- Zentrum für Entwicklungsforschung -
Rheinische Friedrich-Wilhelms-Universität Bonn

A Micro-Economic Analysis of Farm Restructuring in the Khorezm Region, Uzbekistan

Inaugural-Dissertation

zur

Erlangung des Grades

Doktor der Agrarwissenschaften
(Dr.agr.)

der

Hohen Landwirtschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität

zu Bonn

vorgelegt am 25. März 2008

von
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aus
Taschkent (Usbekistan)

Die vorliegende Arbeit wurde von der Hohen Landwirtschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn als Dissertation zugelassen.

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Tag der mündlichen Prüfung:	15. Mai 2008
Erscheinungsjahr:	2008

Diese Dissertation ist auf dem Hochschulschriftenserver der ULB Bonn http://hss.ulb.uni-bonn.de/diss_online elektronisch publiziert.

“The great thing about being the only species that makes a distinction between right and wrong is that we can make up the rules for ourselves as we go along.”

- *Douglas Adams*

“No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be...“

- *Isaac Asimov*

Abstract

A Micro-economic Analysis of Farm Restructuring in the Khorezm Region, Uzbekistan

Ever since its independence several reforms in agriculture of Uzbekistan have been taken as part of a gradual transition process towards a market-based economy. These processes include: market liberalization, reformation of land relations, structural changes, and creation of supporting market infrastructure. Furthermore, there has been considerable promotion of input market liberalization, abolishment of state procurement system, introduction of water charges and improvement of the livestock sector. The understanding of the effects of these reforms on the agricultural producers and consumers is very important for further decision making. This work is part of ZEF's project in development research on the 'Economic and ecological restructuring of land and water use in Khorezm, Uzbekistan'.

In order to formalize the key aspects of sectoral decision making, the major task of this research is to develop a model for policy analysis which reflects the unique features of the agricultural sector of Khorezm. The developed model integrates linear supply and non-linear demand modules at the point of partial equilibrium under observed values from 2003. The supply module consist of the regional crop and animal production activities over three farm groups. The demand module is based on a Normalized Quadratic – Quadratic Expenditure System which specifies both an Engel curve and relative price effects consistent with microeconomic theory. The demand module consists of food and manufactured commodities including leisure time with endogenous prices over two consumer types. A large amount of aggregated and micro-economic data on the regional agriculture sector is used for providing the necessary information to understand the construction of the model and the results.

To ensure that the base solution of the model fits the observed values of modeled activities and that the model simulations include the characteristics of regional demand and supply, the model parameters both for demand and supply modules are adjusted separately. This study contributes to the field of known calibration techniques for positive mathematical programming models. The developed method solves the overspecialization problem, maintains model flexibility, and allows the model exactly replicate the observed situation by recovering its original specification.

The model results eventually show that, despite higher input prices and water pricing being introduced, positive effects of water use efficiency and market liberalization may dominate. Furthermore, it could be shown that the livestock sector serves as a security tool in rural households for maintaining their income level. Moreover, the improvement in livestock productivity shows the potential to decrease water consumption in the agricultural sector of the region. The market liberalization will not necessarily lead to an increase in the regional production of cotton. In general, the market liberalization has a positive effect on the regional rice sector which can be cultivated on land released from the procurement quotas in case the land is suitable for rice cultivation.

Kurzfassung

Eine Mikroökonomische Analyse des Landwirtschaftlichen Strukturwandels in der Region Khorezm, Usbekistan

Seit der Unabhängigkeit von der ehemaligen Sowjetunion fand in Usbekistan eine Vielzahl von wirtschaftspolitischen Reformen statt, die auf einen schrittweisen Umbau der Wirtschaftsordnung, einschließlich des Agrarsektors, in Richtung Marktwirtschaft abzielten. Diese Reformen betrafen Gütermarktordnungen, Eigentums- und Nutzungsrechte landwirtschaftlicher Flächen, sowie infrastrukturelle Maßnahmen. Darüber hinaus wurden insbesondere die Märkte für landwirtschaftliche Vorleistungen liberalisiert, die staatliche Intervention weitgehend abgeschafft, Gebühren für Wassernutzung eingeführt und Maßnahmen zur Förderung der Tierproduktion ergriffen. Ein tieferes Verständnis der Auswirkungen dieser Reformen auf die landwirtschaftlichen Betriebe wie auch auf den gesamten Agrarsektor ist von grundlegender Bedeutung für die Formulierung weiterführender politischer Strategien. Die hier vorgelegte Studie wurde im Rahmen des Projekts 'Economic and ecological restructuring of land and water use in Khorezm, Uzbekistan' am Zentrum für Entwicklungsforschung der Universität Bonn durchgeführt.

Im Zentrum der durchgeführten Analysen stand die Entwicklung eines quantitativen Modells, das die relevanten politischen Maßnahmen und die Besonderheiten des regionalen Agrarsektors in formalisierter Weise darstellt. Das hierzu entwickelte Modell verbindet ein lineares Angebotsmodul mit einem nicht-linearen Nachfragemodul mit Hilfe eines partiellen Gleichgewichtsmodells. Das Angebotsmodul beinhaltet landwirtschaftliche Produktionsverfahren dreier standardisierter Betriebstypen auf regionaler Ebene. Das Nachfragemodul basiert auf einem normalisiert quadratisch-quadratischem Ausgabensystem (NQ-QES), welches Einkommenseffekte wie auch relative Preiseffekte konsistent mit mikroökonomischer Theorie abbildet. Das Nachfragemodul berücksichtigt als endogene Variablen den Konsum von Nahrungsmitteln und weiterverarbeiteten Gütern, wie auch die Nachfrage nach Freizeit und damit das Angebot und den Preis für landwirtschaftliche Arbeitskraft. Es werden zwei Haushaltstypen unterschieden. Der enorme Datenbedarf des Modells wird durch offizielle Statistiken für den Agrarsektor und eigene Erhebungen gedeckt.

Die strukturellen Parameter des Nachfrage- und Angebotsmoduls wurden in einem zweistufigen Verfahren so kalibriert, dass die Beobachtungen des Basisjahrs 2003 vom Modell repliziert werden. Diese Studie leistet mit der hierzu angewendeten Methode einen Beitrag im Bereich der positiv-mathematischen Programmierung und der Anwendung von Kalibrierungstechniken für partielle Gleichgewichtsmodelle.

Die Modellrechnungen zeigen, dass die Einführung von Gebühren für Wassernutzung, wie auch die Verringerung der staatlichen Beihilfen für landwirtschaftliche Vorleistungen, durch Steigerung der Wassereffizienz und weitere Marktliberalisierung kompensiert werden können. Darüber hinaus wurde deutlich, dass Tierhaltung einen großen Beitrag zur Stabilisierung der ländlichen Einkommen leistet. Eine Verbesserung der Produktivität in diesem Bereich würde daher zu einer Verminderung der Abhängigkeit von pflanzlicher Produktion führen und potentiell den regionalen Bedarf nach Wasser verringern. Die regionale Produktion von Baumwolle würde durch eine Liberalisierung der Marktordnung eher sinken, so dass die frei werdenden Flächen zum Teil zum Anbau von Reis genutzt werden könnten.

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List of Acronyms and Abbreviations

CIS	Commonwealth of Independent States
CBU	Central Bank of Uzbekistan
CROPWAT	Decision Support System Developed by FAO
FAO	Food and Agricultural Organization of the United Nations
FBS	Food Balance Sheets in FAO Statistics Division
GDP	Gross Domestic Product
KhoRAMS	Regional Sector Model for Agriculture of Khorezm
MAWR	Ministry of Agriculture and Water Resources of Uzbekistan
MCP	Marginal-Cost Pricing
ME	Maximum Entropy
MET	Metabolizable Energy
MTP	Machinery and Tractor Park
NQEF	Normalized Quadratic Expenditure Function
NQ-QES	Normalized Quadratic-Quadratic Expenditure System
NQRIUF	Normalized Quadratic Reciprocal Indirect Utility Function
OblNeft	Regional Diesel and Oil Fuel Distributing Agency in Khorezm
OblStat	Regional Department of Statistics in Khorezm
OblSelKhozKhim	Regional Department of Chemical Production in Khorezm
OblSelVodKhoz	Regional Department of Agriculture and Water Resources in Khorezm
OblZem	Regional Department of Land Planning in Khorezm
O&M	Operation and Maintenance
PDFA	Regional Department of Private and *Dekhqan* Farms in Khorezm
PMP	Positive Mathematical Programming
SUA	Supply Utilization Accounts in FAO Statistics Division
UNDP	United Nations Development Programme
USD	United States Dollar
UzSelKhozKhim	National Chemical Producing Conglomerate in Uzbekistan
VAT	Value Added Tax
WARMAP	Water Resources Management and Agricultural Production project
WATSIM	World Agricultural Trade Simulation Model
WUA	Water Users Association
WUE	Water Use Efficiency

Acknowledgments

This thesis would have been a lot more difficult, if not impossible, without the tremendous support and encouragement of many people. My sincere gratitude goes to my academic supervisors. Prof. Dr. Klaus Frohberg contributed a considerable amount of his time to improve the theoretical foundation of the study, especially by challenging me with constructive criticism on the application of a demand system that greatly improved the model. I am thankful to PD Dr. Peter Wehrheim for his introduction to the analysis and modeling at the farm level, which sparked my interest to build a sector model for the Khorezm region, and for providing substantial guidance during my study.

I am particularly thankful and indebted to Dr. Marc Müller for his truly inspiring guidance, valuable advice, constant encouragement and friendship, which contributed to such an enjoyable time in Bonn, both academically and personally. It was especially comforting to share one office with him for a long time, and I feel grateful for his patient and inspiring help in GAMS programming and for his enormous and sustained readiness to discuss and think about things related to my thesis.

I am also thankful to Prof. Dr. Thomas Heckelei and Dr. Wolfgang Britz from the Department for Economic and Agricultural Policy of Bonn University for their lectures which were crucial. I am grateful to Daniel Hawes for his thorough review of draft chapters of this work and valuable critical comments. I am thankful to Dr. Jennifer Franz for her valuable comments which helped to make the thesis readable and consistent. I acknowledge Dr. Rolf Sommer and Omonbek Salaev for joint work on the FLEOM model which gave me time for inhaling fresh air and reevaluating the importance of this study. I thank Prof. Dr. Peter Kroll from Marburg for returning to me the full sight of life's priorities.

I am grateful for the enjoyable experience in the scholars society of ZEF to Dr. Günther Manske, Mrs. Rosemarie Zabel, Mr. Volker Merx, Mrs. Gisela Ritter-Pilger and Mrs. Karin Hagedorn-Mensah, without who some things would never have been accomplished or at least not as smoothly.

Special thanks are due to the team of the Khorezm project. I express my cordial thanks to the project coordinators, PD Dr. Christopher Martius and Dr. John Lamers, for continued encouragement, good ideas, patience and a friendly atmosphere on the project. Furthermore, my field trips to Urgench and Bonn would not have been as successful without the help of Prof. Dr. Ruzimbay Eshchanov, Dr. Nazar Ibragimov, Liliana Sinn, Natalia Shermetova and

Sandra Staudenrausch. This study also could not have been conducted without the assistance of the staff and students from the Economic faculty of Urgench State University. I also greatly appreciate the remarkable support from Najmetdinova Golshat (Galina) Kusnyukovna, Shokir Jabbergenov, Artur Kim and Konstantin Kolosov.

I would like to express my thanks and appreciation to all my friends and colleagues without whom my time in Bonn would not have been nearly as interesting, both academically and personally: Ihtiyor Bobojonov, Mehriddin Tursunov, Muyassar Yakubova, Gleb Pogodaev, Dilfuza Djumaeva, Dr. Inna Rudenko, Oksana Forkutsa, Dr. Kai Wegerich, Dr. Bernhard Tischbein, Dr. Susanne Herbst, Dr. Christopher Conrad, Dr. Darya Zavgorodnyaya, Tina Schieder, Tommaso Trevisani, Zliha Tileuova, Elena Kan and Oybek Egamberdiev. Especially, I am grateful to Kirsten Kienzler, Dr. Akmal Akramkhanov, Alexander Tupitsa, Dr. Irina Forkutsa, Dr. Asia Khamzina, and Dr. Hayot Ibrakhimov for all the emotional support, fun-loving spirits and care they provided both in Bonn and Urgench. I am grateful to my friends in Tashkent who were always available to help me rediscover Tashkent which changes each time I return.

Finally, I am most thankful to the people I do not need to justify and each would deserve a page of their own: my dear mother and brother, for their constant love and immeasurable moral support through difficult periods of field work, model development and writing. I am very thankful to a special person to me, Norida, for her moral support and love at present and in the future.

I dedicate this accomplishment to my father.

Funding for the research was generously provided by the German Ministry for Education and Research (BMBF; project number 0339970A).

1. Introduction

1.1 Problem Setting

Uzbekistan has some distinctive economic features compared to other transitional countries, such as high rates of population growth, a high percentage of rural population and of an economically active population in agriculture (Bloch 2002). Uzbekistan has a small percentage of arable land and very little arable land per capita of rural population (FAO 2003). In Uzbekistan, especially in Khorezm, agricultural production is highly dependent on irrigation, the arable land is almost entirely irrigated and its further expansion is limited (Abdolniyozov 2000). Agriculture remains the most important sector of Uzbekistan's economy, providing national food security and currency earnings. In Uzbekistan, around 65% of the population is rural, and almost 35% of total labor force is employed in agriculture (Spoor 2004). In 2001, the share of agriculture was about 30% of national GDP, and agricultural exports contributed around 35% of total national exports (Spoor 2004).

The agricultural policy of Uzbekistan has four objectives central in line of the agricultural reforms (Guadagni et al 2005). First, it is stated that cotton production should allow stabilization of the country's export revenues. Therefore, the agricultural sector of Uzbekistan is specialized in cotton production (Spoor 2004). Second, the country should be self-sufficient in wheat production; to this end, the area under wheat cultivation in Uzbekistan has been dramatically increased since 1992 (Babu and Tashmatov 2000). The third objective of the agricultural policy is that agricultural revenues are to be used to finance industrialization in Uzbekistan (Spoor 2004). In this case, a majority of state revenue from agricultural taxation in Uzbekistan comes from implicit taxes such as low procurement prices for the main export crop, cotton (Guadagni et al 2005). Finally, the agricultural policies are directed at the improvement of rural standards of living. For instance suitable industries have been established in rural areas and the private farming has been promoted (ADB 2000).

Since independence, several reforms in agriculture have been taken as part of a gradual transition to a market-based economy, including market liberalization, reformation of land relations, structural changes, and creation of supporting market infrastructure. With respect to market liberalization, the consumer prices for most commodities were liberalized and the number of commodities under state procurement was reduced (Sirajiddinov 2004). However, since agriculture is the main source of the country's export, state involvement in this sector remains substantial via a state procurement system and distribution of essential agricultural inputs (Zettelmeyer 1999). To provide incentive for agricultural producers to increase wheat production, the size of procurement quotas for wheat was reduced and its procurement price was increased to market level (Müller 2006). Nevertheless, the production of the state target crops has remained substantial in land and input use in Uzbekistan (Spoor 2004).

Farm restructuring and land reform in Uzbekistan have covered several steps including the conversion of state farms into collective farms and the further transformation of these collective farms into private farms (Griffin, Khan and Ickowitz 2002). With the completion of the state farm fragmentation process, a new system of agricultural producers has emerged in Uzbekistan, where the agricultural commodities are produced by middle scale private farms and traditional small scale households. All these economic features and reforms in the national agricultural sector of Uzbekistan are applicable for the agricultural sector of Khorezm (Kyle and Chabot 1997). The current farm restructuring process, namely transformation of large scale state farms into middle scale private farms, has increased the number of individual producers in Uzbekistan. Further reforms in the agricultural sector are geared toward an increase in producer incentives by abolishing the state procurement system and introducing water charges in agriculture (Bloch and Kutuzov 2001, Bloch 2002). It was argued by many authors that the implicit taxation of the agricultural sector, via the state procurement system, deprived the agricultural producers Uzbekistan of profits (Rosenberg et al. 1999, Guadagni et al 2005, Khan 2005, Spoor 1999, Spoor 2004). The abolishment of the state procurement system may raise incentives for cotton production and lead to a more profitable production pattern. At the same time, the role of the government in maintaining and operating the irrigation and drainage networks in Uzbekistan has been revised, where the water management has been transferred to newly established water user associations (WUA) and the introduction of water pricing mechanism is under discussion (McKinney 1996, Bucknall et al. 2003, Mott MacDonald 2003). Such agricultural reforms may result in unknown consequences on production patterns among different types of agricultural producers and in different districts in Khorezm. While the new policies may have a positive impact on total agricultural output, it is unclear which one will have the most significant impact. Furthermore, it is unclear how the different policies will affect regional production of specific agricultural commodities. Hence, the issue can be reduced to two main questions: how a policy will affect the income of different agricultural producers, and what is the effect of the policy on regional production. The problem, therefore, requires a tool for systematic policy analysis. Understanding the impacts of different policies for the agricultural sector of Khorezm is complex as regional agriculture includes multiple, inter-related commodities and inputs on the level of several groups of agricultural producers and districts. An agricultural sector model is one such tool which can deal with the quantitative problems, while taking into account the specific settings of the regional agricultural sector. Moreover, application of the mathematical programming models can help to obtain a better understanding of the functioning of the regional agriculture sector and to provide a tool for policy analysis. A well defined and documented model may provide valuable information to be used in evaluating policy effects.

1.2 Hypotheses

Considering the features of the agricultural sector of Khorezm, the hypotheses to be examined in this study are as follows:

1. Under the current scenario of no functioning land market, inter-farm shifts of land, i.e. completion of farm restructuring process, could increase economic efficiency of land and water use;
2. Introduction of water prices will shift the regional crop production towards a less water-demanding and towards livestock production;
3. Cotton and input market liberalization will increase the area of cotton cultivation;
4. The livestock sector may be a tool for supporting the incomes of rural households when input markets are liberalized and water pricing is introduced.

1.3 Objectives

The overall goal of this research is to analyze the consequences of different agricultural policies on regional production and consumption patterns. In order to formalize the major aspects of sectoral decision making, the major task of this study is to develop an agricultural sector model for policy analysis, reflecting the unique features of the regional agricultural sector of the Khorezm region. Whereas the empirical results may help policy makers to evaluate alternative policies, the model can be used to improve other empirical models being developed within the ZEF's Khorezm project once more data become available. Methodologically, prerequisites for building a regional programming model for the study region are the existence of a mathematical tool to formulate and solve the problems of agricultural development and availability of basic regional data reflecting the problems to be solved. The specific objectives of this study and thus the model selection criteria included are as follows:

1. to develop a mathematical programming model on the basis of empirical and economic information available for the Khorezm region;

2. to use the model as a policy information tool with which quantitative policy analysis can be conducted in order to better understand the factual information available for policy-makers;
3. to simulate alternative policy options to assess the associated income changes of agricultural producers;
4. to provide information about possibilities to restructure agricultural production such that economic efficiency of land and water use can be improved;
5. to establish an elegant technique for calibrating a mathematical programming model.

1.4 Overview of Research Procedure

The study is part of the development research project on 'Economic and ecological restructuring of land and water use in Khorezm region'. One of the objectives of the project is to develop concepts for landscape restructuring in the Khorezm region with proposals for legal-administrative and ecological restructuring measures using sustainable natural resource management concepts. The study focuses on basic commodity production in the regional agricultural sector under specific regional conditions. This study was conducted in three steps: First step related to the theoretical section, collection of the relevant publications and literature addressing the issues of agricultural production in Uzbekistan and the Khorezm region. The second step was the data collection for the empirical section from surveys and official statistical institutions to give an understanding on the agricultural sector in the study region. To determine and analyze the impacts of different policy options in regional production and consumption considering the local conditions, a mathematical programming model was then developed. In this study, a comparative static analysis of the development of regional production and consumption is adopted. To ensure that base solution of the model fits the observed values of modelled activities, and to ensure that the model simulations include the characteristics of regional demand and supply, the model parameters both for demand and supply are adjusted. First, the parameters of the supply side were adjusted via the technology coefficients of the model. Next, the demand side was calibrated by deriving the parameters for flexible demand functions. After both supply and demand sides were calibrated, different simulations were run for selected policies and their impacts on different groups of agricultural producers and districts as well as for the whole of the Khorezm region. The calibration of the supply side is based on a new approach which is presented here as an alternative to positive mathematical programming. The calibration of the demand side is based on an approach advocated by Frohberg and Winter (2001).

1.5 Thesis Organization

The content of this dissertation is as follows: Following this introduction, Chapter 2 provides an overview of the regional agricultural sector in Khorezm. The farm restructuring process is introduced and basic information on main agricultural producers, the performance of the agricultural sector and production technologies, and major agricultural policies are discussed. Chapter 2, therefore, provides the reader with the necessary information to understand the model construction and analysis presented in the subsequent chapters. In Chapter 3, the general structure of the applied model is presented. Both the supply and demand sides of the model are described separately. Chapter 4 describes the approach used for calibrating the supply and demand sides of the model. First, the approach used to calibrate the supply side of the model is presented as an alternative for standard calibration approach knows as 'positive mathematical programming'. Following this, the approach applied for calibration of the demand side of the model is presented. Finally, in this chapter, the results of the supply side calibration are discussed, highlighting the most relevant information for understanding how the applied approach adjusted the technology parameters of the model. Chapter 5 first provides motivation for and describes the selected set of policy simulations based on ones which are already introduced or their introduction is widely discussed in Uzbekistan. The first scenario simulates the increase in water efficiency via improving maintenance and rehabilitation of the existing irrigation and drainage system. In the second scenario, water pricing was introduced as a mechanism for to recover the operation and maintenance costs of water suppliers. The simulation included both an increase in crop yields and water efficiency. The simulation assumes that the collected water charges are invested into improving the regional irrigation and drainage system guaranteeing timely supply and better quality of irrigation water, decreasing soil salinity and ground water level. The next scenario was the market liberalization where the state procurement system for cotton is abolished and input subsidies are removed. The fourth scenario includes the scenario with the complete fragmentation of large-scale state producers into private farms. Scenario five simulates the improvement of livestock productivity in Khorezm. Finally, a cumulative scenario is simulated where all the previous five policies are introduced at once. Following the calibration of the model, the selected set of agricultural policies was simulated and their economic impact on regional production, consumption, as well as on the shadow values of the model constraints, was analyzed. Finally, the summary of the study, policy implications and outlook for future research are presented in Chapter 6.

2. Agricultural Land and Water Use in the Khorezm Region

The purpose of this chapter is to provide the reader with background information on the agricultural sector of Khorezm. This descriptive introduction to the study region should help the reader place the analysis presented in later chapters of this thesis into its empirical context. Information on the studied region is presented in order to highlight the major features of agriculture in the Khorezm region, as they pertain to this study. While the study focuses on regional agriculture in the year 2003, it also makes reference to the major changes which have occurred since 1991. The analysis in this chapter is based on data received from the official statistical sources and collected in our own field research. Section 2.1 presents an overview of the process of farm restructuring in the region during the period 1991-2003. Section 2.2 discusses essential features of Khorezm's main agricultural producers. Section 2.3 describes the performance of the regional agricultural sector in the period of 1991-2003. Section 2.4 provides some basic information regarding input endowments and production technologies used by agricultural producers in Khorezm. Regional food consumption and expenditure structures are presented in section 2.5. In section 2.6 we describe the three dominant agricultural policies, state procurement, taxation and subsidization of agricultural producers. The chapter is supplemented by a brief excursion into agricultural reforms in Khorezm; presented in Appendix 1 of this thesis.

2.1 Land Reform and Farm Restructuring

The transition process from a centrally guided economy to a market economy is comprised of several processes such as the abolishment of central planning, reduction of government interventions, and elimination of price controls. Agricultural reforms in Uzbekistan play a fundamental part in the transition to a market economy (Guadagni et al 2005). They are being implemented gradually and include: market liberalization, land reform and the creation of a supporting market infrastructure. Of these reform processes, land reform, explicitly the establishment of private property rights for agricultural land as well as the restructuring of traditional state and collective farms, has been considered the elementary transition process in all former Soviet Union countries (Lerman et al. 2004). In Uzbekistan the aforementioned reform policies aim to achieve four central objectives (Guadagni et al 2005). The first objective is for cotton production to ensure the stabilization of the country's export revenues. Secondly, Uzbekistan aims for self-sufficiency in wheat production. Third, agricultural revenues are to be used to finance industrialization. The final objective of the agricultural policies is to improve rural standards of living. At a regional scale, the farm restructuring process has followed three stages. The process is illustrated in Table 2.1[1]:

Table 2.1: Three stages of farm restructuring process in Khorezm

	First stage	Second stage	Third stage
Period	1992-1998	1998-2003	2003-present
General objective of farm restructuring	Collectivization of state owned farms	Partial decollectivization	Complete decollectivization
Main transformations	Transformation of *sovkhoz*s into *kolkhoz*s	Transformation of *kolkhoz*s into *kolkhoz*s; partial transformation of *shirkat*s into private farms	Complete transformation of *shirkat*s into private farms
Dominant type of agricultural producers	*Kolkhoz*s, *sovkhoz*s and *dekhqan* farms	*Shirkat*s, private farms and *dekhqan* farms	Private farms and *dekhqan* farms
State procurement system	Cotton, wheat and most agricultural products	Cotton and wheat	Cotton and wheat
Land ownership	State ownership; permanent and lifetime inheritable possession	Permanent and lifetime inheritable possession; land lease	Lifetime inheritable possession; land lease
Additionally created service agents	No	Water user associations; machinery and tractor parks	Water user associations; machinery and tractor parks
Dominant form of labor management	Production links (*zveno*) and brigades	Family contracting (*pudrat*s[2])	Permanent and seasonal employment

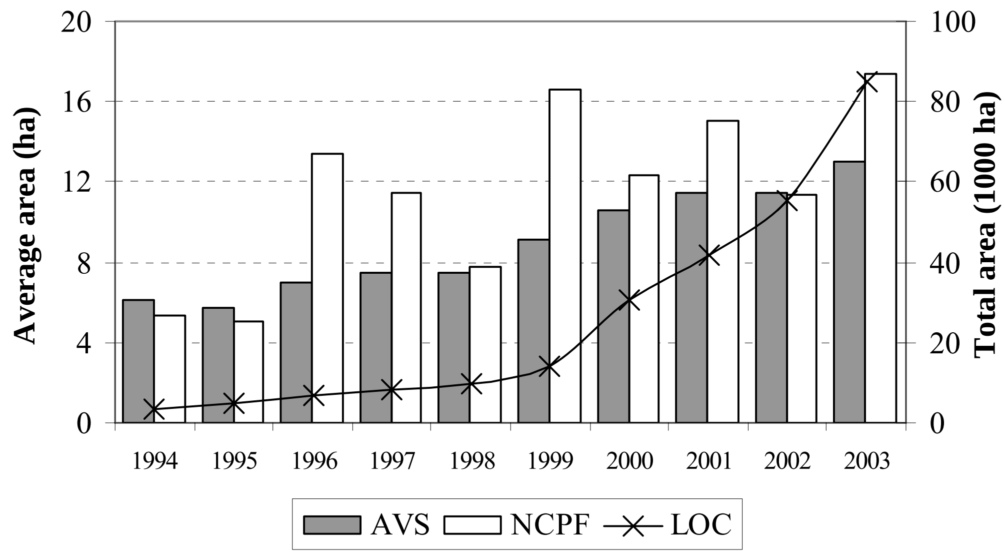
Source: Own compilation

The first stage of agricultural reforms was implemented during the first eight years of independence. This stage was characterized by the transformation of state farms (*sovkhoz*s) into collective farms (*kolkhoz*s) via the transfer of property rights from state ownership to collective ownership, which required former *sovkhoz*s to become operationally self-supporting. During the second stage of farm restructuring which started in 1998, *shirkat*s almost entirely replaced *kolkhoz*s and became the dominant form of agricultural labor employment, and production of strategic crops such as export oriented cotton and import-oriented wheat. In the first year of this second wave of farm restructuring all 132 collective farms in Khorezm were restructured, and 123 of them became *shirkat*s while the remaining

[1] A more detailed description of farm restructuring process is presented in Appendix 1.
[2] In Khorezm region in 2002, the average size of a *pudrat* was 6.9 hectares. An average *pudrat* is contracted from two to five years.

nine *kolkhoz*s were divided into private farm unions (Kandiyoti 2002). The third stage of the farm restructuring process is characterized by an intensified fragmentation of *shirkat*s into private farms. It has been in progress since 2003. In that year the farm restructuring process was shifted from partial reallocation of *shirkat*s' land to private farms to a complete disbandment of all *shirkat*s within an administrative unit (*rayon*) into private farms (Djanibekov 2008). During the third stage of the reform in Khorezm on average 60 to 80 new private farms emerged in the place of one completely disbanded *shirkat* (OblSelVodKhoz 2004b). The 2003 approach has somewhat adjusted to this, by supporting the creation of larger size private farms (PDFA 2004) than had been the case under the 1998 policies [3] (Figure 2.1).

Figure 2.1: Dynamics in establishing private farms in Khorezm



Notes: AVS – Average size of private farm; NCPF – Number of newly created farms; LOC – Total land allocated to farms

Source: PDFA 2004

If the currently held average size of private farms in Khorezm is maintained, there will be about 15,600 private farms with average size of 13.5 hectares by the end of the farm restructuring process (PDFA 2004). Assuming that one household can establish only one private farm, eight percent of households will become owners of a private farm business in Khorezm. The share of households, which will be actively involved in private farming, may be higher if the family relationships between households are considered; e.g. several families can own one private farm.

[3] According to the regional office of association of private and *dekhqan f*arms (PDFA) in Khorezm all *shirkat*s in Yangibazar rayon in 2003 were disbanded into private farms with average size of 17 hectares.

2.2 Main Features of Agricultural Producers

In 2003 the agricultural production in Khorezm mainly took place among three different types of agricultural producers; each distinguishable by their resource endowments, land use rights, production activities and individual policy environments (Djanibekov 2008). Table 2.2 lists the distinctive features of Khorezm's main agricultural producers.

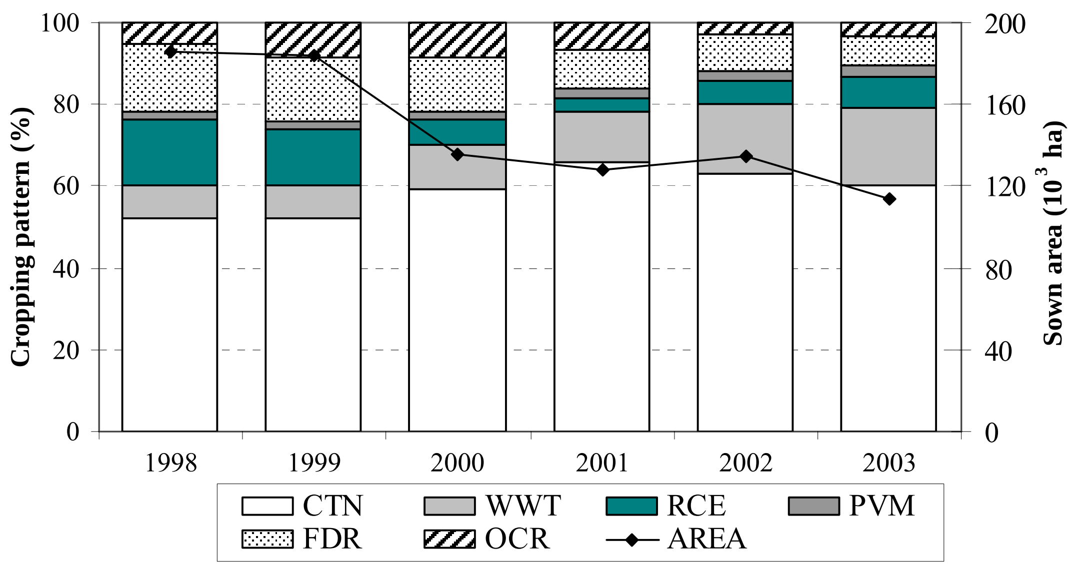
Table 2.2: Main agricultural producers in Uzbekistan

	***Shirkat*s (agricultural cooperatives)**	**Private farm**			***Dekhqan* farm (households)**
		Crop growing	**Gardening and horticultural**	**Livestock rearing**	
Production specialization	Crops	Crops	Vegetables, potatoes, melons; orchards	Livestock, including poultry	Subsistence agriculture
State procurement	Cotton and winter wheat	Cotton and winter wheat	No state procurement	No state procurement	No state procurement
Additional production	Maize, sunflower, rice, vegetables, etc.	Maize, sunflower, rice, vegetables, etc.	Winter wheat and fodder crops	Fodder crops, maize, winter wheat, vegetables, potatoes, melons and rice	Any agricultural crops and livestock, including poultry
Form of land tenure	Permanent possession; based on territory of former *kolkhoz*s and *sovkhoz*s which is about 1.500 ha	Long-term lease (10-50 years); minimum 10 ha	Long-term lease (10-50 years); minimum 1ha	Long-term lease (10-50 years); 0.33 ha per a head of conventional cattle with a minimum of 30 heads of conventional cattle (10 ha)	Lifetime inheritable possession; maximum 0.35 ha
Input subsidies	Direct input subsidies from the state and debt write-offs for all cropping activities	Direct input subsidies from the state and a special credit at low interest rates (5% annual) only for cropping activities under state procurement	None	None	None
Form of labor	Family contracts (*pudrat*s)	Family workers and hired labor	Family workers and hired labor	Family workers and hired labor	Family workers

Source: Own compilation

In 2003, agricultural production mainly took place within large-scale agricultural cooperatives (*shirkat*s). As mentioned above, these agricultural cooperative enterprises were created in place of state and collective farms during the second stage of the farm restructuring process (Djanibekov 2008). As such, *shirkat*s inherited the rights, obligations, input endowments, production targets and rural employment tasks of *sovkhoz*s and *kolkhoz*s. According to corresponding legislation, land was given to *shirkat*s as permanent possession for the specific purpose of agricultural production (OblZem 2004). As successors of state and collective farms, *shirkat*s were included into the system of state procurement quotas and input subsidies. At the end of the first stage of farm restructuring in 1998, *shirkat*s cultivated 82% of total sown area in Khorezm (OblStat 2004a). In 2003, due to an increased rate of farm restructuring, area cultivated by *shirkat*s has decreased to 50% of the regional total (OblSelVodKhoz 2004b). As a result of the *shirkat* disassembly into private farms, the average size of a *shirkat* in Khorezm decreased from 1,850 hectares to 1,445 hectares from 1999 to 2003 (OblZem 2004).

Figure 2.2: Cropping pattern in *shirkat*s in Khorezm



Notes: CTN – Cotton; WWT – Winter wheat; RCE –Rice; PVM - Potatoes, vegetables and melons ; FDR – Maize and fodder crops; OCR – Other crops; AREA – Sown area

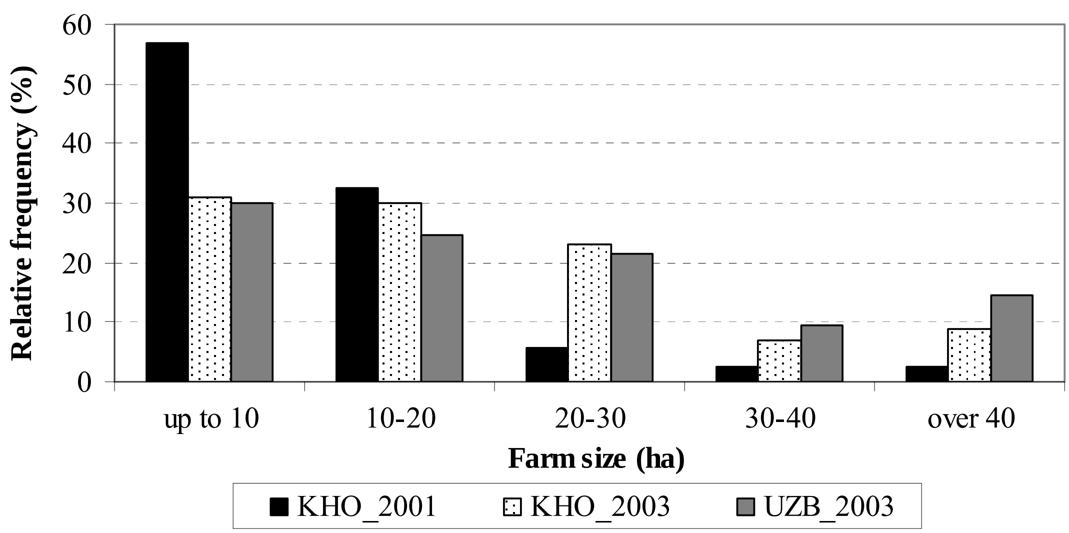
Source: OblStat 2004a

It is notable that the partial fragmentation of *shirkat*s into private farms did not decrease the *shirkat*s' area under cotton and wheat cultivation however (OblStat 2004a). The area used by *shirkat*s to grow state target crops remained fairly unaffected, while reductions were seen in fodder production instead. *Shirkat*s allocate the majority of their land to cotton (Figure 2.2).

By 2003, winter wheat became the crop with the second largest share in *shirkat* production; a result of state initiatives towards achieving national grain self-sufficiency.

Private farms comprise the second type of agricultural producers Uzbekistan. Uzbek law defines the private farms as agricultural enterprises, which are managed by individual families or groups of families on land received under a long-term lease with a maximum period of fifty years. The number of private farms in Khorezm increased significantly during the second and third stage of the farm restructuring process (PFDA 2004). This increase was largely due to the mandatory disbandment of *shirkat*s rather than improvements of infrastructure for private entrepreneurship in the agricultural sector. In 2003, 6,500 private farms cultivated 29% of the total sown area in Khorezm (PFDA 2004, OblStat 2004a). The average size of private farms in the Khorezm region increased from 7.5 hectares in 1998 to 13 hectares by the end of 2003 (PFDA 2004). According to Khan (2005), there exists considerable inequality in the land distribution process for private farming in Uzbekistan. Khorezm replicates this finding at a smaller scale, as a large share of land in the region belongs to a proportionally small number of private farms. Figure 2.3 shows this distribution of farms in Uzbekistan and the Khorezm region with respect to their leased area.

Figure 2.3: Distribution of private farms by size in Khorezm and Uzbekistan



Notes: KHO_2001– Data on Khorezm region in 2001; KHO_2003 – Data on Khorezm region in 2003; USB_2003 – Data for Uzbekistan in 2003

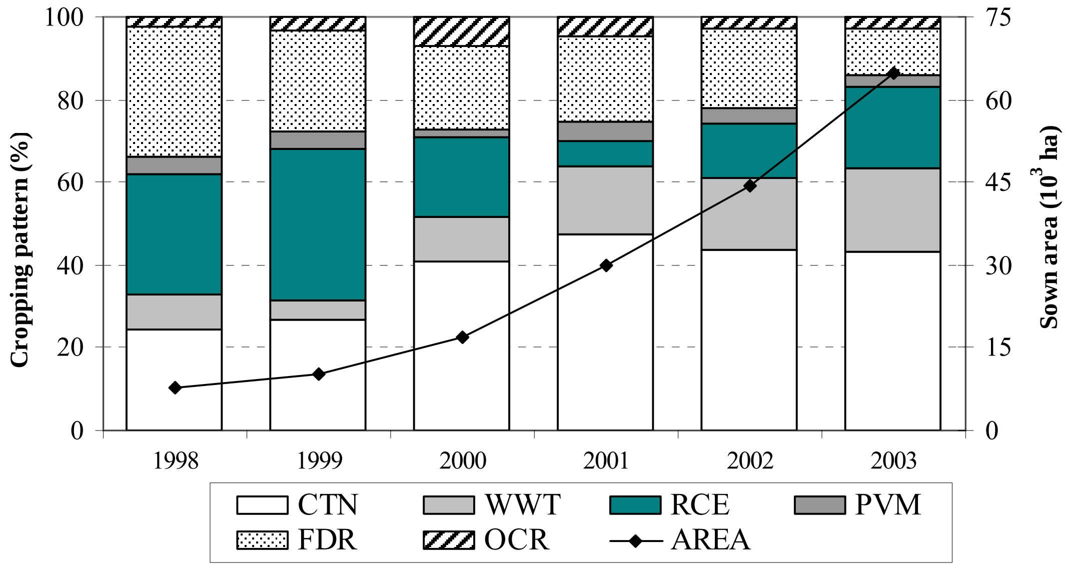
Source: PDFA 2004; MAWR 2004a

In Uzbekistan, the present legislation on private farms distinguishes three different types of private farms, based on their specialization in agricultural production (Table 2.2). The largest and dominant type is comprised of private farms which specialize in crop production. This type of farm enterprise must lease at least 10 hectares of land, designated to it by the government for the production of cotton and cereals. Within the state procurement system, these farms receive state subsidies for producing those two strategic crops. The second farm type is the horticultural private farm, which specializes in gardening and grape growing. This type of farm must be at least one hectare in size and is beyond the state procurement system. The main crops, which are produced by these enterprises, are fruits and grapes. However, this type of private farm may also produce crops in combination with the production of fruit and grapes, such as winter wheat, potato, vegetables, melons, and fodder crops. Additionally, the horticultural private farms are allowed to keep a small stock of animals. Since the horticultural farms are not included into the state procurement system, they do not receive the state subsidies for agricultural inputs.

The third type of private farms specializes in rearing livestock including poultry. According to the legislation, the area leased to this type of private farms is directly related to their animal stock in the ratio of 0.33 hectare per one conventional cattle unit, meaning that there should be at least 30 heads of cattle equivalents corresponding to 10 hectares of land (PFDA 2004). In addition to animal rearing, livestock farms can produce cash crops such as vegetables, potato and rice. The animal rearing private farms enjoy more decision-making freedom than crop growing private farm, but similarly to the horticultural private farms, they do not receive state subsidies for agricultural inputs.

In official statistics, crop growing and horticultural private farms are classified into one group of private farms, whereas animal keeping private farms are considered as a separate group. The share of land used by livestock keeping farms in the total area leased by private farms has decreased from 33% in 1999 to 10% in 2003 (OblStat 2004a). The remaining 90% of private farm land is leased to crop growing and horticultural farms. The average size of a private farm in the group of crop growing and horticultural is 14.8 hectares, and of livestock rearing private farms is 13.1 hectares (PFDA 2004). In the first year of the farm restructuring process, private farming in Khorezm had a more commercial orientation. Rice production in private farms amounted to one third of farms' sown area, while cotton and wheat were grown on 25% and 10% of private farm fields, respectively (Figure 2.4). Since having replaced *shirkat*s, private farms have received the *shirkat*s' share in cotton and wheat production for state procurement. Since 1998, the crop pattern of private farms has shifted towards cotton (40%) and wheat (21%) production (OblStat 2004a). As result, by the end of 2003, the private farm fields were mainly allocated to cotton, wheat and fodder crops (Figure 2.4). According to the farm survey conducted by the author in Khorezm in 2003, the state procurement for cotton and wheat accounted for almost two-thirds of the area sown by crop growing private farms in 2002.

Figure 2.4: Cropping pattern in private farms in Khorezm



Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice; PVM – Potatoes, vegetables and melons ; FDR – Maize and fodder crops; OCR – Other crops; AREA – Sown area

Source: OblStat 2004a

The third type of agricultural producers in Uzbekistan is rural households (*dekhqan* farms[4]). Their agricultural production is based on family labor and takes place on small household plots received on lifetime inheritable possession[5]. The individual household, which averages about 6-7 people in Khorezm, can be considered the smallest agricultural production unit (Djanibekov 2008). Household plot farming in rural Uzbekistan serves to complement income and food security (Spoor 2004), and is not a part of the state procurement system. There were almost 200,000 *dekhqan* farms in Khorezm in 2003, possessing in total 33,000 hectares of land (PFDA 2004). In 2003, *dekhqan* farms cultivated 17% of the total arable area in Khorezm (OblStat 2004a). According to official statistics, between 1998 and 2003, household's sown area in Khorezm increased by 20% (OblZem 2004).

In Uzbekistan, the *dekhqan* farm (household) operates two types of plots (Djanibekov 2008). The "attached plot" (*uy tomorqa*) is practically a yard where household buildings and gardens

[4] The word '*dekhqan farm*' was often used with respect to private farms in papers on agriculture in Uzbekistan. The distinction of '*dekhqan* farm' or '*dekhqan hojalik*' from 'private farm' is word '*dekhqan*' meaning a peasant or individuals whose livelihood is largely dependent on personal subsidiary plots and rural subsistence-type activities. Thus, in this study the terms '*dekhqan farm*' and '*dekhqan hojalik*' are referred to rural households.

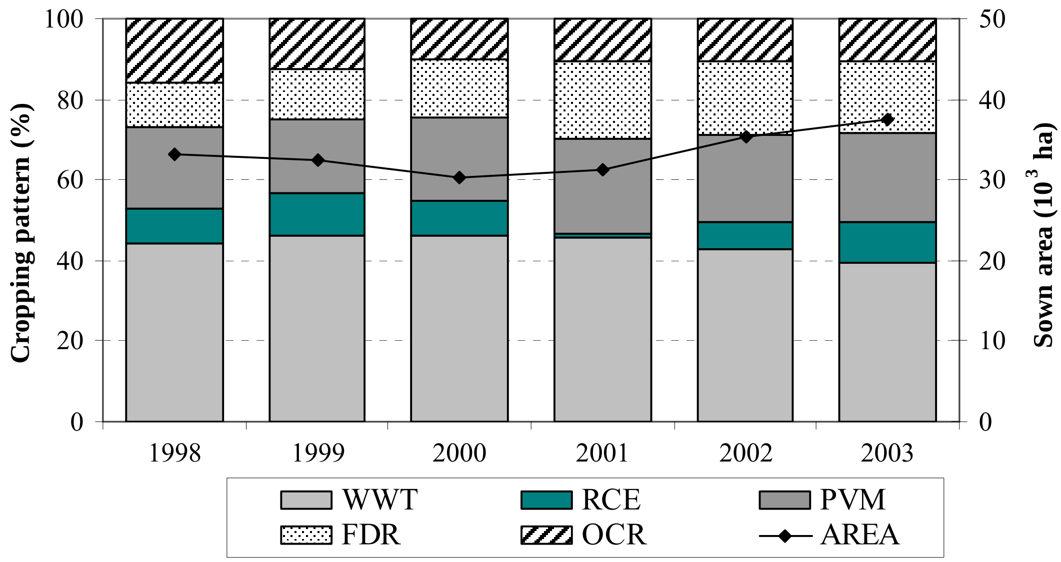
[5] The study deals only with rural households. However, 50% of urban households have access to the plots similar to *dekhqan* plots (Khan 2005).

are located. The *uy tomorqa* averages about 0.1 hectare in size, with 30% of the area occupied by household dwelling and buildings. The second type is the "distant plot" (*qushimcha tomorqa*), which is located separately from household buildings. Two thirds of the rural households possess distant plots. These distant plots can be anywhere from 20 meters to 7 km away from the *uy tomorqa,* with an average distance of around 1.1 km in Khorezm (Djanibekov 2006a). The average size of the distant plot is 0.1 hectare. Although, according to legislation, *dekhqan* farms can have 0.35 hectare of irrigated land, a rural household in Khorezm with both attached and distant plots has an average size of 0.17 hectare of arable land, while the rest is occupied by dwellings and buildings (Djanibekov 2008). The average size of arable land in households which do not posses a distant plot is about 0.09 hectare. The attached and distant plot may constitute one piece if they border with each other, which is considered most favorable for rural households in terms of income. In such a case, the attached and distant plots are joined to each other composing a 0.25 hectare large plot of arable land[6]. Due to their cultivated area, the distant plots dominate in the use of production inputs such as manure, labor, machinery services and nitrogen fertilizers in rural households. The cropping pattern between the two plots is distinct (Djanibekov 2006a). Potato, vegetable and melons are grown mainly on the attached plots. Wheat and rice are mainly grown on the distant plot. A double cropping scheme is intensively used on both household plots (Djanibekov 2006a).

Households largely allocate their plots to wheat, potato, vegetables and melons (Figure 2.5). However, according to a household survey conducted by the author in Khorezm in 2004, the small size of household plots resulted in very small marketing shares of produced food commodities; the largest share being used for own consumption (Djanibekov 2006a). The crops, which are produced by households in surplus and hence marketed, are rice, potato, vegetables, fruits and grapes. Moreover, despite the majority of household's agricultural area in Khorezm being allocated to winter wheat, most rural households are net receivers of wheat. Annual wheat production of an average household can cover only one third of its annual consumption requirements.

[6] However, according to the legislation, households that have the attached and distant plots adjoined are not allowed to cultivate rice in their household plots.

Figure 2.5: Cropping pattern in households in Khorezm



Notes: WWT – Winter wheat; RCE – Rice; PVM – Potatoes, vegetables and melons; FDR – Maize and fodder crops; OCR – Other crops; AREA – Sown area

Source: OblStat 2004a

Since 1991, the total number of livestock kept in households doubled and accounted for almost 92% of the total regional animal stock. About 82% of the total regional poultry is raised by households (OblStat 2004a). According to the results of household survey, cows and calves are common in rural households: 89% and 79% of the surveyed households had respectively cows and calves. Poultry rearing was also widespread (84% of the surveyed households). Because of scarcity of pastures, sheep are not popular in Khorezm. Only 17% of interviewed households fed sheep; mainly for selling and own household ceremonies. On average, a household in Khorezm had one milking cow, one calf and 16 units of poultry.

2.3 Agricultural Production

2.3.1 Crop Production

The regional GDP per capita in Khorezm in 2003 was about 255 USD (OblStat 2004b). The agricultural sector accounted for roughly 67% of the total regional GDP in 2003 (OblStat 2004a). Crop production amounted to 43% and the animal sector produced almost 56% of the agricultural sector's total output in 2003 (OblStat 2004a). In 2003, the output of the agricultural sector per hectare of sown area was about 1,044 USD.

The reforms developed to achieve the transition to a market economy and grain self-sufficiency changed the cropping pattern in Khorezm considerably (Table 2.3). Four major observations regarding the regional cropping pattern can be made for 1993-2003. First, the area under cultivation of food crops, especially winter wheat increased drastically. Second, the cotton cultivated area has been kept unchanged. According to the state procurement system, the regional land allocation is determined primarily by the government and the state procurement quota. Remaining arable land may then be allotted to other crops at the discretion of agricultural producers. Consequently, with the intensification of the farm restructuring process, the land allocated under cash crops has not increased. Hence, the increase in wheat area was achieved at the expense of perennial fodder crops. Fourth, except for the drought period in 2000 and 2001 the total regional crop area has been increasing steadily. These four points will be discussed further.

Table 2.3: Cropping pattern in Khorezm, 10^3 ha

Crop	1993	1995	1997	1999	2001	2002	2003	Share in national product in 1992-2003, %
Cereals	42.2	64.5	78.7	73.0	49.2	68.9	86.0	6.1
Winter wheat	4.2	16.9	27.0	30.5	36.0	46.3	51.2	3.4
Rice	32.1	38.2	47.0	39.9	9.8	19.1	30.6	32.3
Cotton	112.6	102.1	100.3	100.3	109.6	110.7	102.3	7.4
Potato	1.9	3.1	2.6	2.2	2.7	2.6	2.9	4.1
Vegetables	8.2	9.6	6.5	5.7	7.1	7.9	8.7	5.1
Melons	4.0	3.1	2.6	2.4	4.0	4.1	3.3	8.3
Maize and fodder	70.2	62.4	52.1	42.2	30.7	31.7	26.9	8.3
Total crop area	239.1	244.8	242.8	225.8	203.3	225.9	230.1	6.0
Gardens	15.7	15.6	19.2	11.7	11.5	11.9	12.3	4.9
Total sown area	254.8	260.4	262.0	237.5	214.8	237.8	242.4	5.9

Source: MAWR 2004a; OblStat 2004b

In 2003, 80% of the crop area in Khorezm was used for the cultivation of cotton, wheat and rice (OblStat 2004a). The production of other crops such as maize, potato, vegetables, melons, and fodder crops was less significant as they covered only 18% of the total crop area. Additionally, there was an attempt to introduce sugar beet cultivation in the Khorezm region in 1998-2001, based on an import substitution policy (OblStat 2004a). However, due to low yields and low sugar extraction rates the sugar cultivation in the Khorezm region was abandoned.

Being the primary strategic crop because of its export value, cotton was cultivated on 45% of total crop area in Khorezm between 1992 and 2003 (OblStat 2004a). The total regional production of cotton in 1992 and 2003 amounted to 7.4% of total cotton production in Uzbekistan (MAWR 2004a). The general tendency in cotton production is that the cotton yield has been decreasing both at the national and the regional levels (OblStat 2004a). Since 1998, when the farm restructuring process was accelerated, cotton production has been transferred from *shirkat*s to private farms without affecting the total cotton area under cultivation in Khorezm (OblStat 2004a).

Winter wheat is the main crop used in the double cropping system in Khorezm (Djanibekov 2006a). In the double cropping system, it is grown as a first crop and is followed by rice or maize and sorghum for fodder in the summer period. In general, the regional production of wheat accounted for 3.4% of the total wheat production in Uzbekistan from 1992 to 2003 (MAWR 2004a). Similar to cotton, wheat production has been transferred to private farms (OblStat 2004a), and the area of wheat cultivation in *shirkat*s was maintained via decreasing the area under fodder crops. In Khorezm, wheat yield tripled during 1997-1999 and further dropped by almost half during the drought in 2000 and 2001 (OblStat 2004a). Major changes in the regional cropping pattern occurred due to the introduction of winter wheat as part of the state program of achieving food self-sufficiency. After the establishment of the program for grain independence in 1992, area allocated to wheat in Khorezm increased to 23% of total sown area in 2003 (OblStat 2004b). This was achieved through the decrease of fodder area, mainly lucerne (OblStat 2004a). At the same time, the area cultivated for cotton remained relatively stable. Overall, the expansion of winter wheat in the region did not affect the production of crops, which could still be grown in a short period after winter wheat.

In 1992 and 2003, almost one-third of rice in Uzbekistan was produced in Khorezm (MAWR 2004a). According to official statistics, the area under rice in Khorezm in 2003 was almost at the same level as in 1990 (OblStat 2004a). Rice cultivated area had remained relatively stable in the period of 1990-1999, but the drought years of 2000 and 2001 resulted in a drastic 80% decrease of rice production in the Khorezm region (OblStat 2004a). The strategic character of cotton in the national economy is a main reason why rice showed such drastic decreases in cultivated area during the drought years (Müller 2006). Depending on the sowing period, there are two methods of rice cultivation in Khorezm. The first method involves varieties of rice which are sown in spring as a first crop. The second method includes the varieties of rice which are planted after winter wheat in summer. Both cultivation methods allow for winter wheat sowing after the rice harvest. In the first years after introduction of winter wheat according to the state program on self-subsistence, the area of rice in Khorezm likely increased in part due to the increase in the use of the double cropping system.

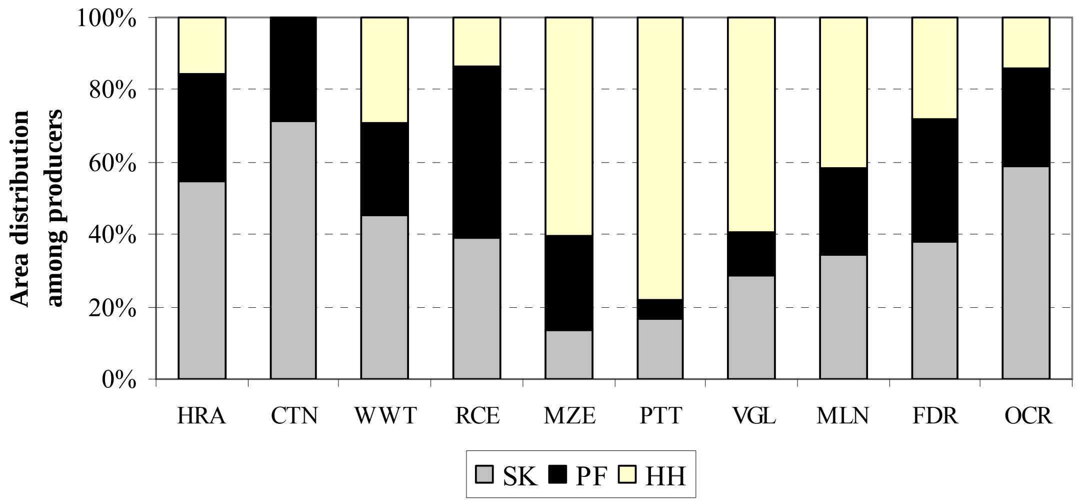
The area allocated to food crops such as potatoes, vegetables and melons has been continuously increasing in proportion to regional population growth (OblStat 2004a, OblStat 2004b). In the period of 1992-2003 the regional production of potato, vegetables and melons accounted for 5.4% of total production in Uzbekistan (MAWR 2004a). In Khorezm, almost two thirds of these food crops were produced on rural household plots, and mostly for own consumption with only a small surpluses being marketed (OblStat 2004a, Djanibekov 2006a).

Maize is third among grains in terms of sown area in Khorezm (OblStat 2004a), and is mostly produced as a forage grain for livestock and poultry feeding (Djanibekov 2006b). Since 1991, the production of maize in Khorezm region has been decreasing; as is the case throughout Uzbekistan (OblStat 2004a, MAWR 2004a). In 2003 the production of maize for grain in Khorezm was about 28% of its production volume in 1991 (OblStat 2004a); accounting for 2% of total national production. There are two maize cultivation methods that differ according to the date of sowing and time of harvest. In the first method, maize is sown early in spring and harvested after full ripeness of grains. Then the primary product, maize grains, and the byproduct, the maize stem, are used in poultry and livestock feeding. The second method involves a short growing season for fodder maize in summer; i.e. in-between winter wheat cultivation periods. In this method, fodder maize is harvested as a stem before its full ripeness. In Khorezm in 1991-2003, 85% of the area allocated to maize production was cultivated according to the second cultivation technique (OblStat 2004a).

The increase of wheat production in Khorezm came at the cost of the area for perennial fodder crops. Between 1991 and 2001, the area of fodder crops in Khorezm decreased 2.8-fold and the ratio of forage sown area to livestock quantity diminished 3.6-fold (OblStat 2004a). Forage production was partially transferred from *shirkat*s to households and later to private farms (OblStat 2004a).

The distribution of products varied depending on the type of agricultural producer (Figure 2.6). While *shirkat*s and private farms were specialized in producing cotton and grains, households dominated in production of horticultural crops. According to official statistics (OblStat 2004a), *shirkat*s occupied about 56% of total sown area and produced 22% of total output of the agricultural sector in 2003 (OblSelVodKhoz 2004b, OblStat 2004b). Private farms occupied 30% of sown area and produced 10% of total agricultural output. Households occupied 17% of total sown area and produced about 68% of total agricultural output in 2003. Due to its double cropping properties (Djanibekov 2006a), the wheat production in rural households of Khorezm region makes up a significant part of the regional wheat production (OblStat 2004a).

