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ASSISTING THE CENTRAL ASIA REGIONAL ECONOMIC COOPERATION INSTITUTE KNOWLEDGE PROGRAM (PHASE 1)

DECISION TOOLS FOR ECONOMIC POLICY

DAVID ROLAND-HOLST AND GUNTUR SUGIYARTO

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David Roland-Holst is Professor of Economics at the University of California Berkeley. Guntur Sugiyarto is Senior Economist at the Economics and Research Department of the Asian Development Bank. *The authors thank Drew Behnke, Namkyu Chang, Samuel Heft-Neal, Eunice Kim, Adam Soliman, and Eric Suan for excellent research assistance and colleagues at the Asian Development Bank for productive discussion. The views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the Asian Development Bank.*

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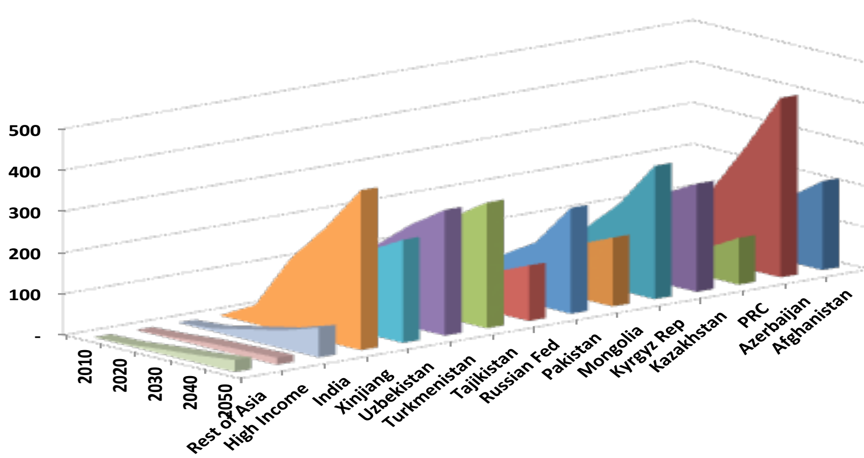
EXECUTIVE SUMMARY

1. This report presents results from a multi-country general equilibrium assessment of a large road corridor project that is the inception initiative of CAREC. The approach used here, multi-country general equilibrium modeling, is particularly suited to estimating the extensive indirect effects of such a commitment to infrastructure. Our results show that the overall benefits of the CAREC Corridors dramatically outweigh their costs. Transboundary spillovers confer significant growth leverage on other regional economies and benefit even distant trade partners.

Figure 1: Real GDP Growth to 2050
(Difference from Baseline as a Percent of 2010)



2. These findings are fully consistent with intuition and regional policy expectation, that large and coordinated infrastructure investments are a potent catalyst for long term economic growth. More detailed analysis reveals the inclusive features of infrastructure, driving down information and transit costs to expand the profitable horizon of investment for enterprises of all scales and workers of all income levels. As expected, infrastructure confers market access that is the key to self-directed poverty reduction.

3. More extensive model application and scenario analysis will improve our understanding of a wider range of policy options. In parallel, more intensive data development, possibly including models for each individual CAREC member economy, can improve resolution of the analysis, allowing identification of more beneficiaries as well those who might need targeted incentives or adjustment assistance. Finally, innovative user interfaces will help integrate all these quantitative tools into decision making and dialog, facilitating more evidence based policy across this region and helping to realize its vast economic potential.

Acronyms Used:
AMC – ADB Asian Member Country
AMS – Agriculture, Manufacturing, and Service sectors
CGE – Computable General Equilibrium Model
DMC – Asian Development Bank Developing Member Country
IMF – International Monetary Fund
OECD – Organization for Economic Cooperation and Development
TFP – Total Factor Productivity
TT – Trade and Transport

1. INTRODUCTION

4. Regional economic integration is accelerating in Central Asia, thanks in significant part to determined national and international commitments to infrastructure and other investments. This has been complimented by substantial progress on the institutional side, promoting a more open multilateral trade and investment environment. The next phase of policy planning can sustain this progress and expand economic potential for robust enterprise environment, continued poverty reduction, and generally higher living standards. In a rapidly evolving regional economy, however, decision makers need support for more evidence based strategic planning and engagement. This project will develop a new generation of decision tools for forward-looking economic analysis and policy dialog, nationally, regionally and with international development partners.

5. As part of its commitment to the CAREC initiative, ADB has commissioned the development of sophisticated decision support tool, including a regional economic scenario model and software to disseminate its findings to nontechnical audiences. The proposed research products will improve visibility for public and private actors regarding pathways for greater CAREC regional development and cooperation. In particular, we will extend prior ADB research to develop a CAREC regional economic modeling facility, with structural detail at the national level and integrated assessment of regional linkages and their potential to act as catalysts for growth, further integration, and sustainable development.

6. The modeling facility represents a new, state-of-the-art regional economic model that for the first time includes all CAREC member countries, integrating them into a regional model that captures CAREC and global trade linkages. This modeling facility provides detailed assessment of short and long-term market interactions, tracing patterns of supply, demand, employment, income, and resource use across the region and within national economies. Updated with the most recent data resources on national economic structure, the facility can be used for national planning by counterpart policy institutions in member countries. In its multi-country form, the model can be used to support more effective and coherent, evidence based regional and international policy dialog. Although the core of the CAREC modeling facility will be a sophisticated general equilibrium forecasting model, the project is also developing a user-friendly, web-browser interface that combines GIS and graphics with more traditional tabular output. Together, these data resources and decision tools provide a new generation of research support for Asian regional policy dialog.

2. CAREC REGIONAL CGE MODEL

7. The primary deliverable for this project is a regional dynamic economic forecasting model, providing structural detail for each of CAREC's member countries. This framework, named the Central Asian Regional General equilibrium mOdel (CARGO), has now been completed.[1] The model's structure is summarized in an annex below and fully explained in a companion technical document (Roland-Holst, Sugiyarto, and Suan: 2013).

Table 1: Country, Regional, and Sector Aggregation of the CARGO Model

	Countries/Regions		Sectors
1	Afghanistan	1	Crops
2	Azerbaijan	2	Livestock & Fishery
3	China	3	Coal
4	Kazakhstan	4	Oil
5	Kyrgyz Rep	5	Gas
6	Mongolia	6	Other Minerals & Mining
7	Pakistan	7	Processed Food
8	Russian Federation	8	Textiles & Apparel
9	Tajikistan	9	Light Manufacturing
10	Turkmenistan	10	Heavy Manufacturing
11	Uzbekistan	11	Utilities
12	Xinjiang	12	Transportation
13	India	13	Services
14	High Income Asia		
15	Rest of Asia		
16	Europe		
17	United States		
19	Rest of World		

Note: The first 12 economies comprise the membership of CAREC. China component does not include Xinjiang, which has been disaggregated as a separate CAREC economic region.

[1] CARGO is based on the LINKAGE model, developed and maintained by the World Bank, which assumes no responsibility for this analysis or its results.

8. The model is calibrated to the latest version (8.0) of the GTAP international trade database[2], with supplemental information as needed to support this project's country emphasis and policy research priorities. In particular, because some CAREC member countries are not yet covered by GTAP, we have developed datasets for these from independent sources and integrated them into a combined regional database with the following 18 country and regional trading partners:

9. Currently, the regional database covers 13 production activities and five factors of production (Skilled and Unskilled labor, capital, land, and natural resources).[3] Detail is provided on essential food, energy, transport, and infrastructure activities as well as a variety of other single digit ISIC sectors.

10. The CARGO framework provides a consistent framework for policy analysis across CAREC, including scenarios for economic integration, investment, and other regionally linked initiatives. Because it captures inter-country spillovers, this kind of framework is especially well suited to supporting multilateral policy dialog and coordination with bilateral and multilateral agency development partners. In its current form, this CARGO framework is ready for implementation by ADB and CAREC counterpart policy researchers who want to evaluate regional initiatives in a mutually consistent framework. As this project advances, we envision CARGO as an integrating platform for scenario analysis to assess regional investment and trade facilitation initiatives, although it can be applied to a wide variety of other issues. Because it is a relatively technical decision support tool, this capacity is best installed in technical offices such as ERD, trade and finance ministries. We propose below a capacity transfer activity to achieve this in Manila and CAREC regional capitals.

11. Because of the value of this modeling framework for promoting evidence based policy dialog, we also recommend localizing the CARGO framework, extracting and disaggregating each CAREC member country component into more detailed national CGE models. The degree of disaggregation will depend on local data availability, but for most regional partners this process will yield much more detailed scenario tools for examining patterns of investment, trade, and development. Proceeding in this top-down manner, from a state-of-the-art regional model to detailed individual country CGE's, has the combined advantages of standardizing technical methods and information requirements. The former means that regional and development partner policy dialog will be

[2] GTAP refers to the Global Trade Analysis Project based at Purdue University. For more information see Hertel, 2012.

[3] As needed, the sectoring can be disaggregated to 57 activities.

more coherent in terms of issues, methods, and interpretation. More uniform data standards will greatly facilitate sharing of information and lessons learned. Both aspects are fully consistent with the Knowledge Program at the foundation of this regional initiative.

12. Disaggregating CARGO on a country-by-country basis would be a very productive activity to include in the Phase II of this TA. Sequencing of countries would depend upon local commitments for data provision and training candidates, but this process would help secure local ownership of the overall decision framework and facilitate equal participation in dialog. An appropriate office of ADB can act as a data hub for the information resources developed, and these can be integrated with transport and other assessment/monitoring data streams coming from sponsored investment projects. In this way, ADB can act as a clearinghouse for policy research technology and regional economic data.[4]

A. Why use an economic model?

13. Due investment diligence and fiduciary assessment of direct project costs and benefits is important, but the indirect effects of infrastructure can far outweigh direct effects. A project of this magnitude, involving services so important to the cost basis of economic activity (i.e. trade and transport margins), will affect costs, market participation, and profitability across most sectors of the economy. Large-scale infrastructure exerts pervasive influence on economic behavior by changing microeconomic costs, incentives, and terms of market participation. Much more than a just financial investment, infrastructure can be a critical component of economic development. This broader economic role needs to be better understood, particularly for projects with a large public financing component.

B. Why a regional model?

14. Because of unique geographic and institutional characteristics, the CAREC needs its own research capacity to support its own policies. The role of trade as a catalyst for growth makes regional and international assessment essential. Policy coherence and evidence-based dialogue: Public and private stakeholders need more accurate prior information about the adjustment process to participate effectively. Projects may be local or

[4] At the World Bank, for example, one of the most important initiatives of the Wolfenson presidency was to build out information services in this way. These activities, including compiling and standardizing LSMS, macroeconomic, and a wide variety of MDG-related data, have made an immense contribution to aid effectiveness.

national, but spillover effects implicate stakeholders across borders. This can arouse both cooperative and competitive interest, both of which need to be anticipated.

C. Why a general equilibrium model?

15. General Equilibrium (GE) models capture extensive interactions, thought markets, production systems, and expenditure decisions. These forecasting tools reveal more detailed economic impacts and support more effective policy in from three perspectives:

- *Complexity* - Given the complexity of today's market economies, policy makers relying on intuition and rules-of-thumb alone are assuming substantial risks.
- *Linkage* - Indirect effects of policies often outweigh direct effects.
- *Political sustainability* - Economic policy may be made from the top down, but political consequences are often felt from the bottom up.

16. GE models, supported by reliable data resources, can elucidate these linkages and improve visibility for policy makers. Moreover, this kind of simulation framework permits them to identify benefits and costs ex ante, recruiting those who gain to support policies and anticipating the adjustment needs of others.

3. INFRASTRUCTURE FROM AN ECONOMIC PERSPECTIVE

17. In economics, both the theoretical and policy literature recognize the importance of infrastructure. In this section, the issue is reviewed from both perspectives. The next subsection provides a conceptual framework for understanding infrastructure's primary economic effects. This is followed by an overview of the available empirical literature on estimating the real impacts of infrastructure investments. In both contexts, macro- and microeconomic analyses are included.

18. There is broad agreement on what constitutes infrastructure, yet its economic agency is quite diverse. A convenient way to understand infrastructure's role is by decomposition into three functional economic categories:

- *Keynesian*. This refers to the pure expenditure component of infrastructure, as reflected in national, regional, and local aggregate demand and employment stimulus.

- *Ricardian.* This relates to infrastructure's effect on the cost of transport and distribution. Reducing trade margins can have a potent effect on prices and competitiveness, intensifying comparative advantage and increasing both domestic and international trade flows.

- *Neoclassical.* Modern economic theory recognizes infrastructure's contribution to increasing productivity, as technology embodied in transport, communication, and distribution systems increases the efficiency of search, transactions, and shipments. These are generally termed endogenous growth benefits, and are considered among the most important economic contributions of modern infrastructure investments.

D. Keynesian Stimulus

19. The direct macroeconomic benefits of public investment have long been recognized, and infrastructure spending itself is a popular means of direct medium-term or transitory employment stimulus. In many economies, programs such as the Worker Protection Act in the United States (US), work relief in the PRC, and the heavy countercyclical and recurrent fiscal commitments to public works in Japan, often have employment as their primary goal and downstream benefits as a secondary one.

