FINAL REPORT

Mainstreaming of ecosystem services into sectoral and macroeconomic policies and programmes of Republic of Kazakhstan

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Ecosystem Services Economics (ESE): The United Nations Environment Program

Final Report – Kazakhstan
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Table of Contents

Final Report – Kazakhstan
Terry Roe and Rodney Smith
U of Minnesota

EXECUTIVE SUMMARY:

Overview: This project develops a tool for mainstreaming ecosystem service valuation that helps understand (and measure) the impact of policy on natural asset wealth, and illustrates how to use the tool and interpret the results. The focus of the analysis is are two regions in Kazakhstan; South Kazakhstan and Kyzylorda. The report analyses three policy options: the status quo, defined as Syr Darya agriculture receiving 10,500 km^3 of water each year that gets allocated across cotton, rice and other agricultural producers along the river basin. The second policy examines the potential benefit of allowing oblasts along the Syr Darya to trade water use rights among themselves. The third policy examines the potential benefit to farmers of improving irrigation efficiency. Perhaps the major contribution of the report is the mainstreaming of land and water asset (stock) values to evaluate the impact of policy – here natural resource policy – on natural asset wealth. Natural resource stock values provide what appears to be a natural index to use to compare the impact of policy on natural resource (or ecosystem) wealth, and if stands up to more careful scrutiny, become a part of any analytical attempts at mainstreaming ecosystem services.

Results: Each model examines and predicts: (i) current and future levels of gross domestic product (GDP), (ii) the contribution of water and land to agricultural value-added along the Syr Darya, and agricultural value-added in the rest of Kazakhstan, and (iii) the stock (or wealth) value of land and water in Kazakhstan. The model results are given for the 50 year period, 2007 through 2057. The results suggest trading water use rights could increase the wealth/wellbeing of those controlling the use rights of land and water by 9%. Irrigation improvements, however, yield smaller gains (less than 1%). The manner in which irrigation efficiency is modeled, however, most certainly underestimates the potential gain, and deserves further examination.

The study also illustrates how policy can impact specific natural asset values in different ways. For example, trading water use rights lead to a decrease in the stock (wealth) value of water, but an increase in the stock value of land. Improving irrigation efficiency tends to increase the wealth values of both land and water.

Future Research: The present model design does not directly measure the benefit of water diversions to the Aral Sea – it only allows us to calculate how much income the Syr Darya basin would lose be using less water. A more comprehensive study would measure the tradeoffs between Aral Sea economic activities (e.g., fisheries and services) and agriculture production. Implementing this type of project would require very close collaboration between economists and hydrologists – hydrologists with expertise on Aral Sea restoration dynamics.

Another topic for future research is that of more carefully measuring the agricultural production technologies: the more accurate is the measure of how output levels change when we use an additional unit of water, the more accurate will be the model's estimation of land and water, flow and stock values. With minor revisions, the model can examine the impact of traditional macroeconomic (trade or industrial) policy on natural asset contribution to sector and total value-added, and the corresponding stock values. Finally, the current modeling effort aggregated Kyzylorda and South Kazakhstan manufacturing and services into an "all Kazakhstan" manufacturing and "all Kazakhstan" service sector. It is possible to disaggregate manufacturing (and services) into Kyzylorda manufacturing, SK manufacturing and the rest of Kazakhstan manufacturing. The marginal value of such an exercise is likely to be marginal.

Acknowledgement: The report is an application of the conceptual model detailed in UNEP, Ecosystem Services Economics Working Paper No. 20, *Ecosystem Services and the Macroeconomy: A Review of Linkages and Evaluation of Analytical Tools*.

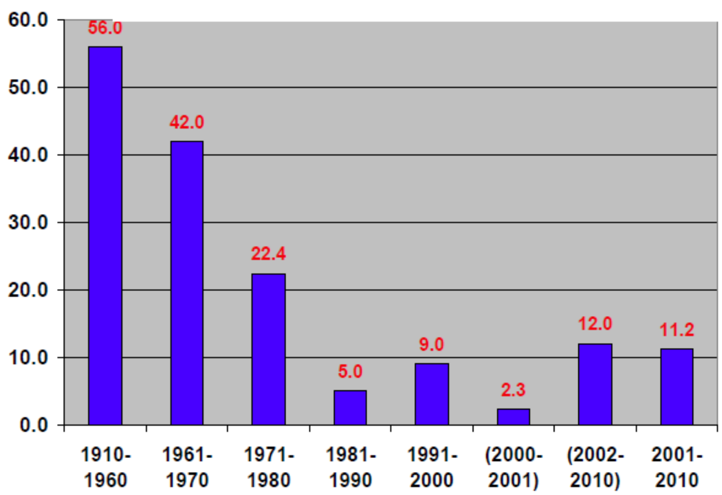
Final Report – Kazakhstan

Terry Roe and Rodney Smith
U of Minnesota

Introduction

Micklin (2014) notes that in 1960, the Aral Sea was the fourth largest lake in the world, with a surface area of over 67,000 km^2 and a volume of almost 1,100 km^3. By 2013, its' volume had shrunk to 7,600 km and surface area fell to 83 km^3. A major contributor to the Aral Sea's demise was the increased level of irrigation along its two tributary rivers – the Amu Darya and Syr Darya – which saw irrigated area grow from 5 million hectares in 1960 to 8.2 million hectares by 2010. The increased levels of irrigation combined with the natural evaporation levels of the Aral Sea, led to a significant fall in the net flow of water entering the sea (see figure 1). Over time, consistent low water inflow levels triggered significant declines in the Aral's surface area and volume.

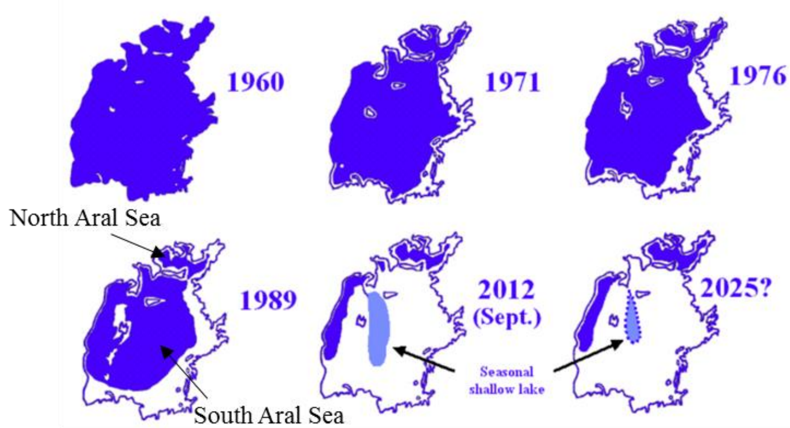
Figure 1. Inflow to the Aral Sea, 1910 – 2010 (in km^3)



Source: Micklin, 2014)

By 1987, the Aral Sea had roughly divided into two major water bodies: the North Aral Sea and the South Aral Sea (see figure 2). The North Aral lay entirely within Kazakhstan, with its' water inflows deriving mostly from the Syr Darya Basin. The boundaries of the South Aral Sea lay within both Kazakhstan and Uzbekistan, with its' water inflow deriving mostly from the Amu Darya Basin. By 2012, the South Aral had receded to what is now known as the (East) South Aral Sea, while surface area and volume increased some in the North Aral Sea.

Figure 2. The Changing Profile of the Aral Sea: 1960-2025



Final Report – Kazakhstan
Terry Roe and Rodney Smith
U of Minnesota

Source: Micklin, 2014 (South and North captions added)

According to Micklin (2014), restoring the Aral Sea to its' 1960s levels is possible, but unlikely "in the foreseeable future." Doing so would require average river inflow levels of about 56 km^3 per year, and take over 100 years; the sea could reach 91% of its' former state, however, in 43 years. Increasing inflow levels to 56 km^3 per year is unlikely, but regional efforts to restore the North Aral Sea have been quite successful. To raise water levels, increase surface area and lower salinity levels in the North Aral Sea, local agencies built an earthen dyke in 1992 to control the outflow of water down the channel to the South Aral. The dyke was breached several times and eventually replaced with the structurally sound Kok-Aral Dike, completed in 2005. See Micklin (2014) or Micklin et al. (2014) for further details. The Kok-Aral Dike did, in fact, help raise the water level and decrease salinity levels, and only required 3.5 km^3 of inflow each year: in 2003, the North Aral's surface area was 3200 m^2 and 30 meters deep – by 2006 its' surface area was 3600 m^2 and 42 meters deep.[1]

The Kazakh government is about to begin another phase of North Aral restoration, by building a dike and dam at the mouth of the Gulf of Saryshaganak, and divert water to the gulf. The major goal of this project is to raise the water level in the gulf to 50 meters, and in doing so, extend the surface area of the North Aral Sea to Aralsk, a town once famous for its active fishing industry. A recent World Bank document (Ghany and Shawky, 2014) suggests $126 million US has been earmarked for the project.

To raise the water level in the Gulf of Saryshaganak, and maintain the height and salinity levels of the entire North Aral Sea, requires water from the Syr Darya, which to date is mostly allocated to agriculture or North Aral Sea restoration. Table 1 illustrates how Syr Darya water was allocated across competing uses in Kyzylorda and South Kazakhstan, between 2006 and 2014. In both regions, water intake levels directed to agriculture accounted for the lion's share of total intakes, with Kyzylorda agriculture receiving over 99% of water, and South Kazakhstan agriculture receiving at least 96% of water. The data suggests that, on average, Kyzylorda agriculture and South Kazakhstan industry received increased water assignments over the period. Data not reported here suggests the increased intake levels for Kyzylorda agriculture is the result of investments in irrigation canal restoration and repair.

Table 1. Water intake levels in Kyzylorda and South Kazakhstan (million m^3)

	Sector	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Kyzylorda	Agriculture	3442.1	3570.4	3053.5	3429.1	3457.0	3632.4	3717.9	3563.8	3785.9
	Industry	13.6	12.0	9.6	8.4	10.4	9.4	9.5	8.5	6.1
	Household	4.5	5.1	5.9	5.0	4.0	5.3	4.8	4.3	3.4
	Fishery	4.8	4.6	4.6	4.6	4.6	4.6	4.8	4.8	4.8
	Total	**3465.0**	**3592.1**	**3073.6**	**3447.1**	**3476.0**	**3651.7**	**3737.0**	**3581.4**	**3800.2**
S. Kazakhstan	Agriculture	3503.7	3296.3	2926.1	3172.4	2968.2	3212.8	3804.6	3754.6	3856.9
	Households	33.2	36.9	37.5	36.9	36.5	36.3	29.8	32.4	33.3
	Industry	45.4	40.2	48.1	51.4	56.4	61.7	79.9	78.9	79.8
	Fishery	7.6	6.5	8.3	9.3	8.9	9.1	15.4	13.4	13.0
	Total	**3589.9**	**3379.9**	**3020.0**	**3270.0**	**3070.0**	**3319.9**	**3929.7**	**3879.3**	**3983.0**

This report examines *part* of the economic tradeoff between water uses across the two activities. Specifically, it develops a mainstreaming tool that measures the economic value of water in agricultural production along the Syr Darya basin: doing so gives us a better idea of water's importance to the regional economy, and an idea of what is at state when asking farmers to diverting water from agricultural uses to the North Aral Sea. The analysis that

[1] Japan Aerospace Exploration Agency, http://www.eorc.jaxa.jp/en/imgdata/topics/2007/tp071226.html

follows uses two measures of value: one measure is the shadow rental value of water and land used in agricultural production, the other is the stock – or investment – value of water. The *shadow rental value* of water (land) is the resource's contribution to gross domestic product (GDP) – sometimes referred to as the *value added* of the resource – and is the amount farmers would be willing to pay for to use additional units of water (over a specific time period, say a growing season). The stock value of water (land) is the amount farmers would pay to own the resource, and is calculated as the discounted present value of future shadow rental values.

Some readers will observe we use a dynamic, general equilibrium model to measure the two values. We do this because water's shadow rental value is heavily influenced by the levels of other resources with which it is combined to produce agricultural output. For instance, if labor is a scarce resource, then combining a little more labor with water, capital, fertilizer and land, increases the productivity of water (and the other factors) – meaning, using a little more labor increases the shadow rental value of water. Another reason for using such a framework is natural resource and physical capital stock values are relative. More specifically, Nelson, Roe and Smith (2015) show that the stock values of water and land hinge crucially on the stock price of (manmade) capital, and that the values can move together. They also show that when this connection is ignored, stock measures of land and water values in Punjab agriculture are seriously underestimated – yielding stock values less than one third or more of their correctly measured values. Smith and Gemma (2014) find similar results for water and land used in Japanese agricultural production.

One implication of the Nelson, Roe and Smith (2014) study is, unless the stock value of capital is linked to the stock value of a natural resource, the estimated stock values of the natural resource are likely to be biased – and the bias could be significant. Their results also suggest a resource's value over time is influenced by the relative competitiveness of the sector using it, where a sector's competitiveness is influenced by it relative capital intensity. Their empirical model's results suggest, on average, the more capital intensive sectors realize faster increases in shadow rental values over time. This observation suggests competitiveness affects the future shadow values of a resource, and hence, its value is influenced by the choices made by agents in other parts of the economy. In other words, conducting a macro-level valuation exercise while ignoring the rest of the economy – using partial equilibrium frameworks – is likely to yield undesirable results.