Figure 2.6: Area distribution among agricultural producers in Khorezm in 2003



Notes: HRA – Harvested area; CTN – Cotton; WWT – Winter wheat; RCE – Rice; MZE – Maize; PTT – Potato; VGL – Vegetables; MLN – Melons; FDR – Fodder crops; OCR – Other crops; SK – *Shirkat*s; PF – Private farms; HH – Rural households

Source OblStat 2004a

Table 2.4 shows the differences in crop yield and crop gross margins in 2003 with respect to type of the agricultural producer. According to this data, in Khorezm, cotton and fodder were the crops produced with losses in 2003. While cotton production was mandatory, the losses from fodder cultivation were offset by livestock production.

Table 2.4: Comparison of crop yield and gross margins in Khorezm in 2003

Activities	Crop yield, t ha^{-1}				Gross margins, USD ha^{-1}			
	SK	PF	HH	REG	SK	PF	HH	REG
CTN	1.6	1.6	–	1.6	-86.4	-39.0	n.a.	-72.8
WWT	3.0	3.2	4.9	3.6	220.3	224.6	482.2	295.7
RCE	4.1	4.5	4.9	4.4	639.3	696.8	723.6	678.0
MZE	3.2	2.6	3.5	3.2	346.2	288.4	388.4	356.8
POT	13.2	10.8	13.7	13.5	511.0	374.8	904.6	812.6
VGL	19.3	13.9	20.5	19.4	453.5	396.5	901.5	713.3
MLN	14.8	9.1	18.8	15.1	300.4	149.1	590.9	385.7
FDR	10.5	12.7	17.1	12.9	-4.5	-10.4	-8.2	-4.1

Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice; MZE – Maize; PTT – Potato; VGL – Vegetables; MLN – Melons; FDR – Fodder crops; SK – *Shirkat*s; PF – Private farms; HH – Rural households; REG – Average in Khorezm

Source: OblStat 2004a; OblSelVodKhoz 2004a; Private farm survey 2003; Household survey 2004

2.3.2 Animal Production

The animal sector produced almost 60% of the agricultural sectors total output measured in monetary value in 2003 (OblStat 2004a). In contrast to other CIS countries the transition period in Uzbekistan was not accompanied by a drastic decrease in the number of livestock and outputs from livestock (Iñiguez et al. 2004). On the contrary, in Khorezm (Table 2.5) and general in Uzbekistan, the number of livestock and sheep flock increased during 1992-2003. In fact, the only observed decreases are found in terms of poultry and eggs per capita and are due to the decrease in maize production (Table 2.5). Livestock and poultry account for 8.1% and 8.6% respectively of the total stock of these types of animals in Uzbekistan, while the regional share of sheep is only 2.1% of total national flock (MAWR 2004a). Since 1991 there has been a slight change in the composition of Khorezm's animal stock. The count of sheep and cows has increased and that of poultry and bulls has decreased (Table 2.5). Despite being negatively affected by the decreasing area of fodder production, and lack of pastures, animal production in Khorezm has proven to be less sensitive to natural conditions, such as droughts (e.g. in 2000-2001), than has crop production.

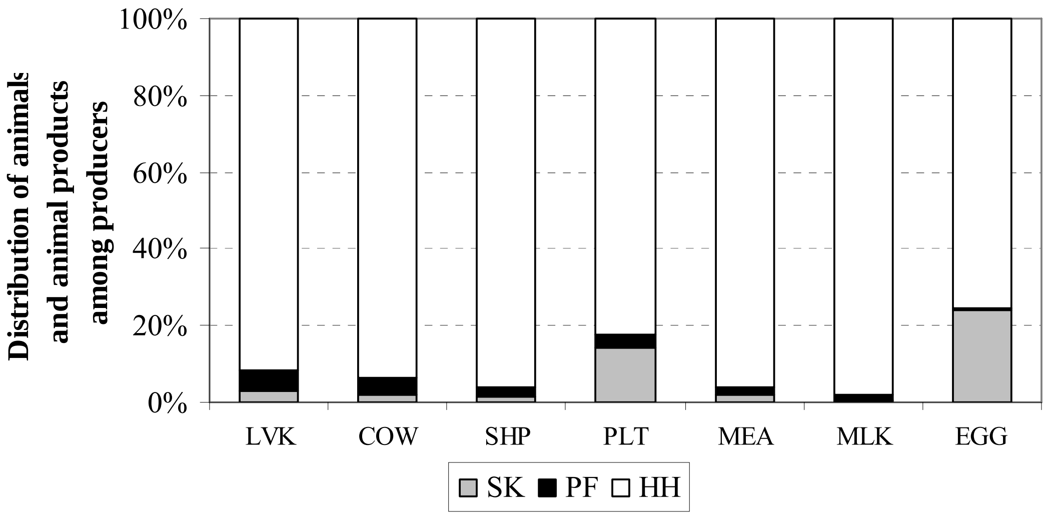
Table 2.5: Livestock and poultry rearing in Khorezm

Parameter	1993	1995	1997	1999	2001	2002	2003
Animals, 1000 heads							
Livestock	400.4	431.3	441.5	445.1	450.0	446.9	448.7
including cows	155.1	167.3	179.4	183.5	186.3	188.2	189.7
Sheep and goats	157.6	174.9	197.2	206.5	208.9	219.1	219.4
Poultry	1,646.4	1,348.2	994.0	1,345.7	1,194.0	1,302.4	1,437.6
Production, 1000 tons							
Meat	23.8	23.2	29.1	30.6	32.3	33.3	37.5
Beef	20.6	21.2	26.2	24.6	30.9	31.9	34.7
Mutton	1	0.8	2.1	4.7	0.8	0.9	1.1
Poultry	1.7	1	0.6	1.2	0.6	0.5	1.4
Milk	323.7	340.8	350.6	377.7	383.8	388.1	419.6
Eggs, mln units	109.1	94	97.4	104.9	110.3	114.9	130.5

Source: OblStat 2004a

In 2003, milk and meat were almost entirely produced by rural households (OblStat 2004a), while a quarter of eggs were produced by *shirkat*s and private farms (Figure 2.7). As the figure shows, although the share of land use by private farms increased drastically by 2004, their share in livestock sector was still small. Despite a role of livestock in the livelihood of rural households (listed below), private farms find it relatively more complicated to be involved into livestock rearing than crop growing activities which tacitly imply the mandatory land allocation under cotton and winter wheat. The government when deciding the transfer of land to a new private farm gives preference to ones which specialize in crop growing.

Figure 2.7: Agricultural product distribution among producers in Khorezm in 2003



Notes: LVK – Livestock; COW – Cows; SHP – Sheep; PLT – Poultry; MEA – Meat; MLK – Milk; EGG – Eggs; SK – *Shirkat*s; PF – Private farms; HH – Rural households

Source OblStat 2004a

In general, livestock rearing plays an important role for rural households of Khorezm and provides them certain benefits. First, it provides households with a daily source of food, such as milk, which may also be sold to markets for additional income. In rural households that don't have distant plots, livestock is the primary source of food and income (Djanibekov 2006b). Second, livestock is considered both an asset and an item of security for many households. In Khorezm, both households and private farms practice a short-term fattening of bulls for sales purposes to solve cash liquidity problems. Livestock can also represent savings, in that it is recognized as private property and considered a relatively stable storage resource (Djanibekov 2006b). Livestock can also earn interest in the form of offspring. Third, even if the agricultural producers in Khorezm do not use animal traction for field operations, livestock has an input function for crop production in the form of manure as an organic fertilizer. Fourth, rural households producing crops and employed in *shirkats* and private farms receive additional low-value byproducts. By feeding these crop residues to livestock, households convert them to high-valued animal products. Fifth, labor demands of animal husbandry does not feature peak periods, as does e.g. crop growing, but is fairly smoothly spread over the entire year.

2.4 Inputs and Production Technologies

2.4.1 Land and Water

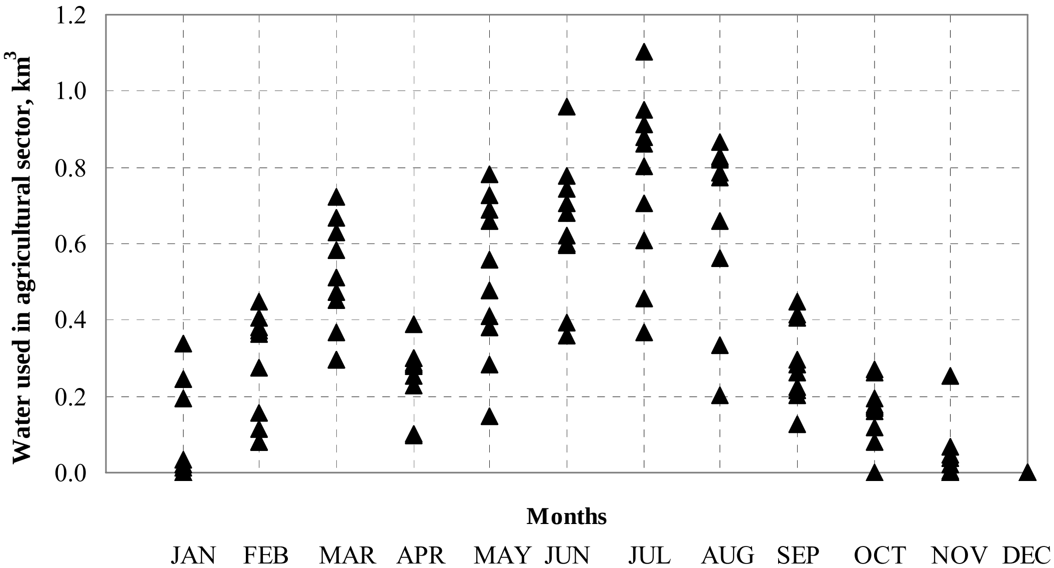
The Khorezm region is divided into two parts by the Amu Darya river. The right bank of the river is approximately 230,000 hectares and only slightly used for agricultural production (OblZem 2004). The left bank has an area of 455,000 hectares, from which 276,000 hectares can be irrigated and used for agriculture. Irrigable area almost doubled between 1990 and 2003, from 137,000 hectares to 276,000 hectares (Abdolniyozov 2000). The region consists of ten almost equally-sized administrative districts; six of which are located in the upstream area and four in the downstream area. According to the data of OblZem (2004), the basic type of land use in Khorezm in 2003 was sown area (31.2%), hayfields and pastures (25.3%). The sown area presents annual and perennial crops. The share of idle land, i.e. land which is not used for agricultural production, is about 26.6%. Additionally, poor reclamation lands amount to about 0.3%. Perennial plantations (2.0%) cover land that is occupied by fruit trees and vineyards. Hayfields and pastures are registered as land that may be used for animal husbandry. Mostly, this area is located on the right bank of the Amu Darya. Due to the low level of annual precipitation, land identified as pastures and hayfields has low fodder content and is not used for animal grazing (Abdolniyozov 2000). The area under forest (8.6%) presents wood plantations, which serve mainly as shelterbelts on agricultural land. Land allocated for household dwellings (6.1%) is registered separately since it comprises composite land usage such as buildings, perennial plantations and crops.

Given the low level of precipitation, water from the Amu Darya is the only source for irrigation and agricultural production in Khorezm. In general, the water inflow into Khorezm meets the demand (Müller 2006). However, the region has experienced water shortages, e.g. in the period of 1982-1999. The likelihood for water-shortages in Khorezm has definitely increased such that the probability of attaining sufficient amounts of water fell from 82% in 1992 to 74% in 1999; meaning that at the observed conditions of 1999, there can be three drought years on average in a decade (Müller 2006). The annual water used during the drought period of 2000-2001was 2.5 km^3, compared to 3.8 km^3 in 2002 and 2003 (OblSelVodKhoz 2004g).

Water from the Amu Darya is channeled to agricultural fields by gravity through a hierarchically arranged irrigation network; including main, inter-farm, and on-farm channels (Khamzina 2006). The main and inter-farm irrigation channels have a combined length of 2,372 km, and on-farm irrigation channels measure 13,616 km in combined length

(Abdolniyozov 2000). The water arriving in Khorezm is collected in the Tuyamuyun water reservoir, and its volume is rationed depending on the monthly water demand in the region. During the droughts of 2000 and 2001 water availability in the irrigation seasons decreased double and threefold respectively (Figure 2.8).

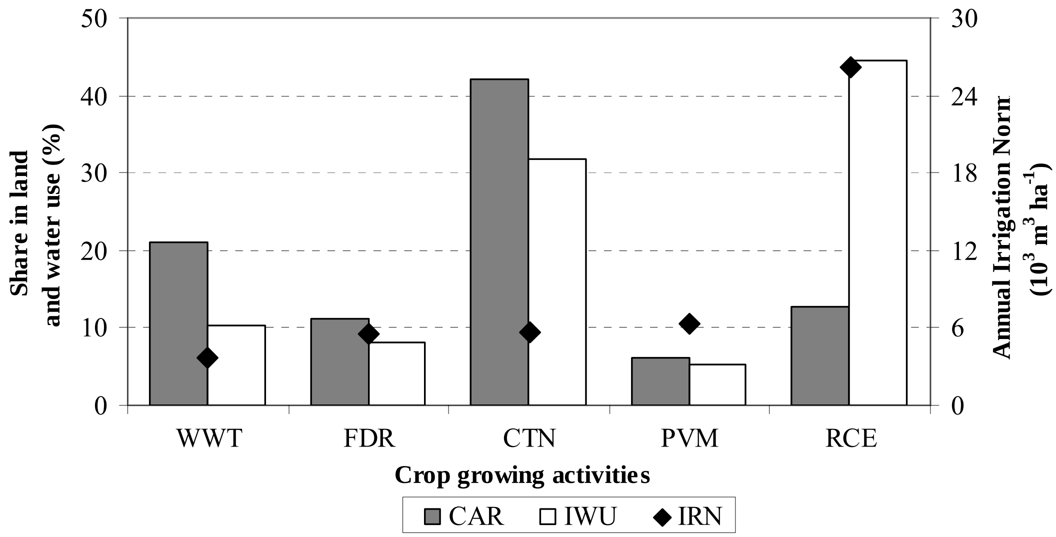
Figure 2.8: Monthly water use in Khorezm in 1994-2004



Source: OblSelVodKhoz 2004g

As Figure 2.8 shows, annually, there are two distinct cycles of water use in agriculture in Khorezm. The first cycle covers the period from February to March, in which water is used for flushing salts from the top soil, i.e. the leaching period. Annually leaching is undertaken on 80-85% of irrigated area (Abdolniyozov 2000). The second cycle covers May-September; i.e. the main crop vegetation period. The water demand schedule is estimated annually depending on crop area, cropping structure, crop water requirement and leaching norms; all of which were developed in the early 1980s (OblSelVodKhoz 2004d, OblSelVodKhoz 2004g). The most water consuming crop cultivated in Khorezm is rice (Figure 2.9). According to the recommended values on irrigation, rice was grown on 12% of the total sown area in Khorezm and used about 44% of all irrigation water in 2003 (OblStat 2004a, OblSelVodKhoz 2004d). As shown in Figure 2.12 there are river bordering districts which have immediate access to the irrigation water and off-stream districts which have no direct access to the river. The districts without direct access to the river are dependant in their water supply on the water consumption in the districts that border the Amu Darya directly (Müller 2006). They were also the ones most affected during the drought years. During 1999-2001, which includes two drought years, the average irrigation rate per unit of area decreased by 65% in the off-stream located districts, while the losses range from 48% to 57% along the river (Müller 2006).

Figure 2.9: Water use according to irrigation norms in Khorezm in 2003



Notes: WWT – Winter wheat; FDR – Maize and fodder crops; CTN – Cotton; PVM – Potato, vegetables and melons; RCE – Rice; CAR – Area allocated under crop; IWU – Annual irrigation water used for crop; IRN – Annual irrigation norms for crop

Source: OblSelVodKhoz 2004d

In general, the regional irrigation system suffers from leakage and seepage due to technical shortcomings. Therefore the conveyance losses are high. According to Abdolniyozov (2000), the efficiency coefficient of the main irrigation channels in Khorezm is 0.9-0.96. The efficiency coefficient of intra-farm channels is 0.7. The whole irrigation network has a coefficient of efficiency of 0.50-0.55; meaning that 44-45% of irrigation water is lost into the drainage system (Abdolniyozov 2000). According to estimates, based on the recommended irrigation amounts as well as official statistics for planted area, water loss in 2003 was 43% of total water used for irrigation. The average amount of water used in the irrigation period is about 14,100 m^3 per hectare. The water used for leaching is about 5,200 m^3 per hectare (Abdolniyozov 2000).

2.4.2 Labor and Machinery

In 2003, the population size in Khorezm was over 1.4 million people, and constituted about 5.5% of the Uzbekistan's total population (OblStat 2004b). The average arable area per capita in the region was 0.2 hectare. Even if the population in Khorezm was growing steadily in the period between 1992 and 2003, its annual growth rate has been declining from 3.1% in 1992 to 1.4% in 2003 (OblStat 2004b). The share of rural population increased from 74.6% in 1992 to 77.2% in 2003 (Table 2.6). The total regional labor force is about 738.3 thousand people; of which 497 thousand people are employed. Almost 40% of the employed labor force, or 183.1 thousand people, are employed in the agricultural sector (OblStat 2004b).

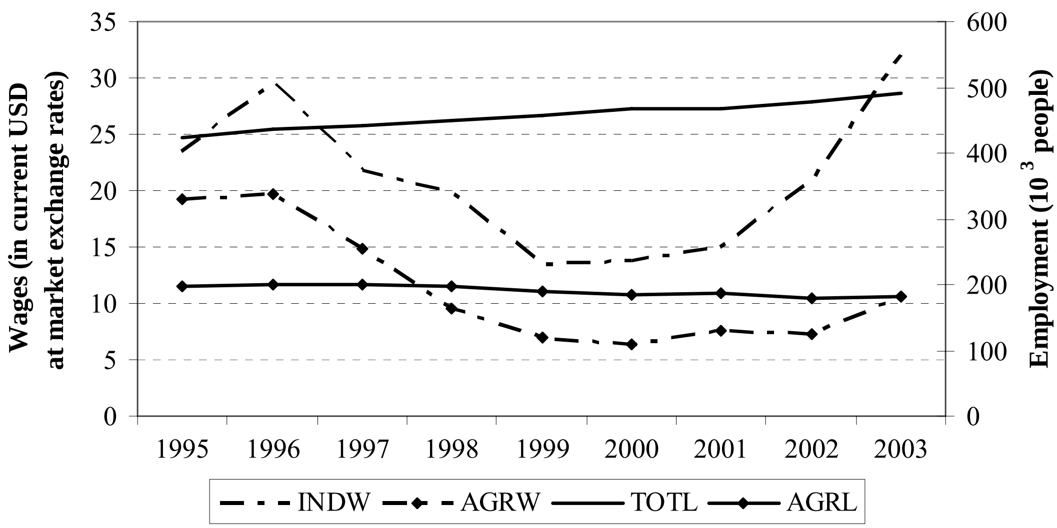
Table 2.6: Population in Khorezm in 2003

	Regional population, 1000 people	Share of each category in total regional population, %
Size and distribution		
Total population	1,412.8	100.0
Rural	1,091.0	77.2
Urban	321.8	22.8
Age structure		
Male aged below 16	260.7	18.5
Male aged 16-65	366.9	26.0
Male aged above 65	59.0	4.2
Female aged below 16	270.8	19.2
Female aged 16-65	383.1	27.1
Female aged above 65	72.3	5.1

Source OblStat 2004b

In general, during the period of 1992-2003, the total labor employment in the agricultural sector has declined by 20% (Figure 2.10).

Figure 2.10: Dynamics in wages and employment in Khorezm



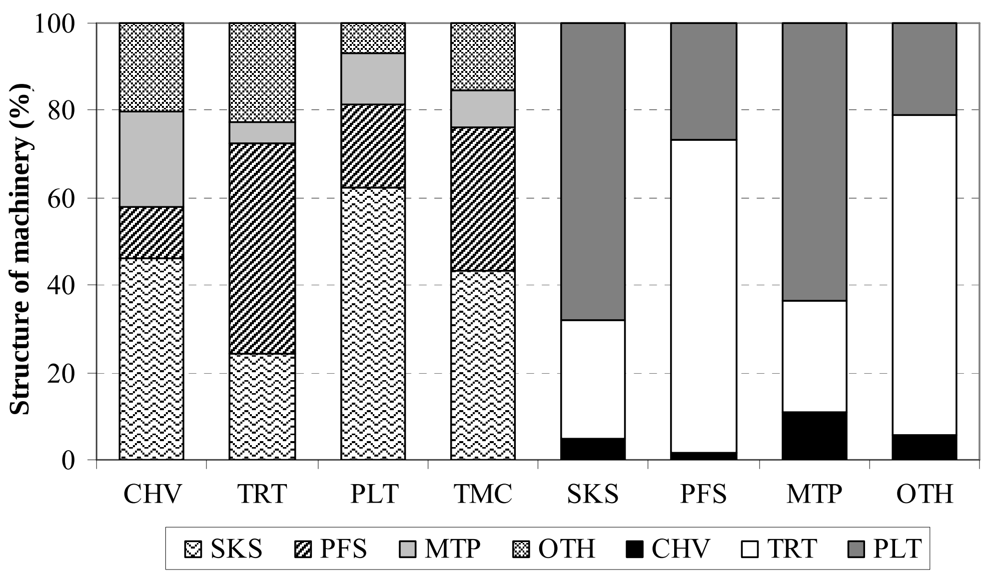
Notes: INDW – Industrial sector wage; AGRW – Agricultural sector wage; TOTL – Total regional employment; AGRL – Employment in agricultural sector

Source: OblStat 2004b

First of all, the introduction of wheat, which is a less labor-intensive crop, requires fewer people to be employed as permanent workers in *shirkat*s and private farms. Comparing to the land allocated for cotton growing *pudrat*s, contracts for wheat growing are made for larger areas with less workers (OblSelVodKhoz 2003). Second, in the framework of the agricultural reforms, to restructure the structure of production costs, *shirkat*s have been shedding their workers since 1999 (OblStat 2004b). In comparison to the number of workers employed in *kolkhoz*s in 1999, their number in *shirkat*s has decreased by 30% in 2003 (OblStat 2004b). Third, private farms rely mostly on own family and seasonal hired labor and, thus, tend to employ less people than *shirkat*s. Fourth, the gap between wages in the agriculture sector and in the industry has increased.

The fragmentation of *shirkat* assets during the third stage of the farm restructuring process features several aspects. First is the collection of a tractor fleet, formerly used on the territory of the *shirkat*. As shown in Figure 2.11, in 2003 most tractors and harvesters belonged to *shirkat*s and private farms. After the fragmentation of *shirkat*s into private farms, the heavy and expensive machinery, such as grain harvester combines and heavy ploughing tractors were transferred to machinery and tractor fleets (OblSelVodKhoz 2004e). The established private farms own cheap, small and multifunctional tractors for ploughing, cultivating and transportation to ensure adequately timed field work. Quite remarkable, the delays in service provisions by MTP to private farm fields, caused by the scarcity of equipment during peak periods, were mentioned as main factor affecting crop yields in Khorezm. In general during the period of 1999-2003 the level of mechanization in agriculture has decreased by 20% for Khorezm (OblSelVodKhoz 2004e).

Figure 2.11: Structure and distribution of machinery in Khorezm in 2003



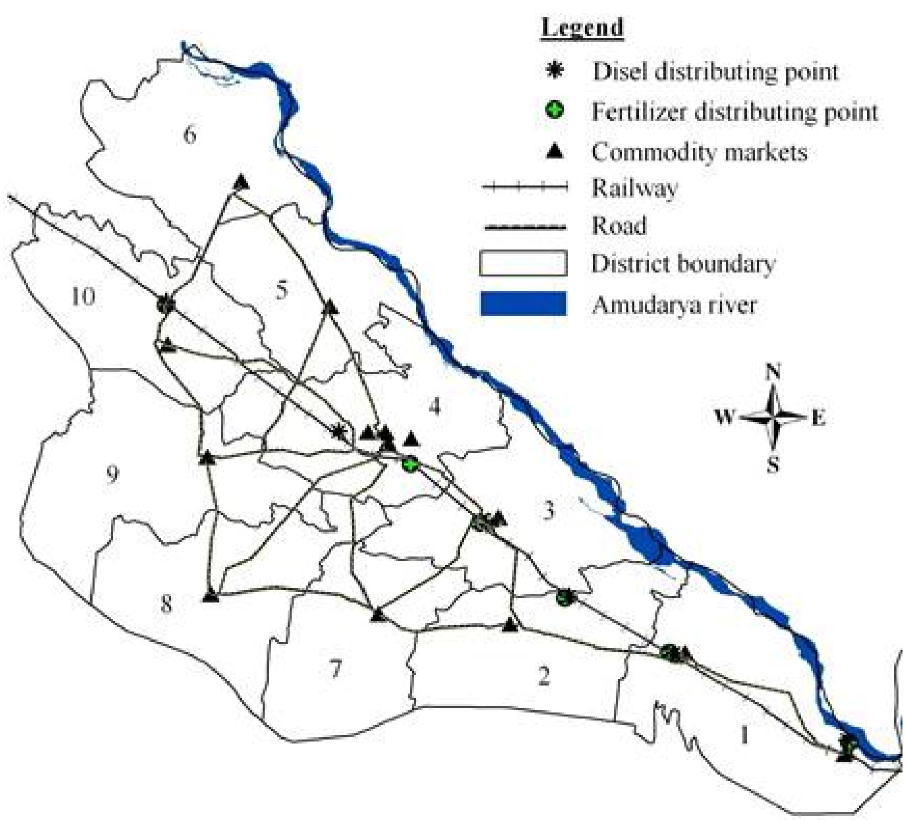
Notes: SKS – *Shirkat*s; PFS – Private farms; MTP – Machinery and tractor parks; OTH – Other organizations; CHV – Grain harvester combines; TRT – Tractors used to transport of freight; PLT – Ploughing tractors

Source: OblSelVodKhoz 2004e

2.4.3 Fertilizer and Diesel

In Uzbekistan, most inputs are distributed via state-controlled agencies. They are to be used under the state procurement system for strategic crops. The input prices are entirely determined by the central government and there is no private input market. Nevertheless, most inputs are informally traded to input abandoned or input scarce produces. In Khorezm there are no fertilizer and diesel producing factories, and these inputs are imported into the region by state agencies from other regions of Uzbekistan via railroad (Figure 2.12).

Figure 2.12: Map of input distribution and commodity markets in Khorezm



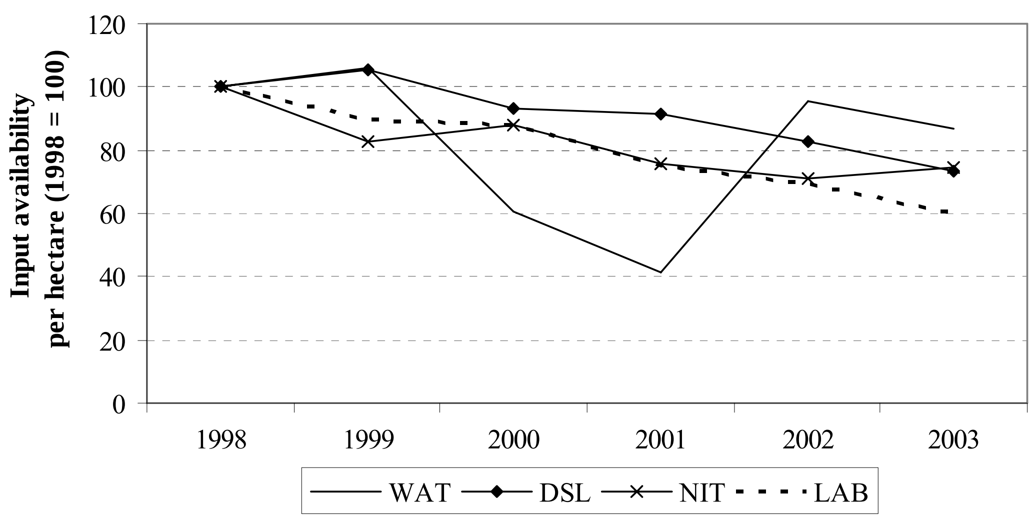
Districts:
1. Khazarasp
2. Bagat
3. Khanka
4. Urgench
5. Yangibazar
6. Gurlen
7. Khiva
8. Yangiarik
9. Kushkupir
10. Shavat

Source: GIS Lab of ZEF/UNESCO project 2005

Further, these inputs are distributed among the input selling facilities, from which agricultural producers can receive them only via an application procedure. Fertilizer markets are represented by state branches of the national chemical producing conglomerate, *UzSelKhozKhim*. The amount of fertilizer and diesel to be delivered into the region and then distributed further to the agricultural producers is estimated centrally and depends on the crop grown and area cultivated. At present, households and farms, which are beyond the state procurement system, are usually not included into the demand estimation (Djanibekov 2005). Hence these production units have to purchase these inputs on informal markets.

Fertilizers are used at 50% of recommended rates (Kudat et al. 2000) and they are often in shortage in the region. Furthermore, the current norms on fertilizer application developed by the state research institutes do not allow the agricultural producers achieving the economic optimum. For instance, under the factor availability and prices observed in 2003, the agricultural producers in Khorezm should apply nitrogen fertilizer at the higher rates than ones suggested by research institutes to achieve the maximum net return (Djanibekov 2005). Furthermore, the official norms are given equal among *shirkat*s and private farms without considering the scales of production (Djanibekov 2005). Locally produced fertilizers in Uzbekistan are nitrogen, phosphorous and compound fertilizers (FAO 2003). The demand of potassium fertilizers in Uzbekistan and Khorezm is very low (FAO 2003). The amount of fertilizer imports to Khorezm has seasonal variations (OblSelKhozKhim 2004a). In general, in 1998-2003, the total amount of nitrogen fertilizer delivered to regional producers dropped by 27% (OblSelKhozKhim 2004a). According to the official statistics, in 1998 to 2003 the total volume of diesel delivered to agricultural producers in Khorezm dropped by 29% (OblNeft 2004). In the period between 1998 and 2003, there was a decrease in diesel, nitrogen fertilizer and labor use per hectare of sown area in Khorezm (Figure 2.13).

Figure 2.13: Dynamics of inputs availability in Khorezm



Notes: WAT – Irrigation water (m^3 ha^{-1}); DSL – Diesel (kg ha^{-1}); NIT – Nitrogen fertilizers (kg ha^{-1}); LAB – Labor employed in agriculture (h ha^{-1})

Source: OblSelVodKhoz 2004f; OblSelVodKhoz 2004g; OblStat 2004b

2.4.4 Fodder

The main fodder crops in Khorezm are maize, fodder maize and lucerne. Their calculated nutritional value, based on one kilogram of dry weight, for Khorezm is presented in Table 2.7.

Table 2.7: Nutritional value of main crops in Khorezm

Crop	Fodder	Ratio to main crop product	Fodder Units	Digestible Protein, g	Calcium, g	Phosphorus, g
Cotton	Seed cake	0.24	1.0	230	5.0	6.5
	Husk	0.15	0.2	20	3.0	3.6
Winter wheat	Bran	0.18	0.7	106	3.0	6.2
	Grain	0.02	1.2	122	1.8	2.7
	Straw	1.30	0.2	12	4.7	1.3
Paddy rice	Bran	0.36	0.7	106	3.0	6.2
	Grain	0.01	1.1	77	2.0	2.4
	Straw	1.50	0.3	6	4.4	1.0
Maize	Grain	1.00	1.2	91	2.5	2.4
	Stem	3.00	0.2	21	1.9	0.6
Fodder maize	Stem	1.00	0.3	30	1.7	0.8
Lucerne	Stem	1.00	0.2	50	6.0	0.9

Source: Dalakyan and Rakhmanova 1986

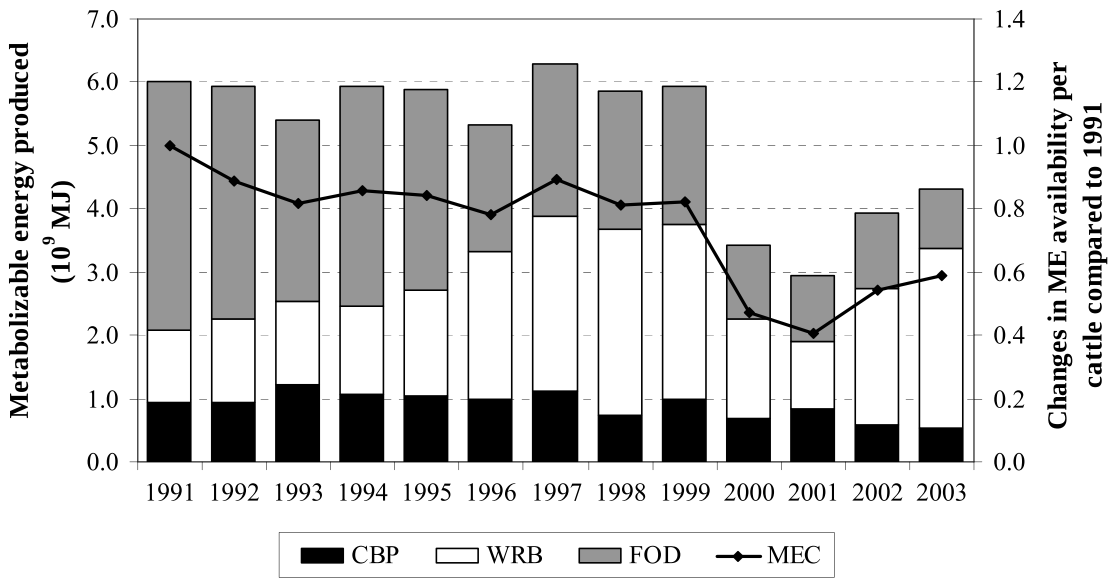
Since there is only little area available for use as pasture, animal feeding follows an intensive regime, where most fodder is created as a byproduct from regional sources such as cotton and cereal (Djanibekov 2006b). Seeds extracted from cotton ginning are processed into two fodder products: cotton-seed husk and cotton-seed cake. Among the fodders produced in Khorezm, cotton-seed cake has the highest content of feed nutrients (Figure 2.14). Winter wheat and rice production also make a significant contribution to animal feeding in Khorezm through their byproducts bran, grain residuals and straw (Djanibekov 2006b). Total metabolizable energy[7] production in Khorezm between 1991 and 2003 remained stable due to an increase in the production of grains (Figure 2.14).

Nevertheless, there was a significant change in the composition of metabolizable energy production. In 1991, the largest share of metabolizable energy in Khorezm was produced via fodder crops such as annual grass and lucerne, but in 2003 the grain byproducts became dominant in the structure of metabolizable energy produced (Djanibekov 2006a). A significant decrease in the availability of metabolizable energy occurred after 1999, largely due to decreases in the production of maize, fodder maize and lucerne, and constant increases

[7] Metabolizable energy production is calculated using the metabolizable energy content in each fodder as presented by Dalakyan and Rakhmanova (1986), according to OblStat data on cropping pattern.

of animal stock in Khorezm. For instance, in 2003, the metabolizable energy available for a unit of conventional cattle decreased by a factor of 1.7 in comparison to its value in 1991.

Figure 2.14: Composition of metabolizable energy production in Khorezm



Notes: CBP – Metabolizable energy via cotton byproducts; WRB – Metabolizable energy via byproducts of wheat and paddy rice; FOD – Metabolizable energy via fodder crops; MEC – Metabolizable energy per cattle

Source: OblStat 2004b; Dalakyan and Rakhmanova 1986; Own calculations

2.5 Food Consumption

The official statistics regarding expenditures presented in Table 2.8 were obtained from the Regional Department of Statistics (*OblStat*). According to primary estimations provided by the official statistical bulletin, regional income was about 224 million USD in 2003 (OblStat 2004b), or 159 USD per capita. In 2003, the total expenditures of population in Khorezm was about 192 million USD (OblStat 2004b), or 136 USD per capita, from which expenditures for purchases and services were about 171 million USD, and payments for credits were estimated at about 21 million USD (OblStat 2004b). The total expenditures for food and non-food in Khorezm in 2003 were about 76.6 million USD, from which 87.8% were spent for food consumption purposes (OblStat 2004b). Between 1992 and 2003 the actual share of total value of food expenditures in total expenditures for Khorezm was on average 81.6% (OblStat 2004b). However, the official estimates of 18.4% of non-food (manufactured) commodities in total expenditures in Khorezm seem very low. For example, FAO (1998) reports that in

Uzbekistan the share of food expenditures in total population expenditures was 34.7%[8]. Therefore, the total nonfood consumption value presented above is lower than the one used in our calculation which relies on the data from FAO/SUA on the average daily food consumption per capita in Uzbekistan. According to the author's calculations, meat and other food commodities had the largest share in total food expenditures for Khorezm in 2003 (Table 2.8). Wheat and grains (except rice and maize) are the main food commodities and contribute strongest to energy intake per capita in Khorezm. Meanwhile, these food commodities are produced in deficit in Khorezm. The annual consumption per capita of wheat and grains, potato and vegetables, milk and eggs in Uzbekistan increased from 1995 to 2003[9]. However, the daily intake of energy per capita in kilocalories declined from 2,659 in 1995 to 2,310 in 2003 (FAO 2007).

Table 2.8: Agricultural food commodity balance in Khorezm in 2003

Commodity	Units	Consumed quantity	Produced quantity	Difference (+ export, – import)	Share in food expenditure, %	Calorie share, %
WWT	10^3 ton	247.3	184.0	-63.4	10.6	57.5
RCE	10^3 ton	19.5	119.0	99.4	2.3	3.8
POT	10^3 ton	63.8	39.2	-24.6	3.1	2.4
FRT	10^3 ton	74.4	38.1	-36.3	13.9	2.5
VGL	10^3 ton	132.4	164.0	31.7	10.7	2.3
MLK	10^3 ton	198.5	427.3	228.8	13.2	10.2
EGG	10^6 pieces	80.5	131.6	51.0	1.9	0.5
MEA	10^3 ton	34.4	64.2	29.7	25.4	6.1
OTH	10^3 ton	48.3	0.0	-48.3	18.9	14.8

Notes: WWT – Wheat and grain products; RCE – Rice; POT – Potato; VGL – Vegetables; FRT – Fruits and melons; MLK – Milk and milk products; EGG – Poultry eggs; MEA – Meat and meat products; OTH – Other food commodities

Source: FAO Statistics Division 2007; Own calculation

Foreign trade turnover of the region in 2003 was about 48 million USD, from which export accounted for 74%; creating a trade surplus of 23.3 million USD (OblStat 2004b). Despite this, in 2003 the region was still a net importer of food commodities (Table 2.9). Cotton was the dominant item of regional export (81.4%) and the overall regional trade balance (61%) in 2003 (OblStat 2004b). In 2003 the region was still a net importer of food commodities (35% of total import). Rice, vegetables, milk, meat and eggs were the food commodities produced

[8] The official statistical data on population expenditures and consumed quantities is based on quantities sold in local shops and markets. According to the author's own observation the major part of commodities is sold at small rural markets, and therefore those quantities are not presented in the official statistical datasets, e.g. rice and milk consumption are not reported in the official statistics.

[9] Aggregation of commodities is presented in Sections 3.2.2.

in surplus in Khorezm. Wheat and grains, potato, fruits and melons, are the food commodities imported in Khorezm in 2003 (Table 2.9).

Table 2.9: Export and import structure in Khorezm

Shares of	1995	1996	1997	1998	1999	2000	2001	2002	2003
Export in Trade balance, %	83.7	69.8	53.8	60.9	71.5	73.6	64.8	49.7	74.3
Share in Export, %									
Cotton	93.8	95.9	85.6	77.7	69.6	81.4	83.8	83.5	81.4
Food commodities	4.2	1.1	2.6	2.9	4.5	5.1	4.8	4.9	1.0
Services	0.1	0.7	0.3	0.3	0.1	0.9	2.1	1.5	2.2
Others	1.8	2.3	11.5	19.1	25.8	12.6	9.3	10.1	15.4
Import in Trade balance, %	16.3	30.2	46.2	39.1	28.5	26.4	35.2	50.3	25.7
Share in Import, %									
Food commodities	4.8	52.4	17.8	29.9	41.0	54.6	48.3	5.9	34.9
Services	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0
Others	95.2	47.6	82.2	70.1	56.2	45.4	51.7	94.1	65.1

Source: OblStat 2004b

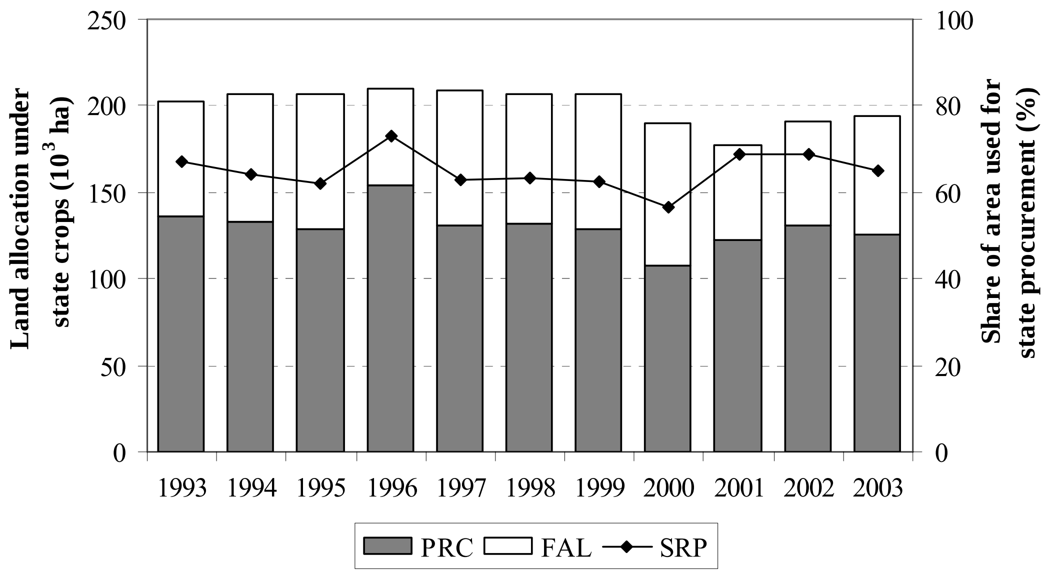
2.6 State Regulation

2.6.1 State Procurement System

In Uzbekistan, the market reforms initiated since 1991 were aimed at gradually liberalizing agricultural commodity markets, and raising producer-level prices. In addition to these reforms, the farm restructuring process was also to aid the transition to a market economy. The procurement system in form of production plans and cultivated area allotments for specified crops has remained the main component of the pursued economic development strategy. Cotton procurement is mostly export-oriented, and is practiced as part of an income redistribution policy (Guadagni et al. 2005). The procurement policy for cereals is designed to strengthen food security by stabilizing cereal production, and is integrated into the import substitution policy. Land allocation to cotton and cereals according to the procurement tasks dominates agricultural production (in terms of total cultivated area) (Figure 2.15). The regulations on cotton and cereal procurement differ from one another. On papers, to encourage the sale of cotton directly at local markets, as well as through trade agents for export, the government established a regulation that left 70% of the produced raw cotton at the producer's disposal. However, unlike the situation for cereals, there exist no local cotton markets, and therefore, no alternative marketing channels for cotton in Uzbekistan. The state procurement is only subject to assigned procurement, meaning that only a certain share (50%)

of the production must be sold to the state at procurement prices. Upon fulfilling their obligations for the procurement contract, agricultural producers can sell any remaining surplus of cereals at the market. Rice is also considered part of the state procurement system, but agricultural producers are not given the mandatory production quotas for rice in the same fashion as for cotton and wheat. Instead, every year agricultural producers need to receive official permission in form of a license to produce paddy rice. Producers without a license are prohibited to produce rice. The farms which receive a license for rice production are obliged to sell a part of their harvest to the state agency at the state procurement price, which is below the local market price.

Figure 2.15: Land allocation for cotton and cereals in Khorezm

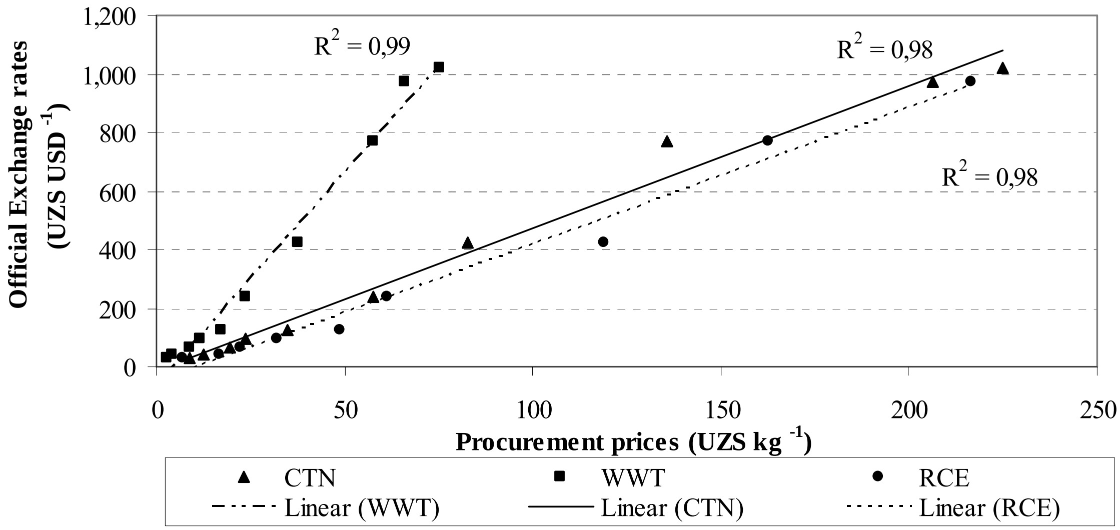


Notes: PRC – Area sown for procurement task; FAL – Area sown without procurement task; SRP – Share of land sown for procurement task

Source: OblStat 2004b

Following independence, two major changes in the state procurement system occurred (Khan 2005). First, a new cotton pricing system was introduced to increase producer incentives. According to the new price formation method, the procurement price for cotton is established on the basis of the net world price minus ginning, transportation, custom and certification costs, and taxes paid by intermediate participants. As a result, the cotton procurement price has increased drastically, although it is still lower than the world price (Guadagni et al. 2005). Moreover, followed by the state policy on achieving grain self-sufficiency, the procurement prices for cereals have increased about 25% compared to their level in 1995. However, the state procurement prices are set with consideration of changes in the official exchange rate of the local currency to the US dollar (Figure 2.16).

Figure 2.16: Correlation between procurement prices and exchange rate in Khorezm



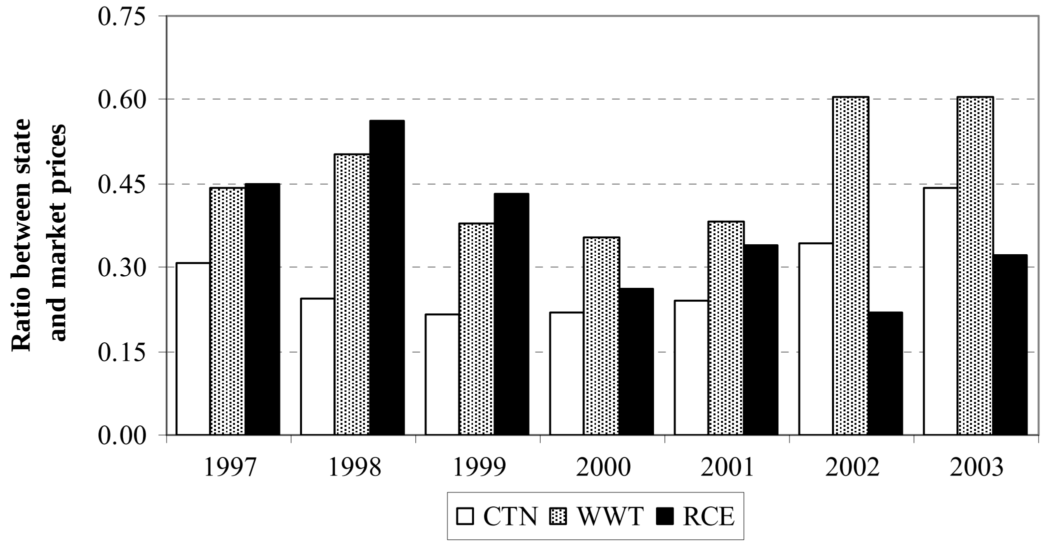
Notes: CTN – Cotton; WWT –Wheat; RCE – Rice; Linear (CTN) – Linear trend between raw cotton price and official exchange rate; Linear (WWT) – Linear trend between wheat price and official exchange rate; Linear (RCE) – Linear trend between price of rice and official exchange rate

Source: OblStat 2004c; CBU 2004; Own calculation

In years when official exchange rates diverge highly from the black-market exchange rates, the procurement prices tend to be much lower than the export prices. The second change in the state procurement pricing of cotton and cereals has been the introduction of the "double pricing system" according to which half of the procurement quota of cotton and cereals must be sold at the state procurement price. The other half of the cotton harvest is sold at the contract, i.e. negotiated, price, which is 20% higher than the state procurement price, but only applied in cases where producers fulfill the procurement quota. In the case that a farmer fails to reach the procurement task, the state procurement price is applied for the total harvest. After these changes in the procurement system the cotton prices continue to be lower than international prices and procurement prices for cereals continue to be lower than the local market prices (Figure 2.17)[10].

[10] In order to better reflect the real situation, the ratio of the cotton procurement price to the world market price was calculated using black-market exchange rates for relevant years in Uzbekistan.

Figure 2.17: Comparison of market and procurement prices in Khorezm

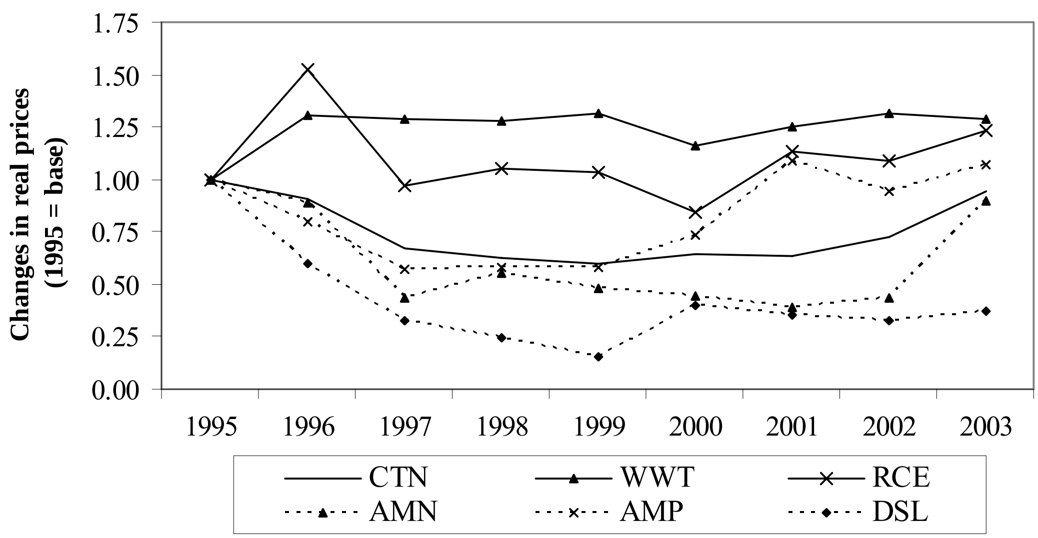


Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice

Source: OblStat 2004c; Müller 2006

Before the exchange rate unification in 2003, the official exchange rate was overvalued and the gap between official and black-market exchange rates was threefold. Before the unification of the currency exchange rate in Uzbekistan the average procurement price for wheat was equal to 40% of the local market price (MAWR 2004a, OblStat 2004c).

Figure 2.18: Dynamics in real prices of output and inputs in Khorezm



Notes: CTN – Cotton; WWT – Wheat and grains; RCE – Rice; AMN – Ammonium nitrate fertilizer; AMP – Ammophos fertilizer; DSL – Diesel fuel

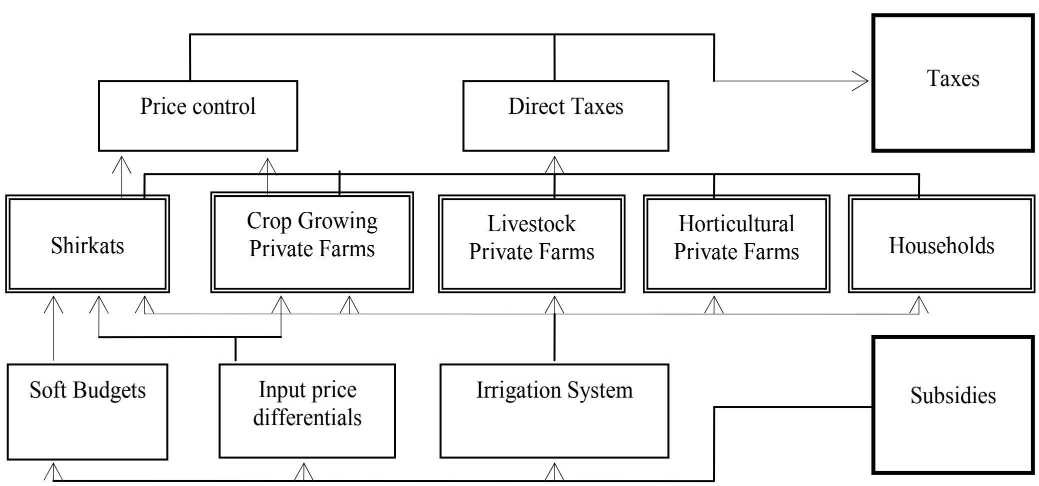
Source: OblStat 2004c; OblSelKhozKhim 2004b; OblNeft 2004; Own calculation

Since the exchange rate unification in 2002, the procurement price for wheat has increased to 60% of the local market level. If the official procurement prices are adjusted to 1995 price levels, there is a substantial drop in real procurement prices for cotton, and for 2003 it is only around five percent less than its level in 1995 (Figure 2.18). The decline in the real agricultural product price for cotton shows that its nominal price increase has remained lower than the inflation rate. Along with changes in the procurement policy, which were to give incentives for producers to specifically increase yields for cotton and grins, the input prices have also been increased to provide more economic incentives to agricultural producers to increase factor productivity in general. However, the state control over input distribution and input endowment in farms for machinery, fertilizer, diesel and seeds remains virtually unchanged. Consequently, the procurement price increase has only marginally improved incentives to agricultural producers, since the commodity price increases have been partially offset by increases in state prices for inputs.

2.6.2 Agricultural Taxes and Subsidies

The transition from a centrally planned to a market-oriented economy included the transformation of the old agricultural tax policy into one featuring new producer incentives. The system of agricultural subsidies for and taxation of agriculture in Uzbekistan can be distinguished by the type of agricultural producer and the crops which are included into the state procurement system. The simplified scheme of the budget inflows (in the form of implicit and explicit taxes) and budget outflows (in form of subsidies) is presented in Figure 2.19.

Figure 2.19: Taxes from and subsidies into agriculture in Uzbekistan



Source: Own compilation

The largest share of state revenues from agricultural taxation come from implicit taxes such as low procurement prices for the main export crop, cotton. According to the study of Guadagni et al. (2005), in 2003 the producer price control presented the main form of agricultural taxation, and was followed by direct taxes such as income and land taxes. The implicit taxation of the agricultural sector in form of procurement prices has been particularly discussed by many authors (Rosenberg et al. 1999, Guadagni et al. 2005, Khan 2005, Spoor 1999). In order to offset the negative effects of the taxation regime, the state provides significant subsidies for irrigation, financing and other inputs to agricultural producers (Guadagni et al. 2005). However, these are not direct subsidies but rather involve indirect measures, such as price differentials for inputs and cotton byproducts, arbitrary allocation and reallocation of financial resources, maintenance and operating costs of irrigation system as well as credit postponements, debt write-offs, tax remissions and lax crediting. Most of these subsidies are not directly allocated to producers, but rather allocated to the agricultural sector as a whole. Table 2.10 shows the difference between official and informal market prices for the main nitrogen fertilizer and diesel in 2002-2003[11]. Those input price differentials are producer-oriented and crop-oriented; meaning that only those agricultural producers who have a state procurement task have access to subsidized inputs. As a result of the input price differential, which is a state controlled discrimination scheme, regarding input availability, agricultural producers select either to apply inputs under a state procurement crop, or crops with higher market values, or transfer them for activities with higher incomes (Guardani et al 2005).

Table 2.10: State and market prices for fertilizer and diesel

	Units	**Ammonium nitrate**		**Diesel fueld**	
		2002	**2003**	**2002**	**2003**
State price	USD ton^{-1}	35	73	79	116
Market price	USD ton^{-1}	49	100	91	140
Difference	%	38	37	16	21

Source: OblSelKhozKhim 2004b; OblNeft 2004; Household survey 2004

Moreover, due to the absence of formal supplementary input markets, the extra amount of inputs necessary for production is available only via black markets. The demand for this informal input market is primarily sustained by agricultural producers beyond the state procurement system, who are not given access to subsidized inputs from the government. Further liberalization of agricultural markets, particularly the cotton market, is needed to increase production incentives as well as to raise agricultural productivity and producer incomes. As such, cotton production under the state procurement policy has less relevance for

[11] Converted using average market exchange rates for 2002 of 1,300 USZ/USD and for 2003 of 1,052 USZ/USD

the economy of Uzbekistan than often stated (Müller 2006). On the other hand, since other sources of state revenues have been made available, there is currently less need for agricultural taxation (Khan 2005). Since the procurement system accumulates only a little share of the state revenues, but ensures a desirable composition of output; one may argue that this may also be achieved by more market oriented policies.

After this chapter, the reader should receive a general understanding of main features of the agricultural sector in Khorezm to follow the model development and policy simulations in the next chapters.

3. Structure of the Agricultural Sector Model for the Khorezm Region

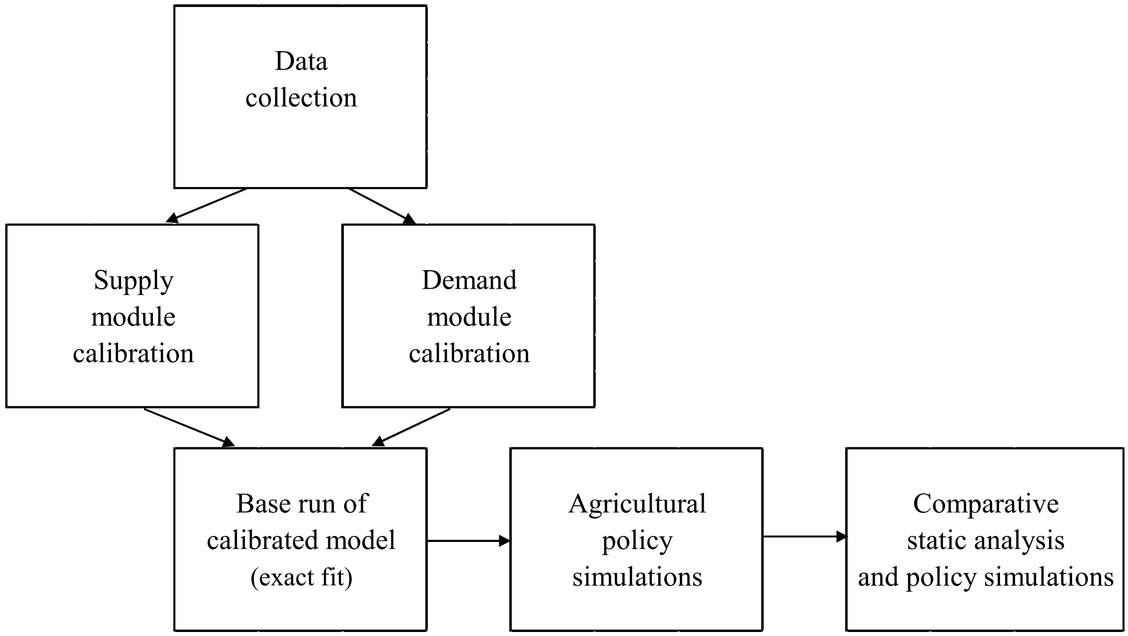
In this chapter we present a modeling framework for the agricultural sector of Khorezm. The objective of the chapter is to build on a model and to show how it can be adopted and used in a regional context. Particularly data limitations constitute a constraint and have to be circumvented in an intelligent way. In fact, the novelty of this study lies in adapting standard versions of this model to the complex reality an individual region in such a transition economy as Uzbekistan.

