Transformational development projects and water resources in drylands

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PRISE

Pathways to resilience in semi-arid economies

Research for climate-resilient futures

Transformational development projects and water resources in drylands

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Acronyms

CPEC	China–Pakistan Economic Corridor
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FATA	Federally Administered Tribal Areas
GDP	Gross Domestic Product
NGO	Non-Governmental Organisation

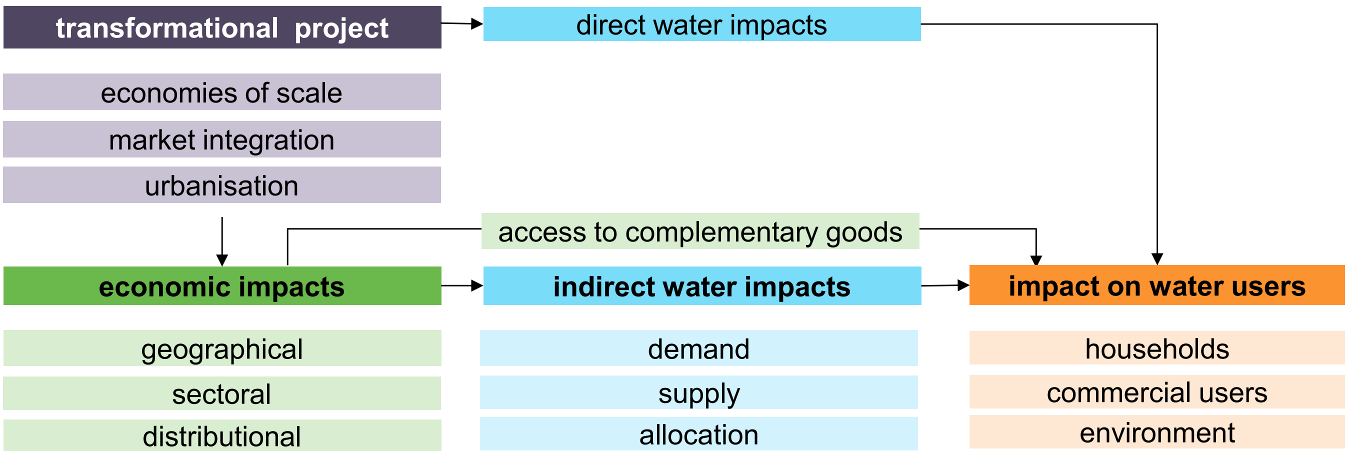
Executive summary

This study frames the ways in which transformational infrastructure programmes can affect water availability for different users in semiarid and arid regions of the world. The analysis draws out critical challenges associated with managing these impacts, and reviews these challenges and the associated policy response in the case of the ongoing China-Pakistan Economic Corridor (CPEC) project.

Transformational infrastructure projects aim to cause a step change in economic activity that can indirectly affect water availability. The economic rationale for a transformational project is to create the conditions for further investment. This can very rapidly shift the geographical, sectoral, and distributional characteristics of the economy, in particular by spurring urbanisation and industrialisation. Economic transition in turn causes shifts in water demand and supply conditions and can alter the way in which allocation between users is determined – shifts that are termed 'indirect water impacts' in this study.

These indirect water impacts pose particular risks for the poor and the environment. While the economic transition supported by transformational infrastructure programmes can have many positive implications, these indirect water impacts may negatively influence users' welfare – and the greatest risks will tend to be in arid and semi-arid regions where water is already typically scarce. The poor and the environment are likely to be particularly vulnerable, especially where policy making capacity is weak. Figure 1 below illustrates the pathways by which transformational projects impact on water users.

Figure 1: Transformational projects affect water users directly and indirectly as a result of shifts in economic activity



Source: Vivid Economics

The effective management of these impacts poses four critical challenges for planners, and experience highlights the pitfalls associated with failing to meet them. Planning challenges are greatest where the government cannot rely on private sector adjustment to produce a satisfactory outcome, but where policy intervention is also fraught with difficulty. This study finds the four areas of greatest challenge associated with managing the indirect water impacts to be:

- managing uncertainty so water users do not bear too much risk and cost savings from flexible approaches are realised where possible;
- planning necessary water infrastructure to accommodate the shifts in water demand and supply, in particular identifying and exploiting savings from coordination with the wider programme and opportunities for beneficiaries to fund water resource infrastructure;

- allocating water between users efficiently throughout the lifetime of the project to avoid investors locking in water-inefficient technology in industry and agriculture and protect ecosystems from irreversible collapse;
- protecting the poor, who may stand to gain considerably from transformational projects, but who nonetheless are most vulnerable to loss of water access, particularly where economic development moves ahead of policy responses.

A review of a generic planning process shows that the scoping, option refinement, impact analysis, and follow-up phases of project development are most important in responding to these challenges.

CPEC is a transformational project that promises to greatly improve Pakistan's economic performance and reduce poverty. It comprises a $46bn programme of infrastructure designed to address severe energy shortages through new power generation capacity and to increasing trading opportunities through transport corridors that traverse the length of Pakistan. It holds the promise of unlocking investment in some of Pakistan's least developed regions, including Balochistan, Gilgit Baltistan and the Federally Administered Tribal Areas (FATA), and alleviating poverty in some of its largest cities. The project includes investment in coal, solar, wind and hydropower to add 10,000 megawatts of electricity generating capacity by 2020. Transport projects under CPEC aim to improve existing infrastructure, such as the Karakoram Highway and Pakistan's railway system, as well as to develop new transit links.

The project's implications for water availability are significant. Pakistan is currently a highly water stressed country facing population growth and climate change impacts that are expected to lead it to absolute water scarcity by 2035. Much of the economic development from CPEC is set to be concentrated in its driest regions in the south and west of the country, notably including the port of Gwadar, and in cities that lack sufficient water supply infrastructure, especially for the poor.

This study highlights a number of areas where Pakistani authorities could more effectively meet the four critical challenges above. Considering each in turn:

- efforts to manage uncertainty are hampered by a lack of data, and policy makers have not approached the problems of managing risk and valuing flexibility in a formal manner;
- institutions to deliver water infrastructure are improving with the establishment of regional water planning boards, but coordination with CPEC plans appears to be reactive. Plans to expand water supply infrastructure in Gwadar do not fully address the supply-demand imbalance that CPEC will cause and possible opportunities to fund infrastructure through investor contributions do not appear to have been explored;
- on water allocation, a policy architecture for effective user tariffs exists but does not extend to water discharges or groundwater, and there is no evidence that tariffs or the monitoring and enforcement mechanisms that support them are to be revised or strengthened in advance of the effects of CPEC;
- though they may be expected to benefit from CPEC, the poor generally lack representation in infrastructure planning in Pakistan, which can cause initiatives designed to protect their interests to be unsuccessful. The experience of infrastructure development in FATA, which will be a focus of CPEC investment but where the poor have little role in shaping policy, is of particular concern.

The work presented here is intended as a starting point for further research and open questions remain over how best to meet the four challenges set out in the study. This study presents an analytical framework that allows challenges to be articulated, but does not consider in detail how the process of meeting these challenges can be integrated into a planning process or what trade-offs might be involved in doing so. It also leaves open the question of what the correct policy responses to these challenges might be, and how choices depends on local circumstances including the nature of the wider transformational programme;

A better understanding of what Pakistani officials should do to address current shortcomings in managing CPEC's water impacts could be very valuable. The CPEC case study offers insights into critical areas where policy improvements are possible. Given the size of the programme and its prospective impact on the livelihoods of many of Pakistan's poorest communities, there is considerable value in exploring these questions in more detail. Studies might investigate how Pakistan could adapt its water management practices so they are better aligned with CPEC or consider how CPEC itself might be better coordinated with these efforts.

1. Introduction

1.1. Motivation and aim

Transformational development projects are investment programmes designed to induce a step change in economic development within a region. They are typically designed to exploit scale or network effects, allowing them to greatly reduce the cost of various forms of production, investment, trade and resource extraction. These projects therefore aim to catalyse activity across a range of sectors, which can lead to a change in the local development trajectory, particularly through facilitating urbanisation and industrialisation (see, for example, Calderon & Serven, 2004). **In recent years, a number of such projects have been proposed and developed**, such as the Lamu Corridor programme (LAPPSET) in Kenya or the Addis Ababa – Djibouti Railway. Such programmes cover a variety of sectors, including transport, energy, agriculture, and urban development.

The water impacts of transformational projects can be particularly substantial in drylands, but these impacts are not currently well understood by practitioners. One potentially important impact of transformational projects, particularly in arid or semi-arid regions where water is likely to be scarce, is on the water available for different users. Projects may affect water supply, water demand and the way it is allocated between users. The poor are likely to be particularly vulnerable. But at present there is little research on what these effects might be, how they are managed, and how this management might be improved, even as the importance of these issues increases with the parallel impacts of climate change and rapid population growth on water availability in many of these regions (Gosling & Arnell, 2013; IPCC, 2014). This study focuses on improving the understanding of two questions:

- first, how transformational projects in arid and semi-arid regions may affect water availability, and in particular on how this can shape outcomes for the poor;
- second, how these impacts can be managed through planning, and how this compares to current practice.

1.2 Scope and methodology

This study meets the aims set out above by providing the following outputs:

- an analytical framework to help planners understand and manage the critical water resource challenges that transformational projects in arid regions can present, with a particular focus on outcomes for the poor;
- a case study that puts the framework to use by demonstrating how these challenges arise in the China-Pakistan Economic Corridor (CPEC) project, with an assessment of the response by policymakers; and
- an agenda for further research and capacity building to improve the practice of project planning, evaluation, and financing as it applies to this topic.

The study methodology included literature reviews, expert interviews, and field work. The analytical framework was developed drawing on a literature review and the authors own expertise in water-resource management. The CPEC case study drew on a review of publically available literature and fieldwork and policymaker interviews in Pakistan.