The empirical analysis of this study examines three policy options. The status quo policy establishes the baseline income – i.e., the shadow rental values of land and water – farmers in Kyzylorda and South Kazakhstan would likely receive over time. We then use this data to calculate agricultural wealth – the asset value of land and water – over time. The second policy asks the question: could we increase natural resource asset values by allowing oblasts to trade water among themselves. The answer is yes, with South Kazakhstan typically renting water from the other regions along the Syr Darya, and total asset values increasing by a little over 1.6 percent. The third policy examines the wealth impact of improving canal efficiency along the Syr Darya. The results suggest farmers improving irrigation efficiency increases the total value of land and water wealth by a nominal amount, but we note the measure is almost certainly an underestimate of the impact.

The current study should not be viewed, however, as a full measure of the tradeoffs of allocating water between agriculture and Syr Darya restoration/maintenance, as we only measure the potential income farmers forego when using less water, and say, not expand cultivated area. A full valuation would measure the economic benefit to the region of the expanded fishery industry accompanying an improved North Aral Sea ecosystem. Such an analysis, however, is beyond the scope of the current study.

The next section provides an overview of prior analysis of Syr Darya Basin economics, and the third section provides a brief description of the economic model used to conduct the valuation and policy impact analysis – details of the model are relegated to appendix 1. The fourth section describes the data used to parameterize the empirical model(s) that follow, and their sources. The fifth section presents the empirical results from the four policy simulations. The last section sums up results of the analysis and suggests future studies.

Literature review

A relatively large literature exists on the history of the physical characteristics of the Aral Sea and how irrigation activities along the Amu and Syr Darya led to its demise. Attention has also focused on the success of the Kazakh government's efforts to restore the North Aral Sea. See Micklin, Aladin and Plotnikov (2014) for an impressive review of the literature on these topics and summary of the Aral Sea's history and rehabilitation efforts. Below, we summarize information in the literature directly

One point that emerges from the Aral Sea's story is Kazakhstan's water endowments depend critically on how much water its upstream neighbors Tajikistan and Kyrgyzstan and Uzbekistan release downstream: South Aral Sea restoration relies mostly on water from the Amu Darya via Tajikistan, while North Aral Sea restoration relies mostly on water from the Syr Darya via Uzbekistan and Kyrgyzstan. The literature suggests the relationship between the countries has sometimes been contentious, but the countries have evolved a mutually beneficial sharing of resources. Kazakhstan, Uzbekistan and Kyrgyzstan share energy and water resources – with Kyrgyzstan providing Kazakhstan and Uzbekistan electric power and releasing water for agricultural production, in return for coal, natural gas and oil from Kazakhstan and Uzbekistan (see Murry-Rust et al, 2003, and Micklin et al, 2014).

To our knowledge, few published studies exist that examine water valuation or water productivity in agriculture. One notable exception is a 2004 World Bank study that suggests the value of irrigation water along the Syr Darya ranges from \$20 to \$50 US per thousand cubic meters (km^3). Another is a 2003 study by the International Water Management Institute (IWMI), that develops estimates of land productivity (in US \$/hectare) and water productivity (in US \$/m^3) in several regions of Kazakhstan and Uzbekistan. The study included estimates of land productivity (rental) values of cotton, wheat and rice in South Kazakhstan and in Kyzylorda. Both the land and water productivity values, however, are average values for the production of all three crops, not individual values. The IMWI land and water productivity values for Kyzylorda and SK are repeated in table 2.

Table 2. Land and water productivity values (rental values)

	Land (US \$/hectare)		Water (US \$/km^3)	
	Kyzylorda	South Kazakhstan	Kyzylorda	South Kazakhstan
Cooperatives	552	599	30	150
Private farms	725	1,475	40	220
District water management organizations	452	591	20	140

Although studies exist that estimate the flow value of water along the Syr Darya, this report is almost certainly the first attempt to estimate the stock value of Syr Darya water and link it to North Aral Sea recovery.

Water allocation along the Syr Darya: The supply of water to SK and Kyzylorda is the result of a complex allocation process. First the Syr Darya Basin Valley Organization (BVO) and Amu Darya BVO decide how much water to allocate to their respective rivers (Syr-Darya and Amu-Darya). Next, the Ministry of Agriculture and Water Management [CONFIRM THIS] decides how much water goes to the irrigation systems within each state, including interstate, inter-district and interfarm canals. Next, sub-provincial water management units, called oblvodkhozes, determine how much water to distribute to each district. See Murry-Rust et al (2003) for more details.

The water allocation process uses three volume measures: the irrigation water limit (IWL), irrigation water demand (IWD) and irrigation water supply (IWS). The IWL is the maximum amount a region will be allocated, and is typically linked to projected water availabilities. The IWD is an estimate of the amount of water a region (province, oblast, and district) would demand given its production goals, climate and soil conditions.[2] The IWS is the actual amount of water allocated to the region, and will not necessarily be equal to a region's IWL. Again, see Murry-Rust et al (2003) for more details. Table 3 presents Kyzylorda's and South Kazakhstan's IWD, IWL and IWS levels for the years 2005 through 2014.

Table 3. Average water allocations to Kyzylorda and South Kazakhstan (in m^3/season)

		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Kyzylorda	IWD	3878.0	4398.0	3652.0	3200.0	3605.5	4027.0	3953.7	3818.8	4088.7	4152.3
	IWL	3878.0	4398.0	3652.0	3200.0	3605.5	4027.0	3953.7	3818.8	4088.7	4152.3
	IWS	3375.6	3442.1	3570.5	3053.5	3429.1	3457.0	3632.4	3717.9	3563.9	3786.0
S. Kazakhstan	IWD	4359.0	4360.0	4380.0	4392.0	4410.0	4438.0	4433.0	4453.0	4469.0	4629.0
	IWL	3060.0	3211.0	3100.0	2659.0	2948.0	2649.0	2880.0	2794.0	3047.0	3267.0
	IWS	2334.0	2408.0	2443.0	2115.0	2384.0	2175.0	2310.0	2213.0	2413.0	2540.0

Table 3 suggests South Kazakhstan's water demand exceeded its allocation each year. Anecdotal evidence suggests water supplies had fallen over time, but canal restoration efforts are beginning to increase water availability to the region. [ARE THE IWD VALUES FOR KYZYLORDA CORRECT?] Straightforward calculations suggest that on average, the Kyzylorda canal system delivers about 90% of the Syr Darya water to its farmers, while South Kazakstan delivers about 78% of the water to its farmers. Recently, Bekchanov, Ringler and Bhaduri (2014) suggest Kyzylorda and South Kazakhstan could increase canal conveyance efficiency from 70 to 90 percent. Table 3 suggests Kyzylorda has already achieved its water delivery efficiency goals. This could be linked to Kyzylorda's stated objective of increasing the level, volume and surface area of the North Aral Sea.

The conceptual model, and the corresponding empirical model, divides Kyzylorda agriculture into two sectors; rice and other-Kyzylorda-agriculture. The reason for this aggregation is hinted at in table 4, which reveals that rice production typically accounts for over 80% of Kyzylorda agricultural water use. We also disaggregate South Kazakhstan agriculture into two subsectors; cotton and other agriculture, primarily because of cotton's dominance in water use before 2007. The other reason is available data suggests water productivity in cotton is quite different than that of water productivity in the rest of South Kazakhstan, with water accounting for 6% of non-cotton value added and accounting for 16% of cotton value added (see the social accounting matrix in appendix 2).

Table 4. Water allocation shares

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Kyzylorda										
Rice	0.820	0.860	0.820	0.806	0.809	0.806	0.818	0.769	0.779	0.831
Lucerne	0.082	0.060	0.081	0.086	0.090	0.089	0.079	0.132	0.118	0.093
Other agriculture	0.098	0.080	0.098	0.107	0.101	0.105	0.103	0.099	0.103	0.076
South Kazakhstan										
Cotton	0.446	0.448	0.471	0.410	0.303	0.288	0.312	0.291	0.256	0.234
Forage (annual and perennial grasses)	0.246	0.258	0.261	0.288	0.354	0.352	0.336	0.288	0.353	0.353
Other agriculture	0.205	0.196	0.179	0.203	0.236	0.254	0.266	0.330	0.316	0.314

[2] Note that nothing is assumed about the optimality of this demand.

Policy issues: As noted above, this study examines three policy questions. The status quo policy is to keep IWL levels unchanged over time. The second policy examines the impact of keeping IWL levels unchanged, but allowing oblasts to trade water use rights each year. The third policy examines the economics of improving irrigation efficiency. For each scenario we project the land and water flow values over time, and calculate the corresponding stock values of the two assets.

MODEL BASICS

The valuation exercise implemented in this study takes as its point of departure, the theoretical framework and corresponding empirical methodology presented in Roe, Smith and Saraçoglu (2010). Although the models developed in Roe, Smith and Saraçoglu (RSS) are dynamic, they each have a static and a dynamic component. The static component models the behavior of two types of agents – consumers and producers – and describes the results of their interactions. Producers combine capital, labor and other inputs to produce final goods and services. Consumers use income to purchase final goods and services (today) and save (for future consumption). The groups of agents interact in "markets" which help determine how resources ultimately get allocated across competing demands. The dynamic component models the optimal savings and consumption decisions of consumers over time.

The static component begins with a utility function for the "representative consumer," and a production function for each productive sector of the economy. The utility function is used to derive an *expenditure function* for the consumer, which the theoretical and empirical model uses to determine how much of a good households demand (or how much they will spend on the good). The production function is used to derive a *cost function* or *value added function* for each sector. The theoretical and empirical model uses the cost and value-added functions to predict how much capital, labor and other inputs a sector will demand, and how much output it will produce. The economy combines physical capital, labor, land and water to produce agricultural, manufactured and service goods. Although other natural resources like minerals and oil are natural endowments, we ignore them in the analysis that follows, and bury them into the economics governing the manufacturing sector.

Capital and labor are used by each sector, and are mobile across the economy. Land is used in agricultural production only, and is fixed to a region or sector, where shortly we discuss when it is possible to view a sector and region as equivalent. Water will initially be viewed as allocated to a specific sector, but we relax this condition when examining water policy options. We assume all final good markets are perfectly competitive, with the implication being no single consumer or producer can influence market prices.

In the models that follow, the structure of agricultural production is such that South Kazakhstan is the major region producing cotton, while Kyzylorda is the major region producing rice. Both regions produce other agriculture, and in SK we aggregate non-cotton production into "SK other agriculture" and in Kyzylorda we aggregate all non-rice production into "Kyzylorda other agriculture." Presently, it appears that rice production uses at least 90 percent of IWS in Kyzylorda. Initially, SK devoted almost half its water endowment to cotton production, but as shown above, this share has fallen quite a bit over time. Still, before understanding these dynamics, model construction had begun and we decided to stick with the original model structure.

Our current understanding is that manufacturing contributes a relatively small amount to Kyzylorda or SK gross domestic product (GDP). Also, manufacturing uses very little water drawn from the Syr Darya. Given these two conditions, we decided to integrate Kyzylorda and SK manufacturing GDP into an aggregate manufacturing sector for all of Kazakhstan. The same reasoning applied to the service sector. Hence, the conceptual (and analogous empirical) model has seven sectors: cotton, rice, other agriculture in SK, other agriculture in Kyzylorda, other agriculture in the rest of Kazakhstan, manufacturing and services.

DATA

We parameterize the model using data from several sources. The major data source is a year 2007 social accounting matrix (SAM) for Kazakhstan developed by the Global Trade Analysis Project (GTAP). The SAM was aggregated to match the five sectors discussed above: South Kazakhstan cotton, Kyzylorda rice, the rest of agriculture in Kazakhstan, and all of Kazakhstan manufacturing and services. The second major data source is the World Bank's World Development Indicator (WDI) data on Kazakhstan's gross fixed capital formation, labor force and gross domestic product, with the WDI data used to create a capital stock series. The third data source is hydrological data from various Kazakh and web-based publications.

The factor categories in the GTAP SAM are capital, labor and land. In the prototype model, we disaggregated the land account into land and water factor accounts. Although the current factor account breakdown will likely be changed once more data on land and water productivity becomes available, the land/water adjusted GTAP SAM allows us to link the conceptual model to an empirical prototype. The empirical prototype allows us to code and debug the empirical model, and the running model gives us an idea of how the modeled economy behaves. The working prototype model may need one or two additional adjustments – e.g., disaggregating manufacturing into South Kazakhstan manufacturing and the rest of Kazakhstan manufacturing – fortunately, doing so at this point is straightforward. Once the model's final parameter values are decided, we simply need to introduce the new values in the beginning of the simulation code and implement the model. Appendix 2 presents the GTAP sourced SAM.

The labor force, gross fixed capital formation and GDP data serve two purposes. First, it allows us to estimate a capital stock series for Kazakhstan, which combined with the social accounting, water use and labor force data, allows us to fully parameterize the production technologies for each sector. Second, it allows for calculating the rate of exogenous technical change for Kazakhstan – an important parameter in economic growth models.

