# ECONOMIC IMPACTS OF CLIMATE CHANGE ADAPTATION

## A Subnational View For Kazakhstan

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Registered offices:
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Address:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Köthener Str. 2
10963, Berlin, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de/en

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Project Manager:
Dr. Sebastian Homm
sebastian.homm@giz.de

Authors:
Dr Anett Großmann, Frank Hohmann
GWS - Gesellschaft für Wirtschaftliche Strukturforschung | Institute of Economic Structures Research, Osnabrück

Contributions:
Aidyn Bakdolotov, Ramin Kazymov, Baltabay Syzdykov
Economic Research Institute, Astana

Editors:
Dr. Sebastian Homm, Eschborn
Dana Yermolyonok, Karaganda

Design:
Alvira Yertayeva, Astana

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On behalf of
German Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)

Germany, 2023

# ECONOMIC IMPACTS
# OF CLIMATE CHANGE ADAPTATION

## A SUBNATIONAL VIEW FOR KAZAKHSTAN

subnational extension of e3.kz – a simplified approach

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| | |
|---|---|
| Bn. | Billion |
| COMSTAT | Committee of Statistics in Kazakhstan |
| CRED | Climate Resilient Economic Development |
| ERI | Economic Research Institute |
| EWE | Extreme weather events |
| GDP | Gross domestic product |
| GRP | Gross regional product |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| GWS | Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung) |
| IMPLAN | Economic Impact Analysis for Planning |
| IO | Input-Output |
| IRIO | Interregional Input-Output |
| KZT | Kazakh Tenge |
| MIT | Massachusetts Institute of Technology |
| Mn. | Million |
| MRIO | Multiregional Input-Output |
| NAP | National Adaptation Plan |
| NUTS | Nomenclature des unités territoriales statistiques |
| RCP | Representative Concentration Pathways |
| REF | Reference scenario |
| REMI | Regional Economic Models, Inc. |
| RIMS | Regional Input-Output Modelling System |
| UIB | University of the Balearic Islands |

# GLOSSARY

| | |
|---|---|
| Adaptation to climate change | In human systems, the process of adjustment to actual or expected climate and its effects, in order to mitigate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. |
| Climate change | Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. |
| Climate hazard | The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. |
| Cost-benefit analysis | A systematic approach to estimate costs and benefits of a project. It compares the discounted value over the whole lifetime of the project – the net present value (NPV) – of the costs and the benefits. A project is recommended if the benefits outweigh the costs (NPV > 0). |
| E3 (economy, energy, emission) model | An E3 model is a model covering the demand-and-supply-relationships of an economy and its main connections to the environment, i. e. the use of energy resources and the input of $CO_2$ emissions into the environment. This integrated modelling approach of the 3Es in one model framework assures a consistent view of possible transition pathways. It enables to calculate macroeconomic and sector-specific impacts as well as conclusions to be drawn on social balance and ecological benefits. |
| Extreme weather events | "The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable" (IPCC 2012, p. 117) with respect to a given reference period and a specific region. |
| Resilience | Resilience is defined as the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring the |

| | |
|---|---|
| | preservation, restoration, or improvement of its essential basic structures and functions. |
| Scenario | Scenarios are consistent sets of quantified assumptions describing the future development. Scenarios should not be considered as precise forecasts. Instead, they show possible development paths that are reactions to the assumptions made. |
| Vulnerability | Vulnerability is defined as the propensity or predisposition to be adversely affected. In the field of disaster risk, this includes the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events. |

Source: Based on IPCC (2018) for climate-related terms.

# EXECUTIVE SUMMARY

Climate change poses major challenges for Kazakhstan. The north of Kazakhstan is mainly affected by droughts, while the south must cope with floods. Although the damage is mainly regional or even local, the economic impact is not only local but can also be felt beyond the region due to the economic ties between the regions of Kazakhstan. Likewise, adaptation measures show economic implications not only in the region implementing such measures. Due to regional economic specialization, positive effects are also visible in other regions not directly affected.

So far, the macroeconomic effects of climate change and adaptation options have been evaluated for Kazakhstan at national level only. The macroeconomic evaluation shows that climate change puts food and energy security at risk. If no adaptation measures are taken, economic growth, jobs and income are endangered not only in directly impacted economic sectors but also by indirect and income-induced effects. Adaptation measures help to reduce these risks and provides win-win options for the economy, employment, and environment.

A better understanding of the subnational effects of adaptation action is key to promote effective adaptation planning. First, it is important to understand the region-specific impacts of climate change and where adaptation action is most effective. Second, the regional level is an important level of climate action. Subnational adaptation action has been identified as a key approach by the 2019 report on Entry Points for Vertical Integration of Climate Action in Kazakhstan[1]: “(…) the integration of climate-resilient planning into sub-national development planning presents an entry point for action. This would ensure access to funding for climate actions and make investments across all provinces climate-proof.”

Since 2021, climate change adaptation in Kazakhstan is governed by the Environmental Code. According to the code requirements, the impacts of climate change should be taken into account in policy planning in the medium and long-term perspective at both national and sub-national levels. Sub-national level executive bodies are obliged to plan adaptation measures in the pre-defined priority areas (agriculture, water, forestry, disaster risk reduction).

Responding to this potential, the CRED project supported the extension of the existing macroeconomic model to explicitly assess economic effects at the subnational level.

For a regional analysis of the economic consequences of climate change and climate change adaptation, a subnational extension of the e3.kz model was performed.

Regional economic indicators were incorporated and linked to corresponding indicators at the national level using a simplified top-down regionalization approach. GDP and

1 napgn-en-2019-entry-points-for-vertical-integration-of-climate-action-in-kazakhstan-1.pdf (napglobalnetwork.org)

sector-specific employment effects for Kazakhstan are allocated to the regions based on a shift share approach.

The following questions can be answered with this extended modelling approach:

- Which Kazakh regions ("oblast") suffer the most from climate change in terms of e.g., GDP and employment by economic sectors?
- Which Kazakh regions benefit the most from adaptation measures in terms of e.g., GDP and employment by economic sectors?

In addition to the results from the climate change adaptation scenarios at national level, the subnational analyses show that:

- All regions in Kazakhstan are directly and / or indirectly affected from the impacts of climate change and adaptation.
- From a regional perspective, climate damages are even more significant than at national level.
- In particular those regions suffer / benefit from the sectoral impacts at national level for which the respective economic sector(s) is (are) key.
- Regions that have a significant sector-specific focus are exposed to a higher economic risk if climate change negatively affects that economic sector. Then, adaptation to climate change is in particular relevant for the region. Diversification of the economic structure may support to reduce this risk.
- Regions with a focus on economic sectors that profit from climate change adaptation such as construction and "green" industries, which e.g., support deployment of renewable energy, profit the most from climate-resilient strategies.
- Shocks affecting agriculture are of concern in particular for North Kazakhstan, Akmola, and Jambyl region. More or less all regions are affected from shocks impacting trade & transport as well as service sectors.

Data for damages of climate hazards are typically not recorded in a systemic, structured way. In course of the CRED project, past damages from extreme weather events (EWE) were collected in an Excel file categorized by regions, EWE, year, and type of damage as well as the effected sector (if available). For a more intuitive access, interactive maps were created allowing for a quick overview of past climate hazards and their quantified damages.

# 1 INTRODUCTION

Climate change has regional and local effects, as shown by the historical analysis of climate change damages in Kazakhstan. The economic consequences of climate change may impact the region itself as well as other regions. Likewise, adaptation to climate change has a variety of economic effects for Kazakhstan and its regions.

In the national Report Kazakhstan (GIZ 2022), the macroeconomic effects of climate impacts and of adaptation measures were evaluated for the national economy. While the effects on GDP and employment in a world with climate change but without adaptation are predominantly negative, adaptation measures show positive effects for these indicators.

This report addresses the question of how severely the regions (at the NUTS1[2] level (oblast)) of Kazakhstan are affected by climate change and how much they could benefit from adaptation. The economic specialization of the regions provides first insights.

The simplified methodological approach used here allocates the impacts of climate change and adaptation from the national level to the regions using a "top-down" approach that considers the economic structure of the regions. These are reflected by regional economic indicators such as GDP and employment by economic activities.

For regionalization, a shift-share approach[3] is used, which considers both general sector-specific trends and regional disparities when transferring the development of the national development to the subnational regions. This enables the projection of regional developments for selected economic indicators and sectors until 2050.

The subnational extension of the e3.kz model supplements the macroeconomic analyses of climate change and adaptation at national level by giving insights into the regional economic effects. Impacts that may seem small for the national economy may be big from a regional perspective.

The extended e3.kz model is applied in the same way as it was for the evaluation of climate change and adaptation scenarios at the national level. First, a scenario is designed to be simulated with the model. A climate change scenario includes the frequency of the respective climate hazard and the expected regional, future damages for the affected economic sector(s). Adaptation scenarios include sector-specific costs and benefits of adaptation measures. Subsequently, the effects for the economy a national and subnational level as well as the environment are analysed by comparing the scenarios with and without adaptation.

The effects are reflected with varying intensity in the regions. A change in e.g. employment in agriculture is particularly evident in the regions that have their economic specialization in that sector. The region-specific differences in economic structure are significant for the implications of climate change and adaptation.

This report is organized as follows:

Chapter 2 describes the regional damage recording database that has been created with the help of Kazakh experts as well as the geomap tool in Microsoft Excel which helps to visualize and evaluate the historic extreme weather events (EWEs) recorded in the database. Chapter 3 describes the modelling approach of the subnational economic extension to the national e3.kz model. Chapter 4 gives an overview of the economic results from the reference scenario at the subnational level. Chapter 5 describes the implementation and economic

2 NUTS (Nomenclature des unités territoriales statistiques) is the nomenclature for identifying and classifying the spatial reference units of official statistics of the EU.
3 Dunn, Edgar S. (1960): A statistical and analytical technique for regional analysis. Regional Science 6 1: 97-112

effects of three different climate change scenarios (drought, heat wave and extreme precipitation). Chapter 6 reveals the economic effects of five different climate change adaptation scenarios for the agriculture, energy, and infrastructure sectors. Chapter 7 summarizes key findings and possible extensions to the subnational modelling approach.

# 2 STOCKTAKING OF PAST CLIMATE CHANGE DAMAGES AT SUBNATIONAL LEVEL

## 2.1 DATA COLLECTION

One important prerequisite for the analysis of climate change adaptation scenarios is quantified data about past damages from climate hazards. For analyses on a subnational level (NUTS1), this data is usually not easily available, mostly because damages related to climate change events were not explicitly recorded.

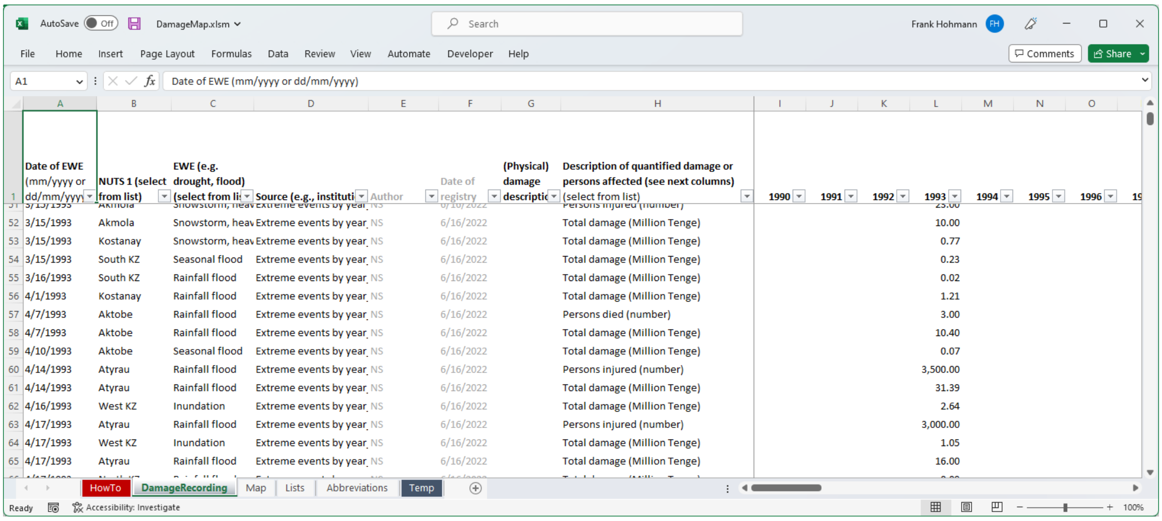
For stocktaking of past climate change damages in Kazakhstan at the subnational level, a desk study has been conducted with Kazakh experts who collected data from different information sources such as Kazhydromet and the Ministry of Emergency Situations, national and international scientific literature, and public media coverage[4] (e.g., Broka et al. 2016, Ministry of Energy et al. 2017, OECD 2019a, Reliefweb[5]).

For a systematic evaluation, the available data must be converted into a unified format. For this purpose, a data register template was developed in Microsoft Excel which was sent to and filled in by the Kazakh experts. The set of information that is recorded in the template contains for each event:

- Date of event
- Region
- Kind of extreme weather event (e.g., drought, flood)
- Source of information
- Author
- Date of registry
- (Physical) damage description (e.g., total damage in mn. KZT)
- Columns for each year to enter quantified damage value

Each event is described in one row of the table for the respective region.

[4] For example, total.kz reported on the consequences of a drought in Kazakhstan. (https://total.kz/ru/news/gossektor/825_millionov_tenge__viplacheno_postradavshim_ot_zasuhi_fermeram_kazahstana_date_2021_10_29_19_24_41?fbclid=IwAR2nk-A2wpp1JyuHep37brPpWJ2VyoNdkphxVxFchP_igfYIn-Ha4Sdr8p8)
[5] https://reliefweb.int/disasters



| | Date of EWE (mm/yyyy or dd/mm/yyyy | NUTS 1 (select from list) | EWE (e.g. drought, flood) (select from li | Source (e.g., instituti | Author | Date of registry | (Physical) damage descriptic | Description of quantified damage or persons affected (see next columns) (select from list) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 52 | 3/15/1993 | Akmola | Snowstorm, heav | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 10.00 | | | |
| 53 | 3/15/1993 | Kostanay | Snowstorm, heav | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 0.77 | | | |
| 54 | 3/15/1993 | South KZ | Seasonal flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 0.23 | | | |
| 55 | 3/16/1993 | South KZ | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 0.02 | | | |
| 56 | 4/1/1993 | Kostanay | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 1.21 | | | |
| 57 | 4/7/1993 | Aktobe | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Persons died (number) | | | | 3.00 | | | |
| 58 | 4/7/1993 | Aktobe | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 10.40 | | | |
| 59 | 4/10/1993 | Aktobe | Seasonal flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 0.07 | | | |
| 60 | 4/14/1993 | Atyrau | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Persons injured (number) | | | | 3,500.00 | | | |
| 61 | 4/14/1993 | Atyrau | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 31.39 | | | |
| 62 | 4/16/1993 | West KZ | Inundation | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 2.64 | | | |
| 63 | 4/17/1993 | Atyrau | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Persons injured (number) | | | | 3,000.00 | | | |
| 64 | 4/17/1993 | West KZ | Inundation | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 1.05 | | | |
| 65 | 4/17/1993 | Atyrau | Rainfall flood | Extreme events by year | NS | 6/16/2022 | | Total damage (Million Tenge) | | | | 16.00 | | | |

Figure 1: Damage recording template

Source: Own illustration based on data collections from Kazhydromet, and other Kazakh partners.

It must be pointed out that the damage recording template does not reflect the full set of information about past climate change events, because (1) it only contains publicly available information and data received from e.g., Kazhydromet and (2) for some climate hazards the quantified damage was not available.

As of February 2023, the list of recorded damages contains around 3,000 entries. To simplify the evaluation of the dataset, a geomap-based tool in Microsoft Excel's VBA programming language has been developed which is depicted in the next section.

## 2.2 DATA VISUALIZATION IN INTERACTIVE MAPS

An interactive Excel-based tool using geomaps has been developed to simplify the evaluation of the regional damage recording database.

The geomap tool does not rely on Microsoft's own geomap implementation for the following reasons:

- Microsoft's implementation needs an active internet connection,
- Data is sent to Microsoft servers for processing,
- Only recent versions of Microsoft Office can utilize the geomap feature.

For the evaluation, the damage recording database is used which is stored in the same Excel workbook as the geomap tool. The tool allows for selecting specific EWEs, damage types (e.g., total damage in mn. KZT), years and display types. The information will be immediately transformed into coloured maps at the subnational level. By clicking a single region, a summary is computed reflecting all recorded events for the respective region based on the selected damage type and year.

The following screenshot shows the user interface of the tool presenting available information about forest fires for all recording years in mn. KZT. The table depicts all recorded events for the East Kazakhstan.

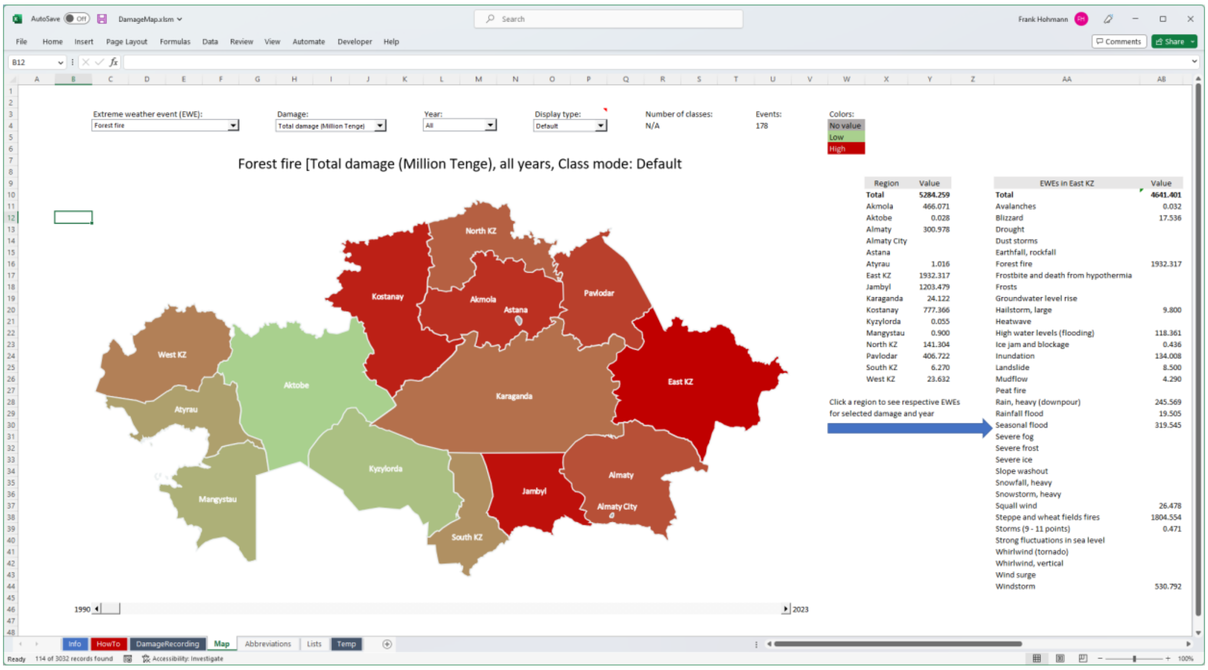



Figure 2: Interactive damage map

Source: Own illustration.