The layout of this chapter is as follows: First, in section 3.1, the selected approach is justified via a description of features of mathematical programming models. Then, arguments for favoring the price-endogenous sector model approach are presented and supported. Section 3.2 demonstrates the structure of the price-endogenous regional model for the agricultural sector in Khorezm. The process for aggregating administrative districts, producers and consumers, production activities and commodities requirements is presented in section 3.2.2. Sections 3.2.3 and 3.2.4 include a step-by-step presentation of our agricultural sector model.

Section 3.3 describes the structure of the model's supply module. Section 3.4 describes the structure of the model's demand module. The choice of the functional form for the assumed demand system is justified in section 3.4.1. Since the construction of an agricultural sector model has large data requirements, we list these separately for the demand and supply modules in sections 3.3.4 and 3.4.4. The equations and definitions which link the demand and supply modules in the general agricultural sector model are presented in section 3.5. Finally, section 3.6 discusses scope and limitations of the model.

In general, the application procedure of agricultural sector model for Khorezm (KhoRASM) consists of several steps (Figure 3.1). These are: database collection and arrangement; building the full model based on demand and supply modules; calibration of the demand and production modules; analysis of the calibration results; policy simulations and comparative static analysis and policy implications and conclusions. The KhoRASM model is programmed in GAMS modeling language. It is calibrated and solved as a non-linear optimization, using the numerical solver CONOPT3.

Figure 3.1: Stages of the model building



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3.1 Selection of the Modeling Approach

In chapter 2, we paid special attention to the empirical environment of Khorezm's agricultural sector in Khorezm, so as to provide a framework within which to locate the assumptions for the sector model we present now. The approach used for modelling the agricultural sector of Khorezm should capture the basic features of the regional agriculture: First, the model should capture the interrelations of production activities most prevalent to the region (see chapter 2). Second, the model should replicates the nature of the sector in terms of allowing for various changes in the fixed production factors and input-output relationships; e.g. changes in prices, animal feeding practices, yields, irrigation water availability, consumption structure and relevant state. Third, the model should feature regionally specified input-output parameters and restrictions on resource availability in order to capture comparative advantages between modelled districts and producers.

Moreover, the approach should be applicable through available datasets and for simulations. First, there are problem of data availability, e.g. long time-series information, especially, when working on developing countries or transition economies such as Uzbekistan this factor often comes into play. This problem is related to the limited degrees of freedom which make infeasible the estimation of all kind of interrelations between different production variables due to a short period historical observations data (Hazell and Norton 1986). Next, the approach should be applicable for the analysis of new policy changes which involve significant deviations from the observed past trends (Hazell and Norton 1986). This study includes a set of policy simulations never observed in the agricultural sector of Khorezm, such as the introduction of water pricing and the abolishment of state procurement quotas, so that this point becomes valid. For instance, in case of lack of data and for unprecedented scenarios the econometric approach is rarely applicable.

The generally used tool for modelling agricultural sector for quantitative policy analysis is mathematical programming approach. This modelling approach imposes behavioural assumptions over a mixture of historically observed and synthetic data to arrive at a representation of the sector in a multi-output and multi-input framework that is consistent with economic theory (McCarl and Spreen 1980). For several reasons, this approach is the most appropriate for modelling the agricultural sector of Khorezm. First, mathematical programming model incorporates relationships between different production variables, regional cross-effects (Apland, Öhlmér and Jonasson 1994). Second, it does not depend upon long-term historical data, and can be applied as a quantitative tool for assessing development and policy alternatives; especially potential effects of previously unprecedented policy scenarios (Norton and Solis 1983, McCarl and Spreen 1980). Third, this approach seems most suitable given constraints such as limited data availability and lack of historical observations (Buysse, Van Huylenbroeck and Lauwers 2007). Forth, providing a framework to systematize and categorize available information, it allows for a detailed description of the dependencies of production variables on exogenous changes in the regional agriculture and more detailed analysis of problems with spatially competing dimensions (Hazell and Norton 1986).

One important feature of the mathematical programming model is that its structure allows specification of changes in the economic environment. Using such a model, a modeler can introduce specific policy changes into the model and observe the simulated response (McCarl and Spreen 1997). The agricultural sector model based on mathematical programming allows incorporating exogenous changes for policy simulations in appropriate attributes of the model (Hazell and Norton 1986), which renewed recently an interest in programming models. For instance, the effect of introduced water pricing can be evaluated by exogenously increasing the variable costs for crop production per unit of irrigation water required in the model. The liberalization of cotton and input markets can be examined by removing the minimum production level constraints for cotton and using new input prices.

On the other hand, the fact that mathematical programs are usually based on behavioral norms instead of observed actions is one of the weaknesses of the programming models (Buysse, Van Huylenbroeck and Lauwers 2007). As a result, the mathematical programming approach can neither describe nor predict exact outcomes for specific years suggesting the possible best solution according to the economic environment (Hazell and Norton 1986) in a way that its solutions demonstrate what “should” happen rather than what will happen. One approach to bridge this gap between observed data and theoretical properties of the model in question is the positive-mathematical programming approach (PMP), mainly introduced by Howitt (1995) in the context of agricultural sector modeling. Nevertheless, even if the approach is called mathematical programming, it combines both econometric and mathematical programming approaches. For instance, the price and income responsive commodity demand functions are estimated using econometric methods and then introduced into the mathematical programming model (Takayama and Judge 1971). All the above stated motivates using a mathematical programming approach for our analysis of assessing the impacts of policy changes on agricultural

Furthermore, for the regional sector model the prices should be defined endogenously to recognize the price-quantity interrelationships (McCarl and Spreen 1980). Therefore, in order to reflect this premise, the demand functions needs to be introduced in the optimization model. This requires a specification of the functional form of demand system. Lau (1986) summarized a set of criteria for the specification of a complete demand system which can deal with important theoretical issues. Those criteria were further classified into eight categories by Frohberg and Winter (2001) into i) theoretical consistency, ii) domain of applicability, iii) flexibility, iv) maintained hypotheses, v) computational facility, vi) factual conformity, vii) extrapolative robustness, and viii) the interdependence of these characteristics, e.g. introduction of cross-effects between consumption levels of different commodities to fulfill theoretic consistency. However, the simultaneous fulfillment of all these requirements by a functional form of a demand system is generally impossible (Frohberg and Winter 2001). Therefore, the ones which satisfy the most relevant criteria for transition country should be applied. Moreover, the selected functional form for a demand curve should sufficiently describe the consumer behavior to allow for analysis of the relevant welfare components. This requires specification of both an Engel curve and relative price effects consistent with utility maximization (Banks, Blundell and Lewbel 1997). The inclusion of income effects are very important for modeling commodity demand in Khorezm, since the influence of pronounced variations of income on demand is one of essential to the analysis of transition country demand structures (Frohberg and Winter 2001). According to this criterion, the selected functional form of demand should reflect the driving influence of income changes on demand. Functional forms involving non-linear Engel curves on disproportional modifications in

consumption patterns and expenditure shares by growing income are more in line with empirical evidence and more suitable for empirical analysis (Frohberg and Winter 2001).
A well known candidate for demand analysis which fulfills the mentioned requirements is the Normalized Quadratic – Quadratic Expenditure System (NQ-QES) (Ryan and Wales 1999). This demand system developed by Ryan and Wales (1996, 1999) encompasses the Normalized Quadratic Reciprocal Indirect Utility Function (NQRIUF) and the Normalized Quadratic Expenditure Function (NQEF), both proposed by Diewert and Wales (1988), as special cases of demand analysis. The Normalized Quadratic – Quadratic Expenditure System fulfils three requirements of building a mathematical model for demand analysis. First, in the system Engel curves are quadratic in income, i.e. the quantities demanded are quadratic functions of total expenditure or income. Linear Engel curves assume a proportional increase in demand for each commodity. Second, the system is flexible in a Diewert-sense meaning all first derivatives of demands with respect to prices and income are arbitrary at a reference point (Pollak and Wales 1992). In other words, the demand system can replicate the demanded quantities, income derivatives and own- and cross-price derivatives at a specified price-expenditure situation (Ryan and Wales 1999). Thirdly, the curvature condition, which is required by micro-economic theory, may be easily imposed locally during the estimation, if not satisfied at the reference point, without destroying flexibility (Ryan and Wales 1999). The properties of NQ-QES are discussed in the following sections. Following this, the model consists of three components: (1) agricultural sector model; (2) linear supply module; (3) non-linear demand module, which are discussed in the following sections. The developed model integrates both linear supply module and non-linear demand module at point of partial equilibrium under observed values from 2003.

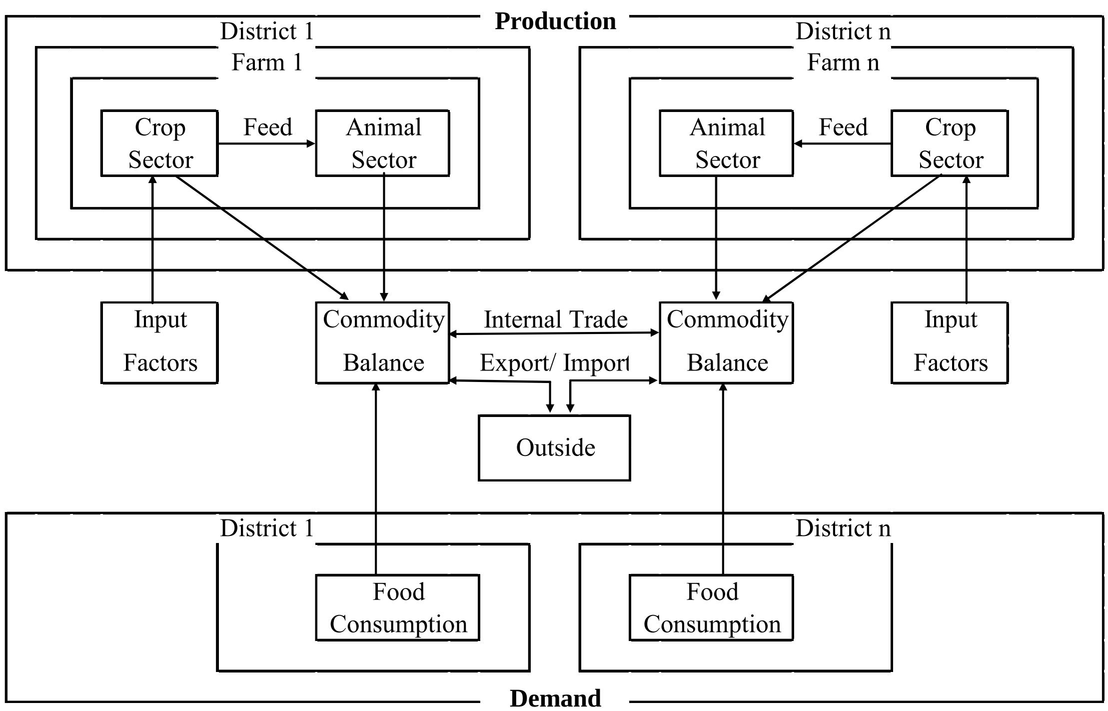
3.2 Structure of KhoRASM

3.2.1 Main Features

The first prerequisite for building a mathematical programming model is a proper definition of the model which comprises the choice of the functional form of the objective function and constraints and the definition of endogenous variables, exogenous variables and parameters to be calibrated (see Section 4). KhoRASM is designed according to the framework presented by Hazel and Norton (1986) for evaluating the impact of external shocks on production and consumption patterns and commodity prices. KhoRASM is a static model, and assumes that the adaptation of the agricultural sector on the intervention occurs simultaneous without a time lag. KhoRASM is a partial equilibrium model, which means that explicit connections to other sectors of the general economy are not included into the model. In the base run solution, KhoRASM replicates the agricultural production activities of Khorezm in 2003. Results obtained after implementing an exogenous shock in the model are compared with the base run results. Like the model, the comparisons of scenario simulations are static. The obtained solution describes the agricultural sector as it were under assumptions of perfect competition in regional commodity markets (Hazell and Norton 1986). Despite the possible existence of transaction costs in commodity production and marketing as well as information gaps regarding regional prices for producers and consumers, two characteristics make the assumption of a perfectly competitive market reasonable for the agricultural sector of Khorezm. First of all, the regional agricultural sector consists of a large number of consumers and agricultural producers which interact with a single regional commodity market, except cotton market where production quantities and prices are controlled by state. Commodity prices (except for cotton, maize and fodder) are determined by aggregate market behavior of producers and consumers, and no price influencing power exists with single producers /consumers, i.e. they are price takers. Second, there exist no strong preferences for differentiations in commodities. That is producers and consumers appear to regard commodities groups as being fairly homogenous. Third, agricultural producers purchase inputs before information on crop price changes become available, which is only during the crop harvesting period. With respect the factor markets, it is assumed that the agricultural producers in Khorezm cannot influence the factor prices, except for labor. The definition of labor prices is described in the Section 3.2.2 and 3.5. Given these realities, the behavioral implications of the KhoRASM model seem to be suitable with the theoretical economic behavior of the modeled agricultural producers and it can be used to simulate the regional sector response to a specific exogenous shocks.

KhoRASM is structured as presented in Hazel and Norton (1986). The model endogenously determines production activities and commodity prices based on producer and consumer preferences, which in turn are shaped by production technologies and commodity demand functions. KhoRASM consists of supply and demand modules. Consequently, the model optimizes via simultaneous adjustments in supply and demand sides which will be presented separately in the following sections of this chapter. The supply module includes all the input and output items of crop, animal sector and fodder sector. The demand module consists of commodity consumption by the regional population (Figure 3.2). Each of supply and demand modules is divided respectively into several production and consumption blocks with regard to producer, consumer and district aggregates. The behavior of producers in the supply module is depicted at an aggregate level and restricted in terms of initial resource endowments, while the behavior of consumers in the demand module is depicted via commodity demand functions. Agricultural producers maximize their profits within a set of crop growing and animal keeping activities (see section 3.3.). Each production activity is depicted via specific technology coefficients, and subject to input as well as output constraints (e.g. policy instruments). Consumers spend their entire income on consumption. They maximize utility from consumption (see section 3.4). Each produced commodities can be consumed, exported, imported or traded between districts.

Figure 3.2: Structure of KhoRASM



Source: Own compilation

Compared to the depiction of the agricultural sector model presented in Hazel and Norton (1986), KhoRASM has a number of simplifications: First, it does not feature resource exporting and importing activities. Secondly, the model omits commodity processing activities. We do this mainly because of data scarcity, but one may argue that the relatively underdevelopment state of the regions processing sector 2003 further justifies this omission. To simplify the features of the regional agricultural sector of Khorezm several assumptions for the model were formulated as follow:

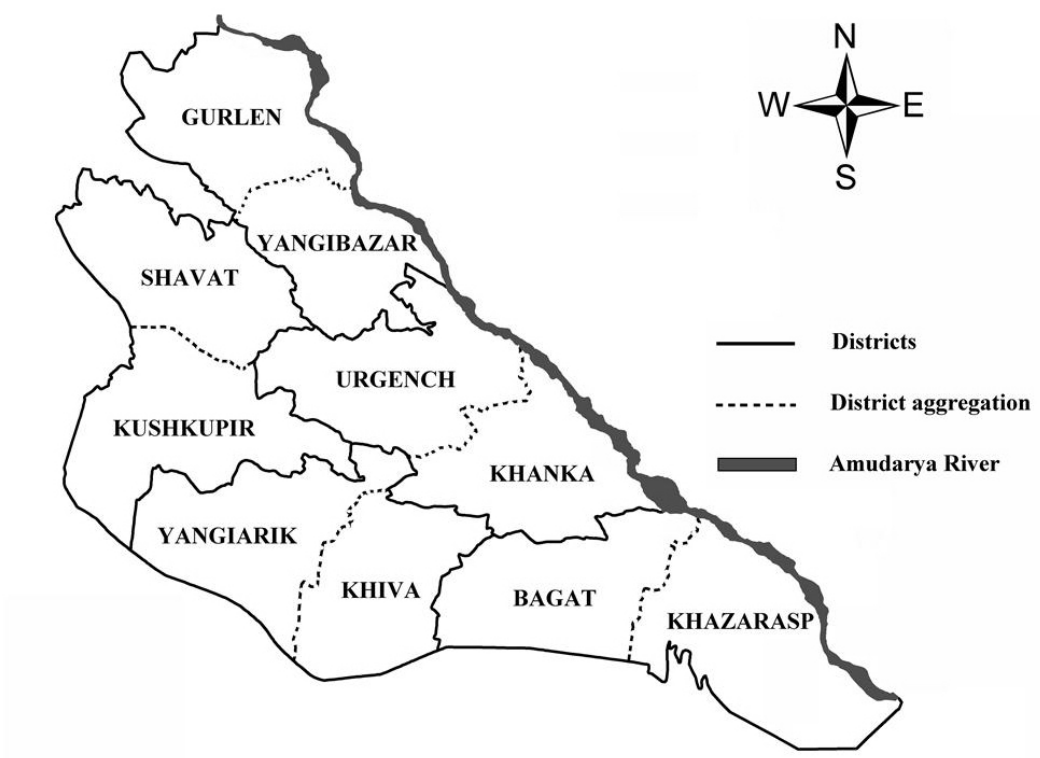
- The model is a partial equilibrium model, maximizing consumer's and producer's surpluses;

- The region is too small to affect national commodity prices;
- Products within each commodity type are homogeneous;
- Commodity consumption is determined by commodity prices and income;
- Relationships between inputs and outputs are linear in form of single Leontieff technologies.

3.2.2 Aggregation of Districts, Producers, Consumers and Commodities

For reasons of computational necessity and data needs, the model' demand and supply sides are aggregated over districts, producers, consumers and commodities. As a spatial model, in order to more explicitly analyze the effects of exogenous changes on the production structure in different areas of Khorezm and to account for differences in available technology, resource supplies and product demand, the model is spatially disaggregated over districts (*rayon*s). In the model, the region is separated into five district aggregates according to their location to the Amu Darya river (Figure 3.3). Each district is described by its resource endowments and technology coefficients.

Figure 3.3: District aggregation in KhoRASM



Source: GIS Lab of ZEF/UNESCO project 2005

Following (Hazell and Norton 1986) the production module includes three different submodels to represent the agricultural producer groups defined by Uzbek legislation; i.e.

rural households (*dekhqan*s), private farms, and large agricultural enterprises (*shirkat*s). Other farm types, such as remaining collective farms (*kolkhoz*s), state animal keeping enterprises, and subsidiary farms, are considered in the model in the producer aggregate of *shirkat*s. These three producer aggregates define the total crop and animal production in Khorezm in 2003. Aggregation at the producer level is based on the assumption of technological homogeneity (Hazell and Norton 1986) according to which producer groups are defined by a different set of input/output coefficients and constraints. This type of aggregation makes procedural sense, especially since official statistical data for production patterns and input endowments are available only at this level of aggregation. In KhoRASM, producer aggregates of *shirkat*s and private farms are only producers of commodities. Analogous to the agricultural producers, the consumers are also aggregated into separate groups. The rural household aggregate is included into the group of consumers of food and non-food commodities and leisure. In addition to the rural households, the urban households are introduced as consumers of food and non-food commodities. These two groups of consumers define the total consumption in Khorezm in 2003.

Consequently, there are four separate groups in the model. The first two groups are producer aggregates and include *shirkat*s and private farms. Their behaviour is limited to production decisions (Table 3.1). Since the behavior of rural households is based on supply and demand responses on the markets (de Janvry, Fafchamps and Sadoulet 1991), in KhoRASM, the rural households are aggregated into a group of consuming as well as producing. The fourth group, urban households, only engages in consumption decision.

Table 3.1: List of producer and consumer aggregates in KhoRASM

	Producers	Consumers
State enterprises (*shirkat*s)	1	
Private farms	1	
Rural households (*dekhqan* farms)	1	1
Urban households		1

Source: Own compilation

KhoRASM consists of produced and consumed commodities which are observed for the study region. The model includes 14 commodity aggregates which can be produced, consumed, traded or used for animal feeding (Table 3.2). First of all, in KhoRASM, commodities are differentiated into ones with endogenous and exogenous prices. Commodities which are consumed by rural and urban households have endogenous prices. All other products have fixed prices; i.e. cotton, maize and fodder maize.

Table 3.2: List of commodities in KhoRASM

Commodity	Produced	Human consumption	Used as fodder for animal feeding	Tradable
Cotton	1			1
Wheat	1	1	1	1
Rice	1	1	1	1
Potato	1	1		1
Vegetables	1	1		1
Fruits and melons	1	1		1
Maize for grains	1		1	1
Fodder maize	1		1	1
Milk by cows	1	1		1
Eggs by poultry	1	1		1
Meat by bulls	1	1		1
Other food commodities		1		1
Non-food commodities		1		1
Leisure		1		

Source: Own compilation

The consumed commodities include food commodities produced in Khorezm, other food commodities imported from outside of the region, manufactured (non-food) commodities and leisure. According to labor economics, the allocation of time of households to either production activities or leisure is a decision problem (Barnett 1979). Therefore, leisure is defined as a separate consumption commodity only for rural households. In this way the total income of two consumer aggregates is allocated over leisure and aggregated food and non-food consumption. All commodities, except leisure, can be marketed, in as much as they participate in inter-district flows, exporting and importing activities. Further information on consumed commodities is given in section 3.4.

3.3.3 Model Activities

A price-endogenous mathematical programming sector model typically contains several groups of activities which represent commodity production, demand and commodity flows (McCarl and Spreen 1980). There are several groups of activities in the model.

1. A first group consists of production activities which are entirely constructed using single production activities both for crops and livestock. This group consists of eight crop growing and three animal keeping activities. Similar to crop production, animal production has a single activity with a single feeding regime for each producer and district

aggregates. According to inter-relationships among cropping and animal keeping activities, some crops are intermediate products which can be used for animal feeding. Therefore, the fodder producing activities are limited by the levels of animal keeping activities and animal feeding regimes of each producer type through the modeled districts;

2. The second group of activities includes those related to the demand. Demand activities are limited to commodity aggregates which feature in human consumption. Available demand activities are specific to consumer type and districts. The demand activities include consumption of eight agricultural food commodities produced in the region, one agricultural food commodity and one manufactured commodity produced outside of the region, and leisure time;
3. The third group of activities consists of commodity flows between different districts and exporting and importing activities for commodities. All produced and consumed commodities are assumed to be tradable, except for leisure. This means that they can be traded between the districts, imported to and exported from outside of the region.
4. The fourth group of activities consists of labor flows from rural households to *shirkat*s and to private farms and districts. In Khorezm, the rural households are suppliers of labor, and the production in *shirkat*s and private farms is mostly or completely dependent on hired labor from households;
5. The endogenous prices for commodities are introduced as separate activities defined only for food commodities, manufactured commodities and leisure time. The commodity prices in demand and supply model are identical. Separate prices are formed for the five district aggregates considering the arbitrage conditions;
6. The final group of model activities includes activities related to definition of the demand components, such as the endogenous commodity prices and the definition of variables for household income. These demand forming equations are presented in section 3.4.

3.3.4 Objective Function of KhoRASM

The price-endogenous programming model is used for the agricultural sector analysis of Khorezm. The optimization problem consists of a system of equations reciprocally relating changes in commodity quantities to equilibrium commodity prices. (McCarl and Spreen 1997) The objective function of such price-endogenous model transforms price-dependent product-demand schedules into a measure of summed consumer and producer surplus; i.e. net social benefit (Hazell and Norton 1986). In other words, it maximizes the area under the demand curve above the price curve, i.e. consumer’s surplus, and the area above the supply curve and below the price curve, i.e. producer's surplus (Hazell and Norton 1986). In case of KhoRASM, which models a competitive market with export and import activities, the objective function is the maximization of consumer and producer surpluses plus the net trade surplus less production and transportation costs.

To attach a welfare measurement to the areas under the ordinary demand function, the demand function should be integrable. The general problem of incorporating demand functions of complex form directly into the objective functions of the mathematical programming models, is that these functions are difficult to integrate. Moreover, the model consists of a demand module which is measured in units of indirect utility and a supply module which is measured in money units. Consequently, the welfare effects of price changes can be measured via specification of a money metric utility function (Mas-Colell, Whinston and Green 1995).

To join the demand and supply modules in KhoRASM, the cross-effects of consumption, prices and income, established by the demand module, are included into KhoRASM via the rescaling of the indirect utility function into a money metric utility function. The resulting equilibrium prices enter the objective function via demand functions (Hazell and Norton 1986). Price responsiveness is introduced into the demand functions in form of a nonlinear objective function. In the following upper case letters denote variables. Lower case letters denotes parameters and indices. The complete listing of individual items belonging to the various sets is given in the Appendix 2.

The indices in the model are as follows:

Code	**Description**
x	Production activities;
i,j,k,l	Commodities;
r,r1	Districts aggregates;
z	Production factors;
f,f1	Agricultural producer and consumer groups.

The variables of the model are as follows:

Code	**Indices**	**Description**
Welf		Regional welfare;
MoneyM		Money metric indirect utility function;
NTSurp		Definition of net trade surplus of producers;
PrCost		Definition of production costs;

Wage	*r*	Agricultural wage paid by *shirkat*s and private farms;
Xlevl	*r,f,x*	Production activity levels;
Xflows	*r,i*	Export flows of commodities (not allowed for leisure);
Mflows	*r,i*	Import flows of commodities (not allowed for leisure);
LabrF	*r,r1,f,f1*	Inter-district and inter-farm labor flow between producers;
Incm	*r,f*	Total income of consumers (consumption expenditure);
g	*r,f*	Component of demand system (described in section 3.4.2).

The parameters of the model are as follows:

Code	**Indices**	**Description**
pex	*i*	Border price of commodity;
dist	*r,r1*	Distance between districts;
edist	*r*	Distance from districts to the border;
trc	*r,i*	Transportation costs of commodity;
varc	*r,f,x*	Production costs;
g^0	*r,f*	Demand system element (see section 3.4) at reference point.

Following a standard welfare analysis (Just, Hueth and Schmitz 2004), total welfare of the study region consists of money metric indirect utility function, i.e. consumer surplus, and agricultural income, i.e. producer surplus. Thus, the objective function of the model is defined as following:

$$max\ Welf = MoneyM + NTSurp - PrCost \tag{3.1}$$

Consumer surplus is calculated by using the money metric indirect utility function (Varian 1992), which behaves as a utility function, but measured in money terms. Since utility is unobservable, the selection of its measuring unit is up to the researcher's discretion (Diewert and Wales 1988a). The only requirement is that the transformed utility function should be an increasing function of one variable (Diewert and Wales 1988a). The proposed definition of the money metric indirect utility function is close to an example of money metric utility scaling suggested by Samuelson (1974). In KhoRASM, it is assumed that at the base period indirect utility function is measured in units of total income of consumers, i.e. rural and urban households. The money metric utility function is shaped according to the indirect utility function given in equation 3.11.

$$MoneyM = \sum_r \sum_f \frac{g^o_{r,f}}{g_{r,f}} Incm_{r,f} \tag{3.2}$$

where *r* refers only for rural and urban households.

Agricultural income is calculated as the sum of net trade of agricultural commodities less the costs of commodity transportation and agricultural production. Evoking the small-country assumption (Burniaux et al 1990; Jonasson and Apland 1997), in KhoRASM, the export and import prices for commodities are exogenously fixed. Thus, the net trade surplus is the difference between net trade earnings as export revenues minus import costs and the transportation costs:

$$\begin{aligned} NTSurp \; = & \sum_{r}\sum_{i}(XFlows_{r,i} - MFlows_{r,i})\, pex_{i} \\ & -\sum_{r}\sum_{i}(XFlows_{r,i} + MFlows_{r,i})\, edist_{r}\, trc_{r,i} \\ & -\sum_{r}\sum_{r1}\sum_{f}\sum_{i} Flows_{r,r1,i}\; dist_{r,r1}\, trc_{r,,i} \end{aligned} \tag{3.3}$$

The second cost component of the agricultural income refers to the agricultural production costs. In 2003, the state agencies defined centrally the maximum amount of physical inputs such as diesel and fertilizer which agricultural producers could purchase and apply. Moreover, the inputs were purchased during the first months of the year. Consequently, it is assumed that the agricultural producers made their production decisions without considering the prices of these inputs, but rather based on their current endowment in these inputs. Thus, the various cost component (*varc*) contains only the costs of inputs which affect the producer decisions such as costs of seeds and pesticides without imposing an endowment constraint. Full payments for hired labor and fodder costs are included into total production costs as follows:

$$\begin{aligned} PrCost \; = & \sum_{r}\sum_{f}\sum_{x} varc_{r,f,x}\; Xlevl_{r,f,x} \\ & +\sum_{r}\sum_{f}\sum_{x}\sum_{i} Xlevl_{r,f,x}\, feed_{r,f,i,x}\, Price_{r,i} \\ & +\sum_{r}\sum_{r1}\sum_{f}\sum_{f1} LabrF_{r1,r,f1,f}\; Wage_{r} \end{aligned} \tag{3.4}$$

where *i* depicts only maize and fodder crops.

The model solves for the optimal values of production, consumption, input use and commodity trade by consumer/producer groups and districts, while generating equilibrium commodity prices.

3.3 Supply Module

The supply module includes the production components of the general model (KhoRASM) such as production activities, commodity flows and constraints. The individual elements of the money metric utility function, such as commodity demand and prices, and the components of the flexible demand system are set to zero and removed from the equations. Consequently, the objective function of the supply module can be reduced to the maximization of revenues from trading activities and becomes:

$$max\ \ Revn = NTSurp - PrCost \tag{3.5}$$

The transportation constraints included into the objective function consider the linear cost of inter-district flows, as well as export and import flows for food and non food commodities as defined in equation (3.3). The linear transport costs are defined as per km transportation fees multiplied by the transported quantity of commodities and distance. The distance values for modeled districts are calculated as average distances between central markets in two administrative districts (Table 3.3). It is assumed that only one district, i.e. Khazarasp-Bagat aggregate, has access to the external commodity markets.

Table 3.3: Distances between modeled district aggregates, km

	KKAURG	YZRGLN	KVAYRK	KKRSVT	OUTSID
KSPBGT	45.2	86.0	40.0	78.7	200.0
KKAURG		40.8	30.1	47.7	
YZRGLN			54.4	31.0	
KVAYRK				37.5	

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; OUTSID – A market point outside of the region

Source: GIS Lab of ZEF/UNESCO project 2005; Own calculation

The undeclared variables of the supply module are as follows:

Code	**Indices**	**Description**
λ	*r,f,z*	Shadow price of input constraints;
ν	*r,f*	Shadow price of labor constraint;
μ	*r,f,x*	Shadow price of state procurement constraint for cotton;
π	*r,i*	Shadow price of commodity market balance;
Demand	*r,f,i*	Consumption level (see Section 3.4.1).

The undeclared parameters of the supply module are as follows:

Code	**Indices**	**Description**
labr	*r,f,x*	Labor application norms;
labrav	*r,f,x*	Labor availability for agricultural work and leisure;
inpt	*r,f,z,x*	Input application for production activity;
inptav	*r,f,z*	Input endowments;
feed	*r,f,i,x*	Animal feeding regime;
yild	*r,f,i,x*	Production yield per activity;
sord	*r,f,x*	State procurement constraint for cotton.

All other indices, variables and parameters as declared above.

3.3.1 Production Constraints

Within the supply module, the optimality conditions imply that activities are selected and their values remain within the feasible set or within the boundaries of the constraint set (Hazel and Norton 1986). The constraints are imposed due to limited supplies of resources, food consumption needs and state policy instruments. In the model, the constraints are classified into two groups such as resource constraints and state policy instrument constraints.

Resource availability constraints belong to the technical constraints and depict the limited resources in Khorezm. In the model the production a single set of technology is initially specified for each crop production activity in fixed proportions of land, labor, nitrogen fertilizer, diesel fuel and grain harvester combines and vary between farm aggregates. It is assumed that the resources cannot be traded between district aggregates. There are no importing and exporting activities of resources. Additionally, since the model is not dynamic, the monthly projected inputs cannot be stored over month periods. Animal rearing activities are restricted by available fodder from crop growing activities and imported from other modeled districts or from outside of the region. Due to the computational limitations each animal production activity has a single feeding regime which varies between farm aggregates across the modeled districts. Other inputs were excluded from the model, since they are of less interest methodologically, although they may be indispensable in real-life production, such as changes in soil parameters. In order to capture the peak periods of resource use, the endowments of specific inputs such as land and water, have seasonal dimensions.

In the model, the policies are decided exogenously and they are static and deterministic. Since the annual land allocation targets for cotton are determined centrally, the main state policy implied in the model is the state production target for cotton.

Using all given features, the resource constraints in the model are expressed as:

$$\sum_{x} XLevl_{r,f,x} \quad inpt_{r,f,z,x} \leq inptav_{r,f,z} \qquad \left[\lambda_{r,f,z}\right] \tag{3.6}$$

1. *Total labor availability*. Although labor does not constrain agricultural production in Khorezm, and there is relatively high rural underemployment in the agricultural sector, the significance of including labor as a restraint in this study is to analyze the potential employment creation by agricultural production activities. This constraint is also used a balance equation for agricultural time of rural households used for on-farm and off-farm activities and leisure. Labor is provided by rural households only, while *shirkat*s and private farms can only hire labor. The labor endowment data was formed by summing the total annual hours worked in agriculture, and the leisure hours of the rural population in Khorezm for 2003. The total annual hours worked in agriculture are inferred from information on the share of the rural population employed in the regional agricultural sector plus the working hours spent on individually owned rural household plots. The total leisure hours in rural households is set as a fixed proportion of the time spent for non-working activities in rural households. To define the total working and leisure hours, the rural population is transformed into adult equivalents, according to official recommendations for calculating adult manpower by MAWR. The units are in terms of adult working hours with weights of 1 for males and females between 15 and 65 years old, 0.8 for males and females over 65, and 0.5 for children aged less than 15. Labor endowment is specified by type of agricultural producer and by district. The labor constraint includes labor flow variables which represent the labor hiring-in activities in *shirkat*s and private farms and hiring-out activities in rural households.

$$labrav_{r,f} + \sum_{r1}\sum_{f1} LabrF_{r1,r,f1,f} \geq \sum_{x} XLevl_{r,f,x} \; labr_{r,f,x} + \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1} \qquad \left[\nu_{r,f}\right] \tag{3.7}$$

2. *Total land availability.* In the model, land is required for annual crop growing and animal keeping. The land constraint consists of a single soil type and is specified at the aggregate farm for each district according to the official statistical reports on sown area in 2003. The cropping calendar is introduced into the land constraint in order to cover a feature of regional agriculture within a double cropping schedule. It allows two crops being grown and harvested from the same field during one agricultural year. In the land constraint, the number of time periods is kept at a minimum to cover the basic cropping schedule

options. The land occupation in rural household is divided into two seasons, i.e. seasons when land is occupied by winter wheat and a season when rice or fodder crops can be sown. Due to the production of cotton in *shirkat*s and private farms, their cropping calendars have more periods in the year.

3. *Total water availability.* The demand for water is generated by the cropping activities. The water endowments are fixed at monthly volumes of surface water used for crop cultivation in each district aggregate according to data obtained from regional statistical reports for 2003. The irrigation technology, i.e. the surface crop water requirement, is specified according to the values developed by the research institutes for different soil types in Khorezm (OblSelVodKhoz 2004c; OblSelVodKhoz 2004d). The average water requirements vary among district aggregates in relation to the soil structure prevalent in each district aggregate. In the model, irrigation water, which is not applied for crop cultivating, cannot be stored over periods.

4. *Total nitrogen fertilizer availability.* In the model, the fertilizer constraint is presented as the total annual real elementary nitrogen content in each fertilizer applied by farm aggregates in modeled districts according to the observed cropping pattern in 2003. The nitrogen fertilization schedule for crop cultivation differs among agricultural producer and district aggregates. Unused amount of nitrogen fertilizer can not be stored, traded and used in the next period. Although rural households and farms, which are beyond the state procurement system are left beyond the central distribution of fertilizer, it is assumed that they each have nitrogen fertilizer constraint and at the observed situation in 2003 they could not purchase additional amount of fertilizers in the markets.

5. *Total diesel availability.* In the model, the diesel constraint is presented as the total annual diesel fuel used by farm aggregates in modeled districts according to the observed cropping pattern in 2003. Diesel is required for crop production in terms of fuel costs for field operations using machines. Additionally the diesel requirements for crop production include the diesel costs for transportation between local markets, as well as the diesel costs of irrigation. The diesel application technology varies between agricultural producer aggregates and district aggregates. Similar to the nitrogen fertilizer, unused amount of diesel can not be stored, traded and used in the next period. It is assumed that all agricultural producers have diesel constraints and at the observed situation in 2003 they could not purchase additional diesel in the markets.

6. *Grain harvester combines and transporting vehicles constraint.* According to farm and household surveys conducted in Khorezm, scarce supply of grain harvester combines is considered to be a significant constraint in crop production. This grain harvester combine constraint is specified according to monthly use at the district level, which depends on the total grain combining machinery hours available within farm aggregates and in district tractor fleets. The transporting vehicle constraint is measured in total working hours of transporting vehicles in district aggregates.

7. *Policy instrument constraints* relate to government policy objectives for regional and national development and are similar to target variables. The state policy instrument constraint of the model requires that activity levels for cotton production in *shirkat* and private farm aggregates are not less than the assigned area in 2003:

$$XLevl_{r,f,x} \geq sord_{r,f,x} \qquad \left[\mu_{r,f,x}\right] \tag{3.8}$$

   There are no additional constraints on crop rotation, except for state policy instruments which require a certain amount of land be allocated for cotton production, ad adherence to a cropping calendar.

3.3.2 Market Balance Constraint for Commodities

KhoRASM features commodity market balance equations for each model district, which guarantee that demand equals supply in each district. This means that production, imports and purchases from other districts must be balanced with human consumption, animal feeding, export and sales to other districts. The commodity balance of KhoRASM can be expressed as follows:

$$\begin{aligned} &\sum_f \sum_x Xlevl_{r,f,x} yild_{r,f,i,x} + MFlows_{r,i} + \sum_{r1} Flows_{r1,r,i} \quad \geq \\ &\sum_f Demand_{r,f,i} + \sum_f \sum_x Xlevl_{r,f,x} feed_{r,f,i,x} + XFlows_{r,i} + \sum_{r1} Flows_{r,r1,i} \end{aligned} \qquad \left[\pi_{r,i}\right] \tag{3.9}$$

The maize grains and fodder crops can be traded between producers within and across districts and additional amount can be imported into the region. In the supply model human demand is given exogenously as the volumes consumed in 2003.

3.3.3 Data Components of Supply Module

A large amount of data is required for sector models (McCarl and Spreen 1980). For the supply module we use data from our own field research, e.g. private farm survey in 2003 and household survey in 2004, as well as secondary data acquired from official governmental agencies, e.g. OblSelVodKhoz, OblStat, MAWR and PDFA. The model consists of three agricultural producer aggregates, each of which should be described by the relevant database. While there is an official record on large state-owned agricultural enterprises available in official statistical reports, the data on households and newly emerged private farms is poor. Therefore, a private farm survey and a household survey were conducted separately in most production districts.

Private farm and household surveys were administered in 2003 and 2004. The surveys used a standardized questionnaire and informal interviews. The questionnaire was designed to provide a suitable database for a quantitative and qualitative analysis of private farming and household production in Khorezm. Both questionnaires consisted of open-ended and closed-answer questions. Altogether 356 private farms and 400 households were interviewed.

First of all, both surveys provided data for structuring relevant activities and constraints of each farm aggregate within an agricultural sector model of Khorezm. The main objective of the surveys was to provide data concerning production technologies for private farms and households, such as nitrogen fertilizer and manure application, labor use, seeding, and animal feeding regimes. Additionally, the budgets and the schedules of crop growing and animal keeping in private farms and households were estimated from the survey results. Moreover, the field research supplemented the existing information about input and commodity prices obtained from local official statistic departments. The collected data was generalized for all households and private farms in the different district aggregates of Khorezm.

More aggregated data was obtained from official agencies. However, much of the required data was not available from secondary sources and had to be collected by means of farm and household surveys. The dataset is compiled from values for 2003 and consists of several categories such as social and political conditions of the region, regional prices, production pattern, household information, input-output coefficients, economic and natural resource endowments. Due to the absence of information on total export and import values of crops and animal production, their values were generated within the base run solution of the transportation model.

Annual reports from 2003 by the regional department of statistics of Khorezm (OblStat) provide the main source of data on crop and animal production, cropping area and animal stock, crop and animal product yields, on-farm input availability and policy constraints. The official statistical report of OblStat also serves as a dataset for land use and animal stock in Khorezm by farm sizes. The cropping calendar of the modeled crops is based on private farm and household survey data. In addition, the information on market prices in 2003 was obtained from OblStat. Since only a small portion of the surveyed households sell their products at local markets, price information for most crops could not generated from our survey data. Instead, state procurement and market prices for crops and animal products were obtained from the annual report on 2003 by the OblStat. The prices for fodder crops such as maize and fodder were taken from the household survey. Input prices in the model are exogenous and there is a distinction made between state and market prices. The state input prices for fertilizers, diesel fuel, machinery services, seed, and average salary used in production of strategic crops in 2003 were obtained from OblStat. In line with state policy, the state prices for inputs are uniform for all districts of Khorezm. The market prices for those inputs were obtained from the household survey.

Resource endowments such as total labor supply, and available real elementary nitrogen, total working hours of grain harvester combines and transporting vehicles in 2003 were obtained from the official reports of OblStat. The total values of water use for crop production in districts in 2003 were obtained from the Department of Agriculture and Water Resources of Khorezm Region (*OblSelVodKhoz*). The total diesel use over districts and the diesel prices in 2003 were collected from the official reports of the regional fuel distributing agency (*OblNeft*).

Obtaining microeconomic data, such as production cost calculations and domestic production technologies presented the greatest challenge of this study. Data relevant for crop budgets and costs of animal keeping had to be calculated according to the type of agricultural producer and district as well as according to cross-sectional data and subjective sources, such as interviews with local veterinarians and experts in livestock breeding (Djanibekov 2005). The survey data and officially recommended norms of input application are combined into input-output tables for each cropping and animal keeping activity in the model. The production cost calculations for *shirkat*s are based on the official microeconomic datasets obtained from *shirkat*s' annual accounting reports to OblSelVodKhoz.

Data on animal feeding requirements and recommendations, as well as nutrient content of crops was obtained from literature on animal keeping in Khorezm region and Uzbekistan from Abdolniyozov (2000) and Dalakyan and Rakhmanova (1986). Annual feeding costs per livestock and poultry unit were derived from household survey results. Additionally, in order to successfully set up the model's nutrient based constraints, parameters are needed to explain the amount of each nutrient that is present in each feedstuff as well as the dietary minimum and maximum requirements of animals for that nutrient. The content of fodder elements in crops and crop byproducts were specified, using the feeding recommendations adopted from Dalakyan and Rakhmanova (1986).

While the application quantities for most physical inputs are available from the surveys, the data on leaching and irrigation volumes and periods, on diesel costs for crop cultivation, as well as those on hours for grain combining and transportation services, were not covered in the survey questionnaires. The monthly irrigation requirements of specific crops were obtained from studies conducted in Khorezm by the Ministry of Agriculture and Water Resources (MAWR 2004c, OblSelVodKhoz 2002). In the model the actual crop water requirements are the crop water norms corrected by the coefficient of efficiency of the irrigation system including distribution and conveyance losses from on-farm and field canals, and field application efficiency. The data on diesel use, working hours of grain harvester combines and commodity transportation costs is based on norms developed by the Ministry of Agriculture and Water Resources of Uzbekistan (MAWR) in 1997.

3.4 Demand Module

3.4.1 Description of Normalized Quadratic – Quadratic Expenditure System

Following Howe et al. (1979) and van Daal and Merkies (1989), Ryan and Wales (1999) show that for a quadratic system to be theoretically plausible, the demand functions must have a form expressed in terms of some auxiliary functions *fm*, *g*, *h* and their first partial derivatives with respect to prices such as follows:

$$Demand_{r,f,i}=\frac{h_{r,f,i}}{g_{r,f}}(Incm_{r,f}-fm_{r,f})^2+\frac{g_{r,f,i}}{g_{r,f}}(Incm_{r,f}-fm_{r,f})+fm_{r,f,i} \tag{3.10}$$

where index *f* refers only to the modeled consumers such as rural and urban households; *fm* and *g* are functions restricted to be homogenous of degree one in prices and *h* is homogeneous of degree zero in prices. These demand functions are generated by the indirect utility function (Ryan and Wales 1999) for each consumer group in different districts:

$$\psi(P,Y)=-\frac{g_{r,f}}{Incm_{r,f}-fm_{r,f}}-h_{r,f} \tag{3.11}$$

In order to derive NQ-QES as member of this family of functions, *fm*, *g* and *h* and their first derivatives are the following:

$$fm_{r,f}=\sum_k Price_{r,k}d_{r,f,k} \quad \text{and} \quad fm_{r,f,i}=\frac{\partial fm_{r,f}}{\partial Price_{r,i}}=d_{r,f,i} \tag{3.12}$$

$$g_{r,f}=\sum_k Price_{r,k}b_{r,f,k}+\frac{1}{2}\left(\frac{\sum_k\sum_l B_{r,f,k,l}Price_{r,k}Price_{r,l}}{\sum_k \alpha_{r,,k}Price_{r,k}}\right)$$

and $$g_{r,f,i}=\frac{\partial g_{r,f}}{\partial Price_{r,i}}=b_{r,f,i}+\frac{\sum_k B_{r,f,i,k}Price_{r,k}}{\sum_k \alpha_{r,,k}Price_{r,k}}-\frac{1}{2}\frac{\alpha_{r,,i}\sum_k\sum_l B_{r,f,k,l}Price_{r,k}Price_{r,l}}{\left(\sum_k \alpha_{r,,k}Price_{r,k}\right)^2} \tag{3.13}$$

$$h_{r,f}=\sum_k a_{r,f,k}log(Price_{r,k}) \text{ and } h_{r,f,i}=\frac{\partial h_{r,f}}{\partial Price_{r,i}}=\frac{a_{r,f,i}}{Price_{r,i}}, \tag{3.14}$$

with condition that NQ-QES functions are homogenous of degree zero in prices:

$$\sum_k a_{r,f,k}=0 \tag{3.15}$$

Using equations (3.10), and from (3.12) to (3.15), the full version of the demand function is the following:

$$Demand_{r,f,i}=\frac{a_{r,f,i}}{Price_{r,i}g_{r,f}}\left(Incm_{r,f}-\sum_k Price_{r,k}d_{r,f,k}\right)^2+\left(\frac{b_{r,f,i}+\frac{\sum_k B_{r,f,i,k}Price_k}{\sum_k \alpha_{r,k}Price_k}-\frac{1}{2}\alpha_{r,i}\frac{\sum_k\sum_l B_{r,f,k,l}Price_{r,k}Price_{r,l}}{\left(\sum_k \alpha_{r,k}Price_{r,k}\right)^2}}{\sum_k Price_{r,k}b_{r,f,k}+\frac{1}{2}\left(\frac{\sum_k\sum_l B_{r,f,k,l}Price_{r,k}Price_{r,l}}{\sum_k \alpha_{r,k}Price_{r,k}}\right)}\right)\left(Incm_{r,f}-\sum_k Price_{r,k}d_{r,f,k}\right)+d_{r,f,i} \tag{3.16}$$

where the total income (expenditure) is defined as following:

$$Incm_{r,f}=\sum_i Demand_{r,f,i}Price_{r,i} \tag{3.17}$$

According to equation (3.17), total income of each consumer is equal to total expenditures for food and non-food commodities in case of rural and urban households (and plus leisure only in case of rural households).

where undeclared variables of the demand module are as follows:

Code	**Indices**	**Description**
Price	*r,i*	Endogenous commodity prices.

The undeclared parameters of the demand module are as follows:

Code	**Indices**	**Description**
a	*r,f,i*	Independent parameter of NQ-QES;
b	*r,f,i*	Independent parameter of NQ-QES;
d	*r,f,i*	Independent parameter of NQ-QES;
B	*r,f,i,j*	Independent parameter of NQ-QES;
α	*r,i*	Positive predetermined parameter.

All other indices, variables and parameters as declared above.

The Engel relationship presented in equation (3.16) suggests that marginal budget shares depend on the present level of expenditure, i.e. at different income levels consumers spend different fractions of their income on different commodities (Pollak and Wales 1992).

3.4.2 Regularity Conditions and Flexibility

At the reference vector of commodity prices the following conditions are assumed for the demand parameters:

$$\sum_k B_{r,f,i,k} Price^o_{r,k} = 0 \text{ and } B_{r,f,i,j} = B_{r,f,j,i} \tag{3.18}$$

Since the demand system is homogeneous of degree zero in *a*'s, *b*'s and *B*'s, normalization is imposed via setting the follows restriction on *b*'s and *d*'s:

$$\sum_k b_{r,f,k} = 1 \tag{3.19}$$

$$\sum_k d_k Price^o_{r,k} = 0 \tag{3.20}$$

Finally, it is assumed that the predetermined α parameters satisfy the restriction:

$$\sum_k \alpha_{r,k} Price^o_{r,k} = 1 \tag{3.21}$$

Using these restrictions, the shorter version of demand functions can be written for the reference prices and incomes as follows:

$$Demand^o_{r,f,i} = \frac{a_{r,f,i}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} {Incm^o_{r,f}}^2 + \frac{b_{r,f,i}}{\sum_k Price^o_{r,k} b_{r,k}} Incm^o_{r,f} + d_{r,f,i} \tag{3.22}$$

The derivatives of the shorter version of demand function with respect to total income and prices are as follows:

$$\frac{\partial Demand^{o}_{r,f,i}}{\partial Incm^{o}_{r,f}} = \frac{2a_{r,f,i} Incm^{o}_{r,f}}{Price^{o}_{r,i} \sum_k Price^{o}_{r,k} b_{r,f,k}} + \frac{b_{r,f,i}}{\sum_k Price^{o}_{r,k} b_{r,f,k}} \tag{3.23}$$

$$\frac{\partial Demand^{o}_{r,f,i}}{\partial Price^{o}_{r,j}} = \frac{-a_i Incm^{o}_{r,f}{}^{2} \left(\delta_{i,j} \sum_k Price^{o}_{r,k} b_{r,f,k} + Price^{o}_{r,i} b_{r,f,j} \right)}{\left(Price^{o}_{r,i} \sum_k Price^{o}_{r,k} b_{r,f,k} \right)^2}$$
$$- \frac{-2a_{r,f,i} d_{r,f,j} Incm^{o}_{r,f}}{Price^{o}_{r,i} \sum_k Price^{o}_{r,k} b_{r,f,k}} + \frac{Incm^{o}_{r,f}}{\sum_k Price^{o}_{r,k} b_{r,f,k}} B_{r,f,i,j} \tag{3.24}$$
$$- \frac{Incm^{o}_{r,f} b_{r,f,i} b_{r,f,j}}{\left(\sum_k Price^{o}_{r,k} b_{r,f,k} \right)^2} - \frac{b_i d_{r,f,j}}{\sum_k Price^{o}_{r,k} b_{r,f,k}}$$

where the undeclared parameters of the demand module are as follows:

Code	**Indices**	**Description**
$Incm^0$	r,f	Observed consumer's income (expenditure) level;
$Price^0$	r,i	Observed commodity prices;
$Demand^0$	r,f,i	Observed level of consumption;
δ	i,j	Kronecker's delta.

All other indices, variables and parameters as declared above.

The microeconomic theory requirements are satisfied only when the conditions given in equations (3.15) and from (3.18) to (3.20) are fulfilled. The adding-up condition given in equation (3.17) depends on the fulfilment of conditions (3.15) and from (3.18) to (3.20). Then inserting equations (3.15) into equation (3.23) it can be seen that the adding-up condition holds only if the mentioned above conditions of the functional parameters are fulfilled.

$$\sum_i Demand^{o}_{r,f,i} Price^{o}_{r,i} = \frac{\sum_i a_{r,f,i}}{\sum_k Price^{o}_{r,k} b_{r,f,k}} Incm^{o}_{r,f}{}^{2}$$
$$+ \frac{\sum_i b_{r,f,i} Price^{o}_{r,i}}{\sum_k Price^{o}_{r,k} b_{r,f,k}} Incm^{o}_{r,f} + \sum_i d_{r,f,i} Price^{o}_{r,i} = Incm^{o}_{r,f} \tag{3.25}$$

Frohberg and Winter (2001) demonstrate that homogeneity is a functional property of the restricted NQ-QES, which can be computed by inserting equation (3.23) and equation (3.24) such as:

$$\sum_j \varepsilon_{r,f,i,j} = \sum_j \frac{\partial Demand^o_{r,f,i}}{\partial Price^o_{r,j}} \frac{Price^o_{r,j}}{Demand^o_{r,f,i}}$$
$$= \frac{-2a_{r,f,i} {Incm^o_{r,f}}^2}{Demand^o_{r,f,i} Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} - \frac{Incm^o_{r,f} b_{r,f,i}}{Demand^o_{r,f,i} \sum_k Price^o_{r,k} b_{r,f,k}} \quad (3.26)$$
$$= \frac{\partial Demand^o_{r,f,i}}{\partial Incm^o_{r,f}} \frac{Incm^o_{r,f}}{Demand^o_{r,f,i}} = -\varepsilon^y_{r,f,i}$$

where undeclared variables of the demand module are as follows:

Code	**Indices**	**Description**
ε	*r,f,i,j*	Calibrated price elasticities of demand (see Section 4.2.1);
ε^y	*r,f,i,*	Calibrated income elasticities of demand (see Section 4.2.1);

All other indices, variables and parameters as declared above.

The economic theory requires the substitution matrix of compensated price responses, i.e. the Slutsky matrix, to be concave as a consequence of consistent preferences and the concavity of the expenditure function (Deaton and Muellbauer 1980). In other words, the Slutsky matrix, i.e. the sum of the uncompensated price effect and the income effect, should be symmetric and negative semi-definite. Ryan and Wales (1996) prove that in case of a flexible demand function with quadratic Engel curves the curvature property can be imposed only locally following a Cholesky-decomposition procedure. According to this procedure the curvature constraints are imposed at a reference point by forcing the Slutsky matrix to be negative semidefinite at that point. The Slutsky matrix is defined as follows:

$$S_{r,f,i,j} = \frac{\partial \chi_{r,f,i}}{\partial Price^o_{r,j}} = \frac{\partial Demand^o_{r,f,i}}{\partial Price^o_{r,j}} + \frac{\partial Demand^o_{r,f,i}}{\partial Incm^o_{r,f}} Demand^o_{r,f,j}$$
$$= \frac{a_{r,f,i} b_{r,f,j} {Incm^o_{r,f}}^2}{Price^o_{r,i} \left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} + \frac{a_{r,f,j} b_{r,f,i} {Incm^o_{r,f}}^2}{Price^o_{r,j} \left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} \quad (3.27)$$
$$+ \frac{2a_{r,f,i} a_{r,f,j} {Incm^o_{r,f}}^3}{Price^o_{r,i} Price^o_{r,j} \left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{a_{r,f,i} {Incm^o_{r,f}}^2 \delta_{i,j}}{{Price^o_{r,i}}^2 \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{Incm^o_{r,f}}{\sum_k Price^o_{r,k} b_{r,f,k}} B_{r,f,i,j}$$

where undeclared variables of the demand module are as follows:

Code	**Indices**	**Description**
S	*r,f,i,j*	Slutsky substitution matrix.

All other indices, variables and parameters as declared above.

3.4.3 Data Components of Demand Module

In order to trace the cross-effects between commodities, this study uses a system of eleven commodities including nine food commodity aggregates, one manufactured commodity aggregate and leisure. The demand system is derived for each of the five modeled sub-regions (districts) and both types of households (i.e. rural and urban). The values used in calibration of the parameters that steer the adjustment reaction on the demand side of the model are not estimated endogenously within the model, but predominantly obtained from the international literature and official statistics.

First of all, consumed quantities and income (expenditure) are given by household type and district. Due to the lack of data on regional consumption patterns, the information on consumption in Uzbekistan for 2003 was taken from the Supply Utilization Accounts (SUA) and Food Balance Sheets (FBS) in FAO Statistics Division[12]. First, items presented in the FAO database were aggregated into nine main food categories according to the author's own discretion. In order to incorporate the demand for non-modeled food commodities, non-food (manufactured) commodities in the calibration procedure, the extra commodity aggregate, is included into the model which represents 'all other food commodities' left outside of the model and equal to the consumed quantities of all other food commodities presented in SUA database for Uzbekistan in 2003. Consumption per capita was inferred based on this aggregation rule for Uzbekistan (see Table A6 in Appendix 3).

Next, consumed food quantities for Khorezm in the base period of 2003 were assigned based on the national average and proportionally assigned to the regional level based on population shares. (see Table A7 in Appendix 3). An aggregate for non-food (manufactured) commodities includes all products and services produced in the non-agricultural sector and valued in monetary terms of other non-food commodities consumed by the population in Khorezm. The total value of manufactured commodities was proportionally inferred using their share in total expenditures for Uzbekistan as reported by FAO (1998). Leisure is included into the calibration process as a separate commodity. It is equal to a determined part

[12] No commodity price information for Uzbekistan was available in the database of FAO Statistical Division by 02.02.2007.

of total hours which rural households in Khorezm assumedly spent for non-working activities in 2003. The total available time in rural households in Khorezm is calculated proportionally to the total population of these households based on data obtained from OblStat. It is assumed that urban households consume more expensive commodities at higher rates than rural households. Additionally, urban households do not have leisure consumption (see Table A7 in Appendix 3).

The initial price vectors for food commodities were obtained from the official statistical reports of OblStat as average annual market prices observed in Khorezm in 2003. Initial prices for food aggregates such as melons and vegetables are values derived by dividing the total value of commodities in these groups by their total metric weight. Initial prices for non-food commodities are assumed to be equal to their unit values, i.e. 1000 USD. The initial price for leisure is the average labor price derived from monthly wages paid by private farms to hired seasonal workers as observed in Khorezm in 2003.

