan.

[23] Because comparable measures of subnational governance for Pakistan are unavailable, the exercise excluded the effects of governance from the simulations. Hence, the simulations are based on the baseline estimations for India that did not include the governance variable as an interaction term (the estimation results presented in appendix table A.2, panels a through d).

The Simulation Results

Appendix table A.6 presents the simulated impacts of the CPEC on WEBs. As stated, the focus is on the spatial variation in impacts, and not the mean impact. We also limit the discussion to those outcomes for which there were statistically significant interaction effects with one or more initial market conditions in the case of the GQ. Thus, even though output per capita is an important outcome variable, it is not discussed here because the simulations could not estimate how the impact depends on market conditions with sufficient precision. We can predict that the proposed corridors will have a positive impact on output per capita, but not how it will vary spatially.[24]

Map 2, panel a, depicts the simulated impact on per capita consumption expenditure of households (in logs) through a "heat map." The district-level predicted impact was normalized by its mean value across all the treatment districts, thus showing its relative value across districts.

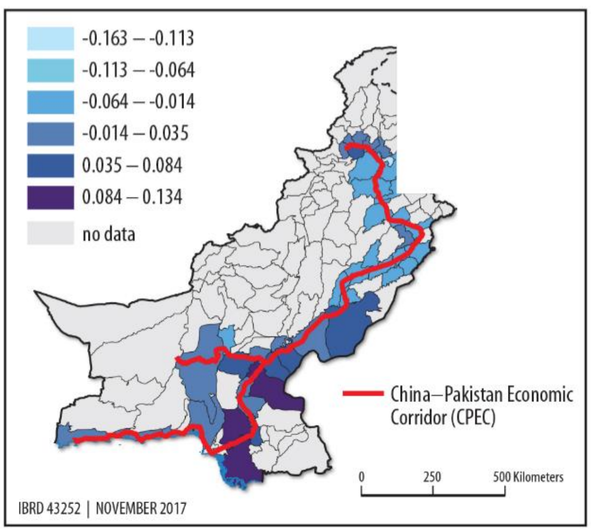
The average impact of the GQ on household expenditure was measured imprecisely (that is, it is statistically insignificant). However, its dependence on land market conditions (the share of cropland in total area) and output market conditions (the percentage of firms that are privately owned) was statistically significant. The positive impact on household expenditure could be expected to be smaller in districts with a larger share of cropland. As discussed, one explanation is that districts with more land devoted to farming could find it harder to reallocate land to industrial uses and the service sector, limiting their ability to benefit from improved market access. In contrast to cropland, greater private ownership of firms is expected to enhance the positive impact of corridors on household expenditure—most likely because of greater market contestability in those districts.

[24] Recall that the impact estimate for the GQ is +4 percent.

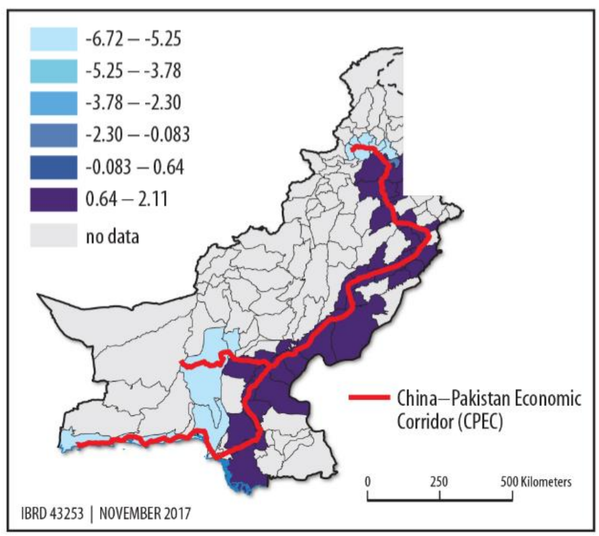
The spatial variation across districts in the share of cropland in Pakistan is greater than is the spatial variation in the share of private ownership. Moreover, the predicted impact on household expenditure is more sensitive to the share of cropland, based on the estimated model for India. The simulation therefore suggests that, for the proposed transport corridor, the spatial variation in impacts on household expenditure will be mostly influenced by variation in the share of cropland—that is, by the variation in land market constraints. For example, districts close to Karachi could experience the biggest impacts on household expenditure because they have more land available for industrial uses.