The colours used in the map may be adjusted by selecting appropriate colours for the lowest and highest values as well as for elements which have no data.

Given the rich set of selection options, the tool effectively supports the evaluation of recorded damage data from a subnational perspective. The damage recording template may be used to develop additional data views.

It must be pointed out that many combinations of selections do not reveal any values. This only means that the current damage dataset has no recorded entry for the selected EWEs, damage type and year. There might have been respective events in the past, but the corresponding data has either not been available or has not yet been added to the damage dataset. Once new damage data becomes available, it can be easily added to the damage recording template (c.f. Figure 1). The more past and current damage data is added, the better the data basis for macroeconomic modelling.

# 3 SUBNATIONAL ECONOMIC EXTENSION OF THE E3.KZ MODEL

The subnational dimension of economic transformation processes and policies is an important basis for decision-making. While climate impacts have a regional perspective if not a local one, climate policies are embedded in policy planning at national and subnational level (e.g., NAP, Ecological Code).

Policies have different impacts on different regions. Thus, regional modelling is an important tool for policy-makers to determine economic effects at subnational level. From an economic perspective, the regionally different dimensions of gross regional product (GRP), employment and value added are of particular interest. The regional economic structure plays an important role in the regional economic development process. Some regions are more affected by transformation processes than others due to their economic specialisation.

Scenario analysis is an appropriate methodology to simulate different future development pathways including unexpected events such as EWEs or climate policies. In combination with E3 models, impacts of such scenarios for the economy and environment can be evaluated. The subnational extension of the national e3.kz model allows for projecting subnational pathways for selected economic variables as well.

## 3.1 APPROACHES FOR SUBNATIONAL MODELING

There are different approaches to model the subnational impacts of developments in superordinate regions ranging from “top-down” approaches with low data requirements to very complex, data intensive multi- and interregional input-output (IO) models.

**Simple regionalization approaches** use measures of spatial concentration and regional specialization to derive the regional distribution of industries. Spatial concentration – measures by e.g., Krugman’s concentration index and the location quotient – means the clustering of sector-specific companies or jobs in one or a few regions, while regional specialisation describes the concentration of a region on one or a few sectors (Palan 2010). Reasons for the regional concentration and specialization are usually not explained and interregional trade is ignored. However, the identified spatial patterns can be used for the regionalization of national data.

**Shift-share analysis** is another regionalization method which is used for the analysis of developments of subordinate regions in the context of superior region usually measured by employment. It examines subnational changes differentiating the overall cyclical effect, the economic structure effect (“share” effect), and specific locational factor (“shift” effect; Farhauer et al. 2009, Bernardt et al. 2020).

The classical shift-share approach (Dunn 1960) has low data requirements and is a descriptive and easily feasible technique to analyse regional growth. Basic economic shift-share analyses can be performed using the “constant share” approach. The “share” is calculated from the ratio of a sector-specific economic indicator in a subordinate region to its superordinate region for a given historical year. This share stays constant for the future. If this share is greater for a subordinate region than in the superior region, the effect in the superior region will impact the subordinate region above average, and vice versa. A change of the sector-specific economic indicator at the superordinate regions implies the same growth in the subordinate region (structural effect). As a result, the absolute changes in the economic indicator differ in the subordinate regions due to the different regional economic structure.

The “shifted-share” approach compares these shares for the superordinate and subordinate region at two points in time. Typically, the shares vary over time due to region-specific factors. However, spillover effects between regions and the inter-industry relationships are neglected and the reasons behind such an observed shift cannot be explained with this method (Farhauer et al. 2009, Bernardt et al. 2020).

For a full analysis of the explanation of regional development, the shift-share-regression approach is better suited than the classical shift-share approach though it requires more data (Zika et al. 2020). This approach is based on econometrics and aims at reducing the uncertainty regarding the chosen historical period and dealing with outliers. Additional variables can be included in the regressions considering specific regional factors such as the number of households or the age of population which have an impact on the construction and health sector (e.g., Ulrich, Wolter 2013, Bernardt et al. 2020).Other regional approaches apply **regional input output multipliers** for employment, income, or output to measure the impacts of national policies and shocks at subnational level such as the RIMS II model of the U.S. Bureau of Economic Analysis (BEA 2013). For the same purpose, multi-regional models like IMPLAN and REMI are using **regional purchase coefficients** (Lindall et al. 2005, Mills 1993) which consider the proportion of regional production in regional demand for a certain economic sector (Miller et al. 2009). Everything that cannot be produced regionally, thus, must be imported.

The most comprehensive, data-intensive regionalization approaches are multi- and interregional IO (MRIO, IRIO) models. Since 1950, different types of such models were developed which differ with respect to the number of regions considered and the degree of detail in interregional trade (Ulrich et al. 2022, Großmann et al. 2020, Többen 2017, Schröder and Zimmermann 2014, Miller et al. 2009, Sargento 2009, Flegg and Webber 1995). IRIO and MRIO models allow for the direct consideration of regional investment and consumption as well as their impacts on (inter-)regional production activities and interregional trade.

## 3.2 SUBNATIONAL MODELING APPROACH CHOSEN FOR KAZAKHSTAN

As briefly described in section 3.1, there are different regionalisation approaches, ranging from a simplified distribution of national developments to the subnational regions using a top-down approach to a complex regional modelling. For the subnational extension of the e3.kz model, a simplified regionalisation approach was preferred, which considers the data situation at subnational level and reduces the modelling effort. At the same time, the regionalised e3.kz model enables to evaluate the subnational, economic effects from climate change and adaptation for 16 Kazakh regions shown in Figure 3.

An important prerequisite for quantitative models is data. At national level, there is usually plenty of data available, at subnational level often only a limited set of data. Model projections are derived from past observations and thus, consistent time series of historical data are a prerequisite for the subnational extension of e3.kz. To link the subnational economic developments with the national e3.kz model, the respective economic indicators must be available for the regions as well. For 16 regions at NUTS1[6] level, consistent subnational data is available for GRP as well as value added and employment by economic sectors.

[6] Administrative-territorial structure of the country changed over the years, e.g., in 2018 Shymkent city is not part of South Kazakhstan anymore and South Kazakhstan was renamed to Turkestan. In 2022, three new regions were created Ulytau, Abay and Zhetysu. To avoid inconsistent time series, the data sets (available until 2021) were harmonized, aggregated from 17 to 16 regions as shown in Figure 3. Additionally, the free Excel-based maps are only available for these 16 regions.


Figure 3: 16 Kazakh regions (oblasts)

Source: Map used under MIT license from https://github.com/ahuseyn/interactive-svg-maps.

The subnational modelling is based on an empirical analysis of regional economic structures and a systematic analysis of sector-specific growth differences between subnational regions and the national level in Kazakhstan. This extended modelling is embedded in the consistent, integrated macroeconomic e3.kz model which enables a comparative analysis of economic indicators such as employment and GRP with other subnational regions. By conducting scenario analysis, the economic impacts of various climate change and adaptation scenarios can be evaluated at national and subnational level (Figure 4).

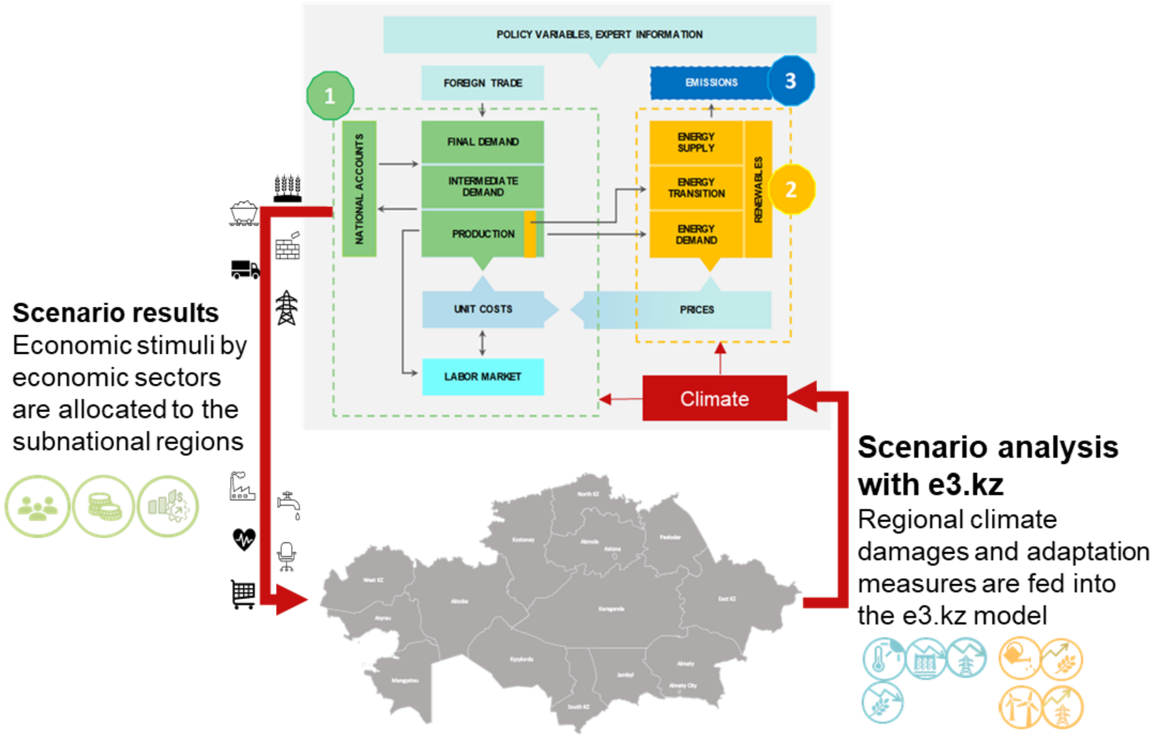



Figure 4: Subnational modelling

Source: Own illustration. Map used under MIT license from https://github.com/ahuseyn/interactive-svg-maps.

The mapping of the existing economic structure in the regions is an important prerequisite for regionalisation. Both the historical development and the current situation in the regions are important factors for the future development of the region-specific indicators.

If the economic structure of a region differs significantly from the national average, the region will react differently to economic stimuli. For example, regions with a high share in mining are more dependent on foreign trade than those with a low share. Other sectors are more affected from domestic demand such as construction or service sectors. The greater the importance of an economic sector in the region, the stronger the impact from the national development, and vice versa.

The approach chosen here follows the “shifted share” approach, which has already been successfully applied for regionalisation down to the district level in Germany (Zika et al. 2023). Due to the data situation (e.g., no sufficient time series), an econometric approach as in the dynamic shifted share regression approach was not adopted. The selected approach is less data-intensive, less complex and shows that a region develops differently but it cannot explain the reasons. This approach allows both the transfer of sector-specific trends at the national level to the subnational level and the consideration of regional disparities. Employment by 19 economic activities is the link between the national and subnational level given the data available.

In the "shifted share" approach, the share of all economic sectors of a subordinate region in the superordinate region is first determined based on historical data. A comparison of these shares shows either similar or divergent developments in the respective region and the national average. Reasons for strongly divergent developments are, for example, location factors in a region that lead to relocations of companies in one sector to another region. Exceptional / atypical developments are not taken into account when determining the observed average “competitive advantage factors” (Zika et al. 2023, Bernardt et al. 2020).

These empirically derived factors for each region and each economic sector are applied to project the historical regional, sector-specific employment based on the employment projections at national level. It should be considered that regional competitive advantages once gained can disappear again in especially in the long-term. Thus, it is assumed that the “competitive advantage factors” will gradually decrease.

For policymaker, another important economic indicator is value added or the gross domestic product. To derive value added by economic sectors, the regional, sector-specific labour productivity – which develops as the labour productivity at national level – is applied to regional employment. Finally, GRP can be determined from sectoral value added considering net taxes on products. For all regional economic indicators, the national values are determined by aggregation across all regions.

With the “shifted share” approach presented here, regional employment, value added, and GRP can be consistently linked to the corresponding e3.kz model variables (for further details see GIZ 2022). Thus, the extended e3.kz model can also be used for first evaluations of the economic impacts of climate change and adaptation at the subnational level.

# 4 REFERENCE SCENARIO: RESULTS FOR THE ECONOMY AT SUBNATIONAL LEVEL

The results presented in this chapter for the subnational level, follow the macroeconomic pathway (reference scenario REF) until 2050 described in the national report for Kazakhstan (GIZ 2022). The projection is based on the economic relationships observed in the past. Assumptions have been aligned as far as possible with the business-as-usual results of the LEDS-project (DIW Econ 2021). The specific subnational developments depend on the economic structure of each region and the modelled relationship between the region and the national level which means Kazakhstan as a whole (c.f. section 3.2).

Regional structures are typically shown in maps which are more intuitive. However, such maps must be interpreted with care. Not the representation of the regions in terms of the size is significant for the interpretation, but the respective value.

### Population

According to third-party forecast of DIW Econ, population will continue to grow by approx. 30% between 2020 and 2050 and thus will increase from 19 mn. people in 2020 to 24 mn. by 2050 (DIW Econ 2021). If each region contributes to national population growth as in the past, Astana city (+95%) and Mangystau region (+71%) will attract even more people while, for example, North-Kazakhstan (-28%) and Kostanay regions (-13%) still show a population decline (Figure 5). The population projection does not consider changes in migration flows, any other aspects impacting population dynamics such as fertility rates or economic decisions of people to migrate.

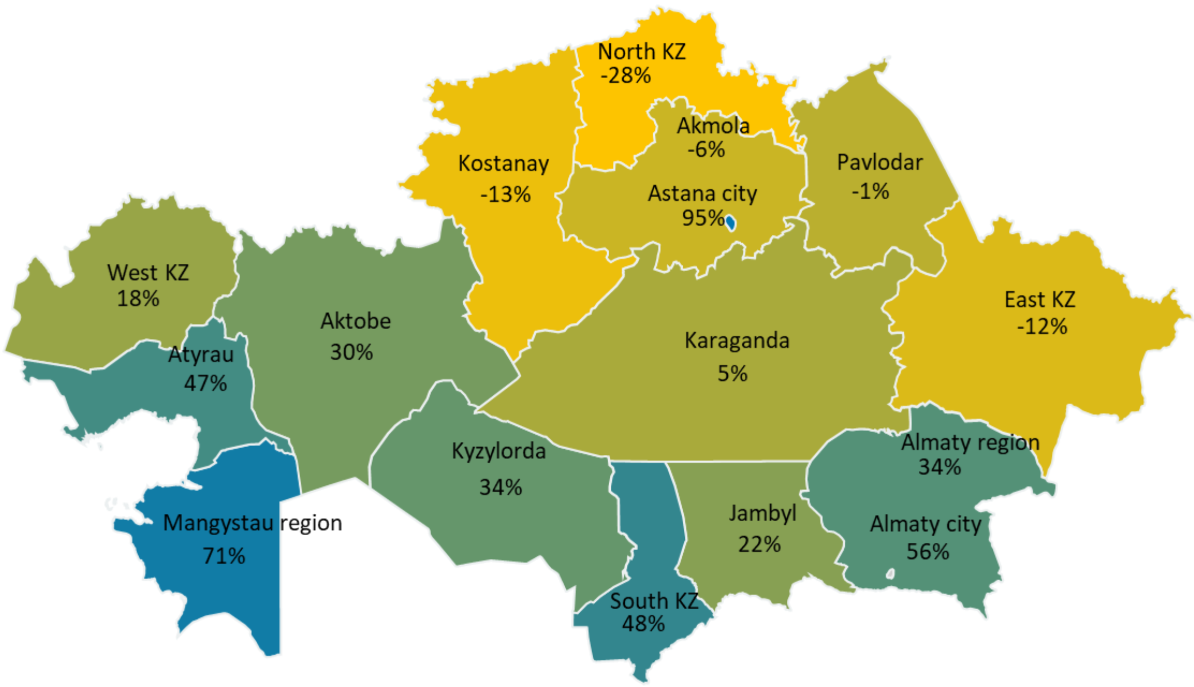



Figure 5: Population growth in %, 2020-2050

Source: e3.kz results. Map used under MIT license from https://github.com/ahuseyn/interactive-svg-maps.

Most of Kazakhstan's inhabitants will continue to live in the South-East of Kazakhstan. The most people live in South-Kazakhstan with 4.5 million persons which is 19% of total population, followed by Almaty city with 3 million resp. 12% and Almaty region (2.8 million resp. 11%).

### Gross regional product

According to the REF scenario, economic growth is expected to continue until 2050 but at a lower path than in the history. Table 1 shows at the top the average annual growth rates of nominal GDP for Kazakhstan for five decades and for the projection period 2020-2050.

For all regions, the deviations in percentage points from the growth at national level is shown. Positive (negative) values mean an accelerated (decelerated) growth compared to the growth at national level. The example of Akmola in 2000-2010 shows that the growth of GRP in Akmola (21.6%) is 2.1%-points lower than in Kazakhstan meaning that Akmola is at a slower economic growth path.

Mainly regions in the South-East of Kazakhstan (Almaty city, Almaty region, South Kazakhstan[7], Jambyl) as well as Astana city show an above national average growth over almost all decades (Table 1).

Table 1: GDP growth in nominal values in % (*) and deviations of GRP in nominal values from national GDP growth in percentage points (**) for selected periods.

| | 2000-2010 | 2010-2020 | 2020-2030 | 2030-2040 | 2040-2050 | 2020-2050 |
|---|---|---|---|---|---|---|
| **Kazakhstan*** | **23.7%** | **12.5%** | **8.4%** | **6.3%** | **3.3%** | **5.9%** |
| Akmola** | -2.1 | 2.1 | -0.1 | 0.5 | -0.1 | 0.1 |
| Aktobe** | 2.1 | -2.8 | -0.1 | -0.9 | -0.2 | -0.4 |
| Almaty region** | -0.6 | 1.6 | 1.3 | 1.1 | 0.3 | 0.9 |
| Atyrau** | 4.1 | -1.9 | 0.6 | -2.3 | -0.2 | -0.6 |
| West KZ** | 0.7 | -2.4 | -0.8 | -3.1 | -0.5 | -1.5 |
| Jambyl** | -1.0 | 3.1 | 1.1 | 1.9 | 0.7 | 1.2 |
| Karaganda** | -3.6 | 0.1 | -1.4 | -1.7 | -0.7 | -1.2 |
| Kostanay** | -5.3 | 0.4 | -1.0 | -0.8 | -0.4 | -0.7 |
| Kyzylorda** | 7.3 | -5.8 | 0.1 | -0.2 | 0.1 | 0.0 |
| Mangystau** | 3.9 | -4.9 | -0.4 | -1.2 | 0.3 | -0.4 |
| Pavlodar** | -3.8 | -0.8 | -0.8 | -0.7 | -0.5 | -0.7 |
| North KZ** | -3.0 | 0.4 | -1.1 | 0.3 | -0.5 | -0.4 |
| South KZ** | -2.7 | 2.5 | 0.1 | 1.1 | 0.2 | 0.4 |
| East KZ** | -5.8 | 1.5 | -2.2 | -1.0 | -0.7 | -1.3 |
| Astana city** | 5.7 | 3.7 | 2.0 | 2.1 | 0.7 | 1.6 |
| Almaty city** | 1.5 | 0.7 | -0.1 | 0.6 | -0.2 | 0.1 |

Source: Until 2020 historical data based on COMSTAT, e3.kz results (2021-2050)

7 Throughout the report, South Kazakhstan includes Shymkent city.

However, all 16 Kazakh regions show a positive economic development in the future of 4.4% to 7.4% p.a. (Figure 6). Almaty city (20% of GDP), Astana city (18%), Atyrau (9%) and South Kazakhstan (8%) are the most important regions for the national development. Each of the regions have an economic specialization – the cities mainly in tertiary sector (services) and Atyrau and Karaganda in the primary and secondary sectors (mining and manufacturing).