Following the Kuhn-Tucker conditions, the commodity prices in the modeled district aggregates will differ exactly by the unit transportation costs between these districts (Apland, Öhlmér and Jonasson 1994). Therefore, the new price system for modeled commodity aggregates can be derived as the equivalents of the shadow prices of the relevant commodity market balances (equation (3.9)) in the supply module for each district aggregate (see Table A6 in Appendix 3). The total income (expenditure) value is a sumproduct of total consumed quantities for each food and non-food aggregates and leisure and their respective prices (see Table A7 in Appendix 3).

Available records do not cover a sufficient time period to allow the estimation of price and income elasticities. Therefore, the primary values for demand elasticities were obtained from literature. The primary (uncalibrated) values used for the demand elasticities are the values obtained from the WATSIM[13] model's base-run dataset on the rest of the world and then adjusted according to the author's own knowledge on food consumption reaction to the price changes in Khorezm such as sign and approximate value of the elasticities. The initial (uncalibrated) values of income elasticities were generated at the author's discretion (see Table A8 in Appendix 3). The uncalibrated price and income elasticities are provided as a uniform value for each district and consumer type.

[13] The WATSIM is a recursive-dynamic spatial world trade model for agricultural commodities. It is mainly applied for the medium-term analysis of trade policy changes (Kuhn 2003).

3.5 Links between Supply and Demand Modules

The demand and supply modules in the general KhoRASM model are linked via concept of nonseparability such as the rural households' decisions regarding their production are affected by their consumer characteristics. First, the objective function of KhoRASM model includes the consumer's and producer's surpluses in terms of the money metric utility function. Second, in the full version of KhoRASM, the commodity consumption is a function of income and commodity prices, which changes in accordance to the commodity market balance reached between the demand and supply modules. Consequently, changes in commodity demand caused by different levels of consumer incomes and commodity prices, and the production activities defined by the producer technologies and input endowments reciprocally affect each other. Third, the agricultural time available to rural households can be used for on-farm, i.e. production activities in the rural household plots, and off-farm activities, i.e. employment of rural household members for production activities in *shirkat*s and private farms, and for leisure time consumption. Next, in the optimum solutions, the marginal revenue product of labor, i.e. shadow price of labor in the supply module, is equal to the marginal utility of leisure time consumption, i.e. price of leisure in the demand module (Benjamin 1992). Furthermore, the shadow prices of labor are equal to the agricultural wages which rural households receive for being hired by *shirkat*s and private farms. Therefore, the following condition is introduced:

$Wage_r = Price_{r,'lsr'}$, where *lsr* is a leisure time. (3.28)

Fourth, in KhoRASM, profits from agricultural activities, as defined in the supply module add up with the constant amounts of nonagricultural income to be equal to total expenditure for commodity consumption defined in the demand module.

$$Incm_{r,f} = AgrIncm_{r,f} + nagrIncm^{o}_{r,f} \quad (3.29)$$

The agricultural profit of rural households is defined as total output from agricultural production activities in household plots less production and animal feeding costs, plus the earnings from being hired in *shirkat*s and private farms, i.e. off-farm activities, at the agricultural wage equal to the price of leisure time:

$$\begin{aligned} AgrIncm_{r,f} &= \sum_{i}\sum_{x}\left(Price_{r,i}Yild_{r,f,i,x} - varc_{r,f,x}\right)Xlevl_{r,f,x} \\ &- \sum_{i}\sum_{x} Xlevl_{r,f,x}feed_{r,f,i,x}Price_{r,i} \\ &+ \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1}Wage_{r,f} - \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1}dist_{r,r1}lc_{r} \end{aligned} \quad (3.30)$$

where *f* is defined only for rural households.

In the model, the total income (expenditure) of urban households equals the consumption expenditures presented in equation (3.17) and fixed over all scenarios.

The non-agricultural income of rural households equals to the difference between observed consumption expenditures of rural households less the observed value of agricultural profits as follows:

$$\begin{aligned} nagrIncm^{o}_{r,f} &= \sum_{i} Demand^{o}_{r,f,i} Price^{o}_{r,i} \\ &- \sum_{i}\sum_{x}\left(Price^{o}_{r,i} Yild_{r,f,i,x} - varc_{r,f,x}\right) Xlevl^{o}_{r,f,x} + \sum_{i}\sum_{x} Xlevl^{o}_{r,f,x} feed_{r,f,i,x} Price^{o}_{r,i} \\ &- \sum_{r1}\sum_{f1} LabrF^{o}_{r,r1,f,f1} Wage^{o}_{r} + \sum_{r1}\sum_{f1} LabrF^{o}_{r,r1,f,f1} dist_{r,r1} lc_{r} \end{aligned} \qquad (3.31)$$

where *f* is defined only for rural households.

The undeclared variables of the model are as follows:

Code	**Indices**	**Description**
AgrIncm	*r,f*	Agricultural profit in rural households.

The undeclared parameters of the model are as follows:

Code	**Indices**	**Description**
$Xlevl^0$	*r,f,x*	Observed levels of production activities;
$nagrIncm^0$	*r,f*	Observed level of non-agricultural income in rural households;
$wage^0$	*r*	Observed level of agricultural wages.
lc	*r*	Labor flow costs

All other indices, variables and parameters as declared above.

3.6 Model Limitations

Although KhoRASM has advantages inherited by the nature of the price-endogenous programming model, it also has some limitations. These relate to some of the model specifications and aggregation assumptions. First of all, since the model is static and based only on a single reference year, it does not cover the simulation behavior of the regional agricultural sector to exogenous shocks over several periods. A second limitation is related to the objective function of KhoRASM, which is the maximization of producer and consumer surpluses. In reality, the regional agricultural sector does not behave exactly as an optimization model. In contrast to the optimization algorithm, the real world agricultural producers may not be able to maximize their profits because of frictions, uncertainty and imperfect information in the market (Hazell and Norton 1986). Also, producers may have other considerations in their decision-making which are impossible to include into the model. Furthermore, it is assumed that all of the modeled producer aggregates pursue the same objective, namely maximization of their income, though, in fact, the objectives of each producer aggregate may vary. The producer aggregation in KhoRASM is based on current legislations regarding agricultural producers in Uzbekistan. Here, the aggregation problem may occur since natural and economic conditions vary considerably from one producer to another within each farm aggregate. In a more precise study, the private farm aggregate should be disaggregated into several groups according to land size, production technology, and input endowments. Moreover, the model does not include the labor flow to other sectors of regional economy. Thus, any labor discharge by the agricultural sector is treated as increase in leisure consumption.

The assumption of product homogeneity is another problem related to the aggregation. The difference with respect to quality of crops and animal products may affect their price and demand levels in the region (Hazel and Norton 1986). The next problem of KhoRASM is related to the aggregation of the administrative districts which was done due to limits in computing facilities, e.g. further disaggregation of modeled increases enormously the time of calibration, validation and simulation runs of the model. It is necessary to bear in mind that any disaggregation of the model components is time consuming and data intensive (McCarl 1982) and therefore, could not be done in the confines of this study. However, future development of computing facilities will allow such modifications in KhoRASM, for instance changing the model's regional structure via replacing the aggregated districts by administrative ones.

Furthermore, the environmental issues such as salinization and water logging are also central to the region, but could not be included into this analysis. Finally, KhoRASM is based on an input/output framework with fixes technical coefficients in a Leontieff sense (1941). This of itself may limit the simulation output such as the yield response and factor substitution in such model specification are considered through including a set of alternative activities or piecewise linear approximations (Hazell and Norton 1986). The introduction of a non-linear yield function and, thus, incorporating the input substitutability, might improve the model specification. Finally, the model does not adequately depict the informal input markets since the input trading activities between producers are not incorporated.

4. Calibration of Supply and Demand Modules of KhoRASM

This chapter covers step two of the model application presented in Figure 3.1. In order to incorporate the regional characteristics of production module, the supply side of the model needs to be calibrated to replicate the production levels of the observation period. The selection process and additional features of our calibration approach for the supply side are described in section 4.1. It should be noted that literature on the applied approach is still very scarce. In order to incorporate the regional demand characteristics, the demand module likewise needs to be calibrated. The approach used in calibration of the demand module is presented in section 4.2. The demand module calibration consists of two separate calibration procedures. First, price and income elasticities of demand are calibrated to fulfill the theoretical consistency as presented in section 4.2.1. Secondly, the functional parameters of the selected demand system are derived from the calibrated elasticities of demand as presented in section 4.2.2. During the study, several drawbacks of the calibrations of supply and demand modules were observed which are discussed in sections 4.1.3 and 4.2.3 respectively.

4.1 Calibration of Supply Module

The validity of the model is evaluated by comparing its base run solution to the actual observed situation (McCarl and Spreen 1980). In the mathematical programming models, it is usually assumed that basic knowledge of the system is sufficient and, thus, parameters of the objective function and constraints are not calibrated to historical data. The main drawback of this assumption is that such model does not guarantee that the observed or reference data will be reproduced at its base run (McCarl and Spreen 1980). An often observed trend is that results are close for activities with large production values, while calculations for activities with very small production values tend to deviate stronger from the true observations. It is claimed that if a good fit to the observation is not achieved than the quality of the model is poor. There are several reasons for the differences between the base run optimal solution and the observed activity levels. First of all, models by definition are simplified abstraction of a real system and as a result will drop information. This is why they require verification against actual behavior (Howitt 2002). The differences between modeled and observed values may be a result of an omission of factors influencing production activities. However, it is possible, that even if the base run solution results deviate from the observed situation, the model is still specified correctly.

A lack of data availability and reliability can be another reason that the activity levels in the base run optimal solution do not correspond to their observed values. Normally, a sector model is based on two types of information; i.e. aggregated and micro-level data. The aggregated data in the sector models consists of information on regional production activities, total production, yields, and inputs endowments, and is usually collected from the official statistical reports. The micro-level data consists of information on the production technologies applied by agricultural producers. This information is often obtained from microeconomic studies and surveys. In most cases, modelers introduce the averages of their surveyed data into their models; e.g. as linear input-output parameters suggested by Leontief (1941). A third reason is that regional sector models are normally validated via the comparison of the model's base run results to the aggregated data on the observed values for the model's variables obtained from official statistical departments. However, in transition economies, official statistics may provide inadequate measures of the actual production activities (Poganietz et al. 2000). Such combination of aggregated and micro-level data in one model may produce the base run solution where the model's activities deviate from their observed values.

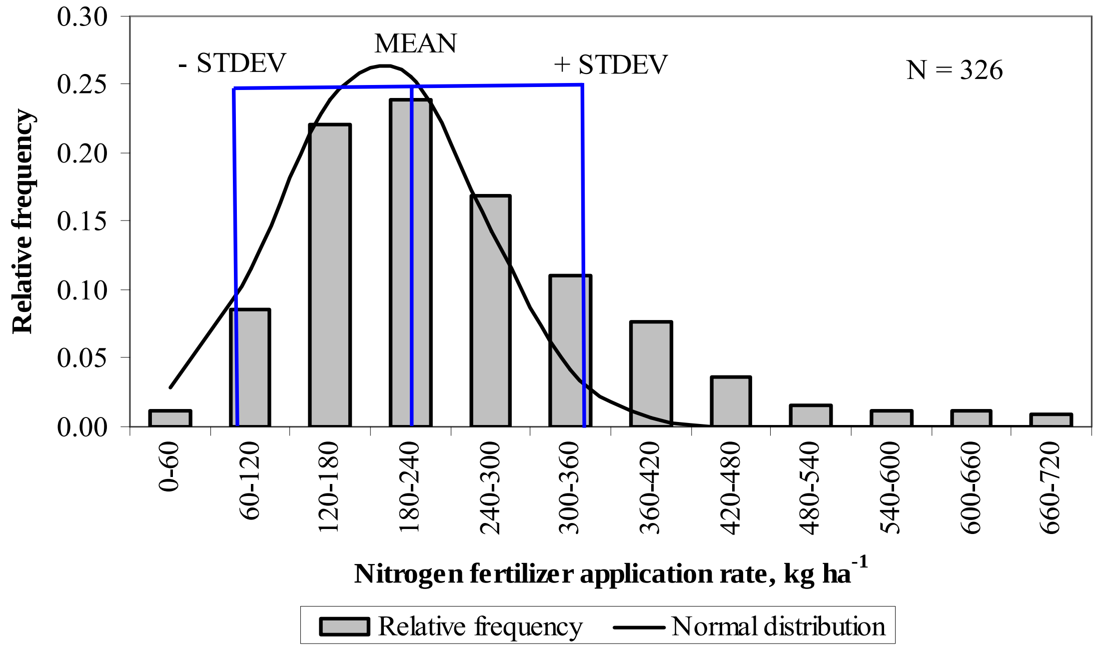
Policy analysis based on programming models that show a wide deviation between the model's base period outcomes and the actual production patterns is generally unacceptable (Howitt 2005). Only after being calibrated in order to exactly reproduce the base period data, may programming models be used for policy simulation (McCarl and Spreen 1980). Consequently, the objective of our calibration should be the proper adjustment of KhoRASM's supply side, in the sense that its base run optimal solution exactly replicates the observed activity levels without limiting the model's flexibility. This means that that the calibrated version of the model should solve the optimization problem without requiring additional constraints. This can be achieved via a calibration procedure which explicitly incorporates the information on the actual observed activity levels for the base year in an attempt to adjust certain model parameters while keeping the number of the model constraints unchanged (Howitt 2002).

Therefore, some parameters of the mathematical programming model needs to be adjusted for reproducing exactly a given reference point without restraining the model's flexible and realistic simulation behavior. An elegant approach to do so is 'Positive Mathematical Programming' (PMP) calibration (Heckelei 2002). The standard PMP calibration solves the overspecialization problem, maintains flexibility of the model, and produces the exact fit of the activities in the base run solution to their observed values (Howitt 1995). Such calibrated mathematical models may require less data than the standard approaches of calibrating linear programming models (Umstätter 1999). Nevertheless, the standard PMP approach has a set of drawbacks. One of the main shortcomings of the standard PMP calibration approach is that the introduction of unreasonably high cost terms into the original model is not easily intuited or interpreted (Umstätter 1999). Also according to the general idea of the PMP approach, the incorporation of a nonlinear cost function into the specification of the programming problem may affect the shadow prices of resource constraints and marginal cost values in the original version of the model (Heckelei 2002). As a result, the shadow prices and marginal values of the PMP-calibrated model may be incompatible with those of a dual version of the original model. The next critique regarding PMP calibration is that this approach involves an arbitrary specification of the objective function and may lead to implausible response behavior of the calibrated model (Heckelei and Britz 2000, Heckelei 2002).

Heckelei (2002) reviews several methods to avoid the problems occurred by standard PMP calibration based on extending it via the application of consistent econometric tools and the incorporation of additional information on system behavior. However, these methods complicate the calibration process and it may be difficult for the modeler to implement them if the required external data is expensive or not available for the studied area and period. Consequently, alternative theoretically consistent econometric approaches must employ other estimating equations than the ones used in PMP; thus allowing for recovery of the original model specification with increasing data information (Heckelei 2002).

Since the optimal solution of sector models is usually validated by comparing the activity levels with the observed output values available at aggregated level from the statistical offices, it is assumed that these aggregated values are accurate. On the other hand, the technology coefficients of the sector models obtained from micro-level studies such as farm and household surveys are used by the modelers only at average values. This neglects the information on technology coefficients contained in the sample data, such as standard deviation of the sample, which may be useful for calibrating the aggregated sector models. Additionally, the micro-level data relies on subjective responses of the respondents. In surveys, for several reasons the respondents, i.e. farmers and rural households, may give unreliable answers regarding the application of production inputs. As a result, the input applications per hectare, obtained from surveys, may have stretched distribution which is presented in Figure 4.1, where the micro-level dataset has a high standard deviation and a wide range of observed application rates.

Figure 4.1: Nitrogen fertilizer application in rural households in Khorezm, kg ha⁻¹



Note: MEAN – Sample mean; STDEV – Standard deviation of the sample; N – Number of respondents

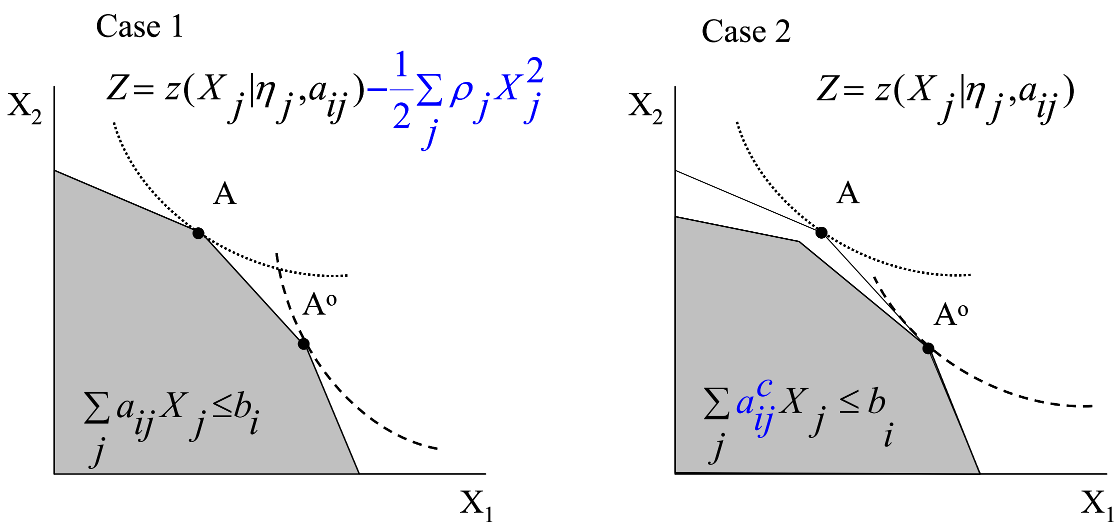
Source: Household survey 2004

As result, micro-level data such as technology coefficients may be considered the least reliable information in the sector model, and the main reason for the model's deviations in the base run solution. Hence, the model can be calibrated via adjustments in the technology coefficients obtained from surveys and literature and without altering its original structure. If the technology coefficients are adjusted correctly, the original model will exactly reproduce the base year values of production activities without requiring an additional set of constraints.

The general idea of model calibration via PMP and the selected alternative approach are visually presented in Figure 4.2. The presented model is a nonlinear model with maximization of objective function (Z) via production activities (X_j) over activity gross-margins (η_j) and technologies (a_{ij}). In its base run, the model solves at point A, while the actual values of the base year were observed to be at point A^o. Case 1 demonstrates the general idea of the standard PMP calibration. In order to obtain the exact fit of the model's results to the observed values, PMP calibrates the model without altering the shape of the feasible solution space. However the specification of the objective function is altered through the incorporation of the non-linear production cost term (ρ_j). Case 2 demonstrates the calibration approach for positive mathematical programming models via adjustment of technology coefficients. Since information on technology coefficients is included explicitly both in the feasible solution space and the objective function of the model, their modification will alter both, the feasible solution space and the location of the objective function. However, in contrast to standard calibration of PMP, the original specification of the objective function is not changed.

The selected approach calibrates via an explicit use of the implicit information about the observed activity levels, as well as on the dual values of the original model constraints. Hence, the calibration process involves two consecutive steps. Step one, consists of the estimating the dual values of the original model constraints. Step two consists of the incorporation of the actually observed activity levels and the derived dual values into the model calibration.

Figure 4.2: Comparison of standard PMP and alternative calibration approaches



Source: Own compilation

The original version of the supply module of KhoRASM consists of the equations (3.5) to (3.9) with their corresponding shadow prices. In this section, the calibration of the KhoRASM model is described in detail. The presented calibrating process is based on the following assumptions:

1) The observed levels of activities represent an equilibrium in the agricultural sector of Khorezm for the base year of 2003, i.e. the producers achieved maximum surplus for their constraint sets;
2) The actual observed values of production activities, input and output prices, input endowments, and quantitative policy constraints obtained from the official statistical reports are correctly specified;
3) The micro-level data on technology coefficients obtained from the farm and household surveys are of least reliability among all information fed into the model.

The adjustment of the technology coefficients included into the model specification will steer the model to exactly reproduce in its base run optimal solution the observed activity levels of the base year of 2003. The main advantage of this calibration approach is that similar to PMP, it avoids overspecialization, retains the model's flexibility, and calibrates exactly. Moreover, this calibration approach allows the modeler to incorporate more information obtained via surveys. In general, as a starting point, the selected calibration approach allows the modeler to use minimum amounts of data for policy simulations. The next section will address how these parameters can be adjusted while relying only on minimum data amounts. The calibration procedure presented in this study is consistent with the modeler's observations on the actual practice of agriculture producers in Khorezm.

4.4.1 Stage 1: Estimation of Shadow Prices

The first step of the supply module calibration is related to the first assumption of the selected approach; i.e. that the observed situation was in fact the optimal equilibrium for the modeled system in the base year. Consequently, in order to incorporate the information on the observed activity levels into the calibration process, in the second step of the calibration process the Kuhn-Tucker conditions will be imposed providing the necessary and sufficient conditions for a constrained maximum at the observed activity levels (Takayama and Judge 1986 and McCarl and Spreen 1980). In case the Kuhn-Tucker conditions are satisfied in the second stage of the calibration process, the supply module's optimal solution will exactly reproduce the observed equilibrium outcome in the base run.

Incorporation of the Kuhn-Tucker conditions requires a set of shadow prices from the original model constraints; e.g. dual values (shadow prices as presented in equations 3.6 to 3.9) of resource and policy instrument constraints and commodity market balances. The expected values of the shadow prices for some production inputs were inferred by the author from the household and private farm survey components, such as unofficial land rents, black-market prices for diesel and fertilizers, and total value of agricultural wage which includes also the value of payments in kind. Expected values of shadow prices which could not be inferred from the surveys, such as shadow prices of water and of nutrient elements in fodder, were derived from the dual version of the supply module. The intervals around the expected values were determined by either using the standard deviation of the sample (if available) or by qualitative assumptions in the case of the shadow prices obtained from the dual solution, such as the assumption that the shadow price of the water constraint cannot be negative as a relaxation of this constraint can under rationality assumption never result in lower farm income. The dual specification of the original version of the supply module produces information, that is useful for calibration in cases where production costs are correctly specified in the model, but the production technologies are unreliable (Howitt 2005). Therefore, the dual specification of the model fulfills the second assumption of the selected calibration approach on the incomplete information regarding production technology coefficients. In summary, the objective of the first step of the supply module calibration is to derive the shadow prices associated with binding input (λ) and labor (ν) constraints, policy instrument constraints (μ), and commodity balances (π) using the dual model.

The specification of a programming model's dual version is presented in Hazell and Norton (1986). The objective function of the dual problem of the supply module is a minimization of the total imputed value or opportunity cost of the resources constraints less the total shadow value of policy instrument constraints:

$$\begin{aligned} min\, W = & \sum_r \sum_f \sum_z inptav_{r,f,z} \lambda_{r,f,z} + \sum_r \sum_f labrav_{r,f} v_{r,f} \\ & - \sum_r \sum_f \sum_x sord_{r,f,x} \mu_{r,f,x} - \sum_r \sum_f \sum_i Demand^{o}_{r,f,i} \pi_{r,i} \end{aligned} \tag{4.1}$$

The constraints of the dual model are derived using the first order conditions of the original model's Lagrangian function with respect to the original model activities; e.g. production activities and commodity and labor flows. Equations (4.2. to (2.6) show the constraints which have been derived from the dual model. First derivative of Lagrangian over production activities associated with the constrained maximization of the supply module:

$$\begin{aligned} \frac{\partial L}{\partial XLevl_{r,f,x}} = & \sum_i \pi_{r,i} \left(yild_{r,f,i,x} - feed_{r,f,i,x} \right) - varc_{r,f,x} \\ & - v_{r,f}\, labr_{r,f,x} - \sum_z \lambda_{r,f,z} inpt_{r,f,z,x} + \mu_{r,f,x} \quad \leq 0 \end{aligned} \tag{4.2}$$

First derivative of Lagrangian of the supply module over commodity inter-district flows:

$$\frac{\partial L}{\partial Flows_{r,r1,i}} = -dist_{r,r1} trc_{r,i} + \pi_{r,i} - \pi_{r1,i} \quad \leq 0 \tag{4.3}$$

First derivative of Lagrangian of the supply module over labor flows:

$$\frac{\partial L}{\partial LabrF_{r,r1,f,f1}} = -dist_{r,r1} lc_r + v_{r,f} - v_{r1,f1} \leq 0 \tag{4.4}$$

First derivative of Lagrangian of the supply module over commodity export:

$$\frac{\partial L}{\partial XFlows_{r,i}} = pex_i - edist_r trc_{r,i} - \pi_{r,i} \le 0 \tag{4.5}$$

First derivative of Lagrangian of the supply module over commodity import:

$$\frac{\partial L}{\partial MFlows_{r,i}} = -pex_i - edist_r trc_{r,i} + \pi_{r,i} \le 0 \tag{4.6}$$

where all indices, variables and parameters have been declared above.

The dual variables, i.e. shadow prices of the original model constraints, measure the sensitivity of the optimal solution values to changes in the original constraints. In this sense they have the same role as the as Lagrangian multipliers in classical optimization problems. (Chiang 1984). The opportunity cost of producing a unit of commodity cannot be less than the commodity price. Consequently, the marginal opportunity costs of constraints in equation (4.2) states that the total sum of the shadow prices per unit of activity level must be greater or equal to the total revenue per unit of production activity. At the observed levels of activities, the commodity prices are the shadow prices of commodity balances (π) and reflect the relative scarcity of the commodities supplied in the region (Hazell and Norton 1986).

4.4.2 Stage 2: Adjusting Technology Coefficients

In the second stage of the supply module calibration, the shadow prices of the original constraints and the observed activity values are used to adjust the technology coefficients.

After developing the KhoRASM model, the optimality conditions are derived for calibrating the model. Both the necessary and the sufficient conditions for an optimum must be satisfied. For the mathematical programming model with a nonlinear objective function and linear constraints, the so-called Kuhn–Tucker conditions form the necessary conditions. Thus, imposing the Kuhn–Tucker conditions forms the set of additional calibration equations. Once the calibration has satisfied the Kuhn-Tucker conditions, the technology coefficients are adjusted to values which will steer the original model to replicate the observed situation in the system in the base period. Therefore, following the assumption that the observed production in Khorezm in 2003 was in equilibrium, i.e. regional producers maximized their surplus, the constraints of the dual model given in equations (4.2) and (4.6) are set to the equalities. The next set of equations associated with the Kuhn-Tucker conditions comprises the complementary slackness equalities, which stipulate that the optimally binding constraints will have non-zero-valued shadow prices.

Because the shadow prices of the original model constraints and the technology coefficients are expressed in a single data point, the problem of calibrating the supply module can be considered as ill-posed. Shadow prices are provided as estimates of the dual model and technology coefficients are represented by the average values of the actual observations taken from household survey. Therefore, technology coefficients are adjusted via the sample mean and standard deviation. The presented calibration approach is based on finding a unique solution to the ill posed problem via the incorporation of additional sample information.

Maximum Entropy (ME) estimation allows one to solve such ill-posed problems of parameter modification, via the incorporation of the additional information. According to Golan et al. (1996), in the ME estimation is generally motivated by two incidents. The first being insufficient information for proceeding in a traditional manner. The second being prudence. An attractive feature of the ME approach is that has a functional form with a unique solution at its maximum (Howitt 2002). Generally, the ME estimation has been applied by modelers as a tool for solving the problems posed by false model specifications, data errors, and aggregation bias (Howitt 2002).

The calibration model is as a nonlinear problem with an objective function that maximizes the probability (entropies) of adjusted technology coefficients and shadow prices falling within the original model's constraints. The ME estimation process is to select for each coefficient the ones with the lowest deviation from the original value among the infinite number of the modified parameters. In other words, the ME problem seeks a set of probabilities which adds the least amount of information to the modified parameters (Heckelei and Britz 2000):

$$\begin{aligned} maxH = & -\sum_t\sum_r\sum_f\sum_z\sum_x \overline{\overline{inpt}}_{t,r,f,z,x} ln\left(\overline{\overline{inpt}}_{t,r,f,z,x}\right) - \sum_t\sum_r\sum_f\sum_z \overline{\overline{\lambda}}_{t,r,f,z} ln\left(\overline{\overline{\lambda}}_{t,r,f,z}\right) \\ & -\sum_t\sum_r\sum_f\sum_x \overline{\overline{labr}}_{t,r,f,x} ln\left(\overline{\overline{labr}}_{t,r,f,x}\right) - \sum_t\sum_r\sum_f \overline{\overline{v}}_{t,r,f} ln\left(\overline{\overline{v}}_{t,r,f}\right) \\ & -\sum_t\sum_r\sum_i \overline{\overline{\pi}}_{t,r,i} ln\left(\overline{\overline{\pi}}_{t,r,i}\right) - \sum_t\sum_r\sum_f\sum_x \overline{\overline{\mu}}_{t,r,f,x} ln\left(\overline{\overline{\mu}}_{t,r,f,x}\right) \end{aligned} \quad (4.7)$$

The ME optimization is constrained by the following requirements, presented by Golan et al. (1996), and the Kuhn-Tucker conditions related to equations (4.2) to (4.6) according to which the model adjusts the values of technology coefficients and shadow prices:

1) Definition of a support space for modifying technology coefficients and shadow prices. To solve the ill-posed calibration problem of KhoRASM's supply module, the ME estimation requires additional information on the range within which technology parameters and shadow prices should be adjusted, i.e. a priori information that forms a support space

which consists of lower and upper support points. While the technology coefficients for fertilizer, diesel and labor are modified within based on the data range presented in the survey, the crop water use parameters are calibrated within a range of ±50% of their recommended leaching and irrigation volumes. The support space for shadow prices of the original model constraints equals their absolute values as observed in the surveys and as derived during the first stage of the calibration. Therefore the supporting interval ranges from zero to twice the shadow price. The selected range of the support space for shadow prices will move the feasible solution space such that in the base run solution the binding constraints can be relaxed in order to achieve the observed activity levels.

The support space for the shadow prices is linked with the price of leisure used in the demand module of KhoRASM (see section 3.4): According to the demand system used in KhoRASM and due to the way the labor constraints are formulated, the shadow price of labor in the supply module equals the price of leisure in the demand module.

2) Data moment-consistency requirements, where parameter modification is specified within a feasible range defined by sets of support points. Each support value is multiplied by its associated probability.

3) Normalization-additivity requirements in which the sum of probabilities of modified parameters is equal to unit.

4) For ensuring the fulfillment of the optimal solution at the observed activity values, the marginal commodity value and marginal opportunity cost equalities of the Kuhn-Tucker conditions must be held (equations (4.2) to (4.6) defined as equalities) such as to:

To achieve the observed production activity levels:

$$\sum_i \pi^e_{r,i}\left(yild_{r,f,i,x} - feed_{r,f,i,x}\right) - varc^e_{r,f,x} = v^e_{r,f}\, labr^e_{r,f,x} + \sum_z \lambda^e_{r,f,z} inpt^e_{r,f,z,x} - \mu^e_{r,f,x} \tag{4.8}$$

To achieve the observed commodity flow levels:

$$\pi^e_{r1,i} = \pi^e_{r,i} - dist_{r,r1} trc_{r,i} \tag{4.9}$$

To achieve the observed labor flow levels:

$$v^e_{r1,f1} = v^e_{r,f} - dist_{r,r1} lc_r \tag{4.10}$$

To achieve the observed export flow levels:

$$\pi^{e}_{r,i} = pex_{i} - edist_{r} trc_{r,i} \tag{4.11}$$

To achieve the observed import flow levels:

$$\pi^{e}_{r,i} = pex_{i} + edist_{r} trc_{r,i} \tag{4.12}$$

5) Additionally, the complementary slackness equalities imposed by the Kuhn-Tucker conditions must be held for every constraint and shadow price:

$$\left(\sum_{x} Xlevl^{o}_{r,f,x}\, inpt^{e}_{r,f,z,x} - inptav_{r,f,z} \right) \lambda^{e}_{r,f,z} = 0 \tag{4.13}$$

$$\begin{aligned} &\Big(labrb_{r,f} + \sum_{r1} \sum_{r1} LabrF^{o}_{r1,r,f1,f} \\ &- \sum_{x} Xlevl^{o}_{r,f,x}\, labr^{e}_{r,f,x} - \sum_{r1} \sum_{r1} LabrF^{o}_{r,r1,f,f1} \Big) v^{e}_{r,f} = 0 \end{aligned} \tag{4.14}$$

6) The original model's input endowment and policy instrument constraints, and commodity balances are imposed to ensure that parameters are calibrated under the original structure of the model constraints:

$$\sum_{x} Xlevl^{o}_{r,f,x}\, inpt^{e}_{r,f,z,x} \le inptav_{r,f,z} \tag{4.15}$$

$$\begin{aligned} labrb_{r,f} &+ \sum_{r1} \sum_{r1} LabrF^{o}_{r1,r,f1,f} \ge \\ &\sum_{x} Xlevl^{o}_{r,f,x}\, labr^{e}_{r,f,x} + \sum_{r1} \sum_{r1} LabrF^{o}_{r,r1,f,f1} \end{aligned} \tag{4.16}$$

where the undeclared indices of the supply module calibration are as follows:

t Support space such as maximum and minimum points.

The undeclared variables of the supply module calibration are as follows:

Code	**Indices**	**Description**
$\overline{\overline{inpt}}$	*t,r,f,z,x*	Probabilities of technology coefficients;
$\overline{\overline{labr}}$	*t,r,f,x*	Probabilities of labor use coefficients;
$\overline{\overline{\lambda}}$	*t,r,f,z*	Probabilities of shadow prices of input constraints;
$\overline{\overline{v}}$	*t,r,f*	Probabilities of shadow prices of labor constraints;
$\overline{\overline{\pi}}$	*t,r,i*	Probabilities of shadow prices of market balance;

$\bar{\bar{\mu}}$	*t,r,f,x*	Probabilities of shadow prices of state procurement constraints;
$varc^{e}$	*r,f,x*	Modified production costs;
$inpt^{e}$	*r,f,z,x*	Modified technology coefficients;
$labr^{e}$	*r,f, x*	Modified labor use coefficients;
π^{e}	*r,i*	Modified shadow prices of commodity market balance;
λ^{e}	*r,f,z*	Modified shadow prices of input constraints
ν^{e}	*r,f*	Modified shadow prices of labor constraints;
μ^{e}	*r,f,x*	Modified shadow prices of state procurement constraints.

The parameters of the supply module calibration are as follows:

Code	**Indices**	**Description**
$LabrF^{0}$	*r,r1,f,f1*	Observed values of labor flows between producers and districts;
$Flows^{0}$	*r,r1,i*	Observed values of commodity flows between districts;
$XFlows^{0}$	*r,i*	Observed values of commodity export;
$MFlows^{0}$	*r,i*	Observed values of commodity import.

All other indices, variables and parameters as declared above.

At the optimum solution of the calibration model (in which the probabilities of modified parameters are maximized satisfying the Kuhn-Tucker conditions) the technology parameters are adjusted to new levels so as to steer the model's optimal solution to reproduce the observed activity values in the base year.

4.4.3 Drawbacks of the Supply Module Calibration Approach

The selected calibration approach has shortcomings which are similar to the standard PMP calibration. It is important for this approach to have reliable information to which the technology coefficients are adjusted. Next, although the unique solution for the ill-posed problem of the technology coefficient modification has been found, the problem of arbitrary simulation behavior of the calibrated model remains unsolved, since the ME estimation is heavily dominated by support points (Heckelei and Britz 2000). This means that the modification of technology coefficients is done arbitrarily; meaning that there exist an infinite number of technology coefficient values which may be selected within the calibration process. Consequently, the simple specification of the calibration model can generate unreasonable responses to policy simulations (Heckelei 2002). In further studies additional information on the system behavior should be incorporated into the calibration process. Finally, the calibration approach is *ad hoc*. Since the applicability of this approach for other models has not been tested yet, the author does not claim that this approach can be used as a general method for calibrating programming models. This should be the subject of further studies to check the applicability of this calibration approach for other models.

4.2 Calibration of Demand Module

The objective of the calibration process for the demand module of KhoRASM is to adjust demand parameters for the NQ-QES to the observed levels of prices, income and demanded quantities at the point of optimum utility for consumers in each district. The derivation of parameters for a demand system is a two-step process. First, before deriving the functional parameters of NQ-QES, the implicit components of the demand module, i.e. demand elasticities, are calibrated. Given the set of uncalibrated income and price elasticities of demand obtained from other sources, observed commodity price and consumed quantity levels for Khorezm in 2003, the demand elasticities are modified as little as necessary to their final values consistent with the requirements of microeconomic theory (or in other words with assumed behavior of the regional consumers and with characteristics of domestic consumption in Khorezm). According to Frohberg and Winter (2001), the functional form of NQ-QES will not be flexible in the Diewert-sense without this preliminary procedure in the first step of calibration. Generally, the price and income elasticities at their initial (uncalibrated) values do not meet the requirements of demand theory (Frohberg and Winter 2001). Moreover, the initial information on demand elasticities is not available for Uzbekistan and, therefore, the information from other countries should be adapted to the features of domestic consumption. This requires that, in the first stage, both income and price elasticities are subject to modification, which forces them to fulfil the requirements of micro-economic theory and considerations regarding the domestic consumed quantities and commodity prices observed in Khorezm in the base period of 2003.

In the second stage, after the initial uncalibrated elasticities of demand are modified to a point where the theoretical conditions are met, the NQ-QES parameters can be derived. This two step approach, first suggested by Frohberg and Winter (2001), ensures that NQ-QES is calibrated and all regularity conditions are met; i.e. it exhibits adding up, homogeneity, curvature, and symmetry properties.

4.2.1 Stage 1: Calibration of Income and Price Elasticities of Demand

In this study, the objective function of the original calibration model presented by Frohberg and Winter (2001) was modified in order to solve the problem of finding appropriate values for weighting factors of modified elasticities. In their paper Frohberg and Winter (2001) minimize the square of weighted deviation of calibrated elasticities, i.e. General Least Squares on the elasticities. The scale applied by Frohberg and Winter (2001) to weigh the elasticities is a matrix and vector of the inverse of the corresponding initial elasticity raised to the power 2. However, the introduction of weighting factors does not guarantee that the calibrated values will be treated without considering the magnitude of their original values. In this study, the objective function of this calibration model is a maximization of probabilities (entropies) in which the demand elasticities with the highest probabilities (or which are closest to 1) are selected without considering the magnitude of the original value (Preckel 2001) and the weights (probabilities) are also introduced as variables.

The following set of equations and inequalities describe the calibration model for the demand elasticities: The objective function of the calibration model *(Z^0)* is the maximization of the probabilities of the estimated demand elasticities:

$$max Z^0 = -\sum_t \sum_r \sum_f \sum_i \sum_j \bar{\bar{\varepsilon}}_{t,r,f,i,j} ln(\bar{\bar{\varepsilon}}_{t,r,f,i,j}) - \sum_t \sum_r \sum_f \sum_i \bar{\bar{\varepsilon}}^y_{t,r,f,i} ln(\bar{\bar{\varepsilon}}^y_{t,r,f,i}) \tag{4.18}$$

The non-linear optimization model should generate income and price elasticities in a way that:

1) it takes into account the properties of demand functions, which are derived from neoclassical demand theory of consumer behavior in case of multiple commodities, such as adding-up, homogeneity, symmetry, and negativity with full curvature of all elements of the Slutsky matrix;

2) it allows for a plausible reaction of consumption activities in the model to changes in own- and cross prices and the level of total regional income. This is especially important for countries or aggregates where the starting elasticities look quite dubious (Britz and Tritten 2003) or are simply unavailable and replaced by the other country's elasticity data.

Using the first requirement to the calibration model, a set of restrictions for calibrating the income and price elasticities of demand are imposed according to Frohberg and Winter (2001). The calibration model adjusts the demand elasticities to microeconomic conditions under minimal deviation from their initial values. The following constraints are imposed:

1) Adding-up: This property results from the assumption that the rational consumer spends his entire budget in order to maximize his utility. At their uncalibrated values the demand elasticities do not meet the adding-up and budget restriction (Frohberg and Winter 2001).

Therefore, the adding-up condition is imposed into the calibration model. This also means that the sum of quantities demanded multiplied by their price will be equal to the total available budget of consumers.

$$\sum_i \varepsilon^{y}_{r,f,i} \frac{Demand^{o}_{r,f,i} Price^{o}_{r,i}}{Incm^{o}_{r,f}} = 1 \tag{4.19}$$

2) Homogeneity: The Hicksian demand function is homogeneous of degree zero in terms of prices and income. Then, due to the linear specification of the budget constraint, a proportional change in all prices and of expenditures does not lead to a variation of quantities demanded or of the level of utility. Therefore, the price and income elasticities must be homogenous and satisfy the following equation:

$$\sum_j \varepsilon_{r,f,i,j} = -\varepsilon^{y}_{r,f,i} \tag{4.20}$$

3) Symmetry: The Hicksian, or "compensated", demand function curve is equal to the first derivative of the expenditure function (Varian 1992). Therefore the substitution effect or compensated demand change between two products is symmetric. The Slutsky decomposition reveals that for the demand functions, the cross price derivatives consist of a symmetric substitution effect and an income effect. Essentially, the Slutsky equation decomposes the demand change induced by a price change into the substitution effect and the income effect. Knowing this, the Slutsky equation is used for translating the substitution effects to price and income elasticities:

$$\varepsilon_{r,f,i,j} = \left(\varepsilon_{r,f,j,i} \frac{Demand^{o}_{r,f,j}}{Price^{o}_{r,i}} + \left(\varepsilon^{y}_{r,f,j} - \varepsilon^{y}_{r,f,i} \right) \frac{Demand^{o}_{r,f,i} Demand^{o}_{r,f,j}}{Incm^{o}_{r,f}} \right) \frac{Price^{o}_{r,j}}{Demand^{o}_{r,f,i}} \tag{4.21}$$

4) Negative semidefiniteness: Given a convex utility function and a concave cost function, the matrix of substitution effects must be negative semi-definite. In the calibration of food demand elasticities presented by von Lampe (1999) this requirement is imposed by a necessary condition (although not sufficient) that all own-price substitution effects have to be non-positive. However, the entire matrix of substitution effects (the Slutsky matrix) must be negative semi-definite, rather than only the matrix of price elasticities (Diewert

and Wales 1987). This means that income effects must also express the negative semidefiniteness properties that the substitution effects display. While the calibration method presented by von Lampe (1999) considers the income effects only implicitly, Frohberg and Winter (2001) presented a more elegant way of calibrating the demand elasticities which guaranties the concavity of the Slutsky matrix. This is done via imposing the existence of the Cholesky–decomposition of the Slutsky matrix as suggested by Diewert and Wales (1987):

$$S_{r,f,i,j} = \varepsilon_{r,f,i,j} \frac{Demand^{o}_{r,f,i}}{Price^{o}_{r,j}} + \varepsilon^{y}_{r,f,i} \frac{Demand^{o}_{r,f,i} Demand^{o}_{r,f,j}}{Incm^{o}_{r,f}} \quad (4.22)$$

and $S = -LL^{T}$ (4.23)

5) The second requirement of the calibration model was to not allow implausible values of the calculated elasticities. This was done via defining support spaces within which to adjust income and price elasticities. In cases where the cross-price effects of demand are known to be insignificant for Khorezm, the cross-price elasticities are allowed to have values close to zero. This also allows retaining the sign of the initial elasticities.

6) Data moment-consistency requirements, of defining parameter modifications within a feasible range using sets of support points (Golan et al 1996). Each support value is multiplied by its associated probability.

7) Normalization-additivity requirements in which the sum of probabilities of modified parameters is equal to unit (Golan et al 1996).

Where the undeclared variables of the demand module calibration are as follows:

Code	**Indices**	**Description**
$\bar{\bar{\varepsilon}}$	*t,r,f,i,j*	Probabilities of calibrated price elasticities of demand;
$\bar{\bar{\varepsilon}}^{y}$	*t,r,f,i*	Probabilities of calibrated income elasticities of demand;
L	*r,f,i,j*	a lower triangular matrix wheres L^T is its transpose.

All other indices, variables and parameters as declared above.

The calibration process was programmed and solved as a NLP problem using the CONOPT3 solver in GAMS. After calibration, the concavity of the Slutsky matrix was checked via setting the vector of principal minors of the matrix. For this the ‘*=mdeterm*’ functional command in MS Excel (English version) was used. The Slutsky matrix that is derived from the calibrated final elasticities has a negative first principal minor (upper left own substitution effect), while all other values alternate in signs according to the $(-D)^n$, where n is an order of principal minor; i.e. the Slutsky matrix is strictly concave. After this securing the above properties the functional parameters of NQ-QES can be calibrated in the second step using the now established demand elasticities. The calibrated income elasticities for modeled districts and consumers are presented in Table A9 in Appendix 3. The calibrated price elasticities of rural and urban households are given in Tables A10 and A11 respectively in Appendix 3.

4.2.2 Stage 2: Calibration of Functional Parameters of NQ-QES

When calibrating, conservation of a model's flexibility is a major concern (Britz and Tritten 2003). In the second stage of our calibration of the demand module, equation (4.24) is solved subject to the constraints of equations (4.25) to (4.27) and the conditions of the functional parameters presented in equations (3.15) as well as equations (3.18) to (3.20). Solving (4.24) under these constraints produces an estimate of NQ-QES parameters (Frohberg and Winter 2001). In this stage, the elasticities obtained in the first calibration stage are perfectly matched by the final calibrated elasticities (Frohberg and Winter 2001). Therefore, the objective of the second stage is to solve for the demand parameters via minimizing the squared difference between elasticities obtained in the first stage and the final calibrated elasticities without using scaling weights. Thus, the value of the objective function in the optimal solution must be zero:

$$minZ^F = \sum_r \sum_f \sum_i \sum_j (\varepsilon_{r,f,i,j} - \varepsilon^F_{r,f,i,j})^2 + \sum_r \sum_f \sum_i (\varepsilon^y_{r,f,i} - \varepsilon^{yF}_{r,f,i})^2 \tag{4.24}$$

The final calibrated elasticities are defined as follows:

$$\varepsilon^F_{r,f,i,j} = \left(\frac{-a_{r,f,i} {Incm^o_{r,f}}^2 \left(\delta_{i,j} \sum_k Price^o_{r,k} b_{r,f,k} + Price^o_{r,i} b_{r,f,j} \right)}{\left(Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{-2a_{r,f,i} d_{r,f,j} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} \right.$$
$$\left. + \frac{Incm^o_{r,f}}{\sum_k Price^o_{r,k} b_{r,f,k}} B_{r,f,i,j} - \frac{Incm^o_{r,f} b_{r,f,i} b_{r,f,j}}{\left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{b_{r,f,i} d_{r,f,j}}{\sum_k Price^o_{r,k} b_{r,f,k}} \right) \frac{Price^o_{r,j}}{Demand^o_{r,f,i}} \tag{4.25}$$

$$\varepsilon^{yF}_{r,f,i} = \left(\frac{2a_{r,f,i} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{b_{r,f,i}}{\sum_k Price^o_{r,k} b_{r,f,k}} \right) \frac{Incm^o_{r,f}}{Demand^o_{r,f,i}} \tag{4.26}$$

Additionally, a constraint is imposed which requires that the quantities demanded meet observed values:

$$Demand^{o}_{r,f,i} = \frac{a_{r,f,i}}{Price^{o}_{r,i} \sum_{k} Price^{o}_{r,k} b_{r,f,k}} {Incm^{o}_{r,f}}^{2} + \frac{b_{r,f,i}}{\sum_{k} Price^{o}_{r,k} b_{r,f,k}} Incm^{o}_{r,f} + d_{r,f,i} \qquad (4.27)$$

where the undeclared variables of the demand module calibration are as follows:

Code	Indices	Description
ε^{F}	*r,f,i,j*	Final (calibrated) price elasticities of demand;
ε^{yF}	*r,f,i*	Final (calibrated) income elasticities of demand.

All other indices, variables and parameters as declared above.

To be consistent with the reality, the values of parameter *d,* which expresses a minimal (committed) consumption level when the consumer's income is zero, should be non-negative. However, the condition presented by equation (3.20) requires that at least one commodity should have negative value of committed consumption. This problem can be solved via setting the parameter *d* equal to zero, keeping the quadratic income terms. This will transform NQ-QES into a slightly modified version of the Normalized Quadratic Reciprocal Indirect Utility Function (NQRIUF) with quadratic Engel curves (Frohberg and Winter 2001). Diewert and Wales (1988) showed that the NQRIUF is a flexible functional form.

4.2.3 Drawbacks of the Chosen Demand Module Calibration Approach

In addition to the general limitations of flexible functional forms of demand presented by Pollak and Wales (1992), several post-calibration limitations were detected with regard to the functional form of NQ-QES. The short version of NQ-QES presented in equation (3.22) is used to demonstrate the drawbacks related to the parameter conditions presented in equations (3.15) and (3.18) to (3.20). The first two drawbacks are defined by the condition of parameter *a*. The parameter *a* specifies the Engel curve of a quadratic income response in the system and empirically plausible signs of this parameter for all modelled commodities should be guaranteed Therefore, the parameters *a* should have negative signs for all normal goods. However, according to equation (3.15) at least one modelled commodity must have a positive value. Consequently, this commodity will have followed a *U* shaped path in response to income increases. According to empirical evidence, in developing countries, leisure as a commodity does at times exhibit a positively increasing effect on income increases. However, the flexible formulation of NQ-QES does not guarantee this. This problem can be solved through imposing additional constraints during the calibration of the functional parameters, which would guarantee that *a* parameters for all modelled normal commodities are negative, and the one for leisure is positive. However, the introduction of additional constraints on a demand parameter may reduce the flexibility of the system.

A second drawback of NQ-QES caused by the signs of parameter *a* is related to price effects. As equation (3.22) shows, the demand function has a rectangular-hyperbolic shape with a negative quadratic term. It is increasing in the dependent parameters in response to the increases in the independent parameters. In this case, given the positive values of prices and income, the demand function may have a theoretically inconsistent effect on price increases at a specific range of prices. Given estimated demand parameters which satisfy the conditions in equations (3.15) and from (3.18) to (3.20), a very low positive price will produce a negative demand. Moreover, up to some level of price, the demand effect will be positive to changes in prices, i.e. demand function will be increasing. After this breakeven point of price, the demand will have a decreasing effect to price increases. Therefore, only the range of prices, in which demand is positive and decreasing in response to price increases, is suitable for demand analysis, wherefore upper and lower bounds must be applied to the price and demand variables in KhoRASM.

Finally, the curvature of NQ-QES is not global. Britz and Tritten (2003) argue that a system featuring a non-linear Engel curve which is simultaneously flexible and globally well behaved does not exist, and the curvature is imposed only locally, if at all. Moreover, the imposition of global curvature into a flexible demand function with non-linear Engel curves destroys its flexibility (Barnett and Usui 2006). This means that the values and signs of the substitution, full and income effects will vary with respect to price changes. At very low price levels compared to the referenced (observed) level, the demand system will even produce positive effects of demand to increases in price.

4.3 Post Calibration Results

After supply and demand modules were calibrated, the full version of KhoRASM is solved using the modified technology coefficients and derived demand parameters and in the optimal solution it exactly reflects real production situation in Khorezm in the reference year of 2003 such as the production and transportation activities, commodity prices and consumption are perfectly in line with their observed values. On this basis the calibration of KhoRASM can be considered successful and the calibrated version of the model can be used for further policy simulations and analysis.

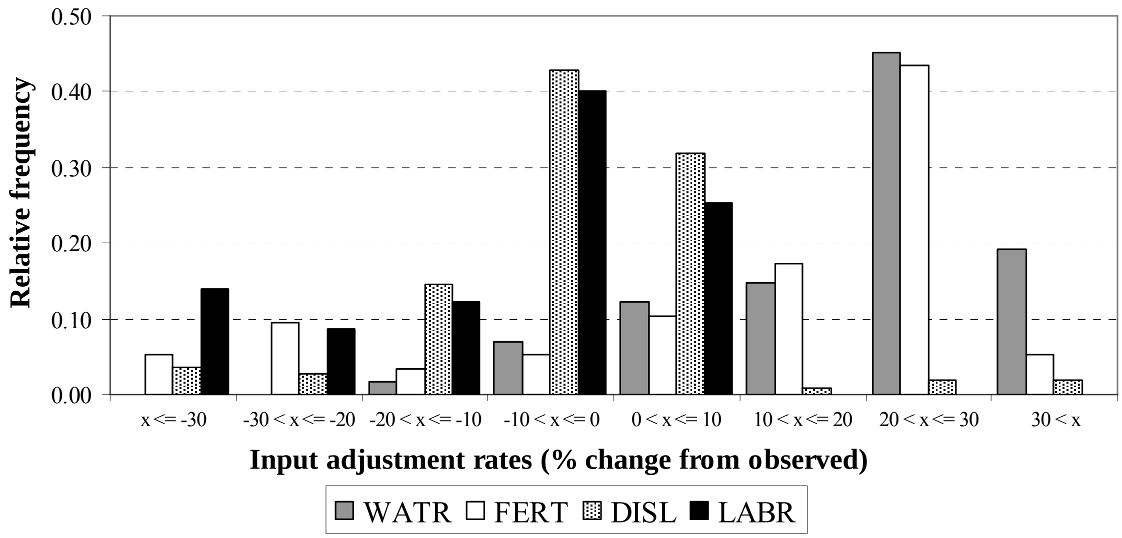
4.3.1 Adjustments in Technology Coefficients

In section 4.1, the technology coefficients of KhoRASM were adjusted within the theoretical consistency framework, such as model in its base run will exactly replicate the observed situation without any structural changes. In order to motivate the results of supply module calibration, the adjusted technology coefficients should be compared with their original values. If the adjusted technology coefficients are inconsistent with empirical observations, the supply module is recalibrated imposing different support space until it produces plausible results. In order to validate the results of supply model calibration, the percentage deviation of adjusted values of technology coefficients was calculated such as absolute difference between the adjusted and observed values divided by the observed value.

Figure 4.3 presents the distribution of percentage deviations (from the observed values) for fertilizers, diesel, water, labor and area for livestock and poultry keeping. The distribution of percentage deviation for water application coefficient is left-skewed. This means that the supply model was calibrated in a way that in order to achieve the reference point at the model's base run, the most of water application coefficients should be higher than their initial (observed) values. Such adjustment of water application coefficients can be accepted due to the high water losses in irrigation system (see section 2.4.1).

The largest negative deviations in case of adjusted water application coefficient are observed in case of water use for fruits and melons in March which is a pre-sowing month when soil is leached. The largest positive deviations of water use coefficient are also observed in case of leaching in March and irrigation in July for vegetables, potato and maize for grains. In fact, in the model, the initial (observed) values for water application for leaching are of less reliability since the data was obtained from literature as equal over crops and time. Hence, the high deviations in adjusted water application coefficients during the leaching were accepted. Similar kind of skewness in distribution of percentage deviations is observed for nitrogen fertilizer application rates. This means that agricultural producers, especially households and private farms are used to apply the fertilizers at higher amounts than they reported during the surveys. In fact, the agricultural producers in Khorezm used to underreport the fertilizer application rates for some crops since the fertilizers are distributed by the state agencies mostly for cotton and winter wheat production purposes. In the meantime, the fertilizer markets do not exist in Khorezm (see section 2.4.3). The distribution of percentage deviations for diesel and labor use coefficients has the right-skewed pattern. This can be explained by the fact, that the original values used for these inputs were obtained from the outdated data bases which were developed in 1980s.

Figure 4.3: Deviation in modified coefficients from observed ones



Notes: WAT – Irrigation water; DSL – Diesel fuel; NIT – Nitrogen fertilizers; LAB – Labor

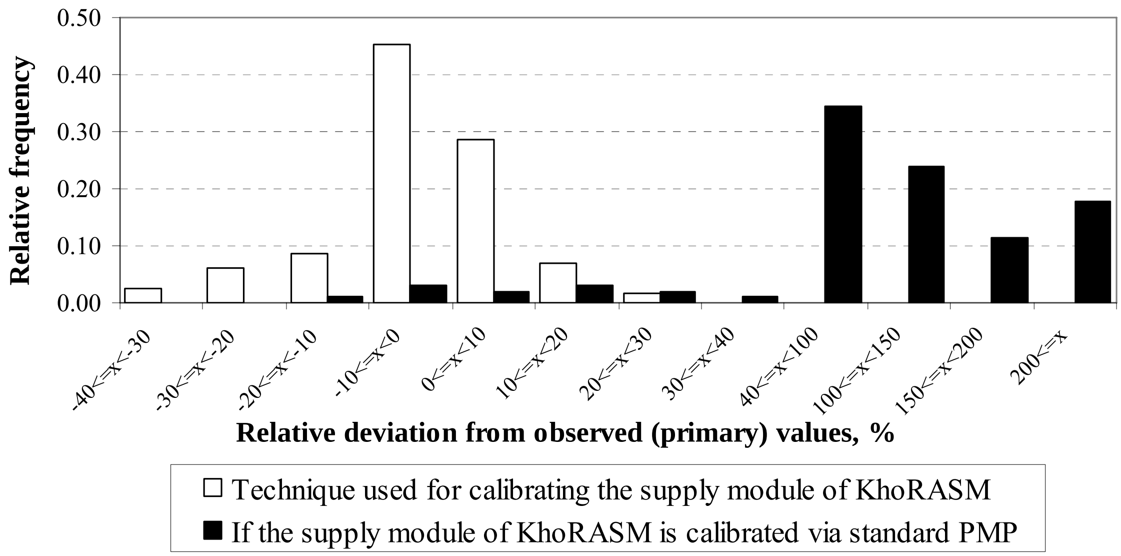
Source: Supply module calibration results

In the last stage of farm restructuring process, newly established private farms tend to deliver irrigation water to their fields using electric-water pumps which reduces the diesel costs per hectare of crop production. Moreover, in comparison to *kolkhoz*s and *shirkat*s, private farms tend to employ less people for field operations and mostly rely on hiring seasonal workers (see section 2.4.2). All other inputs, e.g. seeds, pesticides, animal feeding doses, transportation and harvesting costs, were adjusted within range between -20% and 0% from their observed values. This means, that under the given input endowments, optimum solution can be achieved exactly at the reference point when the agricultural producers underutilize seeds and pesticide, transport and grain harvester combines for crop production and animal feeding nutrients at levels lower than the observed and recommended values.

Compared to a standard PMP approach, which implies quadratic costs functions for each production activity (Heckelei 2002), calibration approach applied in this study results the modification in the production costs via adjustments in technology parameters. Thus, after calibrating the supply module of KhoRASM, the largest deviations in production costs are observed ion the range of ± 10% from the observed values, while in case of the standards PMP calibration technique[14] these deviations are in the range from +40 to more than +200% (Figure 4.4).

[14] Lacking necessary information, this study tested only the standards PMP approach.