20. Because of its generality, this kind of spending can be targeted across a wide spectrum of regions and socioeconomic groups and can be conducted at national, regional, or local level, timed to coincide with cyclical economic events. In the case of real public goods infrastructure, multiplier effects from both direct employment and downstream use can be substantial. Obviously, the latter benefits will be greater if more investment can be focused on real public goods and widely used infrastructure capacity. In this chapter, targeted increases in investment in trade and transport infrastructure for those Asian economies considered to have the greatest unmet needs are examined.

E. Ricardian Stimulus

21. At the microeconomic level, the role of infrastructure in reducing distribution margins is widely acknowledged in the policy and theoretical literature, but explicit treatments are relatively few and not easy to synthesize into a general approach. Policy-oriented discussion emphasizes the obvious advantages of increased market participation, as infrastructure commitments reduce distribution margins, expanding the profitable horizon of market-oriented investments, whether private or public. This is particularly the case in emerging economic environments, where distribution costs are an important source of price distortions that significantly limit market access and reduce economic efficiency. Such access barriers are particularly important in countries with poor, rural majorities, or those between economic “zones” (e.g., South Asia and East Asia) that are separated by more remote subsistence areas. Not only does infrastructure facilitate integration between active zones, it confers growth externalities across the networks so established. In this way, for example, the parallel emergence of the PRC and India has the potential to confer substantial growth externalities across Southeast Asia, especially among the latter’s poorest countries. Cambodia, Lao PDR, and Myanmar are among the areas ideally suited to become pillars of a “growth bridge” between Asia’s two emergent giants.

22. Empirical evidence of the significance of distribution margins is more plentiful and also quite diverse. It can generally be divided into four categories. The first deals with traditional and modern issues related to physical geography. In the second, a large volume of work relates to direct transport costs, including means as well as distance. Third, institutional economics has examined trade margins arising from administrative, regulatory, and political conditions governing transboundary and international commerce. Fourth, there is a special component of international finance that deals with exchange rate and purchasing power parity (PPP) distortions and their influence on underlying commerce.

23. The large literature on geophysical (e.g., spatial) determinants of transportation costs extends from the transport sector itself to general economic geography. This work has a very long history, going back to the founders of trade theory and microeconomics. Heckscher (1916) himself qualified many of his early arguments about the resource basis for trade with caveats about initial physical conditions that might facilitate or hinder trade relations. This perspective was continued down to the present by a variety of authors (recently Obstfeld and Taylor 1997). Samuelson (1952) made early contributions to economic and trade analysis from a spatial perspective, and many later contributions were grounded

in regional analysis and location theory (e.g., Bergstrand 1990). Moreover, contributions from those such as Fujita et al. (1999) have initiated a new era of investigations that expand the understanding of the economics of location. To be more specific, infrastructure reduces trade margins. This in turn has three important structural effects on the economy.

1.1.1 Intensification of Comparative Advantage

24. Classical trade theory states that price differences create incentives for international and interregional exchange of goods and specialization, which increases aggregate efficiency. Distribution margins serve to undermine these price differences, and thus the basis for trade and more efficient specialization. To see this, consider two prices *PH* and *PF* for comparable goods from two different sources (home and foreign), although they could simply be from different regions or even cities in the same country. Given that a trade margin (*M*) is generally symmetric, the ratio of these two prices, with margins taken into account, is given by the following expression, evaluated as *M* rises without limit. Evidently, the higher the margin, the less the degree of comparative advantage for either good across these markets.

$$\frac{P_H + M}{P_F + M} \xrightarrow[M \to \infty]{} 1$$

1.1.2 Improved International Terms of Trade

25. A second advantage of falling margins is improving international terms of trade. Consider now the domestic producer price of exports $PE = PWE - M$, where *PWE* denotes the international price of an export good and *M* the margin that must be debited against the exporter's net revenue (producer) price. Symmetrically, the domestic purchaser price of imports takes the form $PM = PWM + M$ where *PWM* is the corresponding international price of an imported good and the margin *M* must be added to the purchaser price. It can be observed that falling margins induce an increase in terms of trade *PE/PM*. Once again, the double virtue of falling margins and increasing producer prices alongside falling purchaser prices sharpens the incentive for trade.

$$M \downarrow \Rightarrow \frac{PWE - M}{P_D} \uparrow \text{and} \frac{PWM + M}{P_D} \downarrow$$

1.1.3 Improved Agricultural Terms of Trade

26. Finally, margins are inversely related to the rural terms of trade, and thus investments that reduce distribution margins are pro-poor in most developing countries. Consider the rural terms of trade defined as follows:

$$\rho = \frac{P_R^R}{P_U^R} = \frac{P_D - M}{P_D + M}$$

where rural prices of rural products (or rural household producer prices) must be debited for distribution to the domestic market (at prices P_D) and rural prices of urban products (or rural household purchaser prices) must include shipping costs from domestic urban markets. Differentiating this ratio of rural producer prices to rural consumer prices,

$$\frac{\partial \rho}{\partial M} = -2\frac{P_D}{(P_D + M)^2}$$

27. reveals that falling margins increase the rural terms of trade. Note also that, because this relationship is quadratic in margins, high initial barriers make it difficult to animate market incentives.

F. Neoclassical Stimulus

28. Modern economic theory recognizes many “endogenous growth factors,” i.e., economic conditions that facilitate readiness for growth and can accelerate growth when they are present in an economic setting. Many of these are facilitated by infrastructure, including productivity enhancement, technology diffusion, information diffusion, supply chain articulation and other network externalities, and human capital development (including the effects of migration).

29. Many of these factors are among the most sought-after rewards of direct investment, whether domestic or foreign in origin. They are often embodied in new investment, particularly that which is technology oriented, and are thought to contribute strongly to economic and institutional modernization, so accelerating growth, increasing labor productivity and real wage potential, and ultimately contributing to higher sustainable living standards. While these characteristics are widely acknowledged and increasingly understood, many of them are notoriously difficult to measure. This chapter uses counterfactual experiments to appraise their general significance.

G. Empirical Research on Economic Returns to Investment in Infrastructure

30. While the intuition about infrastructure's link to economic growth is widely accepted, actual mechanisms of this linkage are so diffuse institutionally, spatially, and temporally that they often defy quantification. Thus it is widely agreed that infrastructure makes and essential economic contribution, but calibrating this for benefit-cost assessment is notoriously difficult. As with many public goods, even directly targeted willingness to pay surveys are difficult because individuals cannot or will not accurately measure infrastructure's contribution to their individual balance sheets. Despite these challenges, we believe it is important to advance empirical capacity for appraising infrastructure's role in growth and integration.

31. What follows is a survey of the large literature on private growth benefits of public spending on infrastructure.[5] Much of the empirical research to date focuses on OECD countries, where growth rates are low and infrastructure stocks, public and private investment levels, and incomes are relatively high. These characteristics limit the relevance of these results to emerging economies; particularly the lower income Asian countries where initial commitments to infrastructure can achieve dramatic gains in private output, income, and productivity growth. For these reasons, the results examined here probably represent very conservative indications of what responsibly targeted investments in infrastructure could accomplish in emerging Asia.

1.1.4 OECD Results

32. Private returns to public infrastructure investment can be decomposed into two generic categories: top-down and bottom-up studies look at the role the economic returns to public investments in infrastructure. Both approaches have strengths and weaknesses and neither of them offer definitive estimates of the private value of these public investments. Generally, most of these studies suggest limits to the the supply of projects with high economic returns, and there are serious limits growth rate benefits from increases in infrastructure investment, if any. Moreover, some studies recognize a crowding out effect, where public dollars yield less than a dollar of net investment because some portion would probably have been undertaken in any case by private parties or regional/local governments. Because local and regional governments can second guess central government initiatives and refrain from spending their own fiscal resources. central government investment might even discourage other investments and reduce reliance on local knowledge for project selection. This

[5] The material below draws on surveys sponsored by the US government and the World Bank, neither of which bears any responsibility for representations in the present discussion.

trend could undermine project selection quality, reduce the incentive benefits of local ownership, and undermine long term sustainability of the services from these public goods.

1.1.5 Top-Down Approaches

33. Top-down approaches begin with macro or large scale public investments and attempt to identify sector or even firm level welfare benefits. There are a variety of survey articles that summarize and draw conclusions from the assessment literature for physical infrastructure.[6] Some of this research finds insignificant or even negative net economic effects, while others estimate large positive effects. Having said this, a clear majority of studies present evidence that public capital has a measurably positive, but modest impact. In fairness, however, data limitations often preclude definitive conclusions.

34. Perhaps the most compelling study in this literature was an early contribution of Aschauer (1989). Using a simple production function specification and 1949-85 data for commercial profitability. public capital, private capital, employment, and output, he estimates , at the margin a dollar of public capital investment yields a much higher aggregate return than an additional dollar of private capital. This conclusion is directly adducible to high correlation between trends in private productivity and the stock of public infrastructure. In the United States, these two both grew much faster in the first half of the sample period (to 1970) than afterwards.

35. A more modern approach to econometric estimation of investment returns and productivity focuses on empirical cost functions, yet this has not been extensively applied to public capital investment issues. In a recent exceptional case, annual regional-level data for the period 1970-1987 is used to analyze effects of highways, water, and waste treatment facilities systems on private manufacturing costs, finding very significant positive effects. The basic finding is that a marginal dollar of this category of infrastructure saved private manufacturers approximately 31 cents per year in operating costs. Comparable estimates for other regions fell between 16 cents and 18 cents.[7] Such estimated benefits seem quite high, especially when it is acknowledged that manufacturing

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[6] See e.g. Alicia H. Munnell, "Infrastructure Investment and Investment Growth," Journal of Economic Perspectives, vol. 6, no. 4 (Fall 1992), pp. 189-198; Edward M. Gramlich, "Infrastructure Investment: A Review Essay," Journal of Economic Literature, vol. 32, no. 3 (September 1994), pp. 1176-1196; Ronald C. Fisher, "The Effects of State and Local Public Services on Economic Development," New England Economic Review (March/April 1997), pp. 53-67; and Marlon G. Boarnet, "Highways and Economic Productivity: Interpreting Recent Evidence," Journal of Planning Literature, vol. 11, no. 4 (May 1997), pp. 476-486.

[7] Catherine J. Morrison and Amy Ellen Schwartz, "State Infrastructure and Productive Performance," American Economic Review, vol. 86, no. 5 (December 1996), pp. 1095-1111.

represents only about 20 percent of the private economy and hence reflects only a fraction of the total benefit of public capital. Overall, however, these estimates of private savings appear too optimistic to generalize very widely.[8]

36. Another cost-function study examines highway investment. Commissioned by the US Federal Highway Administration (FHWA), this study examined private savings from highway investment for the period 1950-89, detailing effects for 35 distinct industry groups (private returns to personal transport were not considered). This study used two metrics for the highway system as a public good: lineal miles of total highway stock (all central government, regional, and local roads), and the same measure covering the "non-local highway system." The importance of this distinction is that the latter variable excludes local government investments. This research indicated that a marginal dollar invested in the non-local network yielded an average of about 24 annual cents of private benefit to business across the entire sample period. In terms of productivity/profitability, this translates into an annual average rate of private return on public investments of 16 percent, compared with 11 percent for comparable private investment. It is noteworthy, however, that the estimated benefits were highest in the early years, before the advent of the interstate highway system, and these tapered off significantly as the highway network expanded. By the 1980s, it was estimated that the overall stock of non-local highway capital was only 4 percent below the size beyond which further increases would cost more than they would return in benefits to business. Moreover, by this time the total road network was yielding only 10 percent on additional investments, below the reference rate of 11 percent for returns to private capital.[9]

37. Aschauer's work stimulated important innovations in estimation methods from the top-down perspective.[10] Despite this, however, the evidence on private returns to public investment, while generally positive, are neither definitive nor

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[8] After adjusting for inflation in prices of capital goods between 1982 and 1987, gross savings from a marginal dollar of manufacturing capital in 1987 are estimated at 50 cents in the East and 60 cents in the North; net savings after borrowing costs, depreciation, and taxes are 15 cents and 26 cents, respectively. (The 1987 figures reported in the study are somewhat higher, representing nominal-dollar savings per unit of real capital, with the unit defined in 1982 prices.) Morrison and Schwartz, "State Infrastructure and Productive Performance," pp. 1095-1111.

[9] M. Ishaq Nadiri and Theofanis P. Mamuneas, "Contribution of Highway Capital to Industry and National Productivity Growth," report submitted by Apogee Research, Inc., Bethesda, Md., to the Federal Highway Administration, Office of Policy Development, September 1996 (available on the FHWA World Wide Web site at http://www.fhwa.dot.gov/pubstats.html).

[10] See e.g. Jan Egbert Sturm and Jakob de Haan, "Is Public Expenditure Really Productive? New Evidence for the USA and the Netherlands," Economic Modeling, vol. 12, no. 1 (January 1995), pp. 60-72; and Teresa Garcia-Mila, Therese J. McGuire, and Robert H. Porter, "The Effect of Public Capital in State-Level Production Functions Reconsidered," Review of Economics and Statistics, vol. 88, no. 1 (February 1996), pp. 177-180.

precise enough to support calibrated simulation exercises. It should be noted in passing, however, that the studies considered so far look only at the observed pattern of spending on infrastructure. In particular, none of these studies consider or estimate the impact of shifting funds from low-return projects chosen by other criteria to projects with higher returns.