1.3 Report structure

This report presents the findings of the study. The remainder of it is structured as follows:

- Section 2 introduces transformational development projects and frames the ways in which they can spur economic development and consequently affect water availability;
- Section 3 draws out four critical challenges this poses for planners and policymakers, and briefly reviews how these might be addressed in a representative planning framework;
- Section 4 presents the evidence from a case study on CPEC, considering how the challenges identified in Section 3 apply to this project and how Pakistani authorities have attempted to meet these;
- Section 5 concludes with a suggested agenda for further research and policy development in this field.

2. Transformational projects: economic rationale and water-resource impacts

Transformational projects can cause rapid changes in the structure of a region's economy, which in turn can radically affect water availability for different users. Transformational projects are infrastructure programmes designed to create the conditions for substantial further investment. This investment can produce a step-change in the geographical, sectoral, and distributional characteristics of the economy, in particular by spurring urbanisation and industrialisation. In turn, this economic transition causes shifts in water demand and supply conditions as well as the way in which allocation between users is determined. This section introduces transformational projects, explains their economic rationale and impact, and how this can affect water availability.

2.1 Transformational projects

Transformational development projects are infrastructure investment programmes distinguished by their size and their aim of inducing a step change in a region's economy. This study defines a transformational development project as a large programme of infrastructure investment designed to induce a step change in the level of economic development within a region through activity in a wide range of sectors. Two distinctive features of a transformational project are:

- the large size of the capital outlay, where 'large' in this sense is relative to the region's current economy;
- the importance, in the business case for the project, of the step change in the pattern of economic activity caused by the project. In other words, the societal gains from the project are expected to be largely derived from the economic transformation it causes.

Transformational projects tend to rely on public funding and finance. As the benefits of transformational projects are spread across the economy, it may be efficient and equitable to fund at least some portion of the project through general taxation as opposed to charges for infrastructure users (Laffont & Tirole, 1993). There are obstacles to financing large projects privately, especially in developing countries where financial markets lack capacity and future government funding may not be regarded as secure. As a consequence, it is typically cheaper to finance projects through government borrowing, sometimes with assistance from international donors or international financial institutions (World Bank Group, 2015).

This means the public sector usually leads the planning and development of transformational projects. Though planning tasks may be outsourced to the private sector or NGOs, and various stakeholders may be consulted, ultimate control of the decision-making process typically resides with the government.

2.2 Economic rationale and impacts

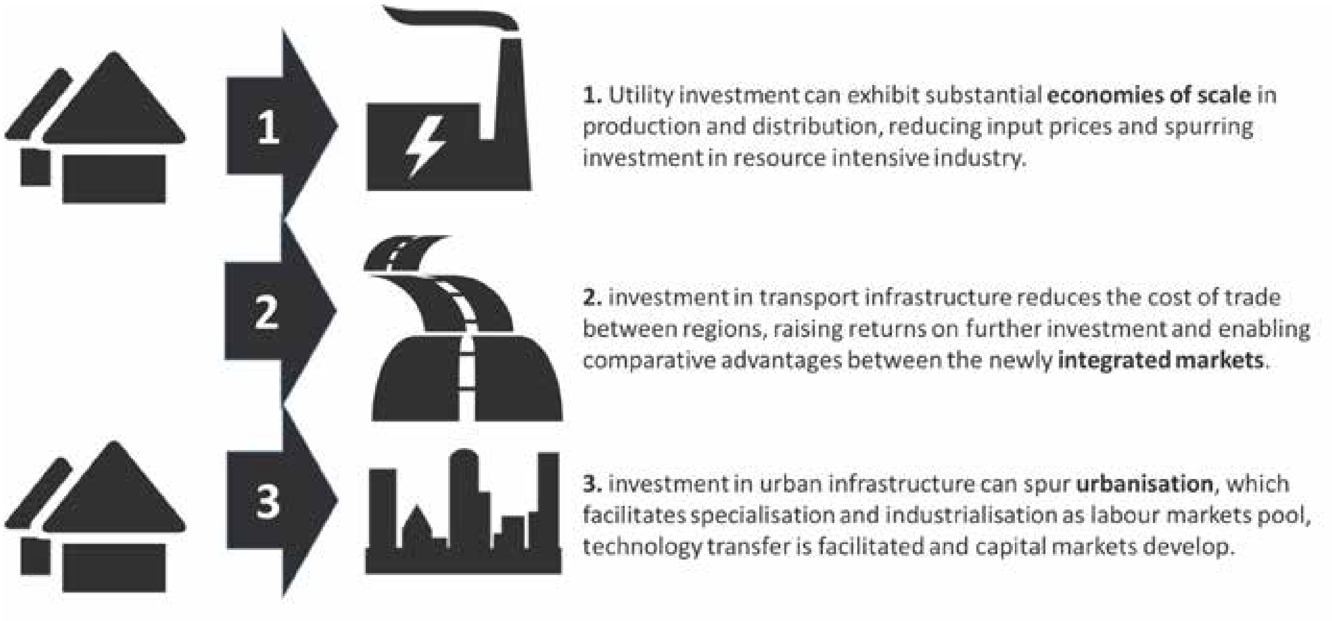
The economic case for a transformational project may rely on economies of scale, market integration, or urbanisation. This study considers three pathways through which a project might engender an economic transformation, though the business case for any given project may cite more than one of these as rationales.

Projects can exploit scale economies to spur investment in other sectors. Many utility industries exhibit substantial economies of scale in production (Pollitt & Steer, 2012): for example, a large power plant or dam may produce cheaper electricity per megawatt hour than a small one. If savings in unit costs from economies of scale are reflected in the prices charged to users, this can spur an economic step change by making activity in sectors using these inputs profitable where previously it was not. Energy intensive industry or water intensive agriculture may be made viable by projects that greatly reduce the cost of producing energy or water.

Projects can integrate markets, promoting trade and investment. Investment in infrastructure, particularly in transport and communication, can reduce the cost of trade between a region and the rest of the world. This can increase the regional economy's value by allowing it to concentrate production in areas of comparative advantage and to invest in larger, more efficient production to serve a wider market (Yeaple & Golub, 2007).

Projects can promote urbanisation. Investment in urban infrastructure or public services such as transport, water supply, sewerage, health or education can increase the productivity and quality of life of city dwellers. This spurs urbanisation, which can increase the region's productivity through agglomeration effects: allowing cities to develop specialised industries that rely on pools of skilled labour, technological know-how and capital-market expertise (Kugelman, 2014). Figure 2 below illustrates the three pathways with examples of transformational projects.

Figure 2: Three pathways by which infrastructure induces transformation



Source: Vivid Economics

Transformational projects are designed to increase overall economic activity, but the nature of the economic impacts can vary widely. As noted in Section 2.1, transformational projects can include investment across a wide range of sectors, so their economic impacts can be correspondingly eclectic. In general, the economic impact brought about by the project will depend on the nature of the project, the region's factor endowments relative to trading partners, and policies governing investment type, all of which determine the amount and type of activity unlocked by the transformational project.

The different economic impacts from a transformational project can be distinguished along three dimensions. Following Tarazona, Chiappe, & Hearle (2014), one can conceive of economic impacts of a transformational project along three dimensions:

- geographical: transformational projects are likely to change the geographical distribution of activity within a region, particularly the balance between production in urban and rural areas. Projects may also shift the balance of economic activity between a region and elsewhere, including by encouraging inward migration towards the region.
- sectoral: within any given sector, transformational projects will tend to change:
  - what is produced, as the region trades more and develops more specialised production, for example in export oriented agriculture;
  - how it is produced, as larger, integrated markets facilitate more capital-intensive methods of production. Less labour intensive production in agriculture may reinforce the geographical shift of the economy to urban centres;
  - the degree of competition in a sector, which increases as markets integrate. This will spur innovation in productive techniques, and thus add to changes in how production is organised. Projects are also likely to change the balance of production between sectors, as the region's economy urbanises and industrialises. Notably, agriculture will form a smaller proportion of national income, which will tend to reduce the economy's overall resource intensity (Jones et al., 2014).

- distributional: the economic impacts of a project are likely to be spread unevenly. Different groups will experience different changes in income, reflecting shifts in the return on labour and capital and changes in the degree of competition in these market. Groups may also experience changes in access to public and environmental services, particularly as regions urbanise, and changes in the distribution of political power and representation associated with economic changes. It should be emphasised that these impacts may be negative and, for reasons explored in Section 3, the poor and the environment are likely to be most vulnerable.

2.3 Effects on water resources and users

Step changes in economic activity can lead to step changes in water availability. Many infrastructure projects have direct effects on the availability water for different users. For example, a new coal power plant will increase water demand for cooling, while a new dam may raise supply by providing storage. However, this study focuses on the indirect effects of projects on water availability, which stem from the economic transformation sought by the project.

These issues are of particular importance in arid or semi-arid regions. There is water scarcity when the total supply of water available for use is less than the total demand for water when it is made freely available to users, including the environment. Changes in water availability in water scarce areas, which are more prevalent in arid and semi-arid regions, are therefore most likely to affect the wellbeing of users by changing the quantity of water available to them.

Transformational projects affect water availability through indirect impacts on water supply, demand, and the way in which water is allocated between users. The quantity, quality, and security of the water available to any user depends on:

- the total demand from all users,
- the total supply of water, and
- the allocation mechanism that matches the supply and demand for water. This might be a market, a form of centrally planned allocation, informal or unmanaged allocation, or some hybrid of these.

Large shifts in the pattern of economic activity can affect all of these factors.

Water demand will follow the geographic and sectoral shifts in economic development. Rising production caused by a transformational project will generally increase the demand for water. There may be larger localised shifts in demand, which will tend to follow the geographic and sectoral changes in the make-up of the economy described above. Urbanisation and industrialisation, in particular, may lead to sharp increases in demand for both the quantity and quality of water in cities, as more clean water is sought for public use.