Figure 4.4: Deviation in production costs from observed values



Source: Supply module calibration results; Standard PMP approach demonstrated by Heckelei (2002)

4.3.2 Functional Parameters of Demand System

The calibration of the demand module of KhoRASM ensures that the demand system is theoretically consistent. At the base run solution the demand module will exactly reproduce the observed levels of commodity prices and consumption. The calibrated price and income elasticities are empirically plausible. Nevertheless, several modifications were done to the standard formulation of NQ-QES. First, since it is theoretically inconsistent to fulfill the condition presented by equation (3.20), the parameter d of NQ-QES is set to zero which transforms the NQ-QES model into NQRIUF (Frohberg and Winter 2001). NQRIUF remains characteristics of flexible demand functions (Diewert and Wales 1988). Next, in order to fulfill the micro-economic theory requirements, the parameter a for food commodities has an upper bound to keep its values to be negative, while non-food commodities and leisure are lower bounded for having positive values. Consequently, the derived functional parameter a of the demand system has positive values for manufactured (non-food) commodities and leisure (see Table A12 in Appendix 3). The calibrated functional parameter β is positive for all commodities (see Table A13 in Appendix 3). The derived functional parameter B for rural and urban households is negative and semidefinite with the elements being symmetric inside the matrix (see Tables A14 and A15 respectively in Appendix 3).

5. Policy Simulations with KhoRASM

The purpose of this chapter is to provide the analysis for policy effects on agricultural production activities, resource use, commodity prices, income and consumption in Khorezm. While the model itself cannot address each effect with absolute precision, it is useful to look at potential short-term shifts in production and consumption patterns in Khorezm. The selected set of agricultural policies includes the most discussed policies which have been implemented or are most likely to be implemented in the future. The different scenarios are formulated when considering the problems under review of the ZEF/UNESCO Khorezm project. First scenario simulates the increasing efficiency of the entire irrigation system. Secondly, a policy simulation is run where a water pricing mechanism is introduced. Thirdly, the abolishment of state quotas for cotton and the simultaneous liberalization of input markets are simulated. The forth policy simulation includes a scenario with full fragmentation of *shirkat* producers into private farms. The fifth experiment simulates an improvement of livestock feeding technologies in Khorezm. Finally, a cumulative scenario which combines five variations is simulated. Each scenario is introduced by exogenously adjusting the values of the technical parameters, fixed prices and input constraints. No changes in model specification, e.g. incorporation of additional activities, are introduced in the six scenarios. In addition, it is assumed that the other sectors of the regional economy are fixed, i.e. not effected, and, thus allowing *ceteris paribus* setting for simulations. The chapter is structured as follows: to begin, the motivation behind each scenario is presented; next, the technical specifications of each scenario of each policy simulation run using KhoRASM are explained. Furthermore, each scenario is analyzed by comparing the values of specified variables to their observed levels in 2003. The comparative static analysis is used where the base-run of the model, i.e. the observed activity values of supply and demand modules for 2003, serves as a reference point against which the consequences of alternative scenarios can be assessed. The results of the simulations are reported by showing changes in gross margins of production activities, levels of production activities, commodity prices and regional demand, land and water use. The model consists of 11 modeled production activities in 3 producer groups and 11 consumption activities in 2 consumer groups in five modeled district aggregates. A detailed presentation of them would create an enormous amount of figures and tables, making their analysis extremely long and difficult to read and interpret. Therefore, the full reports on the simulation outcomes are given in Appendix 4 to this thesis and only the most interesting sets of results, mostly one district with a direct access to the river and one district without a direct access to the river are presented.

5.1 Scenario 1: Improvement of Irrigation and Drainage Systems

The central problems within agriculture of the Khorezm region are those related to the extensive irrigation and drainage network (Kyle and Chabot 1997), and include a poor or insufficient irrigation system efficiency, drainage efficiency, field canal efficiency and field application efficiency (Purcell and Currey 2003). The total length of irrigation canals in Khorezm is about 15,987.5 kilometers, of which 2,371.5 kilometers are inter-farm canals and 13,616 kilometers are intra-farm canals (Abdolniyozov 2000). The total length of drainage canals in the region is about 10,500 kilometers, of which 3,700 kilometers are inter-farm and 6,800 kilometers are intra-farm drainage canals (OblSelVodKhoz 2002). These canals have been in operation without any modernization for the last three decades (Abdullaev 2003) and require maintenance such as removal of sedimentation and weeds from their bed and sides (Forkutsa 2006). However, given the size of the irrigation system, and the annual budget of the responsible structures, which has been declining the between 1995 -2001 (Table 5.1), these maintenance activities have been ignored.

Table 5.1: Operating and maintaining costs in Uzbekistan

O&M Costs	95	96	97	98	99	00	01	02	03
O&M costs per irrigated area (USD ha^{-1})	81	131	104	127	122	87	75	54	56
O&M costs per canal system (USD km^{-1})	979	1,613	1,258	1,540	1,475	1,017	829	603	641
O&M costs per irrigation water (USD 10^{-3} m^{-3})	6.1	9.6	7.1	8.6	7.7	6.8	7.4	3.5	3.8

Source: MAWR 2004c; Müller 2006

Due to the poor condition of irrigation canals, about 63% of the diverted river water for irrigation in Khorezm is lost before it reaches the fields (FAO 1997). According to local authorities, field application efficiency varies between 55-60%, and the values of 62-73% are quoted in country reports (WARMAP 1996). According to WARMAP (1996), the field application efficiency can be lower up to 40%[15]. Additionally, adequate drainage is not ensured due to the average length of drainage canals which is only 37 meter per hectare, while it should be 50 meters per hectare (Kyle and Chabot 1997). All these have been causing the problems of soil salinity and a shallow groundwater table in Khorezm (Kyle and Chabot 1997,

[15] The annual water application in Khorezm can be greater than 50,000 cubic meters per hectare in case of irrigation of rice fields (Kyle and Chabot 1997).

Forkutsa 2006). Because of the high salinity of soil and ground water, water losses in irrigation canals in Khorezm can become ‘real’ unusable loss (WARMAP 1996). Given the canal installation costs, it seems clear that the best approach at present is improving maintenance and rehabilitation of the existing system (Kyle and Chabot 1997).

In this simulation, it is assumed that the improvement in the existing irrigation and drainage system[16] affects both the water application rates and crop yields. First, the system and field efficiency will be improved by cleaning and lining the irrigation canals. The local norms on water application for crops exceed the values calculated by CROPWAT[17]. For instance, the irrigation norms for winter wheat and potatoes are about 40-60% higher than the CROPWAT estimates (WARMAP 1996). The water requirements for other crops, except cotton and early maize for fodder, are 9-28% higher than the CROPWAT estimates. Furthermore, the improvement in irrigation and drainage system will increase the crop yields by achieving a more timely supply and better quality of irrigation water, decreasing soil salinity and ground water levels. The model adaptation is implemented as follows: firstly, it was assumed that the improvement of water efficiency is achieved through investment by the state and does not pose any direct cost to farmers. Secondly, water efficiency for each crop was improved by 10% over each water application month, i.e. water application rates decreased by 10%. Next, yields were increased by 10% for all crops; all other parameters remained fixed. Thus, the productivity of all other modeled factors, which are kept fixed in this scenario, e.g. nitrogen fertilizers, diesel and labor, will also improve.

5.2 Scenario 2: Introduction of Water Charges

The introduction of water charges for agricultural producers is currently being discussed as part of the agricultural reforms in Uzbekistan (McKinney 1996, Bucknall et al. 2003, Mott MacDonald 2003). Due to the features of Khorezm, The implementation of this reform will have a significant impact on the regional agriculture which depends entirely on irrigation water. First, irrigation water scarcity may constrain the regional agricultural production which is substantiated by recent findings showing that since the 1980s, the probability of drought occurring in Khorezm has been increasing (Müller 2006). Secondly, the water distribution system in Khorezm currently results in low water productivity via high distribution and conveyance losses and its improvement requires large investments (Abdolniyozov 2000).

[16] Irrigation system efficiency reviews the volumetric efficiency of components of irrigation and drainage system and can be considered in isolation from crop production (Purcell and Currey 2003).
[17] CROPWAT is a decision support system developed by the Land and Water Development Division of FAO. http://www.sdnbd.org/sdi/issues/agriculture/database/CROPWAT.htm

Third, the current institutional set-up of water use in Uzbekistan does not encourage agricultural producers to use their water efficiently. For instance, after independence, water charges in agriculture were not introduced and the expenditures for irrigation are covered from the state budget. In this context, there is a need to attain a more efficient and productive use of water in the agricultural sector which may be achieved via the direct introduction of water charges for agricultural producers (Tsur et al. 2004).

Following the farm restructuring process in 1998, state policy on O&M of the irrigation and drainage systems has been reconsidered (Bucknall et al. 2003, Mott MacDonald 2003, Zavgorodnyaya 2006, Veldwisch 2008). In the preliminary stage of water reforms, the management of irrigation and drainage systems in Khorezm was transferred from state agents to public suppliers, i.e. water user associations (WUA). Next, in order to ensure that the costs incurred by WUAs are fully or partially covered by agricultural producers, the later will be charged for water via membership fees and payments for provided services. In order to increase the water productivity, the collected water charges are invested into a series of agronomic, technical, managerial and institutional improvements such as clean supply and drainage systems and more precise irrigation schedules (Dinar and Latey 1991, Wallace and Batchelor 1997; Kyle and Chabot 1997; Batchelor 1999;). Consequently, the second objective of implementing water charging can be improvement in water use efficiency[18] (WUE) and crop yield.

Although, the WUE is related to water productivity at the system level, and the crop yield effect is related to water productivity at the agricultural producer level, both of them are interlinked. The WUE improvement refers to the technical efficiency, or to the efficiency of water distribution system, resulted via minimization of water losses and adequate quantity of irrigation water at the right time. The efficiency of water-use by agricultural producers can be increased via the timely supply of irrigation water at particular stages of crop development when crops response to irrigation is highest. The rules of water distribution among the different locations can be improved by imposing better incentives to agricultural producers to reduce their irrigation costs. Furthermore, the producers will benefit from the improved managerial and institutional practices of operating the regional irrigation and drainage system by WUAs which can increase the crop yields via better quality and more timely supply of irrigation water to the farm fields.

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[18] Water use efficiency is related to water use in crop production and has the same meaning as Gross Production Water Use Index which is expressed in terms of total or harvested portion of the crop produced per unit of total water applied (NPRID 1999). The volume of water applied includes both leaching and irrigation.

5.2.1 Selection of Water Charging Method

Worldwide, two mechanisms for water charging, volumetric and non-volumetric, are applied, each with advantages and disadvantages depending on the situation under consideration (Tsur et al. 2004). Prior to the model adaptation, the appropriate method of water charging for the agricultural sector in Khorezm was selected by studying the literature on the main features of volumetric and non-volumetric area-based methods.

Volumetric water charge is the most obvious and widely studied economic instrument assigning a charge to water and making water charge a direct function of the quantity supplied (Hellegers and Perry 2004). The main requirement of this method is regular information on the quantity of water used by each agricultural producer below a point where water being measured (Dinar et al. 1997). In theory, volumetric pricing can lead to improved allocation efficiency, but this method presents several problems which would make its introduction in Khorezm less attractive. The first problem of applying the volumetric pricing mechanism is absence of facilities for accurate and regular volumetric measuring of supply and use of water in Khorezm. The installation and administration of such facilities may be expensive in case of a large number of individual water users. The second problem is related to the policy of state controlled over farms' cropping activities according to which irrigation of cotton during the vegetation season is decided by local administration rather than by agricultural producers. The third problem is related to the fact that the volumetric method ignores equity concerns and the pricing of water is not the same among different types of agricultural producers (Tsur et al. 2004). The forth problem is that in case of continuous water flow, when it is not needed by agricultural producers or during the periods of excess water availability such as flooded months, the water charge value can be equal to zero.

The non-volumetric mechanism of water charging is usually applied in cases with a large number of water users and in cases with imperfect information about actual volumes of water supplied and demanded (Tsur et al. 2004). The main advantage of this mechanism is that it generates a predictable revenue stream to recover the O&M costs of water suppliers. The most applied non-volumetric method is an area and crop based charging mechanism where charges are fixed per hectare depending on the relative crop water requirements and the benefit agricultural producers get from the crops (Hamdy 2002). In this case, the water charges per hectare can be established at higher rates for cash crops, like paddy rice and vegetables in the case of Khorezm, and may also be kept at low rates for staple food production, in the case of small-scale households (Prathapar et al. 2001). In order to consider the equity of income distribution over time water charges can be disaggregated by seasons, producer types and producer location (Tsur et al. 2004).

Considering the pros and cons of each mechanism, the method of water charging selected for the model simulation is a crop-area-based method. In order to include the concepts of water saving and equity, the value of water charge in KhoRASM is defined as shown in Table 5.2. Since the cotton producers in Uzbekistan receive subsidized inputs (Guadagni et al. 2005), the value of water charge for cotton is assumed only half of the selected value. The production of paddy rice by agricultural producers in upstream districts is charged at a 20% higher rate. The water used for fodder production in all district and producer aggregates is not charged. According to household survey conducted in 2004, the irrigation of potato, vegetables, and melons in attached plots (*uy tomorka*) of rural households (*dekhqan* farms) is independent from the conditions of irrigation and drainage networks and these crops are irrigated by the pumping of ground water. The selected water charge rate is 25 USD per 1000 cubic meters of water which is comparable to ones practiced in agriculture of Morocco in 2003 (Chohin-Kuper et al. 2003), Namibia, Algeria, Tunisia, Brazil, Portugal, United States and Spain (Dinar and Subramanian 1997) in 1996. In the simulation the value of water charge is assigned to the official leaching and irrigation recommendations (norms) for crops, developed by research institutes for the study region.

In the model, the improvement in WUE is simulated by decreasing the original values of the technology coefficients of actual crop water requirements by 10%. The WUE and crop yield increase (by 10%) depends on the water charging rules specified for crops, producers and location as presented in Section 5.2.

Table 5.2: Variations in water charges from the selected value, %

District location	Producer	Cotton	Rice	Fodder	All other crops
Upstream districts	*Shirkat*s	-50	+20	n.a.	0
	Private farms	-50	+20	n.a.	0
	Dekhqan farms	n.a.	+20	n.a.	n.a.
Downstream districts	*Shirkat*s	-57.5	+2	n.a.	-15
	Private farms	-57.5	+2	n.a.	-15
	Dekhqan farms	n.a.	+2	n.a.	n.a.

Source: Own compilation

5.3 Scenario 3: Liberalization of Cotton and Input Markets

Like in other transitional countries, which experienced the liberalization of commodity and input markets, the question about abolishing the state procurement system, state control over input and output prices, and the practice of selective subsidization in agriculture was one of the issues widely discussed in Uzbekistan since 1991 (Rosenberg 2001, Guadagni et al. 2005, Müller 2007). According to the current procurement system and subsidization policy, the large and medium size agricultural producers, i.e. *shirkat*s and crop growing private farms, have to fulfill a production quota for cotton at fixed state prices which are below world market prices. In return, these producers receive production inputs at subsidized prices (Guadagni et al. 2005). The abolishment of the state procurement system is considered as a change in economic policy and economic conditions and the results of such a scenario can be highly controversial. This liberalization of cotton markets may increase producer revenues from cotton production and stimulate its regional production. However, the liberalization of input markets may cause lead to a reduction in income for rural households and put downward pressure on domestic commodity prices.

The cotton market liberalization is defined in the KhoRASM model in a way that the state procurement system is eliminated. This means that cotton production, like all other activities in the model, will not be constrained by a minimum level of production and will depend entirely on its comparative advantage over other activities. Next, the liberalization of cotton market assumes the increase in price for raw cotton. The cotton price in Uzbekistan is set by the government and therefore it is incorporated exogenously to the demand system in the KhoRASM model. There is no empirical value capturing the effects of cotton exports from Uzbekistan on the world market price. Consequently, in the simulation, Uzbekistan can be treated as a price-taking small country on the international cotton fiber market (Rosenberg 2001, Müller 2007), and the increase in cotton price is introduced as an exogenous change. Since Uzbekistan does not export raw cotton directly, its border price for shipping abroad is not observable. However, an export price for raw cotton can be derived based on that for cotton fiber and its processing costs (Guadagni et al. 2005, Müller 2006, Müller 2007). An alternative value for the simulated raw cotton price would be the price at which farmers in Kazakhstan sold raw cotton in 2003, i.e. 493 USD per ton. However, this value is rejected because it is 2.27 times higher than the observed state price in 2003 in Uzbekistan. The value for a hypothetical border price for raw cotton reported by Guadagni et al. (2005) was about 276 USD per ton in 2003, which is 28% higher than the observed state price for raw cotton in Khorezm in that year. For this scenario, the last value is used as a new price for raw cotton, (Table 5.3).

The input market liberalization is defined as removal of control over distribution of inputs and canceling the input subsidies. The main inputs selected for the input market liberalization are the ones which are subsidized by the state: cotton seeds, fertilizers and diesel fuel. The change in diesel fuel prices will effects the production costs related to pumping water to the fields. Being the main fertilizers used by agricultural producers in Khorezm, the prices for ammonium nitrate (*selitra*) and ammonium phosphate (*ammophos*) are set to the levels observed in Kazakhstan in 2003. The exogenous changes in raw cotton, cotton seeds, fertilizers and diesel prices are presented in Table 5.3.

Table 5.3: Exogenous changes in observed prices of cotton and inputs

Inputs	Base run (observed in 2003) prices, USD ton^{-1}	Simulated prices, USD ton^{-1}	Increase in price values in the scenario compared to the base run, %
Raw cotton	217	277	28
Cotton seeds	307	393	28
Ammonium nitrate	77	174	126
Ammonium phosphate	157	172	10
Diesel fuel	122	184	51

Sources: OblStat 2004c; OblSelHozKhim 2004; OblNeft 2004; Guadagni et al. 2005; Personal communication with a farmer from Kazakhstan, 2006

In context of input market liberalization, the scenario assumes that the constraints for fertilizer and diesel at producer levels are removed, meaning that agricultural producers can buy as much as desired given the new input prices. According to these exogenous changes in the model, the fertilizer and diesel costs are included into the production costs. Thus the model specification is changed via new formulation of the production costs (see equation 3.4 in Section 3.2.4) as seen in Equation 5.1:

$$\begin{aligned} PrCost = & \sum_r \sum_f \sum_x varc_{r,f,x} \, Xlevl_{r,f,x} + \sum_r \sum_f \sum_i \sum_x Xlevl_{r,f,x} feed_{r,f,i,x} Price_{r,i} \\ & + \sum_r \sum_{r1} \sum_f \sum_{f1} LabrF_{r1,r,f1,f} \, Wage_r + \sum_r \sum_f DislF_{r,f} dislp + \sum_r \sum_f FertF_{r,f} \, fertp \end{aligned} \quad (5.1)$$

where *i* depicts only maize and fodder crops and new variables are the following:

Code	**Indices**	**Description**
DislF	*r,f*	Diesel purchasing by agricultural producers;
FertF	*r,f*	Nitrogen fertilizer purchasing by agricultural producers.

The undeclared parameters are the following:

Code	**Description**
dislp	New market price for diesel;

fertp New market price for nitrogen fertilizer.

All other indices, variables and parameters are as declared above.

Finally, the application raters of fertilizers and diesel (technology coefficients) are decreased by 5% for all crops.

5.4 Scenario 4: Accomplishment of Farm Restructuring

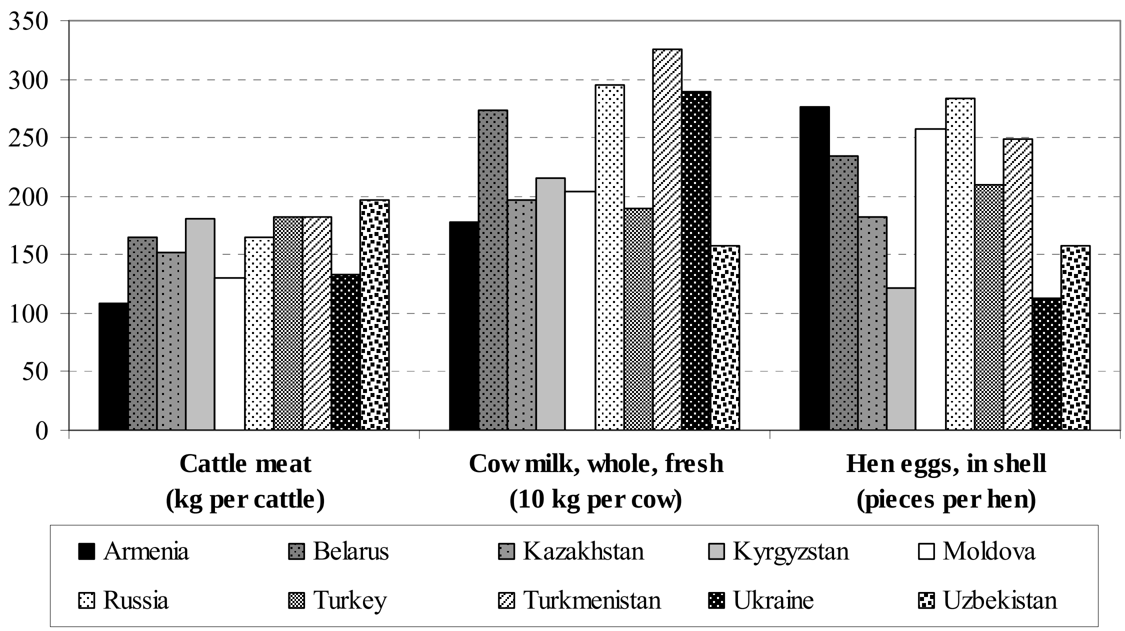
During the field surveys in 2003, the accomplishment of the nationwide farm restructuring process was one of the crucial issues in the agricultural reforms including Khorezm (chapter 2). The main feature of the farm restructuring process was the dismissal of large state enterprises (*shirkat*s), by transferring the land and inputs to the newly established private farms. As a final result of the farm restructuring process, the agricultural production in Uzbekistan will be conducted by only two types of producers: private farms and rural households. In this scenario, the values of input endowments and state procurement policy constraints imposed on *shirkat*s were assumed to be transferred to private farm units. Also, the input-output parameters of the *shirkat* were set to zero, and the ones of private farms and households remained unchanged. Due to these model conditions, obviously the total regional production, commodity consumption and prices, and input use would change to account for differences between private farms and *shirkat*s with regards to yields and other coefficients.

5.5 Scenario 5: Improvement in Livestock Husbandry Technologies

The current livestock production in Uzbekistan is underdeveloped (Figure 5.1). Even if no reliable, accurate and consistent data was available disclosing the different livestock species and feeding regimes and practices in Khorezm, the available data underlined a comparably low productivity of the livestock sector (Martius et al. 2006). Moreover, comparing to the national level, the livestock productivity in Khorezm such as e.g., for beef, has been lower than the average value for Uzbekistan (OblStat 2004, FAOSTAT 2007). The ZEF/UNESCO Khorezm project has been addressing the regional problems of livestock production, which resulted in proposals to improve this sector, which is steadily growing in importance (Martius et al. 2006). Iñiguez et al. (2004) formulated several problems of animal keeping in Central Asia, which are very much similar to the situation in Khorezm. First of all, there is problem of inadequate grazing which includes high feeding costs and scarcity of fodder during winter (see sections 2.3.1, 2.3.2, and 2.4.4). Second, animal health services are provided at an inadequate level to satisfy local demand. Given the growing importance of livestock in household food security and regional development (see Sections 2.2 and 2.3.2; Müller 2006) but the concurrent limited production level which is recurrently affiliated with the insufficient feed availability and the inappropriate feeding regimes, an improvement in livestock feeding technologies was included to estimate the options to meet future challenges in this sector. To develop the animal husbandry sector, the per-head productivity needs to be improved rather than to increase the number of livestock. Livestock productivity can be raised via a set of measures for improved feed supply, hygiene, improvement of husbandry and breeding, and animal health protection (Martius et al. 2006).

The model used in the base case was therefore adapted to this experiment. The values of milk and meat yield per cattle were increased by 10%. Next, the values of livestock feeding technologies were increased by 10% above their modeled values. Additionally, the land constraint imposed for animal keeping activities in terms of area of sheds and buildings was increased by 10% in each producer aggregate.

Figure 5.1: Comparison of animal production in Uzbekistan and other countries



Source: FAOSTAT 2007

5.6 Scenario 6: Cumulative Scenario

This final scenario is a combination of the previous five, and includes changes in production yields for crops and livestock; changes in crop input use and animal feeding; changes in cotton and input prices; removal of state procurement and input constraints (Table 5.4). The original production cost formulation was specified according to Equation 5.1 in Section 5.3.

Table 5.4: Scenario design in KhoRASM

Exogenous changes	EXP1	EXP 2	EXP 3	EXP 4	EXP 5	EXP 6
1) Production yield	+10% (all crops)	+10% (taxed crops)	–	–	+25% (livestock)	+10% (all crops) +25% (livestock)
2) Crop input use per hectare	-10% (water)	-10% (water)	-10% (fertilizer and diesel)	–	–	-10% (water, fertilizers and diesel)
3) Animal feeding coefficients	–	–	–	–	+20%	+20%
4) Variable costs of production	–	+ (by water tax)		–	–	–
5) Produciton costs respecified	–	–	+ by amount of purchased fertilizer and diesel	–	–	+ by amount of purchased fertilizer and diesel
6) Exogenous prices of cotton	–	–	+28%	–	–	+28%
7) Exogenous prices of inputs	–	–	+28% (cotton seeds) +20% (pesticides)	–	+100% (veterinary services)	+100% (veterinary services) +28% (cotton seeds) +20% (pesticides)
8) State procurement constraint	–	–	Removed	–	–	Removed
9) Input constraints	–	–	Removed (for fertilizer and diesel)	All constraints of *shirkat*s are set to zero and their values added to ones of private farms	–	Removed (for fertilizer and diesel) All constraints of *shirkat*s are set to zero and their values added to ones of private farms

Notes: EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

5.7 Simulation Results

5.7.1 Gross Margins of Production Activities

The gross margins (GM) were calculated as output value per unit of activity less the sum of imputed costs per unit of the activity which are not introduced into the model with input constraints. Such production inputs are seeds, pesticides, land tax, and other fixed costs. Therefore, the producer expenditures for purchasing diesel, nitrogen fertilizer and labor are not included into the original specification of the model, except in scenarios where input markets are liberalized. And it would be wrong to discuss the cotton taxation and subsidization via comparing its gross margins in base run and in scenario with cotton market liberalization. But rather, these absolute values should be compared with values of cotton gross margins in Table 2.4. Because under the liberalization of cotton and input markets the gross-margin of cotton increases, this comparison can show that the cotton producers were taxed rather than subsidized in 2003.

Two districts are discussed in this section, while the full table of GMs is given in Table A19 in Appendix 4 to this study. The changes in GM of production activities define the cropping pattern and structure of animals in each producer and district aggregates. The shifts in the values depend on the exogenous changes imposed in each scenario and the endogenous shifts in commodity prices. In the base run of the model, the producers in the district bordering with the river have higher GMs of three main crops, i.e. cotton, rice and wheat, than those which do not have direct access to the river (Table 5.5). In the base run, paddy rice, potato and vegetables are the most attractive production activities for the agricultural producers.

Scenario 1 assumes a 10% increase in crop yields, and the improvement in water efficiency has the highest effect in terms of absolute values on the cropping activities with the largest yields. In this scenario, there is a slight decrease in the GMs of livestock due to the decrease in the prices of milk and meat (see Section 5.7.6). Although the crop yields increase by 10% in Scenario 2, the introduction of water prices reduces the GMs significantly for most cropping activities in *shirkat*s and private farms. Since rural households were levied by water tax only for paddy rice cultivation activities, the GMs of other crops in rural households did not change significantly. After the introduction of water prices, rice remains the crop with the highest GM for private farms, while in *shirkat*s and rural households the highest GMs are observed for potato and vegetables. Since in this scenario the water pricing of cotton in *shirkat*s and private farms is assumed being subsidized, its GM for private farms in districts bordering with the river decreases at a relatively smaller rate than in the case of other crops. However, although being subsidized, cotton does not become more attractive for producers which still cultivate at the level dictated by the state procurement constraint. The liberalization of cotton and input markets (Scenario 3) has the highest impact on GMs for cotton, wheat and fodder crops. Under the scenario of farm restructuring (Scenario 4), a higher positive effect on crop GMs is found in districts bordering the river than in those which do not have direct access to the river.

Table 5.5: Gross margins of production activities

Producer	Activity		KSPBGT							KKRSVT						
			BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
									changes to base (in percent)							
SK	CTN	USD ha^{-1}	198	18	-60	-65	-	0	-	170	19	-54	-74	-	0	-
	WWT	USD ha^{-1}	245	14	-25	-97	-	-6	-	241	14	-17	-102	-	-1	-
	RCE	USD ha^{-1}	865	16	-79	-27	-	3	-	906	12	-62	-29	-	-2	-
	POT	USD ha^{-1}	604	19	-31	-25	-	1	-	878	17	-10	-21	-	1	-
	FRT	USD ha^{-1}	431	17	-24	-27	-	-1	-	278	20	-32	-35	-	11	-
	VGL	USD ha^{-1}	1,297	17	-7	-14	-	0	-	978	18	-7	-10	-	2	-
	MZE	USD ha^{-1}	507	12	-30	-45	-	0	-	379	13	-32	-58	-	0	-
	FOD	USD ha^{-1}	12	59	0	-784	-	0	-	35	27	0	-321	-	0	-
	MLK	USD head^{-1}	106	-1	-3	6	-	20	-	136	-1	0	6	-	18	-
	EGG	USD head^{-1}	2	1	0	4	-	7	-	4	1	1	7	-	7	-
	MEA	USD head^{-1}	121	-1	0	7	-	16	-	147	0	0	7	-	19	-
PF	CTN	USD ha^{-1}	333	14	-32	-41	0	0	-69	164	18	-57	-60	0	0	-113
	WWT	USD ha^{-1}	252	13	-24	-72	3	2	-96	223	14	-20	-66	1	-1	-86
	RCE	USD ha^{-1}	1,004	11	-67	-16	19	6	-83	841	12	-68	-22	2	-2	-87
	POT	USD ha^{-1}	281	26	-79	-71	2	2	-150	253	29	-65	-81	4	2	-146
	FRT	USD ha^{-1}	72	35	-212	-174	2	-3	-387	59	42	-204	-235	5	-9	-440
	VGL	USD ha^{-1}	404	24	-50	-50	2	1	-99	401	24	-35	-41	11	2	-75
	MZE	USD ha^{-1}	178	17	-103	-106	0	0	-209	146	19	-97	-129	0	0	-226
	FOD	USD ha^{-1}	79	18	0	-235	0	0	-217	85	17	0	-149	0	0	-132
	MLK	USD head^{-1}	179	-1	-2	7	16	22	36	148	-1	0	6	32	32	26
	EGG	USD head^{-1}	2	1	0	3	15	7	1	2	1	0	6	18	7	2
	MEA	USD head^{-1}	117	-1	0	7	18	16	37	146	0	0	7	34	39	32
HH	WWT	USD ha^{-1}	421	12	2	-35	1	-2	-23	410	12	0	-34	1	-1	-22
	RCE	USD ha^{-1}	1,108	11	-60	-22	18	5	-83	1,070	12	-51	-28	4	2	-77
	POT	USD ha^{-1}	812	18	1	-45	1	1	-27	536	22	0	-67	2	1	-45
	FRT	USD ha^{-1}	191	31	1	-90	1	-1	-111	317	25	0	-117	1	-2	-92
	VGL	USD ha^{-1}	574	26	0	-49	2	-1	-23	780	24	0	-22	11	2	3
	MZE	USD ha^{-1}	404	13	0	-74	0	0	-61	401	13	0	-72	0	0	-59
	FOD	USD ha^{-1}	155	14	0	-117	0	0	-104	157	14	0	-98	0	0	-84
	MLK	USD head^{-1}	328	-1	-1	7	19	23	36	326	0	0	6	28	20	18
	EGG	USD head^{-1}	4	1	23	3	14	6	1	3	1	0	6	17	6	2
	MEA	USD head^{-1}	245	-1	0	7	19	17	35	217	0	0	7	30	37	31

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CTN – Cotton; WWT – Winter wheat; RCE – Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Cows; EGG – Poultry; MEA – Bulls; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Under an improved livestock sector (Scenario 5), the GMs of livestock increased significantly across all producer aggregates. When all exogenous changes are introduced at once in the cumulative scenario (Scenario 6), the values of GMs decline for all cropping activities, while the GMs in the livestock sector increase for all producers in all modeled districts. Fodder cultivation may become, therefore, more attractive to those producers than potatoes, vegetables and fruits. Nevertheless, in this scenario, rice cultivation remains the most profitable cropping activity in Khorezm.

5.7.2 Shadow Prices of Constraints

The discussion of changes in the shadow values (prices) of input and state procurement constraints of KhoRASM are important for the regional policy makers. Although these values are called prices, they have nothing to do with resource supply and demand in the market and depend solely on the basic information of the optimization problem. A zero shadow value of input constraint indicates that this abundant is underutilized by a producer, i.e. not binding his production activities, due to scarcity of other resources. First, after achieving the exact fit of the model's variables to their observed values in the base run, the comparison of shadow prices of input constraints to their actual prices can be used in evaluating the behaviour of optimization sector model (Hazell and Norton 1986). Hence, the right level of a shadow price of input constraints and policy instruments can be considered an indication of the consistency of KhoRASM. Secondly, with respect to the aim of this study, the KhoRASM model can also be used as a source of information on shadow prices of fixed resources and the state procurement constraint. Looking at the shadow prices of farm resources reveals that each scenario affects the value of these production factors in a different way. In the case of the study region, such information can be valuable for the policy-makers at district and region levels when considering a policy option on the resource pricing, amounts of supplied resource to agricultural producers and the levels of production quota for cotton.

Shadow Price of Land. The land constraint is divided into different periods of the year to reflect the cropping calendar; the shadow values of land are, therefore, also presented in different seasons of the year. Although there is no official land market in Uzbekistan, the shadow prices for land are validated using information on unofficial rents observed during the period of farm and household surveys in Khorezm in 2003 and 2004 respectively. In case of modelling the agricultural sector of Khorezm, the shadow prices for land can be compared with the unofficial payment for renting one hectare of land for a short-period of rice cultivation. In Khorezm in 2003 and 2004, such payments were between 100 USD and 350 USD, depending on soil quality, field location and water availability.

Due to the large size of the full table of shadow values for land, two cases are presented in Table 5.6 for the discussion, while the full table is presented in Table A16 in Appendix 4. Similar to the previous section, these case studies include an aggregate of districts which border the river and an aggregate of districts which do not have direct access to the river. The shadow value of land is the highest in the seasons when it is sown to paddy rice, i.e. between July and September months. Additionally, this season is the peak period for land use since various crops compete with rice for land occupation during this period, including fodder crops, vegetables, melons and potato. Outside the peak period, land is valued very low or close to zero. When the land constraint is not binding, i.e. its value is zero, the agricultural producers' activities are constrained by endowments of other resources and the land is not fully sown. The shadow prices of land in the districts which have direct access to the river are generally higher than those located further from the river because of higher crop yields and lower shadow values of water. Moreover, in the base-run scenario, when the districts bordering with the river have the highest shadow value of land, the land value is zero in the districts which do not have direct access to the river. Thus, this shows that during the peak season of water use, in July, in the districts which do not have direct access to the river, some areas of land remain idle due to the shortage of water. Among agricultural producers, the value of land is highest for rural households, which cultivate crops in small household plots (see Section 2.2), and the value the least in large scale enterprises (*shirkat*s). As Table 5.6 shows, in the water scarce districts, the shadow values of land in *shirkat*s and private farms are smaller than those in rural households. Hence, even a slight decline in crop yields or an increase in costs, e.g. via an increase in input prices, can reduce the values of land to zero and other inputs may become constraining the production activities of producers. In the case when one type of agricultural producer does not fully cultivate the land, i.e. the value of the land is zero, and the activities of other producers are constrained by their land endowments, one may assume that the land could be transferred from the first producers to the latter. However, the model specification assumes that there is no land market (even unofficial) due to the fact that in Khorezm any transfer of land use rights between producers is prohibited and penalized by the government. Among the scenarios, in the one with improvement in water efficiency (Scenario 1) higher values of land in the water scarce districts are found, meaning that with the more water available to the agricultural producers, the value of land increases significantly. The introduction of water prices (Scenario 2) reduces the value of land for all agricultural producers among all modeled districts. In districts located next to the river, the value of land drops below its observed level, while in the water scarce districts it stays at the level above the base run situation. In this scenario, when the water prices are introduced, the cropping pattern might shift towards fodder crops, which require less water, and towards the animal sector. In the districts bordering the river, abolishment of state procurement for cotton and input market liberalization (Scenario 3) increase the value of land for *shirkat*s and private farms at a relatively higher rate rather than for the rural households. In this scenario, although the input prices rise, the land value increases due to the abolishment of the cotton production quota for *shirkat*s and private farms, and the release of fertilizer and diesel constraints for all three producer aggregates. At the same time, the cotton and input market liberalization does not affect significantly the value of land in the districts which do not have direct access to the river since water remains the significant limiting factor in that area.

Table 5.6: Shadow prices of land, USD ha $^{-1}$

District	Producer	Season	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	Jan-Jun	71	132	98	-	-	-	-
		Jul-Sep	327	524	323	435	-	337	-
		Oct	101	353	143	220	-	202	-
		Nov	-	-	-	57	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	92	162	129	-	147	-	93
		Jul-Sep	367	519	249	471	-	391	488
		Oct	92	306	206	269	-	128	291
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	265	346	260	291	229	293	299
		Jul-Sep	463	527	363	497	353	462	472
KKRSVT	SK	Jan-Jun	15	76	54	-	-	-	-
		Jul-Sep	-	480	324	-	-	105	-
		Oct	-	129	114	-	-	314	-
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	19	83	63	-	-	-	64
		Jul-Sep	-	493	351	-	-	67	367
		Oct	5	53	-	11	-	-	7
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	120	313	288	127	118	231	239
		Jul-Sep	-	456	382	-	-	-	395

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; HH – Rural households; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

The completion of the farm restructuring process (Scenario 4) increases the land endowments for private farms and, therefore, the shadow value of land on private farms drops or becomes zero. Increased production in the livestock sector (Scenario 5) also increases the shadow value of land. Although the input prices increase and the water price is introduced, one can observe that, among the simulations tested, the cumulative experiment (Scenario 6) produces one of the highest values for land.

Shadow Price of State Procurement. In the model, the state procurement constraint is imposed as a minimum restriction for area under cotton cultivation in *shirkat*s and private farms. Hence, the shadow price of the state procurement constraint is equal to the increase in regional income once the state quota for mandatory land allocation under cotton production is reduced by one hectare and their values are negative. The existence of a state quota on cotton production for *shirkat*s and private farms implies that these producers would not select, or select lower levels of this activity if they were not forced to do so (Müller 2006). In all scenarios except the ones where it is removed, the state procurement constraint forces the cotton growing activities in *shirkat*s and private farms to its mandatory levels. This means that under any exogenous change introduced during the simulations, cotton production remains unattractive for *shirkat*s and private farms and its production is only dictated by the level of state procurement constraint. According to the simulation results, the shadow value of the state procurement constraint is higher than the shadow value of land, which is given in multi-seasonal dimension. On the other hand, the state procurement constraint is given on an annual basis and, despite that there is no observed information which can be used to validate the shadow price of the state procurement constraint, its value can be assumed to be equal to the opportunity costs of land occupation through an entire agricultural cycle, which in Khorezm also implies a double cropping strategy of agricultural production, e.g. when winter wheat is followed by rice.

The base run results on values of state procurement constraint include valuable information for regional policy-makers. The shadow value for the state procurement quota is the highest for private farms in the base situation (Table 5.7) and, thus, one may conclude that the income of the regional agricultural sector might have higher benefits if the state procurement for cotton for private farms is reduced, rather than for *shirkat*s. Moreover, the districts which border the river have higher shadow values of state procurement both for *shirkat*s and private farms, than those in the districts which have no direct access to the river.

In case of improving the water efficiency (Scenario 1), the shadow value of state procurement in private farms decreases, meaning that other resources became more binding the production activities of private farms, as more water became available. At the same time, the value of the state procurement in *shirkat*s has increased, meaning that the state quota is more constraining for *shirkat*s' activities, as more water becomes available. Consequently, in case of a change in policy, one may argue that under improved water efficiency, the reduction of state procurement for cotton cultivation in *shirkat*s can bring a higher increase in regional income, than in case where the state quota imposed on private farms is reduced. The increase of producer costs after introducing water prices (Scenario 2) decreases the value of the state procurement constraint. This may indicate that the attractiveness of livestock keeping activities in the region increases and, in general, the GMs of crops decrease. The next simulation shows that, despite the increase of regional income in comparison to 2003, the increase of land endowment for private farms through the completion of the farm restructuring process (Scenario 4), the shadow value of state procurement will decrease. The reduction is due to the fact that although the state procurement for private farm increases, its share to total land endowment in private farms has declined. Hence, the availability of other inputs, e.g. water, fertilizers and diesel, becomes more binding the agricultural activities in private farms.

Table 5.7: Shadow prices of state procurement constraint, USD ha $^{-1}$

District	Producer	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	-523	-979	-523	-	-	-846	-
	PF	-1,139	-885	-505	-	-855	-1,016	-
KKAURG	SK	-425	-773	-531	-	-	-701	-
	PF	-1,255	-722	-431	-	-694	-1,158	-
YZRGLN	SK	-577	-776	-534	-	-	-681	-
	PF	-977	-650	-406	-	-538	-919	-
KVAYRK	SK	-487	-767	-467	-	-	-622	-
	PF	-812	-587	-329	-	-479	-792	-
KKRSVT	SK	-409	-626	-399	-	-	-607	-
	PF	-767	-518	-303	-	-457	-731	-

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Shadow Price of Water. According to the model specification, the shadow prices of water constraint vary by district and by month, but are equal among crops and agricultural producers. The validation of the shadow values of irrigation water is problematic for Khorezm since the water charging mechanism has not yet been introduced in Uzbekistan. Nevertheless, the calculated values of shadow prices for water are comparable to shadow prices for water obtained by Müller (2006). Additionally, these shadow prices meet the water charge levels practiced in agriculture of Morocco in 2003 (Chohin-Kuper et al. 2003) which was in the range of 20 USD per 1000 cubic meters to 50 USD per 1000 cubic meters of irrigation water. Dinar and Subramanian (1997) present the data for water charges in Namibia (3.8 USD per 1000 cubic meters to 28 USD per 1000 cubic meters), Algeria (19 USD per 1000 cubic meters to 220 USD per 1000 cubic meters), Tunisia (20 USD per 1000 cubic meters to 78 USD per 1000 cubic meters), Brazil (4.2 USD per 1000 cubic meters to 32 USD per 1000 cubic meters), the United States (12.4 USD per 1000 cubic meters to 43.8 USD per 1000 cubic meters) and Spain, all in 1996 (0.1 USD per 1000 cubic meters to 28 USD per 1000 cubic meters).

Table 5.8: Shadow prices of water, USD 10 $^{-3}$ m $^{-3}$

District	Month	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	May	1.5	-	-	1.6	-	-	-
	Jun	-	-	-	-	-	-	-
	Jul	-	-	-	16.6	9.2	-	9.1
	Aug	-	-	-	8.1	7.2	-	8.7
	Sep	-	-	-	-	-	-	-
KKAURG	May	-	-	-	-	-	-	-
	Jun	-	-	-	10.5	-	-	-
	Jul	-	-	-	15.7	8.7	-	7.9
	Aug	-	-	-	15.2	5.8	-	-
	Sep	-	-	-	-	-	-	-
YZRGLN	May	-	-	-	9.6	-	-	-
	Jun	3.5	-	-	-	13.1	-	-
	Jul	-	-	-	14.1	18.1	-	10.5
	Aug	-	-	-	-	16.8	-	-
	Sep	-	-	-	-	-	-	-
KVAYRK	May	-	-	-	5.1	2.2	-	4.0
	Jun	15.7	-	-	-	13.1	15.3	-
	Jul	24.8	11.1	-	29.6	26.1	22.5	-
	Aug	19.9	-	-	26.4	24.6	20.6	-
	Sep	-	-	-	-	-	-	-
KKRSVT	May	2.7	-	1.4	-	3.4	4.4	1.2
	Jun	6.2	-	-	-	4.6	-	2.6
	Jul	25.6	10.6	2.9	32.6	23.5	24.8	21.7
	Aug	23.1	-	-	30.3	22.9	23.9	13.6
	Sep	-	-	-	3.0	-	-	-

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

For all simulations, the shadow value of water, i.e. the water scarcity indicator, is highest in the districts without direct access to the river. Among the irrigation months, the highest shadow price for water is observed in periods when the field is under rice production, i.e. July and August (Table 5.8). Accordingly, if the water pricing mechanism is introduced in Khorezm, it may have values which vary across irrigation months. According to the simulation results, if the water pricing system is to be introduced in Khorezm, any small value of water charge will affect the total water use in districts with abundant water. At the same time, to reduce the total amount of water use in districts which do not have direct access to the river, the value of water charge should be above the shadow price of water. The districts bordering with the river are not constrained by water in the base run scenario. Although the same amount of water results in higher marginal productivity, the improvement of water efficiency (Scenario 1) reduces the value of water and the shadow values of other inputs, e.g. land, fertilizer and diesel, may increase. The introduction of water prices (Scenario 2) decreases the value of water due to the decline in total regional income. The shadow value of water increases after the liberalization of cotton and input markets (Scenario 3) and completion of the farm restructuring program (Scenario 4).

The liberalization of cotton and input markets allows *shirkat*s and private farms to allocate land, which was previously reserved for cotton cultivation by the state procurement quota, to other more profitable and more water consuming cropping activities which is paddy rice cultivation. Complete decollectivization increases the land, fertilizer and diesel endowments for private farms and does not change the amount of water available to the region. Moreover, although the area under state procurement remains at the base level, the completion of farm restructuring gives private farms additional land for the cultivation of paddy rice. Most surprisingly, the highest values of water are observed in the case where state procurement for cotton cultivation is removed and prices are increased. An improvement of the livestock sector (Scenario 5) contributed to the value of water via an increase of livestock productivity which depends on the cultivation of fodder crops.

Shadow Price of Labor. In the model specification, the shadow price of labor is equal to the agricultural wage for which *shirkat*s and private farms hire one working hour of labor from rural households. Since labor is transferable input between districts, its value differs according to the transport costs within the observed range of wages between 47.9 to 51.4 USD per 1000 working hours. Furthermore, the shadow price of labor is equal to the price for leisure time (see Section 3.5). Hence, the model assumes that the utility of rural household consumers is defined over their income and leisure according to which they shift their available time between work and leisure until the ratio of the marginal utility of leisure to the marginal utility of income is equal to the wage rate. The shadow value of labor, i.e. leisure price, is driven by the dominance of an income effect over a substitution effect for leisure. The changes in shadow values of labor through scenarios are presented in Table 5.9. The improvement of water efficiency (Scenario 1) increases the opportunity of agricultural producers to expand the area under cultivation, thereby increasing the demand for labor and decreasing the agricultural wage. The introduction of water prices (Scenario 2) makes livestock sector, which is less labor intensive, more attractive and, thus, releases labor from *shirkat*s and private farms increasing the agricultural wage. According to the results for the cotton and input market liberalization (Scenario 3) and completion of farm restructuring (Scenario 4), it appears that the high reliance on mechanization during field preparation and cultivation can also reduce the labor demanded for agriculture, while increasing the wage. The improvement of the livestock sector also releases labor from *shirkat*s and private farms since the livestock keeping become more attractive to those producers. Although the water efficiency improved in cumulative experiment (Scenario 6), the income losses from introduction of water price dominate over the gains from increase in water efficiency. This is observable though decline of shadow values of all resources except for the price of labor.

Table 5.9: Shadow prices of labor, USD 10^{-3} h^{-1}

District	Producer	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	51.4	49.5	57.1	65.7	-	52.1	-
	PF	51.4	49.5	57.1	65.7	57.5	52.1	68.5
	HH	51.4	49.5	57.1	65.7	57.5	52.1	68.5
KKAURG	SK	48.8	46.3	55.8	61.4	-	52.8	-
	PF	48.8	46.3	55.8	61.4	54.5	52.8	69.5
	HH	48.8	46.3	55.8	61.4	54.5	52.8	69.5
YZRGLN	SK	50.2	49.4	55.2	64.3	-	50.5	-
	PF	50.2	49.4	55.2	64.3	55.0	50.5	72.4
	HH	50.2	49.4	55.2	64.3	55.0	50.5	72.4
KVAYRK	SK	50.5	48.5	55.8	60.9	-	53.8	-
	PF	50.5	48.5	55.8	60.9	52.3	53.8	71.4
	HH	50.5	48.5	55.8	60.9	52.3	53.8	71.4
KKRSVT	SK	47.9	47.0	59.1	56.9	-	49.3	-
	PF	47.9	47.0	59.1	56.9	57.9	49.3	68.3
	HH	47.9	47.0	59.1	56.9	57.9	49.3	68.3

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; HH – Rural households; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

As the next section shows, being charged for water the *shirkat*s and private farms shifted their cropping pattern from cash crop production towards fodder crops and the expansion of livestock production, both of which require relatively less labor. In all cases, the decrease in rural household income driven by the shift in cropping pattern was compensated by the increase of the agricultural wages, even if some amount of rural household labor was released by *shirkat*s and private farms. Due to the high density of the rural population in Khorezm, the shadow price of labor is relatively low compared to wages in the agricultural sector of developed countries. Most interestingly is that the ratio of shadow values of land (Table 5.6) to labor (Table 5.7) is high. This can be supported by the fact that in the Khorezm region the population density per arable land is high (see Section 2.4.2) and labor is not a significant limiting factor to agricultural production in the rural areas.

Shadow Price of Nitrogen Fertilizer. The shadow value of fertilizer presented in this study is a shadow price of nitrogen fertilizer in physical equivalents for the chemical composition of applied fertilizers. In the base situation, the nitrogen fertilizer does not constrain the cropping activities of rural households and *shirkat*s (Table 5.10). The first apply manure to their plots as an additional fertilizer. The latter are state controlled enterprises and receive a large amount of fertilizer from state controlled organizations.

Table 5.10: Shadow prices of nitrogen fertilizer, USD t $^{-1}$

District	Producer	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	-	-	-	800	-	-	-
	PF	655	690	579	800	-	612	800
	HH	-	720	651	800	-	-	800
KKAURG	SK	-	-	-	800	-	-	-
	PF	640	685	596	800	-	571	800
	HH	-	731	689	800	-	-	800
YZRGLN	SK	-	-	-	800	-	-	-
	PF	590	661	591	800	-	565	800
	HH	-	741	673	800	-	-	800
KVAYRK	SK	-	-	-	800	-	-	-
	PF	533	620	558	800	-	528	800
	HH	-	674	614	800	-	-	800
KKRSVT	SK	-	-	-	800	-	-	-
	PF	528	609	538	800	-	516	800
	HH	-	645	602	800	-	-	800

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; HH – Rural households; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Due to higher agricultural productivity, the districts located next to the river have a higher value of fertilizer in comparison to the districts located far from the river. After the improvement of water efficiency (Scenario 1), when more water becomes available, the availability of fertilizer starts binding the cropping activities of the rural households in all modeled districts. Moreover, among the three types of producers, the value of nitrogen fertilizer becomes the highest in rural households. The introduction of water prices (Scenario 2) and improvement of livestock productivity (Scenario 5) reduces the value of nitrogen fertilizer in private farms. When the input markets are liberalized (Scenarios 3 and 6), the shadow value of fertilizer is equal to the value introduced as a new price system for nitrogen fertilizer. The results of all simulations show that crop production in *shirkat*s is not constrained by availability of nitrogen fertilizer, but rather by their land and water availability at the districts level.

Shadow Price of Diesel. In the base situation, diesel does not constrain the cropping activities of *shirkat*s which receive a sufficient amount of diesel from the state controlled organization (Table 5.11). Diesel is a constraining input in private farms and households. Like in the case of nitrogen fertilizer, due to higher agricultural productivity, the districts bordering with the river have a higher value of diesel in comparison to the districts which have no access to the river.

Table 5.11: Shadow prices of diesel, USD t^{-1}

District	Producer	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	-	-	-	200	-	-	-
	PF	201	214	176	200	-	146	200
	HH	224	276	183	200	221	-	200
KKAURG	SK	-	-	-	200	-	-	-
	PF	209	222	189	200	-	137	200
	HH	228	289	196	200	227	-	200
YZRGLN	SK	-	-	-	200	-	-	-
	PF	204	218	184	200	-	144	200
	HH	227	281	191	200	229	-	200
KVAYRK	SK	-	-	-	200	-	-	-
	PF	195	209	173	200	-	142	200
	HH	212	272	179	200	214	-	200
KKRSVT	SK	-	-	-	200	-	-	-
	PF	198	212	173	200	-	144	200
	HH	213	275	182	200	218	-	200

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; HH – Rural households; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

After the improvement of water efficiency (Scenario 1), the value of diesel constraints increases both for private farms and rural households in all modeled districts. Moreover, the value of diesel remains higher in rural households. This because the improvement of water efficiency implies also increase of crop yields while the diesel use rates are kept fixed at their observed levels. When the input markets are liberalized (Scenario 3), the shadow value of diesel is equal to the value introduced as a new price system for diesel market. The simulation results show that crop production in *shirkat*s remains unconstrained by diesel, but rather by their land and water availability at district level. Most interestingly, the shadow values of diesel and nitrogen fertilizers are higher than their observed values for Khorezm in 2003. The considerable differences between shadow prices and observed values[19] can indicate the failure of the market[20] to supply necessary quantities of diesel and fertilizer to agricultural producers. As follows from the farm survey conducted by the author in Khorezm in 2003, the higher values of fertilizer and diesel in districts located far from the river may be caused by delayed availability of these inputs and by their scarcity.

5.7.3 Production Activities

In each scenario, the shift in the levels of production activities is related to the changes in their GMs. Depending on producers' resource endowments and water availability in districts, the fields cleared after winter wheat are used for rice or fodder cultivation in a second cropping cycle. Therefore, producer's total area of cropping activities can be greater than total land endowment. The relative changes of production activities in each scenario to the base situation are presented for two modeled district aggregates (Table 5.12). For the full results on production activities see Table A20 in Appendix 4 to this thesis. Due to the applied calibration approaches, in the base run, the production activity levels replicate exactly the observed situation in Khorezm in 2003. The improvement in water efficiency (Scenario 1) means more water is available for agricultural producers. Although, the production of paddy rice increases in all districts, its highest relative increase is observed in the districts which have no direct access to the river, i.e. the areas where the rice cultivation is constrained by low water availability. Furthermore, the increase in rice cultivation area in *shirkat*s and private farms is mostly at the expense of area under fodder crops, which in its turn might lead to the decrease in number of livestock. For rural household plots, water efficiency, which also implies an increase in crop yields, substitutes the fruit production in attached household plots (*uy tomorqa*) by potato and vegetables.

[19] In 2003 in Khorezm the price of diesel and nitrogen fertilizer was 110 USD and 500 USD per ton respectively.
[20] In case of Khorezm, special state companies function as fertilizer and diesel distributing agencies.

Table 5.12: Production activity levels in the districts

Producer	Activity		KSPBGT							KKRSVT						
			BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
				changes to base (in percent)												
SK	CTN	10^3 ha	17.565	0	0	-70	-	0	-	16.654	0	0	-75	-	0	-
	WWT	10^3 ha	5.186	10	-33	-100	-	-9	-	6.065	12	-14	-100	-	-10	-
	RCE	10^3 ha	1.772	8	-70	158	-	9	-	1.497	28	-40	226	-	-5	-
	POT	10^3 ha	0.064	156	-63	245	-	63	-	0.143	339	272	329	-	280	-
	FRT	10^3 ha	0.159	1	-36	92	-	0	-	0.205	61	-73	120	-	-100	-
	VGL	10^3 ha	0.346	335	520	3,482	-	149	-	0.680	33	50	2,211	-	34	-
	MZE	10^3 ha	0.027	0	548	2,817	-	45	-	0.051	-7	70	106	-	126	-
	FOD	10^3 ha	1.104	-53	3	-100	-	25	-	1.845	-55	5	-100	-	31	-
	MLK	10^3 head	0.729	-71	-58	44	-	99	-	0.565	-67	61	-80	-	113	-
	EGG	10^3 head	2.540	48	20	34	-	-24	-	5.846	-7	23	42	-	-27	-
	MEA	10^3 head	1.648	-63	49	49	-	30	-	1.489	-13	25	36	-	72	-
PF	CTN	10^3 ha	1.708	0	0	-29	1,028	0	1,000	5.959	0	0	-48	279	0	-100
	WWT	10^3 ha	1.134	20	0	1	457	0	150	3.346	-5	0	36	131	0	454
	RCE	10^3 ha	3.749	11	-14	24	58	11	67	1.336	41	-19	121	-21	20	262
	POT	10^3 ha	0.010	-80	-40	-90	410	40	-100	0.023	774	-100	239	3,655	-100	-100
	FRT	10^3 ha	0.098	105	-100	-100	2	-11	-100	0.150	-93	-100	-100	34	-100	-100
	VGL	10^3 ha	0.045	112	-84	502	791	256	-38	0.201	276	-74	988	456	25	4,448
	MZE	10^3 ha	0.007	0	-100	43	386	-2	-100	0.091	-11	220	-100	276	0	-100
	FOD	10^3 ha	0.677	9	166	-100	18	18	333	1.496	-2	26	-100	270	20	194
	MLK	10^3 head	1.056	-2	17	-8	14	55	128	1.377	-5	37	-54	410	34	481
	EGG	10^3 head	4.890	0	-58	27	81	-11	-67	3.901	-16	6	-63	171	-53	143
	MEA	10^3 head	3.458	-3	33	-25	63	30	71	4.556	0	6	-53	19	22	49
HH	WWT	10^3 ha	3.965	0	0	0	0	0	0	3.400	0	0	0	0	0	0
	RCE	10^3 ha	1.336	8	-40	-3	0	-14	-85	0.141	502	-41	71	326	228	-100
	POT	10^3 ha	0.126	110	60	77	24	2	419	0.567	-53	-81	3	-58	-100	-90
	FRT	10^3 ha	0.293	-80	-85	-86	-45	-4	-100	0.230	-11	-20	-100	-100	-72	-100
	VGL	10^3 ha	0.838	24	21	-49	12	0	-28	0.746	44	68	29	75	36	68
	MZE	10^3 ha	0.113	0	177	0	-1	-7	259	0.291	-1	-17	0	-1	-56	52
	FOD	10^3 ha	0.768	0	26	65	5	38	109	1.607	-25	3	-6	-16	20	21
	MLK	10^3 head	37.069	3	5	11	0	7	5	36.879	-1	1	0	0	8	9
	EGG	10^3 head	225.527	0	13	0	7	5	3	274.516	-2	-17	0	-14	-18	1
	MEA	10^3 head	83.737	1	5	18	3	50	-2	93.305	-1	0	-1	0	5	1

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CTN – Cotton; WWT – Winter wheat; RCE – Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Cows; EGG – Poultry; MEA – Bulls; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

In the case of improving the water efficiency with introduced water pricing (Scenario 2), the rice production drops in all districts. In *shirkat*s, the rice cultivation is substituted by vegetable production, while in rural households it is substituted by fodder crops. In most cases, an increase in the price of water (i.e. the introduction of a price for water) shifts the cropping pattern towards less water intensive crops, i.e. for fodder, and therefore, livestock production increases. This leads to reduction of total water use in all districts and shifting towards less water intensive cropping structure. By improving water efficiency and with the introduction of subsidized water pricing for cotton (see Section 5.2), the area sown to cotton does not increase. In cotton and input market liberalization (Scenario 3), the raw cotton price is increased exogenously by 28%. Thus, despite the absence of subsidies for diesel and fertilizers, the cotton production in some districts reduces, but does not become zero. The area under potato and rice production, both in *shirkat*s and private farms, increases due to the removal of the state procurement quota for cotton cultivation, while the livestock sector is positively affected by an increase in factor prices which decreased the gross margins of most cropping activities. After accomplishment of farm restructuring process (Scenario 4), private farms in districts bordering the river produce more rice in the place of potatoes, fruits and fodder crops. At the same time, the private farms in districts without direct access to the river reduce cultivated area under rice and increase the production of potatoes, vegetables and fodder crops. The area under rice in rural households in districts located further from the river increases at the expense of fodder crops. The improvement of livestock productivity (Scenario 5) increases the area under fodder crops at the expense of rice, wheat, potato and fruits. Due to the absence of alternative options for the first crop in the double cropping system, in all scenarios no changes are observed in areas under winter wheat in distant plots of rural households (*qushimcha tomorqa*). Most interestingly, in case of cumulative scenario in Scenario 6, cotton cultivation in private farms does not decrease drastically in districts with abundant water, while in districts with water scarcity its cultivated area becomes zero.