Regarding the final parameter values, although the GTAP data likely gives us reliable sector GDP values (i.e., close or identical to official Kazakhstan Central Bank values), we want to confirm the factor account entries, as they are crucial for parameterizing the production functions of each sector. The temporary values we have chosen, however, allow us to run and debug the model, but will likely be updated in May or June. These temporary factor shares are given in table 5.

Table 5. Kazakhstan Factor Shares

	Cotton	Rice	Other Ag.	Manufacturing	Services
Labor	0.600	0.600	0.600	0.374	0.630
Capital	0.120	0.072	0.122	0.626	0.370
Land	0.165	0.278	0.066		
Water	0.115	0.050	0.212		

Hydrological data needs are annual water use by cotton and rice producers in cubic meters, and the amount of water, again in cubic meters, that flow through South Kazakhstan and through Kyzylorda. By water use, we mean the amount of water each region takes from the Syr Darya. We define the difference between the amount of water that flows down the Syr Darya and the amount withdrawn from the river equals the amount of water in cubic meters that empties into the Aral Sea.

The consumption shares were also derived directly from the SAM. See Roe, Smith and Saraçoglu (2010) for details on this process. The consumption shares are presented in table 6 below.

Table 6. Kazakhstan consumption shares

Rice	Other Ag.	Industry	Services
0.00004	0.06618	0.1621	0.7716

Simulations

This section presents the results of two simulations. The baseline simulation examines the economics of the status quo policy, where Kyzylorda and South Kazakhstan receive a fixed amount of water each period: rice and cotton producers receive 634 km^3 and 2321 km^3 of Syr Darya water each year, while other agriculture in SK (SKOA) and other agriculture in Kyzylorda (KOA) each receive 1202 km^3 and 536 km^3. The rest of Kazakhstan agriculture (ROKA) is endowed with 9306 km^3 of water. In the baseline model we assume sixty percent of the Basin water eventually reaches the fields. The objective of the first simulation is to establish a baseline set of results, and to understand some of the basic forces operating in the economy and how they link with land and water values. The second simulation keeps the total water allocation the same, but allows the two regions to trade water across regions. The discussion of results traces out the impact of capital deepening (i.e., the impact of an increasing capital to labor ratio) on agricultural and non-agricultural production over time, and on the shadow value of water. Capital deepening occurs when an economy's capital stock grows faster than its labor force.

The baseline scenario

Roe, Smith and Saracoglu (2010) discuss the link between factor intensity, capital deepening and economic structure, and suggest capital deepening tends to favor the more capital intensive sectors. One of the effects of capital deepening is a downward pressure on rates of return to capital and upward pressure on wages, as labor becomes relatively more scarce than capital over time. Although not shown here, capital deepening is predicted to occur, and table 6 summarizes the predictions on sector value-added (often referred to as sector GDP). Production in each sector increases over time, with each of the more labor intensive agricultural sectors' value-added doubling in about 40 years. Value-added in the relatively capital intensive manufacturing and service sectors, however, double in less than 20 years, and more than quadruples in 40 years. This outcome is not too surprising, as capital deepening favors the relatively more capital intensive sectors. In other words, agriculture's relatively high dependence on labor puts it at a disadvantage when competing with manufacturing and services over time. Adding to agriculture's problem is the fact that land and water are fixed factors, which puts an additional drag on the agricultural sectors' ability to compete with the rest of the economy for resources. Table A.1 in appendix 2 shows that although agricultural output increases over time, its importance in the economy falls, as evidenced by the decrease in agriculture's share of value-added over time.

Being a non-traded good, demand forces put upward pressure on service good prices, allowing it to compete better for resources, in spite of its high labor share. Industry, the most capital intensive sector in the economy takes advantage of this position and realizes the largest rate of increase in output over the 50 year period. Unlike agriculture, both the manufacturing and service sector's share of GDP increase over time. Again, one of the main drivers of this structural change is the relative importance of capital across the sectors: in general, the more (less) capital intensive in a sector, the more (less) able it will be in competing for productive resources, and hence, the larger (smaller) will be its share of GDP as the economy grows.

Table 7. Sector value-added (in 1000 US $)

Year	SKOA	KOA	ROKA	Cotton	Rice	Industry	Services	GDP
2007	532,250	99,239	5,979,619	62,847	30,450	46,086,963	40,644,177	93,435,545
2012	533,488	99,470	5,993,530	63,002	30,976	58,851,302	51,317,207	116,888,975
2017	557,859	104,014	6,267,330	65,886	32,730	72,584,647	63,070,983	142,683,449
2022	600,726	112,007	6,748,922	70,954	35,505	87,641,817	76,105,877	171,315,808
2027	660,286	123,112	7,418,056	77,992	39,229	104,381,792	90,674,992	203,375,459
2032	736,286	137,282	8,271,894	86,972	43,906	123,185,702	107,077,598	239,539,640
2037	829,444	154,652	9,318,480	97,979	49,593	144,469,977	125,658,307	280,578,432
2042	941,171	175,483	10,573,698	111,178	56,379	168,697,651	146,810,904	327,366,464
2047	1,073,467	200,150	12,059,991	126,808	64,391	196,389,574	170,984,052	380,898,433
2052	1,228,873	229,126	13,805,919	145,167	73,785	228,136,268	198,689,912	442,309,050
2057	1,410,483	262,988	15,846,236	166,622	84,748	264,611,121	230,514,428	512,896,626

Given that value-added for each agricultural sector increases over time, if land and water endowments remain relatively constant over time, it is reasonably simple to show land and water contributions to GDP must increase as the economy grows. This underscores one important link between natural resource values and growth: natural resource values are influenced by the ability of the sector using the resource to compete for capital and labor. Highly competitive sectors will attract capital and labor at a faster rate than other sectors, and in general, increase the productivity of water and land at a faster rate than those sectors.

Table 8 examines, more closely, water's contribution to GDP. The table presents two types of water values: the *unit shadow rental rate* of water for each of the agricultural sectors, and the aggregate *shadow value added* of water for each sector. Here, the unit shadow rental rate is the amount a farmer would be willing to pay for the right to purchase an additional unit of water in the current period. This is to be contrasted with a sector's unit shadow price of water, which is the amount a farmer would pay for permanent user rights to a unit of water. The reader can verify that, the rate of growth in unit shadow rental rates follows closely, the rate of growth in output from each sector.

Observe at each point in time, the unit shadow rental rates vary across sectors, with SKOA assigning a higher unit shadow rental rate of water than any of the agricultural sectors along the Syr Darya. On average, SKOA values water two and one half times more than cotton producers, and eight times more than rice producers. The estimated shadow rental rates are much smaller than those from the 2003 IWMI study. This result can be due to several reasons, but absent more details on exactly how the IWMI figures were calculated, we are unable to uncover a plausible explanation for the differences.

One policy implication of the distribution of unit shadow rental rates across sectors is the river basin could likely benefit from reallocation water across the agricultural sectors in the region. In this case, the likely outcome of such an institutional change is cotton, rice and KOA would rent some of its water to SKOA. The next section examines the likely outcome of such trades.

Another policy implication imbedded in table 7 relates to the fact that the shadow rental rates will likely change over time: in this case, increase as the economy evolves. Earlier, we note this occurs because real output in each agricultural increases over time. More specifically, this is the result of improvements in technical change, and the corresponding increase in labor productivity. The policy implication here is, if negotiations ever emerge for trading water use rights, the mechanism that implements the water trading scheme will allow for renegotiating prices over time.

Table 8. Water flow shadow values - per unit and total

	Unit shadow rental rate per sector ($ / km^3)					Shadow value-added per sector (1000 US $)					
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice	Total
2007	39.04	16.32	56.68	15.14	4.87	35,212	6,565	395,596	7,198	8,469	453,041
2012	39.13	16.36	56.81	15.18	4.95	35,294	6,581	396,516	7,216	8,616	454,222
2017	40.92	17.11	59.40	15.87	5.23	36,906	6,881	414,630	7,546	9,104	475,067
2022	44.07	18.42	63.97	17.10	5.67	39,742	7,410	446,491	8,127	9,875	511,645
2027	48.44	20.25	70.31	18.79	6.27	43,683	8,145	490,759	8,933	10,911	562,430
2032	54.01	22.58	78.41	20.96	7.02	48,711	9,082	547,246	9,961	12,212	627,213
2037	60.84	25.44	88.33	23.61	7.92	54,874	10,231	616,486	11,222	13,794	706,607
2042	69.04	28.87	100.22	26.79	9.01	62,265	11,610	699,528	12,734	15,682	801,818
2047	78.74	32.92	114.31	30.55	10.29	71,018	13,241	797,857	14,524	17,910	914,550
2052	90.14	37.69	130.86	34.98	11.79	81,299	15,158	913,363	16,627	20,523	1,046,969
2057	103.47	43.26	150.20	40.15	13.54	93,314	17,399	1,048,345	19,084	23,572	1,201,713

Table 8 also presents water's contribution to GDP – or the *flow* shadow value-added – of each sector. Here, the Syr Darya basin accounts for about 13% of water's contribution to agricultural GDP (e.g., in 2007 we have 57.45/453 = 0.1268) with SKOA being the major contributor to water's value added along the basin. These patterns hold across each time period, and is primarily the result of the size of SKOA's water endowment, and its relatively high shadow rental rates. Table A.2, in appendix 2 shows land and water's contribution to GDP is equal to about 2 percent in 2007, but falls to a little under 1 percent 50 years later. This is primarily the result of land and water constant being fixed, whereas the capital and labor grow over the 50 year period.

As noted above, the unit shadow values of water in table 7 are measures of how much a farmer would pay to purchase an additional unit of water in given period of time. The prices and value added levels in table 7 are crucial ingredients in calculating the investment (or stock) value of water: the amount a farmer would pay for permanent rights to use the water. A standard definition of the stock value of an asset is the discounted present value of all future net income streams. In the case of water (and land), the flow shadow value added at a given time is the net income stream for that period. The appropriate discount rate is given by equation (6) in appendix 1, and depends on the rate of return to capital and changes in the stock of water (if any).

Inclusive wealth is a concept of human well-being gaining in popularity among economists, and more recently, policymakers. Simply put, inclusive wealth is the total asset value of four types of capital: natural capital (e.g., minerals, water and land), physical/man-made capital (e.g., machinery and buildings), human capital (embodied in education) and institutional capital (e.g., patent systems and legal systems). We now examine the asset (or stock) value of water.

Table 9 presents the unit stock price of water for each sector. Given the shadow rental rates increase over time, it is necessarily the case that the unit shadow price in period t + 1 will be larger than the unit shadow price in period *t*. Hence, for Kazakhstan, the rate of exogenous technical change and labor force growth leads to an increase in the shadow stock price of water for each sector. Understand, however, that nothing guarantees this outcome universally: if a sector is sufficiently labor intensive, and the rate of technical change and labor force growth is relatively small, it is possible for the shadow stock price of a sector to fall over time.

Table 9 also presents the price/earnings ratio for each sector over time. We do this to illustrate how important it is to use the “correct” discount factor. The “correct” unit price is calculated using the discount factor in equation (6) of appendix 1, while the “traditional” unit price is calculated using the standard calculation – i.e., dividing the water rental rate by the interest rate (e.g., the price/earnings, PE, ratio). For each period in time, the PE ratio is smaller than the corresponding shadow price corrected discounted. The point to stress to technicians is, deriving the “correct” unit stock value of a natural resource ***requires*** exploiting a no-arbitrage condition derived from macroeconomic conditions and variables (equation 6 in appendix 1). It follows that attempting to calculate the stock value of a natural asset in a (static or dynamic) partial equilibrium setting can lead to potentially biased – in this case, seriously biased – unit stock price estimates. In such a case, using the PE ratio can seriously bias downward (in some cases, upward), a natural resource’s contribution to national wealth.

Table 9. Unit stock shadow price of water (US $ / km^3)

	“Correct” calculations					Price/earnings ratio				
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice
2007	1,123.5	469.8	1,631.0	435.9	144.8	624.8	261.2	907.0	242.3	77.9
2012	1,332.9	557.3	1,934.9	517.1	172.8	695.5	290.8	1,009.6	269.8	88.0
2017	1,572.7	657.6	2,283.0	610.2	204.6	786.0	328.6	1,141.0	304.9	100.4
2022	1,846.3	772.0	2,680.2	716.3	240.8	896.1	374.7	1,300.8	347.6	115.4
2027	2,158.6	902.6	3,133.6	837.5	282.0	1,026.9	429.4	1,490.7	398.4	132.9
2032	2,515.7	1,051.9	3,652.0	976.1	329.0	1,180.4	493.5	1,713.5	458.0	153.3
2037	2,925.0	1,223.0	4,246.1	1,134.9	382.8	1,359.3	568.4	1,973.3	527.4	177.0
2042	3,394.8	1,419.4	4,928.1	1,317.2	444.5	1,567.2	655.3	2,275.1	608.1	204.5
2047	3,934.8	1,645.2	5,712.1	1,526.8	515.4	1,808.2	756.0	2,624.9	701.6	236.2
2052	4,556.4	1,905.1	6,614.4	1,768.0	596.9	2,087.2	872.7	3,030.0	809.9	273.0
2057	5,272.4	2,204.5	7,653.9	2,045.8	690.9	2,410.0	1,007.7	3,498.6	935.1	315.4

Why would a policymaker care about the asset value of water, or land? One reason is a calculation of the stock values under the status quo policy gives her a good idea of the value of the asset under that regime. If she is considering another policy regime, almost certainly the policy change will trigger a change in the stock value. In the case of agriculture, if the stock value of land and water increases, the policy improves the income and wealth of the asset owners. If not, the policy worsens their wealth position. Given that stock values are the discounted value of current and future land and water rental payments/income, an increase (decrease) in the stock value is likely accompanied by an increase (decrease) in short run and long run farmer income. Hence, a change in that single index of value signals corresponding changes to income streams in the near and long run. One problem with this index, however, is it can hide the timing and magnitudes of the changes; suggesting if a large change in stock values is predicted, a close look at the predicted income streams is warranted.