1.1.6 Bottom-Up Approaches

38. Bottom-up studies of infrastructure generally begin with sectoral of even agent level profit, efficiency or some other welfare proxy and try to associate changes in this with specific or generic public goods or infrastructure investment. For two principal reasons, estimates from these kind of benefit-cost and rate-of-return studies cannot not clearly delineate the private value of public infrastructure. Most importantly, the scope of variation in rates of return, from losses to very high positive profits, makes it extremely difficult to generalize the handful of results from these case studies. There are a small number of broad compilations of estimates for large numbers of projects. Second, the universe of bottom-up studies differs widely in both scope and rigor. Policy conclusions should ideally rest on independent reviews that evaluate a set of studies from different sources. But again, few such independent reviews exist.[11]

39. The basic challenge of generalizing policy conclusions from bottom-up evidence can be seen in a set of benefit-cost data produced by the US Aviation Administration (FAA) and the FHWA. The FAA data have serious design limitations, as they cover only 18 proposed airport improvement projects evaluated by the agency over a four year period (1994-97). This sample is too restrictive to support conclusions about airports as a category of public investments.

40. By contrast, the more extensive FHWA data provide estimates of nationwide benefit-cost ratios for all improvements to existing highways that are expected to be efficient (that is, have a B/C ratio of at least 1). However, the data are not derived from detailed analyses of thousands of individual projects but from a set of policy simulation models, reflecting some set of simplifying assumptions rather than observed project performance. The models estimate the benefits and costs of various types of paving, widening, and road alignment projects, based on data for about 123,000 segments covering roughly 30 percent of the U.S. highway network. By applying standardized formulas and tables, these models estimate

[11] For more on this, see Gramlich, "Infrastructure Investment," pp. 1183-1184, and Massimo Florio, "The Economic Rate of Return of Infrastructures and Regional Policy in the European Union," Annals of Public and Cooperative Economics, vol. 68, no. 1 (March 1997), pp. 39-64. The latter compiles data from 200 benefit-cost studies submitted to the European Commission and cites analogous data from the World Bank, but those data have limited relevance for the United States.

essential performance relationships, e.g. the influences of weather and truck traffic on pavement condition and of pavement condition on travel times and vehicle operating costs. Overall, these kinds of agency benefit-cost data do not offer reliable or precise evidence on the value of investments in airports and highways, respectively, let alone performance of infrastructure as a whole, but they do illustrate some useful qualitative characteristics.

41. Another strand of bottom up research examines low-cost opportunities to make existing infrastructure more productive through efficient pricing and other management improvements. This is a very promising area for policy research, and in some cases, such efforts may yield higher returns than more traditional investment projects, even compared to new investment with attractive benefit-cost ratios. It should be observed, however, that current taxes and fees do not accurately reflect the costs users of airports and roadways impose on others through congestion and wear and tear. Under rules designed to promote efficiency in infrastructure use, motorists and aircraft operators would pay fees (tolls or landing fees) based on their contribution to congestion of a particular facility at a particular time of day, and commercial truckers would pay taxes based on weight per axle (the key determinant of pavement damage). Winston and Bosworth have estimated that efficient pricing of airport and road use would yield annual benefits of $22.2 billion in 1995 dollars. They also find that combining efficiency pricing with efficient investment--building highways with thicker pavement and adding runways at existing congested airports--would produce additional benefits of $12.7 billion per year, net of the incremental capital cost of $3.0 billion per year.[12]

1.1.7 Non-OECD Evidence

42. Although evidence outside OECD is of greater relevance to ADB's infrastructure agenda, evidence here is very sparse. Despite this fact, however, those studies that have been carried out are positive in their findings for several reasons. Firstly, they make consistent positive links between well-targeted infrastructure and aggregate growth, productivity improvements, and poverty alleviation. Secondly, there is clear evidence from a variety of countries that basic infrastructure has the highest rates of social and private return. Finally, it is apparent from some work that returns to public investment diminish monotonically with respect to aggregate income, a result that means weak

[12] These estimates are from Clifford Winston and Barry Bosworth, "Public Infrastructure," in Henry J. Aaron and Charles L. Schultze, eds., Setting Domestic Priorities: What Can Government Do? (Washington, D.C.: Brookings Institution, 1992), p. 293, converted to 1995 dollars by CBO, using the GDP implicit price deflator.

effects observed for OECD economies do not imply low returns in low income countries.

43. One study of China (Fan and Chan-Kang: 2005), for example, finds high GDP multipliers for public investment in road systems. More strikingly, this study finds the multiples are several times higher for low quality roads than for high quality ones. This strongly supports the notion that the earlier the stage of development, the higher the private return to public investment in infrastructure. In contrast, Lin and Song (2002) focused on the urban sector. Using data for 189 Chinese cities from 1991 to 1998, they found that an increase in paved roads is positively and significantly related to growth in GDP per capita in urban areas. Benziger (1996) provides interesting evidence on the linkages between the urban and rural sectors, testing whether greater access to urban markets increases the intensity of input use and productivity in the rural sector in the province of Hebei. His econometric results show that road density and distance to the nearest city are positively correlated with the use of fertilizer per unit of land, machinery utilization per worker, and average land and labor productivity.

44. Many focused studies in developing countries reach similar conclusions. In the case of road investments, for example, we have positive links to output and productivity reported by Ahmed and Hossain (1990) for Bangladesh, Khandker, Levy, and Filmer (1994) for Morocco, Songco (2002) for Vietnam, Jacoby (2000) for Nepal, and Riverson et al (2004) who reviewed 127 World Bank supported road projects and showed the majority stimulated income and productivity growth. Having said this, the effects on poverty may generally be positive, but inequality is often found to increase because of road development.

45. International comparison studies, mostly in a cross-country panel data context, have confirmed the significant output contribution of infrastructure. For example, Canning (1999) used panel data for a large number of countries and Demetriades and Mamuneas (2000) used OECD data. Roller and Waverman (2001) also find large output effects of telecommunications infrastructure in industrial countries, in a framework that controls for the possible endogeneity of infrastructure accumulation.

46. Among the most comprehensive recent studies is research in the Latin American context byt Calderón and Servén (2003). These authors produce GMM estimates of a hypothetical Cobb-Douglas production technology obtained from a very large (121 country) panel data set, they find positive and significant output contributions by three types of infrastructure assets – telecommunications, transport, and power. The estimated marginal productivity of these assets

significantly exceeds that of non-infrastructure capital. On the basis of those estimates, Calderón and Servén infer that a major portion of the per-capita output gap that opened between Latin America and East Asia over the 1980s and 1990s can be traced to the slowdown in Latin America's infrastructure accumulation during the same period.

47. In contrast with the relatively large literature on the output effects of infrastructure, studies of the impact of infrastructure on long-term growth are not numerous. In a study of the growth impact of government spending, Easterly and Rebelo (1993) find that public expenditure on transport and communications significantly raises growth. Also, Sanchez-Robles (1998) presents evidence that summary measures of physical infrastructure are positively and significantly correlated with growth in GDP per capita. Easterly (2001) reports that a measure of telephone density contributes significantly to growth performance of developing countries over the last two decades, but the strict interpretation of this result is one of correlation rather than causality.

48. A subset of this literature extends the basic analysis of infrastructure stocks and investment to consider quality or efficiency of infrastructure. Prominent among these is Hulten (1996), who finds that differences in the effective use of infrastructure resources explain one-quarter of the growth differential between Africa and East Asia, and more than 40 percent of the growth differential between low- and high-growth countries. In a more generic correlation exercise, Esfahani and Ramirez (2002) find there are significant growth links arising from infrastructure across a large panel data set where explicit account is taken of institutional factors affecting infrastructure's growth performance.

H. What is a General Equilibrium Model?

49. The complexities of today's global economy make it very unlikely that policy makers relying on intuition or rules-of-thumb will achieve anything approaching optimality in either the domestic or international arenas. Market interactions are so pervasive in determining economic outcomes that more sophisticated empirical research tools are needed to improve visibility for both public and private sector decision makers. The preferred tool for detailed empirical analysis of economic policy is now the Calibrated General Equilibrium (CGE) model. It is well suited to trade analysis because it can detail structural adjustments within national economies and elucidate their interactions in international markets. The model is more extensively discussed in an annex below and the underlying

methodology is fully documented elsewhere, but a few general comments will facilitate discussion and interpretation of the scenario results that follow.

50. Technically, a CGE model is a system of simultaneous equations that simulate price directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

51. The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

52. The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

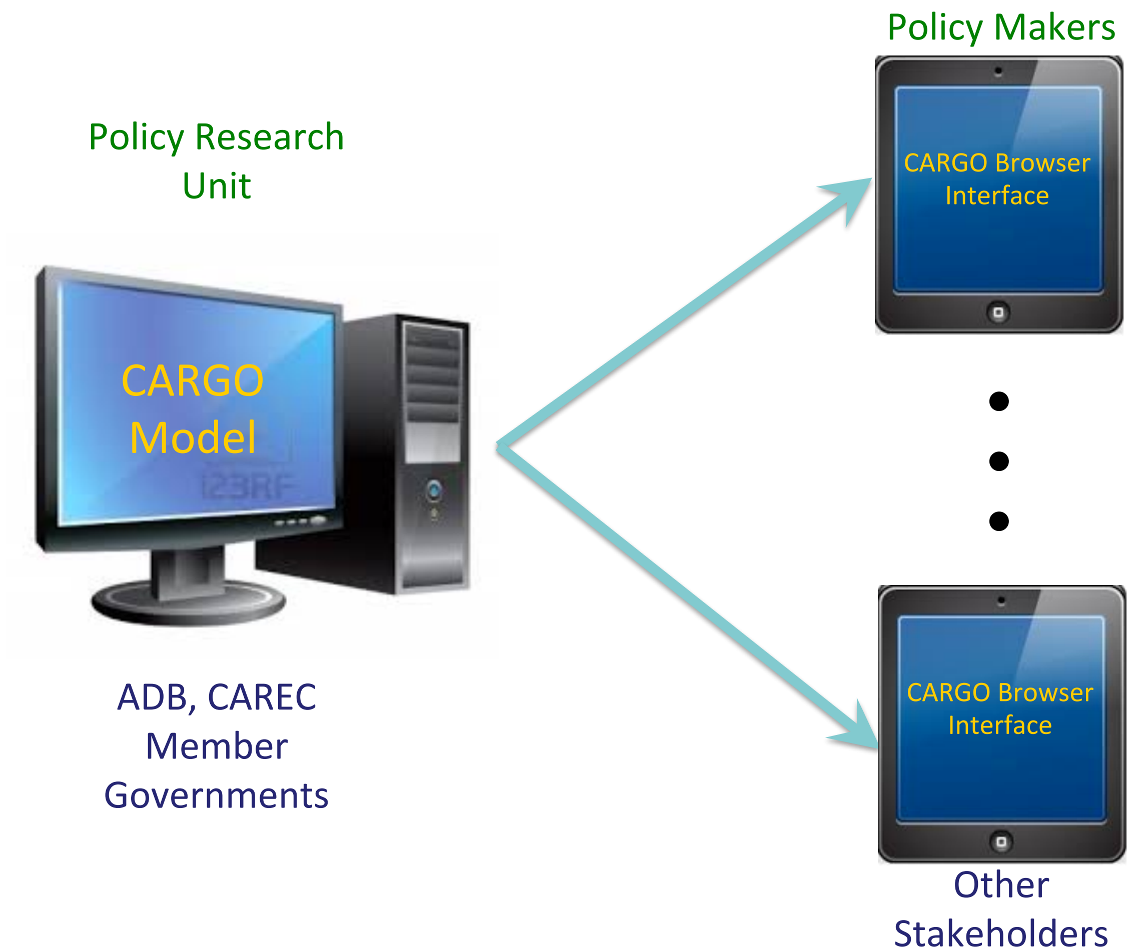
53. For larger scale project evaluation like the present case, significant economic effects can spill well beyond the borders of the domestic economy, and feed back into the subject economy from secondary effects on its trading partners. To capture these linkages, a multi-country forecasting framework like the CARGO model is more appropriate. As one would expect in a region like CAREC, with

relatively weak initial transport infrastructure, our results indicate that spill over effects are a very important.

4. NON-TECHNICAL DECISION SUPPORT TOOL

54. This TA is intended to support wider evidence based policy dialog on CAREC and related regional integration measures. As such, technical activities like data and model development must be complemented by communication and dissemination that effectively reaches the policy community. For this reason we have developed a decision support tool that could be accessible to non-technical audiences, essentially a graphic user interface (GUI) for evaluating and disseminating technical findings of the dynamic economic assessment. The CARGO model itself must represent he highest technical standards for economic impact evaluation, but results and scenario options can still be communicated with more conventional electronic media (laptops, tablets, and even smartphones). We have developed and will transfer this software and content as part of the capacity building phase of the project, enabling the project to to meet the exacting empirical standards, while communicating their findings with the utmost effectiveness.