Map 2. Simulated relative impacts of CPEC transport corridor (Pakistan segment) on household consumption and the reduction in poverty

a. Mean per capita household consumption expenditure (in logs)



b. Reduction in poverty (headcount measure)



Source: ADB et al. 2018.
Note: The red line indicates the highway.

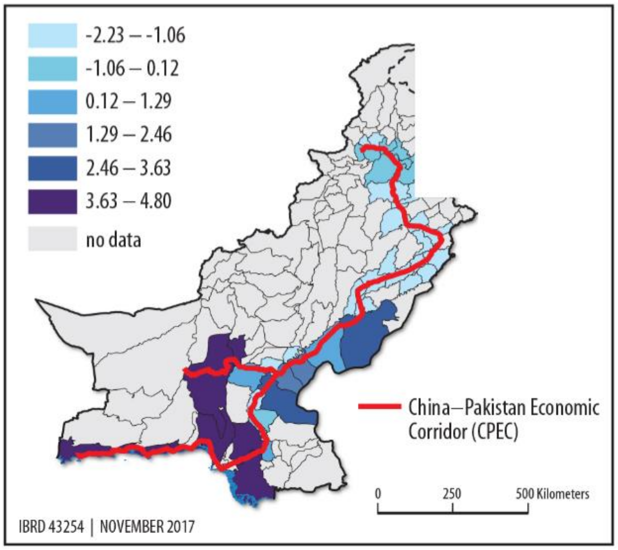
Map 2, panel b, presents simulated impacts on the reduction in the headcount measure of poverty. A more positive effect on this indicator implies a wider sharing of economic benefits. Although the *average* impact on poverty reduction was not estimated precisely for the GQ, it was significantly bigger in areas with a larger share of agro-processing firms in the total number of manufacturing firms. The hypothesis is that in such locations, a relatively large share of low-skilled individuals was already employed in the agro-processing industry, a sector expected to benefit from increased market access. Such workers could be better predisposed to share benefits from better market access associated with highways, moving up the value chain to better jobs without having to acquire new skills or move to new jobs. Even poor workers in agriculture could possibly benefit from the growth of the local agro-industry.

For the CPEC, district-level estimates of the share of agro-processing were not available. Instead, the analysis relied on province-level data. Hence, the simulated impacts show no variation within provinces. Even the variation across provinces is relatively small; much of the eastern arm of the CPEC passes through provinces with similar levels of agro-industry, such as Sindh and Punjab.

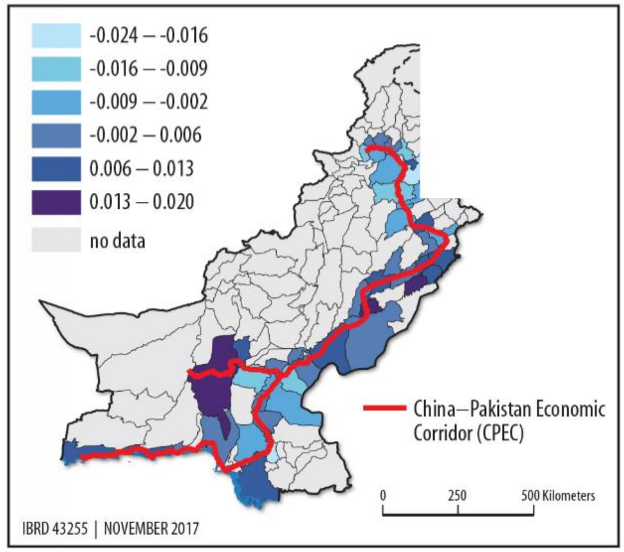
The simulated impacts on the share of regular-wage jobs in female employment—a measure of women's inclusion in the labor market—also vary significantly. The variation depends on the share of cropland in the total land area (map 3, panel a). Land constraints could restrict women's ability to benefit proportionately from improved market access. The range in simulated impacts is in the order of 7 percentage points for the CPEC. Along the CPEC, the land market constraint could dampen benefits in districts nearer to the northern leg of the corridor.