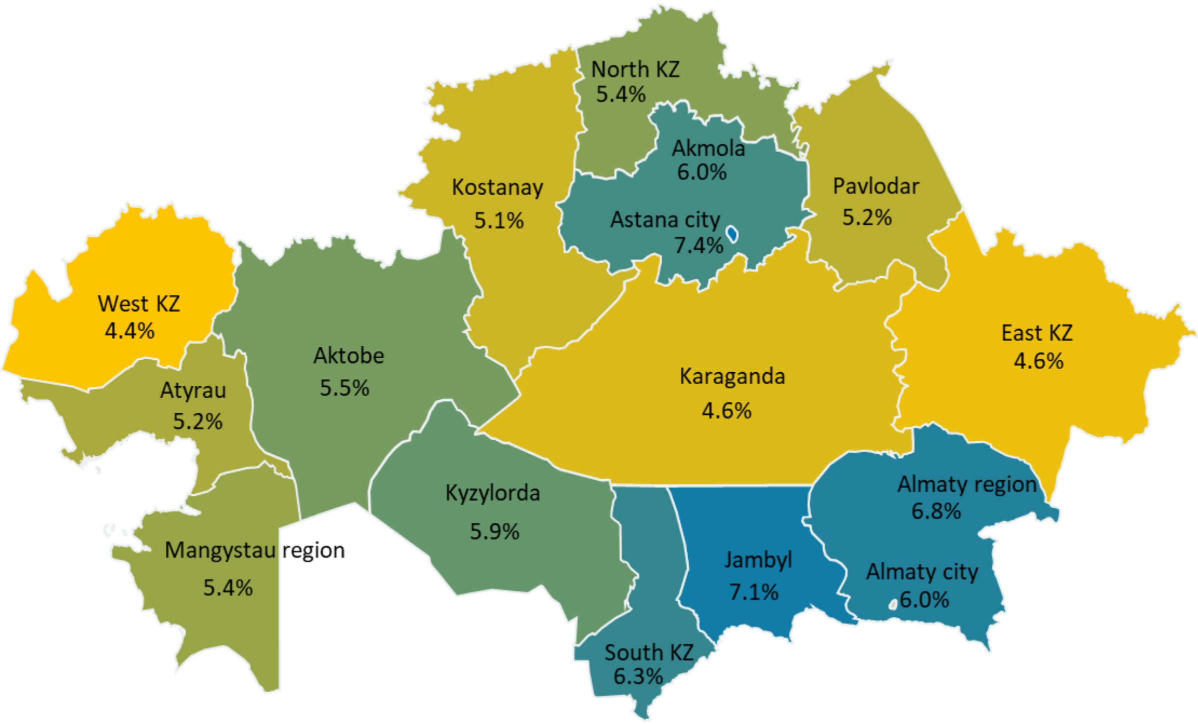



Figure 6: Average annual growth of nominal GRP in %, 2020-2050

Source: e3.kz results. Map used under MIT license from https://github.com/ahuseyn/interactive-svg-maps.

The reasons for the different regional growth paths result from the economic structure in the regions and the sector-specific development of the national economy. The sectoral economic development follows the macroeconomic development at national level, considering interindustry relationships.

### Value added

As described in the national report for Kazakhstan, production as well as value added in the mining sector declines until 2050 which also impacts growth in manufacturing, construction, and professional, scientific, and technical activities (GIZ 2022). Apart from mining & quarrying, all other economic sectors will continue to grow with a rate of 5.7% to 6.9% p.a. during the period 2020 to 2050 at the national level (Table 2).

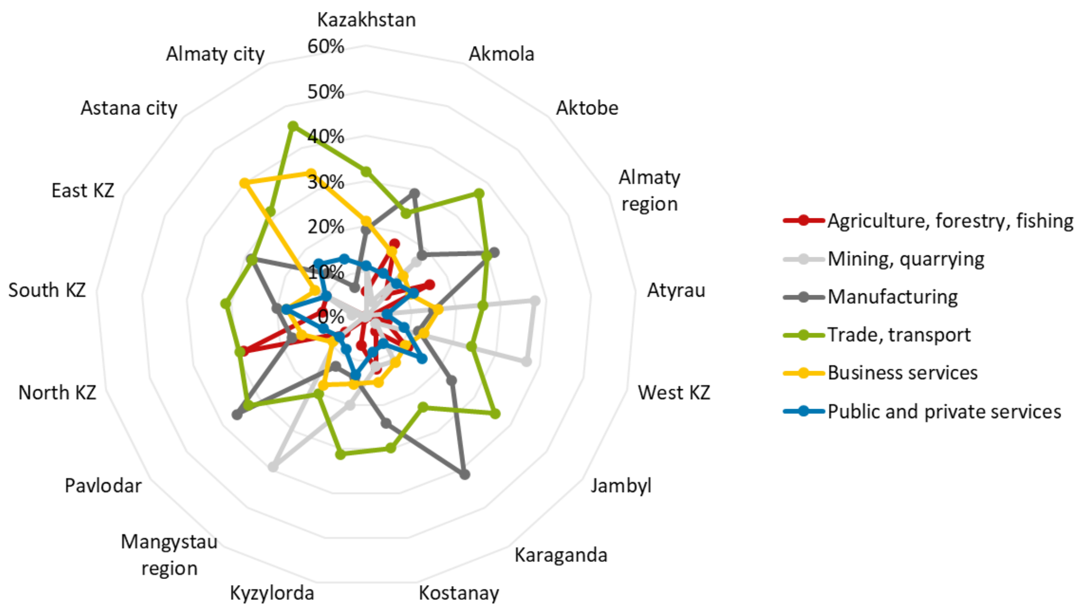
Table 2: Value added by economic sectors, average annual growth rates, 2020-2050

| | Total | Agriculture, forestry & fishing | Mining & quarrying | Manufacturing | Trade & transport | Business services | Public & private services |
|---|---|---|---|---|---|---|---|
| Kazakhstan | 6.0% | 6.8% | -2.3% | 5.7% | 6.2% | 6.8% | 6.9% |

Source: e3.kz results.

Regional economic development depends on the regional sector structure and the corresponding economic development at national level. In addition, the empirically determined correlation between the sectoral economic growth of a region and the national level is of relevance (c.f. section 3.2).

In 2020, for almost all regions, trade & transport contributes the most to total value added. Business services are of high relevance for the cities Astana and Almaty which have a share of 39% (resp. 35%) of total regional value added. Manufacturing & construction are key sectors for Karaganda (40%), Pavlodar (36%) and Almaty region (30%). For Mangystau region (41%), West Kazakhstan (37%) and Atyrau (36%) regions mining & quarrying plays an important role in regional development (light grey line in top Figure 7). By 2050, mining & quarrying plays only a minor role for all regions (light grey line in bottom Figure 7).



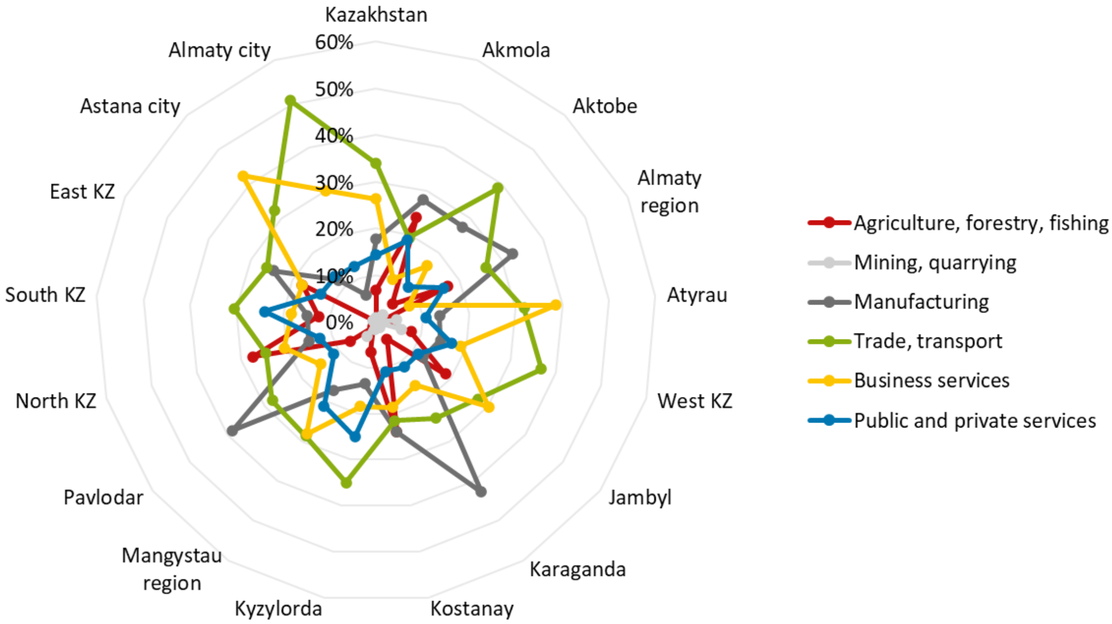



Figure 7: Value added share of economic sectors by region in 2020 (top figure) and 2050 (bottom figure) in %

Source: Historical data (2020) based on Comstat. E3.kz results for 2050.

Figure 8 shows the similarities resp. differences of the regional economic structure measured in terms of value added compared to the economic structure at national level. The smaller the deviations, the more similar the region is compared to the national average. A positive (negative) deviation indicates a greater (lesser) importance of the economic sector in the region compared to the national average. Agriculture (red bar in Figure 8) is of higher relevance for North Kazakhstan compared to the national average. Atyrau, West Kazakhstan and Mangystau regions have an above-average importance of mining & quarrying (light grey bars in Figure 8).

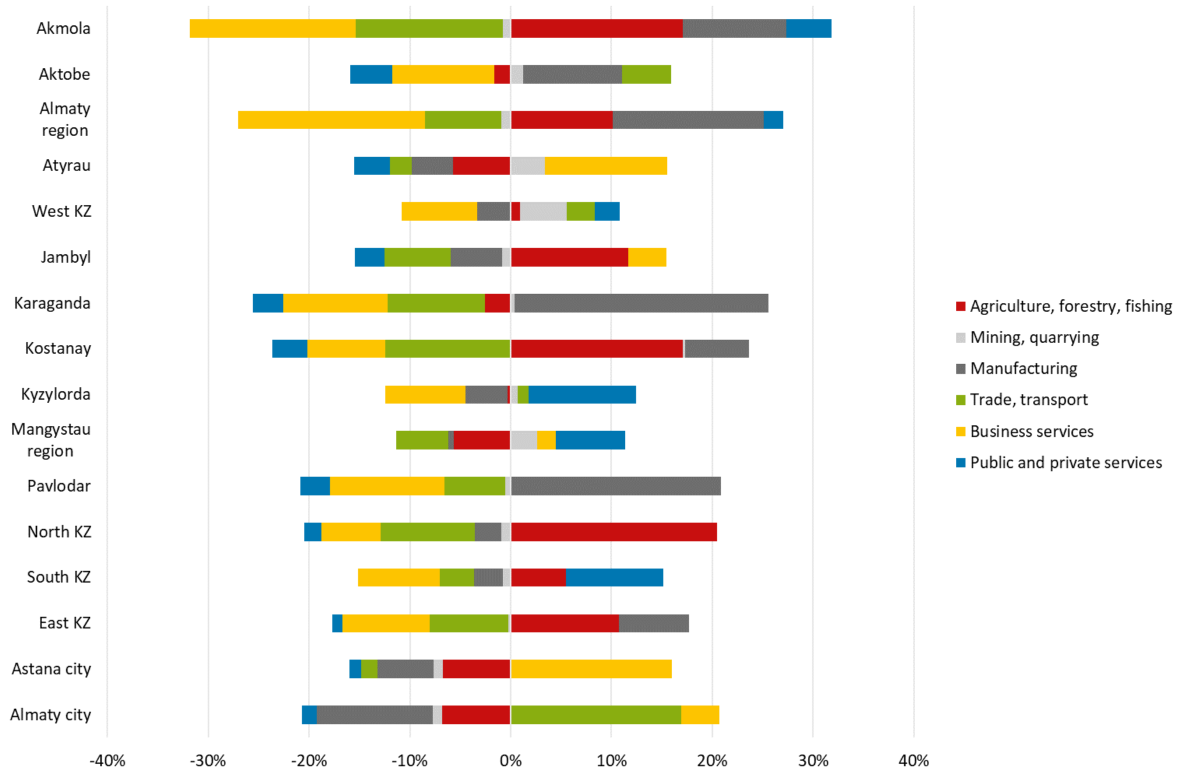



Figure 8: Regional importance of economic sectors measured in terms of value added compared to the national average in 2050 in %

Source: e3.kz results.

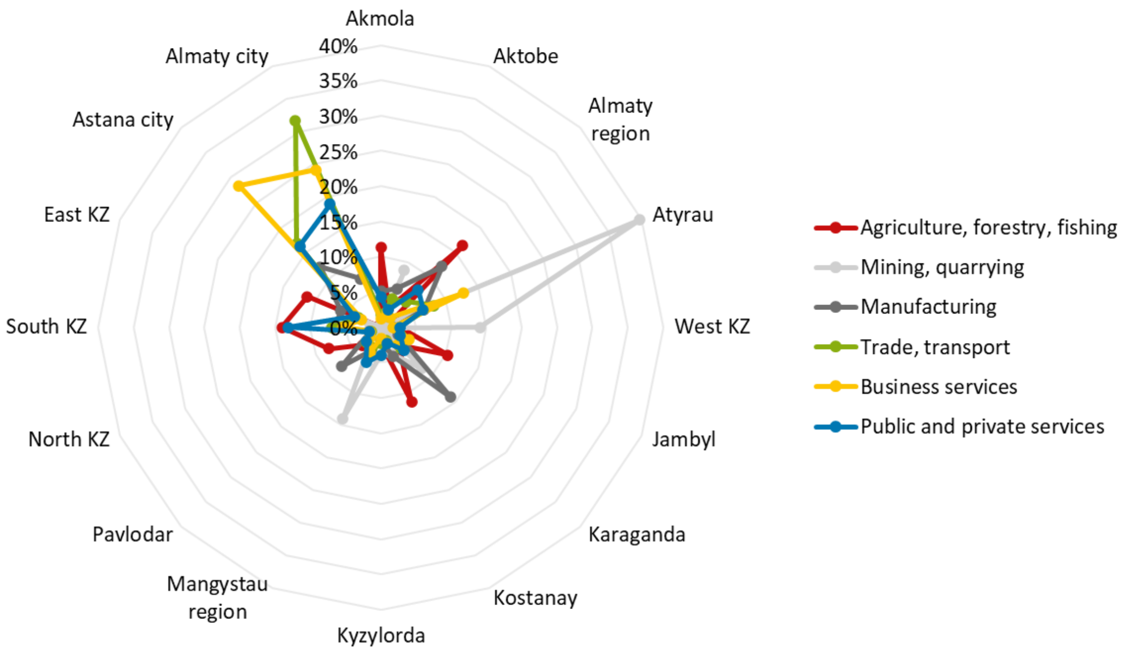



Figure 9: Value added share of regions by economic sectors in 2050 in %

Source: e3.kz results.

The contribution of the regions to the development of sectoral value added at national level shows Figure 9. The cities Astana and Almaty contribute the most to the development of the service sector (yellow, blue, and green line), while still Atyrau contributes the most to mining & quarrying (light grey line) and Karaganda to manufacturing (dark grey line). Regions with a specialization in mining & quarrying such as Atyrau but also West Kazakhstan and Mangystau regions are affected most by the decline in mining by 2050.

### Employment

Employment by economic sectors follows the economic activity and is expected to grow until 2050 except for mining & quarrying (Table 3). Overall, in 2050 employment in Kazakhstan accounts for ten million persons.

Table 3 shows the annual average growth rates of employment by economic sectors for Kazakhstan and its regions between 2020 and 2050. The regional employment by economic sector follows the growth at national level considering the observed relationship between the respective region and the national level (c.f. section 3.2).

For example, employment growth in mining & quarrying is declining in almost all regions. However, the strength of the decline differs for the regions which ranges between -0.1% and -2.6% per year. It should be noted that in regions where there are very few people employed in a sector, even a small deviation in absolute numbers can mean a large deviation in relative numbers. Pavlodar, for example, shows the highest growth rate for mining & quarrying but employs only 2% of all persons employed in the said sector.