Figure 2: Schematic of CARGO Results Dissemination



55. The GUI software facility allows CARGO assessments and forecasts to be uploaded and displayed in a variety of state-of-the-art descriptive and quantitative formats, including tables, graphs, GIS mapping, density surface plots, etc., for the region as well as individual CAREC economies. These visual tools give the analysis an immediacy and relevance to policymakers that cannot be achieved by purely technical reporting, while at the same time being grounded in rigorous impact evaluation.

56. A prototype of the CARGO Browser INterface (BIN) has been developed and will be deployed to ADB counterpart staff for assessment, feedback, and refinement. As with the CARGO modeling framework, setting a uniform standard for information content and technology (communication technology in this case,

econometric technology for CARGO), this high-level decision tool can facilitate dialog across the region, domestically, and with development partners.

5. CAPACITY DEVELOPMENT AND OUTREACH

57. An essential component of this project is communication of scenario research findings and dissemination of data and methods. The first activity, covered in the current contract, scheduled to be undertaken in Manila, Astana, Bishkek, and/or Urumqui at a time mutually convenient to ADB and regional counterparts. In each venue, two seminars will be given, one non-technical briefing for senior policy makers and one detailed methodological presentation to technical specialists. Audiences may consist of public and private stakeholders, but in each case will be determined by consensus between ADB and it's local counterparts.

58. The CARGO BIN GUI software and baseline scenario results would be disseminated during these activities, helping to raise awareness of the importance of evidence based policy research and coherent regional dialog. In Phase II of this TA, it would be possible to achieve a transfer of the full technical capacity to interested CAREC partners. This would be based on an established training model used by the consultant in over 20 countries, targeting policy research specialists with the dual objectives of strengthening local technical capacity and establishing more effective standards for information sharing and dialog.

6. SCENARIO ASSESSMENT FOR CAREC REGIONAL DEVELOPMENT

59. Using the new CARGO model, we have conducted an array of impact assessments that, in the words of the TOR for this project, evaluate the following:

- Analyze the economywide impacts of various investments on the economies of the countries in the Central Asian Region (including Russia) especially with regard to the plan to improve the existing six road corridors into economic corridors.

- A combination of scenarios of additional investments in the corridor roads, in energy that includes energy efficiency improvement, and investments as part of urban development. All are in the context of increasing globalization reflected in the increasing international (global and regional) trades and migration/remittances. Moreover, the additional background of the scenario analysis that should be taken into account are the increasing economic roles of PR China and India; and future role of Europe with respect to the region;

- Conduct an analysis in a dynamic context with the time spans of examination include in the years of 2020, 2030, and 2050. The impacts examined include GDP, Sectoral outputs, Total exports and Imports, Number of workers, and Household incomes for each country in the regions and other trading partners and rest of the world.

60. To this end, we are circulating a scenario menu that captures the main issues above and the scope of the model for their assessment. Based on consultation with ADB counterparts, this menu can be refined to a set of core scenarios and inventory of relevant impact variables for more extended analysis and policy support.

Table 2: Policy Scenarios

	Scenario	Description
1	Baseline	Baseline ("business as usual") scenario
2	VOC	Vehicle Operating Costs - Includes complete project outlays and estimated economic benefits from improved safety, travel time, and reduced vehicle depreciation.
3	Prod	Productivity - Combines above and estimates of productivity gains for transport and distribution sectors.
4	Loss	Loss - Combines above and reductions in product losses due to spoilage, damage, delays, and other adverse effects of roadway inefficiency.
5	Trade	Trade - Combines above and estimates of reduced trade and transport cost margins.

61. To illustrate the kind of regional economic assessment that can be supported with the CARGO model, we forecast the macroeconomic impacts of Phases 1-6 of the regional corridor project. Infrastructure contributes to economic growth through many channels, and we want to elucidate these by decomposing our dynamic assessment scenarios into one baseline and four incremental impact scenarios, summarized in Table 2. The baseline represents consensus growth estimates over the scenario period (2012-2050), assuming no action is taken on the road and rail corridor projects. The first policy scenario (VOC) assumes only the direct benefits of the project are relevant. This includes the Keynesian impact of direct project expenditures and the usual direct project assessment variables, such as Vehicle Operating Costs and other direct benefits to users of the infrastructure.

62. Direct benefits are of course essential to understanding the local returns to infrastructure, but they fail to capture extensive linkage effects across supply and expenditure chains implicating a transport resource of this magnitude. For example, VOC statistics measure the direct cost savings to a vehicle while it is using the corridor, but has nothing to say about the economic significance of the vehicle use. For example, a cargo truck may save 10 percent on transit cost, but these cost benefits will multiple for all the downstream partners of the truck, including intermediate and final buyers of its contents. Moreover, the reduction in transport cost expands the physical horizon of profitability for all transport services, and can be expected to increase capacity use across a wide spectrum of activities. This increases road use, but also integrates the national and regional economy, increases product variety, and sharpens comparative advantage to increase trade and unit profitability by realizing economies of scale.

63. The second policy scenario measures the contribution of trade and transport productivity growth, as distribution sectors experience lower costs and pass these gains on to all their client sectors. The result of this is more transport-intensive growth for the economy at the national, regional, and global level. Because distribution services are essential to market access, rising productivity in the sector accelerates trade for all other sectors, conferring growth leverage from transport services to the rest of the economy.

64. The third scenario component captures the benefit of reduced delays, product losses, and depreciation on transport related products. For perishable products like agriculture, such losses can be prohibitive, and reducing them significantly can dramatically increase rural market participation. For other commodities, even non-perishables, delays still induce economic losses because they escalate inventory and storage costs.

65. The fourth and final scenario component is designed to show the effect of falling trade and transport margins, both domestically and across CAREC borders to the rest of the Asian region and the world. Within the CAREC, transport margins can be very high, in some cases exceeding 100 percent because of low quality roads, border delays, and other soft and hard infrastructure obstacles. Corridors like the one being evaluated can dramatically reduce these costs, increasing the profitable scope of trade and also its intensity.

66. For the fourth, all inclusive Corridor policy scenario, Figure 2 summarizes the macroeconomic impacts on CAREC and other Asian economies. Figures here show annual scenario differences from baseline real GDP, expressed as a percent of 2010 GDP. As can be expected because of proximity and initial (relatively low income) conditions, the main beneficiaries in terms of relative growth are lower income CAREC members.

Figure 3: Real GDP Growth to 2050
(Difference from Baseline as a Percent of 2010)

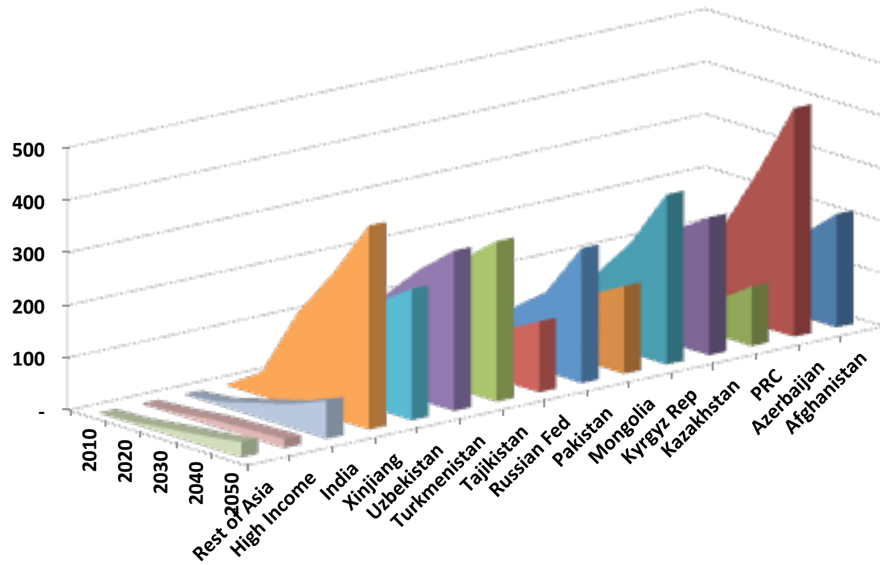


Table 1: Real GDP Growth

Difference from Baseline as a Percent of 2010

	2020	2030	2040	2050
Afghanistan	31	108	154	216
Azerbaijan	37	166	294	435
PRC	8	34	65	113
Kazakhstan	47	161	216	262
Kyrgyz Rep	32	128	211	323
Mongolia	31	95	129	167
Pakistan	27	98	152	257
Russian Fed	18	63	97	135
Tajikistan	44	176	247	305
Turkmenistan	44	174	246	305
Uzbekistan	37	143	202	250
Xinjiang	46	179	275	387
India	7	26	45	72
High Income Asia	4	12	14	17
Rest of Asia	3	12	19	29

67. Having said this, it is important to recognize the important stakes that other Asian and even European trading partners have in regional infrastructure. The

following figure shows the same real GDP results, measured in absolute rather than relative terms (i.e. real 2010 USD millions). Here it is clear that, while percentage effects vary with proximity, level effects depend on initial trade volumes and size of trading partner economies. Thus the PRC, High Income Asia, and more even distant European and US economies capture significant absolute benefits from improved CAREC transport infrastructure because of their strong ties to the region, especially through energy and capital goods markets. Thus the benefits of CAREC integration are truly multilateral. Significant nominal growth accrues to larger economies, suggesting a broader basis for regional project financing and policy support.

68. How do the growth benefits of the CAREC Corridors initiative decompose between the various types of growth effect discussed in the last section? To see this, the figure below shows how real GDP increased to 2030 and 2050 milestones as a result of the project, separating the total benefit for each economy into each of the four sources of stimulus. These results clearing indicate the importance of indirect project effects. Direct effects are nonexistent for CAREC's trading partners because this is regional project, yet they benefit quite significantly from regional and global linkages through the corridors. Even within CAREC, which captures all the Keynesian and other direct project benefits (VOC, light blue), the indirect effects are greater as the efficiency benefits of improved transport propagate across all market related activities in the economy. Indeed, higher productivity from transport and distribution services (Prod) constitutes the largest component of project-induced growth. Although, neoclassical effects dominate the growth stimulus, trade and product conservation are also significant.

Figure 4: Real GDP Growth to 2050

(USD 2010 Millions, annual difference from Baseline)

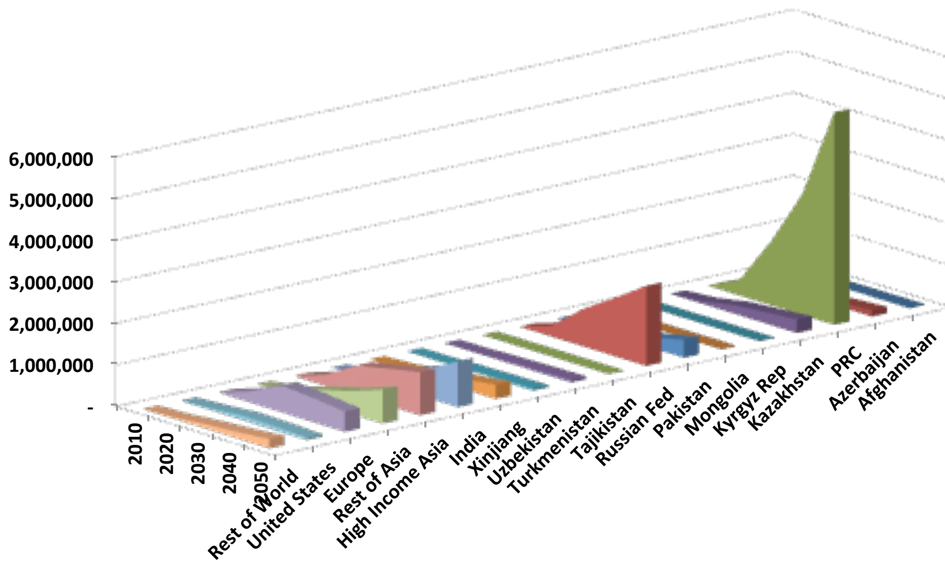


Table 2: Real GDP Growth (difference from Baseline, 2010 USD millions)

	2020	2030	2040	2050
Afghanistan	3,773	13,110	18,597	26,073
Azerbaijan	13,209	58,438	103,853	153,655
PRC	359,966	1,533,113	2,917,417	5,106,239
Kazakhstan	57,931	198,007	265,059	322,242
Kyrgyz Rep	1,414	5,634	9,256	14,198
Mongolia	1,538	4,729	6,455	8,327
Pakistan	45,544	162,943	251,632	425,389
Russian Fed	250,070	897,407	1,390,566	1,922,266
Tajikistan	1,469	5,819	8,191	10,096
Turkmenistan	9,570	37,764	53,270	65,931
Uzbekistan	7,914	30,255	42,739	52,916
Xinjiang	40,059	156,267	240,240	337,725
India	105,481	397,291	677,797	1,094,772
High Income Asia	263,528	724,644	882,321	1,032,256
Rest of Asia	94,572	338,814	540,599	812,433
Europe	266,186	638,070	577,584	488,770
United States	43,724	106,919	87,102	58,186
Rest of World	33,104	102,651	151,721	218,300

Figure 5: Real GDP Growth, Annual Average Premium by Scenario (Percent w.r.t. 2030 Baseline)