Map 3. Simulated relative impacts of the CPEC transport corridor (Pakistan segment) on women's employment and air pollution

a. Share of regular wage jobs in women's employment



b. Air pollution (aerosol optical thickness) (scale of 0−1)



Source: ADB et al. 2018.
Note: The red line indicates the highway. CPEC = China-Pakistan Economic Corridor.

On average, the simulated impact of corridors shows increasing levels of air pollution (as measured by the aerosol optical thickness indicator), but spatial variation is substantial across districts in (map 3, panel b). The spatial variation is driven by differing levels of higher education; air pollution could increase less in districts with higher rates of secondary school completion. Two explanations are possible. First, while the advent of highways should increase road traffic in every treatment district, those with highly educated populations might tend to switch to cleaner vehicles, even if they are relatively more expensive. Second, as the GQ estimates implied, areas with more secondary schooling experience a larger structural transformation toward non-farm jobs. In those districts experiencing greater structural change, farms might burn less straw—a major contributor to air pollution in South Asia (Singh and Kaskaoutis, 2014).

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4. Conclusion

This paper proposed a policy framework to appraise proposed investments in transport corridors and applied it, using reduced-form econometric simulations, to a corridor that has not been built yet, CPEC in Pakistan. Through this application, the paper illustrated how the use of detailed spatial data and econometric analysis can bring more rigor and depth to the appraisal of proposed investments in large scale transport infrastructure.

The appraisal framework emphasized the importance of focusing on ultimate benefits and costs incurred by households and the society. Households are not only the ultimate beneficiary but also the biggest financier of the corridors that are mostly funded from national taxes—despite some potential for user fee and property tax co-funding. The framework also alerts decision makers about likely trade-offs between impacts of a corridor on different development outcomes—such as increasing income at the expense of air pollution or slower creation of formal jobs. Moreover, it alerts decision makers about possibly varied predispositions of population groups and locations to benefit from corridors. These varied predispositions could, alongside winners, produce losers and increase inequality. Therefore, such trade-offs must be managed right from the start using complementary interventions.

To illustrate how this framework could be applied, we used the impact estimates for a benchmark corridors investment—the Golden Quadrilateral highways system in India (Melecky, Sharma, Subhash 2018)—to simulate the expected impacts of the CPEC in Pakistan. This simulation makes the (admittedly strong) assumption that impact mechanics for the proposed CPEC highways match those of the GQ. The simulation aimed to illustrate how project appraisers could screen for significant variations from district to district (spatial variations) in the expected impacts of a corridor project, and identify the complementary reforms that are most needed to spread and amplify wider economic benefits.

The simulations suggest that the CPEC corridor in Pakistan could have significantly varied impacts on household expenditure, poverty, the inclusion of women in the labor market, and air pollution. The variation would be driven by spatial differences in land market constraints, levels of higher education, and industrial composition along the path of the proposed corridor. For example, in districts located in the northern end of the CPEC, the impact on women's employment in regular-wage jobs should be lower because of constraints on land use, which limit women's shift from farm to non-farm jobs. The results also illustrated the potential environmental trade-offs from transport corridors because of expected increases in particulate air pollution—more so in districts with a low share of higher education. While not surprising given the increase in traffic, this potential negative impact is largely absent from policy discussions.

References

ADB. 2008. Greater Mekong Subregion: Maturing and Moving Forward. Operations Evaluation Department, ADB.

ADB, DFID, JICA, and WBG (Asian Development Bank, UK Department for International Development, Japan International Cooperation Agency, and World Bank Group). Forthcoming. *The WEB of Transport Corridors in South Asia.* Washington, DC: World Bank.

Andrés, Luis, Dan Biller, and Matías Herrera Dappe. 2013. "Reducing Poverty by Closing South Asia's Infrastructure Gap." World Bank and Australian Aid.

Bakker, P., C. Koopmans, and P. Nijkamp. 2010. "Appraisal of Integrated Transport Policies." *In Integrated Transport: From Policy to Practice,* edited by David Banister,117−36. Abingdon, UK: Routledge.