Changes in water supply are largely contingent on policies. Rapid economic development facilitated by transformational investments will increase water supply to the extent that the proceeds of growth are re-invested in supply infrastructure. This will depend on the policies and institutions in place to fund and deliver this infrastructure. Alternatively, rapid development may reduce effective water supply if it leads to increased water pollution by cities, factories or farmers. Again, this will largely hinge on policies, including the regulation of effluents and investment in wastewater infrastructure.

Economic impacts may create pressure to change the way water is allocated between users. All three dimensions of economic impact set out in Section 2.2 are relevant here.

- geographical changes in economic activity, including rapid increases in water demand in urban centres, may introduce or greatly exacerbate localised water scarcity. In settings where informal or unmanaged allocation had previously acceptably met users' needs, water scarcity may create pressure to introduce more formal approaches to allocate water, as users seek more reliable supplies.
- sectoral changes, such as industrialisation and the development of commercial agriculture, may create user groups with very substantial economic interests in water with the ability to lobby effectively for improved access to resources or rights to pollute water courses. Where these groups emerge rapidly as a result of a transformational project, there is a risk that resistance to their demands from policymakers or other competing users may be less effective.

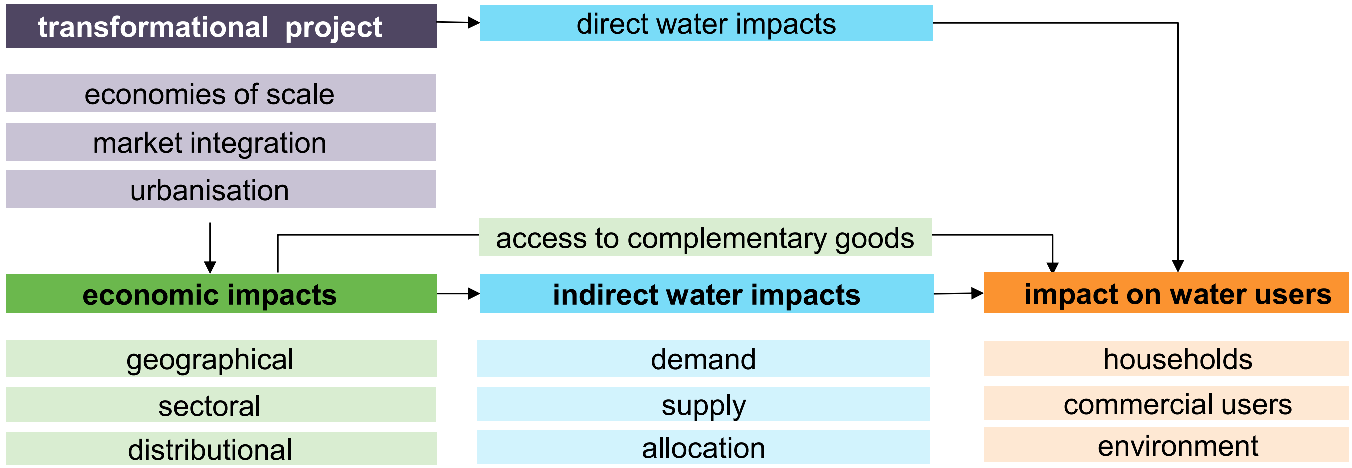
- distributional changes resulting from a project may also affect the way water is allocated, with groups that gain economic power as a result of the project becoming better able to influence policy on water. Where markets for water are used, the way in which water is allocated may remain stable, but the division of water between different users will follow shifts in purchasing power.

The impact on users from changes in water availability will also depends on the availability of complementary goods. The overall effect on any given user from the water resource impacts described above will depend not only on changes to the quantity, quality and security of water available to the user, but also on the user's access to complementary goods that affect the value of water. For households, an example of such a good is healthcare, which may reduce the adverse effects of low water quality; for commercial users the value of water, and hence the impact of changes in its availability, will depend a range of other factors that affect productivity, such as access to capital and skilled labour.

2.4 Summary

Figure 3 below summarises the analytical framework set out in this section.

Figure 3: Transformational projects affect water users directly and indirectly as a result of shifts in economic activity



Source: Vivid Economics

3. Challenges in managing water resource impacts

The water impacts of transformational projects present planners with formidable challenges. These are most acute where the planner cannot rely on private sector adjustment to mitigate impacts and where the government's capacity to intervene is compromised. Four areas that are likely to be problematic in this regard are managing uncertainty, planning and financing water infrastructure, allocating water between users, and protecting the poor. This section explains the nature of these four critical challenges, before briefly considering how they arise in a representative decision making framework.

3.1 Four critical challenges

While transformational projects offer great economic and development promise, they are also highly challenging undertakings for all governments, including those in developing countries. As Section 2.1 explains, it typically falls to governments to lead the planning and financing of transformational development projects: this requires undertaking a series of activities that can be particularly challenging for developing countries. Public sector bodies may lack the requisite project management and procurement capacity for large infrastructure programmes, which may be exacerbated by concerns around corruption, while financing costs can be high where governments lack access to international markets. These challenges can be exacerbated by risks such as uncertain input costs and unforeseen engineering difficulties, which make the difficulties associated with project planning and finance even more formidable.

Managing water resource impacts are a further dimension of this wider challenge. The shifts in water demand, water supply and allocation mechanisms that can be precipitated by a transformational infrastructure project can have profound impacts on the users of water, including the environment. As noted in Section 2.3, the importance of this is greatest in arid or semi-arid regions where water resource impacts are most likely to lead to water scarcity.

The challenges are greatest where markets cannot be relied upon to produce desirable outcomes and where government capacity to intervene is most likely to be found wanting. 'Market failures' occur where self-interested supply and demand decisions lead to inefficient outcomes; and even where markets are efficient, outcomes may have unacceptable properties, notably on equity or access to essential services. Where a transformational project substantially impacts on an area where market outcomes are liable to be undesirable, planners cannot rely on private sector adjustment and may thus need to intervene correctively. However, in many areas of policy there are significant risks of 'government failure', where interventions by policymakers fail to address or even exacerbate the problems they target (Datta-Chaudhuri, 1990).

This study identifies four areas where the challenges involved in managing water resource impacts are associated with transformational projects likely to be most acute. All of the challenges involve from market and government failures, and experience elsewhere highlight significant pitfalls associated with ineffective policy making. The four areas are:

- managing uncertainty;
- planning and financing water infrastructure;
- allocating water between users; and
- protecting the poor.

Table 1 provides a summary of the challenges and potential pitfalls that arise in each of these areas. Sections 3.1.1-3.1.4 examine these in more detail.

Table 1: Challenges for managing impacts on water users stem from market and government failures

Area	Relevant market problems	Potential government failure	Pitfalls	Selected examples
Planning under uncertainty	Financial market failures	Lack of data Lack of planning capacity	Not accounting for water impacts Excessive risk and inefficient risk sharing Inflexible plans	Lack of adaptive water planning worldwide
Water infrastructure planning	Natural monopoly for infrastructure	Lack of data Lack of planning capacity Inefficient funding arrangements	High-cost of infrastructure Low levels of service	Egypt – New Valley Project China – infrastructure planning India – cost recovery
Water allocation	Tragedy of the commons	Lack of data Exposure to lobbying	Loss of economic value Environmental system collapse	Ethiopia – Awash Basin Pakistan – Kuchlagh Aquifer
Protecting the poor	Access to essential services Financial market failures	Poor lack representation Lack of data	Increased poverty and inequality Poor bear risks	China – Three Gorges Dam, 1993

Source: Vivid Economics

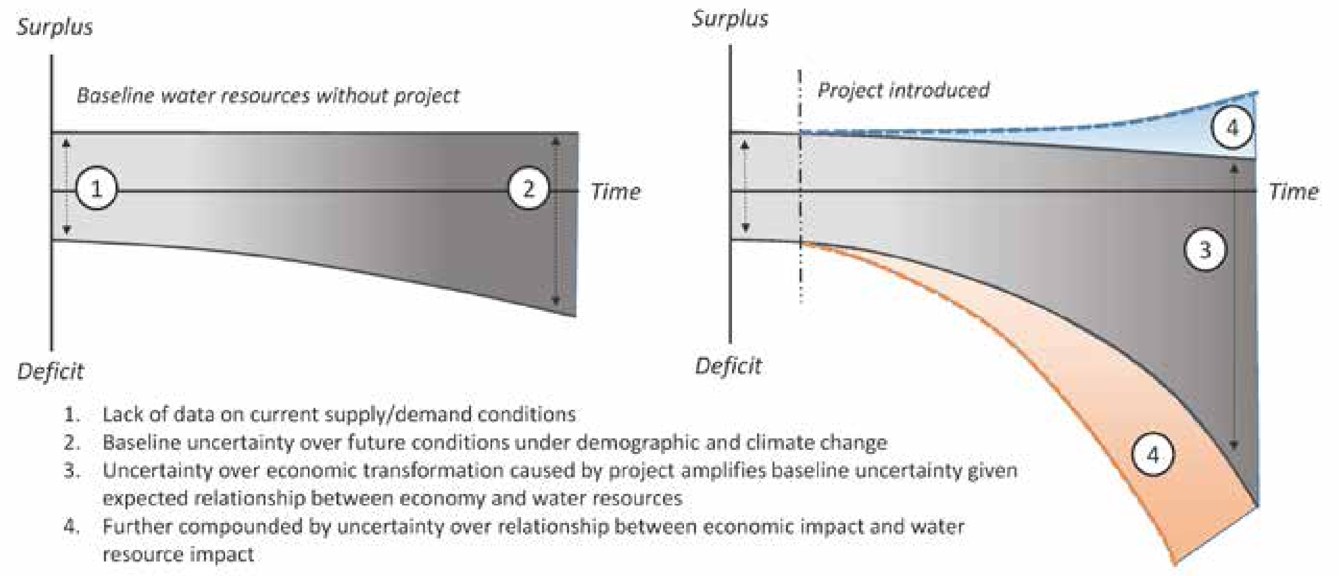
3.1.1 Uncertainty

Uncertainty is a pervasive feature of the general challenge of managing water resource impacts. It features in planners' problems at a number of levels:

- baseline uncertainty surrounding the trajectories of water supply and demand in the absence of the transformational project, which is likely to be exacerbated by limited data availability;
- uncertainty over future supply and demand conditions. This includes uncertainty over the effect of demographic change on water demand and the effects of climate change on water supply, both of which, in many geographies, are likely to be severe in the medium term (Jones et al., 2014);
- uncertainty over the economic impacts of the project. As explained in Section 2.2, the case for a transformational project relies on it creating conditions for further investment by third parties. Specific forecasts on the geographical, sectoral, and distributional details of economic impacts are thus likely to be subject to very substantial uncertainty; and
- uncertainty over the relationship between the economic impacts of a transformational project and the changes it can have on water supply, demand and water allocation mechanisms. Among other factors, this will depend on how demand is determined by technologies chosen by investors, over which there is substantial uncertainty, and the relationship between water management policies pursued by the government and the supply and demand for water. Future migration patterns reflecting urbanisation brought about by the project will be an important determinant of local water demand, but the scale and timing of these will inevitably be uncertain (Skeldon, 2013).

Figure 4 depicts how a transformational project may substantially increase uncertainty over future water resource scarcity.

Figure 4: Transformational projects are likely to substantially compound existing uncertainty over water resource availability



Source: Vivid Economics

Uncertainty affects the risks borne by water users, which cannot be fully managed in financial markets. Users may wish to insure themselves against risks related to water resource impacts of projects, but most users, notably the poor, will not be able to access insurance policies at actuarially fair prices (Clarke & Dercon, 2009) and the environment will always be unable to insure itself.

Limits to technical capacity and data availability prevent planners from efficiently managing risks on behalf of water users. Planning frameworks have been developed to implement sophisticated models of decision making under uncertainty, but their use requires advanced technical capacity that developing countries' public sectors may not be able to access. Even in developed countries, the use of advanced evaluation methods such as real options and robust decision making are underdeveloped in water resource planning (UKWIR, 2002). More fundamentally, planners are very likely to lack the data required to operationalise these approaches, which includes long-run forecasts for and sensitivities around supply and demand.

Governments struggle to implement strategic plans that respond to uncertainty. Given the degree of uncertainty surrounding water resource impacts, the optimal management of these impacts is likely to involve the use of strategic, flexible pathways, where plans are adapted as more information on supply and demand conditions becomes apparent (Jones et al., 2014). However, countries that do not collect data on water supply and demand will not be able to regularly update the information they have available and will therefore be unable to implement these strategies. Even where reliable data is available, the adoption of a pathway can entail a commitment to construct infrastructure under certain conditions in the future: a commitment many countries will lack the institutional and financial capability to make. Section 3.1.2 below expands on this latter point.

Not taking water-resource uncertainty into account can raise costs and risks. The pitfalls associated with failing to account for uncertainty around water resource impacts include:

- higher costs as inflexible approaches are adopted that do not make use of information as it becomes available. This is widespread in the developing work;
- insufficiently precautionary approaches that expose users to too much risk. Again, failure to protect users from risk resulting from underinvestment in water resource infrastructure is common across the developing world (Hall & Lobina, 2006);
- solutions that fail to share risks between different groups of users efficiently or equitably. The poor are likely to require particular protection (see Section 3.1.4), as does the environment where ecosystems are vulnerable to irreversible collapse if water availability falls below a certain threshold (Atkinson, Neumayer, & Dietz, 2007).

Uncertainty accentuates the challenges governments face in planning water infrastructure, allocating water between users and managing impacts on the poor. All of the above concerns apply to the planning problems described in more detail in Sections 3.1.2-3.1.4 below.

3.1.2 Infrastructure planning and finance

New water infrastructure is very likely to be needed as part of a transformational programme. The various changes described in Section 2.3 will affect the balance of supply and demand and are thus liable to lead to scarcity in certain locations, particularly in arid regions. New public water supply infrastructure may be needed in growing cities, sewer networks and wastewater treatment facilities may be required to accommodate urbanisation and industrialisation, and new storage reservoirs may be needed as agricultural production expands or shifts towards more water intensive crops.

In almost all cases, water infrastructure is a natural monopoly that the market is not suited to provide. As with transformational projects themselves, the government and public sector agencies are thus required to lead, or at least regulate, the development of this water infrastructure.

Data and technical capacity limit developing-country public sectors' ability to efficiently plan water infrastructure needed in a transformational programme. As explained in Section 3.1.1, planning is complicated by baseline uncertainty over the capacity of existing water supply assets and the demand from local populations, for which census data may be unavailable or unreliable, and businesses, many of which may be unregistered. The technical challenge of planning water infrastructure is complicated by factors including:

- the need to coordinate the development of water infrastructure with other aspects of the transformational programme. For example, there may be significant savings from designing a dam that produces hydro energy so that it also provides water to the local supply system at the right level of security. Such coordination can be problematic where there are multiple public sector agencies, potentially from multiple countries, with responsibilities for different aspects of the programmes;
- the need for long-term planning in water supply. Water infrastructure is characterised by significant economies of scale (Wenban-Smith, 2009), meaning it is often less costly to develop capacity to meet long-term needs rather than building it incrementally. However, planners may lack reliable data on future demand and supply or the capacity to use this data to scope efficient infrastructure programmes; and
- the need for flexible planning in the face of substantial uncertainty surrounding the economic impacts of transformational projects, as set out in Section 3.1.1 above. Where there are also economies of scale in building infrastructure, there may be trade-offs between realising these and maintaining flexibility.

Self-funding utilities may reduce the costs of delivering infrastructure. Though the public sector will own or at least regulate water utilities, structures that promote utilities' independence from government will tend to improve their capacity to plan effectively over the long term. Such structures might mandates to recover costs directly through user tariffs, rather than from central government revenues. In urban areas in particular, there may be significant savings from setting up independent water utilities with access to finance to pay for new infrastructure. This reflects two features of the economic impacts of transformational projects: rapid urbanisation, which requires up-front expenditure on new infrastructure to meet long-term needs; and uncertainty, which demands a flexible approach to infrastructure development, and thus reliable access to finance over a period of time.

However, such bodies can sometimes be difficult to establish. Reliable access to finance requires reliable access to funding, which for water utilities would include user tariffs, connection charges, fines and penalties. However, self-funding water utilities face a variety of obstacles, including: a lack of capacity to prevent illegal access to networks or illegal self-supply through unauthorised private wells; a lack of capacity to enforce tariffs; and the reliance on government guarantees to lower borrowing costs (McRae, 2015; Rodriguez, Van Den Berg, & McMahon, 2012). As a consequence, many water utilities are financed directly by central or local governments that lack a focus on efficiently delivering infrastructure in the long run (Rodriguez et al., 2012). More generally, the lack of stable funding this implies can be inimical to developing planning capacity.

A reliance on central government funding can raise costs and miss one-off opportunities for beneficiaries to contribute. In general, raising funds through taxation often creates greater economic distortions than user fees (Laffont & Tirole, 1993; Rouse, 2007). Furthermore, there may be greater scope to ask users who benefit from water infrastructure – perhaps particularly large commercial users – to contribute towards this infrastructure as it is developed, rather than after it has been installed. Transformational development projects, where development is rapid, may thus face a limited window of opportunity to substantially reduce costs to general taxpayers.

Inefficient infrastructure development can cause high costs and poor levels of service that are difficult to unwind. Pitfalls from not meeting the challenges outlined above include:

- insufficient infrastructure provision, leading users to self-supply from private sources at higher costs to themselves and the environment. For example, the cost of trucked water is nearly ten times higher than that of network water, which falls disproportionately on lower income and disadvantaged groups who live in areas with the worst network service (IMF, 2015).
- uncoordinated development with other parts of the transformational project. Egypt's New Valley Project is one example where water supply plans were entirely disconnected from plans for land reclamation and settlement, which led to poor project outcomes and put a strain on international relations among countries in the Nile River basin (Waterbury & Whittington, 1998).
- an incremental approach that fails to respond to the rapidity of development and locks in high costs, a frequent problem in China's water resource development (See, for example, Liu et al., 2013).
- a failure to reduce costs by ensuring beneficiaries pay for the infrastructure. Highly subsidised services are common in many countries, including India (Singh, Upadhyay, & Mittal, 2005).

3.1.3 Mechanisms to allocate water

The free availability of water creates a 'tragedy of the commons' where resources are over-exploited to the detriment of the environment and other users, and this is likely to be particularly damaging in arid regions. Free access to water or ability to pollute water leads to a market failure that should be addressed by policy interventions to reduce withdrawals or moderate discharges of waste into waterbodies. Such policies may include user tariffs, tradeable water rights, permits, or some combination of these – both economic mechanisms and strong institutions are needed to moderate supply, demand and allocation of water resources.

Government failures in addressing over-exploitation can stem from a lack of data and/or a lack of monitoring and enforcement capacity. Data collection for water allocation policies is particularly challenging in relation to renewable groundwater reserves and the water required to sustain ecosystems (Mosello et al., 2015). Accurate data on these typically requires monitoring use by different groups which requires investment in metering devices and ongoing expenditure to maintain and read the meters, and access to the associated funding and skilled labour. Effective enforcement of policies requires both monitoring and some credible means of redress where users fail to pay tariffs or exceed their allocations: this can often be difficult to establish.