The total asset value of land and water is given in table 10. The water asset values are derived by simply multiplying the stock price of water for a sector by the quantity of Syr Darya water it is allocated. Land asset values are derived by solving equation (5) in appendix 1. One thing that might not be obvious, however, is while the model pays close attention to water quantity levels and unit prices, the quantity of arable land is normalized to unity. This means we interpret land rent as the total value of rental payments to landowners, not rent per hectare.

Table 10. The stock value of water and land

	Stock value of water (US $ / km^3)					Stock value of land				
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice
2007	810,604	151,139	9,106,853	165,756	201,678	2,600,934	484,950	29,220,489	238,626	36,273
2012	961,658	179,304	10,803,893	196,655	240,633	3,085,612	575,319	34,665,656	283,108	43,279
2017	1,134,667	211,562	12,747,600	232,042	284,954	3,640,738	678,823	40,902,285	334,053	51,251
2022	1,332,080	248,370	14,965,463	272,419	335,325	4,274,164	796,927	48,018,580	392,181	60,310
2027	1,557,426	290,386	17,497,143	318,509	392,675	4,997,216	931,742	56,141,793	458,532	70,625
2032	1,815,113	338,433	20,392,170	371,212	458,144	5,824,041	1,085,905	65,430,853	534,405	82,400
2037	2,110,378	393,486	23,709,374	431,600	533,073	6,771,440	1,262,550	76,074,521	621,341	95,877
2042	2,449,318	456,682	27,517,245	500,920	619,015	7,858,975	1,465,323	88,292,556	721,136	111,334
2047	2,838,972	529,334	31,894,880	580,612	717,760	9,109,236	1,698,437	102,338,751	835,862	129,094
2052	3,287,448	612,954	36,933,352	672,334	831,366	10,548,233	1,966,741	118,505,326	967,907	149,526
2057	3,804,071	709,280	42,737,430	777,993	962,196	12,205,888	2,275,814	137,128,444	1,120,015	173,057

Calculating the full inclusive wealth of Kazakhstan is beyond the scope of this analysis. One can, however, compare the wealth derived from water and land with the wealth derived from physical capital, as the no arbitrage condition implicitly defines the asset value of land and water in terms of the value of physical capital – whose unit price is normalized to unity. Table A.3 in ap7endix 2 shows the asset value of land and water is 18 percent that of physical capital in 2007, and drops down to 12 percent in 2057. These values warrant a closer look, and considering we have not included the asset values of minerals and crude oil, suggest natural resources hold a prominent position in Kazakhstani wealth.

One reason for this study is to develop a model for measuring the value of natural resources, in this case water, in an economy. The other objective is to discuss ways to "mainstream" the economic information above into the policymaking process. We conclude this section with a summary of what the information in tables 6 through 9 conveys to the astute policymaker. First, if predicted unit shadow water rents increase over time, the agricultural ministry can be confident that agriculture is reasonably competitive with manufacturing and services in the markets capital and labor (factor markets) – competitive enough to not contract as the economy grows. Second, if the unit shadow water rents vary across sectors, it may be worthwhile setting up a commission to investigate the potential gains from water trading. Third, the stock value of water and land is a scalar index of the value of current and future income farmers will receive from land rent and shadow water rent. These values, almost certainly, are influenced by the agricultural policy environment: industrial policy can affect these stock values, too – especially if an industrial policy gives manufacturing or services an edge in competing for capital and labor. In any event, the careful minister will insist on conducting an exercise that estimates the stock values of the assets under her purview, given the proposed policy change. If the stock values of land and water increase with a proposed policy (e.g., water trading or purchasing Syr Darya water for Aral Sea restoration), one can cautiously assume farmers, and possibly society in general, are benefitting from the policy. An additional look at the aggregate rental values over time can increase her level of confidence in supporting the policy; if for each year, the water and land rental values under the new policy regime are higher than those under the old regime, she can safely conclude the policy is beneficial to farmers. If the rental values are higher in some years, but not in others, a more careful consideration of the tradeoffs is likely warranted.

Oblast water trading

Table 8 revealed, on average, SKOA producers place the highest value on water, and if presented a chance to purchase – either per period, or permanent – water rights, they would seize the opportunity. If water trading occurred, the expected outcome would be for a single price to emerge such that the last unit of water used in each sector would have the same value – economists would write that the marginal value product of water is the same for sector. The rationale underlying this outcome goes something like this: if SKOA was willing to pay a little more than everyone else for an additional unit of water, then someone along the river basin (say one of the rice producing oblasts) would be willing to give up some of their water to SKOA. Doing so would make water a little scarcer in the rice region, and hence, push up its (marginal) valuation of water. It would make water a little less scarce in SKOA, and put downward pressure on its (marginal) value of water. Barring one or more sectors facing irrigation system constraints in using additional water, this process would tend to nudge water trading prices along the river basin towards a single trading value.

One of the main points to take away from the previous section is: policy can influence both the flow and the asset value of natural resources. This section takes a closer look at the potential benefits of allowing oblasts to trade water use rights among themselves, over time. As in the prior section, the results assume the Syr Darya basin has been allocated about 6980 km^3 of water, and on average, 60% of that water eventually reaches the fields. The overall economy dynamics here are similar to those in the base scenario, and aside from a quick comparison of sector value added levels, are not discussed in this section. Instead, we focus attention on the unit and total, flow and stock prices of water across the agricultural sectors along the Syr Darya. One thing we will look for is whether a water trading environment increases, or decreases, the asset value of water.

Perhaps as a reminder, sector value-added is measured as the sum of payments to labor, capital, land and water used to produce output in each sector. Table 11 shows that, as in table 7, as the economy grows, value-added in each sector increases over time. Simple calculations will show, for each sector, the rates of growth between 2007 and 2057 are similar, with all but rice and services growing slightly faster with water trading. The rice sector virtually closes, but most of the foregone production income is recovered from income it gets from renting water to SKOA.

Table 11. Sector value-added with water trading (in 1000 US $)

Year	SKOA	KOA	ROKA	Cotton	Rice	Industry	Services
2007	690,678	98,134	5,963,110	58,376	31	45,948,101	40,734,542
2012	692,846	98,442	5,981,865	58,572	35	58,687,630	51,403,872
2017	724,901	102,996	6,258,656	61,292	39	72,390,633	63,154,524
2022	780,908	110,954	6,742,235	66,034	44	87,412,238	76,187,424
2027	858,568	121,988	7,412,769	72,607	50	104,111,201	90,755,992
2032	957,579	136,056	8,267,637	80,985	57	122,868,084	107,159,681
2037	1,078,887	153,291	9,315,010	91,247	65	144,098,495	125,743,232
2042	1,224,339	173,958	10,570,844	103,552	75	168,264,438	146,900,540
2047	1,396,540	198,425	12,057,630	118,119	86	195,885,524	171,080,388
2052	1,598,802	227,163	13,803,956	135,228	99	227,550,824	198,795,082
2057	1,835,153	260,744	15,844,601	155,220	114	263,932,039	230,630,744

Table A.4 in appendix 2 reveals Kyzylorda produces very little rice, and table 12 reveals it earns almost all of its value-added on water rent received from SKOA oblasts. Table 12 suggests that each year, SKOA producers would purchase water from each of the other agricultural sectors along the Syr Darya, buying almost all of the rice water available each year. For example, in 2007, SKOA pays the other sectors over $30,000,000 US for 1464 km^3 of water, with over $29,000,000 US used to purchase water from the rice producing oblasts.

Table 12. Water trading levels (supply) and values by sector[#]

Year	Unit rental price / km^3	Levels (km^3)				Values (1000 US $)			
		SKOA	KOA	Cotton	Rice	SKOA	KOA	Cotton	Rice
2007	20.91	-1464.0	11.2	60.5	1392.3	-30,608	235	1,265	29,110
2012	20.97	-1463.9	11.2	60.4	1392.2	-30,704	236	1,268	29,201
2017	21.95	-1463.8	11.2	60.4	1392.2	-32,124	247	1,325	30,552
2022	23.64	-1463.8	11.2	60.4	1392.2	-34,606	266	1,427	32,913
2027	25.99	-1463.8	11.3	60.4	1392.2	-38,047	292	1,569	36,186
2032	28.99	-1463.7	11.3	60.3	1392.2	-42,434	326	1,749	40,359
2037	32.66	-1463.7	11.3	60.3	1392.1	-47,810	368	1,970	45,472
2042	37.07	-1463.7	11.3	60.3	1392.1	-54,255	417	2,236	51,602
2047	42.28	-1463.7	11.3	60.3	1392.1	-61,886	476	2,550	58,860
2052	48.40	-1463.7	11.3	60.3	1392.1	-70,849	545	2,919	67,385
2057	55.56	-1463.7	11.3	60.3	1392.1	-81,322	626	3,351	77,346

[#] Positive values represent supply, negative values represent demand.

These results, however, should not be taken too seriously, as the magnitude of water trades between Other-Ag SK and rice producers is unlikely, and is the result of the functional form (Cobb-Douglas) used in the numerical model: the specification yields an outcome where a small change in water rental rates leads to large swings in water demand. Gemma and Smith (2015) examine the effect of different production and utility function specifications on rice production quota trading in Japan.[3] We suspect a re-specification of the production technologies along the lines of Gemma and Smith (2015) will yield similar market water rental rates predicted in the current model, but much smaller water trading levels.

Returning to the model results, the entries in table 13 give the level differences between agricultural value added in the market and base scenarios. The major observation to make here is water trading leaves cotton, rice and Kyzylorda other agriculture worse off by $5,300,000 US – but SKOA gains over $158,000,000 US. These values give any ministries involved in implementing such a program, the benefit side, of a cost-benefit analysis of the program. The SKOA gain leaves ample room for SKOA to compensate the KOA, cotton and rice oblasts for their lost income. Introducing a lump sum tax on water trades might be one way to raise compensation income: for

[3] Using four different model specifications, Gemma and Smith (2015) estimate the equilibrium levels of five variables: the price of two types of rice, the land rental rates associated with each type of rice produced (identical in equilibrium), and the number of production quotas traded. The model specifications involve: Cobb-Douglas production and utility, Cobb-Douglas production and Almost-Ideal-Demand-System (AIDS) utility, "quasi-Leontief" production and Cobb-Douglas utility functions, and "quasi-Leontief" production and AIDS utility. They find each model yields close to identical rice prices and land rent, but quite different quota trading levels.

example, if estimates suggest cotton, rice and other agricultural production in Kyzylorda would lose $10 million if a water trading scheme was implemented, and SKOA was composed of 100 (for the present, identical) oblasts, then charge an purchase entry fee of $100,000 per oblast, and distribute the proceeds across the cotton, rice and KOA oblasts proportionally (according to their projected losses). This would still leave the SKOA oblasts with a generous program surplus. Of course, other sharing arrangements can be envisioned, and could generate quite a bit of dialogue along the river basin.

Table 13. Sector value-added gains and losses with water trading (in 1000 US$)

Year	SKOA	KOA	Cotton	Rice	Total income lost	Surplus to SKOA
2007	158,652	-839	-3,186	-1,300	-5,325	153,327
2012	159,585	-761	-3,142	-1,731	-5,634	153,951
2017	167,254	-741	-3,250	-2,130	-6,122	161,132
2022	180,374	-760	-3,476	-2,541	-6,776	173,597
2027	198,454	-807	-3,801	-2,986	-7,595	190,860
2032	221,447	-878	-4,225	-3,484	-8,587	212,860
2037	249,580	-973	-4,749	-4,051	-9,773	239,806
2042	283,289	-1,091	-5,380	-4,697	-11,168	272,122
2047	323,181	-1,234	-6,130	-5,441	-12,805	310,376
2052	370,024	-1,405	-7,012	-6,297	-14,714	355,310
2057	424,754	-1,607	-8,044	-7,284	-16,935	407,819

One outcome of water trading is, at each point in time, farmers across the Syr Darya pay the same unit rental price of water. Again, since the rental rates increase over time, it follows that the unit stock price of water will increase over time, as will the total land rent for each sector. Table 14 presents the trajectory of unit stock water prices, and the corresponding PE ratios. As with the base model, the “correct” unit stock price is a little more than twice that of the corresponding PE ratio. Again, this has implications for inclusive wealth analysis: PE based wealth values will likely underestimate water’s contribution to the economy.