Berg, C. N., U. Deichmann, Y. Liu, and H. Selod. 2017. "Transport Policies and Development." *The Journal of Development Studies* 53 (4): 465–80.

Bloom, N., S. Bond, and J. Van Reenen. 2007. "Uncertainty and Investment Dynamics." *Review of Economic Studies* 74 (2): 391–415.

Chatterjee, Bipul, and Surendar Singh. 2015. "An Opportunity for India in Central Asia." *The Diplomat*, May 4.

Demir, F. 2009. "Macroeconomic Uncertainty and Private Investment in Argentina, Mexico, and Turkey." *Applied Economics Letters* 16 (6): 567−71.

Evans, J.P. 2016. "Taking the tiger by the tail: Leading effective tiger teams and working groups on flight projects." *Aerospace Conference, 2016 IEEE*: 1-6.

Fuss, C., and P. Vermeulen. 2008. "Firms' Investment Decisions in Response to Demand and Price Uncertainty." *Applied Economics* 40 (18): 2337−351.

Ghani, Ejaz, Arti Grover Goswami, and William R. Kerr. 2016. "Highway to Success: The Impact of the Golden Quadrilateral Project for the Location and Performance of Indian Manufacturing." *Economic Journal*, Royal Economic Society, 126 (591): 317−57.

Koppenjan, J. F. M. 2005. "The Formation of Public-Private Partnerships: Lessons from Nine Transport Infrastructure Projects in The Netherlands." *Public Administration* 83: 135–57.

Laird, J. J., and A. J. Venables. 2017. "Transport Investment and Economic Performance: A Framework for Project Appraisal." *Transport Policy* 56 (2017): 1–11.

Macário, R., J. Ribeiro, and J. D. Costa. 2015. "Understanding Pitfalls in the Application of PPPs in Transport Infrastructure in Portugal." *Transport Policy* 41: 90−99.

Makovšek, D. 2013. "Public–Private Partnerships, Traditionally Financed Projects, and their Price." *Journal of Transport Economics and Policy* 47 (1): 143−55.

Melecky, Martin, Siddharth Sharma, and Hari Subhash. 2018. "Wider Economic Benefits of Investments in Transport Corridors and the Role of Complementary Policies." Policy Research Paper No. 8350, World Bank, Washington, DC.

Melo, P. C., D. J. Graham, and R. Brage-Ardao. 2013. "The Productivity of Transport Infrastructure Investment: A Meta-analysis of Empirical Evidence." *Regional Science and Urban Economics* 43 (5): 695−706.

Ordabayev, A. 2015. "The Geopolitics of Transport Corridors in Central Asia." Working Paper, The Institute of World Economics and Politics (IWEP). http://iwep .kz/files/attachments /article/2015-07-05 /geopolitics_of_transport_corridors_in _central_asia.pdf.

Ordabayev, A. 2016. "Transport Corridors of South Asia and Caucasus." Working Paper, The Institute of World Economics and Politics (IWEP). http://iwep.kz/files/attachments/article/2016-09-23 /transport_corridors_of_south_asia_and _caucasus.pdf.

Palit, Amitendu. 2017. "India's Economic and Strategic Perceptions of China's Maritime Silk Road Initiative." *Geopolitics* 22 (2): 292−309.

Redding, S. J., and M. A. Turner. 2014. "Transportation Costs and the Spatial Organization of Economic Activity." NBER Working Paper 20235, National Bureau of Economic Research, Cambridge, MA.

Roberts, M., U. Deichmann, B. Fingleton, and T. Shi. 2012. "Evaluating China's Road to Prosperity: A New Economic Geography Approach." *Regional Science and Urban Economics* 42 (4): 580–94.

Roberts, M., M. Melecky, T. Bougna, and Y. Xu. 2018. "The Estimated Wider Economic Benefits of Transport Corridors: A Critical Review of the Literature." World Bank Policy Research Paper 8302, World Bank, Washington, DC.

Shepard, Wade. 2017. "India and Japan Join Forces to Counter China and Build Their Own New Silk Road." *Forbes,* July 31.