Misguided policies to address over-exploitation can increase overall social costs. 'Command and control' conservation policies – as opposed to allocation mechanisms such as tariffs or tradeable abstraction rights, which may still be set by a central authority – inflexibly allocate water between users or are prescriptive about the technologies users can adopt in areas such as irrigation and industrial production. Though these can have the advantage of simplicity, they risk imposing costly misallocations between users, which can potentially be more costly than over-exploitation.

The rapidity of economic development spurred by transformational projects makes government failure more likely. Fast developing regions may quickly transition from a state of water abundance to one of scarcity or from moderate to severe scarcity as they experience economic and demographic change (Vorosmarty, Green, Salisbury, & Lammers, 2000). This means the apparatus for setting and implementing allocation policies may need to be set up or greatly expanded during a short space of time, with little pre-existing capacity to address the potential government failures described above. Lobbying from users to resist any policy intervention is more likely to be successful in the absence of existing policies.

Furthermore, an initial failure of water allocation policy in the wake of a transformational project can be very costly to unwind. There are at least three reasons for this:

- technological: if investments unlocked by the transformational project are made in the expectation of freely accessible water, then users will be more likely to adopt water-inefficient or polluting technologies, particularly in irrigation and industrial production. These technologies are likely be expensive to replace or upgrade, so their installation raises the cost of subsequently reducing water exploitation;
- ecological: as noted in Section 3.1.1, there are water thresholds beyond which ecosystems are liable to collapse irreversibly. An initial failure to conserve water for environmental use can thus lead to permanent damage;
- political economy: industrialisation and the expansion of commercial agriculture brought about by transformational projects can create groups with very significant economic interests in retaining access to low-priced water. These groups may form an effective lobby in undermining or demanding compensation for any new water allocation mechanism, raising the cost of reform.

The pitfalls associated with water allocation policies are illustrated by experience. For example:

- overexploitation and environmental harm is common, particularly when water resources are poorly quantified, which is often the case for groundwater. Pakistan's policy of subsidising boreholes, for example, has led to falling water tables and unsustainable exploitation of groundwater that has contributed to the salinization and water-logging of irrigated land (Altaf et al., 2009) and exhausted the Kuchlagh aquifer in the Balochistan region after three decades of intensive, unmanaged use (van Steenbergen, Kaisarani, Khan, & Gohar, 2015).
- costly misallocation between users is also widespread. For example, a lack of integrated water resource planning in Ethiopia has prioritised the use of water in commercial agriculture over domestic use, even where this is not economically efficient (Mosello et al., 2015).

3.1.4 Interventions to protect the poor

Transformational projects present great opportunities for the poor, allowing them to escape poverty by moving to more productive work in cities and factories. If accompanied by investment in public services, development programmes can disproportionately improve the quality of life for the poorest groups in society (see, for example the Kenya Electricity Expansion Project: World Bank, 2015). Even where their access to water is compromised by a project, the poor might still stand to gain considerably from it overall.

However, the poor are more vulnerable to water scarcity than others, so where projects threaten water access, remedial policy may be needed. The poor are particularly vulnerable to reductions in water availability that may follow from a project, having less access to complementary goods (see Section 2.3) and less ability to adapt to changing circumstances by drawing down on wealth or borrowing from the financial sector. Furthermore, if the poor lose reliable access to water, the effect of the project may be to entrench rather than alleviate poverty by impairing people's health and restricting their ability to participate in the labour market. Women may be particularly vulnerable (Parker et al., 2016). Where communities' access to water comes under threat, protective policy interventions can therefore be justified. Interventions may take on a wide range of forms, including subsidised infrastructure or social water tariffs, free water allowances, or the expansion of general social security schemes (OECD, 2015).

The poor are also vulnerable to government failure. The poor are generally less well equipped than other groups to promote their interests in policymaking forums, making it less likely that policy will serve their needs; indeed, some groups in some regions suffer active discrimination from the government. Even where policy attempts to address problems faced by the poor, inadequate official data on informal settlements or economic activity can prevent initiatives achieving their aims.

There is a risk that the poor suffer disproportionately from water impacts associated with transformational projects that fail to account for their needs. These risks include pitfalls associated with all of the challenges described in Sections 3.1.1-3.1.3:

- bearing excessive risk, particularly due to their inadequate access to fair insurance (Clarke & Dercon, 2009);
- having inadequate access to water supply infrastructure (Hogarth; & Granoff, 2015); and
- mis-allocations of water that do not place adequate priority on the needs of the poor.

3.2 Addressing the challenges in a planning framework

The consideration of water resource impacts in the planning of transformational projects provides a number of opportunities to start addressing these challenges. Though the challenges set out in Section 3.1 do not have straightforward solutions, a first stage in addressing them is to identify water resource impacts during the planning of the transformational project. This has the following advantages:

- it flags problems so that scarce capacity for data collection and policy development can be allocated where it is most needed;
- it reveals opportunities to change the project in a way that mitigates the impacts; and
- it reveals opportunities for coordination including on financing.

This section briefly considers how the four challenges described in Section 3.1 can be better understood at each of the steps of a generic decision frameworks for infrastructure projects, as outlined in Table 2. The framework is based on UNEP's guidelines on environmental impact assessments (Abaza, Bisset, & Sadler, 2004).

Table 2: There are various 'entry points' in the decision process where the challenges of transformational projects can be addressed

	Uncertainty	Infrastructure	Allocation	Protect poor
Scoping	✓✓✓	✓✓✓	✓✓	✓✓
Option development	✓✓	✓✓✓	✓	✓
Impact analysis	✓✓	✓✓	✓✓	✓✓✓
Option refinement	✓✓	✓✓✓	✓✓✓	✓✓✓
Evaluation	✓✓	✓	✓	✓✓
Decision	✓	✓	✓	✓
Reporting	✓	✓	✓	✓
Follow up	✓✓✓	✓✓✓	✓✓	✓✓
Consultation	✓	✓	✓	✓

Note: ✓= no specific relationship to challenge ✓✓= some relationship ✓✓✓= strong relationship

Source: Vivid Economics

Scoping entails characterising the problem to be solved by the project by setting assessment criteria, such as contribution to GDP or reduction in poverty, and collecting baseline data on the criteria characterising the status quo. Scoping is particularly important for water infrastructure planning and managing uncertainty, as it allows critical features to be included in the baseline. A baseline on the supply-demand balance for water is essential if pressures on water availability are to be taken into account. A baseline should:

- be long-term and reflect planned interventions so infrastructure can be efficiently planned and phased;
- be disaggregated by geography and user group including the poor, women and the environment, in order to understand where current allocations may come under pressure as a result of the project. This should include the poor, women and the environment; and
- reflect baseline uncertainty, relating to current economic activity and climate change.

Option development involves characterising the set of options to be considered and an initial qualitative comparison between the options on the assessment criteria, screening out options as appropriate. This is particularly important in revealing opportunities to co-ordinate infrastructure plans. By explicitly considering projects as 'packages' that include water resource programmes, it will be possible to more easily identify coordination opportunities.

Impact analysis involves understanding how each of the remaining options performs according to each of the assessment criteria and why there are differences between the performances of the options. It should account for the impacts of the project on water resources, as set out in the scoping phase, which will likely require explicit modelling of uncertainty. It is important to conduct an analysis of the distributional effects of the project at this stage in order to understand, so that mitigating options can be considered if needed in the next phase.

At the **option refinement** stage, having understood the source of any weaknesses in the options, the planner can seek improvements and refinements of the initial choice set to reach a final choice set. Notably, these refinements may involve defining pathways that account for uncertainty, opportunities to coordinate water infrastructure with other parts of the programme, interventions to improve the efficiency of water allocations, or exploring different ways of funding the project to mitigate the incidence on different groups.

Evaluation, decision and reporting involve assessing the final options, choosing one and appropriately documenting that choice. Consideration of the four challenges in managing water impacts should be made before these steps.

Follow-up involves pursuing monitoring or any further action as required under the decision. It is critical for ensuring that the project responds flexibly to unfolding uncertainty, and for monitoring long-term infrastructure planning and financing. Allocative instruments, such as permits and pricing, may require updates, and societal and environmental outcomes will require close attention to ensure the intended outcomes are being met.

Consultation involves engaging stakeholders at various stages of the process to seek their input to different parts of the planning process, perhaps including seeking their approval of the decision. It offers substantial opportunities to manage water impacts by allowing planners to better understand the needs of water users and how they are affected by the programme.

4. Case study: China-Pakistan Economic Corridor

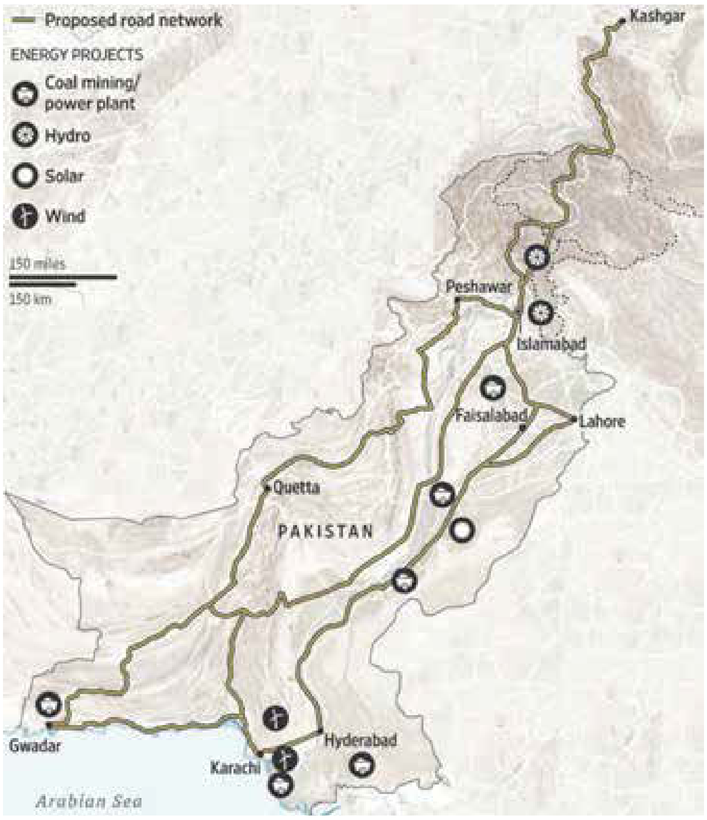
The China-Pakistan Economic Corridor (CPEC) is a leading current example of a transformational project in an arid region. Its success could not only have profound effects on the economic structure of the region but also on the region's water resources. This section considers how the challenges described in Section 3 arise in CPEC, the extent to which they have been met by public policy interventions, and the risks associated with the current Pakistani policy trajectory. It begins with context and a brief project overview before detailing each of the four critical challenges in managing water resource impacts in turn: uncertainty, infrastructure planning and finance, water allocation, and protecting the poor.