Table 3: Regional employment by economic sectors, average annual growth rates, 2020-2050

| | Total | Agriculture, forestry & fishing | Mining & quarrying | Manufacturing | Trade & transport | Business services | Public & private services |
|---|---|---|---|---|---|---|---|
| **Kazakhstan** | 0.5% | 0.6% | -0.3% | 0.1% | 0.2% | 0.5% | 0.8% |
| Akmola | 0.2% | 0.5% | -1.5% | 0.1% | -0.1% | -1.9% | 0.5% |
| Aktobe | 0.3% | -1.8% | 0.8% | 1.0% | 0.2% | -0.1% | 0.3% |
| Almaty region | 0.8% | 0.6% | -1.5% | 0.9% | 0.6% | -0.3% | 1.1% |
| Atyrau | 0.8% | -1.5% | -0.2% | -0.1% | -0.3% | 2.1% | 1.2% |
| West KZ | 0.1% | -0.3% | -0.1% | -0.6% | 0.5% | -0.9% | 0.6% |
| Jambyl | 0.8% | 2.5% | -1.8% | -0.9% | -1.3% | 1.1% | 0.6% |
| Karaganda | -0.5% | -1.7% | 0.0% | -0.9% | -0.7% | -1.0% | 0.2% |
| Kostanay | -0.1% | 1.4% | -0.8% | -0.5% | -1.7% | -1.5% | -0.1% |
| Kyzylorda | 0.6% | -1.0% | 0.2% | 0.7% | -0.3% | 0.2% | 1.3% |
| Mangystau region | 1.3% | 0.4% | -0.1% | 1.0% | 0.7% | 0.9% | 2.4% |
| Pavlodar | -0.5% | -0.9% | -2.6% | -0.7% | -0.8% | -1.2% | 0.3% |
| North KZ | -0.6% | -1.1% | 0.1% | -0.6% | -0.8% | -0.9% | 0.0% |
| South KZ | 1.0% | 0.8% | -1.4% | 0.3% | 0.7% | 1.8% | 1.4% |
| East KZ | -0.6% | -0.1% | -1.3% | -1.2% | -0.7% | -1.3% | -0.3% |
| Astana city | 1.7% | 2.3% | -0.5% | 1.2% | 1.9% | 2.2% | 1.4% |

| | Total | Agriculture, forestry & fishing | Mining & quarrying | Manufacturing | Trade & transport | Business services | Public & private services |
|---|---|---|---|---|---|---|---|
| Almaty City | 0.2% | -1.6% | -2.0% | 0.1% | 0.9% | -0.6% | 0.0% |

Source: Historical data until 2020 based on COMSTAT, e3.kz results (2021-2050)

In 2050, most persons are employed in trade & transport (2.2 mn. persons resp. 22% green line in Figure 10) and public & private services (3.5 mn. persons resp. 35%; blue line in Figure 10) which are the most relevant economic sectors for almost all regions. Manufacturing (dark grey line) is a key sector for Pavlodar (23%), Karaganda (22%) and Aktobe (22%) regions. Agriculture (red line) is important in terms of employment in particular for Jambyl (45%), Kostanay (40%), Akmola (31%), and North Kazakhstan (26%) regions but almost non-existent e.g., in Mangystau region and in the cities Astana and Almaty.

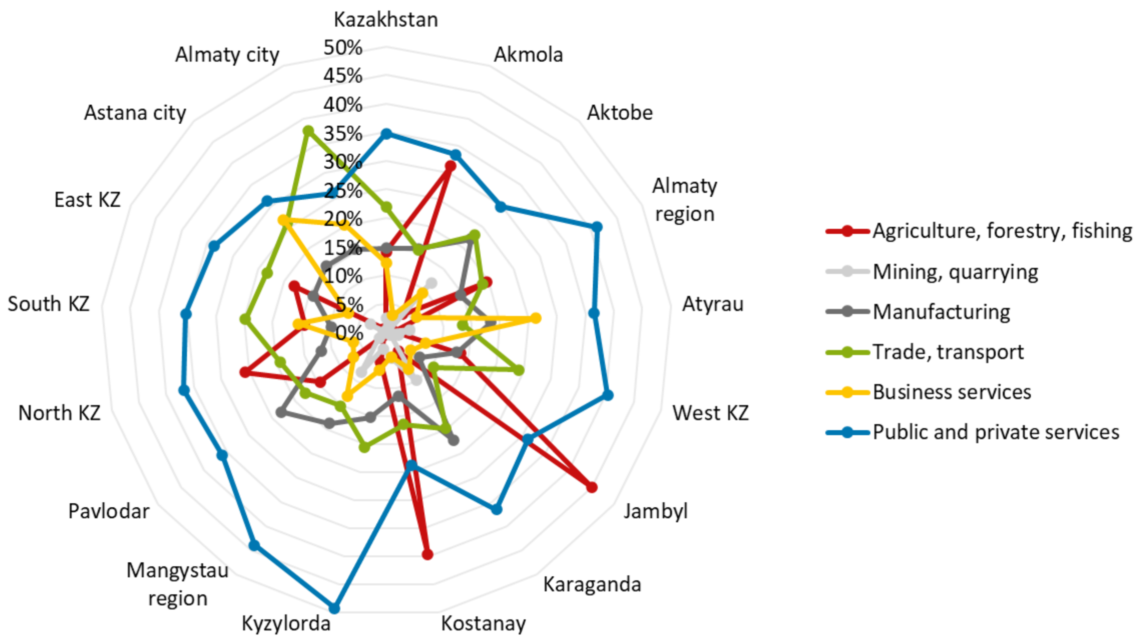



Figure 10: Employment share of economic sectors by region in 2050 in %

Source: e3.kz results.

A comparison of the economic structure at national level (measured by the employment share in the respective economic sector in total employment) with the economic structure in the regions reveals the importance of a region which is shown in Figure 11.

The greatest difference (+/-31%) from the national average shows Jambyl region, the smallest difference can be observed in East Kazakhstan (+/-6%) with respect to employment. In cities and densely populated areas, the primary sector is usually below national average which can be seen for example in the cities Astana and Almaty.

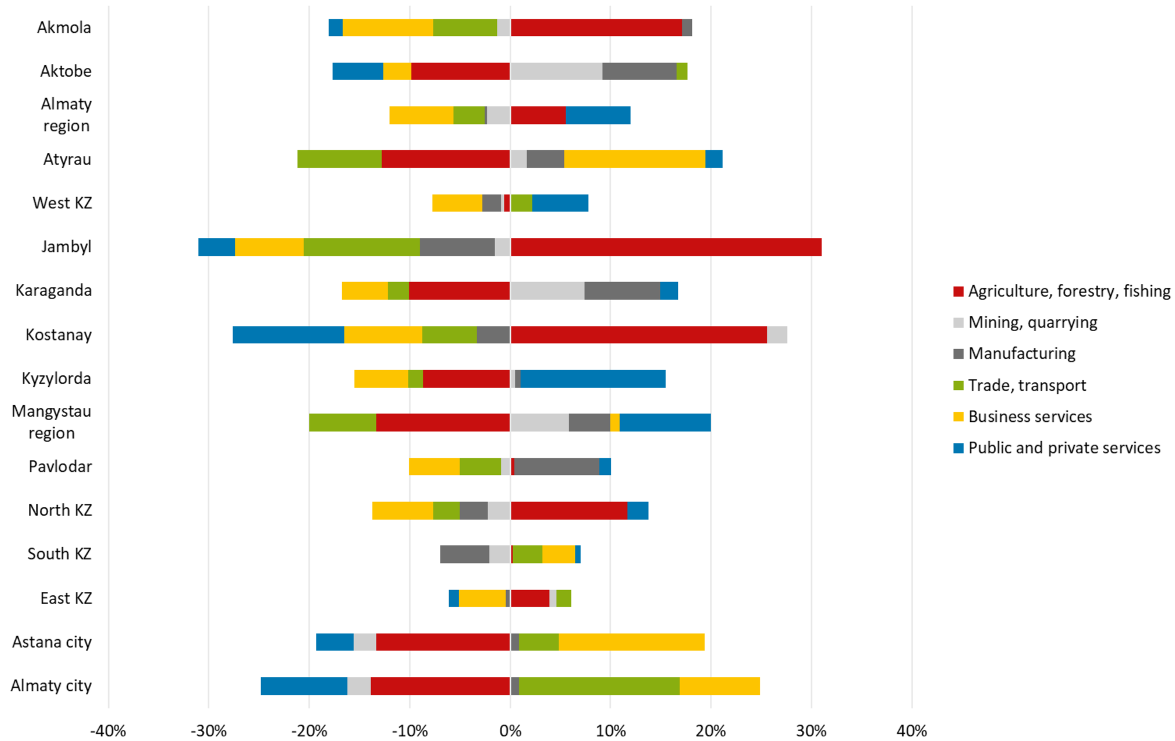



Figure 11: Regional importance of economic sectors measured in terms of employment compared to the national average in 2050 in %

Source: e3.kz results.

The contribution of the regions to the sector-specific employment at the national level differs: In total, South Kazakhstan, Almaty region, and Almaty city are the regions with the most employed persons of more than one million each. South Kazakhstan is one of the regions that is of relevance for all economic sectors apart from mining & quarrying (Figure 12). Additionally, Almaty city is of significance in terms of employment in all economic sectors excluding the primary sector (agriculture, mining).

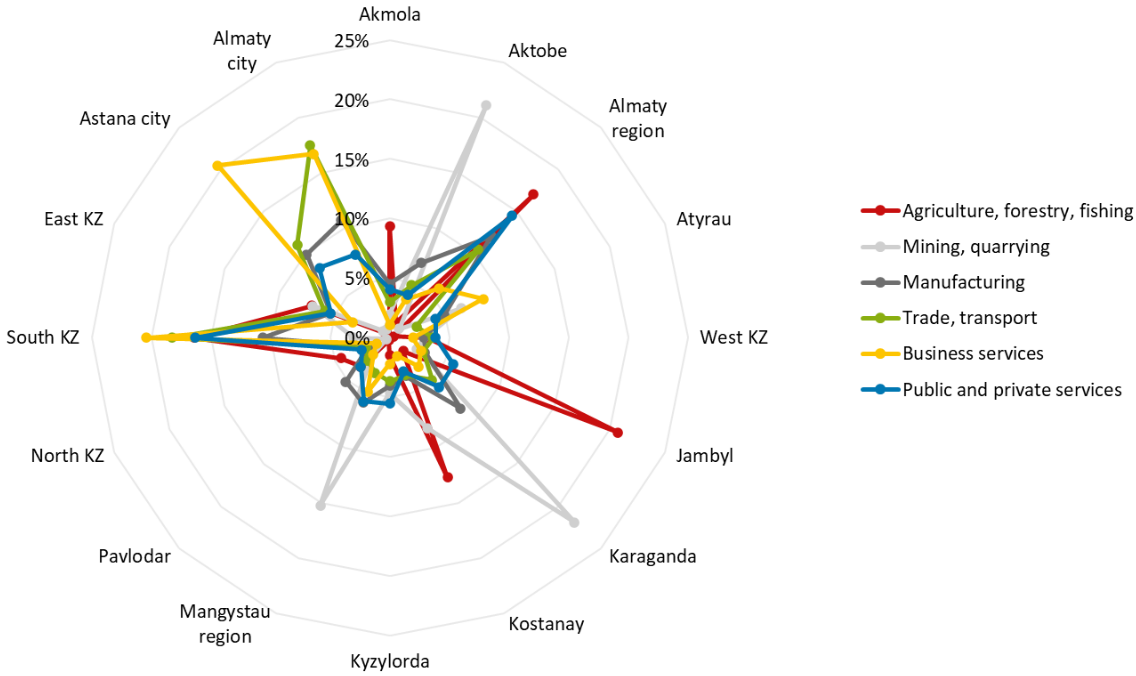



**Figure 12: Employment share of regions by economic sectors in 2050 in %**

Source: e3.kz results.

Trade & transport (green line in Figure 12) is more or less equally distributed over the regions with hot spots in South Kazakhstan (18%) and Almaty city (17%). Similar is true for public & private services (blue line in Figure 12) with South Kazakhstan (16%) and Almaty region (15%) contributing the most to overall employment in the said sector.

Jambyl (21%), Almaty region (17%), and South Kazakhstan (16%) contribute the most to the overall (national) employment in agriculture (red line in Figure 12). Employment in mining & quarrying is highest in Karaganda (22%), Aktobe (21%) and Mangystau regions (15%, light grey line).

# 5 ECONOMIC EFFECTS FROM CLIMATE CHANGE SCENARIOS AT SUBNATIONAL LEVEL

In the following sections, selected case studies already evaluated for the national economy are now analysed for the subnational regions in Kazakhstan. The results of various climate hazards are described regarding their subnational economic impacts for the year in which the hazard is assumed to occur. The description of results is intended as a supplement to the overall economic impacts for Kazakhstan, which are described in detail for the macroeconomy as well as the energy sector and emissions in GIZ (2022).

The direct, sectoral effects of climate hazards are particularly evident in subnational regions that have already been affected by these climate hazards in the past. Other intersectoral effects triggered by climate hazards, which are quantified in the national model, will vary across regions, determined by the prevailing economic structure.

For example, if agriculture is an important sector for a region, the overall economic development of the region is similar to that of the agricultural sector at the national level. The greater (smaller) the importance of an economic sector in a region, the stronger (weaker) the impact from national sectoral development.

## 5.1 DROUGHT

### 5.1.1 SCENARIO ASSUMPTIONS AND IMPLEMENTATION

The analysis from Navarro Soto and Jordà (2021) revealed that in particular North and Central Kazakhstan and Almaty region are affected by extreme droughts.

To analyse possible regional economic impacts of droughts in agriculture and the energy sector, the following assumptions have been made:

- Droughts are expected to occur every four years,
- Akmola, Kostanay, North Kazakhstan and Almaty region face drought impacts in agriculture,
- Karaganda and Pavlodar are affected by droughts in the energy sector,
- Expected damages in terms of wheat yield losses and decline in livestock production are taken from UNDP (2020) which sum up to 778 Bn. KZT by 2050,
- Expected damages for the energy sector are lower electricity generation potential for hydro power (-20%, IEA 1998) and thermoelectric power (-4%, van Vliet et al. 2016)

These possible impacts of a drought are implemented into the e3.kz model. Results for the national level (Kazakhstan) are described in GIZ (2022). In the following subsection economic results for the subnational level are presented.

### 5.1.2 SCENARIO RESULTS

Under a climate change scenario corresponding to RCP 8.5 scenario for Kazakhstan, real GDP is 2.4% resp. 2,031 Bn. KZT lower compared to a situation with no drought (Figure 13). The subnational regions facing the impacts of the droughts in agriculture and energy suffer the most. GRP for these regions is lower and ranges between -2.4% (Karaganda) and -6% (North Kazakhstan). But also other subnational regions show a decelerated economic growth due to indirect and induced effects stemming from intersectoral linkages and lower income levels due to job losses. These subnational regions have a GRP which is at max. -2.0% lower than in the REF scenario and lower compared to the national average.

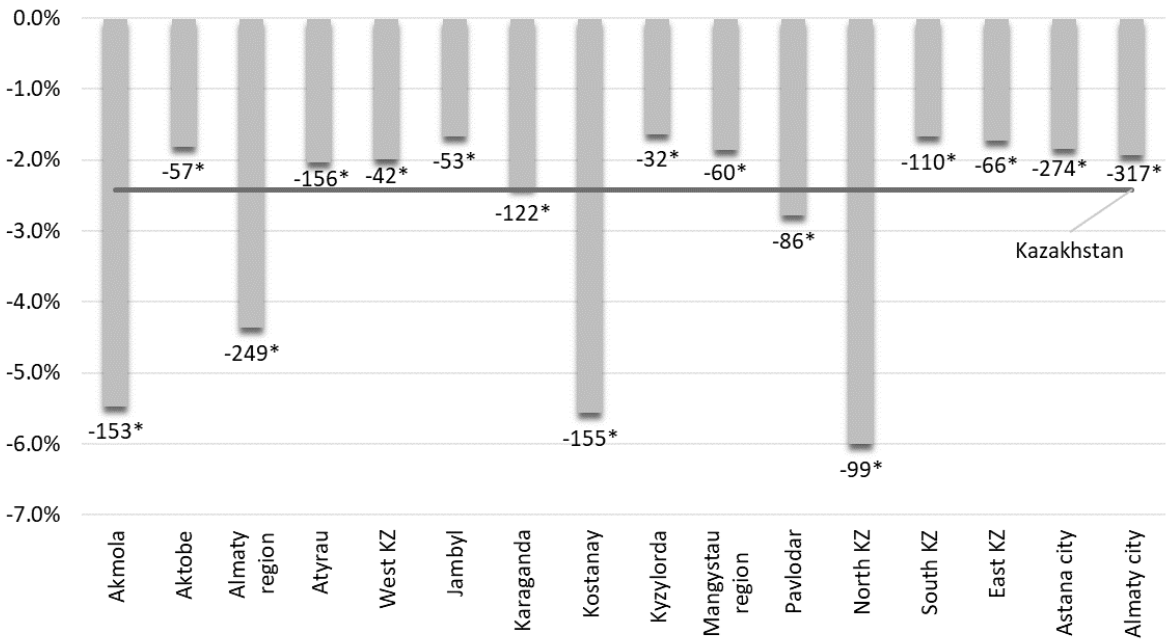



Figure 13: “Drought” scenario (RCP 8.5.): Real gross regional product, 2050, deviations from a hypothetical “no drought” (REF) scenario in percent

Source: Own illustration based on e3.kz results

Regional value added by economic sectors gives insights which subnational regions and sectors are affected most through value chain impacts and feedback effects. Apart from the directly affected sectors agriculture and energy, in particular trade and transport, business services as well as manufacturing sectors (e.g., chemical industry and food production) are impacted. Those subnational regions with a specialization on these sectors show a stronger decline compared to other regions (Figure 14).

For example, trade & transport as well as business services are important sectors for the cities Astana and Almaty which show in absolute terms (trade & transport: 59 Bn. KZT resp. 110 Bn. KTZ blue bar in Figure 14; business services: 92 Bn. KZT resp. 87 Bn. KTZ brown bar in Figure 14) a relatively strong impact on the regional value added compared to the hypothetical “no drought” scenario. Manufacturing (dark grey bar in Figure 14) is relevant for almost all subnational regions and thus the impact can be seen with different magnitudes in all regions.

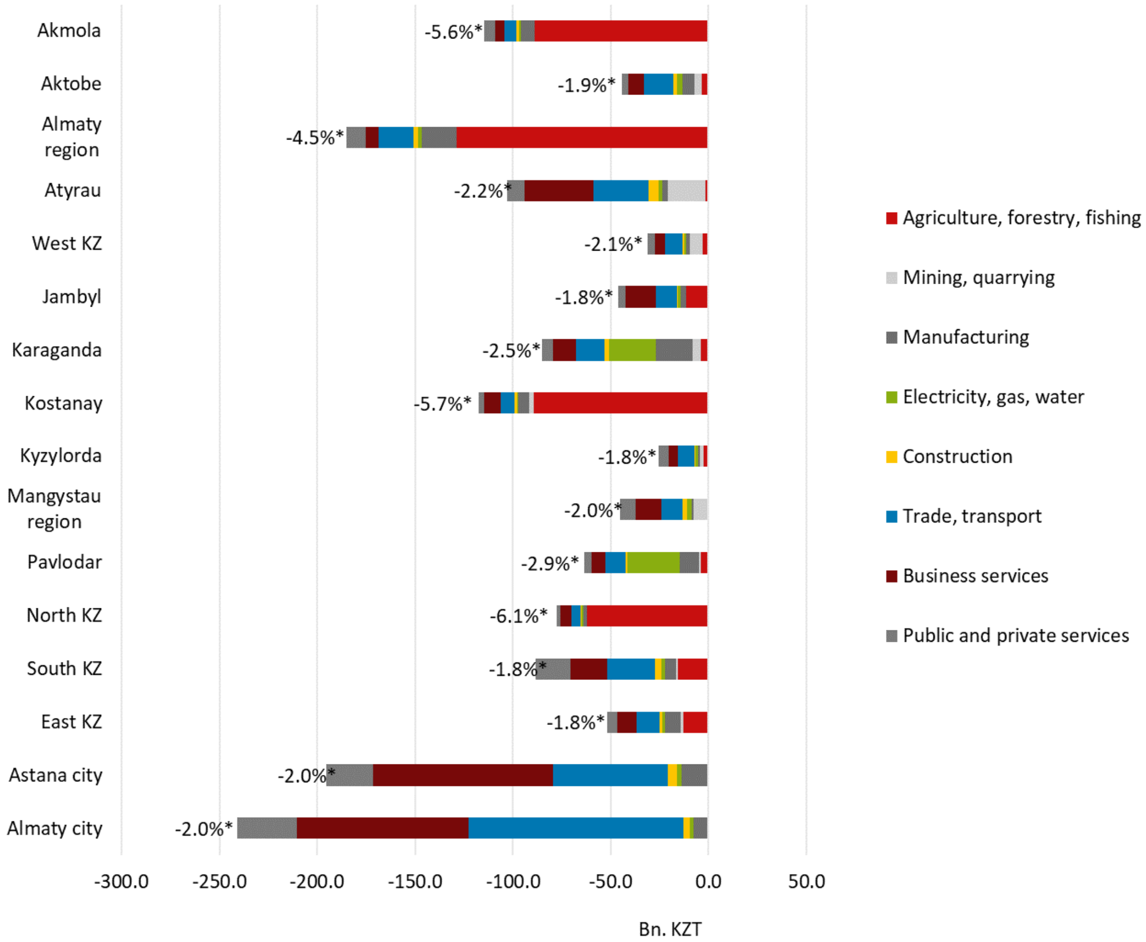



Figure 14: “Drought” scenario (RCP 8.5.): Regional value added by economic sectors in real values, 2050, deviations from a hypothetical “no drought” (REF) scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The regional employment impacts are in line with the effects seen for value added taking also into account the different sectoral labour intensities which are highest in agriculture and service sectors. In total, employment is -1.4% resp. -141 thousand persons lower compared to a “no drought” scenario. Akmola, Almaty region, Kostanay and North Kazakhstan show the greatest impacts on employment in relative and absolute deviations from the REF scenario which range between -3.3% (Almaty region) and -6.1% (Kostanay region) resp. -40 thousand employed persons (Almaty region) and -10 thousand (North Kazakhstan) mainly caused by changes in employment in agriculture (Figure 15).