Singh, R.P., and D.G. Kaskaoutis. 2014. "Crop Residue Burning: A Threat to South Asian Air Quality." *EOS, Transactions, American Geophysical Union*, 37 (95): 333-340.

Srivastava, P., and U. Kumar, eds. 2012. *Trade and Trade Facilitation in the Greater Mekong Subregion*. Manila: Asian Development Bank.

Straub, S. 2011. "Infrastructure and Development: A Critical Appraisal of the Macro-Level Literature." *Journal of Development Studies* 47 (5): 683−708.

Appendix

Table A.1. Summary of market condition variables

Market variable	Source code	Market type	No. of obs.	25th percen-tile	Med-ian value	75th percen-tile	Mean value	Stan-dard devia-tion
Households' access to banking services	G	Capital market	1708	24.26	32.6	44.05	34.86	14.09
Access to financial services, private nonagricultural enterprises	H	Capital market	1708	1.5	2.75	4.5	3.61	3.21
Literacy rate, 7+ years (percent of population group)	D	Labor market	1708	55.7	63.6	72.3	63.5	12.66
Secondary education completion rate, 15+ years (percent of population group)	I	Labor market	1708	17.0	22.8	28.95	23.2	8.46
Cropland (percent of area)	A	Land market	1708	29.05	60.1	88.3	56.79	32.25
Food/beverage/tobacco manufacturing (percent of establishments)	J	Product market	1708	13.2	20.8	32.25	25.31	17.34
Diversification index of nonagricultural enterprises, ISIC 3.1 2-digit (index)	H	Product market	1708	3.6	4.7	5.87	4.83	1.5
Nonagricultural enterprises by ownership, privately owned (percent of establishments)	H	Product market	1708	90.7	93.6	95.8	92.5	4.79

Source: Melecky, Sharma, and Subhash 2018.
Note: ISIC = International Standard Industrial Classification.

Table A.2. Conditional Impacts of Highways

a. Conditional impacts of GQ on welfare outcomes

Market variable	Mean household consumption (in logs)	GDP per capita (current USD, in logs)
Households' access to banking services	-0.0031*	
Access to financial services, private non-agricultural enterprises		
Literacy rate, 7+ years (percent of population group)		
Secondary education completion rate,15+ years, total (percent of population group)		
Cropland (percent of area)	-0.0017**	
Food/beverage/tobacco manufacturing (percent of establishments)	0.0015	-0.0012
Diversification index of non-agricultural enterprises, ISIC 3.1 2-digit (index)		
Non-agricultural enterprises by ownership, privately owned	0.0128**	-0.0051
Number of observations	1661	854
Adjusted R-squared	0.3	0.8

Source: Melecky, Sharma, and Subhash 2018.
Note: GQ = Golden Quadrilateral Highway; ISIC = International Standard Industrial Classification. NSEW = North-South-East-West Highway.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

b. Conditional impacts of the GQ on inequality outcomes

Market variable	Percentage of households above the poverty line (total)	Percentage of households above the poverty line (rural)	Percentage of households above the poverty line (urban)
Households' access to banking services	-0.0032*	-0.0041**	
Access to financial services, private nonagricultural enterprises	0.0096	0.0116	
Literacy rate, 7+ years (percent of population group)			
Secondary education completion rate,15+ years, total (percent of population group)			

Cropland (percent of area)	-0.0007		-0.001
Food/beverage/tobacco manufacturing (percent of establishments)	0.0024**	0.0026**	0.0018
Diversification index of nonagricultural enterprises, ISIC 3.1 2-digit (index)			
Nonagricultural enterprises by ownership, privately owned	0.007	0.0072	
Number of observations	1661	1661	1626
Adjusted R-squared	0.3	0.4	0

Source: Melecky, Sharma, and Subhash 2018.
Note: GQ = Golden Quadrilateral Highway; ISIC = International Standard Industrial Classification. NSEW = North-South-East-West Highway.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

c. Conditional impacts of the GQ on labor market inclusion

Market variable	**Regular wage employed (total)**	**Regular wage employed (female)**
Households' access to banking services		-0.0019*
Access to financial services, private non-agricultural enterprises		
Literacy rate, 7+ years (percent of population group)	-0.0011	
Secondary education completion rate, 15+ years, total (percent of population group)		
Cropland (percent of area)	-0.0008***	
Food/beverage/tobacco manufacturing (percent of establishments)	-0.0005	
Diversification index of non-agricultural enterprises, ISIC 3.1 2-digit (index)		-0.0083
Non-agricultural enterprises by ownership, privately owned		-0.005
Number of observations	1626	1626
Adjusted R-squared	0	-0.2