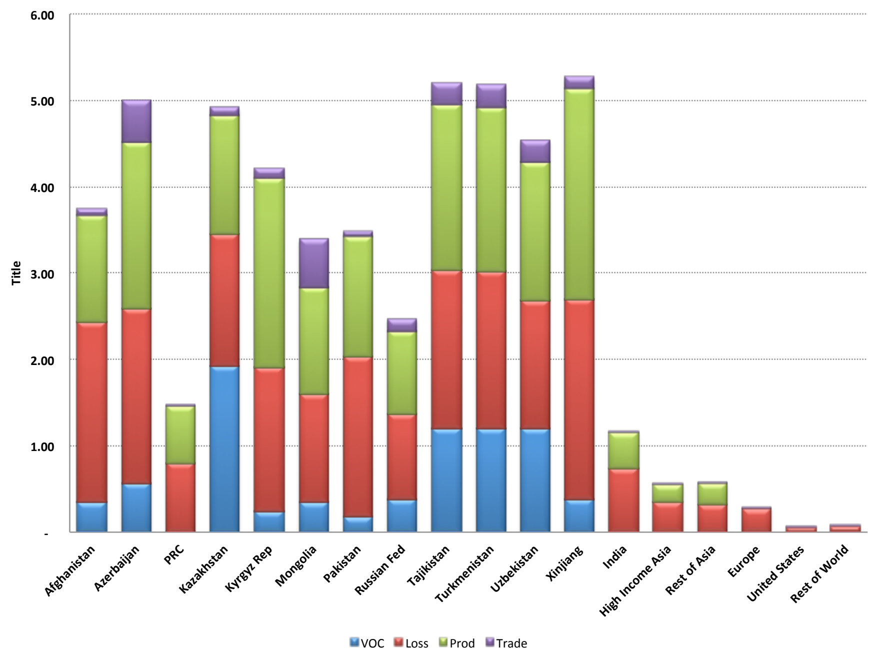


Table 5: Real GDP Growth, Average Annual Premium by Scenario (incremental percent w.r.t. 2030 Baseline)

	VOC	Loss	Prod	Trade
Afghanistan	0.34	2.09	1.23	0.07
Azerbaijan	0.56	2.03	1.93	0.48
PRC	0.00	0.80	0.65	0.02
Kazakhstan	1.93	1.52	1.37	0.10
Kyrgyz Rep	0.24	1.67	2.19	0.12
Mongolia	0.35	1.25	1.24	0.55
Pakistan	0.18	1.86	1.39	0.05
Russian Fed	0.38	0.99	0.96	0.14
Tajikistan	1.20	1.83	1.91	0.25
Turkmenistan	1.20	1.82	1.91	0.25
Uzbekistan	1.20	1.49	1.60	0.25
Xinjiang	0.38	2.31	2.44	0.13
India	(0.00)	0.74	0.41	0.01
High Income Asia	(0.00)	0.36	0.20	0.01
Rest of Asia	(0.00)	0.33	0.24	0.00

Figure 6: Real GDP Growth Premium by Scenario

(Percent w.r.t. 2050 Baseline)

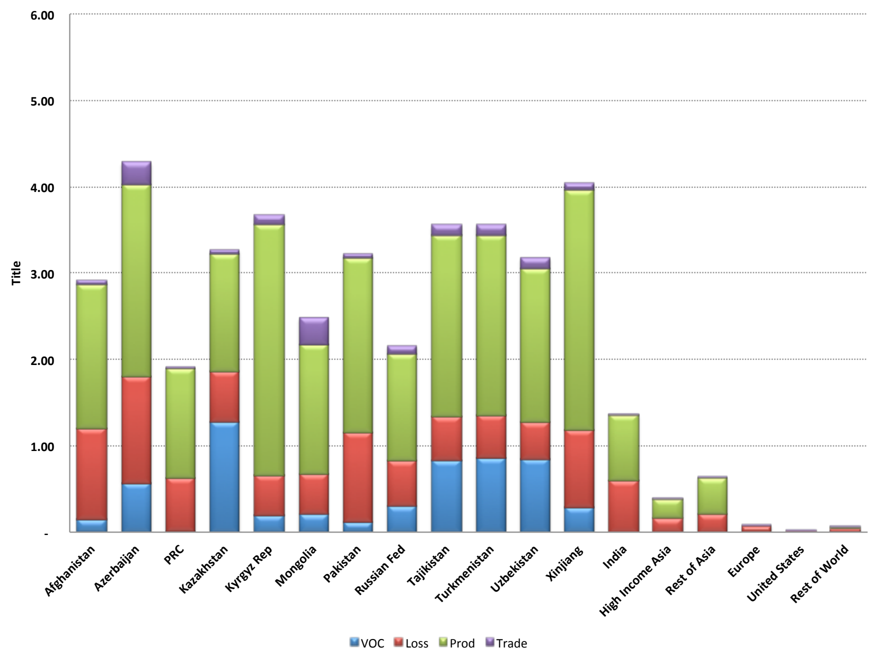


Table 6: Real GDP Growth Premium by Scenario

(incremental percent w.r.t. 2050 Baseline)

	VOC	Loss	Prod	Trade
Afghanistan	0.15	1.06	1.66	0.05
Azerbaijan	0.57	1.24	2.22	0.26
PRC	0.00	0.62	1.26	0.02
Kazakhstan	1.28	0.58	1.36	0.05
Kyrgyz Rep	0.20	0.47	2.91	0.11
Mongolia	0.21	0.46	1.50	0.31
Pakistan	0.12	1.04	2.02	0.05
Russian Fed	0.31	0.51	1.24	0.09
Tajikistan	0.84	0.50	2.10	0.12
Turkmenistan	0.85	0.50	2.09	0.12
Uzbekistan	0.85	0.43	1.78	0.12
Xinjiang	0.29	0.90	2.78	0.07
India	(0.00)	0.60	0.75	0.01
High Income Asia	(0.00)	0.16	0.22	0.01
Rest of Asia	(0.00)	0.22	0.41	0.01

69. While productivity (Prod) effects are significant aggregate growth stimulus, they are even more important to real output. As intuition suggests and the following figures attest, the benefits of infrastructure are widespread, improving productivity and competitiveness across most economic activities, and in some proportion to the importance of transportation services. Indeed, the growth benefits across CAREC economies are so widespread that generalization is difficult, but clearly there should be broad support in the enterprise community for these investments. Note also that sectoral benefits are relatively uniform for local economies, more varied for trading partners.

Figure 7: Sectoral Output Growth

(multiple of Baseline in 2030)

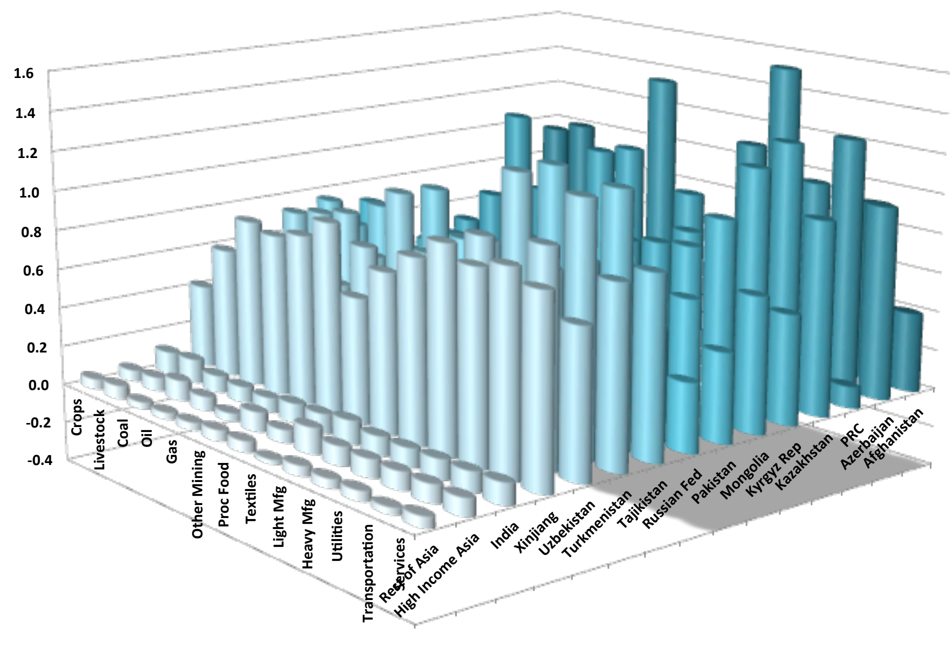


Table 3: Sectoral Output Growth

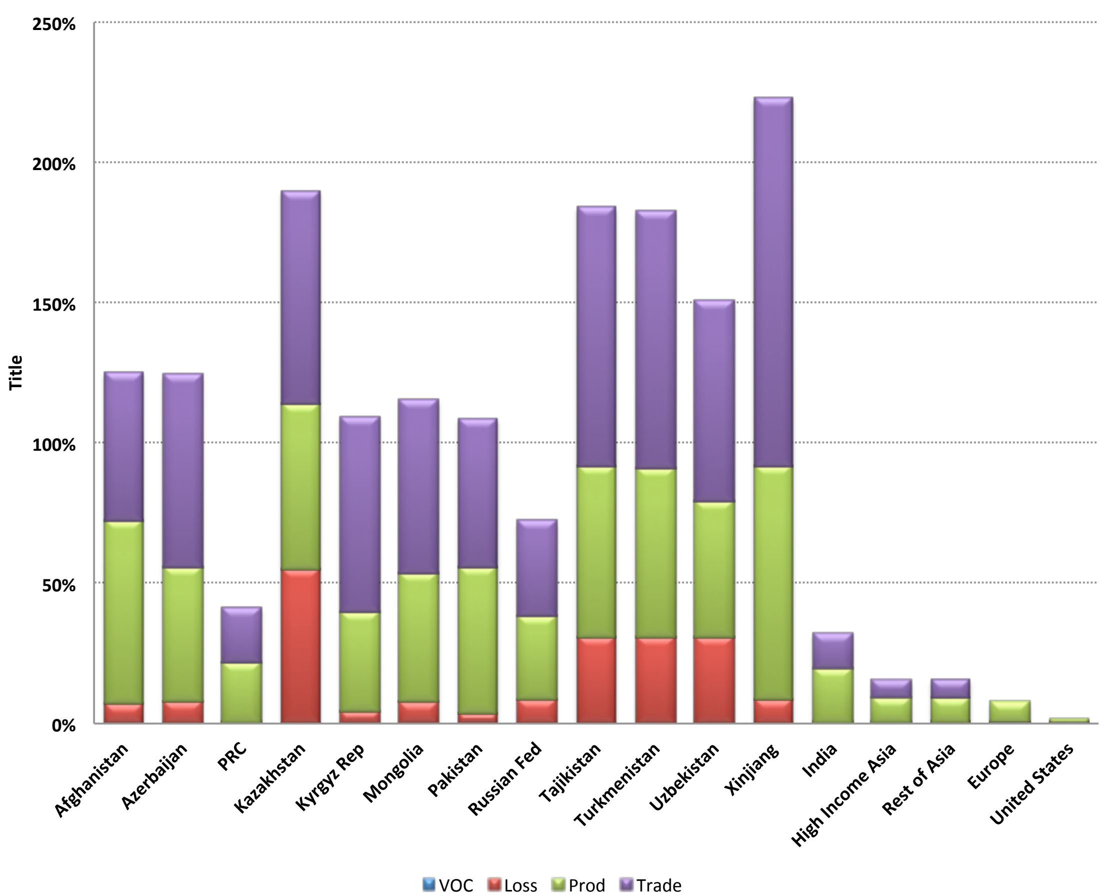
(multiple of Baseline in 2030)

	afg	aze	chn	kaz	kgz	mng	pak	rus	tjk	tkm	uzb	xin	ind	hya	roa
Crops	1.95	1.09	1.08	1.52	1.40	1.18	1.71	0.98	1.46	1.42	1.36	1.42	1.11	1.06	1.05
Livestock	2.00	1.25	1.09	1.70	1.41	1.51	1.51	1.17	1.82	1.79	1.66	1.65	1.12	1.07	1.07
Coal	1.02	1.00	1.11	2.16	1.25	1.58	1.42	1.36	1.73	1.82	1.67	1.84	1.09	1.10	1.04
Oil	0.70	1.39	1.11	1.80	1.56	1.40	1.32	1.23	1.86	1.86	1.72	1.81	1.08	1.07	1.04
Gas	0.69	1.46	1.11	1.69	1.49	1.00	1.24	1.29	1.68	1.68	1.57	1.85	1.08	1.04	1.04
Other Mining	1.03	2.39	1.12	2.07	1.52	1.55	1.24	1.32	2.02	2.03	1.80	1.95	1.10	1.10	1.06
Proc Food	1.31	1.24	1.09	2.12	1.30	1.16	1.30	1.19	1.81	1.77	1.64	1.63	1.10	1.07	1.06
Textiles	1.36	1.33	1.10	1.66	1.71	1.27	1.32	1.33	1.63	1.57	1.48	1.79	1.12	1.13	1.02
Light Mfg	1.24	2.15	1.11	1.95	1.74	1.65	1.38	1.40	1.90	1.91	1.73	1.91	1.10	1.10	1.05
Heavy Mfg	0.88	2.57	1.12	1.72	1.83	1.38	1.12	1.40	2.28	2.28	2.01	2.02	1.10	1.09	1.05
Utilities	1.08	2.02	1.11	1.87	1.63	1.84	1.44	1.36	1.87	1.86	1.69	1.95	1.10	1.09	1.05
Transportation	1.92	2.28	1.10	2.31	2.22	2.01	1.66	1.56	2.25	2.24	2.05	1.99	1.10	1.09	1.03
Services	1.41	1.98	1.11	1.97	1.55	1.68	1.45	1.34	1.90	1.89	1.73	1.93	1.11	1.09	1.06

70. It should also be observed that relative output gains are greatest in the lower income economies, suggesting that leveling the logistical playing field strongly promotes economic convergence. Having said this, larger economies, with larger absolute trade flows, will capture larger absolute gains from the Corridors. This is to be expected because of the access characteristics of public goods, but could help justify user charges to redistribute aggregate regional benefits. Nominal gains are much more varied, depending on initial scale and trade shares. Nominal gains are much more varied, depending on initial scale and trade shares.