Karaganda and Pavlodar regions are directly impacted from the droughts in the energy sector. However, labour intensity in the said sector is low and thus employment effects are also small. Subnational regions with a greater service sector could have significant employment effects as for example, Almaty city (-7.3 thousand persons resp. -0.7%), Astana city (-6.2 thousand persons resp. -0.7%), and South Kazakhstan (-7.4 thousand persons resp. -0.5%).

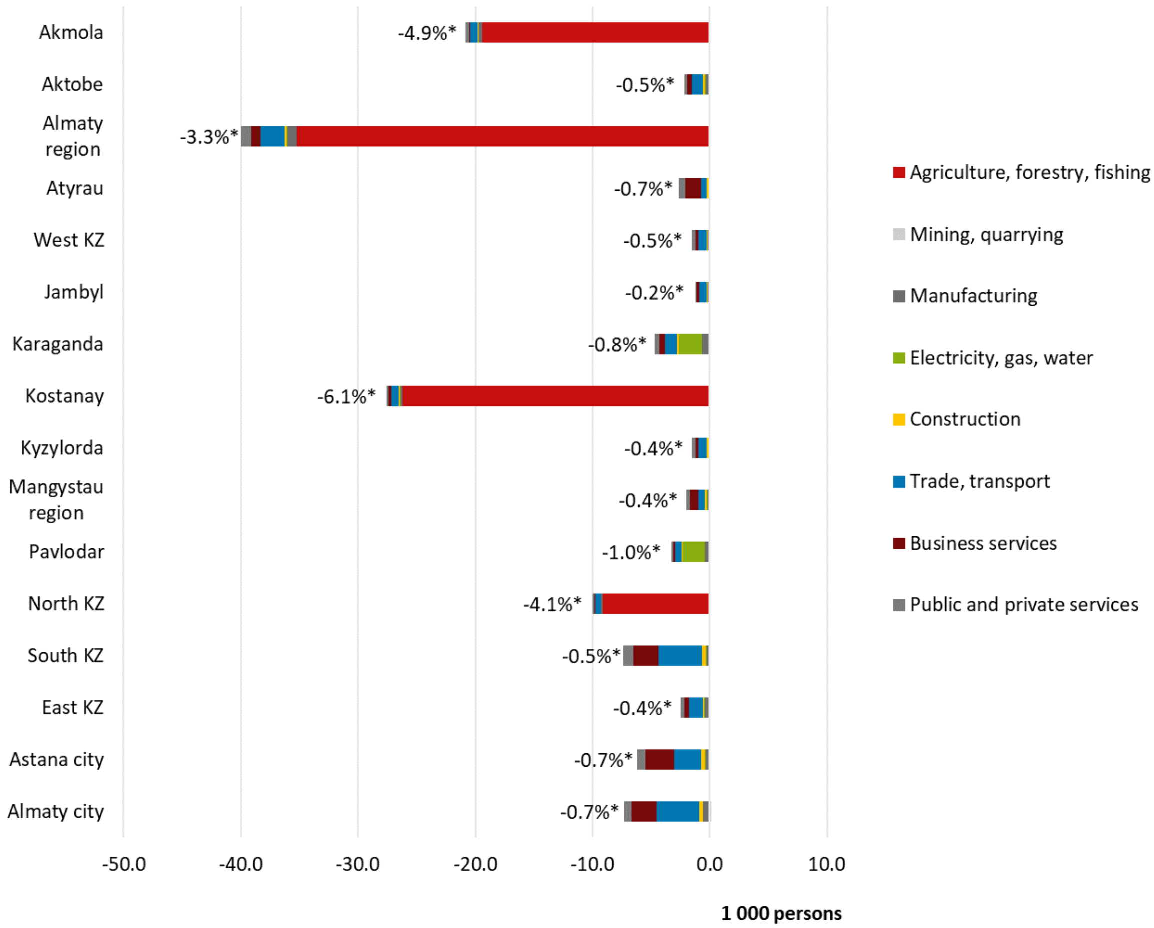



Figure 15: "Drought" scenario (RCP 8.5.): Employment by economic sectors and subnational regions, 2050, deviations from a hypothetical "no drought" (REF) scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

## 5.2 HEAT WAVE

### 5.2.1 SCENARIO ASSUMPTIONS AND IMPLEMENTATION

In line with the heat wave scenario calculated for the national economy (GIZ 2022), it is assumed that agriculture, energy, health and beverage sectors are affected. In contrast to floods, for example, which tend to be more localized, heat waves tend to occur over a larger area. Additionally, Navarro Soto and Jordà (2021) project heat waves in many regions with an increased frequency.

To analyse the regional economic impacts of heat waves in the several sectors affected, the following assumptions have been made:

- Heat waves are expected to occur every five years,
- Akmola, Kostanay, North Kazakhstan and Almaty region face heat wave impacts in agriculture (output losses due to less productive workers and water scarcity),
- Expected damages in terms of wheat yield losses and decline in livestock production are taken from UNDP (2020) which sum up to 778 Bn. KZT by 2050,

- Karaganda and Pavlodar are affected by heat waves in the energy sector,
- Expected damages for the energy sector are lower electricity generation potential for hydro power (-20%, IEA 1998) and thermoelectric power (-4%, van Vliet et al. 2016)
- All subnational regions facing the heat wave impacts in the health and manufacturing sectors. The increased expenditures for health care services of +0.3% and beverages of +3% at national level (see GIZ 2022, p.66) are allocated to the subnational level regarding their sectoral economic structure (c.f. section 3.2).
- The same is true for the allocation of production losses due to less productive workers in construction accounting for a loss of 0.05% of working hours.

### 5.2.2 SCENARIO RESULTS

The impact on the real GDP for Kazakhstan (1.4% resp. 1,074 Bn. KZT) and all subnational regions is lower compared to a "No heat wave" scenario (Figure 16). Regions such as Akmola, Almaty region, Kostanay and North Kazakhstan which rely more on agriculture than the national average, show a stronger deceleration in economic growth than Kazakhstan as a whole. In these regions GRP ranges between -2.5% (Almaty region) and -4.3% (North Kazakhstan) compared to a situation without a heat wave.

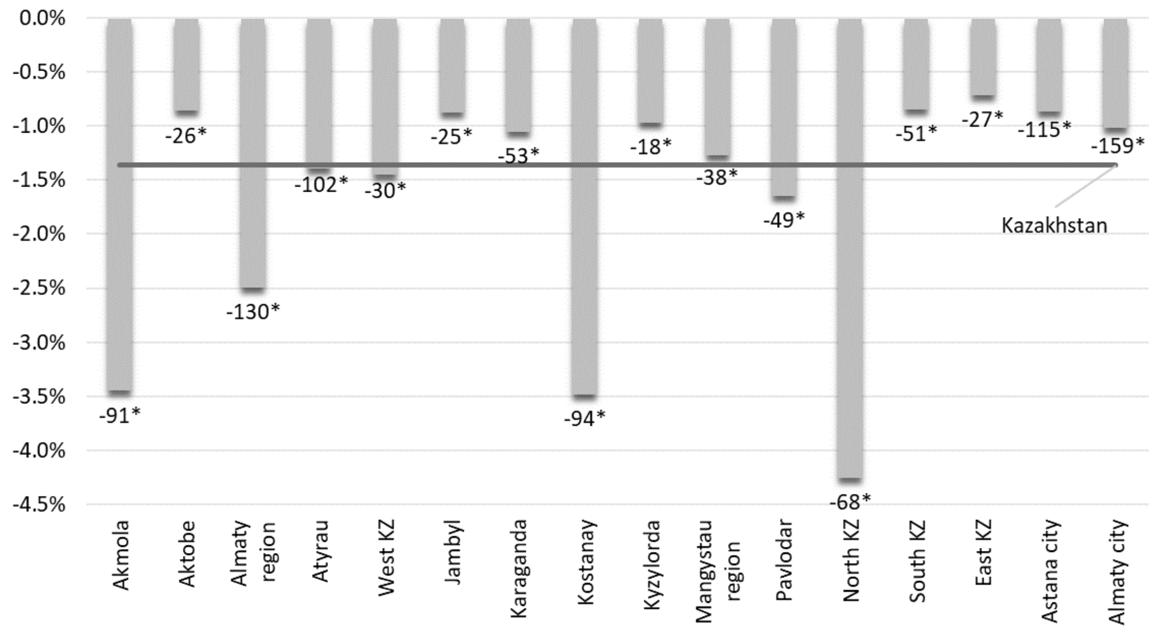



Figure 16: "Heat wave" scenario (RCP 8.5.): Real gross regional product, 2042, deviations from a hypothetical "No heat wave" (REF) scenario in percent

Source: Own illustration based on e3.kz results

Figure 17 shows the deviations in real value added by economic sectors and subnational regions. Impacts range between -4.3% (North Kazakhstan) and -0.8% (East Kazakhstan) compared to a "No heat wave" scenario depending on the economic structure in the regions.

Agriculture, energy, and mining & quarrying are negatively impacted by heat waves. Additionally, mining & quarrying is indirectly negatively impacted from heat waves. Thermoelectric power potential is reduced due to insufficient cooling and thus, energy plants need less fossil fuel inputs. Atyrau, Mangystau, Karaganda and

West Kazakhstan regions are mainly affected from less fuel demand. Additionally, heat stress limits output in construction and agriculture due to less productive workers.

Positive effects can be seen in the regions where manufacturing is a key sector such as in Karaganda, Almaty region, and Pavlodar. Higher beverage consumption causes an increase in production in this manufacturing sector.

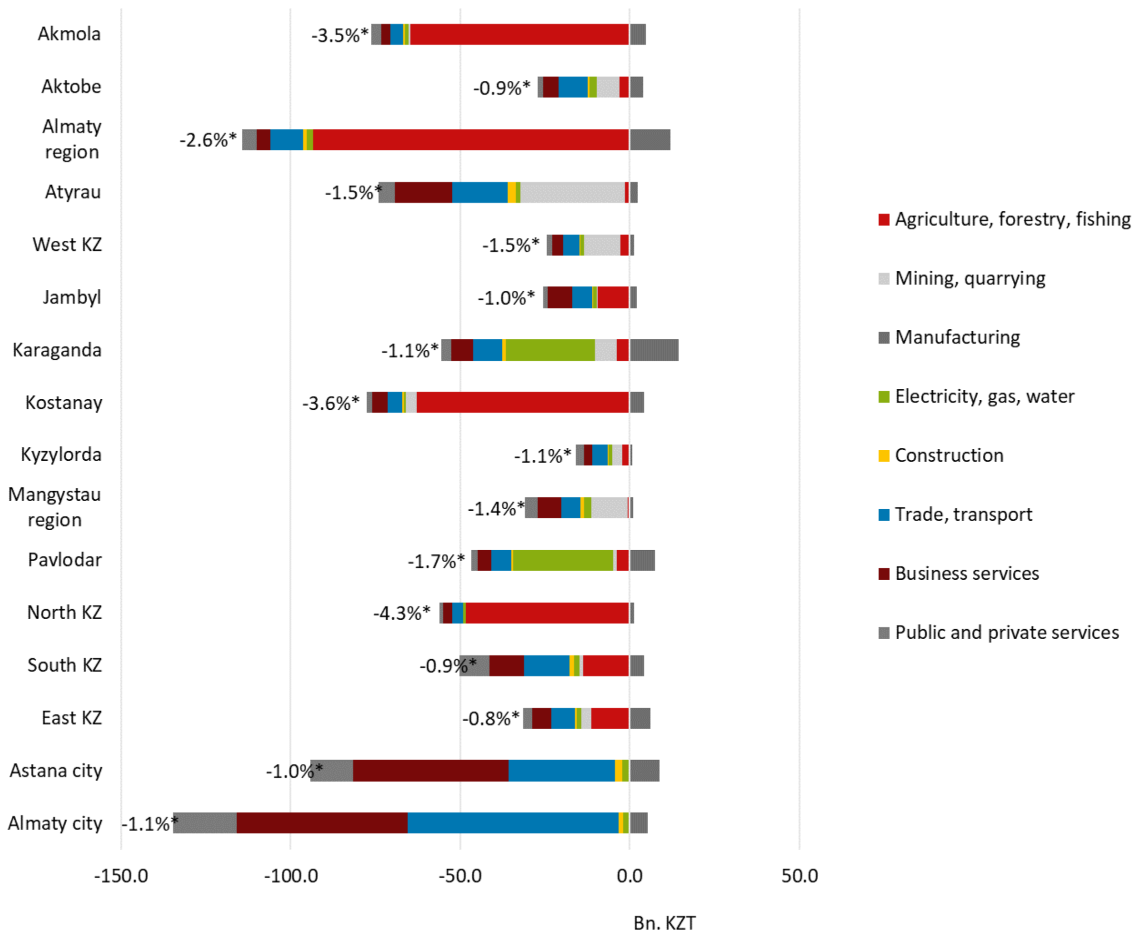



Figure 17: “Heat wave” scenario (RCP 8.5.): Regional value added in real values by economic sectors, 2042, deviations from a hypothetical “no heat wave” (REF) scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

For Kazakhstan, total employment is 92.8 thousand persons resp. 1% lower in 2042 compared to a situation without heat waves. The impact on regional employment shows Figure 18. Employment in agriculture and energy is affected the most and thus Akmola, Almaty region, Kostanay and North Kazakhstan suffer in particular. The employment effects range between -0.1% and -4.5%. To a limited extent, there is a higher employment level in the manufacturing sector.

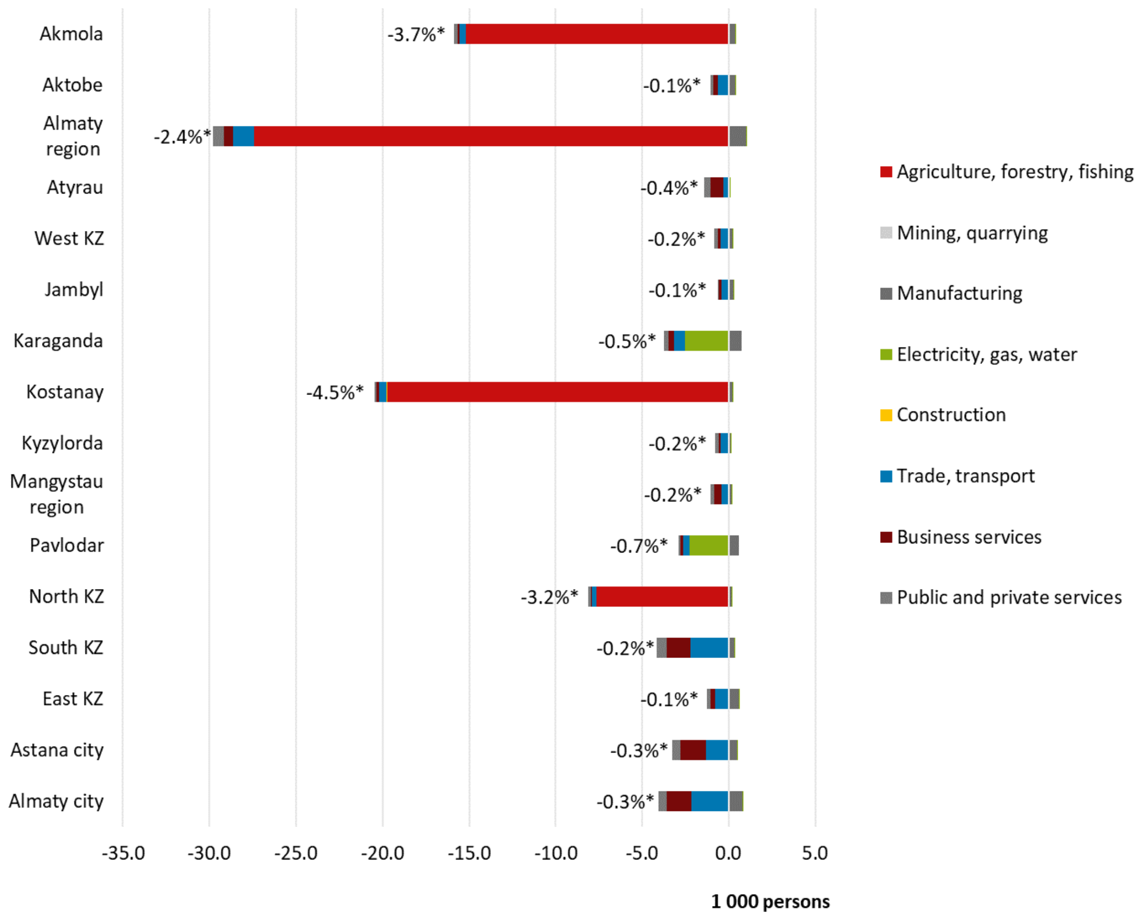



Figure 18: "Heat wave" scenario (RCP 8.5.): Employment by economic sectors and subnational regions, 2042, deviations from a hypothetical "no heat wave" (REF) scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

## 5.3 EXTREME PRECIPITATION

### 5.3.1 SCENARIO ASSUMPTIONS AND IMPLEMENTATION

The following scenario is characterized by an increased intensity of extreme precipitation events and floods in particular in the south-eastern regions of Kazakhstan (Navarro Soto and Jordà 2021). According to the assumptions set in the extreme precipitation scenario for the national economy, the same settings are applied in this scenario (see GIZ 2022, section 5.1.3):

- Extreme precipitation events occur every five years affecting South Kazakhstan, East Kazakhstan, Almaty region and Jambyl.
- Damages to building, energy, and road infrastructure are likely to occur causing accelerated demand for construction services and manufactured products such as electrical equipment and concrete.
- Production losses are expected in manufacturing, mining, and service sectors due to power failures.