4.1 Project overview

CPEC is one of the world's most ambitious packages of infrastructure investments. CPEC is a collection of investments in energy, road, rail and pipeline networks located mostly in Pakistan and scheduled for completion by 2030. The package targets substantial economic development in Pakistan driven by the new infrastructure, aiming to link the western Chinese city of Kashgar to a new deep water port at Gwadar in southwest Pakistan. It is estimated the programme will cost US$46 billion, roughly 20 per cent of Pakistan's current annual GDP (Bhattacharjee, 2015), with much of the finance originating in China via concessionary loans from the Chinese government and distributed by state-owned banks. Box 1 lists the project aims and highlights possible links to China's wider strategic interests.

Around three quarters of the investment aims to foster transformation by radically expanding the supply of energy across Pakistan. Pakistan currently experiences severe power shortages, with supply shortfalls of around 25 per cent of demand typical, rising to almost 50 per cent of demand, or 8.5 gigawatts (GW), in extreme circumstances (Kugelman, 2015). These shortages will be addressed by a large programme of generation capacity, with an array of coal, wind, solar and hydro generation set to add 10.4GW to the national grid by 2017, with a further 6.6GW of capacity planned by 2030, as well as a new natural gas pipeline from Iran to Gwadar. Figure 5 illustrates the geographic distribution of projected generation investment, which is concentrated in the more populous east.

Figure 5: Power capacity projects are concentrated in the more populous east



Source: Vivid Economics, adapted from the Wall Street Journal. This map makes no claim as to the accuracy of the international boundaries it depicts.

A further $12 billion of investment in transport infrastructure aims to better integrate markets. A new commercial deep water port in Gwadar is a cornerstone of CPEC, making it substantially easier for goods, particularly commodities, to enter and exit the region. The remainder of the infrastructure investments aim to link Gwadar to other population centres in Pakistan and western China. The government is simultaneously developing three routes for the programme, with priority given to a western corridor that traverses Balochistan. The programme will include upgrading a railway line between Karachi and Peshawar, and enhancing the country's highway network by adding motorways between Karachi and Lahore and between Rawalpindi and the Chinese border (Bengali et al., 2015). These new transit links are intended to connect existing markets and support the development of new industry in concert with the efforts to improve power provision.

Box 1: Aims and potential challenges to supporting Pakistan's development

The official aims of the project include (Abid & Ashfaq, 2015):

- to offer equal opportunities to all regions of Pakistan to develop economically and socially;
- to help overcome Pakistan's energy crisis;
- to foster peace and trade between China and Pakistan;
- to establish industrial parks;
- to identify tourism prospects; and
- to efficiently utilise and conserve resources, including water.

However, it is not clear how any conflicts between the project's official goals are to be managed, and few details of the planning process that developed the current programme have been made public.

The economic impacts of the project could materially improve the quality of life for millions of people. The programme commits significant investment to some of Pakistan's poorest, least well connected regions: by promoting development in these areas, it holds out the prospect of greatly improving opportunities for poor Pakistanis and substantially alleviating poverty. Electricity shortages, for example, are estimated to have cost Pakistan four per cent of GDP (Kugelman, 2015) and are cited as a major credit risk by international investors (Moody's, 2015).

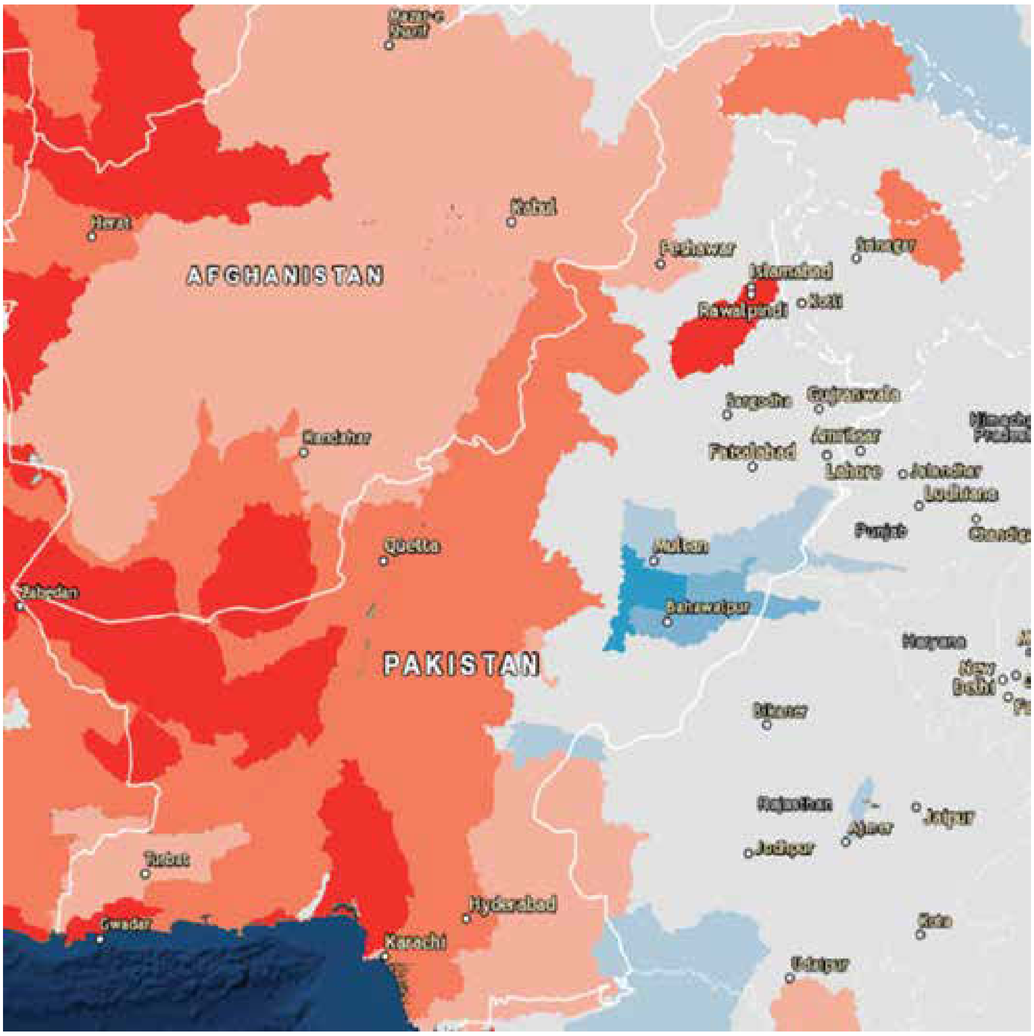
Direct water impacts associated with investment are likely to be substantial. Though figures are not publicly available, the expansion of coal fired generation is expected to add significantly to water stress. By way of a parallel, thermal power generation accounts for nearly 12 per cent of national water withdrawals in China, exacerbating water stress in regions already experiencing it (China Water Risk & International Renewable Energy Agency, 2016).

Indirect impacts on water resources are potentially an even greater challenge. CPEC targets rapid economic development in Pakistan (see Box 1) and, as noted above, this offers the prospect of significant improvements in the quality of life of a large number of people. While official aims also include the efficient use of water, as set out in Section 2.3, the concomitant impact on local water supply and demand conditions, especially due to urbanisation, industrialisation, and migration, could be substantial and offset some of the promise that the project offers. Official sources on CPEC acknowledge that the transformational project will have significant water impacts, though such statements tend to be generic.

These water resource impacts will be experienced in conditions of severe water stress that, even without the impact of CPEC, is expected to deteriorate further in the future. Pakistan is already one of the most water stressed countries in the world, and business as usual projections predict that it will be the region's most stressed by 2040 (Maddocks, Young, & Reig, 2015). The UN's Food and Agriculture Organisation (FAO) estimates a current annual availability of 1,090 cubic metres per head, requiring the withdrawal of 74 per cent of total renewable water resources (Food and Agriculture Organization of the UN, 2015). For comparison, the FAO considers water stresses to be high if the rate exceeds 25 per cent, while neighbouring India and Afghanistan have withdrawal of 34 per cent and 31 per cent respectively. Moreover, growing populations, inefficient supply management and the effects of climate change are expected to cause per capita water availability to fall further, implying that competition between water demands will increase (Mustafa, Akhter, & Nasrallah, 2013). Over the longer term, the Himalayan glaciers that contribute to 40 to 50 per cent of the water used downstream in Pakistan (Mustafa et al., 2013) are expected to be very sensitive to climate change, melting and increasing flows in the near term, with dramatically reduced flows after approximately 2050, as the glaciers recede or disappear completely (Immerzeel, van Beek, & Bierkens, 2010; Lutz, Immerzeel, Shrestha, & Bierkens, 2014; Xu et al., 2009). Improving the efficiency of water allocation along economic principles could help reduce water stress, but this would require changes to existing allocation systems and entitlements, particularly in agriculture (Cai, Sharma, Matin, Sharma, & Gunasinghe, 2010), which CPEC projects are likely to become entangled in due to their associated water demands.