Source: Melecky, Sharma, and Subhash 2018.
Note: Golden Quadrilateral Highway; ISIC = International Standard Industrial Classification; NSEW = North-South-East-West Highway.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

d. Conditional impacts of the GQ on environmental outcomes

Market Variable	Aerosol particle radius (percent of small particles) in logs	Aerosol optical thickness (thickness scale 0–1)	Nitrogen dioxide levels (billion molecules/mm^2, in logs)
Households' access to banking services	-0.1558**		
Access to financial services, private non-agricultural enterprises		0.0034	
Literacy rate, 7+ years (percent of population group)	0.2869***		
Secondary education completion rate,15+ years, total (percent of population group)		-0.0015**	
Cropland (percent of area)		0.0003	
Food/beverage/tobacco manufacturing (percent of establishments)			
Diversification index of non-agricultural enterprises, ISIC 3.1 2-digit (index)	1.086**	-0.0076*	1.9606
Non-agricultural enterprises by ownership, privately owned			
Number of observations	854	854	854
Adjusted R-squared	0.6	0.6	0.6

Source: Melecky, Sharma, and Subhash 2018.
Note: Golden Quadrilateral Highway; ISIC = International Standard Industrial Classification; NSEW = North-South-East-West Highway.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.3. Summary Statistics of Market Condition (Interaction) Variables, Pakistan

Interaction terms	**Source of data**	**Geographical level of data availability**	**Mean value**	**Standard deviation**	**25th percentile**	**75th percentile**
For districts 0–40 km from or intersected by proposed eastern China-Pakistan Economic Corridor (CPEC)						
Households' access to banking services (percentage of total households)	PLSM 2012–2013	District	29.40	16.16	17.00	40.00
Private non-farm enterprises borrowing from financial institutions (percentage of enterprises)	Enterprise Survey - Pakistan 2013	Province	2.63	3.29	0.70	1.52
10+ literacy rate (percent of population group)	PLSM 2012–2013	District	55.74	11.94	47.00	62.00
Secondary education complete (percent of population)	PLSM 2012–2013	District	26.10	7.15	20.00	30.00
Cropland (percent of area)	MODIS Land Cover Type I product, 2013	District	66.72	34.15	47.00	94.00
Formal manufacturing, food/beverage/tobacco (percent of establishments)	Pakistan CMI Survey 2005–2006	Province	27.88	5.49	25.00	31.00
Non-farm Diversification Index[a]	Pakistan CMI Survey 2005–2006	Province	6.04	0.82	5.70	6.07
Private non-farm enterprises (percent of establishments)	Pakistan CMI Survey 2005–2006	Province	91.26	5.27	91.00	95.00
For all districts						
Interaction terms	Source of data	Geographical level of data availability	Mean value	Std. deviation	25th percentile	75th percentile
Households' access to banking services (percentage of total households)	PLSM 2012–2013	District	29.93	17.81	16.00	42.00
Private non-farm enterprises' borrowing from financial institutions (percentage of enterprises)	World Bank Enterprise Survey - Pakistan 2013	Province	3.31	3.79	1.49	1.52
10+ literacy rate (percent of population group)	PLSM 2012–2013	District	50.62	13.60	42.00	59.50

Secondary education complete (percent of population)	PLSM 2012–2013	District	23.47	7.22	18.00	28.00
Cropland (percent of area)	MODIS Land Cover Type I product, 2013	District	47.69	36.19	14.00	84.00
Formal manufacturing, Food/beverage/tobacco (percent of establishments)	Pakistan CMI Survey 2005–2006	Province	25.06	6.53	19.00	31.00
Non-farm Diversification Index[a]	Pakistan CMI Survey 2005–2006	Province	6.35	1.13	5.70	6.07
Private non-farm enterprises (percent of establishments)	Pakistan CMI Survey 2005–2006	Province	89.70	6.49	91.00	95.00