Figure 2: Real Household Income Growth

(Percent difference from 2030 Baseline)



71. Households gain as much from trade as other sources of stimulus, with greater marketing opportunities and increased purchasing power for imports.

Importantly, trade liberalization benefits households more than producers because, by lowering the CPI, it increases their real incomes.

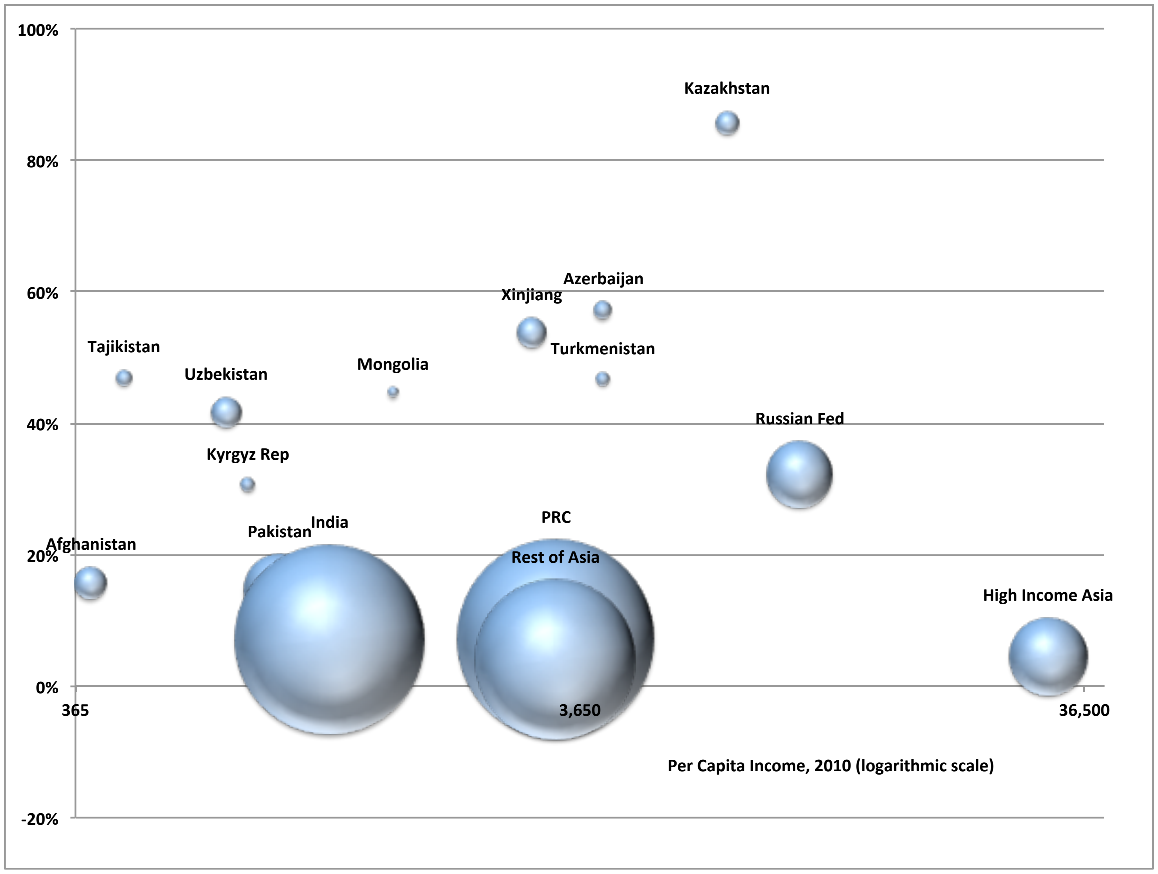
Table 4: Real Household Income Growth

(Percent w.r.t. 2030 Baseline)

	VOC	Loss	Prod	Trade
Afghanistan	0%	7%	72%	125%
Azerbaijan	-1%	8%	55%	124%
PRC	0%	0%	22%	41%
Kazakhstan	-4%	51%	109%	186%
Kyrgyz Rep	0%	4%	39%	109%
Mongolia	-1%	7%	53%	115%
Pakistan	0%	3%	55%	108%
Russian Fed	-1%	8%	38%	71%
Tajikistan	-2%	29%	89%	182%
Turkmenistan	-2%	29%	89%	181%
Uzbekistan	-2%	29%	77%	148%
Xinjiang	-1%	8%	91%	222%
India	0%	0%	20%	32%
High Income Asia	0%	0%	9%	16%
Rest of Asia	0%	0%	9%	16%
Europe	0%	0%	8%	5%
United States	0%	0%	2%	1%

72. Another important mechanism of household benefits is real wage appreciation. Because most CAREC economies are still low income, wage improvements are a primary driver of poverty alleviation and average livelihoods improvement. As the following figure makes clear, lower income countries experience the greater wage growth from CAREC Corridor development. This happens because transport is an essential facilitator of market access, the primary gateway out of poverty. By lowering movement costs for individual workers and small enterprises, the Corridors change the fundamentals of labor, commodity, and service markets at all levels. Because technology and energy are more expensive for the poor (as a percent of income), they gain more from these margin reductions. In this way, infrastructure facilitates and essential development dynamic: self-directed poverty reduction.

Figure 9: Average Wage Changes by Country and GDP Per Capita (percentage change from Baseline in 2030, bubble diameter proportional to population



Note: HiInc Asia=High Income AMC's. Countries/regions are listed in order of increasing per capita income.
Source: Authors' estimates from GTAP. Horizontal axis depicts annual per capita real GDP. Bubble size is proportional to population.

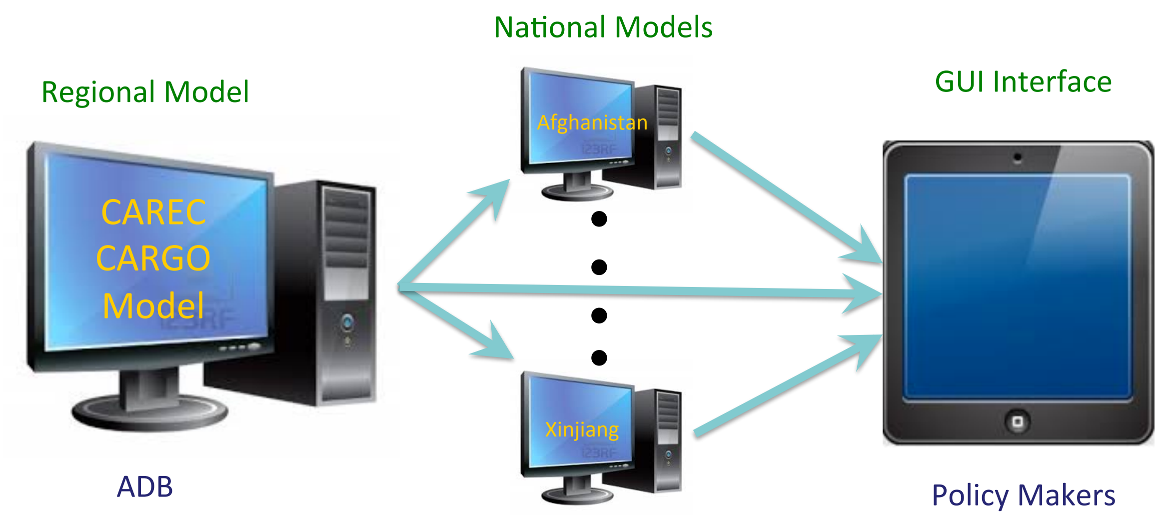
7. EXTENSIONS

73. When using GE models for policy analysis, two alternative but complelmentary perspectives can be adopted, region (multi-country) and national (single country). Because they can be calibrated to very detailed datasets, single country models generally support deeper insights into domestic welfare effects and more comprehensive economic impact evaluation. This makes them well suited to studying issues of distribution and economic inclusion, public finance, and other effects on microeconomic behaviour and institutions. These models

can also be used to “zoom in” and examine the detailed and even spatial effects of smaller scale infrastructure commitments.

74. The regional CARGO model was a centerpiece of the first phase of this TA. In Phase II of this TA, it would be possible to transfer more complete technical capacity to individual interested CAREC partners. This would be based on single country models for each of the 12 CAREC member economies, at significantly higher detail but consistent with the regional CARGO model. These would then be transferred to members using an established training model that targets policy research specialists with the dual objectives of strengthening local technical capacity and establishing more effective standards for information sharing and regional dialog. Results from both the regional and national models would be disseminated with the CARGO BIN user interface.

Figure 10: Schematic Phase II Deployment of Regional and National Models, with browser based results dissemination.



75. Other areas of relevant policy research application include Public Finance, particularly alternative and complementary project financing options, including multilateral and public/private partnerships. Analysis of other regional agreements and their relevance to the region can also be evaluated. Finally, new categories of infrastructure, including energy and climate adaptation needs, can be reliably assessed with the same framework.

76. Beyond the present exercise, it would be desirable to transfer the technical capacity to regional capitals and ADB headquarters. This will support higher

standards for information sharing, policy research, and more coherent policy dialog. In addition to this, ADB and its member partners will be interested a wide range of policy research issues that can be evaluated with such a framework, both regionally and on a country-by-country basis. These would include, but not be limited to:

1. Regional assessment of more detailed trade and investment potential and trends.
2. Transport pathways: Detailed regional and national impact analysis.
3. Energy pathways: Detailed regional and national impact analysis.
4. Detailed dynamics of regional growth and poverty reduction.
5. Trends in urbanization and rural development.
6. Resource development, public investment, and fiscal sustainability.
7. Demographic assessment, including impacts of migration, labor force development and employment patterns, and other socioeconomic trends.
8. Corridor project and other public policy impacts on development indicators, MDG's, etc., nationally and regionally.
9. Coordination with agent-based GIS modeling to improve policy targeting and impact evaluation.

8. CONCLUSIONS

77. This report presents results from a multi-country general equilibrium assessment of a large road corridor project that is the inception initiative of CAREC. The approach used here, multi-country general equilibrium modeling, is particularly suited to estimating the extensive indirect effects of such a commitment to infrastructure. With this framework, it is apparent that the overall benefits of the CAREC Corridors dramatically outweigh their costs. Transboundary spillovers confer significant growth leverage on other regional economies and benefit even distant trade partners.

78. More specifically, Keynesian (project finance) benefits are positive but small compared to productivity, efficiency, and trade stimulus effects. Productivity gains are the largest source of growth benefits, but reduced losses and trade stimulus are of nearly equal benefit. Lower income economies generally have larger proportional growth dividends from CAREC participation, promoting an over all objective of Asian economic convergence. Trade benefits help the overall economies, and extend far beyond the borders of CAREC and its immediate neighbors, to large but distant trading partners like the EU-25 and the United States. Trade margin and tariff reductions also sharply increase domestic purchasing power and household real incomes.

79. Our overall empirical findings are fully consistent with intuition and regional policy expectations, that large and coordinated infrastructure investments are a potent catalyst for long term economic growth. At more detailed levels of analysis, however, we can see the inclusive features of infrastructure at work, driving down information and transit costs to expand the profitable horizon of investment for enterprises of all scales and for workers of all income levels. As we have seen many times before in the dynamic Asian development experience, infrastructure confers market access that is the key to self-directed poverty reduction.

80. More extensive scenario analysis will improve our understanding with respect to a wider range of policy options. In parallel, more intensive data development, possibly including development of individual models for CAREC member economies, will improve resolution of analysis, allowing identification of both beneficiaries and those who might need more specific targeting of incentives or adjustment assistance. Finally, innovative user interfaces will help integrate all these quantitative tools into decision making and dialog, facilitating more evidence based policy across this region and helping to realize its vast economic potential.

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10. ANNEX: CARGO - SUMMARY OF THE CAREC DYNAMIC CGE MODEL

81. The Central Asian Regional General equilibrium mOdel (CARGO) is in reality a constellation of research tools designed to elucidate patterns of economic growth potential generally and the role of hard and soft trade infrastructure in particular. For the purposes of this report, the GTAP 8 database, to which the model is calibrated, was aggregated along certain dimensions, but can be disaggregated for other applications. The detailed equations of the model are completely documented elsewhere (Roland-Holst, Sugiyarto, and Suan: 2013), and for the present we only discuss its salient structural components.