Table 14. Unit stock price of water (US $ / km^3)

Year	“Correct”	PE ratio
2007	482.9	268.2
2012	572.9	298.6
2017	675.9	337.6
2022	793.4	384.9
2027	927.6	441.1
2032	1081.0	507.1
2037	1256.8	584.0
2042	1458.6	673.3
2047	1690.6	776.8
2052	1957.7	896.7
2057	2265.3	1035.4

Earlier it was suggested that policy could, in principle, affect asset values. Table A.5 in appendix 2 presents the stock value of land and water across sectors under the water trading scenario. Table 15 summarizes the potential sector gains and losses in water and land wealth when implementing a water market policy. Overall, a more "efficient" allocation of water increases the wealth value of the natural assets – or worded differently – increases the wealth value of the ecosystem services provided by the assets. Table 15 also reveals policy can have distributional impacts. In each of the sectors along the Syr Darya, a tradeoff occurs between water and land wealth. In the case considered here, water trading establishes an equilibrium water rent rate that is lower than the SKOA's shadow rental rate in the base scenario, but higher than the shadow rental rates that prevail in the cotton, rice and KOA sectors. This makes SKOA's water endowment less valuable, but increases the value of water in the other sectors. With cheaper water, SKOA demands more water, and more water enables SKOA to compete more effectively in the capital and labor markets. These forces all contribute to increasing land productivity, and hence, the asset value of SKOA land increases.

On the other hand, higher unit water prices increase and the total asset value of water increases for the cotton, rice and KOA sectors. Trading away some of their water to SKOA, however, put downward pressure on the productivity of capital, labor and land. Hence, land rental rates and land wealth falls. In each sector, though, the gains dominate the losses, and overall welfare improves. If land and water use rights are typically held by the same individual(s), then "one hand washes the other" and the distributional impact of the policy is reasonably neutral. If resource use rights are held by different parties, as in Texas and other parts of the U.S., then the policy could have unpopular consequences. The point here, is if income distribution is an important policy consideration, even if wealth indices improve with a policy, ministries may want to look closely at the distributional impact of the policy: if implementing a policy increases asset wealth, almost certainly enough income will be generated to compensate the loser. Table A.6 in appendix 2 summarizes the net gains in water and land wealth in the presence of water trading.[4]

Table 15. Gains and losses in asset value with water trading (1000 US $)

Year	Stock value of water					Stock value of land					Total Gain
	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice	
2007	-462,186	4,232	4,416	17,889	470,870	674,651	-24,446	58,914	-34,397	-42,428	667,514
2012	-548,343	5,007	4,340	21,197	557,184	774,474	-33,815	80,327	-45,057	-52,042	763,272
2017	-647,034	5,891	4,005	24,981	656,322	887,802	-44,728	99,914	-57,418	-63,069	866,665
2022	-759,647	6,897	3,573	29,301	769,639	1,015,854	-57,415	116,501	-71,710	-75,693	977,299
2027	-888,193	8,047	3,124	34,233	899,140	1,160,884	-72,111	129,377	-88,193	-90,145	1,096,164
2032	-1,035,185	9,364	2,698	39,875	1,047,345	1,325,992	-89,055	137,899	-107,140	-106,692	1,225,100
2037	-1,203,609	10,873	2,310	46,343	1,217,257	1,515,140	-108,479	141,348	-128,831	-125,634	1,366,716
2042	-1,396,943	12,608	1,966	53,769	1,412,378	1,733,294	-130,585	138,984	-153,533	-147,297	1,524,641
2047	-1,619,200	14,604	1,666	62,309	1,636,758	1,986,684	-155,517	130,297	-181,472	-172,024	1,704,105
2052	-1,875,006	16,902	1,408	72,141	1,895,062	2,283,189	-183,308	115,621	-212,793	-200,168	1,913,047
2057	-2,169,680	19,551	1,186	83,468	2,192,659	2,632,921	-213,799	97,438	-247,501	-232,077	2,164,168

The ratio of land and water wealth to normalized capital stock wealth is very close to that found in the base scenario – starting at 18 percent of physical asset wealth and falling to 13 percent (see table A.6 in appendix 2).

[4] Another policy experiment not implemented here would be to introduce a water market, but decrease the amount of water to trade enough to keep total asset wealth at least as large as the status quo outcome.

We summarize this section by reminding the reader that the analysis eventually focused on the wealth value of land and water, and used the indices to understand the impact of a natural resource policy on natural asset wealth. The primary purpose of the simulation was to illustrate how natural asset (or ecosystem service valuation) can be used to guide and understand the impact of policy. Although the illustration was natural resource policy, the notion that policy can affect natural resource wealth or the value of ecosystem service flows extends to almost any economic policy, be it trade, fiscal or industrial policy in general.

Improving irrigation efficiency

This section reports the results of a simulation where irrigation efficiency improves for each of the agricultural sectors along the Syr Darya. We begin with the baseline efficiency assumption of 75% of the IWD reaching crops, and gradually increase irrigation efficiency over a twenty year period. By 2027, 90% of the IWD reaches the crops. Aside from Syr Darya agriculture, the sector value added levels and shares follow closely those of the base model (see tables A.8 and A.9 in appendix 2). As in the base and water market models, production in each sector increases over time, agricultural value-added doubling in about 40 years, value-added in manufacturing and service sectors double in less than 20 years.

Table 16 summarizes differences between the base model results and the model with improved irrigation efficiency. Improved irrigation efficiency increases the effective water endowment of each sector, which increases the productivity of capital, labor and land in Syr Darya agricultural production. In turn, the region's ability to compete for capital and labor increases over time. These forces enable Syr Darya agriculture to increase its production relative to base model levels.

Table 16. Percent difference in sector value-added: $\left(\frac{\text{efficiency improvement}}{\text{base}} - 1\right)$

Year	SKOA	KOA	ROKA	Cotton	Rice	Industry	Services	GDP
2007	-0.002	-0.002	-0.002	-0.002	-0.002	0.009	-0.004	0.003
2012	0.010	0.010	0.001	0.018	0.036	0.005	-0.004	0.001
2017	0.021	0.021	0.002	0.036	0.072	0.003	-0.004	0.000
2022	0.032	0.032	0.003	0.053	0.108	0.001	-0.004	-0.001
2027	0.041	0.041	0.004	0.069	0.143	0.000	-0.004	-0.002
2032	0.050	0.050	0.004	0.085	0.178	-0.001	-0.004	-0.002
2037	0.059	0.059	0.004	0.100	0.213	-0.002	-0.003	-0.002
2042	0.067	0.067	0.004	0.115	0.247	-0.003	-0.003	-0.002
2047	0.075	0.075	0.004	0.129	0.280	-0.003	-0.002	-0.002
2052	0.082	0.082	0.003	0.143	0.314	-0.004	-0.002	-0.002
2057	0.089	0.089	0.003	0.156	0.347	-0.003	-0.001	-0.002

A byproduct of this enhanced ability to compete for resources is revealed in table 17, which shows the total rate of growth in sector value-added over the 50 year period, 2007 – 2057. The rate of growth in Syr Darya agricultural output increased at the expense of industry and service sector growth (slightly). This result reveals an important aspect of ecosystem service and natural resource valuation: in general, resource abundance should enhance the competitiveness of sectors drawing on its services.

Table 17. Total rate of growth in sector value-added between 2007 and 2057

Growth	SKOA	KOA	ROKA	Cotton	Rice	Industry	Services	GDP
Base	1.650	1.650	1.650	1.651	1.783	4.742	4.672	4.489
Improved irrigation efficiency	1.892	1.892	1.662	2.072	2.755	4.674	4.684	4.466

Table 18 compares unit shadow rent levels and total shadow rental value levels across sectors (see table A.10 in appendix 2 for the irrigation efficiency model's unit and total shadow rental values). With water increasingly more abundant relative to the base model, water unit shadow rental rates are lower at each point in time (imperceptibly in the initial period), across each sector. For each sector, the total shadow rental value – or shadow value-added – is higher in the increased irrigation efficiency model relative to the base case: this occurs because the rate of growth in water quantities is larger than the rate of decline in the unit shadow rental rate. Increasing the sector water endowments leads to a wider variation in shadow rental rates, suggesting again, that trading water use rights might lead to improved farmer and aggregate welfare.

Table 18. Percent difference in water shadow rental values – per unit and total: $\left(\frac{\text{efficiency improvement}}{\text{base}} - 1\right)$

	Unit shadow rental rate per sector ($/km^3)					Shadow value-added per sector (1000 US $)					
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice	Total
2007	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
2012	-0.030	-0.030	0.001	-0.023	-0.006	0.010	0.010	0.001	0.018	0.036	0.002
2017	-0.057	-0.057	0.002	-0.044	-0.010	0.021	0.021	0.002	0.036	0.072	0.006
2022	-0.083	-0.083	0.003	-0.064	-0.015	0.032	0.032	0.003	0.053	0.108	0.009
2027	-0.108	-0.108	0.004	-0.084	-0.020	0.041	0.041	0.004	0.069	0.143	0.011
2032	-0.131	-0.131	0.004	-0.102	-0.025	0.050	0.050	0.004	0.085	0.178	0.013
2037	-0.153	-0.153	0.004	-0.120	-0.030	0.059	0.059	0.004	0.100	0.213	0.015
2042	-0.174	-0.174	0.004	-0.137	-0.035	0.067	0.067	0.004	0.115	0.247	0.016
2047	-0.194	-0.194	0.004	-0.153	-0.040	0.075	0.075	0.004	0.129	0.280	0.018
2052	-0.213	-0.213	0.003	-0.169	-0.045	0.082	0.082	0.003	0.143	0.314	0.019
2057	-0.231	-0.231	0.003	-0.184	-0.049	0.089	0.089	0.003	0.156	0.347	0.020

Table 19 presents the percent difference in land values and unit water prices for each sector (see table A.11 in appendix 2 for the irrigation model's land and unit water stock prices). Again, since water is more abundant, it is less scarce, and unit stock price of water is initially lower with more efficient irrigation. On the other hand, more water makes land more productive, and hence, increases land values. Given the structure of agricultural production, improvements in irrigation technology lead to a nominal increase in natural asset wealth (the

Table 19. Percent difference in stock land value and unit stock shadow price of water: $\left(\frac{\text{efficiency improvement}}{\text{base}} - 1\right)$

	Unit stock price of water					Stock price of land					
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice	Total
2007	-0.1253	-0.1253	-0.0015	-0.0995	-0.0288	0.0425	0.0425	-0.0015	0.0762	0.1709	-0.0011
2012	-0.1143	-0.1143	-0.0019	-0.0822	0.0058	0.0508	0.0508	-0.0019	0.0912	0.2037	-0.0002

2017	-0.1002	-0.1002	-0.0021	-0.0625	0.0412	0.0578	0.0578	-0.0021	0.1038	0.2319	0.0007
2022	-0.0837	-0.0837	-0.0022	-0.0411	0.0772	0.0639	0.0639	-0.0022	0.1147	0.2564	0.0018
2027	-0.0653	-0.0653	-0.0021	-0.0180	0.1136	0.0691	0.0691	-0.0021	0.1242	0.2777	0.0030
2032	-0.0451	-0.0451	-0.0020	0.0064	0.1505	0.0737	0.0737	-0.0020	0.1323	0.2961	0.0042
2037	-0.0232	-0.0232	-0.0018	0.0323	0.1878	0.0776	0.0776	-0.0018	0.1391	0.3117	0.0055
2042	0.0007	0.0007	-0.0015	0.0597	0.2257	0.0808	0.0808	-0.0015	0.1446	0.3244	0.0069
2047	0.0266	0.0266	-0.0012	0.0888	0.2640	0.0832	0.0832	-0.0012	0.1488	0.3339	0.0082
2052	0.0548	0.0548	-0.0009	0.1197	0.3029	0.0848	0.0848	-0.0009	0.1516	0.3400	0.0095
2057	0.0855	0.0855	-0.0007	0.1527	0.3424	0.0855	0.0855	-0.0007	0.1527	0.3424	0.0108

Table 20 gives the difference in water and land stock values. With increased irrigation efficiency, farmers realize a net gain in wealth relative to the base scenario. These results suggest investing in irrigation infrastructure repair, should yield benefits to Syr Darya agriculture. These values, however, likely underestimate the gain from improving irrigation efficiency. As modeled here, increased water endowments are spread over the same level of cultivated area. A more realistic specification would allow cultivated area to increase with improved irrigation efficiency. In addition to increasing the number of hectares earning rent, this modeling adjustment would have increased the productivity of water: doing so would, without question, increase the stock value of the ecosystem (natural resources). Viewed another way, table 20 also provides a measure of another policy: increasing irrigation efficiency and then sending the additional water (reaching plants) down the Syr Darya to the Aral Sea. In this case, agriculture forgoes an additional 14,5 million in natural asset wealth.