Source: The source for each interaction variable is listed in the table, in the source of data column.
Note: Of the 151 districts in Pakistan, 43 districts are either within 40 km of the purposed highway or the highway passes through part of its territory. Karachi and Lahore are classified as nodal districts in this study. CMI = Pakistan Census for Manufacturing Industry; MODIS = Moderate Resolution Imaging Spectroradiometer; PLMS = Pakistan Social and Living Standard Measurement Survey.
a. The Diversification Index of non-agriculture enterprises is generated from Pakistan CMI Survey, which covers only the manufacturing sector. The index captures the level of diversification of economic activities only within the manufacturing sector.

Table A.4. Districts in Pakistan within 40 km of or Intersected by the Proposed Eastern CPEC

	District name	Province	Distance to highway (km)
Nodal	Karachi	Sindh	0.6
	Lahore	Punjab	0.8
0−40 km	Sheikhupura	Punjab	1.3
	Matiari	Sindh	1.6
	Khanewal	Punjab	1.8
	Naushehro Feroze	Sindh	2.7
	Peshawar	KP	4.6
	Sahiwal	Punjab	4.8
	Shikarpur	Sindh	9.6
	Okara	Punjab	9.8
	Gwadar	Balochistan	9.9
	Multan	Punjab	10.1
	Lodhran	Punjab	10.4
	Hafizabad	Punjab	10.6
	Swabi	KP	11.1
	Charsadda	KP	13.3
	Chakwal	Punjab	13.8
	Lasbela	Balochistan	15.2
	Nowshera	Balochistan	19.6
	Shaheed Benazirabad	Sindh	20.4
	Mardan	KP	21.7
	Ghotki	Sindh	21.9
	Kasur	Punjab	23.3
	Khuzdar	Balochistan	23.4
	Islamabad	ICT	24.4
	Hyderabad	Sindh	24.6
	Larkana	Sindh	25.0
	Rawalpindi	Punjab	26.6
	Sukkur	Sindh	28.3
	Rahim Yar Khan	Punjab	28.9
	Haripur	KP	30.7
	Kashmore-Kandhkot	Sindh	31.3
	Jhal Magsi	Balochistan	31.5
	Sargodha	Punjab	33.8
	Pakpattan	Punjab	36.2
	Toba Tek Singh	Punjab	39.0

Highway passes through	Nankana Sahib	Punjab	40.6
	Attock	Punjab	48.1
	Jamshoro	Sindh	48.6
	Bahawalpur	Punjab	53.4
	Jhelum	Punjab	54.8
	Thatta	Sindh	75.5
	Khairpur	Sindh	77.9

Source: Melecky, Sharma, and Subhash 2018.
Note: The distance is the linear distance from the highway to the district centroids. ICT = Islamabad Capital Territory.