### 5.3.2 SCENARIO RESULTS

Extreme precipitation events result in a decelerated economic growth for the national economy. In 2047, for Kazakhstan real GDP is 0.9% resp. 777 Bn. KZT lower compared to a situation without such an event. At subnational level, real GRP is even lower in relative deviations for Almaty region (-2.3%), Jambyl (-1.5%), South (-1.7%) and East Kazakhstan (-2%, Figure 19). Regions that are not directly affected from the climate hazard show smaller negative impacts which ranges between -0.4% (Mangystau region) and -0.8% (Almaty City).

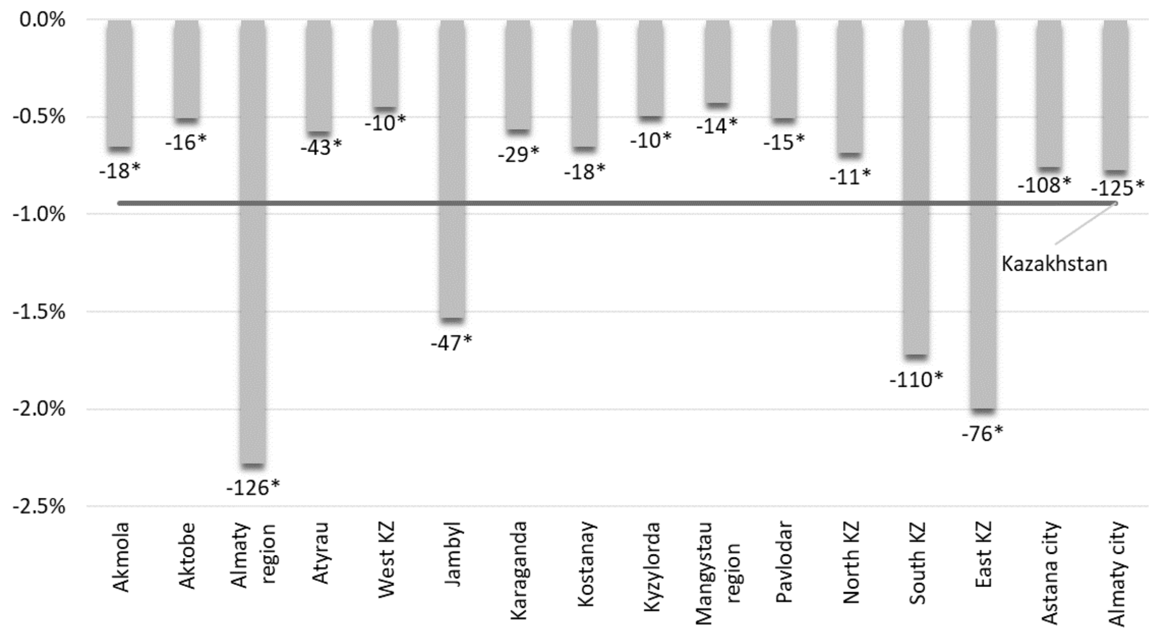



Figure 19: "Extreme precipitation" scenario (RCP 8.5.): Real gross regional product, 2047, deviations from a hypothetical "no extreme precipitation" (REF) scenario in percent

Source: Own illustration based on e3.kz results

In particular the manufacturing, trade & transport and service sectors suffer from production losses caused by damaged infrastructure and power outages. Due to the multiple sectoral impacts, many regions are affected. The impacts on real regional value added ranges from -2.3% (Almaty region) to -0.4% (Mangystau region, Figure 20). Although the cities Almaty and Astana are not directly impacted from the extreme precipitation events, the impacts in absolute deviations of real value added are significant. This is mainly due to the negative value added effects in the trade & transport and service sectors cause by power outages and thus, closed retail stores and restaurants.

Although the repair activities of destroyed buildings and roads have positive impacts on construction activities and supplying sectors such as the non-metallic mineral producers (e.g., concrete), these impacts are offset by the overall negative economic impacts.

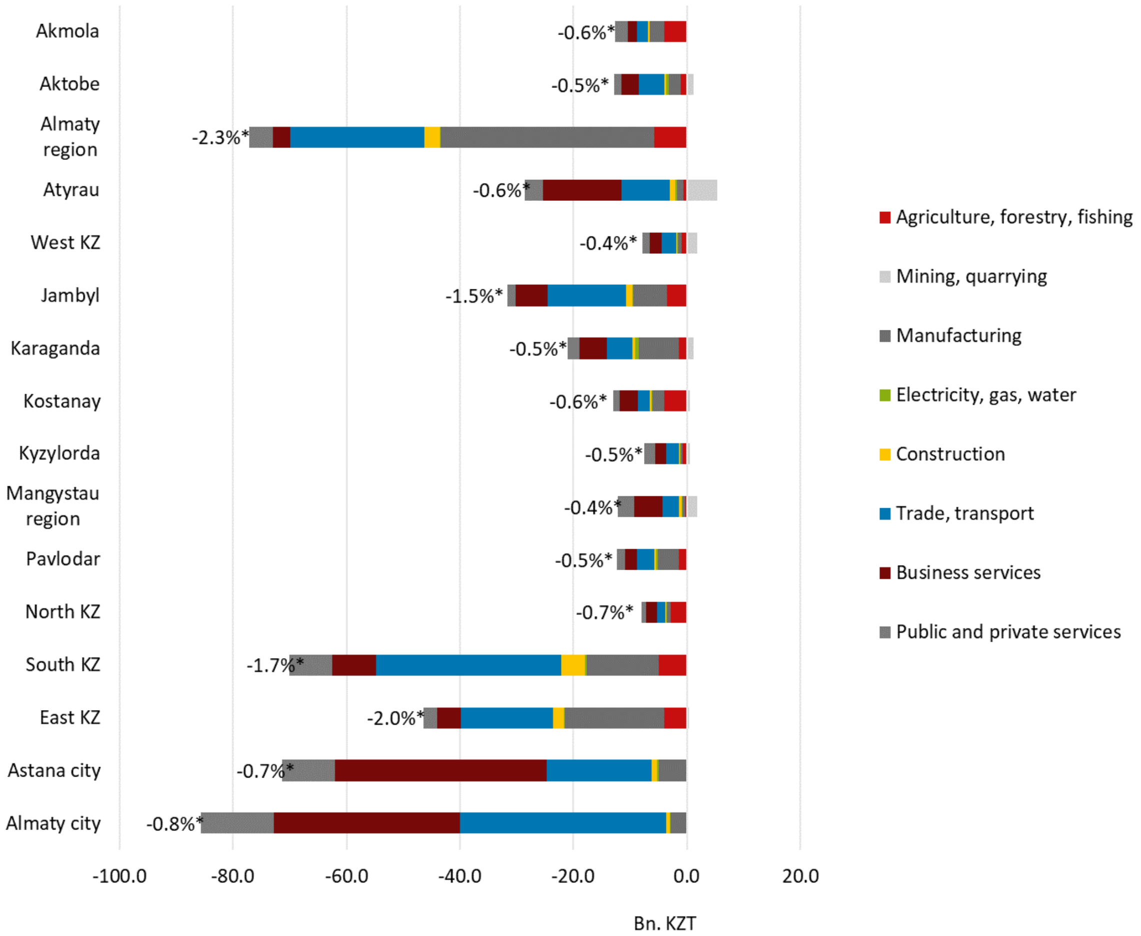



Figure 20: "Extreme precipitation" scenario (RCP 8.5.): Regional value added in real values by economic sectors, 2047, deviations from a hypothetical "No extreme precipitation" (REF) scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The total number of employed persons is -0.25% resp. 25 thousand persons lower compared to a "No extreme precipitation" scenario. Employed persons in manufacturing, trade & transport, and agriculture are affected the most. The largest impacts at subnational level show South Kazakhstan (-0.5% resp. -7.9 thousand persons), East Kazakhstan (-0.7% resp. -3.9 thousand persons), Almaty region (-0.5% resp. -6.6 thousand persons) and Jambyl (-0.4% resp. -2.5 thousand persons, Figure 21). These regions are mainly affected by this EWE not only regarding the economic impacts such as income losses in particular in the service sectors and trade & transport. Due to the comparatively high population in the regions, the likelihood of persons being affected, injured, or dying in such an EWE is probably higher than in other, less populated areas. However, economic models cannot predict the impact on people.

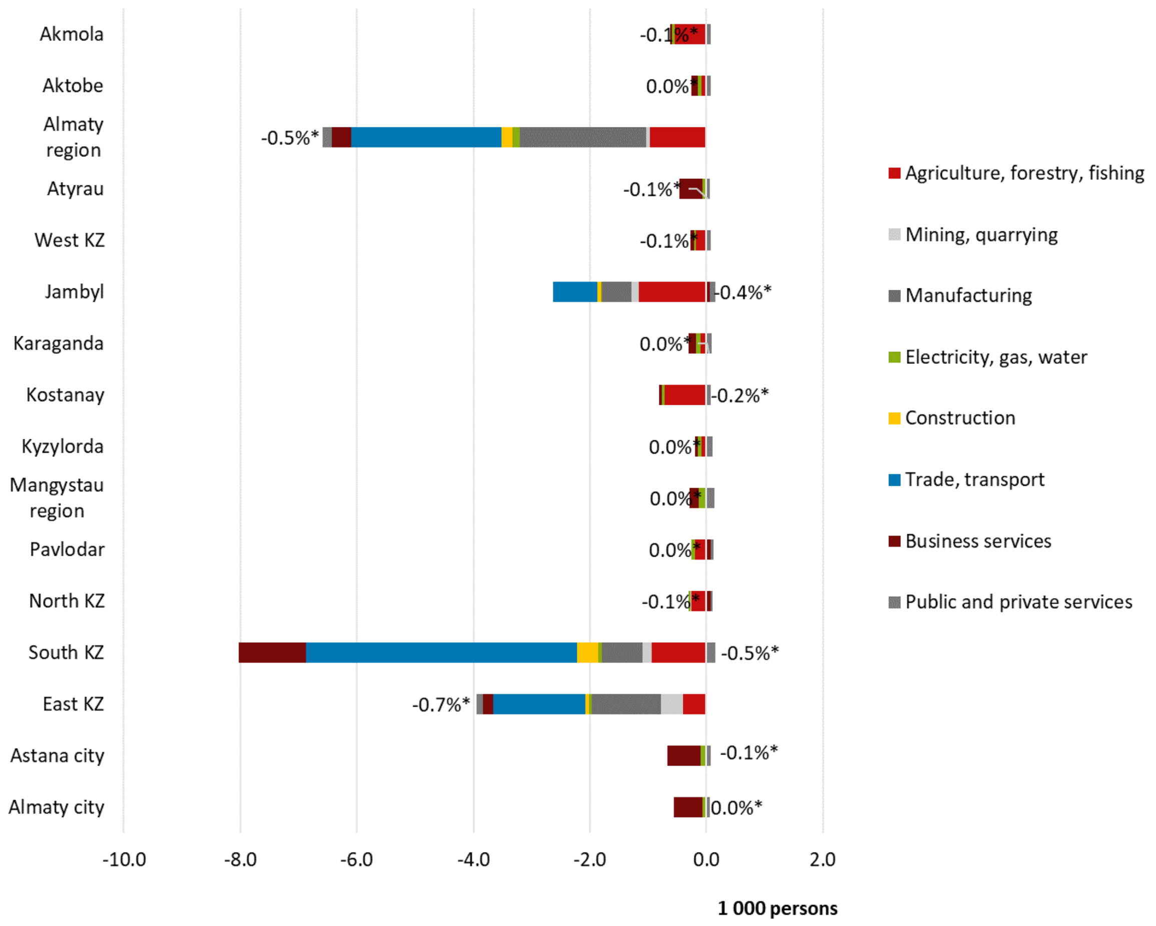



Figure 21: “Extreme precipitation” scenario (RCP 8.5.): Employment by economic sectors and subnational regions, 2047, deviations from a hypothetical “No extreme precipitation” (REF) scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

# 6 ECONOMIC EFFECTS FROM CLIMATE CHANGE ADAPTATION SCENARIOS AT SUBNATIONAL LEVEL

The previous analysis has shown that, depending on the EWE, some regions are particularly affected due to their economic structure. It is particularly important for these regions to adapt to climate change.

In the following sections, the results of selected adaptation measures in agriculture, energy and infrastructure sectors with the larger macroeconomic impacts are illustrated regarding their subnational economic impacts and are intended as a complement to the macroeconomic impacts for Kazakhstan. These effects are described in detail for the macroeconomy as well as for the energy sector and emissions in GIZ (2022) with the exception of two adaptation measures in agriculture presented in section 6.1.2 and 6.1.3.

## 6.1 ADAPTATION IN AGRICULTURE

### 6.1.1 INVESTING IN IRRIGATION SYSTEMS

#### 6.1.1.1 Scenario assumptions and implementation

The expansion, modernization and rehabilitation of irrigation systems are one option to prevent drought impacts in agriculture. In line with the irrigation scenario calculated for the national economy, the following scenario settings are taken to analyse the economic impacts at subnational level (see GIZ 2022, section 6.2.1.1):

- Investments in reconstruction of canals and reservoirs amount to 2,894 Bn. KZT (2022-2050),
- Investments in drip irrigation result in cumulated investment of 105 Bn. KZT (2022-2050),
- Agricultural output is expected to increase by 537 Bn. KZT resp. 47 Bn. KZT per year,
- Regions suffering from droughts take adaptation measures to prevent the negative effects of droughts.
- It is expected that the respective regions have sufficient capacities to repair and expand the water canals and reservoirs.

#### 6.1.1.2 Scenario results

The macroeconomic effects for Kazakhstan are positive. In 2030, real GDP is 1.2% resp. 830 Bn. KZ higher compared to a situation without adaptation and droughts. Akmola, Almaty region, Kostanay and North Kazakhstan benefit the most in terms of real GRP which increases by 2.5% (Almaty region) and 3.6% (North Kazakhstan) in 2030 (Figure 22). The other subnational regions have a higher real GRP which ranges between 0.9% and 1.0%.

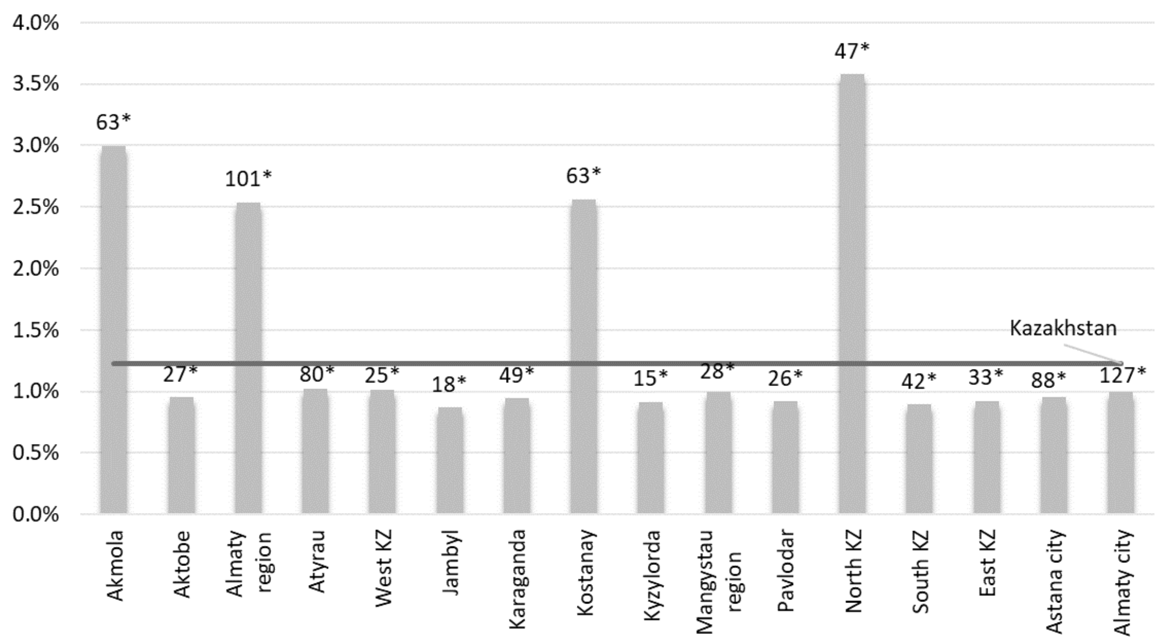



Figure 22: Effects of the "irrigation" scenario on real gross regional product, 2030, deviations from the "drought" scenario in percent

Source: Own illustration based on e3.kz results

The four regions that construct and install the irrigation systems show in particular positive percentage deviations stemming from direct impacts in agriculture (red bar) and construction (yellow bar, Figure 23). Also, other economic sectors are positively affected such as manufacturing as well as trade & transport also benefits due to further indirect and induced effects.

For the construction of the water canals e.g., concrete is needed which calls for additional production in manufacturing of non-metallic mineral products. As most of the drip irrigation systems must be imported, the impact for drip irrigation manufacturers is small.

Other sectors along the value chain are indirectly positively affected such as manufacturers of food and chemicals, mining and quarrying as well as several service sectors and trade. The main beneficiaries of the various impacts are the subnational regions for which this (these) sector(s) is (are) of key importance.

The cities Almaty and Astana benefit in particular from the increased demand in services and trade & transport. For example, Atyrau and Karaganda regions are specialized in mining & quarrying and manufacturing, which means that national developments in these economic sectors have a greater impact on these regions.