Table 20. Water and land wealth in the water market and base scenarios (1000 US $)

	Irrigation Efficiency Scenario			Base Scenario			Difference (efficiency – base)		
Year	Water	Land	Total	Water	Land	Total	Water	Land	Total
2007	10,279,294	32,691,971	42,971,265	10,436,037	32,581,271	43,017,308	-156,743	110,700	-46,043
2012	12,216,335	38,806,993	51,023,328	12,382,151	38,652,974	51,035,124	-165,815	154,019	-11,796
2017	14,446,075	45,816,223	60,262,297	14,610,835	45,607,150	60,217,985	-164,761	209,073	44,312
2022	17,003,280	53,821,401	70,824,681	17,153,669	53,542,162	70,695,832	-150,389	279,239	128,850
2027	19,937,100	62,967,051	82,904,151	20,056,152	62,599,908	82,656,060	-119,052	367,143	248,091
2032	23,308,956	73,432,802	96,741,758	23,375,087	72,957,604	96,332,692	-66,131	475,198	409,066
2037	27,192,303	85,431,449	112,623,752	27,177,929	84,825,729	112,003,659	14,374	605,720	620,093
2042	31,673,472	99,210,083	130,883,555	31,543,201	98,449,324	129,992,526	130,270	760,759	891,029
2047	36,853,207	115,052,992	151,906,199	36,561,583	114,111,380	150,672,963	291,623	941,612	1,233,236
2052	42,848,716	133,285,584	176,134,299	42,337,482	132,137,733	174,475,214	511,234	1,147,851	1,659,085
2057	49,796,098	154,278,629	204,074,727	48,991,002	152,903,219	201,894,220	805,097	1,375,410	2,180,507

Finally, the ratio of land and water wealth to normalized capital stock wealth is similar to that estimated in the base and market scenarios – starting at around 17 percent of physical asset wealth and falling to a little over 12 percent (see table A.13 in appendix 2).

We conclude this section by noting the stock value of natural resources seems promising as an economic index of potential value to policymakers, and exploits the fact that, in general policy choices affect the underlying wealth embedded in ecosystems and natural resources. Our understanding is this is a relatively new use (or at least actual application) of natural asset stock values: as such, one should view our interpretations with a critical eye. Still, it appears that measuring the impact of a proposed policy on natural asset values has potential as a tool for mainstreaming ecosystem services into regional and macroeconomic policy debate.

Conclusion

The objective of this report has been to develop a tool for mainstreaming ecosystem services into Syr Darya water management. The empirical applications presented above build on the conceptual model outlined in Smith (2014) – a model having its roots in the dynamic, general equilibrium models introduced in Roe, Smith and Saracoglu (2010). Perhaps one of the most important features of the tool is its use of natural asset wealth measures to understand the impact of policy. Another side benefit of the analytical tool is its departure from using the price/earnings ratio as an estimate of (natural) asset value – an approach that can underestimate asset values by at least one half its value when calculated properly. We name the mainstreaming tool, the ???.

The report uses the mainstreaming tool to analyze the impact of three policy scenarios: the status quo policy of allocating a fixed amount of water across four agricultural sectors along the Syr Darya; a policy that allows oblasts along the Syr Darya to trade water use rights among themselves each year; and a policy that improves the efficiency in which irrigation water is delivered to the field. Results suggest significant welfare/income gains might exist if the water authorities along the Syr Darya basin could implement an efficient water trading mechanism. Current results suggest more modest gains would be realized when improving irrigation efficiency – with a warning that, almost certainly, the current model setup is underestimating the potential gains from such a policy.

One desired objective of this study was to examine the tradeoffs between keeping water in agriculture and reallocating some agricultural water to Aral Sea restoration and maintenance. This analysis was not pursued because we lacked a clear understanding of how diverting water from agricultural uses to the Aral Sea influenced changes in its height, volume and area, and how these changes would evolve over time. Also absent was an understanding of how Aral Sea height/volume/area influenced the level of economic activity in the region. As such, the present model design only allows for a partial measure of the net benefit of Syr Darya basin water policy. Our current understanding is information might exist to support such a study, but implementing this type of project would require very close collaboration between economists and hydrologists – hydrologists with expertise on Aral Sea restoration dynamics. Still, understanding the economic tradeoffs of Aral Sea restoration is important, as a carefully designed mainstreaming tool would provide information needed (or at least, very useful) to integrating Syr Darya and Aral Sea policy design. Such information could also prove very useful in negotiating water sharing arrangements with upstream countries who control Syr Darya water flows.

Although not discussed here, given total water and land stock values increase over time, one would likely conclude current water use is "sustainable."[5] This conclusion highlights the importance of developing a mainstreaming tool that actually measures what policy makers want measured. For example, if the objective is to understand whether a given policy supports sustainable natural asset values, the models above are sufficient. If the objective is to understand if Syr Darya and Aral Sea water management is sustainable, the models are not up to the task. They would conclude agricultural production is a sustainable use of water and allow the kind of decimation of the Aral Sea observed between the 60s and 90s. A mainstreaming tool with the features alluded to in the previous paragraph would have given planners and policymakers a more clear understanding of the cost of agricultural production.

Another topic for future research is that of more carefully measuring the agricultural production technologies: the more accurate is the measure of how output levels change when we use an additional unit of water, the more accurate will be the model's estimation of land and water, flow and stock values. This project would require collecting (or analyzing existing) data on agricultural production: e.g., oblast or farm level data on the quantity of rice produced, hectares planted to rice, labor used in rice production, a measure of the capital used in rice production, quantity of pesticide used in rice production, quantity of fertilizer used, and most importantly, the

[5] Asset wealth is non-declining over time.

quantity of water applied. Ideally, this data would be collected over several years, and the panel would be used to measure a simple Cobb-Douglas function for the crops of interest (see Smith and Gemma, 2014). There are several ways to approach this problem, and if sufficient interest exists, further discussions should be scheduled.

With minor revisions, the model can examine the impact of traditional macroeconomic (trade or industrial) policy on natural asset contribution to sector and total value-added, and the corresponding stock values. Finally, the current modeling effort aggregated Kyzylorda and South Kazakhstan manufacturing and services into an "all Kazakhstan" manufacturing and "all Kazakhstan" service sector. It is possible to disaggregate manufacturing (and services) into Kyzylorda manufacturing, SK manufacturing and the rest of Kazakhstan manufacturing, but we felt was an unnecessary complication given the report's focus on water management policy.

References

Gemma, M., and R.B.W. Smith. "The Economics of Rice Production Quota Trading." Working paper, Department of Applied Economics, University of Minnesota, August, 2015.

Ghany, A. and Shawky, A. 2014. "Project Information Document (Concept Stage) - Syr Darya Control and Northern Aral Sea Project, Phase 2 - P152001," World Bank, Washington, DC. (http://documents.worldbank.org/curated/en/2014/09/20234171/project-information-document-concept-stage-syr-darya-control-northern-aral-sea-project-phase-2-p152001)

Micklin, P. 2014. "Introduction to the Aral Sea and Its Region," in *The Aral Sea: The Devastation and Partial Rehabilitation of a Great Lake*, editors P. Micklin, N.V. Aladin and I Plotnikov. Springer, New York.

Micklin, P, N.V. Aladin, and I. Plotnikov. *The Aral Sea: The Devastation and Partial Rehabilitation of a Great Lake*. Springer, New York, 2014.

Murray-Rust, H. I. Abdullaev, ul M. Hassan, V. Horinkova. *Water productivity in the Syr-Darya river basin*. Research Report 67. Colombo, Sri Lanka: International Water Management Institute, 2003.

Smith, R.B.W., Nelson, H., and T. L. Roe. "Groundwater and Economic Dynamics, Shadow Rents and Shadow Prices in General Equilibrium Settings." Forthcoming in *Water Economics and Policy*.

Roe, T.L., R.B.W. Smith, and Sirin Saracoglu. *Multisector Economic Growth Models: Theory and Applications.* Springer, New York, 2010.

Smith, R.B.W. "Ecosystem Services and the Macroeconomy: A Review of Linkages and Evaluation of Analytical Tools." United Nations Environment Program, Ecosystem Services Economics, Working Paper Series, Division of Environmental Policy Implementation, Paper No 20. September, 2013.

Smith, R.B.W., and M. Gemma. "Valuing Ecosystem Services in Macroeconomic Settings," in *Economics of Biodiversity and Ecosystem Services*, edited by P. Nunes, P. Kumar and T. Dedeurwaerdere, Edwin Elgar, June, 2014.

Appendix 1 – The economic model, baseline scenario[6]

Denote the economy's time t endowment of physical capital, labor, land and water by $K(t)$, $L(t)$, Z and $H(t)$ respectively.[7] Firms use these factors to produce five final goods: three agricultural goods (cotton, rice and other agriculture), manufactured goods and service goods. In what follows, $K_j(t), L_j(t), H_j(t)$ and Z_j represents the amount of an input used by sector j – e.g., K_j and L_j are the respective amounts of capital and labor demanded by sector j. As a warning, most variables that follow are functions of time, but in an effort to minimize mathematical notation, we almost always drop the time variable. For example, although the amount of capital demanded by cotton producers can vary over time, we will typically represent it by K_{a1} instead of $K_{a1}(t)$.

Capital and labor are used by each sector, and are mobile across the economy. Land is used by agricultural production only, and is fixed to a region or sector, where shortly we discuss when it is possible to view a sector and region as equivalent. Given the discussion above, water will initially be viewed as a sector specific resource, but relaxed when examining water policy options. We assume all final good markets are perfectly competitive, with the implication being no single consumer or producer can influence market prices.

The structure of agricultural production is such that South Kazakhstan is the major region producing cotton, while Kyzylorda is the major region producing rice. Both regions produce other agriculture, and as noted above, we aggregate all non-cotton production into a SK other agriculture, and all non-rice production into a Kyzylorda other agriculture. Let Y_{a1} represent cotton production in South Kazakhstan, and Y_{a2} as rice production in Kyzylorda. We then let Y_{a31} represent other agricultural production in SK, Y_{a32} represent other agricultural production in Kyzylorda, and Y_{a33}, all other agricultural production in the rest of Kazakhstan. The unit price of cotton and rice are denoted p_{a1} and p_{a2}, respectively, and the unit price of the rest of agriculture is denoted p_{a3}. A single price for other agriculture implies households make no distinction between the composite "other agricultural goods". We assume each agricultural price is exogenous and determined by world prices.

Denote manufactured and service output by $Y_m(t)$ and $Y_s(t)$, respectively. The manufacturing good is traded internationally at exogenous world price p_m, while the service good is non-traded and traded at the endogenous price $p_s(t)$. Our current understanding is that manufacturing contributes a relatively small amount to Kyzylorda or SK gross domestic product (GDP). Also, manufacturing uses very little water drawn from the Syr Darya. Assuming these two conditions hold, we integrate Kyzylorda and SK manufacturing GDP into the aggregate manufacturing sector for all of Kazakhstan. The same is true for the service sector. Hence, the modeled economy has seven productive sectors, but five final goods.

Household preferences, savings and consumption Represent utility with a Cobb-Douglas function, namely

$$U(Q_{a2}, Q_{a3}, Q_m, Q_s) = Q_{a2}^{\gamma_{a2}} Q_{a3}^{\gamma_{a3}} Q_m^{\gamma_m} Q_s^{\gamma_s}$$

Here, $Q_{a2}(t)$, $Q_{a3}(t)$, $Q_m(t)$ and $Q_s(t)$ represent the quantity (indices) of rice, other agriculture, manufacturing and services consumed by households. The parameters $\gamma_j, j = a2, a3, m, s$, represent the share of household expenditure spent on good j.

The expenditure function associated with $U(\cdot)$ is defined as

[6] The model for the third scenario (improved irrigation efficiency) is almost identical to the model presented in this section. Modeling the second scenario (water trading) requires a few changes in the modeling setup: water becomes a choice variable in Syr Darya agriculture's production functions, and one needs to introduce a market clearing condition for water.
[7] Land is fixed at each point in time.

$$E(p_{a2}, p_{a3}, p_m, p_s, \mu) \equiv \min_{Q_{a2}, Q_{a3}, Q_m, Q_s} \{p_{a2}Q_{a2} + p_{a3}Q_{a3} + p_m Q_m + p_s Q_s : \mu \leq Q_{a2}^{\gamma_{a2}} Q_{a3}^{\gamma_{a3}} Q_m^{\gamma_m} Q_s^{\gamma_s}\}$$

The expenditure function derived from any strictly concave, twice (continuously) differentiable utility function, is itself twice continuously differentiable, as well as being non-decreasing and concave in final good prices.

The household's optimal savings decision solves the following dynamic optimization problem:

$$\max_{\mu(t)} \int_0^\infty \ln \mu(t)\, e^{-\rho t}\, dt$$

subject to; (i) the initial conditions $K(0), H(0), Z, L(0)$; (ii) the flow budget constraint (suppressing the time argument)

$$\dot{K} = wL + rK + \Pi^{a3}(p_{a3}, r, w, Z_{a3}) + \sum\nolimits_{j=a1,a2} \Pi^{ja}\left(p_a, r^k, w, Z_j, H_j\right) - E(p_{a2}, p_{a3}, p_w, p_s, u)$$

and (iii) the transversality condition

$$\lim_{t\to\infty} \left\{K(t) e^{-\int_0^t r^k(v)dv}\right\} = 0$$

Here $\dot{K}(t) = dK(t)/dt$ is the time derivative of the capital stock, δ is the rate of capital depreciation and ρ is the household's discount factor.