Much of the economic development associated with CPEC is set to take place in areas where water scarcity is most acute. National statistics on water stress conceal significant local variation: as Figure 6 below illustrates, water stress is projected to become substantially more severe in southern and western Pakistan relative to present levels. These are the regions that account for a large portion of the spending and associated economic development arising from CPEC, particularly the transport corridors in Gwadar and Thar. Similarly, CPEC power projects are concentrated around large urban sources of electricity demand in the eastern Pakistan, but interviewees report that these urban centres are also the locations of some of the most dramatic water scarcity and poor water management.

Figure 6: Water stress in southern and western Pakistan is expected to increase by 2040



Note: This map shows changes in water stress relative to the baseline. Red and dark red areas are expected to experience increased water stress in 2040 relative to present levels.

Source: Vivid Economics based on WRI Aquaduct database

4.2 Planning challenges

The previous section shows that CPEC faces a considerable challenge in its managing water resource impacts. This section expands on this, by considering in more depth how the four planning challenges set out in Section 3.1 apply to the project and, to the extent that this is evident to interviewees and in public documents, how the Pakistani authorities have addressed these challenges.

4.2.1 Uncertainty

Uncertainty is a prominent characteristic of the CPEC planning problem. All of the sources of uncertainty identified in Section 3.1 – baseline uncertainty, uncertainty over future supply and demand conditions, uncertainty over economic impacts of the project, and uncertainty over the associated water resource impacts – are highly relevant. From the perspective of this study, they are amplified by the general opacity of the planning process and lack of published data on the project.

The lack of baseline data on water demand is particularly profound in Pakistan. The last census in Pakistan was taken in 1998, meaning that the total population, its geographical distribution and hence the location of water demand are unclear. Most water consumption is either unmonitored or recorded with substantial error, with even some industrial users lacking current and accurate usage measurements, so there is little understanding of demands by sector. Finally, environmental demands are poorly understood and rarely considered: for example, upstream water abstraction for irrigation has long been understood to be a major contributing factor behind severe habitat degradation in the Indus Delta, but the water needs and economic value of this are not accounted for in basin management (Laghari, Vanham, & Rauch, 2012).

Water supply is also highly uncertain, particularly renewable rates of groundwater extraction. Surface water is measured at 'rim stations' on the edges of the Indus River basin, with balances reported annually, but there is little data available that allows the spatial and temporal complexities of water availability to be understood (Laghari et al., 2012). Eighty per cent of the annual flow of the western rivers of the Indus basin, which account for more than 70 per cent of the available surface water in Pakistan, occurs in the three kharif, or summer months (Mustafa et al., 2013), but there is insufficient information available to successfully characterise water availability at the local or seasonal resolution needed to manage localised scarcity effectively. Many parts of Pakistan, including the South West, rely on groundwater, but there is little information on available reserves and sustainable withdrawal rates throughout the country (Qureshi, McCornick, Sarwar, & Sharma, 2010).

No systematic attempt has been made to project water supply and demand forward at a local level, or to account for the economic impact of CPEC. No comprehensive water resource management plan has been published by Pakistan's national or provincial governments, and an unpublished water policy framework developed ten years ago is the most recent substantial policy development. The economic impact estimates of CPEC projects that exist are not publically available, but interviewees report that these do not systematically estimate water resource impacts. Policymakers are aware of the threats posed by climate change and have placed a high importance on resilience when considering new projects, but the focus seems to be on technical solutions rather than responding flexibly to uncertainty as it unfolds.

This study found no evidence of efforts to manage water resource risks to users resulting from CPEC or to achieve savings through flexible planning. Though some aspects of CPEC, notably hydroelectric dams, will reduce some water risks in some regions, the programme does not appear to have been calibrated to a particular target level of risk. This may represent a missed opportunity to protect the poor and the environment. Furthermore, there is also no evidence of the use of flexible pathways in infrastructure development, which may have allowed the programme to save costs and yield greater benefits.

A more systematic approach to addressing water resource uncertainty could substantially improve plans and make the other issues set out below less problematic. On the basis of the evidence reviewed, it appears that CPEC would benefit significantly from a more comprehensive and rigorous view of the uncertainty related to water resource impacts and how this may be managed, supported by more extensive data collection. This is highly likely to make the challenges surrounding water infrastructure development, water allocation, and protecting the poor listed below less problematic.

4.2.2 Infrastructure planning frameworks and financing

The economic development expected from CPEC is centred in areas that suffer from current water infrastructure deficits, especially the South West and North West of the country.

Pakistan faces a significant water-supply infrastructure deficit, particularly in the arid areas in the southwest of the country and in agriculture. Southwestern Pakistan has a low natural endowment of surface water flows and high levels of groundwater extraction has depleted aquifers. The region also has no history of long-term water infrastructure planning, with none of the canal systems for bulk water distribution found elsewhere in the country. As a consequence, water is often trucked to urban centres at high cost, providing citizens with low levels of available water and little security of supply. In addition, irrigation systems developed in the 1930s provide relatively little storage: on average, capacity amounts to only 30 days' worth of usage in Pakistan's portion of the Indus watershed, compared 120 to 220 days across India or 700 days in Egypt (Mustafa et al., 2013). This is problematic given the highly seasonal nature of water flow in the region discussed above.

Flood defence infrastructure is unable to cope with seasonal floods in the northwest. Climate change is causing the glaciers in the Himalayas to melt very rapidly during the summer months, dramatically increasing flows in the Indus basin. Though this might increase water availability, local catchments and infrastructure cannot absorb these flows and floods are a recurring problem in the Indus valley. Northwest Pakistan suffered a catastrophic flood in 2010, which covered roughly one-fifth of Pakistan's land area, displacing millions, destroying 2.2 million hectares of crops, 450,000 head of livestock and US$10 billion of infrastructure (Disasters Emergcy Committee, 2010).

As well as developing new infrastructure, there is scope to address this deficit by better maintaining existing assets. The Tarbela Dam, for example, has lost nearly 30 per cent of its storage capacity since the 1970s, and the lack of retained water threatens irrigation supplies (Altaf et al., 2009). Pakistan's large canal irrigation system suffers from poor transmission and seepage stemming from a lack of maintenance, losing 76 million acre-feet per year (Kamal, 2009). Maintenance problems reflect poor management, which can contribute to a dearth of available funds, an issue that could be remedied by adopting a more widespread use of well managed systems for beneficiaries of the infrastructure to pay usage fees (Oates, Jobbins, Mosello, & Arnold, 2015).

At present, Pakistan does not have an operational infrastructure planning framework through which to efficiently address these challenges. Pakistan's policy response to water shortages tends to focus almost exclusively on new infrastructure, such as dams and other storage-generating engineering projects, while little attention is paid to the maintenance or improvement of existing projects, or on reducing demand through efficient use (Bengali, 2009). The most recent comprehensive water management plan was endorsed in the 1960s and does not reflect current needs, though it is still used to prioritise infrastructure projects as many of the initiatives set out in the plan have yet to be delivered. Efforts to update this are hampered by the lack of data on supply and demand described in Section 4.2.1 above: a lack of long-term, geographically granular data is a substantial barrier to prioritising the local interventions needed in order to build infrastructure to an efficient scale, and to use pathways to account for uncertainty.

A root cause of the lack of planning capacity is a multiplicity of overlapping institutions, accountable to different interests. Infrastructure investment tends to be decided at the national or provincial level, but these decisions are not well coordinated with regional authorities. The Indus River System Authority aims to coordinate interprovincial water sharing across Pakistan, but its rulings have been ignored by provinces in the past (Khan, 2009).

Current efforts to address these problems by establishing water boards may improve planning, but these would be further enhanced by providing boards with greater financial independence. The government of Pakistan's flagship initiative to improve water planning is to set up water boards, independent planning authorities whose remit includes urban water supply and surface water management. The establishment of these boards offers the promise of improving decision making by reducing overlaps between competing institutions and creating single, coherent resource management plans. However, at present, boards are reliant on central or regional government funding: as noted in Section 3.1.2, this reduces their incentive to recover infrastructure costs from users and reduces their financial security.

CPEC may assist in meeting Pakistan's water infrastructure deficit by providing storage and flood defence, but at present there is a low level of coordination between it and the water boards. As explained above, several new dams are being constructed for hydropower as a part of CPEC, including the US$1.65 billion Karat hydro-power plant for which construction started in January 2016. However, CPEC development and planning is separate from and parallel to water supply infrastructure investment. There may therefore be opportunities to improve coordination, saving overall costs while achieving the outcomes desired by both CPEC and the water boards. Coordination might also allow the identification of beneficiaries from CPEC who could be a source of funding to improve water supply infrastructure.

This lack of coordination risks exacerbating water shortage problems by increasing demand in arid and urban regions. Box 2 explores the consequences for the port city of Gwadar in the South West.

Box 2: Regional focus: Gwadar

Gwadar, a port city in Balochistan in southwestern Pakistan, is a major component of the CPEC project. Though the region's population is only approximately 200,000, the area is a particular target for CPEC funds and is expected to grow very substantially. A new deep-water port was completed in 2006, and its expansion is underway. CPEC funds are also adding an airport and a coal-fired power plant in the area, and Gwadar is a terminal of the proposed natural gas pipeline from Iran.

Figure 7: Gwadar relies solely on the Akra Kaur Dam for water supply

Source: Vivid Economics

Southwestern Pakistan has an arid climate, and Gwadar relies on the nearby Akra Kaur Dam, a US$24 million project constructed in 1995, as its sole source of fresh water. The dam's reservoir is rain fed, and has run dry several times in the past six years. As a consequence the town's population has resorted to boiling seawater or buying water at great expense (US$115 to $150 per container truck) from trucks that make the 85 to 100 km journey from the more distant Mirani Dam's reservoir.