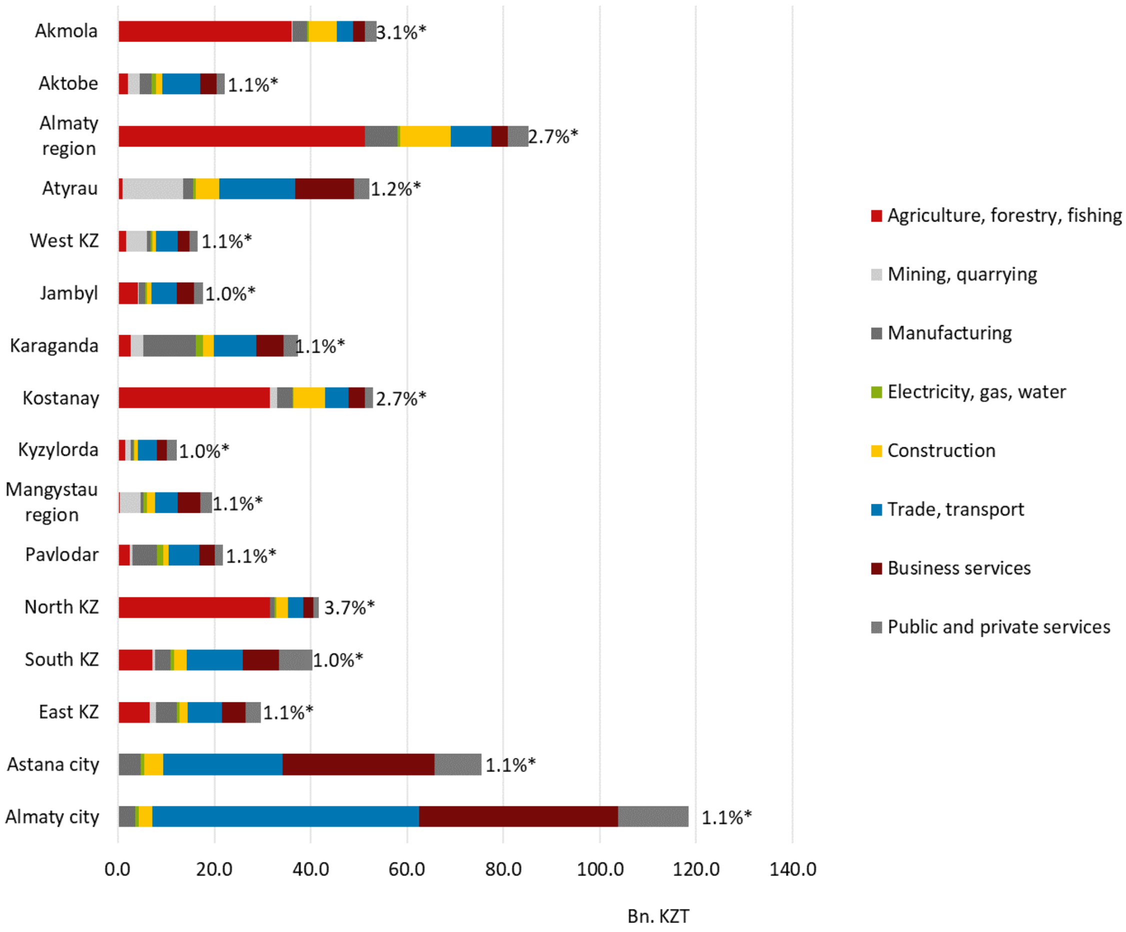



Figure 23: Effects of the "irrigation" scenario on regional value added in real values by economic sectors, 2030, deviations from the "drought" scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The effect on employment depicts Figure 24. Agriculture and construction are directly affected from the adaptation measure and Akmola (12 thousand persons resp. 3%), Almaty region (23.4 thousand persons resp. 2.2%), Kostanay (13.8 thousand persons resp. 3.1%) and North Kazakhstan (7 thousand persons resp. 2.7%) benefit the most from these additional jobs. While jobs in agriculture can be preserved, new jobs in construction can be created during the construction phase as well as afterwards during maintenance. In total, 78 thousand additional jobs are created by 2030 of which 46 thousand in agriculture, 4.7 thousand in construction, 11 thousand in trade & transport sector and 12.5 thousand in service sector. Sectoral economic activity and labour intensity are important factors influencing job creation.

Regions not directly affected by the adaptation measure also show positive employment effects. These range between 0.2% (0.9 thousand in Jambyl) and 0.4% (4 thousand in Almaty city) above regional employment level without adaptation and drought and can be seen in especially in service sectors.

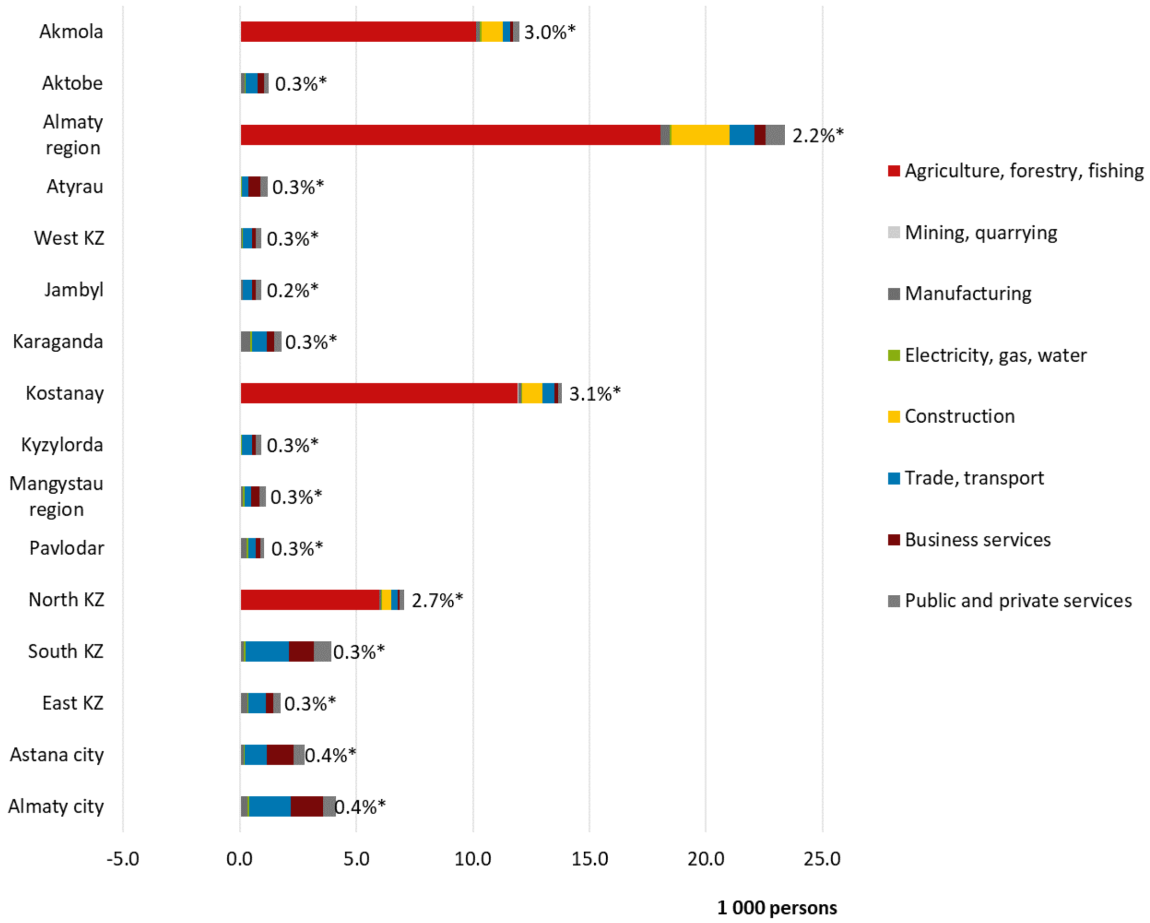



Figure 24: Effects of the "irrigation" scenario employment by economic sectors and subnational regions, 2030, deviations from the "drought" scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

## 6.1.2 INVESTING IN NO-TILL FARMING

### 6.1.2.1 Scenario assumptions and implementation

Another option to prevent from the impacts of climate change impacts is no-till farming which is a moisture saving agriculture technology. Investment in modified and direct seeders are necessary to conserve agricultural land. According to EBRD et al. (2018) 263 mn. USD must be invested. Currently 36% of the estimated potential of approximately seven million hectares are adopted. It is expected that after 15 years the full potential is reached. Afterwards replacement investment will take place. In total, investments cumulate to 213 bn. KZT (2022-2050). Most of the machinery must be imported. The investments are assumed to be financially supported by the government which leads to expenditure cuts in other areas of public spending.

Adaptation benefits in terms of higher agricultural output are estimated with 250 mn. USD per year. The regions suffering from droughts take the adaptation measure to prevent from the negative effects of droughts.

#### 6.1.2.2 Scenario results

The economy-wide impacts of the investments in no-till farming are positive. The investments increase GDP which is up to 0.16% higher compared to a situation without adaptation and droughts (Figure 25). Furthermore, due to increased agricultural output, agricultural exports (+0.1% in 2037) can be increased while agricultural imports can be avoided.

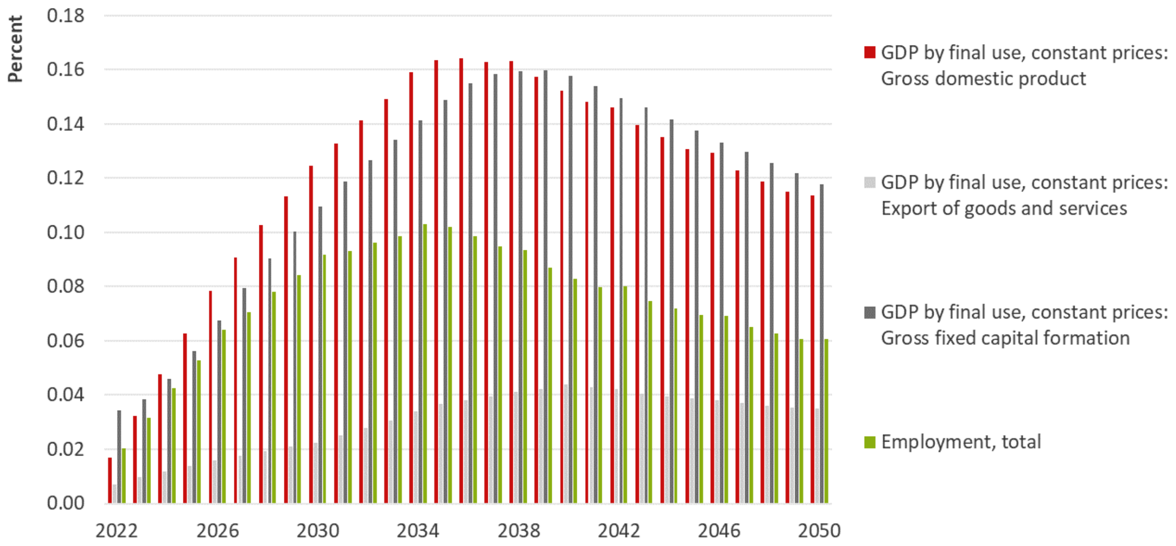



Figure 25: “No-till farming” scenario: Key impacts, 2022-2050, deviations from the “drought” scenario in percent

Source: Own illustration based on e3.kz results

Compared to the “irrigation” scenario, the macroeconomic impacts are lower (c.f. section 6.1.1). On the one hand, the investment stimulus and the expected increase in agricultural output are smaller. On the other hand, agricultural machinery must be partly imported, and domestic production is limited. Indirect and induced effects are positive, but less compared to the "irrigation" scenario.

In 2037, the impacts on GRP are highest for Akmola (+0.34%), Almaty region (0.28%), Kostanay (0.32%) and North Kazakhstan (0.39%) and above real GDP which is 0.16% (Figure 26).

The economic sectors benefitting the most shows Figure 27. In 2037, agricultural output increases by +0.7%, followed by manufacturing of machinery and equipment (+0.2%). Also, the positive indirect and induced effects, for e.g., manufacturing of chemical products, food production and several services, are visible.

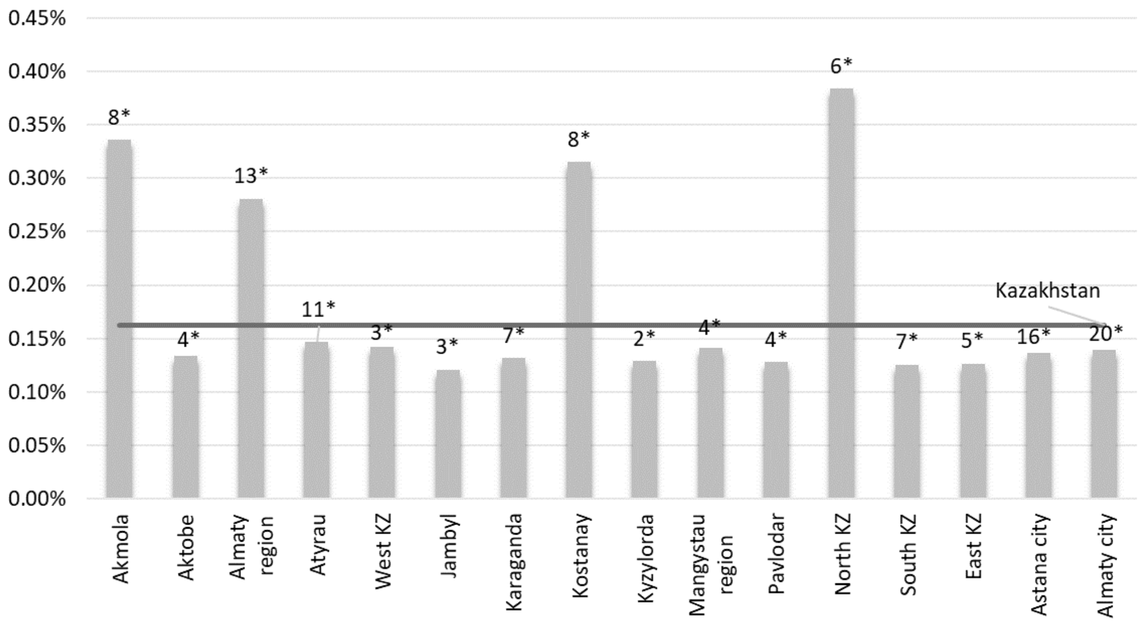



Figure 26: Effects of the "no-till farming" scenario on real gross regional product, 2037, deviations from the "drought" scenario in percent

Source: Own illustration based on e3.kz results

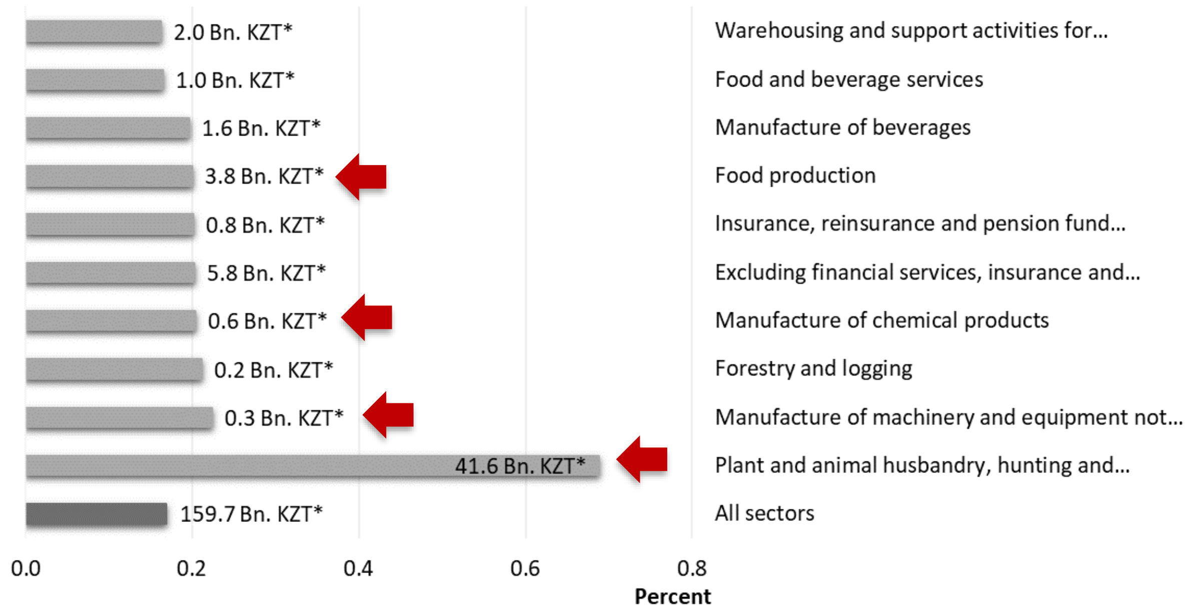



Figure 27: Effects of the "no-till farming" scenario on real production, 2037, deviations from the "drought" scenario in percent (x-axis) and respective bn. KZT (*)

Source: Own illustration based on e3.kz results

Thus, the said regions with a focus on agriculture benefit the most in terms of real value added (Figure 28). However, from the positive impacts in the trade and service sectors the cities Almaty and Astana can benefit the most. Regions with manufacturing sectors show also a smaller positive impact.

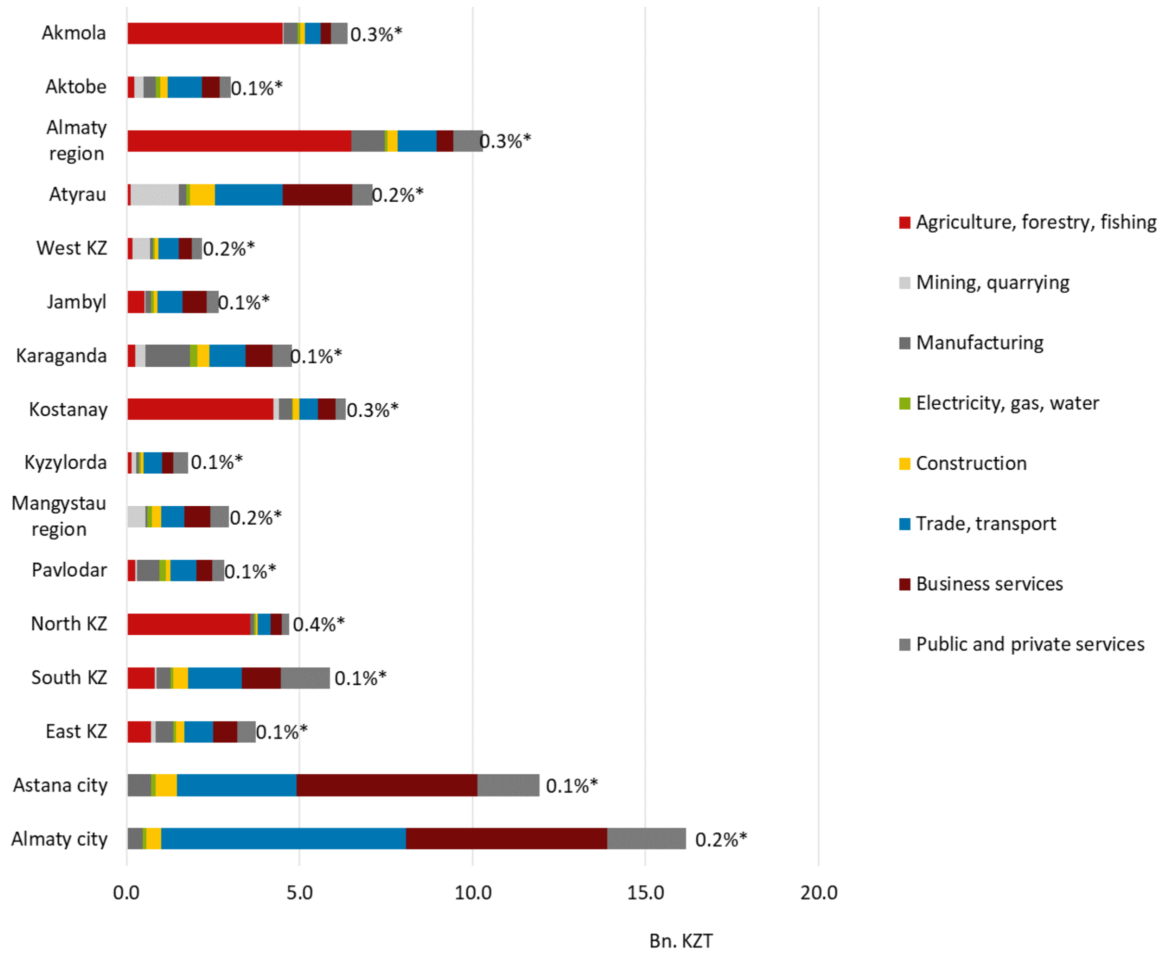



Figure 28: Effects of the "no-till farming" scenario on real value added by economic sectors and subnational regions, 2037, deviations from the "drought" scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The positive macroeconomic development has positive impacts on employment which increases by up to 0.1% resp. 9 thousand persons. The higher economic activity as well as the sectoral labour intensities in agriculture (+5 thousand), trade & transport (1.4 thousand persons) as well as service sectors (1.8 thousand persons) leads to the highest employment effects in those sectors.