Table A.5. Comparing Sources of Data for India and Pakistan

Market	Measure	India	Pakistan	Geographical level of data availability
Interaction terms				
Capital market	Households' access to banking services, total (percent of households)	Census of India–House Listing and Housing Census	Pakistan Social and Living Standard Measurement Survey 2012−2013	District
Capital market	Private non-farm enterprises' borrowing from financial institutions (percentage of enterprises)	Economic Census (EC)/Enterprise Survey	World Bank Enterprise Survey - Pakistan 2013	Province
Labor market	10+ literacy rate, total (percent of population group)	Literacy rate 7+ years, Census of India	Pakistan Social and Living Standard Measurement Survey 2012−2013	District
Labor market	Secondary education completion rate, 15+ years, total (percent of population group)	Household Consumption Expenditure Survey	Pakistan Social and Living Standard Measurement Survey 2012−2013	District
Labor market	Gross primary enrollment, total (percent of population group)	Census of India	Pakistan Atif Ailan Education Index 2015−2016	District
Land market	Cropland (percent of area)	MODIS Land Cover Type I product	MODIS Land Cover Type I product (2013)	District
Product market	Diversification Index of non-farm enterprises (ISIC 3.1, 2-digit level)	Economic Census (EC)	Pakistan Census for Manufacturing Industry Survey 2005−2006	Province
Product market	Non-Farm Enterprises Privately Owned (percent of establishments)	Economic Census (EC)	Pakistan Census for Manufacturing Industry Survey 2005−2006	Province
Product market	Formal manufacturing, food/beverage/tobacco (15, 16) (percent of establishments)	Annual Survey of Industries	Pakistan Census for Manufacturing Industry Survey 2005−2006	Province
Outcomes				
Environment	Aerosol particle radius (percent of small particles)	(NASA) Earth Observations (NEO-ND)	(NASA) Earth Observations (NEO-ND)	District
Environment	Aerosol optical thickness (thickness scale 0−1)	(NASA) Earth Observations (NEO-ND)	(NASA) Earth Observations (NEO-ND)	District
Environment	Nitrogen dioxide levels (billion molecules/mm^2)	(NASA) Earth Observations (NEO-ND)	(NASA) Earth Observations (NEO-ND)	District
Equality	Poverty rate (headcount below poverty line)	Household Consumption Expenditure Survey	Pakistan Multi-Dimensional Poverty 2013−2014	District

Inclusion	Employed/total population	Census of India	Pakistan Social and Living Standard Measurement Survey 2012−2013	District
Inclusion	Females employed/female total population	Census of India	Pakistan Social and Living Standard Measurement Survey 2012−2013	District
Inclusion	Regular wage employed/total employed	Census of India	--	--
Inclusion	Females regular wage employed/total female employed	Census of India	--	--
Inclusion	Total employed on farm/total employed	Census of India	--	--
Inclusion	Total females employed on farm/total females employed	Census of India	--	--
Inclusion	Total employed on non-farm/total employed	Census of India	--	--
Inclusion	Total females employed on non-farm/total females employed	Census of India	--	--
Welfare	Mean household consumption expenditure per capita	Household Consumption Expenditure Survey	--	--
Welfare	GDP (current US$, millions)	Directorate of Economics and Statistics, Planning Commission, Government of India	Pakistan Bureau of Statistics 2016	Province
Welfare	GDP per capita (current US$)	Directorate of Economics and Statistics, Planning Commission, Government of India	Pakistan Bureau of Statistics 2016	Province
Welfare	Light intensity per area	DSMP-OLS Radiance Calibrated Nighttime Lights (RCNTL)	n.a.	n.a.
Welfare	Light intensity per 1000 people	DSMP-OLS Radiance Calibrated Nighttime Lights (RCNTL)	n.a.	n.a.

Source: Melecky, Sharma, and Subhash 2018.
Note: MODIS = Moderate Resolution Imaging Spectroradiometer; n.a = not applicable; -- = not available.

Table A.6. Predicted Impact of China-Pakistan Economic Corridor (CPEC)

		Prediction for CPEC districts			
	Estimate of average impact of GQ statistically significant?	**Mean**	**10th percentile**	**50th percentile**	**90th percentile**
Aerosol optical thickness (thickness scale 0–1)	Y	0.024	0.012	0.021	0.039
Reduction in poverty rate (rural)	N	4.01	3.55	4.15	4.42
Reduction in poverty rate (total)	N	1.25	5.07	2.08	-3.02
Regular wage earners, female (total female employed)	N	-0.62	-3.62	-0.25	2.23
Regular wage earners, total (total employed)	N	0	0	0	0
Farm employment, female (total female employed)	N	-6.62	-5.62	-7.43	-6.17
Farm employment, total (total employed)	N	-5.51	-4.32	-6.10	-5.53
Non-farm employment, female (total female employed)	N	6.05	2.81	7.13	7.75
Non-farm employment, total (total employed)	N	5.83	4.55	6.41	5.94
Log of mean household consumption (current US$)	N	-0.05	-0.07	-0.05	-0.03
Log of GDP per capita (current US$)	Y	0.0402	0.0402	0.0402	0.0402

Source: Melecky, Sharma, and Subhash 2018.
Note: Nodal districts (Karachi and Lahore) are excluded from the calculation of the average impact. GQ = Golden Quadrilateral Highway.