Cotton production as a share of regional agriculture remains very sensitive to a reduction in the state procurement (Table 5.13). Introduction of all exogenous shocks at once (Scenario 6) reduces the total land cultivated under cotton and rice in favor of fodder production and increases livestock production in the region. Thus, in the cumulative scenario, although the cotton and input markets are liberalized, the introduction of water prices leads to a decrease in land use and the cropping pattern shifts towards less water intensive crops and towards livestock production. The water pricing, input market liberalization, farm restructuring and increase in livestock productivity negatively affect the total area under wheat production. At the same time, more land is allocated under rice cultivation in all scenarios except the scenario when water prices are introduced, and the state procurement for cotton is not abolished. In fact, the cotton market liberalization almost doubles the area under rice.

The introduction of water prices reduces the area under potato production as producers find it more attractive to engage in livestock production and, thus, increase the area under fodder. Introduction of water prices, farm restructuring and improvement of livestock productivity, all decrease the area under fruit production in favor of vegetable cultivation. In fact, vegetable production benefits all scenarios, especially when the cotton market is liberalized under increased input prices. Similar to vegetables, maize production increases except in the case of increased livestock productivity. When the livestock productivity increases, producers prefer to increase the production of short season fodder crops which are used for feeding their livestock. The number of livestock in the region increases in all scenarios due to improvements in its productivity, similarly, when there is an increase in fodder crop yields, a rise in factor prices, and introduction of water charges for rice production in rural households.

Table 5.13: Production activity levels in the Khorezm region

Activity		**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
			changes to base (in percent)					
CTN	10^3 ha	97.7	0	0	-67	0	0	-72
WWT	10^3 ha	50.8	4	-12	-45	-6	-4	15
RCE	10^3 ha	27.2	17	-30	90	1	3	9
POT	10^3 ha	2.9	25	-3	63	56	-11	12
FRT	10^3 ha	2.5	13	-19	5	-34	-15	-23
VGL	10^3 ha	8.5	66	84	726	16	14	382
MZE	10^3 ha	1.7	24	69	87	39	-1	-10
FOD	10^3 ha	16.4	-13	9	-52	-4	33	55
MLK	10^3 head	202.1	0	4	8	3	1	12
EGG	10^3 head	1,437.6	-4	0	5	-5	-7	-7
MEA	10^3 head	492.3	0	3	3	2	19	4

Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Cows; EGG – Poultry; MEA – Bulls; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

The complete table of producers' profits is given in Table A21 in Appendix 4. In the base situation, unlike in *shirkat*s and private farms, the total profit of rural households from livestock keeping activities dominates over those from crop growing activities (Table 5.14). While the profit per hectare of rural households seems exceptionally large, one needs to bear in mind that this type of producer is the smallest in Uzbekistan, with average holdings of 0.19 hectare of arable land (see Section 2.2). The structure of total agricultural profits of each producer group remains over all simulations. Improvement of water efficiency (Scenario 1) produces the highest profit per hectare for all producers in all districts due to the increase of crop yields and reduction of costs related to irrigation. At the same time the introduction of water prices (Scenario 2) gives the highest decrease in producers' profits per hectare. The market liberalization (Scenario 3) increases profits from cropping activities in *shirkat*s because more land becomes available for more profitable cropping activities after the state procurement for cotton is removed. At the same time, market liberalization decreases profits from crop growing activities per hectare in private farms and rural households due to the increase of factor prices. The increase in factor prices shifts the production activities of rural households towards livestock production. Thus, although the profits from the animal sector for private farms drops, in rural household the profits from animal keeping activities increase.

Table 5.14: Profits from agricultural production activities

Producer	Activity		KSPBGT							KKRSVT						
			BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
				changes to base (in percent)												
SK	CROP	10^3 USD	6,858	47	-30	156	-100	11	-100	6,581	37	-38	168	-100	5	-100
	ANIMAL	10^3 USD	282	-63	19	58	-100	74	-100	318	-25	34	16	-100	107	-100
	TOTAL	10^3 USD	7,140	43	-28	153	-100	13	-100	6,899	34	-34	161	-100	10	-100
	CROPHA	USD ha^{-1}	262	40	-27	185	-100	8	-100	242	32	-36	180	-100	4	-100
	TOTHA	USD ha^{-1}	272	36	-25	181	-100	11	-100	254	30	-33	172	-100	8	-100
PF	CROP	10^3 USD	4,700	23	-61	-8	227	16	-41	3,081	41	-52	-3	147	7	-38
	ANIMAL	10^3 USD	603	-3	26	-13	73	62	155	879	-1	13	-50	180	70	221
	TOTAL	10^3 USD	5,302	20	-51	-9	209	21	-19	3,960	32	-37	-13	154	21	19
	CROPHA	USD ha^{-1}	633	11	-64	-7	-26	7	-86	245	31	-52	-5	-21	3	-79
	TOTHA	USD ha^{-1}	714	8	-54	-7	-30	11	-81	314	23	-37	-15	-19	17	-59
HH	CROP	10^3 USD	3,952	22	-22	-39	9	-3	-49	2,873	47	0	-37	27	7	-22
	ANIMAL	10^3 USD	33,676	1	6	23	21	58	35	33,059	-1	0	6	29	37	30
	TOTAL	10^3 USD	37,628	3	3	16	20	51	26	35,931	3	0	2	29	35	26
	CROPHA	USD ha^{-1}	531	19	-20	-38	8	-5	-49	411	-2	1	2	25	35	24
	TOTHA	USD ha^{-1}	5,058	0	5	18	19	49	26	5,146	41	1	-37	24	7	-24
DIST	CROP	10^3 USD	15,510	34	-37	57	27	9	-69	12,535	40	-32	79	-10	6	-67
	ANIMAL	10^3 USD	34,561	0	6	22	21	58	36	34,256	-1	1	4	32	39	34
	TOTAL	10^3 USD	50,070	11	-7	33	23	43	3	46,791	10	-8	24	21	30	7
	TOTHA	USD ha^{-1}	1,219	5	-6	43	25	38	11	1,001	5	-7	27	21	28	13
	CROPHA	USD ha^{-1}	377	26	-36	68	29	5	-67	268	34	-31	82	-10	4	-65

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CROP – total profits of producer from crop growing activities; ANIM – Total profits from livestock and poultry keeping activities; TOTAL – Total profits from crop growing and livestock and poultry rearing activities; TOTHA – Total profit per hectare of sown area; CROPHA – Profit from cropping activities per hectare of sown area; KSPBGT – KKRSVT – Aggregate for Kushkupir and Shavat districts; Base – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Most interestingly, in districts with abundant water, the benefits are higher in case of the elimination of state procurement for cotton and farm restructuring reforms, while the districts with water scarcity have higher benefits in case of improving water efficiency and increasing the productivity of the livestock sector. The modeled districts and the region, in general, are better off in case of improvement in water efficiency (Scenario 1), development of the livestock sector (Scenario 5), farm restructuring (Scenario 4) and market liberalization (Scenario 3). While in the cumulative scenario (Scenario 6), the decrease of district and regional profits from cropping activities are compensated by the profit increase from the livestock sector, the introduction of water pricing (Scenario 2) decreases the profits from crop growing at levels for which the profit increase in the livestock sector cannot fully compensate.

5.7.4 Land and Water Use

An important question in the context of this research is related to the effects of selected policies on land and water use in the region. The full simulation results on land and water use are presented in Table A18 in Appendix 4. As Table 5.15 shows, in the base-run simulation, the districts bordering the river use more water per hectare than those without direct access to the river. At the same time, the private farms with the highest share of area sown to rice have the highest water use per hectare among the producers.

Table 5.15: Land and water use

Districts	Producer	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
			change to base (in percent)					
Land Use (10^3 ha)								
KSPBGT	SK	26.2	1.2	-0.1	-0.1	-	-0.1	-
	PF	7.4	-0.1	-0.6	2.0	342.7	1.1	364.6
	HH	7.4	-0.3	-0.5	0.1	0.0	-0.9	0.8
KKRSVT	SK	27.1	10.2	9.5	-2.7	-	0.3	-
	PF	12.6	9.9	9.7	-4.1	213.1	1.6	249.9
	HH	7.0	10.2	9.5	4.3	0.5	3.1	10.7
REGION	ALL	207.7	5.7	0.3	-2.3	-0.4	1.5	-3.9
Water Use (10^6 m^3)								
KSPBGT	SK	479.8	-5.1	-11.3	1.2	-	-0.1	-
	PF	141.0	-8.1	-11.9	3.0	336.4	-1.1	315.6
	HH	133.5	-5.8	-2.7	-2.6	-0.1	-3.6	-4.8
KKRSVT	SK	473.7	0.0	-0.5	0.1	-	0.0	-
	PF	232.6	-0.1	-0.9	0.1	173.5	-0.1	172.1
	HH	121.0	0.0	0.0	0.1	0.1	-0.1	-0.4
REGION	ALL	5,968.9	-4.1	0.0	2.4	6.8	8.8	-11.1
Water Use (10^3 m^3 ha^{-1})								
KSPBGT	SK	18.3	-6.2	-11.2	1.3	-	0.0	-
	PF	19.0	-7.9	-11.3	1.0	-1.4	-2.2	-10.5
	HH	17.9	-5.5	-2.2	-2.8	-0.1	-2.7	-5.6
KKRSVT	SK	17.5	-9.2	-9.1	2.9	-	-0.3	-
	PF	18.5	-9.1	-9.7	4.4	-12.6	-1.7	-22.2
	HH	17.3	-9.3	-8.7	-4.1	-0.5	-3.2	-10.0
REGION	ALL	18.0	-6.4	-7.5	2.8	-3.0	-2.5	-12.1

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; REGION – Khorezm region; SK – *Shirkat*s; PF – Private farms; HH – Rural households; ALL – All agricultural producer groups; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Simulations which reduce the value of crop gross margins (Scenarios 2, 3 and 6) decrease the land and water use in the Khorezm region compared to the base situation. Improving the water use efficiency (Scenario 1) decreases the total water consumption in the districts with direct access to the river. Despite greater water availability in this scenario, land remains the main restraining factor in these districts. In contrast, the improvement of water efficiency in districts without direct access to the river increases the total sown area. Consequently, the total water use in those districts does not drop significantly. The introduction of water prices (Scenario 2) shifts the cropping pattern towards less water intensive crops and the total water use in both districts declines while the total sown area may increase. Liberalization of cotton and input markets (Scenario 3) does not increase the cultivated area in *shirkat*s which are considered fertilizer and diesel abundant producers in Khorezm, while the sown area in private farms and household producers, which receive a relatively low amount of fertilizer and diesel, increases significantly. Removing the state procurement quota for cotton increases rice cultivation in *shirkat*s and private farms significantly. This new cropping pattern leads to higher water use per hectare in water abundant districts, while land remains the limiting factor of production. In contrast, *shirkat*s and private farms in the districts without direct access to the river reduce the total cultivated area in favor of rice production. The decline in water use per hectare in private farms after the completion of the farm restructuring process (Scenario 4) is due to the increased procurement quota for cotton. The improvement in livestock productivity (Scenario 5) shifts the production activities towards fodder cultivation and, thus, leads to a slight increase in the cultivated area in the districts located far from the river. In the case multiple policies are implemented simultaneously (Scenario 6), the water use in the district with direct access to the river decreases; the cropping pattern in these districts shifts towards less water intensive crops. At the same time, the cultivated area in rural households in districts without direct access to the river is the largest in Scenario 6. This shows that, despite the increase in factor prices, water use efficiency and market liberalization improve conditions for increasing the cultivated area in these districts.

5.7.5 Use of Other Production Factors

Table 5.16 shows the changes in input use per hectare in two selected district aggregates. In the presented table, the production costs per hectare are total costs of crop growing and animal keeping activities of all producers in a district aggregate divided by total sown area in the district aggregate. In the base situation, the districts without direct access to the river have higher application rates for the listed inputs than those which border the river. Improving water efficiency (Scenario 1) increases the total sown area in districts where cropping activities are constrained by water availability; thereby leading to a decrease in labor, nitrogen fertilizer and diesel use in those districts. Increased water efficiency does not, however, significantly affect application rates of these inputs in districts with direct access to the river where water is an abundant production factor. Although the water efficiency is improved, the introduction of water prices (Scenario 2) will decrease the input application rates in all districts. This indicates that the agricultural producers shift their cropping patterns towards cropping activities which require less intensive use of these inputs, i.e. fodder crops, and find livestock keeping activities more attractive. Abolishment of state procurement for cotton and liberalization of input market (Scenario 3) reduce the labor use per hectare in all districts due to a significant reduction in cultivated area under cotton which among the most labor intensive crops in Khorezm. Furthermore, more nitrogen fertilizers and diesel become available for private farms and households, shifting their cropping pattern towards more profitable crops with lower requirements in labor and higher requirements in fertilizer and diesel such as rice, potato and vegetables. Under the scenario of accomplishment of farm restructuring process (Scenario 4) there is a decrease in the labor demand in the agricultural sector mostly because private farms, if compared to *shirkat*s, use labor less intensively and more intensively fertilizer and machinery. The reduction in labor use is can be seen by the increase of fertilizer and diesel use per hectare in all districts.

Table 5.16: Labor, nitrogen fertilizer and diesel use

Parameter	District	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
			change to base (in percent)					
LABRHA	KSPBGT	1,920	1.1	-2.6	-9.2	0.5	1.2	-11.4
(h ha^{-1})	KKRSVT	1,983	-7.0	-9.3	-5.5	0.4	0.6	-17.3
	REGION	1,932	-5.4	-0.3	-7.6	0.4	1.1	-17.9
FERTHA	KSPBGT	210	0.7	-3.6	8.2	1.6	-3.6	2.0
(kg ha^{-1})	KKRSVT	211	-8.5	-9.0	5.8	0.5	-3.0	-4.7
	REGION	210	0.6	-7.3	7.7	1.6	-3.9	0.7
DISLHA	KSPBGT	244	0.0	-2.4	7.3	1.9	-3.8	4.0
(kg ha^{-1})	KKRSVT	237	-4.6	-6.1	5.2	0.9	-2.5	-8.1
	REGION	238	-2.1	-3.7	5.5	1.0	-1.8	1.9
COSTHA	KSPBGT	399	1.3	47.9	24.7	5.1	-4.1	66.2
(USD ha^{-1})	KKRSVT	394	1.2	44.8	23.0	5.5	-3.5	66.0
	REGION	397	-1.3	42.1	19.8	3.9	-3.3	57.8

Notes: LABRHA – Labor use in the agricultural production per hectare; FERTHA – Nitrogen fertilizer applied per hectare; DISLHA – Diesel used per hectare; COSTHA – Total costs of agricultural production per hectare; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; REGION – Khorezm region; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Improvement in livestock productivity (Scenario 5) increases livestock production and area under fodder crops and, thus, similarly puts downward pressure on rural employment. Moreover, in this scenario, a shift in cropping patterns towards fodder crops causes a slight decrease in fertilizer and diesel use rates in all districts. The cumulative application of all exogenous changes (Scenario 6) decreases employment in the agricultural sector in all districts. In contrast to the districts which have direct access to the river, the production activities in those with water scarcity shift towards the fodder production and livestock keeping and, thus, fertilizer and diesel use in these districts declines.

5.7.6 Regional Commodity Balance and Prices

The commodity prices change within a limit defined by the commodity prices outside of the region and the transportation costs fulfilling the arbitrage condition (Table 5.17).

Table 5.17: Commodity prices

Commodity	District	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
			change to base (in percent)					
WWT	KSPBGT	104	4	3	4	1	-4	3
(USD t^{-1})	KKRSVT	107	4	3	4	2	-4	3
RCE	KSPBGT	264	4	14	4	4	3	2
(USD t^{-1})	KKRSVT	254	4	14	4	6	3	3
POT	KSPBGT	86	5	5	5	5	5	3
(USD t^{-1})	KKRSVT	89	5	6	5	8	4	4
FRT	KSPBGT	41	4	5	5	5	-4	3
(USD t^{-1})	KKRSVT	43	4	5	4	7	-4	3
VGL	KSPBGT	104	3	4	3	4	4	1
(USD t^{-1})	KKRSVT	102	3	3	5	5	4	5
MLK	KSPBGT	155	-2	-2	7	19	-3	4
(USD t^{-1})	KKRSVT	149	-2	-2	6	27	-3	4
EGG	KSPBGT	56	1	1	3	14	6	1
(USD 10^{-3} $piece^{-1}$)	KKRSVT	54	1	1	6	16	6	2
MEA	KSPBGT	1,877	-2	-2	8	18	-8	5
(USD t^{-1})	KKRSVT	1,792	-2	-2	8	28	-5	4
OTH	KSPBGT	990	0	0	0	0	0	0
(USD t^{-1})	KKRSVT	1,025	0	0	0	0	0	0
MFR	KSPBGT	990	0	0	0	0	0	0
(USD t^{-1})	KKRSVT	1,025	0	0	0	0	0	0
LSR	KSPBGT	51	-4	11	28	12	-1	33
(USD 10^{-3} h^{-1})	KKRSVT	48	-2	23	19	21	3	43

Notes: WWT – Winter wheat; RCE –Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MLK – Milk; EGG – Eggs; MEA – Meat; LSR – Leisure; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

The regional production and consumption of the commodities is presented in Table 5.17 and Table 5.18. The full data on consumption and prices is given in Table A17 in Appendix 4.

Table 5.18: Regional commodity production and consumption

Commodity		**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
Production			change to base (in percent)					
CTN	10^3 t	153.0	10	10	-66	7	0	-58
WWT	10^3 t	184.0	14	-5	-37	-1	-3	29
RCE	10^3 t	119.0	28	-27	84	6	1	23
POT	10^3 t	39.2	36	2	51	31	-14	24
FRT	10^3 t	38.1	24	3	15	-39	-8	-1
VGL	10^3 t	164.0	73	93	628	8	12	326
MZE	10^3 t	5.4	33	72	103	24	-3	9
FOD	10^3 t	211.8	0	11	-40	9	31	105
MLK	10^3 t	427.3	0	3	7	2	19	31
EGG	10^3 pieces	131.6	-3	2	9	-16	-5	-18
MEA	10^3 t	64.2	1	2	3	2	44	24
OTH	10^3 t	-	-	-	-	-	-	-
MFR	10^3 t	-	-	-	-	-	-	-
LSR	10^6 h	-	-	-	-	-	-	-
Consumption / Animal Feeding			change to base (in percent)					
CTN	10^3 t	-	-	-	-	-	-	-
WWT	10^3 t	247.3	-2	-1	-2	-1	3	-2
RCE	10^3 t	19.5	-6	-14	-6	-9	-6	-4
POT	10^3 t	63.8	-3	-4	-3	-5	-3	-2
FRT	10^3 t	74.4	-2	-2	-2	-3	3	-1
VGL	10^3 t	132.4	-2	-3	-3	-3	-3	-3
MZE	10^3 t	14.4	-4	0	5	-5	-7	-7
FOD	10^3 t	2,083	0	3	4	2	36	28
MLK	10^3 t	198.5	2	2	-4	-8	5	-3
EGG	10^3 pieces	80.5	-2	-2	-6	-14	-8	-3
MEA	10^3 t	34.4	1	1	-3	-5	4	-1
OTH	10^3 t	48.3	0	0	10	12	1	8
MFR	10^3 t	271.2	0	0	27	7	4	28
LSR	10^6 h	205.2	-5	7	17	5	0	31

Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Milk; EGG – Eggs; MEA – Meat; OTH – Other food commodities; MFR – Non-food manufactured commodities; LSR – Leisure; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Total regional leisure consumption in rural households increases in all scenarios except in one with improvement of water efficiency, where unemployment among rural workers decreases at lower wage levels (Table 5.17). This indicates that the selected setting of demand in the model establishes a positive relation between agricultural wage and leisure consumption. According to this, the increase in wages leads to increase of rural households' income and, therefore, increases leisure consumption. Thus, the total income of rural household consumer increases enough to compensate this decline on overall employment in the agricultural sector and, thus, to increase the total consumption of leisure. This means the positive income effect in rural households outweighs a negative price effect in leisure consumption. Regional export and import values are related to changes in values of production activities in *shirkat*s, private farms and rural households, as well as commodity consumption by rural and urban households. In the base situation, the region is an exporter of cotton, rice, vegetables, milk, eggs and meat, and an importer of wheat, potato, fruits, maize, fodder other food and manufactured commodities (see Section 2.5). The same regional position for all listed commodities stays over all simulation (Table 5.19).

Table 5.19: Regional commodity export and import

Commodity		**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
Export			change to base (in percent)					
CTN	10^3 t	153.0	10	10	-66	7	0	-58
RCE	10^3 t	99.4	35	-29	101	8	3	28
VGL	10^3 t	31.7	388	496	3,268	54	76	1,703
MLK	10^3 t	228.8	-1	4	17	11	32	62
EGG	10^3 pieces	51.0	-5	9	32	-21	1	-43
MEA	10^3 t	29.7	0	4	10	10	89	54
Import			change to base (in percent)					
WWT	10^3 t	63.4	-50	10	100	1	19	-91
POT	10^3 t	24.6	-66	-14	-89	-62	14	-44
FRT	10^3 t	36.3	-29	-7	-19	36	14	-2
MZE	10^3 t	8.9	-27	-44	-54	-22	-9	-17
FOD	10^3 t	1,871.4	0	2	9	2	37	19
OTH	10^3 t	48.3	0	0	10	12	1	8
MFR	10^3 t	271.2	0	0	27	7	4	28

Notes: CTN – Cotton; WWT – Winter wheat; RCE – Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Milk; EGG – Eggs; MEA – Meat; OTH – Other food commodities; MFR – Non-food manufactured commodities; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

According to the model specification, cotton yields are higher in private farms than in *shirkat*s, and, thereby, the completion of the farm restructuring process (Scenario 4) increases regional production and exports of cotton under the same area of its cultivation. Improving water efficiency (Scenario 1) increases wheat production and, thus, decreases its imports. Furthermore, regional production and export of rice increases in response to increased water efficiency. Under Scenario 3, although liberalization of the input market increases total regional production for all food commodities; wheat becomes less favorable for producers and its regional production decreases. In scenarios which shift the production from crop growing activities towards livestock production (Scenario 2, 5 and 6), the production of fodder crops is not sufficient to cover the increased number of livestock in the region and, thus, the regional import of forage increases. The abolishment of cotton procurement quota (Scenarios 3 and 6) reduced the total export of cotton. Moreover, the market liberalization leads to a significant increase in rice and vegetable exports, and imports of wheat and manufactured commodities. An increase in cotton production and exports is observed only in cases with an increase in crop yield under improved water efficiency (Scenarios 1 and 2), but only at its observed level of land allocation according to the state procurement quota.

The model specification according to which the commodity prices change within a range determined by the arbitrage conditions is one of the major limitations of the model, since it does not allow agricultural producers to get higher commodity prices when the factor prices increase. The largest deviations are observed in prices for leisure and animal products. The increase in commodity prices explains the declining level of rural and urban consumption. Although, in the model, the consumed quantity and prices of commodities have negative relation, the substitution effect dominates over the price effect in all commodities, except for leisure. Furthermore, the simulation results uncover one of the weaknesses of the model specification. Since the model allows for imports and exports to be infinitely small or large, the agricultural producers eventually expand or reduce area under certain crops at once. Hence, it might be argued that the model should require minimum and maximum levels for export and import activities. Technically, this is only possible via structural change of the model. Incorporating such structural change in the model was not carried out to date, but would be an area of future research.

5.7.7 Rural Household Income

The changes in rural household income in the modeled district aggregates are shown in Table 5.20. Although, the water efficiency improved (Scenario 1) and the cropping pattern changes in favor of crops with the highest gross margins, rural household income decreased as agricultural wages decreased. With the introduction of a water pricing system (Scenario 2), annual production of most crops became less profitable. The *shirkats* and private farms reduced the level of cropping activities under this scenario, thereby demanding less labor. Household income can be expected to drop drastically in this situation. However, losses in household income are compensated by the expansion of livestock production, increase in crop yields and commodity prices. Furthermore, as the agricultural wages increase in Scenario 3, leading to an increase in household income level, the removal of input subsidies for cotton producers might also have a positive impact on household income. In this scenario, the abolishment of state procurement quota for cotton, which is the most labor intensive crop in Khorezm, discharges labor from the agricultural sector and increases the level of agricultural wages. The completion of the farm restructuring process (Scenario 4) discharges labor from agricultural sector, since private farms rely mostly on seasonal hired. This might lead to a decrease in household income level. However, farm restructuring increases the price received for livestock and poultry products significantly, which may compensate the income loss of households. In Scenario 5, the livestock sector shows the potential to positively influence household income both in districts bordering the river and districts without direct access to the river. Hence, further development of the livestock sector could present a sustainable development path for Khorezm. Despite the introduction of water prices and an increase in factor prices in the cumulative scenario (scenario 6), household income levels increase. This indicates that the positive effects of improving water efficiency and livestock productivity dominate over the effects if water pricing and input market liberalization are in effect.

Table 5.20: Income levels of rural households, 10^6 USD

District	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
		change to base (in percent)					
KSPBGT	89.2	-0.4	4.3	1.6	3.2	3.2	16.3
KKAURG	78.8	-0.8	4.6	1.4	3.0	3.1	21.8
YZRGLN	51.9	-0.7	4.1	1.8	5.5	3.3	19.9
KVAYRK	68.4	-0.2	2.0	0.9	3.4	3.0	20.9
KKRSVT	74.5	-0.5	2.4	1.0	4.9	2.1	23.0

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

There are several key findings that can be drawn from the different scenarios. Firstly, the model simulations indicate regional gains when the productivity of inputs is increased; similarly, large losses are seen under conditions which impose an increase in factor prices. Districts with abundant water will have the greatest benefit when the markets are liberalized and farm restructuring is completed. The water scarce districts will have higher benefits when the water efficiency improves and productivity of the livestock sector increases. Abolishment of cotton procurement quota might drastically increase profits of *shirkat*s, because of releasing their activities from mandatory cotton cultivation. At the same time, market liberalization decreases profits of private farms and rural households due to the increase in factor prices. Unlike for private farms, the rural household could compensate losses under this scenario by shifting towards livestock production. Additionally, losses by private farms and rural households caused by the increase in factor prices are compensated by the profit increase in *shirkat*s and, thus, in general, the market liberalization might have a positive effect on regional income. Next, the districts and region are better off in the case of improved water efficiency, development of the livestock sector and farm restructuring. In the final scenario, the decrease of district and regional profits from cropping activities are compensated by increased profits from livestock production; however, water pricing can present an additional burden on agricultural producers which cannot be compensated by increased profitability of the livestock sector. Under the base-case scenario, due to the higher factor productivity in private farms than in *shirkat*s, the abolishment of cotton procurement will have a greater and positive impact on private farms than on *shirkat*s. In contrast, with improved water efficiency, regional income might rise at a higher rate when the state requirements for cotton production are reduced for *shirkat*s, than for private farms. Nevertheless, through all simulated exogenous changes, cotton production remains unattractive for agricultural producers. Consequently, under the simulated conditions, regional production remains sensitive to changes in the cotton procurement quota. Under the given condition of input markets, when the producer's endowments of fertilizer and diesel are regulated centrally by the state agency, and the land markets being absent, the completion of the farm restructuring program might create a situation where land in private farms is not fully cultivated. Land remains the main constraining factor of production in districts bordering the river and the improvement of water efficiency will significantly decrease total water consumption in these districts. At the same time, the improvement of water efficiency significantly increases total land use in the districts without direct access to the river and, thus, the total water use in these districts does not show a dramatic decrease. Abolishment of state procurement quota for cotton and input market liberalization, combined with an increase in water use efficiency, might allow the use of arable land by agricultural producers to its full capacity resulting in higher shadow values of land both in districts with direct access to the river and in districts with water scarcity. In general, abolishment of state procurement quota and input market liberalization increases the value of land in districts which border the river and the shadow value of water in districts which do not have direct access to the river. With respect to production factors, the lower the availability of fertilizer, diesel or water, the lower are the prices which agricultural producers will be willing to pay for additional land. Due to a significant reduction in cultivated area under cotton, combined with the liberalization of input markets, the labor use per hectare drops in all districts. The accomplishment of the farm restructuring process also might decrease labor employment in the agricultural sector. The labor discharge by the *shirkat*s and private farms under increased factor productivity and prices is the main concern of the results of the various policy simulations. Although the introduction of water prices makes the production of most crops less profitable, the income loss in rural households might be compensated by the expansion of the livestock sector, increase of crop yield and commodity prices. Furthermore, the introduction of water prices might increase the level of agricultural wages. Consequently, rural households will additionally offset for income losses caused by increased water pricing through increases in the level of agricultural wages. The introduction of water pricing shifts the cropping pattern towards fodder production and livestock production. Market liberalization has a positive effect on the regional rice and potato sector releasing land from the cotton procurement quotas in *shirkat*s and private farms. Livestock production is also positively affected by the input market liberalization, since it becomes more attractive for agricultural producers when prices for fertilizer and diesel increase. The accomplishment of the farm restructuring process increases the production of rice at the expenses of potato, fruit and fodder production in private farms in districts bordering the river. At the same time, the farm restructuring process would decrease rice production and increase potato, vegetable and fodder production in private farms in districts located far from the river. An increase in livestock productivity will lead to an increase in the area under fodder crops at the expense of rice, wheat, potato and fruits. In the cumulative scenario, although the cotton and input markets are liberalized, the introduction of water prices leads to a decrease in land use and the cropping pattern shifts towards less water intensive crops and towards livestock production. Furthermore, the cumulative scenario shows that the effects of increased water efficiency and improved livestock production appear to dominate over the effects of introduced water pricing and increased factor prices.

6. Summary, Policy and Research Conclusions

6.1 Problem Statement

After Uzbekistan declared its independence in 1991, a set of economic reforms was implemented in the agricultural sector affecting agricultural production activities. This study has described several agricultural reforms, such as farm restructuring, national wheat self-sufficiency, developments in the state procurement policy and agricultural subsidization for *shirkat*s and private farms. Since the economy of Uzbekistan is in transition from a planned to a market-driven economy, further reforms in the agricultural sector will include the policies which do not have historical observations for Uzbekistan. These reforms in this study include the improvement of water efficiency, introduction of water charges, full abolishment of state procurement system and input market liberalization, accomplishment of farm restructuring process, and increase in livestock productivity.

The condition of the irrigation and drainage system in Khorezm is poor and water efficiency has, as a consequence, been declining. The maintenance and rehabilitation of the existing system can increase water availability to the agricultural producers, which is of particular interest for the producers in water scarce districts and increase their crop yields. Regarding the introduction of a price for water, the water management in Khorezm is transferred entirely to the newly established non-governmental organizations, which deliver water and maintain and operate irrigation and drainage system while receiving payments from the water users. The further introduction of water pricing system will ultimately affect production levels and less water will be consumed by agricultural producers.

With the abolishment of the state procurement for cotton, it is recurrently mentioned that incentives for cotton production will rise and lead to more profitable production pattern in Uzbekistan (Guadagni et al. 2005). After the intensification of the farm restructuring process, the fragmentation of large state enterprises into private farms became the most tangible reform in Uzbekistan. The final goal of this reform is to fully transfer land and non-land production assets from *shirkats* to private farms. Like any policy change, the substitution of large scale production technologies to smaller-scale ones will affect the production activities of the latter and the regional commodity prices. Furthermore, the current livestock productivity is underdeveloped in Khorezm, although of paramount importance for household security. It is believed that an improvement of livestock rearing practices and feeding regimes will lead to increased livelihood and higher agricultural incomes in the region.

All these agricultural reforms will impact but in a different way on the activity levels of different types of agricultural producers and consumers performing in different areas of the study region Khorezm. To increase the understanding how the different policies may impact on the regional production of specific agricultural commodities, much can be learned from assessing these policies with the help of a quantitative model such as the mathematical programming model.

This study is a first application of the modeling framework for the agricultural sector of Khorezm, while splitting the regional agricultural production into several districts and the by considering the major agricultural producer and consumer groups as well as their location to the Amu Darya river as a proxy for the availability of irrigation water. The consideration of the regional agricultural system in such partial equilibrium model will support decision makers and researchers to understand the policy or non-policy effects on the levels of regional prices, production activities and quantities. The results of such a sector model can be used to improve decision making.

6.2 Objectives

The study itself has aimed at providing a suitable instrument for analyzing the agricultural sector in Khorezm. Therefore, the overall objective of this study was to develop an economic framework to analyze the impact of different policies on the agricultural sector of the region. Additionally, the study includes a set of specific objectives: such as to develop an agricultural sector model for improved policy analysis, reflecting the unique features of supply and demand of agricultural commodities in Khorezm. The second specific objective is, following the completion of the agricultural sector model, to develop and apply an alternative technique for calibrating the model. The third objective is to simulate a set of selected policies. Based on the simulation results, modified agricultural policies to improve the welfare of regional producers and consumers are proposed. These specific objectives allowed an increased understanding of the possibilities to restructure the agricultural production while concurrently improving the economic efficiency of land and water.

6.3 Analytical Approach

KhoRASM reflects the unique features of the region’s agriculture. The model integrates three components: (1) agricultural sector model; (2) linear supply module; (3) non-linear demand module. The developed model follows closely the general guidelines of the non-linear agricultural sector models presented by Hazell and Norton (1986). The optimization mechanism in the model is not driven by exogenous changes but within the model via a price-endogenous solution mechanism. Following a standard welfare analysis, in the objective function of the model, total welfare of the study region consists of money metric indirect utility function, i.e. consumer surplus, and agricultural income, i.e. producer surplus. Hence, to join the demand and supply modules in the objective function of the model, the cross-effects of consumption, prices and income, established by the demand module, are introduced via the rescaling of the indirect utility function into a money metric indirect utility function.

For reasons of computational necessity and data needs, the model' demand and supply sides are aggregated over districts, producers, consumers and commodities. The supply module is linear and reflects the basic crop and animal production activities in the region divided into three different submodels representing main farm aggregates in the study region. The constraints are imposed due to limited supplies of resources and the existing state procurement system which implies that a pre-determined share of agricultural land has to be used for cotton production which is then sold at pre-determined prices to parastatal agencies. The supply module incorporates trade flows between modeled districts and with external regions under a small country assumption. Thus, import and export prices are constant and defined exogenously, applying the small country assumption. The demand module is specified at district aggregates for rural and urban households based on a Normalized Quadratic – Quadratic Expenditure System (NQ-QES) which assumes the non-linear income effect and cross-price effects on households' consumption. The demand module consists of food and non-food commodities and leisure time with endogenous prices over two types of consumers such as rural and urban households. According to the concept of nonseparability, the rural households' decisions regarding their production are affected by their consumer characteristics and, thus, in the optimum solution, the marginal revenue product of labor (agricultural wages) in the supply module is equal to the price of leisure time in the demand module. The study is based on the large amount of data and information dealing with agricultural sector in Khorezm. The data used in the model mostly include micro-economic data for 2003. Information about input-output coefficients of agricultural production, resource quality and quantity, input-output prices were collected via farm and household surveys conducted in Khorezm in 2003 and 2004 respectively. The background information on the empirical environment of the agricultural sector of Khorezm was collected from the official statistical reports.

The KhoRASM model is especially interesting because it raises a discussion about calibration techniques for mathematical programming models. The calibration of the KhoRASM model needed an innovative approach since the traditional calibration approaches require large set of additional information, which was unavailable, incomplete or unreliable. While most other agricultural sector models have used the standard calibration approach of positive mathematical programming, an alternative approach was developed and applied for calibrating the KhoRASM model under assumption that the micro-economic information included into the model is incomplete. To ensure that the activity values of the base-run solution of the model fits the observed values of modelled activities and to ensure that the model simulations include the characteristics of regional demand and supply, the model parameters both for demand and supply sides were adjusted separately. The supply module was calibrated via simultaneous adjustments in technology coefficients and the shadow values of constraints. To ensure that the observed levels of prices, income and demanded quantities represent the point of optimum utility for consumers, the demand module parameters were adjusted using an approach advocated by Frohberg and Winter (2001). The model calibration underlined the model's ability to simulate the impact of different policies and its use as a supportive tool for decision-making on future agricultural policy planning for Khorezm. Following the calibration of the model, different simulations of agricultural policies became possible as to measure their impacts on regional supply and demand. Results obtained after implementing an exogenous shock in the model are compared with the observed situation in 2003 and discussed. The model is programmed using the GAMS modelling language; it was then calibrated and solved as a non-linear optimization, using the numerical solver CONOPT3.

6.4 Results

Two types of results are covered in this study. The first results are related to the developed calibration approach for the supply module, whereas the second group of results is related to the simulation of policy scenarios.

The study shows that, as a starting point for policy simulations, the chosen calibration approach allows the modeller to calibrate the model using the basic amount of data included into the original specification of the model. The advantage of this calibration approach is that it avoids overspecialization, retains the model's flexibility, and calibrates exactly without changing the specification of the original objective function of the model. Moreover, the presented calibration approach allowed calibrating the supply module of KhoRASM while using the original dataset of the model and while incorporating more properties of information on the agricultural technologies obtained via the farm and household surveys.

The results of the policy simulations in the study depend on assumptions of the model. These assumptions were mandatory in order to reduce the complexity of the situation and to be able to represent in a relatively sophisticated model which is not only theoretically sound but is also based on primary and secondary data. Therefore, the simulation results should be treated with caution. Nevertheless, it is believed that these results are reliable and can contribute to the discussion on how the simulated policy can affect the regional income, production pattern and factor use in the agricultural sector.

The improvement of water efficiency in districts with less water availability increases total land use, and water use in these districts does not decrease dramatically. Despite relatively more water availability after improving water efficiency, land remains the restraining factor in water abundant districts. The improvement in water efficiency will increase the area under the crops with the highest gross margins in water scarce districts. However, this does not affect the area under cotton and its production level is still determined by the state procurement quota.

The introduction of water prices shows that under the given assumptions the water pricing will decrease the total production of rice, the most water intensive crop in the region, and shift the cropping pattern towards fodder. Despite the fact, that introduction of water charging as a single policy decreases regional income, the model is comparative static and the negative income effects of water pricing may well turn positive if long-term effects would be taken into account, such as investments into water efficiency and positive environment effects. Furthermore, the income loss caused by the introduction of water prices may be compensated by the expansion of the livestock sector. Hence, the second hypothesis is accepted that the introduction of water prices will shift the regional cropping pattern towards the less water demanding production pattern.

As such, the model shows that in the base situation, the reduction of state procurement of cotton for private farms may have a higher positive impact on regional income than its reduction in *shirkat*s. However, as the model simulation shows, the abolishment of the cotton procurement system under an input market liberalization scenario might decrease the profits of private farms, while increasing profits for *shirkat*s. Unlike private farms, in case of an increase in factor prices, the rural household could offset the losses of profits from cropping activities from shifting towards livestock keeping activities. In general, the region benefits from market liberalization since the losses by private farms and rural households are overcompensated by profit increase in *shirkat*s. Furthermore, despite the removal of input subsidies after the market liberalization, the cotton production in some districts reduces, but does not become zero. Thus, the results of this policy experiment reject the third hypothesis of this study which says that market liberalization will lead to an increase in the regional production of cotton.

As such, the market liberalization shows the better conditions for rice production and the livestock sector. The new cropping pattern leads to higher water consumption in water abundant districts under the same cultivated area. In contrast, *shirkats* and private farms in the districts with the water scarcity reduce total cultivated area in favor of rice production. In general, this reform increases the regional income, but it may reduce labor employment in agriculture due to significant reduction of cultivated area under cotton, which is one of the most labor intensive crops in Khorezm. This indicates that currently, the state procurement system which also implies subsidies for cotton production in *shirkat*s and private farms may have a positive impact also on the income of rural households such as it allows employment in rural areas to be maintained.

The completion of the farm restructuring process will lead to increased regional income and allow achieving higher regional income using less land and water. Thus, the first hypothesis is accepted that while no land market is yet functioning, inter-farm shift of land is one possibility to increase the efficiency of land and water use in the region. However, the completion of the farm restructuring process might also decrease the labor employment in the agricultural sector, because in Khorezm private farms mostly rely on seasonal workers and use labor less intensively than *shirkat*s.

An improvement in livestock feeding regimes may shift production activities towards fodder and lead to a slight increase in cultivated area in water scarce districts. The improvement in livestock productivity shows the potential to maintain and positively influence household income and decrease the total water use in the agricultural sector. This result accepts the forth hypothesis of the study according to which the livestock sector may act as a tool for supporting the incomes of rural households when the input market is liberalized and water pricing is introduced. Hence, further development of the livestock sector in Khorezm can be a reasonable endeavor for the government and research organizations.

In general, among the simulated policies, the ones related to improved water efficiency, improvement of the livestock sector and liberalizing cotton and input markets have the highest positive effect for the income of agricultural producers and the overall sector. Most interestingly, the effects of policies vary between districts with respect to their access to the river. The districts with direct access to the river, i.e. with abundant water, will benefit the most from the market liberalization and farm restructuring reforms, while the districts with no direct access to the river, i.e. with water scarcity, will have higher, positive effect in the case of improving water efficiency and increasing productivity in the livestock sector. Furthermore, if water efficiency is improved, a reduction of the state procurement for cotton production for *shirkat*s may bring a higher increase in agricultural income, than its reduction for private farms. For any exogenous change set by the policy experiments, however, cotton production remains unattractive for agricultural producers which are more in favor of rice cultivation. Thus, cotton and rice production in regional agriculture is very sensitive to a reduction in cotton production targets.

In the cumulative scenario, the area under cotton and rice cultivation is decreased in favor of less water intensive crops, e.g. fodder, and livestock production. Furthermore, the cumulative scenario shows that it is possible to increase household income levels if water prices are introduced and the input prices are increased, meaning that the effects from increasing water efficiency, liberalizing cotton market and improving livestock keeping appear to dominate over the effects of introducing the water pricing and liberalizing the input markets. Furthermore, scenarios related to the improvement of factor productivity, such as improvement of water efficiency and the livestock sector, have the highest increase in regional welfare, as measured by consumer and producer surpluses. In contrast, the scenarios related to the increase in factor prices, such as the introduction of water prices and input market liberation, may decrease the regional welfare comparing to the level observed in the base case scenario.

6.5 Policy Implications

This section addresses decision-makers in government and non-government organizations at regional and national levels. From these simulated results as well as discussion of the main characteristics of the regional agriculture, we can derive several policy recommendations.

Diversity in water prices. The introduction of water prices has the greatest negative impact on the incomes of agricultural producers. Thus, several implications should be considered in this respect. First, the water pricing mechanism should be promoted only gradually over a period of time to allow water users to adjust to higher production costs. Secondly, the water pricing system might have values which differentiate across irrigation months. Therefore, in the periods when the water is in scarcity and the intensity of water use is the highest, the agricultural producers should be charged the highest water price. Furthermore, the water prices should vary between crops. In setting an appropriate price for water, care must be taken to ensure that the districts located furthest from the river are not prevented from meeting their irrigation water needs. Next, water policies should be set such as to protect the poor, i.e. a 'free' allowance of irrigation water to rural households, with payments only for cash crops such as rice. Finally, introduction of water pricing needs to be combined with other measures in order to solve the qualitative and quantitative water resource management problems in the region. The improved management of the irrigation and drainage system via investing the collected payments for water use can provide a more responsive physical environment for adopting new production technologies, new crop varieties within the opportunities for double cropping in Khorezm. Furthermore, effective water management practices tend to increase the effectiveness of fertilizer application and maintain more sustainable systems.

Development of processing sector and input markets. The simultaneous increase in the price for raw cotton to the level of its 'pseudo' border price (by 28%) and input market liberalization does not increase the cultivated area of cotton. This can indicate that cotton producers may still require a set of subsidies in case the government decides to maintain cotton production and increase regional cotton processing. Furthermore, it is clear that under market liberalization, future growth in cotton production will still depend on regional exports. There is much scope for improvement by the development of the cotton processing industry as recently was underlined (Rudenko 2008). The development of such a system could also rely on capital investments by the private sector which would demand a reduction of the state monopoly on cotton processing and an increase in private access to credit and information.

However, the producers in Khorezm can be unable to adjust properly to the liberalization and to gains from these programmes if the market channels are limited.

Among the cropping activities, the results of all scenario shows that when, the cotton market is liberalized under increased factor prices, vegetable production becomes more attractive for agricultural producers. Thus, the regional policy makers should also pay more attention to revitalize the vegetable and its processing sectors in Khorezm. During the Soviet era, Uzbekistan was a supplier of fruit and vegetables to other Soviet republics. These processing capacities have been collapsed following independence and the region has lost its comparative advantage for this market segment. A promotion of on-farm processing technologies should receive more attention, especially in locations next to the rural and urban markets. Greater attention should also be given to developing the non-farm economy and improvement of processing the agricultural products into higher-valued agricultural commodities. But with the regeneration of processing facilities this sector could contribute immense to the regional welfare.

Next, the shadow values of fertilizer and diesel in cases of improved water efficiency and after completion of farm restructuring showed the potential of investments into establishing distribution centers where such inputs can be accessed by agricultural producers without restraints at higher prices.

Development of farm support centers. The completion of the farm restructuring will challenge the development of new institutional arrangements between the state and private farms which would promote the production development on private farms. Furthermore, at present the former agricultural practices still dominate the mind-set of agricultural specialists, and the output of research on many cultivation practices such as fertilization and the general use of chemicals for different crops is needed to be delivered to newly established private farms via systematic brochures on crop fertilization techniques and the development of information systems for nutrient management at the field and farm level. Also there will be a need to establish services indispensable for private farming such as laboratories, research stations, food safety controls which presently are lacking. This, alongside improved irrigation scheduling and better pesticide techniques might improve factor productivity.

Furthermore, when input markets are liberalized, the private sector can fail to adjust to new factor prices. Similarly, when input subsidies are removed, rational producers may be forced to apply less inputs which in turn could lead to a decline in output. Consequently, the reduction of transaction costs and risks that inhibit presently the private sector should be eased, e.g. via improving infrastructure and communications, and relaxing the present regulations that partly paralyze activities of a private sector. The access to finance, particularly short-term seasonal credits, can help mastering obstacles caused by the increase in factor prices.

Worldwide, agricultural extension and farmer education programs have been used as policy instruments for improving the productivity of agriculture while protecting the environment. However, care should be taken as to avoid a poor performance of extension and informal education systems which, worldwide were caused by bureaucratic inefficiency, deficient program design, and some generic weaknesses inherent in publicly-operated, staff-intensive, information delivery systems. The present farm privatization process will certainly profit from the establishment of extension approaches focusing on strengthening the demand for services and on a larger role for the private sector, non-governmental organizations, producer organizations, and a more inclusive approach regarding women, indigenous peoples, and the poor. A series of innovative approaches to financing extension were developed and promoted and could form a suitable starting point. Furthermore, the density of roads in Khorezm could support the access of private farms to the market when their share in total agricultural production increases. However, these policies should be considered by the government without leaving rural household producers isolated, meaning that the latter should be included into these programs.

Development of improved production technologies. The results of liberalization policies such as abolishment of state procurement for cotton, input market liberalization and accomplishment of the farm restructuring process show that it is possible to achieve higher regional income with less land and water use. However, the improvement of land productivity remains the key issue to consider for policy makers in Khorezm where most of the increase in output should be driven by technological change including the improvement in irrigation practices. For instance, after input prices increase during input market liberalization, the problem of possible crop yield declines can be offset and overcome via programmes that aim at increasing the productivity of these inputs such as high-yielding crop varieties, fertilizers, and plant protection. The input application schemes such as for fertilizers, water and machinery in Khorezm is outdated and, therefore, the development of proper input application schemes and their distribution among agricultural producers is vital, especially in the location where the factor values are the highest. The development of improved production technologies, such as soil conservation agriculture, low till or no till technologies for cotton and wheat will reduce production costs while maintaining present yield levels (Tursunov 2008).

Improvement of livestock productivity. Given the present low productivity of the livestock sector in the Khorezm region, even a slight improvement in feeding technologies and veterinary services will very likely have a high impact on regional welfare. Irrespective of the scenarios analyzed such as improving the productivity of livestock, increasing yields of fodder crops, increasing prices of production factors, introducing water charges for rice production in rural households, the regional livestock sector showed its enormous potential to increase further. The improvement of livestock rearing should receive particular attention in districts with regular water scarcity.

Furthermore, since most rural households keep livestock in their backyards, an implementation of programs for improving livestock productivity will generally imply an increase in income for the majority of the rural population and can be used by rural households as a shield against income decreases when factor markets are liberalized or water prices are introduced. Apart from maintaining household income in case of liberalization of the input market, improvements in livestock productivity may have positive impacts on regional environmental indicators without requiring high investments costs as compared to the high investments needed to improve the irrigation and drainage system. Hence, the livestock sector development in Khorezm should receive more attention by the administrative and research institutions, e.g. improved disease management. The latter in particular should focus on the adequate production of fodder crops and grain byproducts, since at present access to sufficient and high quality feed is short in supply. Even so, it needs to be considered that the livestock sector highly depends on the cultivated fodder crops and the grain byproducts, and its access to cheap forage such as haylands and pastures is limited in Khorezm.

In case of further development of the livestock sector, the regional producers might not be able to supply enough forage. Hence, the share of imported forage in total regional fodder use will rise making the regional livestock sector highly sensitive to the fodder supplies from outside of the region and subject to variation in transportation conditions. The fodder prices are introduced into the model as exogenous and, therefore, changes due to the changes in supply and demand are not considered in this study. Consequently, to avoid significant increases in forage prices that would reduce the attractiveness of the livestock sector, emphasis should be given to the promotion of new varieties of fodder crops, intercropping systems and the production of crops with a high feed value such as alfalfa, or annual crops such as clover and the like. Also the present inadequate feeding practices bear much room for improvement of the service provision by veterinarians and zootechnicians. Next, the improvement of the livestock sector can be supported by the investment into the processing industry of, in particular, dairy and meat products.

Employment opportunities for rural population. The results of the model simulations indicate that land and water use can be improved via a set of policy reform which joins both liberalization and tax reforms. Nevertheless, since labor is not a significant limiting factor of agricultural production in Khorezm, it may be possible that such policies will discharge labor from private farms. Although the model specification does not show this, a decrease in employment opportunities may lead to a decrease in rural household incomes. Hence, when concentrating on liberalization programs it should be taken into consideration that the increase of rural unemployment will limit the positive impact on incomes of rural households unless additional programmes would join such liberalization efforts. The government could e.g. consider a set of subsidies for rural households and develop programmes to increase the opportunities of employment in non-agricultural sectors, encourage diversification of rural incomes, improve the livestock productivity, and expand the processing sectors.

Although it is argued that both land, which is a significant limiting factor for the agricultural production, and labor productivity must rise to reduce poverty, the land productivity must rise faster in case of Khorezm. Hence, the consequences for future interventions is that, instead of focusing on increasing labor productivity in the regional agriculture, more attention should be given to methods of increasing crop yields and productivity of land and livestock sector to offset the pressure on land by e.g. research and extension services, public market information, investing in communication infrastructure, implementing market regulations.

The listed activities of improving the regional productivity might consider the fact that the districts with abundant water will benefit the most from the market liberalization and farm restructuring reforms, while the water scarce districts can expect higher positive effects under improved water efficiency and increased productivity of the livestock sector. This therefore does not call for a blue print approach in development but a more targeted approach. Consequently, support programs and policies would be ill-advised if they ignore the locations of agricultural producers to the river.

6.6 Limitations

The main limitation of this study was the availability of data in Khorezm during the period if field work. For instance, the demand module calibration uses information obtained from international sources. As the model is limited by available data, certain restrictions on the model specification and applicability of the results are inevitable.

First, the model is static and does not incorporate information on regional agriculture over several periods. Such a model, therefore, can only be interpreted based on the base year conditions and may be inconsistent for observations in other periods. Secondly, the model does not allow for uncertainty and imperfect information in the markets. The spatial disaggregation presented in the model does not incorporate market imperfections which normally occur in the agricultural sector, such as farm-to-market transportation costs and imperfect flows of market information. Moreover, the model does not include marketing, processing, transportation, exporting, importing and home consumption activities. Next, in the simulations the commodity prices at the district level change within a range defined by the commodity prices outside of the region and the transportation costs. This, the model specification limits the agricultural producers in gaining the higher commodity prices when the factor prices increase. Since the model specification allows for import and export to be infinitely small or large, the agricultural producers eventually expand or reduce area under certain crops at once. Thus, it might be argued that minimum and maximum levels for export and import activities should be incorporated. Furthermore, the environmental issues such as soil salinity and water logging are also essential in Khorezm, but are not included in the analysis. Since no labor flow to other sectors is included, the model treats any labor discharge by the agricultural sector as an increase in leisure consumption in rural households. Furthermore, the national price of commodities is assumed to be exogenous to the regional production, i.e. the commodity price in Uzbekistan is not affected by changes of production pattern and commodity prices in Khorezm. Although this in general is correct, in the case of regional rice production, during 1992-2003 Khorezm had about 32% of total rice production in Uzbekistan and this would conflict the assumption of exogenous price formulation outside of the region.

Further limitations of the study are related to the procedure used for calibrating the supply module. Since the original model and calibration process are static, information is used on production activity levels for only one reference year, the model can be applied only under the base year conditions and can be inconsistent for observations in other periods. Moreover, the calibration outcome is very sensitive to the choice of the support points for modified parameters. During the calibration, the technology coefficients are adjusted arbitrary, meaning that there are an infinite number of values for each modified technology coefficient which might be selected within the calibration process. Finally, the calibration approach applied for the supply module is *ad hoc*. It must be noted here, that the outcomes of the simulations are likely to be different if the model was calibrated with information obtained for later periods. Nevertheless, none of these limitations are believed to fundamentally decrease applicability of the KhoRASM model as a tool to investigate in a comprehensive manner the impacts of different agricultural policies in Khorezm.

6.7 Further Research

The study successfully provided a quantitative model for analyzing the agricultural sector of the Khorezm region. The model results were useful in replicating the performance of the agricultural sector of Khorezm in the base year of 2003 and in simulating selected policies. The model design has considered plentiful flexibility for its future development. Further research could address agro-ecological questions such as the development of alternative land uses on the marginal lands in the region such as tree plantations, livestock rearing, improvement of soil characteristics, adoption of conservation agricultural technologies; and production economics such as introduction of multi-period dimension for analysis of improvement of livestock sector, integration of tree components into the model. Due to the time limitations and data availability, the model is static. As such, the model can be developed into a dynamic agricultural sector model by establishing some extra predicting and adjusting parts to reflect the dynamic processes in agricultural development of Khorezm, such as dynamic definitions of crop and animal production systems and taking into account modifications in soil quality during the production cycles. This may require a development of agro-ecological and socio-economic analytical framework with continuous production functions incorporating factor substitution on different soil attributes.

Next, the complete model can be expected to introduce the inter-farm and inter-district trades of factors such as fertilizers, diesel, and machinery. Land transfers, such as sub-renting, between competing agricultural producers in a district, could more realistically explain the existing unofficial land markets in the Khorezm region. To gain further insight into overall agricultural development, the linkages between the agricultural sector and other sectors such as food processing and input markets can be introduced into a more comprehensive version of the model. The model's aggregation shortcomings can be solved by introducing more types of farms according to size, more commodities according to season and quality, and disaggregating the district subaggregates. The disaggregated version of the model can give more farm, product and district specific results of the policy simulations. Considering the *ad hoc* limitation of the presented calibration approach of the supply module, its applicability can be tested for calibrating other nonlinear programming models.

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Appendices

Appendix 1: Brief Excursion into Evolving Farm Structure in Khorezm (1991 - 2004)

Since the dominant form of agricultural production in Uzbekistan during the first years of independence existed in large-scale collective and state farms, one of the crucial issues in reforming the agricultural sector in Uzbekistan has been farm restructuring (Guadagni et al. 2005). In an effort to achieve this, state owned and collectively operated properties have been transferred into private hands (Khan 2005). In the first stage of the farm restructuring process, the transformation of *sovkhoz*s into *kolkhoz*s was undertaken via Uzbekistan's very first legislative act in regards to farm restructuring (Sirajiddinov 2004). This had some fiscal implications: Discrepancies between central production targets and actually realizable farm output in the late 1980's led to continuing substantial losses at the level of the *sovkhoz*s (Wegren 1989, Aminova 1993), so that reducing the governments financial responsibility for on-farm *sovkhoz* operations, provided the state budget with some expenditure relief (Bloch 2002, Guadagni et al. 2005).

The transformation of *sovkhoz*s into *kolkhoz*s was accompanied by the liberalization of commodity markets such as those for fruits, vegetables and livestock products, for which state procurement quotas had existed prior to this reform (Kyle and Chabot 1997, Müller 2006). State procurement tasks remained only for cotton and grains (Guadagni et al. 2005). However, the reform was not accompanied by much change in the actual management of *kolkhoz*s in post-independence Uzbekistan, as compared to their management during the Soviet Rule (Wegren 1989, Lerman et al. 2002). First, the agricultural production in *kolkhoz*s - being the main components in the state procurement system - was still regulated by the Ministry of Agriculture (Salimov et al. 2004). Secondly, the basic concepts of the Soviet management of agricultural labor persisted; e.g. the policy of lifetime employment of workers at equal wages, lack of land ownership and production assets (Lerman et al. 2002).