The solution to this optimization problem yields the Euler condition:

$$\frac{\dot{\mu}(t)}{\mu(t)} = r(t) - \rho$$

which says the household consumes so the rate of change in consumption is equal to the foregone income she could earn if she invested it in the risk free asset earning return $r(t) = r^k(t) - \delta$.

Production Represent the manufacturing technology by the Cobb-Douglas production function

(1) $$Y_m = \Psi_m K_m^{\alpha_{m1}} L_m^{\alpha_{m2}} \left(Y_{a1}^d\right)^{\alpha_{m3}}$$

The variables in this function are the input levels $K_m(t)$, $L_m(t)$, and $Y_{a1}^d(t)$, while the parameters are Ψ_j, α_{m1}, α_{m2} and α_{m3}, where $\alpha_{m1} + \alpha_{m2} + \alpha_{m3} = 1$. Here, Ψ_j is a "technology" parameter, while α_{m1}, α_{m2} and α_{m3} are the respective factor cost-shares (elasticities) of capital, labor and cotton employed in manufacturing. The cost function corresponding production technology (1) is defined as

$$C^m\left(r^k, w, p_c\right) Y_m \equiv \min_{K_m, L_m, Y_{a1}^d} \left\{r^k K_m + wL_m + p_c Y_{a1}^d : Y_m \leq \Psi_m K_m^{\alpha_{m1}} L_m^{\alpha_{m2}} \left(Y_{a1}^d\right)^{\alpha_{m3}}\right\}$$

The cost function is the minimum cost of producing Y_m units of output given factor prices r^k, w and p_c. Given the properties of the Cobb-Douglas function in equation (1), the cost function is twice (continuously) differentiable, non-decreasing and strictly concave in factor prices and increasing in output.

The service sector technology is represented by

$$Y_s = \Psi_s K_s^{\alpha_{s1}} L_s^{1-\alpha_{s1}}$$

where the variable and parameter definitions are analogous to those in equation (1). The cost function associated with the service sector technology is defined as

$$C^s(r^k, w)Y_s \equiv \min_{K_s, L_s}\{r^k K_s + wL_s : Y_s \leq \Psi_s K_s^{\alpha_{s1}} L_s^{1-\alpha_{s1}}\}$$

As with the manufacturing sector's cost function, $C^s(\cdot)$ is also twice (continuously) differentiable, non-decreasing and strictly concave in factor prices and increasing in output.

Represent the production technology for other agriculture as a function of capital, labor and land, i.e., as

(2) $$Y_{a3} = f^{a3}(K_{a3}, L_{a3}, Z_{a3}) = \Psi_{a3} K_{a3}^{\alpha_{a31}} L_{a3}^{\alpha_{a32}} Z_{a3}^{\alpha_{a33}}$$

where α_{a31} is the factor share coefficient for capital, α_{a32} is the factor share coefficient for capital labor, and α_{a33} is the factor share coefficient for land, and $\alpha_{a31} + \alpha_{a32} + \alpha_{a33} = 1$. The value added function corresponding to equation (2) is defined as

$$\Pi^{3a}(p_{a3}, r^k, w, Z_{a3}) \equiv \max_{K_{a3}, L_{a3}}\{p_{a3}\Psi_{a3} K_{a3}^{\alpha_{a31}} L_{a3}^{\alpha_{a32}} Z_{a3}^{\alpha_{a33}} - r^k K_{a3} - wL_{a3}\}$$

For a given technology, the value added function is the maximum land rent that can be generated for a given land endowment and prices p_{a3}, r^k and w. Given the technology (2), the value added function $\Pi^{3a}(\cdot)$ is twice continuously differentiable in prices, increasing in p_{a3}, decreasing in r^k and w, and satisfies Hotelling's lemma.

Cotton and rice production, and other agriculture in SK and Kyzylorda explicitly depend on capital, labor, land and water, with corresponding production technologies:

(3) $$Y_j = \Psi_j K_j^{\alpha_{j1}} L_j^{\alpha_{j2}} Z_j^{\alpha_{j3}} H_j^{\alpha_{j4}}, \quad j = a1, a2, a31, a32$$

Here, the alpha parameters have the same interpretations as those in equation (2): for example, α_{a11} is the factor share coefficient for capital in cotton production, α_{a12} is the factor share coefficient for capital labor in cotton production, α_{a13} is the factor share coefficient for land in cotton production, and α_{a14} is the factor share coefficient for water in cotton production, with $\alpha_{a11} + \alpha_{a12} + \alpha_{a13} + \alpha_{a14} = 1$. Analogous definitions hold for the rice technology coefficients.

The value-added functions corresponding to (3) are

(4) $$\Pi^j(p_j, r^k, w, Z_j, H_j) \equiv \max_{K_j, L_j}\left\{p_j \Psi_j K_j^{\alpha_{j1}} L_j^{\alpha_{j2}} Z_j^{\alpha_{j3}} Z_j^{\alpha_{j4}} - r^k K_j - wL_j\right\}, \; j = a1, a2$$

Equation (4) is the maximum rent farmers can earn on the natural assets land and water: i.e., it is land and water's contribution to GDP.

Equilibrium: The discussion here follows closely that of Roe, Smith and Saraçoglu (2010).

Given an initial endowment of resources and non-traded good price, $\{K(0), L(0), H(0), Z, p_s(0)\}$, exogenous labor force sequence $\{L(t)\}_{t\in[0,\infty)}$ and exogenous prices (p_{a2}, p_{a3}, p_m), a competitive equilibrium is a sequence of time dependent prices, capital stock, manufactured good and non-traded good levels, and utility indices, $\{w(t), r(t), p_s(t), K(t), Y_m(t), Y_s(t), \mu(t)\}_{t\in[0,\infty)}$, such that: households intertemporal maximize utility, and at each point in time (ii) firms maximize profit, (iii) capital and labor markets clear and (iv) the non-traded good market clears. The appendix discusses equilibrium in more detail.

Characterization of equilibrium: Given initial conditions on endowments and prices and the labor force sequence, equilibrium is satisfied if (at each *t*):

Zero profit conditions hold

$$C^m(r^k, w, p_{a1}) = p_m$$
$$C^s(r^k, w) = p_s$$

Factor markets clear

$$\frac{\partial}{\partial r^k} C^m(r^k, w, p_c) Y_m + \frac{\partial}{\partial r^k} C^s(r^k, w) + \sum_{j=a1,a2,a31,a32,a33} \frac{\partial}{\partial r^k} \Pi^j(p_j, r^k, w, \cdot) = K(t)$$
$$\frac{\partial}{\partial w} C^m(r^k, w, p_c) Y_m + \frac{\partial}{\partial w} C^s(r^k, w) + \sum_{j=a1,a2,a31,a32,a33} \frac{\partial}{\partial w} \Pi^j(p_j, r^k, w, \cdot) = L(t)$$

The service sector market clears

$$\frac{\partial}{\partial p_s} E(p_{a2}, p_{a3}, p_m, p_s, \mu) = Y_s$$

and the following two differential equations are jointly satisfied:

$$\dot{K} = wL + rK + \Pi^{a3}(p_{a3}, r, w, Z_{a3}) + \sum\nolimits_{j=a1,a2,a31,a33} \Pi^{ja}(p_a, r^k, w, Z_j, H_j) - E(p_{a2}, p_{a3}, p_w, p_s, u)$$
$$\dot{p}_s = G(K, p_s)$$

where $G(K, p_s)$ is derived as discussed in Roe, Smith and Saracoglu (2010), chapter four.

The stock and flow values of water: Although not stressed in the earlier discussion, the variable p_h is the price farmers pay for a unit of water. Given there is not market for water, in equilibrium, p_h is the shadow value of an additional unit of water: the amount a farmer would be willing to pay for an additional unit of water. Also, given that p_h embeds the cost of capital, electricity and aquifer rent, it represents the unit gross value of water in agricultural production.

Let $P^h(t)$ represent the shadow "stock price" of water – the amount a farmer would pay to own the water, and let $P^z(t)$ represent the purchase price (not rental rate) of land. Given the natural asset stocks Z and $\overline{H}$, the total value of physical and natural asset holdings, denoted *A*(*t*) is expressed as

$$A(t) = K(t) + P^z(t)Z + P^h(t)\overline{H}(t)$$

Earlier, we noted $\overline{H}(t)$ represents the period *t* stock of water. In the empirical application, $\overline{H}$ is the "economically accessible" stock of water, which is defined as $S(t) = H_0 - \int_0^t Y_h\,(t)dt$, where $H_0 = \int_0^T Y_h\,(t)dt$, with T being some period sufficiently in the future: in the empirical model used here, T = 300.

Assume the natural and physical asset markets are not segmented, and that arbitraging occurs for both types of assets. In such a case, Roe, Smith and Saraçoglu (2010) derive the following no-arbitrage condition between r^k and land rents:

$$r^k = \frac{\Pi^a}{P^z} + \frac{\dot{P}^z}{P^z}$$

where $\Pi^a(\cdot,t)$ is time-*t* agricultural land rent. Smith (2013) derives the following no-arbitrage condition between r^k and the water rent, here interpreted as the gross value of water in agricultural production:

$$r^k = \frac{p_h}{P^h} + \frac{\dot{P}^h}{P^h} + \frac{\dot{\bar{\bar{H}}}}{\bar{\bar{H}}}$$

In this case, if arbitrage conditions hold across natural and physical assets, the time *t* unit stock price of land is given by

$$P^z(t) = \int_t^\infty e^{-\int_t^\vartheta [r^k(v)-\delta]dv}\,\Pi^a(\cdot,t)dt$$

Here $\Pi^a(\cdot,t) = \sum_{j=1}^2 \sum_{i=1}^3 \Pi^{aij}(\cdot)$ is the total land rent for India (Punjab and ROI, rice, wheat and other agricultural land rent). The time-*t* unit stock price of water is given by

(5) $$P^h(t) = \int_t^\infty e^{-\int_t^\vartheta \left[r^k(v)-\delta-\frac{\dot{\bar{\bar{H}}}}{\bar{\bar{H}}}\right]dv}\,p_h(t)dt$$

Here, the expression $\frac{\dot{\bar{\bar{H}}}}{\bar{\bar{H}}}$, captures the impact of a declining aquifer on its' stock price. If negative, then the effective discount rate

(6) $$e^{-\int_t^\vartheta \left[r^k(v)-\delta-\frac{\dot{\bar{\bar{H}}}}{\bar{\bar{H}}}\right]dv}$$

increases, reflecting the loss in value associated with aquifer depreciation. This effect, of course, places a downward pressure on the value of the aquifer.

Appendix 2. Other Tables

Base Scenario

Table A.1. Sector share in GDP

Year	Agriculture	Industry	Services
2007	0.0718	0.4932	0.4350
2012	0.0575	0.5035	0.4390
2017	0.0493	0.5087	0.4420
2022	0.0442	0.5116	0.4442
2027	0.0409	0.5132	0.4459
2032	0.0387	0.5143	0.4470
2037	0.0372	0.5149	0.4479
2042	0.0362	0.5153	0.4485
2047	0.0355	0.5156	0.4489
2052	0.0350	0.5158	0.4492

Table A.2. Value-added from land and water, and its share in GDP (in 1000 US $)

Year	Value added from land and water				GDP	Land and water's share in GDP
	South Kazakhstan	Kyzylorda	ROK	Total		
2007	165.8	37.6	1664.9	1868.3	93435.5	0.0200
2012	166.1	37.9	1668.8	1872.8	116889.0	0.0160
2017	173.7	39.7	1745.0	1958.5	142683.4	0.0137
2022	187.1	42.8	1879.1	2109.0	171315.8	0.0123
2027	205.6	47.2	2065.4	2318.2	203375.5	0.0114
2032	229.3	52.6	2303.2	2585.1	239539.6	0.0108
2037	258.3	59.3	2594.6	2912.2	280578.4	0.0104
2042	293.1	67.4	2944.0	3304.5	327366.5	0.0101
2047	334.3	76.9	3357.9	3769.1	380898.4	0.0099
2052	382.7	88.0	3844.0	4314.7	442309.0	0.0098

Table A.3. Ratio of land/water to physical capital stock values

Year	Land and Water (1000 US $)	Capital Stock (1000 US $)	Ratio
2007	43,017,302	252,503,931	0.1704
2012	51,035,116	334,656,067	0.1525
2017	60,217,976	424,544,361	0.1418
2022	70,695,820	523,348,040	0.1351
2027	82,656,046	632,770,755	0.1306
2032	96,332,676	754,938,553	0.1276
2037	112,003,641	892,356,804	0.1255
2042	129,992,505	1,047,911,576	0.1240
2047	150,672,939	1,224,896,942	0.1230
2052	174,475,186	1,427,067,873	0.1223
2057	201,894,188	1,658,710,739	0.1217