A. Structure of the CGE Model

82. Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

83. The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

84. The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed-form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects

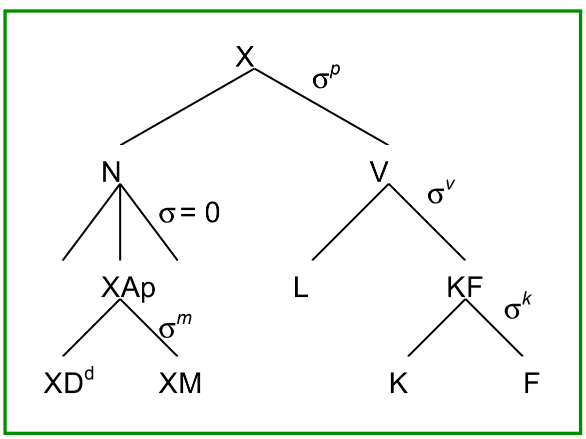
include the trade linkages between countries and regions which themselves can have policy implications.

85. The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language.[13] The result is a single economy model calibrated over the forty year time path from 2010 to 2050.[14]

1.1.8 A. Production

86. Production, *XP*, will be modeled as a series of nested constant-elasticity-of-substitution (CES) functions, which will determine the substitution and complementarity relations across the different inputs into production (see Figure 1).

Figure 1: CES Production Nest



XP:	Output
ND:	Aggregate intermediate demand
VA:	Value added bundle
L:	Demand for labor
KF:	Capital/sector specific capital bundle
K:	Demand for capital
F:	Demand for sector specific factor
XAp:	Input/output matrix (at the Armington
XD^d:	Domestic demand for domestic goods
XM:	Demand for imports
σ^p:	Top level substitution elasticity (*ND* and
σ^v:	Substitution elasticity between *L* and
σ^k:	Substitution elasticity between *K* and *F*
σ^m:	Armington elasticity

87. The top nest will determine demand for an aggregate bundle of intermediate goods, *ND*, and the value added bundle, *VA*. The relevant prices of these two bundles will be *PND* and *PVA*, respectively. At this level, the CES cost function will determine the final unit cost of production, *PX*. Equations (1) and (2) will

[13] See e.g. Meeraus et al (1992) for GAMS.

[14] The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries and/or regions.

reflect the reduced form CES demand functions, and equation (3) will determine the unit cost of production. [15]

(1) $$ND_i = \alpha_i^{nd}\left(\frac{PX_i}{PND_i}\right)^{\sigma_i^p} XP_i$$

(2) $$VA_i = \alpha_i^{va}\left(\frac{PX_i}{PVA_i}\right)^{\sigma_i^p} XP_i$$

(3) $$PX_i = \left[\alpha_i^{nd} PND_i^{1-\sigma_i^p} + \alpha_i^{va} PVA_i^{1-\sigma_i^p}\right]^{1/\left(1-\sigma_i^p\right)}$$

where the substitution elasticity (the *ND-VA* substitution) will be given by σ^p.

88. Assuming perfectly competitive markets, the output price, *PP*, will be equal to the unit cost of production multiplied by an *ad valorem* production tax.

(4) $$PP_i = \left(1+\tau_i^p\right)PVA_i$$

89. The value added bundle will be composed of three factors: labor (*L*), capital (*K*), and a sector-specific factor (*F*). It will be decomposed using nested CES functions. At the top level, labor will be combined with a capital-fixed factor bundle (*KF*). And at the next level, the *KF* bundle will be decomposed into capital, on the one hand, and the fixed factor, on the other. Equations (5) and (6) will determine demand for labor and the *KF* bundle, respectively, where the relevant prices will be *W*, the wage rate, and *PKF*, the price of the *KF* bundle. The substitution elasticity will be given by σ^v . Equation (7) will determine the price of the value added bundle using a CES cost function. The labor demand function will be expressed in efficiency units, where the parameter λ^l will incorporate (potentially sector-specific) changes to labor productivity. The wage rate will not be sector specific. The model will explicitly assume that labor is fully mobile across sectors and, hence, there is a uniform economy-wide wage rate.

(5) $$L_i^d = \alpha_i^l \left(\lambda_i^l\right)^{\sigma_i^v-1}\left(\frac{PVA_i}{W}\right)^{\sigma_i^v} VA_i$$

[15] The model specification will be written in its most general form. The indices *i* and *j* refer to sectors. Summation signs only refer to the sectoral index and it will be implicitly assumed that the summation is from 1 to *N*, where *N* is the number of sectors. A subscript of 0 refers to an initial value.

(6) $$KF_i = \alpha_i^{kf} \left(\frac{PX_i}{PKF_i} \right)^{\sigma_i^v} VA_i$$

(7) $$PVA_i = \left[\alpha_i^l \left(\frac{W}{\lambda_i^l} \right)^{1-\sigma_i^v} + \alpha_i^{kf} PKF_i^{1-\sigma_i^v} \right]^{1/\left(1-\sigma_i^v\right)}$$

90. Decomposition of the *KF* bundle will be expressed by equations (8) and (9), where the parameters λ^k and λ^f incorporate productivity changes for capital and the sector specific factor respectively, and the substitution elasticity is given by σ^k. Equation (10) will determine the price of the *KF* bundle.

(8) $$K_i^d = \alpha_i^k \left(\lambda_i^k\right)^{\sigma_i^k - 1} \left(\frac{PKF_i}{R_i} \right)^{\sigma_i^k} KF_i$$

(9) $$F_i^d = \alpha_i^f \left(\lambda_i^f\right)^{\sigma_i^k - 1} \left(\frac{PKF_i}{PF_i} \right)^{\sigma_i^k} KF_i$$

(10) $$PKF_i = \left[\alpha_i^k \left(\frac{R_i}{\lambda_i^k} \right)^{1-\sigma_i^k} + \alpha_i^f \left(\frac{PF_i}{\lambda_i^f} \right)^{1-\sigma_i^k} \right]^{1/\left(1-\sigma_i^k\right)}$$

91. The left most branch of the nest, aggregate intermediate demand (*ND*), will be decomposed into the input-output matrix of the production side. A simple Leontief structure with no substitution across intermediate inputs will be assumed. Equation (11) will determine intermediate demand for goods and services, *XAp*.[16] Finally, equation (12) will determine the price of aggregate intermediate demand. Given the assumption of the Leontief technology, the price of aggregate intermediate demand will be equal to the weighted sum of the tax inclusive Armington prices, where the weights are given by the Leontief share coefficients.

(11) $$XAp_{ij} = a_{ij} ND_j$$

(12) $$PND_j = \sum_i a_{ij} \left(1 + \tau_{ij}^{itp}\right) PA_i$$

1.1.9 B. Household Income and Final Demand

1. Consumption

[16] All domestic demand components will be expressed as Armington goods. The suffix *p* is used to refer to production demand, *c* for private consumption, *g* for public consumption, and *i* for investment demand.

92. Household income, *YH*, will be derived from factor income augmented by transfers from the government.[17] Disposable income, *YD*, will be equal to after-tax household income adjusted for depreciation.

$$YH = \sum_i \left[WL_i^d + R_i K_i^d + PF_i F_i^d \right] + P.TR_h^g \tag{13}$$

$$YD = (1-\kappa)\, YH - DeprY \tag{14}$$

93. Consumer demand will be modeled using the extended linear expenditure system (ELES) which is similar to the linear expenditure system, but incorporates household saving into the consumer's objective function. Equation (15) will specify consumer demand for the Armington good, *XAc*. It will be the sum of two components. The first component, θ_i, will be the so-called *subsistence minima*. The second will be a share, μ_i, of *supernumerary income*, Y^*, which is residual income after aggregate expenditures on the subsistence minima. Supernumerary income will be given by equation (16). Equation (17) will define household saving by residual. Equation (18) will define the depreciation allowance.

$$XAc_i = \theta_i + \frac{\mu_i Y^*}{\left(1+\tau_i^{itc}\right) PA_i} \tag{15}$$

$$Y^* = YD - \sum_j \left(1+\tau_j^{itc}\right) PA_j \theta_j \tag{16}$$

$$S^h = YD - \sum_i \left(1+\tau_i^{itc}\right) PA_i XAc_i \tag{17}$$

$$DeprY = P.DeprY_0 \tag{18}$$

2. Government

94. The volume of aggregate government expenditures, *XG*, will be fixed. The government will be assumed to have a CES expenditure function (potentially with zero elasticity). Equation (19) will determine the volume of aggregate government expenditures. Equation (20) will specify sectoral government demand, *XAg.* Equation (21) will determine the government expenditure price, *PG*.

$$XG = XG_0 \tag{19}$$

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[17] Exogenous transfers will be multiplied by a price index to insure model price homogeneity. The variable *P* is the GDP price deflator (at factor cost).

(20) $$XAg_i = \alpha_i^g \left(\frac{PG}{\left(1+\tau_i^{itg}\right)PA_i} \right)^{\sigma^g} XG$$

(21) $$PG = \left[\sum_i \alpha_i^g \left[\left(1+\tau_i^{itg}\right)PA_i\right]^{1-\sigma^g} \right]^{1/\left(1-\sigma^g\right)}$$

3. Investment

95. Investment will be determined by savings. The value of domestic investment will be identically equal to the value of domestic savings augmented by the level of foreign savings. The volume of aggregate investment will be given by *XI*, and the investment price deflator will be given by *PI*. Equation (22) will represent the investment-savings closure rule, with public savings given by S^g, foreign savings given by S^f, and the *ER* representing the exchange rate. It will be assumed that, like in the case of government expenditures, a CES expenditure function allocates aggregate investment into sectoral demand, *XAi*.

(22) $$PI.XI = S^h + S^g + ER.S^f + DeprY$$

(23) $$XAi_i = \alpha_i^i \left(\frac{PI}{\left(1+\tau_i^{iti}\right)PA_i} \right)^{\sigma^i} XI$$

(24) $$PI = \left[\sum_i \alpha_i^i \left[\left(1+\tau_i^{iti}\right)PA_i\right]^{1-\sigma^i} \right]^{1/\left(1-\sigma^i\right)}$$

1.1.10 C. Trade Volumes

96. The model will assume that there is a single Armington agent who allocates aggregate demand into two components: demand for goods produced domestically and imports. [18] Given the uniformity in preference, Armington demand will be aggregated across all domestic agents into a single variable, *XA*, which is allocated to domestic goods, XD^d, and to imports, *XM*. Equation (25) will determine aggregate Armington demand. Equation (26) will be the reduced form demand for domestic goods using a CES preference function with a substitution elasticity of σ^m. Equation (26) will determine the demand for imports. Finally, equation (27) will express the aggregate Armington price, *PA*, which is the CES aggregation of the domestic price, *PD*, and the tariff inclusive import price, *PM*.

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[18] The GTAP data set will allow implementation of agent-specific Armington preferences. This specification will significantly increase the dimensions of the model.

$$XA_i = \sum_j XAp_{ij} + XAc_i + XAg_i + XAi_i \quad \textbf{(25)}$$

$$XD_i^d = \alpha_i^d \left(\frac{PA_i}{PD_i} \right)^{\sigma_i^m} XA_i \quad \textbf{(26)}$$

$$XM_i = \alpha_i^m \left(\frac{PA_i}{PM_i} \right)^{\sigma_i^m} XA_i \quad \textbf{(27)}$$

$$PA_i = \left[\alpha_i^d PD_i^{1-\sigma_i^m} + \alpha_i^m PM_i^{1-\sigma_i^m} \right]^{1/\left(1-\sigma_i^m\right)} \quad \textbf{(28)}$$

97. The export supply decision will be treated in a symmetric fashion, using a CET transformation function. It will be assumed that a producer has the capacity to supply domestic and export markets, but the supply decision is constrained by a transformation frontier, where the transformation elasticity determines the degree to which suppliers can switch from one market to the other as a function of relative prices. At one extreme, the transformation elasticity is zero and the markets will be supplied in constant proportions of output. At the other extreme, the transformation elasticity is infinite, and suppliers can seamlessly switch from one market to the other. In the case of the latter, goods to each market are uniform and the law of one price holds. The equations below will be formulated for all possible cases.

98. With *XP* representing aggregate output, the component supplied to the domestic market will be XD^s, and the component allocated to foreign markets will be *ES*. Equations (29) and (30) will specify the allocation decision. When the transformation elasticity is finite, equations (29) and (30) will reflect the reduced form CET supply functions, where the transformation elasticity is given by σ^x. If the transformation elasticity is infinite, the supply functions will be replaced with the law-of-one-price conditions. Equation (31) will represent an equilibrium condition in both cases. In the case of finite transformation elasticity, aggregate supply will be equal to the aggregation of supply across both markets, using the CET aggregation function. Since it is equivalent to the CET revenue function (the CET dual), equation (31) will use the dual formulation (which tends to have better numerical properties).[19] With an infinite elasticity, aggregate supply will identically equal to the sum of supply to the individual markets.