The second stage of farm restructuring started in 1998 with the adoption of laws on agricultural cooperatives (*shirkat*s) and private farms (Khan 2005). The adoption of these laws made the land reform and farm restructuring processes more palpable. First, the majority of *kolkhoz*s in Uzbekistan were reorganized into *shirkat*s (Bloch 2002, Spoor 2004). The process of restructuring *sovkhoz*s and *kolkhoz*s into *shirkat*s implied also a change in the concept of labor management (Bloch and Kutuzov 2001). In order to increase individual responsibility for the products, the production units of *kolkhoz*s, i.e. brigades, were entirely substituted by family contracting units (*pudrat*); making them the backbone of the *shirkat*s' production. Under this form of labor management the *shirkat* acts as both a customer and supplier, providing the land and all necessary physical inputs and services to employed peasants, who perform as contractors (*pudrat*s) who, in turn, supply labor service and deliver the total product output to the *shirkat*s. Nevertheless, the reorganization of *kolkhoz*s into *shirkat*s still did not bring about significant changes in agricultural management as it did not involve any significant internal restructuring (Salimov et al. 2004, Khan 2005). Even though it was broadcast by the government as a decollectivization process, the reorganization of *kolkhoz*s into *shirkats* did not result in a different system from that of the collective farms. In the 'stay as is' approach of farm restructuring implemented by the government, collective farms underwent external restructuring by re-registering and distributing non-land asset shares to their members. But these were in return deposited back to the reorganized collective farm under its new name: agricultural cooperative (Lerman et al. 2002). However, the farm restructuring undertaken during the period of 1998 to 2002 can be considered as the first attempt towards extensive downsizing of agricultural production from large-scale agricultural cooperatives into private farms (Bloch 2002, Khan 2005).

Prior to the introduction of new farm legislations in 1998, private farming in Uzbekistan was based on the system of the lessor-lessee relationships, which resembled the system of private farming in the Soviet Union of the 1980s (Wegren 1989, Salimov et al. 2004, Khan 2005). According to these leasing arrangements, *kolkhoz*s and *sovkhoz*s leased abandoned and unused land to teams, cooperatives within farms, individual families, *kolkhoz* members or *sovkhoz* workers for long-term periods of up to 50 years (Wegren 1989). In addition, output destination was prescribed by contract between lessor (*sovkhoz* or *kolkhoz*) and lessee, according to which the harvest was sold to the lessor or on his behalf to procurement agencies. The lessee, i.e. the private farm, only held decision power over output that exceeded the contractual amounts. The next feature of private farming in the Soviet Union was that private farms depended entirely on the availability of inputs from its lessor of land (Wegren 1989). The introduction of the law on private farms in 1998 has changed this interpretation of private farming in Uzbekistan. According to the 1998 legislation, private farms were to be entirely independent from *kolkhoz*s and *shirkat*s; both in terms of input and output allocation Bloch and Kutuzov 2001, Bloch 2002, Khan2005). Nevertheless, the old concepts of private farming were once again maintained despite the reform efforts of the second stage of farm restructuring. The main reasons for this seem to have been firstly, that private farms were still established via partial allocation of low-yield and low quality lands, operated by *shirkat*s at a net loss (Khan 2005). And secondly, private farms were still being required to fulfill certain state procurement quotas (Salimov et al. 2004). By the end of the second stage of farm restructuring in 2002, the combination of production activities of large-scale *shirkat*s, middle-scale private farms and small-scale rural households had led to a "three-farm" system in Uzbekistan, in which *shirkat*s, however, dominated over private farms in terms of factor endowment and total production. With implementation of this third stage of farm restructuring, the transition to private farm production was meant to be completed by the end of 2006 (Salimov et al. 2004). This process of farm restructuring, by totally dismantling entire *shirkat*s into private farms, can be considered as the process of decollectivization (Swinnen and Mathijs 1997) and it did not lead to the emergence of large-scale private enterprises.

In general, the farm restructuring process can be described as a process of transferring the property rights for agricultural output from state ownership to collective and finally to private ownership (Lerman et al. 2002). In contrast to other countries of the former Soviet Union, the main objective of land reform in Uzbekistan was not a privatization of land per se, but rather a change of land ownership through a restructuring of state and collective farms and an allocation of agricultural land to individuals for private farming via land leasing (Khan 2005). Consequently, farm restructuring in Uzbekistan represents a form of land reform according to which only user and income rights are privatized, while long-term land leasing arrangements are merely transferred from one type of agricultural producer to another[21]. Restitution of collective land and non-land assets to former owners, or their distribution to farm workers and previous contributors to the former *sovkhoz*s and *kolkhoz*s*,* as practiced in many countries of East Central Europe and the former Soviet Union (Swinnen and Mathijs 1997), did not occur in Uzbekistan. The assets of fully dismantled *shirkat*s were either transferred in their entirety to the successive type of agricultural producer, i.e. private farms, via local auctions, or transferred by decree to newly established machinery and tractor parks and water user associations. Moreover, input markets do not seem to have emerged (Block and Kutuzov 2001), and inputs are still supplied and distributed by the same channels that provided inputs to the collective farms and *shirkat*s. Similarly, during the process of fragmentation of *shirkat*s into private farms, the state procurement quotas and subsidies have likewise been transferred from *shirkat*s to private farms (Spoor 1999, Salimov et al. 2004). Issues regarding the features of agricultural producers, the state procurement system, as well as a system of subsidization and taxation of the agricultural sector are discussed in detail in sections 2.4 and 2.6.

[21] Agricultural land is still considered state property, meaning it is limited to nontransferable usufruct rights such as statutory prohibition of land sales, mortgaging, exchanging, and sub-renting between individuals and enterprises. The only exception is small household plots granted to families according to lifetime inheritable land rights.

Appendix 2: Algebraic Description of the Model and Calibration Procedures

Table A1: The indices of the model

Code	Description	Items included
x	Production activities such as land allocation under crop growing and number of livestock and poultry	Crop growing: cotton; winter wheat; rice; potato; fruits and melons; vegetables; maize; fodder crops. Animal rearing: cows; bulls; poultry.
i,j,k,l	Commodities	Food commodities: wheat and other food grains; rice; potato; fruits and melons; vegetables; milk and milk products; eggs; meat and meat products; other food commodities. Non-food manufactured commodities. Leisure.
r,r1	Districts aggregates	Khazarasp – Bagat; Khanka – Urgench; Yangibazar – Gurlen; Khiva – Yangiarik; Kushkupir – Shavat.
z	Production inputs and resources	Land; water; nitrogen fertilizer; diesel; grain harvester combines; transporting vehicles, forage.
f,f1	Agricultural producer and consumer groups	Agricultural producers: *shirkat*s; private farms; rural households. Consumers: rural households; urban households.
t	Support space in maximum entropy calibration models	Points: minimum; maximum.

Table A2: The variables of the model

Code	Indices	Description
Welf		Regional welfare
MoneyM		Money metric indirect utility function
NTSurp		Definition of net trade surplus of producers
PrCost		Definition of production costs
Xlevl	*r,f,x*	Production activity levels
Xflows	*r,i*	Export flows of commodities (not allowed for leisure)
Mflows	*r,i*	Import flows of commodities (not allowed for leisure)
LabrF	*r,r1,f,f1*	Inter-district and inter-farm labor flow between producers
Incm	*r,f*	Total income (consumption expenditure) of consumers

AgrIncm	*r,f*	Agricultural profit in rural households including leisure time
Wage	*r*	Agricultural wages
Demand	*r,f,i*	Consumption level
Price	*r,i*	Endogenous commodity prices
λ	*r,f,z*	Shadow price of input constraints
ν	*r,f*	Shadow price of labor constraints
μ	*r,f,x*	Shadow price of state procurement constraint for cotton
π	*r,i*	Shadow price of commodity market balance
ε	*r,f,i,j*	Calibrated price elasticity of demand
ε^{y}	*r,f,i,*	Calibrated income elasticity of demand
ε^{F}	*r,f,i,j*	Final price elasticity of demand
ε^{yF}	*r,f,i*	Final income elasticity of demand
g	*r,f*	Component of NQ-QES
S	*r,f,i,j*	Slutsky substitution matrix
L	*r,f,i,j*	A lower triangular matrix where L^{T} is its transpose
$\overline{\overline{\varepsilon}}$	*t,r,f,i,j*	Probabilities of calibrated price elasticity of demand
$\overline{\overline{\varepsilon}}^{y}$	*t,r,f,i*	Probabilities of calibrated income elasticity of demand
$inpt^{e}$	*r,f,z,x*	Modified technology coefficients
$labr^{e}$	*r,f, x*	Modified labor use coefficients
$varc^{e}$	*r,f,x*	Modified production costs
λ^{e}	*r,f,z*	Modified shadow prices of input constraints
ν^{e}	*r,f*	Modified shadow prices of labor constraints
μ^{e}	*r,f,x*	Modified shadow prices of state procurement constraints
$\overline{\overline{inpt}}$	*t,r,f,z,x*	Probabilities of technology coefficients
$\overline{\overline{labr}}$	*t,r,f,x*	Probabilities of labor use coefficients
$\overline{\overline{\lambda}}$	*t,r,f,z*	Probabilities of shadow prices of input constraints
$\overline{\overline{\nu}}$	*t,r,f*	Probabilities of shadow prices of labor constraints
$\overline{\overline{\mu}}$	*t,r,f,x*	Probabilities of shadow prices of state procurement constraints
$\overline{\overline{\pi}}$	*t,r,i*	Probabilities of shadow prices of market balance
π^{e}	*r,i*	Modified shadow prices of commodity market balance

Table A3: The parameters of the model

Code	Indices	Description
$Xlevl^0$	r,f,x	Observed levels of production activities
$LabrF^0$	r,r1,f,f1	Observed levels of labor flows between producers and districts
$Flows^0$	r,r1,i	Observed levels of commodity flows between districts
$XFlows^0$	r,i	Observed levels of commodity export
$MFlows^0$	r,i	Observed levels of commodity import
$wage^0$	r	Observed level of agricultural wages
pex	i	Border (outside) price of commodity
dist	r,r1	Distance between districts
edist	r	Distance from districts to the border (outside market point)
trc	r,i	Transportation costs of commodity
lc	r	Labor flow costs
yild	r,f,i,x	Production yield per activity
varc	r,f,x	Production costs
labr	r,f,x	Labor use for production activity
inpt	r,f,z,x	Input application for production activity
feed	r,f,i,x	Livestock and poultry feeding regimes
labrav	r,f,x	Labor availability for agricultural work and leisure
inptav	r,f,z	Input endowments
sord	r,f,x	State procurement constraint for cotton
$Incm^0$	r,f	Observed level of consumers' income (expenditure)
$nagrIncm^0$	r,f	Observed level of non-agricultural income in rural households
$Price^0$	r,i	Observed level of commodity prices
$Demand^0$	r,f,i	Observed level of consumption in rural and urban households
g^0	r,f	Demand system element at reference point
a	r,f,i	Independent parameter of NQ-QES
b	r,f,i	Independent parameter of NQ-QES
d	r,f,i	Independent parameter of NQ-QES
B	r,f,i,j	Independent parameter of NQ-QES
α	r,i	Positive predetermined parameter
δ	i,j	Kronecker's delta

Table A4: The equations of the model

Name of equation	Equation
	KhoRASM model
Objective function of the KhoRASM model	$max\ Welf = MoneyM + NTSurp - PrCost$
Money metric indirect utility function	$MoneyM = \sum_{r}\sum_{f}\frac{g^{o}_{r,f}}{g_{r,f}} Incm_{r,f}$
Net trade surplus of producers	$NTSurp = \sum_{r}\sum_{i}(XFlows_{r,i} - MFlows_{r,i})\ pex_{i}$ $-\sum_{r}\sum_{i}(XFlows_{r,i} + MFlows_{r,i})\ edist_{r}\ trc_{r,i}$ $-\sum_{r}\sum_{r1}\sum_{f}\sum_{i} Flows_{r,r1,i}\ dist_{r,r1}\ trc_{r,i}$
Production costs	$PrCost = \sum_{r}\sum_{f}\sum_{x} varc_{r,f,x}\ Xlevl_{r,f,x}$ $+\sum_{r}\sum_{f}\sum_{x}\sum_{i} Xlevl_{r,f,x} feed_{r,f,i,x} Price_{r,i}$ $+\sum_{r}\sum_{r1}\sum_{f}\sum_{f1} LabrF_{r1,r,f1,f}\ Wage_{r}$
Production costs respecified in Scenario 3 and 6	$PrCost = \sum_{r}\sum_{f}\sum_{x} varc_{r,f,x}\ Xlevl_{r,f,x}$ $+\sum_{r}\sum_{f}\sum_{i}\sum_{x} Xlevl_{r,f,x} feed_{r,f,i,x} Price_{r,i}$ $+\sum_{r}\sum_{r1}\sum_{f}\sum_{f1} LabrF_{r1,r,f1,f}\ Wage_{r}$ $+\sum_{r}\sum_{f} DislF_{r,f} dislp + \sum_{r}\sum_{f} FertF_{r,f}\ fertp$
	Supply module
Inout constraints	$\sum_{x} XLevl_{r,f,x}\ inpt_{r,f,z,x} \le inptav_{r,f,z}$
Labor constraints	$labrav_{r,f} + \sum_{r1}\sum_{f1} LabrF_{r1,r,f1,f} \ge$ $\sum_{x} XLevl_{r,f,x}\ labr_{r,f,x} + \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1}$
State procurement constraints for cotton	$XLevl_{r,f,x} \ge sord_{r,f,x}$

Commodity balance	$\sum_f \sum_x Xlevl_{r,f,x} yild_{r,f,i,x} + MFlows_{r,i} + \sum_{r1} Flows_{r1,r,i}$ $\geq \sum_f Demand_{r,f,i} + \sum_f \sum_x Xlevl_{r,f,x} feed_{r,f,i,x} + XFlows_{r,i} + \sum_{r1} Flows_{r,r1,i}$

Demand module

Full version of the demand function	$Demand_{r,f,i} = \frac{a_{r,f,i}}{Price_{r,i} g_{r,f}} \left(Incm_{r,f} - \sum_k Price_{r,k} d_{r,f,k} \right)^2 + \left(\frac{b_{r,f,i} + \frac{\sum_k B_{r,f,i,k} Price_k}{\sum_k \alpha_{r,k} Price_k} - \frac{1}{2} \alpha_{r,i} \frac{\sum_k \sum_l B_{r,f,k,l} Price_{r,k} Price_{r,l}}{\left(\sum_k \alpha_{r,k} Price_{r,k} \right)^2}}{\sum_k Price_{r,k} b_{r,f,k} + \frac{1}{2} \left(\frac{\sum_k \sum_l B_{r,f,k,l} Price_{r,k} Price_{r,l}}{\sum_k \alpha_{r,k} Price_{r,k}} \right)} \right) \left(Incm_{r,f} - \sum_k Price_{r,k} d_{r,f,k} \right) + d_{r,f,i}$
Condition for positive predetermined parameter	$\sum_k \alpha_{r,k} Price^o_{r,k} = 1$
Total income (expenditure) of consumers	$Incm_{r,f} = \sum_i Demand_{r,f,i} Price_{r,i}$
First derivatives of the shorter version of demand function with respect to income	$\frac{\partial Demand^o_{r,f,i}}{\partial Incm^o_{r,f}} = \frac{2 a_{r,f,i} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{b_{r,f,i}}{\sum_k Price^o_{r,k} b_{r,f,k}}$
First derivatives of the shorter version of demand function with respect to prices	$\frac{\partial Demand^o_{r,f,i}}{\partial Price^o_{r,j}} = \frac{-a_i {Incm^o_{r,f}}^2 \left(\delta_{i,j} \sum_k Price^o_{r,k} b_{r,f,k} + Price^o_{r,i} b_{r,f,j} \right)}{\left(Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k} \right)^2}$ $- \frac{-2 a_{r,f,i} d_{r,f,j} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{Incm^o_{r,f}}{\sum_k Price^o_{r,k} b_{r,f,k}} B_{r,f,i,j}$ $- \frac{Incm^o_{r,f} b_{r,f,i} b_{r,f,j}}{\left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{b_i d_{r,f,j}}{\sum_k Price^o_{r,k} b_{r,f,k}}$

Links between supply and demand modules	
Total profit of rural households	$Incm_{r,f} = AgrIncm_{r,f} + nagrIncm^{o}_{r,f}$
Profits from agricultural activities in rural households	$AgrIncm_{r,f} = \sum_{i}\sum_{x}\left(Price_{r,i}Yild_{r,f,i,x} - varc_{r,f,x}\right)Xlevl_{r,f,x}$ $- \sum_{i}\sum_{x} Xlevl_{r,f,x} feed_{r,f,i,x} Price_{r,i}$ $+ \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1} Wage_{r,f} - \sum_{r1}\sum_{f1} LabrF_{r,r1,f,f1} dist_{r,r1} lc_{r}$
Observed non-agricultural profit in rural households	$nagrIncm^{o}_{r,f} = \sum_{i} Demand^{o}_{r,f,i} Price^{o}_{r,i}$ $- \sum_{i}\sum_{x}\left(Price^{o}_{r,i}Yild_{r,f,i,x} - varc_{r,f,x}\right)Xlevl^{o}_{r,f,x}$ $+ \sum_{i}\sum_{x} Xlevl^{o}_{r,f,x} feed_{r,f,i,x} Price^{o}_{r,i}$ $- \sum_{r1}\sum_{f1} LabrF^{o}_{r,r1,f,f1} Wage^{o}_{r} + \sum_{r1}\sum_{f1} LabrF^{o}_{r,r1,f,f1} dist_{r,r1} lc_{r}$

Table A5: Equations of the supply and demand modules calibration

Name of Equation	Equation
Calibration of supply module	
Stage 1: Estimation of shadow prices	
The objective function of the dual version of the supply module for deriving the shadow values of constraints	$\min W = \sum_{r}\sum_{f}\sum_{z} inptav_{r,f,z}\lambda_{r,f,z} + \sum_{r}\sum_{f} labrav_{r,f} v_{r,f}$ $- \sum_{r}\sum_{f}\sum_{x} sord_{r,f,x}\mu_{r,f,x} - \sum_{r}\sum_{f}\sum_{i} Demand^{o}_{r,f,i}\pi_{r,i}$
First derivative of Lagrangian over production activities	$\frac{\partial L}{\partial XLevl_{r,f,x}} = \sum_{i}\pi_{r,i}\left(yild_{r,f,i,x} - feed_{r,f,i,x}\right) - varc_{r,f,x}$ $- v_{r,f}\, labr_{r,f,x} - \sum_{z}\lambda_{r,f,z} inpt_{r,f,z,x} + \mu_{r,f,x} \quad \leq 0$
First derivative of Lagrangian over labor flows	$\frac{\partial L}{\partial LabrF_{r,r1,f,f1}} = -dist_{r,r1} lc_{r} + v_{r,f} - v_{r1,f1} \leq 0$
First derivative of Lagrangian over commodity inter-district flows	$\frac{\partial L}{\partial Flows_{r,r1,i}} = -dist_{r,r1} trc_{r,f,i} + \pi_{r,i} - \pi_{r1,i} \quad \leq 0$

First derivative of Lagrangian over export	$\frac{\partial L}{\partial XFlows_{r,i}} = pex_i - edist_r trc_{r,i} - \pi_{r,i} \le 0$
First derivative of Lagrangian over import	$\frac{\partial L}{\partial MFlows_{r,i}} = -pex_i - edist_r trc_{r,i} + \pi_{r,i} \le 0$

Stage 2: Adjusting technology coefficients

The objective function of the calibration model of supply side	$maxH = -\sum_t\sum_r\sum_f\sum_z\sum_x \overline{\overline{inpt}}_{t,r,f,z,x} ln\left(\overline{\overline{inpt}}_{t,r,f,z,x}\right)$ $-\sum_t\sum_r\sum_f\sum_z \overline{\overline{\lambda}}_{t,r,f,z} ln\left(\overline{\overline{\lambda}}_{t,r,f,z}\right) - \sum_t\sum_r\sum_f\sum_x \overline{\overline{labr}}_{t,r,f,x} ln\left(\overline{\overline{labr}}_{t,r,f,x}\right)$ $-\sum_t\sum_r\sum_f \overline{\overline{v}}_{t,r,f} ln\left(\overline{\overline{v}}_{t,r,f}\right) - \sum_t\sum_r\sum_i \overline{\overline{\pi}}_{t,r,i} ln\left(\overline{\overline{\pi}}_{t,r,i}\right)$ $-\sum_t\sum_r\sum_f\sum_x \overline{\overline{\mu}}_{t,r,f,x} ln\left(\overline{\overline{\mu}}_{t,r,f,x}\right)$
Kuhn-Tucker conditions to achieve the observed production activity levels	$\sum_i \pi^e_{r,i}\left(yild_{r,f,i,x} - feed_{r,f,i,x}\right) - varc^e_{r,f,x} =$ $v^e_{r,f}\ labr^e_{r,f,x} + \sum_z \lambda^e_{r,f,z} inpt^e_{r,f,z,x} - \mu^e_{r,f,x}$
Kuhn-Tucker conditions to achieve the observed labor flow levels	$v^e_{r1,f1} = v^e_{r,f} - dist_{r,r1} lc_r$
Kuhn-Tucker conditions to achieve the observed commodity flow levels	$\pi^e_{r1,i} = \pi^e_{r,i} - dist_{r,r1} trc_{r,i}$
Kuhn-Tucker conditions to achieve the observed export flow levels	$\pi^e_{r,i} = pex_i - edist_r trc_{r,i}$
Kuhn-Tucker conditions to achieve the observed import flow levels	$\pi^e_{r,i} = pex_i + edist_r trc_{r,i}$
The complementary slackness equalities of input constraints	$\left(\sum_x Xlevl^o_{r,f,x}\ inpt^e_{r,f,z,x} - inptav_{r,f,z}\right)\lambda^e_{r,f,z} = 0$
The complementary slackness equalities of labor constraint	$\left(labrb_{r,f} + \sum_{r1}\sum_{r1} LabrF^o_{r1,r,f1,f}\right.$ $\left.-\sum_x Xlevl^o_{r,f,x}\ labr^e_{r,f,x} - \sum_{r1}\sum_{r1} LabrF^o_{r,r1,f,f1}\right) v^e_{r,f} = 0$
The original model's input constraint	$\sum_x Xlevl^o_{r,f,x}\ inpt^e_{r,f,z,x} \le inptav_{r,f,z}$

The original model's labor constraint	$labrb_{r,f} + \sum_{r1}\sum_{r1} LabrF^{o}_{r1,r,f1,f} \geq$ $\sum_{x} Xlevl^{o}_{r,f,x}\, labr^{e}_{r,f,x} + \sum_{r1}\sum_{r1} LabrF^{o}_{r,r1,f,f1}$
Calibration of demand module	
Stage 1: Calibration of income and price elasticities of demand	
The objective function of the calibration model of income and price elasticities of the demand side	$maxZ^{0} = -\sum_{t}\sum_{r}\sum_{f}\sum_{i}\sum_{j} \bar{\bar{\varepsilon}}_{t,r,f,i,j} ln(\bar{\bar{\varepsilon}}_{t,r,f,i,j}) - \sum_{t}\sum_{r}\sum_{f}\sum_{i} \bar{\bar{\varepsilon}}^{y}_{t,r,f,i} ln(\bar{\bar{\varepsilon}}^{y}_{t,r,f,i})$
Adding-up budget restriction	$\sum_{i} \varepsilon^{y}_{r,f,i} \frac{Demand^{o}_{r,f,i} Price^{o}_{r,i}}{Incm^{o}_{r,f}} = 1$
Homogeneity condition for price and income elasticities	$\sum_{j} \varepsilon_{r,f,i,j} = -\varepsilon^{y}_{r,f,i}$
Symmetry in substitution effect between two products	$\varepsilon_{r,f,i,j} = \left(\varepsilon_{r,f,j,i} \frac{Demand^{o}_{r,f,j}}{Price^{o}_{r,i}} + \left(\varepsilon^{y}_{r,f,j} - \varepsilon^{y}_{r,f,i} \right) \frac{Demand^{o}_{r,f,i} Demand^{o}_{r,f,j}}{Incm^{o}_{r,f}} \right) \frac{Price^{o}_{r,j}}{Demand^{o}_{r,f,i}}$
Definition of Slutsky matrix	$S_{r,f,i,j} = \varepsilon_{r,f,i,j} \frac{Demand^{o}_{r,f,i}}{Price^{o}_{r,j}} + \varepsilon^{y}_{r,f,i} \frac{Demand^{o}_{r,f,i} Demand^{o}_{r,f,j}}{Incm^{o}_{r,f}}$
Cholesky–decomposition of Slutsky matrix to impose a negative semidefinite condition	and $S = -LL^{T}$
Stage 2: Calibration of functional parameters of NQ-QES	
The objective function of the calibration model for deriving the functional parameters of the demand	$minZ^{F} = \sum_{r}\sum_{f}\sum_{i}\sum_{j} (\varepsilon_{r,f,i,j} - \varepsilon^{F}_{r,f,i,j})^{2} + \sum_{r}\sum_{f}\sum_{i} (\varepsilon^{y}_{r,f,i} - \varepsilon^{yF}_{r,f,i})^{2}$
Symmetry restriction of the demand parameter	$B_{r,f,i,j} = B_{r,f,j,i}$
Adding-up restriction of the demand parameters	$\sum_{k} B_{r,f,i,k} Price^{o}_{r,k} = 0$

Adding-up restriction of the demand parameters	$\sum_k a_{r,f,k} = 0$
Adding-up restriction of the demand parameters	$\sum_k b_{r,f,k} = 1$
Adding-up restriction of the demand parameters	$\sum_k d_k Price^o_{r,k} = 0$
Definition of final calibrated price elasticities of demand	$\varepsilon^F_{r,f,i,j} = \left(\frac{-a_{r,f,i} Incm^{o\,2}_{r,f} \left(\delta_{i,j} \sum_k Price^o_{r,k} b_{r,f,k} + Price^o_{r,i} b_{r,f,j} \right)}{\left(Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{-2a_{r,f,i} d_{r,f,j} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{Incm^o_{r,f}}{\sum_k Price^o_{r,k} b_{r,f,k}} B_{r,f,i,j} - \frac{Incm^o_{r,f} b_{r,f,i} b_{r,f,j}}{\left(\sum_k Price^o_{r,k} b_{r,f,k} \right)^2} - \frac{b_{r,f,i} d_{r,f,j}}{\sum_k Price^o_{r,k} b_{r,f,k}} \right) \frac{Price^o_{r,j}}{Demand^o_{r,f,i}}$
Definition of final calibrated income elasticities of demand	$\varepsilon^{yF}_{r,f,i} = \left(\frac{2a_{r,f,i} Incm^o_{r,f}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} + \frac{b_{r,f,i}}{\sum_k Price^o_{r,k} b_{r,f,k}} \right) \frac{Incm^o_{r,f}}{Demand^o_{r,f,i}}$
Shorter version of demand requiring that the quantities demanded meet their observed values	$Demand^o_{r,f,i} = \frac{a_{r,f,i}}{Price^o_{r,i} \sum_k Price^o_{r,k} b_{r,f,k}} Incm^{o\,2}_{r,f} + \frac{b_{r,f,i}}{\sum_k Price^o_{r,k} b_{r,f,k}} Incm^o_{r,f} + d_{r,f,i}$ where d is set to zero

Appendix 3: Information on Demand System

Table A6: Observed consumption per capita in households and prices in 2003

Commodity		Consumption, per capita [1)]			Commodity prices, 10^{-3} USD [2)]				
		REG	RUR	URB	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT
WWT	kg	177	179	170	104	106	108	105	107
RCE	kg	14	13	15	255	249	244	250	245
POT	kg	44	45	43	86	88	89	88	89
FRT	kg	51	52	49	47	50	50	50	52
VGL	kg	94	95	90	96	94	94	95	94
MLK	kg	142	138	153	154	150	147	151	148
EGG	piece	57	58	55	54	52	51	52	52
MEA	kg	24	23	29	1,790	1,743	1,700	1,748	1,709
OTH	kg	33	32	38	990	1,010	1,029	1,008	1,025
MFR	kg	189	179	224	990	1,010	1,029	1,008	1,025
LSR	h	145	188	0	55	54	53	54	53

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; REG – Average in the region; RUR – Rural households; URB – Urban households; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: FAO Statistics Division 2007; OblStat 2004c

Table A7: Observed demand in households and expenditures in 2003

Commodity		Rural Households					Urban Households				
		KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT
WWT	10^3 t	48.8	42.9	27.3	37.1	39.0	5.5	30.1	4.9	8.8	5.5
RCE	10^3 t	3.7	3.2	2.1	2.8	2.9	0.5	2.7	0.4	0.8	0.5
POT	10^3 t	12.2	10.7	6.8	9.3	9.7	1.4	7.5	1.2	2.2	1.4
FRT	10^3 t	14.2	12.5	7.9	10.8	11.3	1.6	8.8	1.4	2.5	1.6
VGL	10^3 t	25.8	22.7	14.5	19.6	20.7	2.9	16.0	2.6	4.6	2.9
MLK	10^3 t	37.7	33.1	21.1	28.6	30.1	4.9	27.2	4.4	7.9	4.9
EGG	10^6 piece	15.9	14.0	8.9	12.0	12.7	1.8	9.8	1.6	2.9	1.8
MEA	10^3 t	6.3	5.6	3.5	4.8	5.0	0.9	5.1	0.8	1.5	0.9
OTH	10^3 t	8.8	7.7	4.9	6.7	7.0	1.2	6.7	1.1	2.0	1.2
MFR	10^3 t	48.9	43.0	27.4	37.2	39.1	7.2	39.7	6.5	11.5	7.2
LSR	10^6 h	51.3	45.2	28.7	39.0	41.0	-	-	-	-	-
EXP	10^6 USD	88.0	78.1	50.1	67.4	71.5	12.0	66.8	11.0	19.4	12.2

Note: WWT –Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; EXP – Total consumption expenditure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: FAO Statistics Division 2007; OblStat 2004b; Own calculation

Table A8: Observed primal values for income and price elasticities

	Cross-Price Elasticity											Income
	WWT	RCE	POT	FRT	VGL	MLK	EGG	MEA	OTH	MFT	LSR	Elasticity
WWT	-0.34	0.18	0.15	-0.10	-0.15	-0.15	-0.15	-0.20	0.05	0.05	0.05	0.70
RCE	0.20	-0.36	0.15	0.10	0.15	-0.15	-0.15	-0.25	-0.15	0.10	0.05	0.80
POT	0.05	0.15	-0.30	0.10	0.20	0.10	0.05	-0.20	-0.15	-0.15	0.01	0.50
FRT	-0.05	0.10	0.10	-0.35	0.25	0.20	-0.10	-0.25	-0.25	0.05	0.05	0.85
VGL	-0.30	0.10	0.30	0.20	-0.35	-0.35	0.10	0.10	0.05	-0.30	0.05	0.70
MLK	-0.10	-0.15	0.10	0.25	-0.20	-0.35	-0.25	-0.20	0.05	-0.05	0.05	1.00
EGG	-0.10	-0.15	0.20	-0.10	0.20	-0.25	-0.54	-0.20	0.05	0.10	-0.10	1.00
MEA	-0.10	-0.10	-0.10	-0.25	0.20	-0.20	-0.20	-0.40	0.05	-0.10	0.01	1.00
OTH	0.10	-0.20	-0.10	-0.25	0.10	0.10	0.10	0.20	-0.60	0.01	0.01	0.90
MFR	-0.05	-0.05	-0.05	-0.10	-0.05	-0.10	-0.10	-0.10	-0.10	-1.25	-0.15	1.40
LSR	-0.05	0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.70	1.00

Note: WWT – Wheat and other food grains; RCE – Rice, POT – Potato, FRT – Fruits and melons; VGL – Vegetables, MLK – Milk and milk products, EGG – Eggs, MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure

Source: WATSIM model's base-run dataset on the rest of the world

Table A9: Calibrated values of income elasticity of demand

Commodity	Rural Households					Urban Households				
	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT
WWT	0.54	0.54	0.54	0.54	0.54	0.59	0.58	0.58	0.58	0.58
RCE	0.61	0.61	0.61	0.61	0.61	0.64	0.63	0.63	0.63	0.63
POT	0.48	0.48	0.48	0.48	0.48	0.51	0.51	0.51	0.51	0.51
FRT	0.65	0.65	0.65	0.65	0.65	0.70	0.70	0.70	0.70	0.70
VGL	0.64	0.65	0.65	0.65	0.65	0.74	0.74	0.75	0.74	0.75
MLK	0.81	0.82	0.82	0.82	0.82	0.88	0.88	0.88	0.88	0.88
EGG	0.87	0.87	0.87	0.87	0.87	0.82	0.82	0.82	0.82	0.82
MEA	0.75	0.76	0.76	0.76	0.76	0.83	0.84	0.85	0.84	0.85
OTH	0.43	0.43	0.43	0.43	0.43	0.46	0.46	0.47	0.46	0.47
MFR	1.25	1.24	1.24	1.24	1.24	1.21	1.20	1.20	1.20	1.20
LSR	1.50	1.50	1.49	1.50	1.49	-	-	-	-	-

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A10: Calibrated cross-price elasticity of demand for rural households

		WWT	RCE	POT	FRT	VGL	MLK	EGG	MEA	OTH	MFR	LSR
KSPBGT	WWT	-0.444	0.065	0.096	-0.029	-0.162	-0.250	-0.033	-0.193	0.271	0.132	0.002
	RCE	0.344	-0.582	0.105	0.096	0.392	-0.467	-0.233	-0.361	-0.468	0.339	0.224
	POT	0.466	0.095	-0.450	0.068	0.169	0.455	0.303	-0.401	-0.511	-0.709	0.030
	FRT	-0.261	0.156	0.123	-0.523	0.498	0.657	-0.315	-0.439	-0.723	0.151	0.027
	VGL	-0.337	0.149	0.070	0.116	-0.545	-0.295	0.150	0.448	0.258	-0.664	0.008
	MLK	-0.234	-0.078	0.079	0.064	-0.130	-0.379	-0.038	-0.180	0.268	-0.187	0.002
	EGG	-0.213	-0.260	0.371	-0.214	0.430	-0.264	-0.582	-0.344	0.294	0.196	-0.285
	MEA	-0.098	-0.031	-0.041	-0.023	0.095	-0.088	-0.025	-0.495	0.133	-0.184	0.008
	OTH	0.165	-0.048	-0.061	-0.046	0.079	0.204	0.033	0.214	-1.017	0.038	0.015
	MFR	-0.027	0.000	-0.025	-0.002	-0.051	-0.051	0.000	-0.107	-0.074	-0.901	-0.009
	LSR	-0.052	0.065	-0.001	0.000	-0.017	-0.042	-0.092	-0.065	-0.060	-0.295	-0.946
KKAURG	WWT	-0.445	0.063	0.097	-0.029	-0.159	-0.246	-0.031	-0.191	0.270	0.131	0.001
	RCE	0.349	-0.581	0.107	0.099	0.394	-0.473	-0.236	-0.363	-0.472	0.340	0.224
	POT	0.469	0.093	-0.452	0.069	0.166	0.451	0.301	-0.390	-0.509	-0.711	0.030
	FRT	-0.261	0.152	0.122	-0.525	0.491	0.643	-0.308	-0.426	-0.715	0.152	0.026
	VGL	-0.344	0.148	0.071	0.120	-0.545	-0.295	0.149	0.450	0.259	-0.666	0.008
	MLK	-0.241	-0.079	0.081	0.066	-0.132	-0.383	-0.038	-0.181	0.273	-0.188	0.001
	EGG	-0.214	-0.262	0.385	-0.223	0.431	-0.264	-0.582	-0.344	0.295	0.196	-0.285
	MEA	-0.102	-0.032	-0.041	-0.024	0.097	-0.089	-0.025	-0.497	0.137	-0.188	0.008
	OTH	0.164	-0.047	-0.061	-0.046	0.077	0.199	0.032	0.211	-1.008	0.038	0.015
	MFR	-0.027	0.000	-0.025	-0.002	-0.049	-0.049	0.000	-0.102	-0.075	-0.904	-0.008
	LSR	-0.053	0.065	-0.001	0.000	-0.017	-0.041	-0.092	-0.062	-0.060	-0.295	-0.947
YZRGLN	WWT	-0.446	0.061	0.097	-0.029	-0.158	-0.244	-0.030	-0.189	0.270	0.131	0.001
	RCE	0.352	-0.581	0.110	0.101	0.396	-0.476	-0.238	-0.364	-0.474	0.341	0.224
	POT	0.471	0.091	-0.453	0.068	0.163	0.446	0.300	-0.381	-0.506	-0.713	0.030
	FRT	-0.261	0.151	0.122	-0.525	0.492	0.637	-0.308	-0.421	-0.712	0.152	0.025
	VGL	-0.350	0.147	0.072	0.121	-0.545	-0.293	0.147	0.451	0.261	-0.667	0.007
	MLK	-0.248	-0.079	0.084	0.067	-0.132	-0.385	-0.039	-0.181	0.277	-0.189	0.001
	EGG	-0.216	-0.264	0.398	-0.227	0.431	-0.267	-0.584	-0.345	0.295	0.196	-0.283
	MEA	-0.106	-0.032	-0.042	-0.024	0.099	-0.090	-0.025	-0.499	0.142	-0.192	0.007
	OTH	0.163	-0.045	-0.061	-0.046	0.076	0.195	0.031	0.208	-0.998	0.038	0.007
	MFR	-0.027	0.000	-0.025	-0.002	-0.048	-0.046	0.000	-0.098	-0.074	-0.907	-0.008
	LSR	-0.054	0.064	-0.001	0.000	-0.016	-0.039	-0.089	-0.059	-0.083	-0.285	-0.926
KVAYRK	WWT	-0.445	0.063	0.097	-0.029	-0.160	-0.247	-0.032	-0.191	0.270	0.131	0.001
	RCE	0.348	-0.582	0.107	0.099	0.394	-0.472	-0.235	-0.362	-0.472	0.340	0.224
	POT	0.469	0.093	-0.452	0.069	0.166	0.451	0.301	-0.392	-0.509	-0.711	0.030
	FRT	-0.261	0.153	0.122	-0.525	0.492	0.645	-0.309	-0.427	-0.716	0.152	0.026
	VGL	-0.343	0.148	0.071	0.120	-0.545	-0.295	0.149	0.450	0.259	-0.666	0.008
	MLK	-0.240	-0.078	0.081	0.066	-0.131	-0.382	-0.038	-0.181	0.272	-0.188	0.001
	EGG	-0.214	-0.262	0.383	-0.222	0.431	-0.264	-0.582	-0.344	0.295	0.196	-0.285
	MEA	-0.102	-0.032	-0.041	-0.024	0.097	-0.089	-0.025	-0.497	0.137	-0.187	0.008
	OTH	0.164	-0.047	-0.061	-0.046	0.077	0.200	0.032	0.212	-1.009	0.038	0.015
	MFR	-0.027	0.000	-0.025	-0.002	-0.049	-0.049	0.000	-0.102	-0.075	-0.903	-0.008
	LSR	-0.053	0.065	-0.001	0.000	-0.017	-0.041	-0.092	-0.062	-0.060	-0.295	-0.947
KKRSVT	WWT	-0.446	0.061	0.097	-0.030	-0.158	-0.244	-0.031	-0.189	0.270	0.131	0.001
	RCE	0.352	-0.581	0.109	0.102	0.395	-0.476	-0.238	-0.364	-0.473	0.341	0.224
	POT	0.471	0.092	-0.453	0.069	0.164	0.447	0.301	-0.383	-0.506	-0.714	0.029
	FRT	-0.261	0.149	0.121	-0.526	0.486	0.633	-0.304	-0.416	-0.706	0.152	0.025
	VGL	-0.348	0.147	0.072	0.123	-0.546	-0.294	0.149	0.451	0.261	-0.668	0.007
	MLK	-0.246	-0.079	0.083	0.068	-0.132	-0.385	-0.039	-0.181	0.277	-0.189	0.001
	EGG	-0.215	-0.262	0.392	-0.227	0.429	-0.265	-0.583	-0.345	0.295	0.196	-0.281
	MEA	-0.105	-0.032	-0.042	-0.024	0.098	-0.090	-0.025	-0.499	0.141	-0.191	0.007
	OTH	0.164	-0.045	-0.061	-0.047	0.076	0.196	0.031	0.209	-0.999	0.038	0.007
	MFR	-0.027	0.000	-0.025	-0.002	-0.048	-0.047	0.000	-0.098	-0.074	-0.907	-0.008
	LSR	-0.054	0.065	0.000	0.000	-0.016	-0.039	-0.091	-0.059	-0.083	-0.285	-0.926

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A11: Calibrated cross-price elasticity of demand for urban households

		WWT	RCE	POT	FRT	VGL	MLK	EGG	MEA	OTH	MFR
KSPBGT	WWT	-0.553	0.143	0.096	-0.031	-0.196	-0.274	-0.041	-0.198	0.314	0.151
	RCE	0.661	-0.671	0.102	0.087	0.428	-0.433	-0.230	-0.345	-0.456	0.222
	POT	0.465	0.107	-0.478	0.080	0.196	0.515	0.302	-0.485	-0.525	-0.686
	FRT	-0.279	0.164	0.145	-0.553	0.541	0.796	-0.351	-0.528	-0.784	0.146
	VGL	-0.408	0.188	0.081	0.126	-0.575	-0.350	0.164	0.506	0.277	-0.752
	MLK	-0.218	-0.072	0.077	0.067	-0.131	-0.420	-0.040	-0.199	0.270	-0.208
	EGG	-0.258	-0.297	0.371	-0.238	0.474	-0.318	-0.641	-0.392	0.264	0.212
	MEA	-0.079	-0.027	-0.038	-0.021	0.082	-0.088	-0.023	-0.537	0.142	-0.245
	OTH	0.153	-0.045	-0.051	-0.041	0.070	0.196	0.024	0.247	-1.055	0.039
	MFR	-0.017	-0.002	-0.018	-0.001	-0.040	-0.043	0.000	-0.108	-0.068	-0.907
KKAURG	WWT	-0.557	0.142	0.097	-0.032	-0.193	-0.268	-0.040	-0.195	0.313	0.151
	RCE	0.682	-0.673	0.103	0.089	0.429	-0.440	-0.231	-0.348	-0.463	0.220
	POT	0.469	0.104	-0.480	0.081	0.193	0.510	0.300	-0.473	-0.524	-0.689
	FRT	-0.279	0.160	0.144	-0.555	0.535	0.781	-0.344	-0.514	-0.775	0.147
	VGL	-0.417	0.187	0.083	0.131	-0.575	-0.350	0.163	0.509	0.278	-0.752
	MLK	-0.223	-0.074	0.079	0.069	-0.132	-0.424	-0.041	-0.200	0.274	-0.209
	EGG	-0.259	-0.299	0.385	-0.247	0.476	-0.319	-0.642	-0.391	0.264	0.211
	MEA	-0.082	-0.028	-0.038	-0.022	0.084	-0.089	-0.023	-0.540	0.147	-0.249
	OTH	0.153	-0.043	-0.051	-0.041	0.068	0.191	0.023	0.243	-1.046	0.039
	MFR	-0.018	-0.002	-0.018	-0.001	-0.039	-0.041	0.000	-0.103	-0.068	-0.910
YZRGLN	WWT	-0.561	0.140	0.097	-0.031	-0.191	-0.264	-0.039	-0.191	0.313	0.151
	RCE	0.702	-0.675	0.105	0.090	0.431	-0.446	-0.233	-0.351	-0.469	0.219
	POT	0.471	0.102	-0.481	0.080	0.190	0.507	0.299	-0.461	-0.524	-0.690
	FRT	-0.278	0.157	0.145	-0.555	0.537	0.775	-0.344	-0.509	-0.774	0.147
	VGL	-0.425	0.185	0.084	0.132	-0.574	-0.350	0.161	0.511	0.279	-0.750
	MLK	-0.229	-0.074	0.082	0.070	-0.133	-0.427	-0.041	-0.199	0.277	-0.210
	EGG	-0.262	-0.301	0.398	-0.253	0.476	-0.320	-0.643	-0.392	0.264	0.211
	MEA	-0.085	-0.028	-0.039	-0.022	0.085	-0.089	-0.023	-0.542	0.151	-0.254
	OTH	0.152	-0.042	-0.051	-0.040	0.066	0.185	0.022	0.239	-1.038	0.039
	MFR	-0.018	-0.002	-0.018	-0.001	-0.037	-0.039	0.000	-0.099	-0.068	-0.913
KVAYRK	WWT	-0.556	0.142	0.097	-0.031	-0.193	-0.269	-0.040	-0.195	0.313	0.151
	RCE	0.679	-0.673	0.103	0.089	0.429	-0.440	-0.231	-0.348	-0.462	0.220
	POT	0.468	0.104	-0.480	0.081	0.193	0.511	0.300	-0.474	-0.524	-0.688
	FRT	-0.278	0.160	0.144	-0.555	0.535	0.783	-0.344	-0.516	-0.777	0.147
	VGL	-0.416	0.187	0.083	0.130	-0.575	-0.350	0.163	0.509	0.278	-0.752
	MLK	-0.223	-0.073	0.079	0.069	-0.132	-0.424	-0.040	-0.199	0.273	-0.209
	EGG	-0.259	-0.299	0.383	-0.246	0.476	-0.319	-0.642	-0.391	0.264	0.211
	MEA	-0.082	-0.028	-0.038	-0.022	0.084	-0.089	-0.023	-0.539	0.146	-0.249
	OTH	0.153	-0.043	-0.051	-0.041	0.068	0.191	0.023	0.244	-1.047	0.039
	MFR	-0.017	-0.002	-0.018	-0.001	-0.039	-0.041	0.000	-0.104	-0.068	-0.910
KKRSVT	WWT	-0.560	0.140	0.097	-0.032	-0.191	-0.264	-0.039	-0.192	0.313	0.151
	RCE	0.698	-0.674	0.105	0.091	0.430	-0.445	-0.234	-0.350	-0.468	0.219
	POT	0.471	0.102	-0.482	0.081	0.191	0.507	0.300	-0.465	-0.523	-0.691
	FRT	-0.278	0.156	0.143	-0.556	0.531	0.771	-0.340	-0.503	-0.769	0.147
	VGL	-0.422	0.186	0.084	0.134	-0.575	-0.351	0.163	0.511	0.278	-0.753
	MLK	-0.227	-0.074	0.081	0.071	-0.133	-0.428	-0.041	-0.199	0.277	-0.210
	EGG	-0.260	-0.299	0.391	-0.252	0.475	-0.318	-0.642	-0.391	0.264	0.211
	MEA	-0.084	-0.028	-0.039	-0.023	0.085	-0.089	-0.023	-0.541	0.150	-0.253
	OTH	0.153	-0.043	-0.051	-0.041	0.067	0.187	0.022	0.240	-1.039	0.039
	MFR	-0.018	-0.002	-0.018	-0.001	-0.038	-0.039	0.000	-0.100	-0.068	-0.912

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A12: Values of calibrated functional parameter α of NQ-QES

Commodity	Rural Households					Urban Households				
	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT
WWT	-8.9E-08	-1.0E-07	-1.6E-07	-1.2E-07	-1.1E-07	-6.0E-07	-1.1E-07	-7.0E-07	-3.8E-07	-6.3E-07
RCE	-1.4E-08	-1.5E-08	-2.4E-08	-1.8E-08	-1.7E-08	-1.1E-07	-2.0E-08	-1.2E-07	-7.0E-08	-1.1E-07
POT	-2.1E-08	-2.4E-08	-3.8E-08	-2.8E-08	-2.7E-08	-1.5E-07	-2.7E-08	-1.7E-07	-9.4E-08	-1.5E-07
FRT	-7.8E-09	-9.1E-09	-1.4E-08	-1.0E-08	-1.0E-08	-4.9E-08	-9.2E-09	-5.6E-08	-3.2E-08	-5.2E-08
VGL	-3.4E-08	-3.7E-08	-5.7E-08	-4.4E-08	-4.0E-08	-1.8E-07	-3.2E-08	-1.9E-07	-1.1E-07	-1.7E-07
MLK	-4.1E-08	-4.5E-08	-6.6E-08	-5.2E-08	-4.7E-08	-2.4E-07	-4.1E-08	-2.3E-07	-1.4E-07	-2.1E-07
EGG	-4.3E-09	-4.8E-09	-7.4E-09	-5.5E-09	-5.2E-09	-4.3E-08	-7.6E-09	-4.6E-08	-2.6E-08	-4.2E-08
MEA	-1.1E-07	-1.2E-07	-1.7E-07	-1.4E-07	-1.2E-07	-7.1E-07	-1.2E-07	-6.8E-07	-4.1E-07	-6.2E-07
OTH	-1.9E-07	-2.2E-07	-3.5E-07	-2.6E-07	-2.4E-07	-1.7E-06	-3.0E-07	-1.9E-06	-1.0E-06	-1.7E-06
MFR	4.6E-07	5.1E-07	8.0E-07	6.0E-07	5.6E-07	3.8E-06	6.7E-07	4.1E-06	2.3E-06	3.7E-06
LSR	5.4E-08	6.0E-08	9.0E-08	7.0E-08	6.3E-08	-	-	-	-	-

Note: WWT – Wheat and other food grains; RCE – Rice, POT – Potato, FRT – Fruits and melons; VGL – Vegetables, MLK – Milk and milk products, EGG – Eggs, MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A13: Values of calibrated functional parameter β of NQ-QES

Commodity	Rural Households					Urban Households				
	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT	KSPBGT	KKAURG	YZRGLN	KVAYRK	KKRSVT
WWT	0.240	0.241	0.241	0.241	0.241	0.238	0.239	0.240	0.239	0.240
RCE	0.017	0.017	0.017	0.017	0.017	0.020	0.020	0.020	0.020	0.020
POT	0.062	0.062	0.062	0.062	0.062	0.063	0.063	0.063	0.063	0.063
FRT	0.065	0.065	0.065	0.065	0.065	0.064	0.064	0.064	0.064	0.064
VGL	0.119	0.118	0.118	0.118	0.118	0.112	0.112	0.112	0.112	0.112
MLK	0.151	0.150	0.149	0.151	0.150	0.171	0.170	0.169	0.170	0.169
EGG	0.061	0.061	0.061	0.061	0.061	0.065	0.065	0.064	0.065	0.064
MEA	0.027	0.027	0.026	0.027	0.026	0.033	0.033	0.033	0.033	0.033
OTH	0.047	0.047	0.046	0.047	0.046	0.058	0.058	0.057	0.058	0.057
MFR	0.125	0.126	0.126	0.126	0.126	0.176	0.177	0.178	0.177	0.178
LSR	0.086	0.086	0.089	0.086	0.088	-	-	-	-	-

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A14: Calibrated functional parameters *B* of NQ-QES in rural households

		WWT	RCE	POT	FRT	VGL	MLK	EGG	MEA	OTH	MFR	LSR
KSPBGT	WWT	-1.3E-03	5.1E-05	2.2E-04	-8.2E-05	-2.1E-04	-1.8E-04	-6.7E-05	-3.0E-06	7.1E-05	9.1E-05	5.3E-05
	RCE	5.1E-05	-4.7E-05	1.8E-05	3.2E-05	5.6E-05	-3.1E-05	-5.1E-05	-1.4E-06	-3.9E-06	9.5E-06	5.5E-05
	POT	2.2E-04	1.8E-05	-4.5E-04	7.8E-05	9.0E-05	1.4E-04	2.4E-04	-5.5E-06	-1.5E-05	-1.2E-05	3.5E-05
	FRT	-8.2E-05	3.2E-05	7.8E-05	-1.0E-03	2.7E-04	2.3E-04	-2.7E-04	-7.5E-06	-2.7E-05	2.7E-05	3.7E-05
	VGL	-2.1E-04	5.6E-05	9.0E-05	2.7E-04	-7.9E-04	-1.2E-04	2.6E-04	3.0E-05	3.7E-05	-2.2E-05	3.8E-05
	MLK	-1.8E-04	-3.1E-05	1.4E-04	2.3E-04	-1.2E-04	-4.0E-04	-6.5E-05	-1.4E-06	5.5E-05	2.9E-05	4.0E-05
	EGG	-6.7E-05	-5.1E-05	2.4E-04	-2.7E-04	2.6E-04	-6.5E-05	-7.0E-04	-5.5E-06	2.4E-05	3.3E-05	-2.6E-04
	MEA	-3.0E-06	-1.4E-06	-5.5E-06	-7.5E-06	3.0E-05	-1.4E-06	-5.5E-06	-7.0E-06	6.2E-06	5.0E-06	9.3E-06
	OTH	7.1E-05	-3.9E-06	-1.5E-05	-2.7E-05	3.7E-05	5.5E-05	2.4E-05	6.2E-06	-4.3E-05	1.4E-05	1.7E-05
	MFR	9.1E-05	9.5E-06	-1.2E-05	2.7E-05	-2.2E-05	2.9E-05	3.3E-05	5.0E-06	1.4E-05	-4.0E-05	2.1E-05
	LSR	5.3E-05	5.5E-05	3.5E-05	3.7E-05	3.8E-05	4.0E-05	-2.6E-04	9.3E-06	1.7E-05	2.1E-05	-1.4E-03
KKAURG	WWT	-1.3E-03	5.1E-05	2.2E-04	-8.0E-05	-2.1E-04	-1.9E-04	-6.5E-05	-3.5E-06	7.0E-05	9.0E-05	5.2E-05
	RCE	5.1E-05	-4.8E-05	1.8E-05	3.2E-05	5.7E-05	-3.3E-05	-5.3E-05	-1.5E-06	-3.9E-06	9.4E-06	5.5E-05
	POT	2.2E-04	1.8E-05	-4.4E-04	7.6E-05	8.9E-05	1.4E-04	2.5E-04	-5.6E-06	-1.4E-05	-1.2E-05	3.5E-05
	FRT	-8.0E-05	3.2E-05	7.6E-05	-9.9E-04	2.7E-04	2.3E-04	-2.7E-04	-7.5E-06	-2.6E-05	2.7E-05	3.7E-05
	VGL	-2.1E-04	5.7E-05	8.9E-05	2.7E-04	-8.0E-04	-1.3E-04	2.7E-04	3.0E-05	3.6E-05	-2.1E-05	3.8E-05
	MLK	-1.9E-04	-3.3E-05	1.4E-04	2.3E-04	-1.3E-04	-4.1E-04	-6.7E-05	-1.9E-06	5.4E-05	3.0E-05	4.0E-05
	EGG	-6.5E-05	-5.3E-05	2.5E-04	-2.7E-04	2.7E-04	-6.7E-05	-7.2E-04	-5.8E-06	2.4E-05	3.3E-05	-2.7E-04
	MEA	-3.5E-06	-1.5E-06	-5.6E-06	-7.5E-06	3.0E-05	-1.9E-06	-5.8E-06	-7.2E-06	6.2E-06	5.0E-06	9.2E-06
	OTH	7.0E-05	-3.9E-06	-1.4E-05	-2.6E-05	3.6E-05	5.4E-05	2.4E-05	6.2E-06	-4.2E-05	1.4E-05	1.7E-05
	MFR	9.0E-05	9.4E-06	-1.2E-05	2.7E-05	-2.1E-05	3.0E-05	3.3E-05	5.0E-06	1.4E-05	-3.9E-05	2.2E-05
	LSR	5.2E-05	5.5E-05	3.5E-05	3.7E-05	3.8E-05	4.0E-05	-2.7E-04	9.2E-06	1.7E-05	2.2E-05	-1.4E-03
YZRGLN	WWT	-1.3E-03	5.0E-05	2.1E-04	-7.7E-05	-2.1E-04	-1.9E-04	-6.5E-05	-3.9E-06	6.9E-05	9.0E-05	5.2E-05
	RCE	5.0E-05	-4.9E-05	1.8E-05	3.2E-05	5.7E-05	-3.4E-05	-5.5E-05	-1.6E-06	-3.8E-06	9.3E-06	5.5E-05
	POT	2.1E-04	1.8E-05	-4.4E-04	7.5E-05	8.8E-05	1.4E-04	2.5E-04	-5.6E-06	-1.4E-05	-1.1E-05	3.5E-05
	FRT	-7.7E-05	3.2E-05	7.5E-05	-9.8E-04	2.7E-04	2.3E-04	-2.8E-04	-7.6E-06	-2.6E-05	2.7E-05	3.6E-05
	VGL	-2.1E-04	5.7E-05	8.8E-05	2.7E-04	-8.0E-04	-1.3E-04	2.7E-04	3.1E-05	3.5E-05	-2.0E-05	3.8E-05
	MLK	-1.9E-04	-3.4E-05	1.4E-04	2.3E-04	-1.3E-04	-4.2E-04	-7.0E-05	-2.4E-06	5.4E-05	3.0E-05	4.0E-05
	EGG	-6.5E-05	-5.5E-05	2.5E-04	-2.8E-04	2.7E-04	-7.0E-05	-7.4E-04	-6.2E-06	2.4E-05	3.3E-05	-2.7E-04
	MEA	-3.9E-06	-1.6E-06	-5.6E-06	-7.6E-06	3.1E-05	-2.4E-06	-6.2E-06	-7.4E-06	6.2E-06	4.9E-06	9.1E-06
	OTH	6.9E-05	-3.8E-06	-1.4E-05	-2.6E-05	3.5E-05	5.4E-05	2.4E-05	6.2E-06	-4.1E-05	1.3E-05	1.3E-05
	MFR	9.0E-05	9.3E-06	-1.1E-05	2.7E-05	-2.0E-05	3.0E-05	3.3E-05	4.9E-06	1.3E-05	-3.9E-05	2.4E-05
	LSR	5.2E-05	5.5E-05	3.5E-05	3.6E-05	3.8E-05	4.0E-05	-2.7E-04	9.1E-06	1.3E-05	2.4E-05	-1.4E-03
KVAYRK	WWT	-1.3E-03	5.1E-05	2.2E-04	-8.0E-05	-2.1E-04	-1.9E-04	-6.6E-05	-3.4E-06	7.0E-05	9.1E-05	5.2E-05
	RCE	5.1E-05	-4.8E-05	1.8E-05	3.2E-05	5.7E-05	-3.3E-05	-5.3E-05	-1.5E-06	-3.9E-06	9.4E-06	5.5E-05
	POT	2.2E-04	1.8E-05	-4.5E-04	7.6E-05	8.9E-05	1.4E-04	2.4E-04	-5.6E-06	-1.4E-05	-1.2E-05	3.5E-05
	FRT	-8.0E-05	3.2E-05	7.6E-05	-9.9E-04	2.7E-04	2.3E-04	-2.7E-04	-7.5E-06	-2.7E-05	2.7E-05	3.7E-05
	VGL	-2.1E-04	5.7E-05	8.9E-05	2.7E-04	-8.0E-04	-1.3E-04	2.7E-04	3.0E-05	3.6E-05	-2.1E-05	3.8E-05
	MLK	-1.9E-04	-3.3E-05	1.4E-04	2.3E-04	-1.3E-04	-4.1E-04	-6.7E-05	-1.9E-06	5.4E-05	3.0E-05	4.0E-05
	EGG	-6.6E-05	-5.3E-05	2.4E-04	-2.7E-04	2.7E-04	-6.7E-05	-7.2E-04	-5.8E-06	2.4E-05	3.3E-05	-2.7E-04
	MEA	-3.4E-06	-1.5E-06	-5.6E-06	-7.5E-06	3.0E-05	-1.9E-06	-5.8E-06	-7.2E-06	6.2E-06	5.0E-06	9.2E-06
	OTH	7.0E-05	-3.9E-06	-1.4E-05	-2.7E-05	3.6E-05	5.4E-05	2.4E-05	6.2E-06	-4.2E-05	1.4E-05	1.7E-05
	MFR	9.1E-05	9.4E-06	-1.2E-05	2.7E-05	-2.1E-05	3.0E-05	3.3E-05	5.0E-06	1.4E-05	-3.9E-05	2.2E-05
	LSR	5.2E-05	5.5E-05	3.5E-05	3.7E-05	3.8E-05	4.0E-05	-2.7E-04	9.2E-06	1.7E-05	2.2E-05	-1.4E-03
KKRSVT	WWT	-1.3E-03	5.0E-05	2.1E-04	-7.8E-05	-2.1E-04	-1.9E-04	-6.4E-05	-3.8E-06	6.9E-05	9.0E-05	5.2E-05
	RCE	5.0E-05	-4.8E-05	1.8E-05	3.2E-05	5.7E-05	-3.4E-05	-5.4E-05	-1.6E-06	-3.8E-06	9.3E-06	5.6E-05
	POT	2.1E-04	1.8E-05	-4.4E-04	7.4E-05	8.8E-05	1.4E-04	2.5E-04	-5.6E-06	-1.4E-05	-1.1E-05	3.5E-05
	FRT	-7.8E-05	3.2E-05	7.4E-05	-9.6E-04	2.7E-04	2.3E-04	-2.7E-04	-7.5E-06	-2.6E-05	2.7E-05	3.7E-05
	VGL	-2.1E-04	5.7E-05	8.8E-05	2.7E-04	-8.0E-04	-1.3E-04	2.7E-04	3.1E-05	3.6E-05	-2.0E-05	3.7E-05
	MLK	-1.9E-04	-3.4E-05	1.4E-04	2.3E-04	-1.3E-04	-4.2E-04	-6.9E-05	-2.3E-06	5.4E-05	3.0E-05	4.0E-05
	EGG	-6.4E-05	-5.4E-05	2.5E-04	-2.7E-04	2.7E-04	-6.9E-05	-7.2E-04	-6.1E-06	2.4E-05	3.3E-05	-2.7E-04
	MEA	-3.8E-06	-1.6E-06	-5.6E-06	-7.5E-06	3.1E-05	-2.3E-06	-6.1E-06	-7.3E-06	6.2E-06	4.9E-06	9.1E-06
	OTH	6.9E-05	-3.8E-06	-1.4E-05	-2.6E-05	3.6E-05	5.4E-05	2.4E-05	6.2E-06	-4.1E-05	1.3E-05	1.3E-05
	MFR	9.0E-05	9.3E-06	-1.1E-05	2.7E-05	-2.0E-05	3.0E-05	3.3E-05	4.9E-06	1.3E-05	-3.9E-05	2.4E-05
	LSR	5.2E-05	5.6E-05	3.5E-05	3.7E-05	3.7E-05	4.0E-05	-2.7E-04	9.1E-06	1.3E-05	2.4E-05	-1.4E-03