In response to this, Balochistan's regional government has developed plans for more supply infrastructure. Initially this will comprise a desalination plant, though accounts suggest that its capacity will fall short of supplying current demands and, though some of the costs are expected to be met by users, the balance of funding will be met by Balochistan's government. There are also more distant plans for another dam in the area, but details on the location, water source, and means of transportation to Gwadar have yet to be resolved. The decision making process followed to arrive at these plans is not clear; and plans to improve the efficiency of distribution and management of consumption do not appear to have come under consideration.

CPEC has some local support in Gwadar and is expected to benefit the area's economy substantially, but there has been little consultation on plans or exploration of how they could better serve the needs of the local economy. In particular, opportunities appear to have been missed in exploring how investment connected to CPEC might be coordinated with water supply development to reduce the impacts of temporary shortages on residents better contribute to the water, or how investment unlocked by CPEC might reduce the costs to Balochistan's government by contributing more to new water infrastructure.

4.2.3 Water allocation

Water misallocations can be highly costly for Pakistan. These are most costly in the country's most water stressed areas where water is correspondingly valuable; as noted earlier, these areas include arid parts of the South and West and densely populated cities.

In common with many other countries, current allocations of water appear to be skewed towards agriculture in Pakistan. Irrigation and agriculture take up 90 per cent of Pakistan's surface water resources, leaving little for industrial and domestic use for 182 million people that reside in the country. Though the returns to agricultural use vary dramatically by area, crop and conditions of application, it can have high opportunity costs, particularly when diverted upstream of urban areas (Rogers, Bhatia, & Huber, 1998). Despite water's value elsewhere, 38 per cent of Pakistan's irrigated lands are waterlogged and 14 per cent are saline as a result of repeated over-irrigation (Kamal, 2009). The salinity problems have recently been reduced through government projects, but the most common technique involves using vast quantities of water to flush salts below crop root zones.

A tariff framework exists for surface water withdrawals in Pakistan, though its form and governance could be improved and it would be beneficial to extend it to groundwater and pollution. Developing Pakistan's current water tariffs system could be greatly beneficial in efficiently managing its water resources and help CPEC achieve its aims. Necessary steps include raising the level of tariffs so that they recover costs including environmental costs (Altaf et al., 2009), increasing the coverage of volumetric tariffs, and accounting for groundwater abstractions and discharges into watercourses in the tariff mechanism. At present, governance is divided between water boards, which control the regulation of surface water abstraction, and the Environmental Protection Agency (EPA), which regulates wastewater effluents, while groundwater withdrawals are uncontrolled. The EPA in particular lacks capacity for enforcement: a 2006 study found chemical and organic runoff from plastics factories, cattle pens and slaughterhouses in the Fuleli Canal, which supplies drinking water to Hyderabad (Altaf et al., 2009). Groundwater contamination is problematic, with 95 per cent of shallow groundwater supplies in the Sindh province are bacteriologically contaminated (Chaudhry & Chaudhry, 2009).

While CPEC infrastructure may alleviate scarcity in some regions, complementary allocation policies have not been considered. This study found no evidence that policymakers have planned for changes to allocation policies as part of the CPEC programme, despite the importance of early interventions to avoid lock-in of inefficient technologies or irreparable ecological damage. Indeed, pre-emptive changes to allocation policies could be worthwhile, allowing impacts on users to be phased in advance of the CPEC impacts.

Environmental impacts are a particular concern. Though interviews with policy makers reveal that environmental impact assessments (EIA) have been conducted for at least some CPEC projects, these are not publically available and it remains unclear which projects have been assessed or what degree of rigour was applied. Accounts suggest that EIAs did not take into account the effects of increased water use on eco-systems, implying a risk that fragile systems could be compromised beyond recovery thresholds. As explained in Section 3.2, better assessment of these impacts in the EIAs could allow them to be mitigated during the option refinement phase.

4.2.4 Protecting the poor

Pakistan's poor are generally vulnerable to the consequences of water stress, particularly in urban areas. Pakistan's urban poor have access to only 10 litres per capita per day of water, a fifth of the minimum human drinking water requirement specified by the World Health Organization (Kugelman, 2014) and water quality is problematic in all major cities, with 30,000 of Karachi's citizens dying each year from unsafe drinking water (Altaf et al., 2009). By contrast, wealthier households are able to obtain clean water for domestic use from public supply agencies or from groundwater pumps that are privately installed (Chaudhry & Chaudhry, 2009).

The poor lack direct representation in the infrastructure planning process and a lack of data hampers efforts to protect their interests. Engagement with the poor in planning is typically mediated by NGOs, and while this can be a worthwhile form of facilitation for can also present a barrier to obtaining representative views. A further hurdle to policymaking is a lack of data: in urban areas almost 50 per cent the population lives in slums for which data collection efforts are limited (UN Millenium Development Goals Indicators, 2015), while in rural areas, where poverty rates are higher, there are entire villages that are unrecorded by government data.

The poor have the most to gain from CPEC's infrastructure investments, but are also most vulnerable to the water impacts described above. Improved infrastructure of the kind CPEC promises is widely recognised as an important element in reducing poverty (see for example, Goal 9 of the UN's Sustainable Development Goals), but the programme is liable to fail in this regard if it reduces access to water. In addition to the pitfalls highlighted in Section 3.1.4, some analysts (for example, International Crisis Group, 2014) and interview respondents have highlighted risks to civil stability stemming from a failure to manage impacts on the poor in Pakistan.

Box 3: Regional Focus: Federally Administered Tribal Areas (FATA)

Located along Pakistan's north-western border with Afghanistan, FATA is a semi-autonomous collection of seven tribal agencies and six frontier areas whose local governmental organisations are governed directly by Pakistan's national government rather than provincially. The vast majority of the area's population is rural and depends on agriculture, with subsistence farming predominant. The area is the most impoverished region in Pakistan, with nearly 60 per cent of FATA households living below the poverty line, and lags behind the rest of the country in almost every socioeconomic indicator (Asian Development Bank, 2002).

The region is arid or semi-arid and suffers from severe water scarcity. The scant rainfall the region receives mostly converts into flash floods and the subsurface water sources that irrigators depend on recharge at a relatively low rate. Four major barriers to improving water availability have been identified with FATA's water sector (Asian Development Bank, 2014):

- too few rain and stream gauges to effectively measure the quantity of water available and the extent of seasonal variation;
- a lack of infrastructure for productively utilising seasonal surface runoff generated in the area;
- aquifers depletion due to overexploitation of groundwater;
- the absence of effective on-farm water management.

These issues relating to water resource management, combined with the deforestation and overgrazing of rangelands has increased runoff and resulted in high rates of soil erosion, lowering water quality and increasing sedimentation downstream.

A number of government funded infrastructure schemes in FATA have attempted to address these problems, but in general these have not performed well. A major factor behind this has been a lack of community ownership and participation, both during the design and implementation and during the post-construction operation and management of the infrastructure. To an extent this reflects wider governance problems in the region and a local sense of disenfranchisement (Asian Development Bank, 2014).

By traversing the region, CPEC will provide access to markets and associated opportunities to improve economic outcomes. There is, however, a risk that inadequate engagement with the local population leads to a failure to realise this potential.

5. Conclusions and further research

This study highlights the ways in which transformational infrastructure programmes can affect water availability for different users in arid regions of the world, draws out critical challenges associated with managing these impacts, and reviews how these challenges apply and how policy makers have responded in the case of the ongoing China-Pakistan Economic Corridor (CPEC) project.

Further research could provide insights into meeting the challenges set out in this study. The objective of this work is to articulate general challenges associated with transformational programmes in arid regions, and in particular how these apply in the case of CPEC. Further work could build on this by considering how these challenges could be met.

At a general level, open questions remain over how to integrate water resource concerns into a planning framework for a transformational programme and what the appropriate policy measures to manage water impacts are. Specifically:

- Section 3.2 touches on some of the issues related to planning water resource impacts, but it does not consider how these concerns might be integrated into a wider planning programme, what governance arrangements are most suitable for this, or offer any assessment of trade-offs involved in different approaches. More work, drawing on case study evidence, could offer valuable insight over these issues.
- though various policies and institutional arrangements are discussed in this report, it is beyond the scope of this analysis to consider which mix of these best serves the public interest in the context of a transformational programme, or how this depends on local contextual factors including the nature of the infrastructure programme. Research into these further questions could provide policy makers with useful guidance.

The case study flags a number of ways in which Pakistani officials could better address CPEC's water impacts. The CPEC case study highlights the need for Pakistan's government to improve policies and institutions across all four areas of challenge identified in the framework. At a general level, reforms should improve the transparency of planning (for example the EIAs) and representation of civil society people in the planning process, notably the poor. More specific water resource planning issues to be addressed include: low quality data on water usage or supply, particularly on groundwater availability and ecological demand; the absence of a long-term planning and funding mechanism for water supply and irrigation infrastructure; and some lack of institutional co-ordination on water allocations.

The case study also points towards areas where more research would be most valuable in ensuring CPEC achieves its aims. These are:

- a scenario analysis, integrating existing sources on water supply and demand in different regions affected by CPEC and creating projections of the programme's impact on these areas for different groups. This will quantify local supply-demand imbalances, allowing mitigation strategies to be prioritised;
- a review of opportunities to change the specification of CPEC to reduce adverse water impacts and to exploit any complementarities between the energy and transport projects it promotes with other water supply infrastructure programmes;
- specific policy recommendations to prevent technological lock-in or ecological systems collapse where CPEC is expected to lead to very rapid changes in water availability, designed to protect poor users where needed;
- local strategies for infrastructure development in areas, such as Gwadar, where urbanisation is expected to be very rapid;
- a programme of engagement with local groups to better understand specific impacts on the poor, including gender impacts, that feed into the planning of CPEC.

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