Market Scenario

Table A.4. The value of agricultural production for each sector (in 1000 US $)

Year	Other-Ag SK	Other-Ag Kyzylorda	Cotton	Rice
2007	690,902	98,165	58,395	31
2012	693,073	98,474	58,592	35
2017	725,113	103,026	61,310	39
2022	781,100	110,981	66,051	44
2027	858,740	122,012	72,622	50
2032	957,733	136,078	80,998	57
2037	1,079,024	153,311	91,259	65
2042	1,224,460	173,975	103,562	75
2047	1,396,648	198,440	118,128	86
2052	1,598,897	227,176	135,236	99
2057	1,835,237	260,756	155,227	114

Table A.5. The stock value of water and land (in 1000 US $)

	Stock value of water					Stock value of land				
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice
2007	348,421	155,371	9,111,272	183,645	672,548	3,386,048	481,100	29,234,660	222,411	45
2012	413,318	184,311	10,808,236	217,851	797,818	4,016,683	570,702	34,679,582	263,857	56
2017	487,638	217,453	12,751,609	257,024	941,276	4,738,891	673,315	40,915,135	311,316	67
2022	572,439	255,268	14,969,041	301,720	1,104,964	5,562,948	790,400	48,030,045	365,464	80
2027	669,239	298,434	17,500,273	352,742	1,291,816	6,503,624	924,054	56,151,819	427,272	94
2032	779,935	347,797	20,394,874	411,087	1,505,490	7,579,338	1,076,895	65,439,511	497,952	111
2037	906,777	404,359	23,711,691	477,943	1,750,331	8,811,961	1,252,029	76,081,933	578,940	129
2042	1,052,385	469,290	27,519,220	554,690	2,031,394	10,226,946	1,453,075	88,298,865	671,909	150
2047	1,219,784	543,938	31,896,556	642,922	2,354,519	11,853,689	1,684,207	102,344,098	778,790	175
2052	1,412,455	629,857	36,934,772	744,475	2,726,429	13,726,034	1,950,235	118,509,844	901,807	203
2057	1,634,407	728,831	42,738,631	861,461	3,154,856	15,882,915	2,256,691	137,132,253	1,043,518	235

Table A.6. Water and land wealth in the water market and base scenarios (1000 US $)

	Market Scenario			Base Scenario			Difference		
Year	Water	Land	Total	Water	Land	Total	Water	Land	Total
2007	10,436,037	32,581,271	43,017,308	10,279,294	32,691,971	42,971,265	-156,743	110,700	-46,043
2012	12,382,151	38,652,974	51,035,124	12,216,335	38,806,993	51,023,328	-165,815	154,019	-11,796
2017	14,610,835	45,607,150	60,217,985	14,446,075	45,816,223	60,262,297	-164,761	209,073	44,312
2022	17,153,669	53,542,162	70,695,832	17,003,280	53,821,401	70,824,681	-150,389	279,239	128,850
2027	20,056,152	62,599,908	82,656,060	19,937,100	62,967,051	82,904,151	-119,052	367,143	248,091
2032	23,375,087	72,957,604	96,332,692	23,308,956	73,432,802	96,741,758	-66,131	475,198	409,066
2037	27,177,929	84,825,729	112,003,659	27,192,303	85,431,449	112,623,752	14,374	605,720	620,093
2042	31,543,201	98,449,324	129,992,526	31,673,472	99,210,083	130,883,555	130,270	760,759	891,029
2047	36,561,583	114,111,380	150,672,963	36,853,207	115,052,992	151,906,199	291,623	941,612	1,233,236
2052	42,337,482	132,137,733	174,475,214	42,848,716	133,285,584	176,134,299	511,234	1,147,851	1,659,085
2057	48,991,002	152,903,219	201,894,220	49,796,098	154,278,629	204,074,727	805,097	1,375,410	2,180,507

Table A.7. Ratio of land/water to physical capital stock values

Year	Land and Water (1000 US $)	Capital Stock (1000 US $)	Ratio
2007	43,795,522	252,503,931	0.1734
2012	51,952,415	334,535,498	0.1553
2017	61,293,724	424,277,313	0.1445
2022	71,952,369	522,915,548	0.1376
2027	84,119,367	632,156,506	0.1331
2032	98,032,990	754,126,079	0.1300
2037	113,976,095	891,327,617	0.1279
2042	132,277,925	1,046,643,848	0.1264
2047	153,318,680	1,223,364,500	0.1253
2052	177,536,112	1,425,239,323	0.1246
2057	205,433,798	1,656,548,608	0.1240

Improving Irrigation Efficiency

Table A.8. Sector value-added with improved irrigation efficiency (in 1000 US $)

Year	SKOA	KOA	ROKA	Cotton	Rice	Industry	Services
2007	531,162	99,036	5,967,396	62,718	30,394	46,487,453	40,499,619
2012	539,024	100,502	5,997,270	64,105	32,085	59,142,215	51,101,801
2017	569,851	106,250	6,281,450	68,237	35,098	72,776,356	62,791,404
2022	619,768	115,557	6,770,688	74,703	39,345	87,731,015	75,773,297
2027	687,505	128,187	7,446,062	83,392	44,855	104,356,120	90,302,924
2032	773,265	144,177	8,305,353	94,367	51,732	123,026,901	106,681,047
2037	878,206	163,743	9,356,815	107,804	60,138	144,158,224	125,691,588
2042	1,004,203	187,236	10,616,212	123,971	70,289	168,335,589	146,843,550
2047	1,153,744	215,118	12,105,455	143,216	82,449	195,969,794	171,017,042
2052	1,329,884	247,960	13,851,923	165,959	96,935	227,650,133	198,724,189
2057	1,536,198	286,427	15,887,776	192,696	114,118	264,048,582	230,550,920

Table A.9. Sector share in GDP

Year	Agriculture	Industry	Services
2007	0.0711	0.4962	0.4323
2012	0.0573	0.5056	0.4369
2017	0.0493	0.5103	0.4402
2022	0.0443	0.5127	0.4428
2027	0.0411	0.5139	0.4447
2032	0.0390	0.5146	0.4462
2037	0.0375	0.5149	0.4474
2042	0.0365	0.5150	0.4483
2047	0.0358	0.5150	0.4489
2052	0.0353	0.5151	0.4494
2057	0.0350	0.5152	0.4496

Table A.10. Water flow shadow values - per unit and total

	Unit shadow rental rate per sector ($ / km^3)					Shadow value-added per sector (1000 US $)					
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice	Total
2007	48.80	20.41	70.85	18.93	6.08	35,140	6,552	394,787	7,183	8,454	452,117
2012	48.92	20.45	71.01	18.97	6.19	35,660	6,649	396,763	7,342	8,924	455,339
2017	51.15	21.39	74.26	19.84	6.54	37,700	7,029	415,564	7,815	9,762	477,871
2022	55.08	23.03	79.96	21.37	7.09	41,002	7,645	447,931	8,556	10,944	516,078
2027	60.54	25.31	87.89	23.49	7.83	45,483	8,480	492,612	9,551	12,476	568,603
2032	67.51	28.23	98.01	26.19	8.77	51,157	9,538	549,460	10,808	14,389	635,353
2037	76.05	31.80	110.41	29.51	9.90	58,100	10,833	619,022	12,347	16,727	717,029
2042	86.30	36.08	125.28	33.48	11.26	66,435	12,387	702,340	14,199	19,551	814,912
2047	98.43	41.16	142.89	38.19	12.86	76,329	14,232	800,864	16,403	22,933	930,760
2052	112.68	47.11	163.57	43.72	14.74	87,982	16,404	916,406	19,008	26,962	1,066,762
2057	129.33	54.08	187.75	50.18	16.93	101,631	18,949	1,051,093	22,070	31,741	1,225,484

Table A.11. Unit stock shadow price of water

	"Correct" calculations					Price/earnings ratio				
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice
2007	982.7	410.9	1,628.5	392.5	140.6	624.4	261.1	906.5	242.2	77.8
2012	1,133.3	473.9	1,931.2	455.6	166.8	674.3	281.9	1,009.7	263.4	87.4
2017	1,306.3	546.2	2,278.1	528.0	196.6	739.8	309.3	1,141.5	291.0	99.2
2022	1,503.7	628.7	2,674.3	610.6	230.5	819.6	342.7	1,301.5	324.5	113.3
2027	1,729.3	723.1	3,126.9	705.0	269.1	913.5	382.0	1,491.6	364.0	129.8
2032	1,988.0	831.2	3,644.8	813.0	313.2	1,022.4	427.5	1,714.5	409.8	149.0
2037	2,285.8	955.7	4,238.6	937.3	363.7	1,147.3	479.7	1,974.3	462.6	171.1
2042	2,630.0	1,099.7	4,920.7	1,080.7	421.8	1,290.0	539.4	2,276.2	523.1	196.7
2047	3,029.6	1,266.7	5,705.1	1,246.7	488.6	1,452.7	607.4	2,626.0	592.3	226.1
2052	3,495.2	1,461.4	6,608.2	1,439.6	565.6	1,637.9	684.8	3,031.0	671.3	260.0
2057	4,040.1	1,689.2	7,648.6	1,664.6	654.7	1,848.5	772.9	3,499.5	761.6	299.1

Table A.12. The stock value of water and land

	Stock value of water (US $ / km^3)					Stock value of land				
Year	SKOA	KOA	ROKA	Cotton	Rice	SKOA	KOA	ROKA	Cotton	Rice
2007	709,045	132,203	9,092,912	149,268	195,866	2,711,397	505,546	29,175,746	256,809	42,474
2012	851,785	158,817	10,783,202	180,492	242,038	3,242,209	604,517	34,599,256	308,914	52,097
2017	1,021,009	190,369	12,720,470	217,530	296,697	3,851,089	718,044	40,815,221	368,733	63,136
2022	1,220,541	227,573	14,932,733	261,236	361,197	4,547,094	847,815	47,913,545	437,174	75,773
2027	1,455,681	271,415	17,459,952	312,770	437,283	5,342,739	996,165	56,022,442	515,465	90,239
2032	1,733,201	323,159	20,351,897	373,604	527,095	6,253,346	1,165,950	65,301,612	605,092	106,802
2037	2,061,525	384,376	23,667,639	445,552	633,211	7,296,821	1,360,508	75,940,585	707,772	125,764
2042	2,451,028	456,999	27,475,904	530,831	758,709	8,493,653	1,583,660	88,159,881	825,443	147,447
2047	2,914,458	543,407	31,855,948	632,143	907,250	9,867,006	1,839,724	102,213,801	960,262	172,199
2052	3,467,494	646,522	36,898,738	752,782	1,083,180	11,442,845	2,133,543	118,394,223	1,114,601	200,371
2057	4,129,468	769,948	42,708,264	896,772	1,291,647	13,249,993	2,470,490	137,034,815	1,291,019	232,312

Table A.13. Ratio of land/water to physical capital stock values

Year	Land and Water (1000 US $)	Capital Stock (1000 US $)	Ratio
2007	42,971,265	253,771,696	0.1693
2012	51,023,328	335,202,827	0.1522
2017	60,262,297	424,366,435	0.1420
2022	70,824,681	522,434,534	0.1356
2027	82,904,151	631,097,549	0.1314
2032	96,741,758	752,470,586	0.1286
2037	112,623,752	889,059,745	0.1267
2042	130,883,555	1,043,777,441	0.1254
2047	151,906,199	1,219,994,169	0.1245
2052	176,134,299	1,421,635,639	0.1239
2057	204,074,727	1,653,373,812	0.1234

APPENDIX 3. Social Accounting Matrix

KAZAKHSTAN SOCIAL ACCOUNTING MATRIX, 2007 (GTAP), MILLION U.S. $

	Expenditure:	Production activities					Commodities					Resources			Institutions			Trade
Receipts:		Rice.	Cott.	Agri.	Mnfc.	Srvc.	Rice.	Cott.	Agri.	Mnfc.	Srvc.	Labor	Capital	Land	HHs	Acmn	Gov't	Exports
	Rice.						131											0
Production	Cott.							323										101
Activities	Agri.								16,420									800
	Mnfc.									88,496								6,205
	Srvc.										131,370							0
	Rice.	33	0	19	22	53									6	1	0	
	Cott.	0	4	0	11	15									240	42	10	
Commodities	Agri.	1	8	3,879	1,210	431									8,811	1,667	412	
	Mnfc.	44	224	4,553	32,389	18,246									22,305	10,443	293	
	Srvc.	22	135	3,353	29,890	53,739									21,760	21,969	11,851	
	Labor	18	31	3,101	11,672	37,084												
Resources	Capital	4	6	777	11,815	21,804												
	Land	8	14	1,538	7,692	0												
	HHs											51,906	34,406	9,252				
Institutions	Acmn														34,123			
	Gov't														12,566			
Trade	Imports						3	0	0	0	11,350							
Expenditure:		131	424	17,219	94,702	131,370	134	323	16,420	88,496	142,720	51,906	34,406	9,252	99,810	34,123	12,566	7,106