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Table A15: Calibrated functional parameters *B* of NQ-QES in urban households

		WWT	RCE	POT	FRT	VGL	MLK	EGG	MEA	OTH	MFR
KSPBGT	WWT	-1.5E-03	1.0E-04	2.2E-04	-1.0E-04	-2.9E-04	-2.2E-04	-1.0E-04	-3.4E-06	8.0E-05	1.1E-04
	RCE	1.0E-04	-5.9E-05	2.0E-05	3.4E-05	7.1E-05	-3.5E-05	-6.1E-05	-1.5E-06	-4.5E-06	1.0E-05
	POT	2.2E-04	2.0E-05	-4.7E-04	9.0E-05	9.9E-05	1.6E-04	2.4E-04	-7.6E-06	-1.6E-05	-9.1E-06
	FRT	-1.0E-04	3.4E-05	9.0E-05	-1.0E-03	2.9E-04	2.8E-04	-3.1E-04	-1.0E-05	-3.1E-05	3.1E-05
	VGL	-2.9E-04	7.1E-05	9.9E-05	2.9E-04	-7.5E-04	-1.6E-04	2.9E-04	3.3E-05	3.9E-05	-2.5E-05
	MLK	-2.2E-04	-3.5E-05	1.6E-04	2.8E-04	-1.6E-04	-4.7E-04	-8.8E-05	-3.2E-06	6.5E-05	4.1E-05
	EGG	-1.0E-04	-6.1E-05	2.4E-04	-3.1E-04	2.9E-04	-8.8E-05	-8.3E-04	-7.1E-06	2.3E-05	3.8E-05
	MEA	-3.4E-06	-1.5E-06	-7.6E-06	-1.0E-05	3.3E-05	-3.2E-06	-7.1E-06	-8.7E-06	8.6E-06	6.6E-06
	OTH	8.0E-05	-4.5E-06	-1.6E-05	-3.1E-05	3.9E-05	6.5E-05	2.3E-05	8.6E-06	-5.5E-05	1.9E-05
	MFR	1.1E-04	1.0E-05	-9.1E-06	3.1E-05	-2.5E-05	4.1E-05	3.8E-05	6.6E-06	1.9E-05	-5.1E-05
KKAURG	WWT	-1.4E-03	1.0E-04	2.1E-04	-9.7E-05	-2.9E-04	-2.2E-04	-9.9E-05	-3.8E-06	7.8E-05	1.1E-04
	RCE	1.0E-04	-6.1E-05	2.0E-05	3.4E-05	7.2E-05	-3.7E-05	-6.3E-05	-1.6E-06	-4.5E-06	1.0E-05
	POT	2.1E-04	2.0E-05	-4.6E-04	8.8E-05	9.9E-05	1.6E-04	2.5E-04	-7.7E-06	-1.5E-05	-8.7E-06
	FRT	-9.7E-05	3.4E-05	8.8E-05	-9.8E-04	2.9E-04	2.8E-04	-3.1E-04	-1.0E-05	-3.0E-05	3.0E-05
	VGL	-2.9E-04	7.2E-05	9.9E-05	2.9E-04	-7.6E-04	-1.7E-04	2.9E-04	3.4E-05	3.8E-05	-2.4E-05
	MLK	-2.2E-04	-3.7E-05	1.6E-04	2.8E-04	-1.7E-04	-4.8E-04	-9.1E-05	-3.9E-06	6.5E-05	4.1E-05
	EGG	-9.9E-05	-6.3E-05	2.5E-04	-3.1E-04	2.9E-04	-9.1E-05	-8.5E-04	-7.4E-06	2.3E-05	3.7E-05
	MEA	-3.8E-06	-1.6E-06	-7.7E-06	-1.0E-05	3.4E-05	-3.9E-06	-7.4E-06	-8.9E-06	8.6E-06	6.5E-06
	OTH	7.8E-05	-4.5E-06	-1.5E-05	-3.0E-05	3.8E-05	6.5E-05	2.3E-05	8.6E-06	-5.3E-05	1.9E-05
	MFR	1.1E-04	1.0E-05	-8.7E-06	3.0E-05	-2.4E-05	4.1E-05	3.7E-05	6.5E-06	1.9E-05	-5.0E-05
YZRGLN	WWT	-1.4E-03	1.1E-04	2.1E-04	-9.5E-05	-2.9E-04	-2.3E-04	-9.8E-05	-4.2E-06	7.7E-05	1.0E-04
	RCE	1.1E-04	-6.3E-05	2.0E-05	3.4E-05	7.3E-05	-3.8E-05	-6.5E-05	-1.8E-06	-4.5E-06	1.0E-05
	POT	2.1E-04	2.0E-05	-4.5E-04	8.7E-05	9.8E-05	1.6E-04	2.5E-04	-7.7E-06	-1.5E-05	-8.3E-06
	FRT	-9.5E-05	3.4E-05	8.7E-05	-9.8E-04	3.0E-04	2.8E-04	-3.2E-04	-1.0E-05	-2.9E-05	3.0E-05
	VGL	-2.9E-04	7.3E-05	9.8E-05	3.0E-04	-7.6E-04	-1.7E-04	3.0E-04	3.5E-05	3.8E-05	-2.3E-05
	MLK	-2.3E-04	-3.8E-05	1.6E-04	2.8E-04	-1.7E-04	-4.9E-04	-9.4E-05	-4.5E-06	6.4E-05	4.1E-05
	EGG	-9.8E-05	-6.5E-05	2.5E-04	-3.2E-04	3.0E-04	-9.4E-05	-8.7E-04	-7.8E-06	2.2E-05	3.7E-05
	MEA	-4.2E-06	-1.8E-06	-7.7E-06	-1.0E-05	3.5E-05	-4.5E-06	-7.8E-06	-9.2E-06	8.6E-06	6.5E-06
	OTH	7.7E-05	-4.5E-06	-1.5E-05	-2.9E-05	3.8E-05	6.4E-05	2.2E-05	8.6E-06	-5.1E-05	1.9E-05
	MFR	1.0E-04	1.0E-05	-8.3E-06	3.0E-05	-2.3E-05	4.1E-05	3.7E-05	6.5E-06	1.9E-05	-4.9E-05
KVAYRK	WWT	-1.4E-03	1.0E-04	2.1E-04	-9.8E-05	-2.9E-04	-2.2E-04	-1.0E-04	-3.8E-06	7.8E-05	1.1E-04
	RCE	1.0E-04	-6.1E-05	2.0E-05	3.4E-05	7.2E-05	-3.6E-05	-6.3E-05	-1.6E-06	-4.5E-06	1.0E-05
	POT	2.1E-04	2.0E-05	-4.6E-04	8.8E-05	9.9E-05	1.6E-04	2.5E-04	-7.7E-06	-1.5E-05	-8.7E-06
	FRT	-9.8E-05	3.4E-05	8.8E-05	-9.9E-04	2.9E-04	2.8E-04	-3.1E-04	-1.0E-05	-3.0E-05	3.0E-05
	VGL	-2.9E-04	7.2E-05	9.9E-05	2.9E-04	-7.6E-04	-1.7E-04	2.9E-04	3.4E-05	3.8E-05	-2.4E-05
	MLK	-2.2E-04	-3.6E-05	1.6E-04	2.8E-04	-1.7E-04	-4.8E-04	-9.1E-05	-3.8E-06	6.5E-05	4.1E-05
	EGG	-1.0E-04	-6.3E-05	2.5E-04	-3.1E-04	2.9E-04	-9.1E-05	-8.5E-04	-7.4E-06	2.3E-05	3.8E-05
	MEA	-3.8E-06	-1.6E-06	-7.7E-06	-1.0E-05	3.4E-05	-3.8E-06	-7.4E-06	-8.9E-06	8.6E-06	6.5E-06
	OTH	7.8E-05	-4.5E-06	-1.5E-05	-3.0E-05	3.8E-05	6.5E-05	2.3E-05	8.6E-06	-5.3E-05	1.9E-05
	MFR	1.1E-04	1.0E-05	-8.7E-06	3.0E-05	-2.4E-05	4.1E-05	3.8E-05	6.5E-06	1.9E-05	-5.0E-05
KKRSVT	WWT	-1.4E-03	1.1E-04	2.1E-04	-9.6E-05	-2.9E-04	-2.2E-04	-9.8E-05	-4.1E-06	7.7E-05	1.0E-04
	RCE	1.1E-04	-6.2E-05	2.0E-05	3.4E-05	7.2E-05	-3.8E-05	-6.4E-05	-1.7E-06	-4.5E-06	1.0E-05
	POT	2.1E-04	2.0E-05	-4.5E-04	8.6E-05	9.8E-05	1.6E-04	2.5E-04	-7.7E-06	-1.5E-05	-8.4E-06
	FRT	-9.6E-05	3.4E-05	8.6E-05	-9.6E-04	2.9E-04	2.8E-04	-3.1E-04	-1.0E-05	-2.9E-05	3.0E-05
	VGL	-2.9E-04	7.2E-05	9.8E-05	2.9E-04	-7.6E-04	-1.7E-04	2.9E-04	3.4E-05	3.8E-05	-2.3E-05
	MLK	-2.2E-04	-3.8E-05	1.6E-04	2.8E-04	-1.7E-04	-4.9E-04	-9.3E-05	-4.4E-06	6.4E-05	4.1E-05
	EGG	-9.8E-05	-6.4E-05	2.5E-04	-3.1E-04	2.9E-04	-9.3E-05	-8.5E-04	-7.7E-06	2.2E-05	3.7E-05
	MEA	-4.1E-06	-1.7E-06	-7.7E-06	-1.0E-05	3.4E-05	-4.4E-06	-7.7E-06	-9.1E-06	8.6E-06	6.5E-06
	OTH	7.7E-05	-4.5E-06	-1.5E-05	-2.9E-05	3.8E-05	6.4E-05	2.2E-05	8.6E-06	-5.2E-05	1.9E-05
	MFR	1.0E-04	1.0E-05	-8.4E-06	3.0E-05	-2.3E-05	4.1E-05	3.7E-05	6.5E-06	1.9E-05	-5.0E-05

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; KSPBGT – Aggregate of Khazarasp and Bagat districts; KKAURG – Aggregate of Khanka and Urgench districts; YZRGLN – Aggregate of Yangibazar and Gurlen districts; KVAYRK – Aggregate of Khiva and Yangiarik districts; KKRSVT – Aggregate of Kushkupir and Shavat districts

Source: Demand module calibration results

Appendix 4: Simulation Results

Table A16: Shadow prices of land, USD ha $^{-1}$

District	Producer	Season	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
KSPBGT	SK	Jan-Jun	71	132	98	-	-	-	-
		Jul-Sep	327	524	323	435	-	337	-
		Oct	101	353	143	220	-	202	-
		Nov	-	-	-	57	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	92	162	129	-	147	-	93
		Jul-Sep	367	519	249	471	-	391	488
		Oct	92	306	206	269	-	128	291
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	265	346	260	291	229	293	299
		Jul-Sep	463	527	363	497	353	462	472
KKAURG	SK	Jan-Jun	66	146	55	-	-	-	-
		Jul-Sep	413	594	419	492	-	392	-
		Oct	201	345	228	222	-	64	-
		Nov	-	-	-	66	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	71	164	78	-	114	-	83
		Jul-Sep	363	580	371	467	-	387	473
		Oct	84	239	87	102	-	104	82
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	236	347	228	259	222	253	233
		Jul-Sep	393	534	396	422	391	413	402
YZRGLN	SK	Jan-Jun	-	96	62	-	-	-	-
		Jul-Sep	351	474	355	423	-	349	-
		Oct	59	202	68	82	-	153	-
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	24	73	35	-	-	35	39
		Jul-Sep	256	496	261	434	-	228	442
		Oct	38	182	75	91	-	84	92
		Nov	-	-	-	14	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	177	308	214	189	175	217	229
		Jul-Sep	336	580	336	357	306	353	337
KVAYRK	SK	Jan-Jun	-	119	76	-	-	-	-
		Jul-Sep	282	478	303	-	-	308	-
		Oct	-	112	76	116	-	-	-
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	-	125	89	-	-	-	79
		Jul-Sep	304	495	318	363	139	201	360
		Oct	-	138	106	87	-	-	142
		Nov	-	41	12	-	-	-	5
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	135	309	246	152	131	226	235
		Jul-Sep	-	452	378	-	-	-	402
KKRSVT	SK	Jan-Jun	15	76	54	-	-	-	-
		Jul-Sep	-	480	324	-	-	105	-
		Oct	-	129	114	-	-	314	-
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	PF	Jan-Jun	19	83	63	-	-	-	64
		Jul-Sep	-	493	351	-	-	67	367
		Oct	5	53	-	11	-	-	7
		Nov	-	-	-	-	-	-	-
		Dec	-	-	-	-	-	-	-
	HH	Oct-Jun	120	313	288	127	118	231	239
		Jul-Sep	-	456	382	-	-	-	395

Notes: KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; SK – *Shirkat*s; PF – Private farms; HH – Rural households; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Table A17: Commodity prices and consumption

Commodity	District	Commodity Prices, USD unit^{-1}							Consumption in Districts, 10^3 units						
		BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
WWT	KSPBGT	104	108	106	108	105	99	106	53.3	52.4	52.9	52.2	53.0	55.0	52.8
ton	KKAURG	106	110	108	110	107	101	109	72.5	71.4	71.8	71.4	72.0	74.6	71.7
	YZRBGT	108	112	110	112	110	104	110	31.9	31.1	31.5	31.1	31.6	32.8	31.5
	KVAYRK	105	110	108	109	107	102	108	45.3	44.1	44.4	44.1	44.8	46.3	44.5
	KKRSVT	107	112	110	112	109	104	111	44.3	43.0	43.5	42.9	43.8	45.1	43.2
RCE	KSPBGT	264	274	300	274	275	273	270	4.1	3.7	3.3	3.7	3.6	3.7	3.8
ton	KKAURG	253	262	287	262	267	262	259	5.9	5.6	5.1	5.6	5.5	5.6	5.7
	YZRBGT	254	263	288	263	270	263	260	2.5	2.3	2.1	2.4	2.2	2.4	2.4
	KVAYRK	257	266	291	265	271	264	262	3.6	3.4	3.1	3.4	3.3	3.4	3.5
	KKRSVT	254	263	288	263	269	262	261	3.5	3.3	3.2	3.3	3.3	3.4	3.4
POT	KSPBGT	86	90	91	91	91	90	89	13.9	13.2	13.2	13.2	13.2	13.3	13.4
ton	KKAURG	88	92	93	92	94	92	91	18.4	17.8	17.7	17.8	17.6	17.8	18.0
	YZRBGT	89	94	95	93	97	93	92	8.3	8.0	7.9	8.0	7.8	8.0	8.1
	KVAYRK	88	92	92	92	94	91	90	11.7	11.3	11.2	11.3	11.2	11.3	11.4
	KKRSVT	89	93	95	93	96	93	93	11.5	11.2	11.2	11.2	11.1	11.3	11.3
FRT	KSPBGT	41	42	42	42	42	39	42	16.2	15.8	15.7	15.8	15.7	16.8	15.9
ton	KKAURG	42	44	44	44	45	40	43	21.5	21.2	21.1	21.2	21.0	21.9	21.3
	YZRBGT	43	45	46	45	47	42	45	9.7	9.5	9.5	9.5	9.4	9.8	9.6
	KVAYRK	42	44	44	43	44	40	43	13.6	13.4	13.3	13.4	13.3	13.9	13.5
	KKRSVT	43	45	45	45	46	42	45	13.5	13.2	13.1	13.2	13.1	13.8	13.2
VGL	KSPBGT	104	107	108	107	108	108	105	28.6	27.6	27.1	27.6	27.3	27.2	28.2
ton	KKAURG	98	101	103	101	102	102	104	38.6	38.0	37.5	38.0	37.6	37.7	37.0
	YZRBGT	102	105	106	106	106	106	106	17.2	16.6	16.5	16.4	16.4	16.4	16.4
	KVAYRK	101	104	105	105	105	105	105	24.2	23.9	23.5	23.6	23.6	23.7	23.5
	KKRSVT	102	105	105	106	106	105	106	23.8	23.2	23.2	22.9	22.9	23.1	22.9
MLK	KSPBGT	155	152	151	166	184	150	161	41.9	42.2	42.2	40.1	39.3	44.3	41.1
ton	KKAURG	151	147	147	160	173	146	157	59.9	61.1	61.1	57.6	56.8	62.6	58.2
	YZRBGT	149	146	145	157	190	144	156	25.4	25.8	25.9	24.3	22.1	26.6	24.3
	KVAYRK	152	148	148	162	187	147	158	36.1	37.2	37.0	34.4	32.4	38.3	34.8
	KKRSVT	149	145	146	159	190	144	155	35.2	36.1	36.0	33.2	31.6	36.9	33.6
EGG	KSPBGT	56	57	57	58	64	60	57	17.5	17.3	17.3	16.7	14.6	16.0	17.3
10^3 pieces	KKAURG	53	54	54	56	62	57	55	23.5	23.3	23.3	22.7	22.2	22.6	23.0
	YZRBGT	53	54	54	55	61	56	54	10.4	9.9	10.0	9.5	8.7	9.2	9.7
	KVAYRK	54	55	55	57	62	58	56	14.7	14.6	14.6	13.6	11.8	13.3	14.3
	KKRSVT	54	55	55	57	63	58	55	14.4	14.1	14.0	13.2	12.4	13.1	14.0
MEA	KSPBGT	1,877	1,839	1,840	2,021	2,210	1,732	1,967	7.2	7.2	7.2	7.0	6.8	7.6	7.0
ton	KKAURG	1,777	1,737	1,739	1,972	2,145	1,662	1,857	10.6	10.8	10.8	10.3	10.1	11.1	10.4
	YZRBGT	1,785	1,749	1,747	1,925	2,300	1,692	1,872	4.4	4.4	4.4	4.3	4.1	4.5	4.3
	KVAYRK	1,814	1,778	1,774	1,973	2,252	1,726	1,898	6.2	6.3	6.3	6.1	5.9	6.5	6.2
	KKRSVT	1,792	1,755	1,751	1,928	2,293	1,707	1,868	6.0	6.1	6.2	5.9	5.7	6.3	6.0
OTH	KSPBGT	990	990	990	990	990	990	990	10.2	10.3	10.2	11.2	11.2	10.5	11.1
ton	KKAURG	1,010	1,010	1,010	1,010	1,010	1,010	1,010	14.6	14.6	14.7	16.0	16.0	14.9	15.4
	YZRBGT	1,029	1,029	1,029	1,029	1,029	1,029	1,029	6.2	6.2	6.1	6.8	7.1	6.2	6.8
	KVAYRK	1,008	1,008	1,008	1,008	1,008	1,008	1,008	8.8	8.8	8.8	9.8	9.9	9.0	9.6
	KKRSVT	1,025	1,025	1,025	1,025	1,025	1,025	1,025	8.5	8.5	8.5	9.3	10.1	8.4	9.2
MFFR	KSPBGT	990	990	990	990	990	990	990	56.5	57.0	55.7	67.5	59.6	61.6	72.7
ton	KKAURG	1,010	1,010	1,010	1,010	1,010	1,010	1,010	82.9	83.1	85.4	105.2	86.8	88.8	114.7
	YZRBGT	1,029	1,029	1,029	1,029	1,029	1,029	1,029	34.8	34.5	33.7	46.6	37.9	34.0	42.0
	KVAYRK	1,008	1,008	1,008	1,008	1,008	1,008	1,008	49.1	49.7	48.7	68.0	52.9	52.1	59.9
	KKRSVT	1,025	1,025	1,025	1,025	1,025	1,025	1,025	47.9	47.0	47.8	57.9	52.1	46.3	57.4
LSR	KSPBGT	51	50	57	66	57	51	69	51.3	49.2	55.9	62.9	56.3	50.5	64.0
10^3 h	KKAURG	49	46	56	61	54	53	70	45.1	42.1	47.6	55.8	46.5	45.3	67.1
	YZRBGT	50	49	55	64	55	50	72	28.7	27.1	31.0	34.9	30.0	27.6	39.4
	KVAYRK	51	48	56	61	52	54	71	39.0	37.1	41.1	43.7	39.7	40.7	49.6
	KKRSVT	48	47	59	57	58	49	68	41.0	39.1	43.7	42.1	42.3	41.2	48.4

Note: WWT – Wheat and other food grains; RCE – Rice; POT – Potato; FRT – Fruits and melons; VGL – Vegetables; MLK – Milk and milk products; EGG – Eggs; MEA – Meat and meat products; OTH – Other food commodities; MFR – Non-food commodities; LSR – Leisure; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; BASE – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Table A18: Land and water use

Districts	Producer	**BASE**	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
					change to base (in percent)			
Land Use (10^3 ha)								
KSPBGT	SK	26.2	26.5	26.2	26.2	-	26.2	-
	PF	7.4	7.4	7.4	7.6	32.9	7.5	34.5
	HH	7.4	7.4	7.4	7.5	7.4	7.4	7.5
KKAURG	SK	28.3	29.1	27.3	27.6	-	29.3	-
	PF	10.0	10.8	9.1	9.4	38.1	10.2	33.3
	HH	6.4	6.7	6.3	5.9	6.7	6.7	6.3
YZRGLN	SK	15.8	16.7	15.5	15.7	-	16.0	-
	PF	23.2	25.1	22.7	22.6	38.8	23.4	31.3
	HH	5.3	5.5	5.1	5.2	5.3	5.3	5.1
KVAYRK	SK	16.5	17.5	15.7	15.4	-	17.3	-
	PF	8.4	9.3	8.4	8.2	25.3	8.4	23.6
	HH	6.1	6.1	6.0	5.9	6.0	6.1	6.0
KKRSVT	SK	27.1	29.9	29.7	26.4	-	27.2	-
	PF	12.6	13.9	13.8	12.1	39.5	12.8	44.1
	HH	7.0	7.7	7.6	7.3	7.0	7.2	7.7
Water Use (10^6 m^3)								
KSPBGT	SK	479.8	455.4	425.7	485.6	-	479.2	-
	PF	141.0	129.6	124.3	145.3	615.3	139.4	586.0
	HH	133.5	125.8	129.9	129.9	133.3	128.7	127.1
KKAURG	SK	486.6	488.1	427.9	470.0	-	455.6	-
	PF	194.3	195.2	188.9	215.4	645.6	214.5	626.5
	HH	107.1	107.8	60.6	63.5	70.4	68.1	59.9
YZRGLN	SK	287.0	298.8	269.2	299.0	-	295.6	-
	PF	441.6	429.4	330.5	374.3	654.8	364.9	631.8
	HH	87.4	88.6	81.9	85.1	87.6	87.5	80.1
KVAYRK	SK	294.9	294.2	274.5	307.8	-	297.4	-
	PF	158.7	159.6	186.7	201.8	501.7	195.2	498.4
	HH	91.2	91.6	136.1	140.6	137.4	141.4	138.6
KKRSVT	SK	473.7	473.7	471.4	474.2	-	473.6	-
	PF	232.6	232.4	230.4	232.8	636.1	232.3	632.9
	HH	121.0	121.0	121.0	121.1	121.1	120.8	120.6
Water Use (10^3 m^3 ha^{-1})								
KSPBGT	SK	18.3	17.2	16.2	18.5	-	18.3	-
	PF	19.0	17.5	16.8	19.2	18.7	18.6	17.0
	HH	17.9	17.0	17.6	17.4	17.9	17.5	16.9
KKAURG	SK	17.2	16.8	15.7	17.0	-	15.6	-
	PF	19.5	18.1	20.8	23.0	17.0	21.1	18.8
	HH	16.8	16.0	9.6	10.8	10.5	10.1	9.5
YZRGLN	SK	18.2	17.9	17.4	19.1	-	18.5	-
	PF	19.0	17.1	14.6	16.6	16.9	15.6	20.2
	HH	16.6	16.1	16.0	16.3	16.7	16.7	15.6
KVAYRK	SK	17.9	16.9	17.4	19.9	-	17.2	-
	PF	18.8	17.1	22.3	24.5	19.8	23.1	21.1
	HH	15.1	15.0	22.7	23.7	23.0	23.4	23.0
KKRSVT	SK	17.5	15.8	15.9	18.0	-	17.4	-
	PF	18.5	16.8	16.7	19.3	16.1	18.2	14.4
	HH	17.3	15.7	15.8	16.6	17.3	16.8	15.6

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; Base – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Table A19: Gross margins of production activities

Activity			KSPBGT							KKAURG							YZRGLN							KVAYRK							KKRSVT						
			Base	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	Base	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	Base	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	Base	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	Base	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	USD ha^{-1}	198	233	78	69	-	198	-	213	250	96	93	-	213	-	119	146	-4	-22	-	119	-	198	233	107	58	-	198	-	170	202	78	44	-	170	-
	WWT	USD ha^{-1}	245	278	184	7	-	231	-	223	254	161	-13	-	223	-	221	253	162	-48	-	221	-	211	241	164	-28	-	211	-	241	274	199	-4	-	239	-
	RCE	USD ha^{-1}	865	1,007	178	635	-	890	-	852	953	167	680	-	843	-	966	1,071	290	789	-	940	-	907	1,008	344	706	-	878	-	906	1,016	343	644	-	884	-
	POT	USD ha^{-1}	604	715	418	453	-	612	-	576	682	386	406	-	576	-	389	473	183	215	-	389	-	643	749	508	474	-	643	-	878	1,025	788	697	-	883	-
	FRT	USD ha^{-1}	431	506	328	314	-	427	-	327	389	211	177	-	327	-	275	331	156	125	-	275	-	526	607	460	377	-	526	-	278	332	188	182	-	308	-
	VGL	USD ha^{-1}	1,297	1,514	1,211	1,122	-	1,302	-	1,108	1,315	1,016	1,088	-	1,105	-	810	976	682	696	-	824	-	1,172	1,397	1,155	1,091	-	1,151	-	978	1,149	911	877	-	994	-
	MZE	USD ha^{-1}	507	571	357	276	-	507	-	244	281	68	23	-	244	-	357	405	197	136	-	357	-	235	271	97	13	-	235	-	379	429	259	157	-	379	-
	FOD	USD ha^{-1}	12	19	12	-83	-	12	-	59	71	59	-59	-	59	-	60	72	60	-56	-	60	-	100	115	100	-19	-	100	-	35	45	35	-77	-	35	-
	MLK	USD head^{-1}	106	104	103	112	-	126	-	136	135	136	143	-	163	-	126	126	126	132	-	148	-	212	212	212	225	-	261	-	136	135	136	143	-	160	-
	EGG	USD head^{-1}	2	2	2	2	-	2	-	8	8	8	9	-	9	-	3	3	3	3	-	3	-	8	8	8	9	-	8	-	4	4	4	4	-	4	-
	MEA	USD head^{-1}	121	120	121	130	-	141	-	115	115	115	128	-	136	-	217	217	217	233	-	262	-	210	210	210	228	-	254	-	147	147	147	158	-	175	-
PF	CTN	USD ha^{-1}	333	380	225	198	333	333	103	188	220	157	85	188	188	-27	169	200	49	64	169	169	18	316	361	235	238	316	316	169	164	194	70	65	164	164	-21
	WWT	USD ha^{-1}	252	286	192	71	259	257	11	330	371	278	174	330	330	122	256	290	198	65	256	256	8	238	270	193	54	238	238	10	223	254	179	76	225	220	32
	RCE	USD ha^{-1}	1,004	1,114	332	845	1,192	1,068	168	1,031	1,148	363	905	1,056	1,021	226	1,059	1,173	393	864	1,364	1,031	202	996	1,106	442	781	1,246	965	227	841	945	272	652	861	821	107
	POT	USD ha^{-1}	281	356	59	82	288	286	-141	395	495	199	188	395	395	-8	468	580	290	257	468	468	79	503	594	352	300	503	503	149	253	325	88	48	264	258	-117
	FRT	USD ha^{-1}	72	97	-81	-53	74	70	-206	176	217	40	34	176	176	-102	168	211	36	25	168	168	11	464	532	386	324	464	464	245	59	83	-61	-79	62	54	-199
	VGL	USD ha^{-1}	404	503	203	204	413	410	3	441	551	254	316	530	439	123	740	904	609	591	811	754	468	769	955	713	641	856	751	593	401	498	261	235	447	410	101
	MZE	USD ha^{-1}	178	209	-5	-11	178	178	-195	147	174	-39	-41	147	147	-226	284	325	117	95	284	284	-72	382	434	261	185	382	382	64	146	174	4	-42	146	146	-184
	FOD	USD ha^{-1}	79	93	79	-106	79	79	-92	147	169	147	23	147	147	44	81	95	81	-24	81	81	-9	137	158	137	-18	137	137	2	85	99	85	-42	85	85	-27
	MLK	USD head^{-1}	179	177	176	191	207	218	244	168	168	168	177	196	203	207	181	180	181	189	239	215	243	166	166	166	176	211	203	217	148	148	148	157	196	196	187
	EGG	USD head^{-1}	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	4	3	3	3	4	3	4	4	4	4	2	2	2	2	2	2	2
	MEA	USD head^{-1}	117	116	117	125	137	135	160	145	145	145	161	182	172	186	182	182	182	195	244	218	254	147	147	147	159	190	173	197	146	146	146	157	196	204	192
HH	WWT	USD ha^{-1}	421	472	429	272	423	414	323	456	511	456	313	456	456	368	492	550	492	304	492	492	363	421	472	421	249	421	421	300	410	460	410	269	413	407	320
	RCE	USD ha^{-1}	1,108	1,224	443	862	1,307	1,164	191	1,334	1,477	692	1,087	1,364	1,322	433	1,114	1,230	450	963	1,424	1,086	303	1,205	1,331	668	1,008	1,491	1,170	470	1,070	1,194	520	772	1,108	1,092	251
	POT	USD ha^{-1}	812	958	820	443	820	819	589	667	784	667	286	667	667	403	630	759	630	278	630	630	407	689	809	689	596	689	689	715	536	651	536	177	546	540	293
	FRT	USD ha^{-1}	191	249	192	19	193	189	-21	233	309	233	-136	233	233	-60	521	618	521	321	521	521	418	428	518	428	258	428	428	347	317	395	317	-52	319	310	25
	VGL	USD ha^{-1}	574	724	575	294	588	568	440	833	1,047	830	737	1,006	830	935	786	983	786	649	872	804	848	1,200	1,444	1,200	1,031	1,314	1,177	1,285	780	969	777	605	869	798	805
	MZE	USD ha^{-1}	404	456	404	104	404	404	156	366	414	366	79	366	366	128	389	440	389	107	389	389	157	441	497	441	171	441	441	226	401	453	401	112	401	401	164
	FOD	USD ha^{-1}	155	176	155	-27	155	155	-6	65	77	65	-99	65	65	-87	223	251	223	98	223	223	126	137	156	137	-19	137	137	0	157	179	157	3	157	157	25
	MLK	USD head^{-1}	328	326	325	349	392	402	445	298	297	298	314	343	363	369	284	283	284	297	367	340	379	336	336	336	357	417	414	440	326	325	326	345	419	393	384
	EGG	USD head^{-1}	4	5	5	5	5	5	5	4	4	4	4	5	4	4	4	4	4	4	5	4	4	8	8	8	8	9	8	8	3	3	3	3	3	3	3
	MEA	USD head^{-1}	245	243	245	262	292	287	331	235	235	235	259	286	281	299	199	199	199	213	261	236	271	222	222	222	240	279	265	295	217	218	217	232	283	298	286

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CTN – Cotton; WWT – Winter wheat; RCE –Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Cows; EGG – Poultry; MEA – Bulls; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; Base – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Table A20: Production activities

Activity			KSPBGT BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	10^3 ha	17.565	17.565	17.565	5.323	-	17.565	-
	WWT	10^3 ha	5.186	5.680	3.452	0.000	-	4.734	-
	RCE	10^3 ha	1.772	1.915	0.536	4.580	-	1.933	-
	POT	10^3 ha	0.064	0.164	0.024	0.221	-	0.104	-
	FRT	10^3 ha	0.159	0.160	0.101	0.306	-	0.159	-
	VGL	10^3 ha	0.346	1.506	2.144	12.394	-	0.862	-
	MZE	10^3 ha	0.027	0.027	0.175	0.787	-	0.039	-
	FOD	10^3 ha	1.104	0.523	1.142	0.000	-	1.384	-
	MLK	10^3 head	0.73	0.21	0.31	1.05	-	1.45	-
	EGG	10^3 head	2.54	3.75	3.04	3.41	-	1.92	-
	MEA	10^3 head	1.65	0.61	2.46	2.46	-	2.15	-
PF	CTN	10^3 ha	1.708	1.708	1.708	1.211	19.273	1.708	18.784
	WWT	10^3 ha	1.134	1.365	1.137	1.141	6.320	1.133	2.833
	RCE	10^3 ha	3.749	4.149	3.219	4.649	5.907	4.163	6.277
	POT	10^3 ha	0.010	0.002	0.006	0.001	0.051	0.014	0.000
	FRT	10^3 ha	0.098	0.201	0.000	0.000	0.100	0.087	0.000
	VGL	10^3 ha	0.045	0.095	0.007	0.271	0.401	0.160	0.028
	MZE	10^3 ha	0.007	0.007	0.000	0.010	0.034	0.007	0.000
	FOD	10^3 ha	0.677	0.735	1.800	0.000	0.800	0.800	2.929
	MLK	10^3 head	1.06	1.04	1.23	0.97	1.20	1.64	2.40
	EGG	10^3 head	4.89	4.89	2.03	6.19	8.84	4.37	1.61
	MEA	10^3 head	3.46	3.37	4.61	2.61	5.64	4.51	5.90
HH	WWT	10^3 ha	3.965	3.964	3.964	3.965	3.965	3.965	3.965
	RCE	10^3 ha	1.336	1.441	0.802	1.301	1.340	1.145	0.200
	POT	10^3 ha	0.126	0.264	0.201	0.223	0.157	0.128	0.654
	FRT	10^3 ha	0.293	0.057	0.045	0.040	0.162	0.282	0.000
	VGL	10^3 ha	0.838	1.038	1.012	0.431	0.938	0.841	0.607
	MZE	10^3 ha	0.113	0.113	0.313	0.113	0.112	0.105	0.406
	FOD	10^3 ha	0.768	0.768	0.964	1.268	0.810	1.059	1.604
	MLK	10^3 head	37.07	38.11	39.00	41.22	37.06	39.51	38.75
	EGG	10^3 head	225.53	225.53	255.62	225.53	241.92	237.00	232.00
	MEA	10^3 head	83.74	84.37	87.76	98.73	86.10	125.42	82.00

Activity			KKAURG BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	10^3 ha	15.922	15.922	15.922	8.825	-	15.922	-
	WWT	10^3 ha	6.199	6.566	4.337	0.000	-	5.508	-
	RCE	10^3 ha	3.583	3.856	2.222	7.135	-	3.517	-
	POT	10^3 ha	0.162	0.221	0.091	0.255	-	0.162	-
	FRT	10^3 ha	0.258	0.582	0.099	0.157	-	0.258	-
	VGL	10^3 ha	0.777	1.334	2.489	10.076	-	1.180	-
	MZE	10^3 ha	0.057	0.128	0.536	0.204	-	0.140	-
	FOD	10^3 ha	1.333	0.522	1.631	0.972	-	2.599	-
	MLK	10^3 head	1.66	1.15	2.15	1.60	-	2.84	-
	EGG	10^3 head	58.91	60.72	72.05	77.14	-	60.11	-
	MEA	10^3 head	6.60	6.20	8.00	7.34	-	9.90	-
PF	CTN	10^3 ha	3.747	3.747	3.747	2.100	19.669	3.747	0.000
	WWT	10^3 ha	2.354	2.870	2.354	2.041	8.553	2.352	15.553
	RCE	10^3 ha	2.991	3.048	1.899	3.565	6.806	2.891	8.574
	POT	10^3 ha	0.022	0.044	0.020	0.020	0.614	0.022	0.000
	FRT	10^3 ha	0.083	0.111	0.054	0.420	0.303	0.083	0.000
	VGL	10^3 ha	0.202	0.317	0.099	0.151	0.549	0.202	1.476
	MZE	10^3 ha	0.057	0.024	0.000	0.006	0.241	0.057	0.000
	FOD	10^3 ha	0.513	0.596	0.922	1.067	1.324	0.820	7.710
	MLK	10^3 head	2.42	2.53	2.95	4.58	6.10	3.97	6.65
	EGG	10^3 head	15.51	7.18	8.59	8.00	73.16	16.04	10.57
	MEA	10^3 head	7.96	7.89	8.49	5.67	19.34	8.03	21.15
HH	WWT	10^3 ha	3.385	3.384	3.366	3.366	3.385	3.385	3.385
	RCE	10^3 ha	0.226	0.230	0.189	0.304	0.321	0.313	0.222
	POT	10^3 ha	0.511	0.566	0.511	0.602	0.511	0.511	0.402
	FRT	10^3 ha	0.062	0.066	0.062	0.000	0.062	0.062	0.000
	VGL	10^3 ha	1.080	1.085	1.080	1.250	1.591	1.080	1.351
	MZE	10^3 ha	0.319	0.415	0.319	0.349	0.218	0.307	0.324
	FOD	10^3 ha	0.777	0.993	0.777	0.000	0.610	1.068	0.644
	MLK	10^3 head	50.44	51.43	50.44	58.71	50.44	41.52	50.84
	EGG	10^3 head	321.71	309.11	331.70	329.88	321.71	301.12	323.70
	MEA	10^3 head	125.26	128.75	125.26	130.26	125.26	164.21	124.24

Activity			YZRGLN BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	10^3 ha	9.211	9.211	9.211	0.000	-	9.211	-
	WWT	10^3 ha	1.969	2.506	1.208	0.000	-	1.873	-
	RCE	10^3 ha	2.817	2.917	1.459	5.078	-	2.812	-
	POT	10^3 ha	0.044	0.040	0.022	1.060	-	0.044	-
	FRT	10^3 ha	0.197	0.207	0.204	0.102	-	0.197	-
	VGL	10^3 ha	0.335	0.582	2.140	9.263	-	0.475	-
	MZE	10^3 ha	0.073	0.073	0.073	0.173	-	0.077	-
	FOD	10^3 ha	1.163	1.157	1.170	0.000	-	1.264	-
	MLK	10^3 head	0.66	0.00	0.22	0.86	-	1.00	-
	EGG	10^3 head	2.29	2.06	2.20	3.44	-	3.26	-
	MEA	10^3 head	2.07	2.43	2.48	2.48	-	2.36	-
PF	CTN	10^3 ha	12.950	12.950	12.950	4.102	22.161	12.950	0.000
	WWT	10^3 ha	4.466	4.512	4.466	4.466	5.966	4.466	6.435
	RCE	10^3 ha	3.493	3.966	3.493	8.493	6.982	3.332	6.720
	POT	10^3 ha	0.051	0.059	0.059	0.033	0.167	0.090	1.657
	FRT	10^3 ha	0.190	0.201	0.080	0.000	0.288	0.066	0.000
	VGL	10^3 ha	0.293	1.274	1.344	3.344	1.026	0.293	14.478
	MZE	10^3 ha	0.202	0.306	0.306	0.335	0.675	0.202	0.000
	FOD	10^3 ha	1.583	1.820	0.000	1.830	1.541	2.025	2.033
	MLK	10^3 head	1.80	1.83	1.77	2.14	2.24	2.09	7.28
	EGG	10^3 head	8.89	9.58	10.20	18.55	11.56	7.34	5.51
	MEA	10^3 head	4.60	6.09	4.46	4.25	8.83	5.53	8.01
HH	WWT	10^3 ha	1.450	1.450	1.450	1.450	1.450	1.450	1.450
	RCE	10^3 ha	1.047	1.327	0.723	1.047	1.049	1.048	0.847
	POT	10^3 ha	0.482	0.492	0.558	0.120	0.503	0.503	0.202
	FRT	10^3 ha	0.319	0.389	0.875	0.506	0.473	0.470	0.444
	VGL	10^3 ha	0.675	0.597	0.043	0.785	0.501	0.504	0.933
	MZE	10^3 ha	0.146	0.135	0.142	0.146	0.144	0.145	0.110
	FOD	10^3 ha	1.138	1.107	1.338	1.161	1.136	1.137	1.150
	MLK	10^3 head	31.09	30.91	33.93	31.58	30.83	25.87	32.42
	EGG	10^3 head	164.61	133.41	162.48	161.61	119.44	141.17	121.59
	MEA	10^3 head	70.33	69.87	73.22	70.57	71.07	58.71	72.96

Activity			KVAYRK BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	10^3 ha	10.437	10.437	10.437	0.000	-	10.437	-
	WWT	10^3 ha	3.801	3.067	2.739	0.000	-	3.801	-
	RCE	10^3 ha	0.983	1.399	0.521	3.492	-	0.971	-
	POT	10^3 ha	0.079	0.134	0.105	0.483	-	0.088	-
	FRT	10^3 ha	0.053	0.091	0.055	0.616	-	0.015	-
	VGL	10^3 ha	0.307	1.120	0.477	10.592	-	0.681	-
	MZE	10^3 ha	0.024	0.221	0.032	0.261	-	0.077	-
	FOD	10^3 ha	0.794	0.983	1.369	0.000	-	1.248	-
	MLK	10^3 head	0.77	1.00	1.45	0.78	-	1.66	-
	EGG	10^3 head	132.88	129.11	135.39	180.24	-	136.42	-
	MEA	10^3 head	1.72	1.33	1.88	1.02	-	2.58	-
PF	CTN	10^3 ha	3.570	3.570	3.570	2.914	14.007	3.570	8.593
	WWT	10^3 ha	1.847	1.847	1.847	1.503	4.875	1.847	0.388
	RCE	10^3 ha	1.260	1.688	1.059	2.756	2.404	1.269	0.951
	POT	10^3 ha	0.037	0.071	0.010	0.006	1.444	0.100	0.321
	FRT	10^3 ha	0.077	0.180	0.079	0.022	0.021	0.370	1.502
	VGL	10^3 ha	0.248	0.590	0.729	0.846	0.126	0.000	9.260
	MZE	10^3 ha	0.078	0.070	0.177	0.181	0.092	0.070	0.094
	FOD	10^3 ha	1.324	1.315	0.899	0.000	2.325	1.315	2.501
	MLK	10^3 head	1.96	1.95	2.07	1.97	3.06	2.62	3.15
	EGG	10^3 head	19.07	14.19	18.66	19.19	128.35	17.23	164.36
	MEA	10^3 head	5.73	5.72	5.84	5.78	7.21	6.76	7.98
HH	WWT	10^3 ha	2.200	2.200	2.200	2.200	2.200	2.200	2.200
	RCE	10^3 ha	1.000	1.195	0.812	1.168	0.984	1.252	0.995
	POT	10^3 ha	0.609	0.526	0.609	0.491	0.010	0.285	0.000
	FRT	10^3 ha	0.148	0.050	0.148	0.018	0.050	0.030	0.000
	VGL	10^3 ha	1.700	1.783	1.700	1.748	2.309	1.222	2.279
	MZE	10^3 ha	0.150	0.155	0.150	0.196	0.192	0.115	0.150
	FOD	10^3 ha	0.248	0.205	0.371	0.111	0.224	0.948	0.404
	MLK	10^3 head	33.60	33.61	33.92	34.03	33.63	36.14	36.57
	EGG	10^3 head	196.51	198.85	196.51	196.01	214.98	186.50	188.50
	MEA	10^3 head	79.83	79.80	81.12	78.56	79.61	89.84	89.95

Activity			KKRSVT BASE	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
SK	CTN	10^3 ha	16.654	16.654	16.654	4.241	-	16.654	-
	WWT	10^3 ha	6.065	6.821	5.234	0.000	-	5.434	-
	RCE	10^3 ha	1.497	1.911	0.894	4.881	-	1.426	-
	POT	10^3 ha	0.143	0.628	0.532	0.614	-	0.543	-
	FRT	10^3 ha	0.205	0.331	0.056	0.450	-	0.000	-
	VGL	10^3 ha	0.680	0.906	1.022	15.717	-	0.911	-
	MZE	10^3 ha	0.051	0.047	0.087	0.105	-	0.115	-
	FOD	10^3 ha	1.845	0.836	1.943	0.000	-	2.426	-
	MLK	10^3 head	0.57	0.19	0.91	0.11	-	1.20	-
	EGG	10^3 head	5.85	5.45	7.18	8.29	-	4.26	-
	MEA	10^3 head	1.49	1.30	1.86	2.03	-	2.57	-
PF	CTN	10^3 ha	5.959	5.959	5.959	3.122	22.613	5.959	0.000
	WWT	10^3 ha	3.346	3.195	3.346	4.546	7.719	3.346	18.551
	RCE	10^3 ha	1.336	1.888	1.077	2.949	1.061	1.609	4.838
	POT	10^3 ha	0.023	0.201	0.000	0.078	0.864	0.000	0.000
	FRT	10^3 ha	0.150	0.010	0.000	0.000	0.201	0.000	0.000
	VGL	10^3 ha	0.201	0.757	0.053	2.187	1.118	0.252	9.142
	MZE	10^3 ha	0.091	0.081	0.291	0.000	0.342	0.091	0.000
	FOD	10^3 ha	1.496	1.459	1.878	0.000	5.533	1.800	4.398
	MLK	10^3 head	1.38	1.31	1.88	0.64	7.02	1.84	8.00
	EGG	10^3 head	3.90	3.27	4.13	1.45	10.57	1.84	9.48
	MEA	10^3 head	4.56	4.54	4.82	2.15	5.40	5.56	6.80
HH	WWT	10^3 ha	3.400	3.400	3.400	3.400	3.400	3.400	3.400
	RCE	10^3 ha	0.141	0.849	0.083	0.241	0.600	0.463	0.000
	POT	10^3 ha	0.567	0.265	0.107	0.582	0.240	0.000	0.058
	FRT	10^3 ha	0.230	0.205	0.184	0.000	0.000	0.065	0.000
	VGL	10^3 ha	0.746	1.073	1.253	0.961	1.303	1.015	1.255
	MZE	10^3 ha	0.291	0.287	0.243	0.291	0.288	0.128	0.442
	FOD	10^3 ha	1.607	1.203	1.655	1.507	1.348	1.925	1.948
	MLK	10^3 head	36.88	36.54	37.07	37.02	36.93	39.76	40.05
	EGG	10^3 head	274.52	270.02	227.87	274.52	236.06	224.42	277.13
	MEA	10^3 head	93.31	92.22	93.73	92.12	93.67	97.61	94.11

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CTN – Cotton; WWT – Winter wheat; RCE –Rice; POT – Potato; VGL – Vegetables; MLN – Melons; MZE – Maize; FOD – Fodder crops; MLK – Cows; EGG – Poultry; MEA – Bulls; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; Base – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results

Table A21: Agricultural profits of producers

Producer	Activity	Unit	KSPBGT BASE	KSPBGT EXP1	KSPBGT EXP2	KSPBGT EXP3	KSPBGT EXP4	KSPBGT EXP5	KSPBGT EXP6	KKAURG BASE	KKAURG EXP1	KKAURG EXP2	KKAURG EXP3	KKAURG EXP4	KKAURG EXP5	KKAURG EXP6
SK	CROP	10^3 USD	6,858	10,100	4,825	17,590	-	7,579	-	8,964	11,523	5,315	16,718	-	9,261	-
	ANIMAL	10^3 USD	282	103	336	445	-	491	-	1,482	1,385	1,823	1,856	-	2,327	-
	TOTAL	10^3 USD	7,140	10,203	5,161	18,035	-	8,070	-	10,447	12,907	7,138	18,575	-	11,588	-
	CROPHA	USD ha^{-1}	262	367	192	745	-	283	-	317	396	194	605	-	316	-
	TOTHA	USD ha^{-1}	272	370	205	764	-	301	-	369	443	261	672	-	396	-
PF	CROP	10^3 USD	4,700	5,797	1,815	4,303	15,351	5,447	2,755	4,762	5,715	2,097	3,849	14,521	4,673	4,362
	ANIMAL	10^3 USD	603	584	758	525	1,045	976	1,535	1,592	1,582	1,745	1,742	4,873	2,223	5,323
	TOTAL	10^3 USD	5,302	6,381	2,573	4,827	16,395	6,423	4,289	6,354	7,297	3,841	5,591	19,394	6,896	9,685
	CROPHA	USD ha^{-1}	633	702	230	591	467	675	89	478	531	231	411	382	459	131
	TOTHA	USD ha^{-1}	714	772	327	663	499	796	139	637	678	422	597	510	678	291
HH	CROP	10^3 USD	3,952	4,840	3,085	2,404	4,313	3,816	2,026	3,268	3,918	3,086	2,505	4,057	3,392	2,752
	ANIMAL	10^3 USD	33,676	33,944	35,565	41,276	40,854	53,049	45,460	45,760	46,817	45,808	53,667	54,586	62,465	57,373
	TOTAL	10^3 USD	37,628	38,784	38,650	43,680	45,167	56,865	47,487	49,029	50,735	48,894	56,172	58,643	65,857	60,125
	CROPHA	USD ha^{-1}	531	633	423	327	576	507	273	514	581	490	427	606	504	435
	TOTHA	USD ha^{-1}	5,058	5,073	5,294	5,950	6,035	7,557	6,386	7,709	7,529	7,756	9,567	8,755	9,791	9,502
DIST	CROP	10^3 USD	15,510	20,737	9,725	24,296	19,663	16,842	4,781	16,994	21,155	10,497	23,072	18,579	17,326	7,115
	ANIMAL	10^3 USD	34,561	34,631	36,659	42,246	41,899	54,516	46,995	48,835	49,784	49,375	57,265	59,459	67,015	62,696
	TOTAL	10^3 USD	50,070	55,369	46,384	66,543	61,562	71,358	51,776	65,829	70,940	59,873	80,337	78,037	84,341	69,810
	TOTHA	USD ha^{-1}	1,219	1,274	1,150	1,740	1,525	1,684	1,352	1,475	1,521	1,401	1,874	1,744	1,826	1,761
	CROPHA	USD ha^{-1}	377	477	241	635	487	397	125	381	454	246	538	415	375	179

Producer	Activity	Unit	YZRGLN BASE	YZRGLN EXP1	YZRGLN EXP2	YZRGLN EXP3	YZRGLN EXP4	YZRGLN EXP5	YZRGLN EXP6	KVAYRK BASE	KVAYRK EXP1	KVAYRK EXP2	KVAYRK EXP3	KVAYRK EXP4	KVAYRK EXP5	KVAYRK EXP6
SK	CROP	10^3 USD	4,696	5,874	2,159	10,720	-	4,725	-	4,285	6,475	2,516	14,481	-	4,714	-
	ANIMAL	10^3 USD	538	532	571	701	-	777	-	1,597	1,540	1,795	1,944	-	2,231	-
	TOTAL	10^3 USD	5,235	6,406	2,731	11,421	-	5,502	-	5,882	8,015	4,311	16,425	-	6,945	-
	CROPHA	USD ha^{-1}	297	352	139	684	-	296	-	260	371	160	938	-	272	-
	TOTHA	USD ha^{-1}	331	384	176	729	-	345	-	357	459	274	1,064	-	401	-
PF	CROP	10^3 USD	7,495	10,049	3,772	9,865	16,078	7,267	8,292	3,281	4,592	2,386	3,513	9,783	3,223	7,586
	ANIMAL	10^3 USD	1,188	1,464	1,160	1,291	2,728	1,679	3,816	1,233	1,212	1,266	1,338	2,578	1,766	2,843
	TOTAL	10^3 USD	8,682	11,513	4,931	11,156	18,806	8,946	12,108	4,514	5,804	3,652	4,851	12,361	4,990	10,429
	CROPHA	USD ha^{-1}	323	401	166	436	414	310	265	389	492	285	427	387	377	321
	TOTHA	USD ha^{-1}	374	459	217	494	485	382	387	535	622	436	590	489	584	442
HH	CROP	10^3 USD	3,191	3,968	2,234	2,285	3,517	3,128	2,004	4,755	5,765	4,109	3,855	5,571	4,219	4,091
	ANIMAL	10^3 USD	23,439	23,162	24,812	25,023	30,401	23,194	32,563	30,504	30,520	30,898	32,547	38,181	40,217	44,102
	TOTAL	10^3 USD	26,630	27,131	27,047	27,307	33,918	26,322	34,567	35,260	36,284	35,008	36,403	43,752	44,436	48,192
	CROPHA	USD ha^{-1}	607	722	436	438	669	595	390	785	943	686	650	933	697	679
	TOTHA	USD ha^{-1}	5,066	4,936	5,273	5,236	6,452	5,007	6,732	5,823	5,934	5,844	6,136	7,330	7,343	7,996
DIST	CROP	10^3 USD	15,382	19,891	8,165	22,870	19,595	15,120	10,296	12,321	16,832	9,011	21,849	15,354	12,156	11,676
	ANIMAL	10^3 USD	25,165	25,158	26,544	27,014	33,129	25,650	36,380	33,334	33,272	33,960	35,829	40,759	44,214	46,945
	TOTAL	10^3 USD	40,547	45,050	34,709	49,884	52,725	40,770	46,676	45,656	50,103	42,971	57,678	56,113	56,370	58,621
	TOTHA	USD ha^{-1}	915	953	801	1,147	1,197	913	1,280	1,474	1,523	1,428	1,948	1,795	1,767	1,978
	CROPHA	USD ha^{-1}	347	421	189	526	445	339	282	398	512	299	738	491	381	394

Producer	Activity	Unit	KKRSVT BASE	KKRSVT EXP1	KKRSVT EXP2	KKRSVT EXP3	KKRSVT EXP4	KKRSVT EXP5	KKRSVT EXP6
SK	CROP	10^3 USD	6,581	9,029	4,104	17,638	-	6,905	-
	ANIMAL	10^3 USD	318	238	425	370	-	659	-
	TOTAL	10^3 USD	6,899	9,267	4,529	18,008	-	7,564	-
	CROPHA	USD ha^{-1}	242	321	155	678	-	251	-
	TOTHA	USD ha^{-1}	254	329	171	692	-	275	-
PF	CROP	10^3 USD	3,081	4,352	1,482	2,987	7,612	3,301	1,906
	ANIMAL	10^3 USD	879	866	994	441	2,464	1,495	2,822
	TOTAL	10^3 USD	3,960	5,218	2,476	3,427	10,076	4,796	4,728
	CROPHA	USD ha^{-1}	245	321	118	232	193	253	52
	TOTHA	USD ha^{-1}	314	385	196	266	255	367	128
HH	CROP	10^3 USD	2,873	4,217	2,883	1,824	3,660	3,073	2,235
	ANIMAL	10^3 USD	33,059	32,670	33,088	34,944	42,690	45,374	43,023
	TOTAL	10^3 USD	35,931	36,887	35,971	36,768	46,350	48,447	45,258
	CROPHA	USD ha^{-1}	411	579	416	261	510	439	315
	TOTHA	USD ha^{-1}	5,146	5,065	5,195	5,266	6,456	6,924	6,372
DIST	CROP	10^3 USD	12,535	17,597	8,470	22,448	11,272	13,279	4,141
	ANIMAL	10^3 USD	34,256	33,774	34,506	35,755	45,154	47,529	45,845
	TOTAL	10^3 USD	46,791	51,371	42,976	58,203	56,426	60,808	49,986
	TOTHA	USD ha^{-1}	1,001	1,049	935	1,269	1,210	1,278	1,135
	CROPHA	USD ha^{-1}	268	359	184	489	242	279	94

Notes: SK – *Shirkat*s; PF – Private farms; HH – Rural households; CROP – total profits of producer from crop growing activities; ANIM – total profits of producer from livestock and poultry keeping activities; TOTAL – total profits of producer from crop growing and livestock and poultry keeping activities; TOTHA – total profit per hectare of sown area; CROPHA – profit from cropping activities per hectare of sown area; KSPBGT – Aggregate for Khazarasp and Bagat districts; KKAURG – Aggregate for Khanka and Urgench districts; YZRGLN – Aggregate for Yangibazar and Gurlen districts; KVAYRK – Aggregate for Khiva and Yangiarik districts; KKRSVT – Aggregate for Kushkupir and Shavat districts; Base – Base situation (observed), EXP1 – Investment into irrigation and drainage system; EXP2 – Introduction of water pricing; EXP3 – Liberalization of cotton and input markets; EXP4 – Accomplishment of farm restructuring; EXP5 – Improvement in livestock sector; EXP6 – Cumulative scenario

Source: Model simulation results