[19] The CET primal expression will be given by the following formula:

$$XP_i = \left[g_i^d \left(XD_i^s \right)^{\nu_i} + g_i^e \left(ES_i \right)^{\nu_i} \right]^{1/\nu_i}$$

where the following relations hold:

$$\begin{cases} XD_i^s = \gamma_i^d \left(\dfrac{PD_i}{PP_i} \right)^{\sigma_i^x} XP_i & \text{if} \quad \sigma_i^x \neq \infty \\ PD_i = PP_i & \text{if} \quad \sigma_i^x = \infty \end{cases} \tag{29}$$

$$\begin{cases} ES_i = \gamma_i^e \left(\dfrac{PE_i}{PP_i} \right)^{\sigma_i^x} XP_i & \text{if} \quad \sigma_i^x \neq \infty \\ PE_i = PP_i & \text{if} \quad \sigma_i^x = \infty \end{cases} \tag{30}$$

$$\begin{cases} PP_i = \left[\gamma_i^d PD_i^{1+\sigma_i^x} + \gamma_i^e PE_i^{1+\sigma_i^x} \right]^{1/\left(1+\sigma_i^x\right)} & \text{if} \quad \sigma_i^x \neq \infty \\ XP_i = XD_i^s + ES_i & \text{if} \quad \sigma_i^x = \infty \end{cases} \tag{31}$$

99. Export demand will be allowed to respond to price signals, i.e. the small country assumption does not necessarily hold for export markets. Equation (32) will determine export demand, *ED*, using a constant elasticity demand function (with a demand elasticity of ε), where WPE^* represents a world price index which is exogenous, and *WPE* is the world export price of domestic exports, i.e. the FOB price (in international currency units). If the small country assumption holds, the world export price will be kept constant, and the world will be assumed to be able to absorb any quantity of exports at the given price.

$$\begin{cases} ED_i = \alpha_i^e \left(\dfrac{WPE_i^*}{WPE_i} \right)^{\varepsilon_i} & \text{if} \quad \varepsilon_i \neq \infty \\ WPE_i = WPE_i^* & \text{if} \quad \varepsilon_i = \infty \end{cases} \tag{32}$$

1.1.11

1.1.12 D. Trade Prices

100. World import prices, *WPM*, are given and are converted to domestic import prices, *PM*, using the exchange rate, *ER*, and applying the tariff rates, τ^m. World export prices will be determined by an equilibrium equation (see below) in the case of finite export demand elasticity, or are given otherwise. They are converted to domestic export prices using the exchange rate and adjusted for

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$\nu_i = \left(\sigma_i^x + 1\right)/\sigma_i^x \qquad \gamma_i^d = \left(g_i^d\right)^{-\sigma_i^x} \qquad \gamma_i^e = \left(g_i^e\right)^{-\sigma_i^x}$

export taxes/subsidies, τ^e (which are applied to the producer price, not the world price).

$$PM_i = ER\left(1+\tau_i^m\right)WPM_i \quad (33)$$

$$PE_i = ER.WPE_i/\left(1+\tau_i^e\right) \quad (34)$$

E. Goods equilibrium

101. There will be two goods market: the domestic market for domestic production and the export market.[20] The domestic price of domestic goods, *PD*, will be determined by the equilibrium expressed in equation (35). The world price of domestic exports will be determined by the equilibrium expressed in equation (36).[21]

$$XD_i^d = XD_i^s \quad (35)$$

$$ED_i = ES_i \quad (36)$$

1.1.13 F. Factor market equilibrium

102. There will be three factor markets, which will be dealt with separately. The labor market will be assumed to clear at the national level, with labor perfectly mobile across sectors. There will be a uniform wage rate that equilibrates supply and demand. Supply will be allowed to be a function of the real wage. The labor supply function will be given by equation (37), with a supply elasticity of ω^l. Equation (38) will determine the equilibrating wage rate.

[20] The small country assumption is assumed for imports, and thus there is no equilibrating price mechanism on this market.

[21] If the transformation elasticity is infinite, these equations will trivially set supply equal to demand, and the price will be determined via the law-of-one-price. If further, the small country assumption holds, all producer prices will equal the prevailing world export price (adjusted by the export tax/subsidy).In the case of infinite export demand elasticity, equation (36) will set world export demand equal to domestic export supply.

(37) $$L^s = \chi^l \left(\frac{W}{P}\right)^{\omega^l}$$

(38) $$L^s = \sum_i L_i^d$$

103. The capital market will be modeled using a CET supply allocation function. Aggregate capital will be allocated across sectors according to sector-specific real rates of return. Unless the transformation elasticity is infinite, the allocation will be imperfect and sectoral rates of return will not be uniform. In the extreme, with zero transformation elasticity, capital would be completely sector specific. Equation (39) will determine the aggregate capital stock, TK^s. Equation (40) will determine its sectoral allocation, K^s, using the reduced form CET supply functions. Equation (41) will determine the average rate of return, TR, using the CET dual price aggregator. With infinite elasticity of transformation, the law of one price will hold, and a uniform sectoral rate of return will be determined by the equilibrium condition. Equation (42) will determine the equilibrium rate of return specific to each sector. The transformation elasticity will be given by ω^k.

(39) $$TK^s = TK_0^s$$

(40) $$\begin{cases} K_i^s = \chi_i^k \left(\dfrac{R_i}{TR}\right)^{\omega^k} TK^s & \text{if} \quad \omega^k \neq \infty \\ R_i = TR & \text{if} \quad \omega^k = \infty \end{cases}$$

(41) $$\begin{cases} TR = \left[\sum_i \chi_i^k (R_i)^{1+\omega^k}\right]^{1/\left(1+\omega^k\right)} & \text{if} \quad \omega^k \neq \infty \\ TK^s = \sum_i K_i^d & \text{if} \quad \omega^k = \infty \end{cases}$$

(42) $$K_i^d = K_i^s$$

104. The sector specific factor will be modeled using a constant-elasticity-of-supply function (for each sector). Equation (43) will reflect sectoral supply, F^s. Equation (44) will be the equilibrium condition determining the equilibrating factor price, PF.

(43) $$F_i^s = \chi_i^f \left(\frac{PF_i}{P} \right)^{\omega_i^f}$$

(44) $$F_i^d = F_i^s$$

1.1.14 G. Closures

105. The model will permit two closures: investment-saving closure and fiscal closure. Investment-saving closure was discussed above. Fiscal closure will assume a fixed government fiscal balance, with the direct tax rate, k, adjusting to achieve the fiscal target. Government revenue will be given by three equations. The first, (45), will determine revenue generated by indirect taxes. The second, (46), will determine revenues generated by the trade distortions. The third will determine aggregate government revenues. Equation (47) will be the fiscal balance equation determining the value of government savings. Equation (48) will determine real government savings. Finally, equation (49) will reflect the fiscal closure rule.

11. SOURCES OF DATA FOR THE INITIAL VERSION OF THE MODEL

106. The CACGEM will be based on social accounting matrices (SAM) of the Central Asian countries and their trading partners, linked together through tables for bilateral trade flows. For the initial version of the model, SAMs of Kazakhstan, Kyrgyz Republic, Xinjiang Autonomous Region of PRC, rest of PRC, and Russian Federation for 2002 will be needed.

107. For Kazakhstan and Kyrgyz Republic, we will use the SAMs compiled as part of the ADB study on Central Asia regional cooperation in trade, transport and transit. For Russian Federation, we will rely on the SAM estimated by the Global Trade Analysis Project (GTAP) of Purdue University. This SAM details 58 production activities/commodities and trade flows for the same sectors with respect to PRC and the ROW. However, like other GTAP tables, the SAM of Russia is estimated for the year 2001. Hence, it will need to be updated to 2002 by non-survey methods. For PRC, a GTAP SAM for 2001 is available, but we have an independently estimated SAM with greater sectoral detail and more recent information. We also have an independently estimated SAM Xinjiang for 2002, which is at a comparable level of aggregation. This SAM will be extracted from the national PRC SAM to obtain a SAM of the rest of PRC.

108. The sectoring schemes in all of these SAMs will be harmonized, using imputation methods, to achieve the highest common level of structural detail. To see how the sectors conform across the SAMs, consider the examples given in the following tables. Table 1 shows the GTAP sectoring scheme that applies to Russia and (in one case) to China. Table 2 is the sectoring scheme for the existing Kazakhstan SAM, followed in Table 3 by that of the Kyrgyz Republic. It is clear that these differing schemes pose challenges. GTAP, for example, has more detail in agriculture, while the other two standards have more detail in light manufacturing and services. All these activities are important, but our ability to include higher levels of detail in the multi-country dataset will be constrained by data on interactions among the detailed sectors.

109. Using a combination of secondary data sources and non-survey estimation techniques, we are planning a synthesis aggregation of about 40 sectors that will be comparable across the countries/part of PRC included in the model and the ROW. We will do so with the existing data constraints in mind, but also with a careful eye on the sector/commodity groups most relevant to the Central Asian countries. These will include not only the sectors/commodity groups in which Central Asian countries have revealed comparative advantages (such as energy and agriculture), but also sectors/commodity groups in which Central Asian countries may have comparative advantages (such as textiles and other light industries).

110. Trade flows among the countries/part of PRC included in the model and the ROW will be estimated by reconciling a variety of sources, including GTAP, national trade statistics by origin and destination, and the COMTRADE multilateral trade database maintained by the UN. Taking all these sources together, we will calibrate base year regional trade flows with respect to the common sectoring scheme.

B. Emissions

111. The CARGO dynamic CGE model model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g. appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity of the inputs used for the activity in question. We model both CO2 and the other primary greenhouse gases, which are converted

to CO2 equivalent. Following standards set in the research literature, emissions in production are modeled as factors inputs. The base version of the model does not have a full representation of emission reduction or abatement. Emissions abatement occurs by substituting additional labor or capital for emissions when an emissions tax is applied. This is an accepted modeling practice, although in specific instances it may either understate or overstate actual emissions reduction potential.[22] In this framework, emission levels have an underlying monotone relationship with production levels, but can be reduced by increasing use of other, productive factors such as capital and labor. The latter represent investments in lower intensity technologies, process cleaning activities, etc. An overall calibration procedure fits observed intensity levels to baseline activity and other factor/resource use levels..

Table A.1 : Emission Categories

Air Pollutants			
	1.	Suspended particulates	PART
	2.	Sulfur dioxide (SO_2)	SO2
	3.	Nitrogen dioxide (NO_2)	NO2
	4.	Volatile organic compounds	VOC
	5.	Carbon monoxide (CO)	CO
	6.	Toxic air index	TOXAIR
	7.	Biological air index	BIOAIR
	8.	Carbon Dioxide (CO_2)	
Water Pollutants			
	8.	Biochemical oxygen demand	BOD
	9.	Total suspended solids	TSS
	10.	Toxic water index	TOXWAT
	11.	Biological water index	BIOWAT
Land Pollutants			
	12.	Toxic land index	TOXSOL
	13.	Biological land index	BIOSOL

112. The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in Table A1.1. Our focus in the current study is the emission of CO2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues.

113. An essential characteristic of the CARGO dynamic model's approach to emissions modeling is endogeneity, i.e. emission rates vary with bevioral decisions about fuel mix and efficiency (technology adoption and use). This feature is essential to capture structural adjustments arising from market based

[22] See e.g. Babiker et al (2001) for details on a standard implementation of this approach.

climate policies such as Pigouvian taxes or cap and trade, as well as the effects of technological change.

Table A.2: Fully Detailed GTAP 8 Sectoring Scheme

	GTAP Label	Sectors/Commodities Definition
1	pdr	Paddy rice
2	wht	Wheat
3	gro	Cereal grains, n.e.s.
4	v_f	Vegetables and fruits
5	osd	Oil seeds
6	c_b	Sugar cane and sugar beet
7	pfb	Plant-based fibers
8	ocr	Crops, n.e.s.
9	ctl	Bovine cattle, sheep and goats, horses
10	oap	Animal products n.e.s.
11	rmk	Raw milk
12	wol	Wool, silk-worm cocoons
13	frs	Forestry
14	fsh	Fishing
15	coa	Coal
16	oil	Oil
17	gas	Gas
18	omn	Minerals n.e.s.
19	cmt	Bovine cattle, sheep and goat, horse meat products
20	omt	Meat products n.e.s.
21	vol	Vegetable oils and fats
22	mil	Dairy products
23	pcr	Processed rice
24	sgr	Sugar
25	ofd	Food products n.e.s.
26	b_t	Beverages and tobacco products
27	tex	Textiles
28	wap	Wearing apparel
29	lea	Leather products
30	lum	Wood products
31	ppp	Paper products, publishing
32	p_c	Petroleum, coal products
33	crp	Chemical, rubber, plastic products
34	nmm	Mineral products n.e.s.
35	i_s	Ferrous metals
36	nfm	Metals n.e.s.
37	fmp	Metal products
38	mvh	Motor vehicles and parts
39	otn	Transport equipment n.e.s.
40	ele	Electronic equipment
41	ome	Machinery and equipment n.e.s.
42	omf	Manufactures n.e.s.
43	ely	Electricity
44	gdt	Gas manufacture, distribution
45	wtr	Water
46	cns	Construction
47	trd	Trade
48	otp	Transport n.e.s.
49	wtp	Sea transport
50	atp	Air transport
51	cmn	Communication
52	ofi	Financial services n.e.s.
53	isr	Insurance
54	obs	Business services n.e.s.
55	ros	Recreation and other services
56	osg	Public administration and defense, education, health services
57	dwe	Dwellings
58	cgds	Investment goods