At the subnational level, Almaty region (0.2% resp. 2.4 thousand), Akmola (0.3% resp. 1.2 thousand), Kostanay (0.3% resp. 1.5 thousand) and North Kazakhstan (0.3% resp. 0.7 thousand) show the greatest employment effects (Figure 29). All other regions show positive employment impacts ranging between 0.02% (Jambyl) and 0.06% (Almaty city).

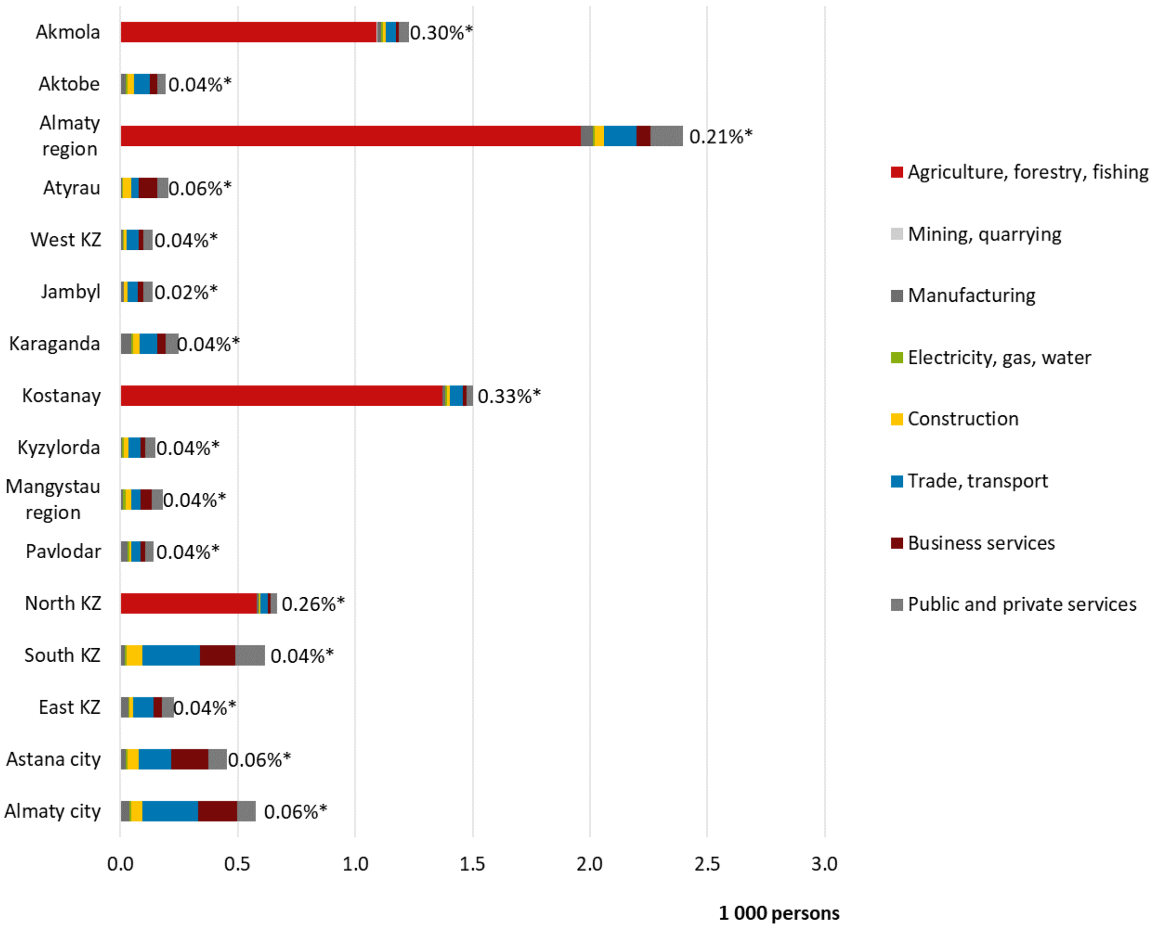



Figure 29: Effects of the “no-till farming” scenario employment by economic sectors and subnational regions, 2037, deviations from the “drought” scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

## 6.1.3 INVESTING IN PASTURE IMPROVEMENT

### 6.1.3.1 Scenario assumptions and implementation

Pasture improvement is another opportunity to combat heat stress and droughts resulting in less water availability for livestock and degraded, dried pastures. This adaptation measure is estimated to provide 70 mn. USD higher agricultural output per year at investment costs of 144 mn. USD for pasture vegetation and infrastructure rehabilitation such as (re-)construction of roads and fences as well as installation of feedlots and waterpoints (EBRD et al. 2018). Application of rotational grazing helps to rehabilitate pasture vegetation. It is expected that the regions suffering from drought impacts in agriculture have sufficient capacities to repair and expand pasture infrastructure.

Pasture improvement is assumed to be financially supported by the government in particular for small-scale farmers.

### 6.1.3.2 Scenario results

Investments in pasture infrastructure (e.g., fences, feedlots, waterpoints and roads) and vegetation increases GDP by up to 0.07% compared to a situation without adaptation and droughts (Figure 30). Due to this adaptation measure agricultural losses from droughts can be reduced and thus, export chances (+0.01% p.a.) can be taken and imports can be avoided (up to -0.06% p.a.). The adaptation benefits can also be achieved in “no drought” years.

The macroeconomic impacts are even smaller than for the other two adaptation scenarios illustrated in the previous sections as the necessary investments related to the respective adaptation option are smaller.

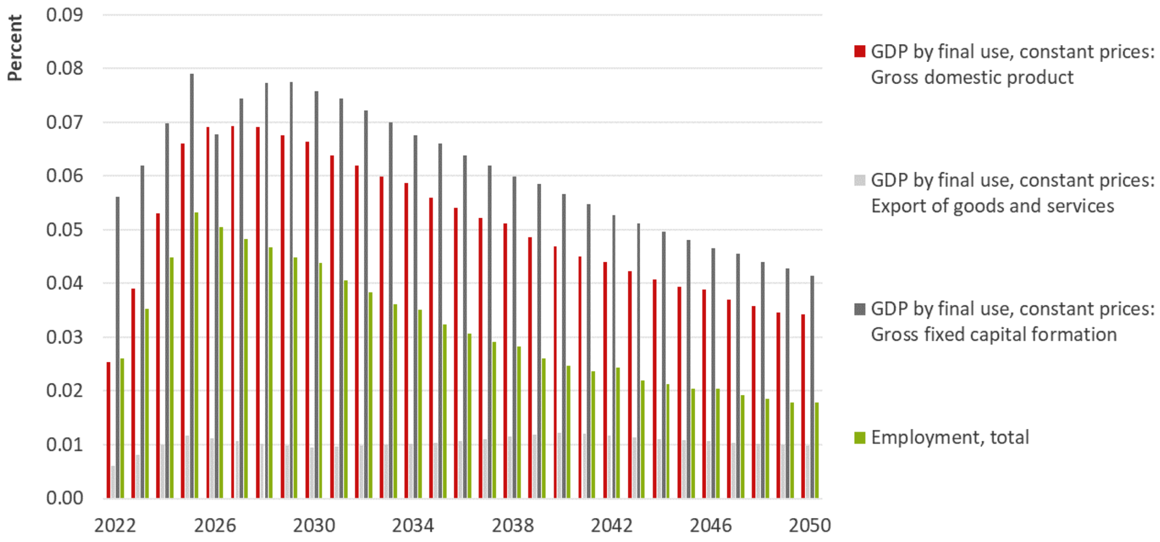



Figure 30: “Pasture improvement” scenario: Key impacts, 2022-2050, deviations from the “drought” scenario in percent

Source: Own illustration based on e3.kz results

Some regions show an above average economic growth ranging between 0.14% (Kostanay, Almaty region) and 0.19% (North Kazakhstan, Figure 31). Reasons are that agriculture is one of the prevailing economic sectors and additional construction activities as well as feedback effects (for e.g. food production) contribute to a slightly higher GRP.

However, the distribution of the various agricultural activities, such as farming and livestock breeding, varies from region to region. North Kazakhstan and Kostanay are the main wheat producing regions. Nevertheless, according to Hankerson et al (2019) livestock is also of relevance for these regions, Akmola, and the South-East of Kazakhstan.[8]

[8] It must be noted that COMSTAT statistics measuring e.g. employment and value added do not distinguish the different agricultural activities. Thus, economic results for the regions may differ when using more detailed data.

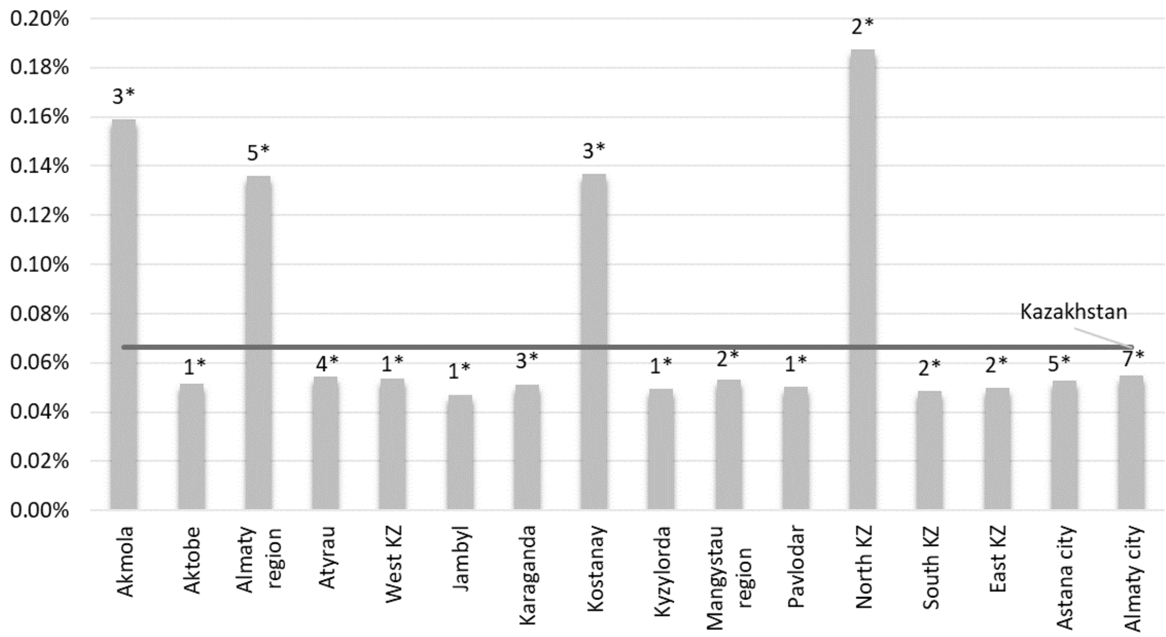



Figure 31: Effects of the "pasture improvement" scenario on real gross regional product, 2030, deviations from the "drought" scenario in percent

Source: Own illustration based on e3.kz results

The economic activity in agriculture and construction are positively impacted from this adaptation measure (Figure 32). Thus, those regions that adapt to climate change can profit from the adaptation benefits but also from the economic activities triggered by the necessary investments.

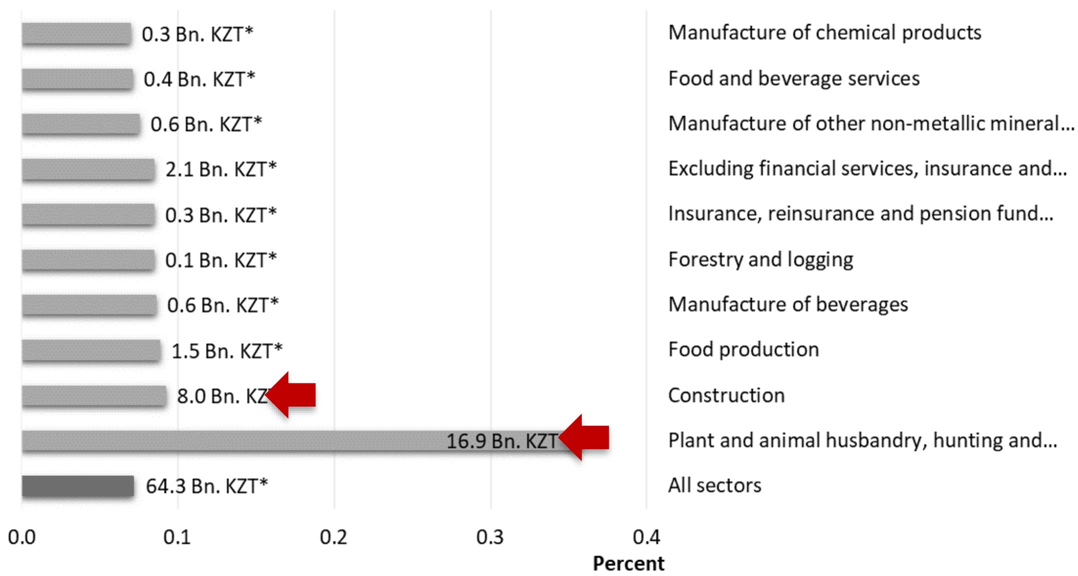



Figure 32: Effects of the “pasture improvement” scenario on real production, 2037, deviations from the “drought” scenario in percent (x-axis) and respective bn. KZT (*)

Source: Own illustration based on e3.kz results

However, also other subnational regions can profit from indirect and induced effects leading to increased income and employment. In total, 4 thousand additional jobs can be created in particular in agriculture (2.3 thousand), trade & transport (0.6 thousand) and construction (0.3 thousand, Figure 33). Akmola, Almaty region, Kostanay and North Kazakhstan show the greatest increase in employment (0.1% to 0.16% resp. 0.4 thousand to 1.2 thousand persons) compared to a situation without adaptation and droughts.

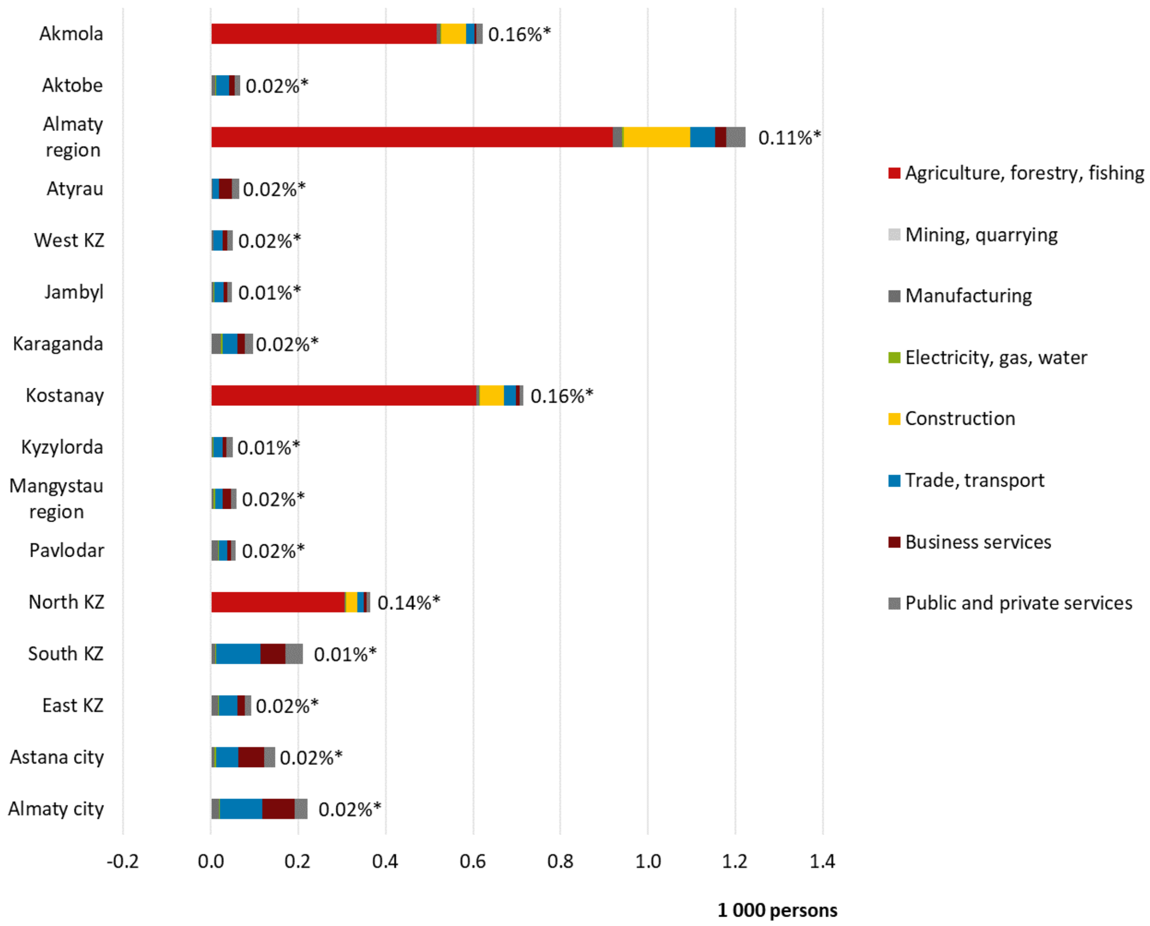



Figure 33: Effects of the "pasture improvement" scenario employment by economic sectors and subnational regions, 2037, deviations from the "drought" scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

## 6.2 ADAPTATION IN ENERGY: EXPANSION OF WATER-INDEPENDENT ENERGY TECHNOLOGIES AND EFFICIENCY IMPROVEMENTS IN THE HOUSING SECTOR

### 6.2.1 SCENARIO ASSUMPTIONS AND IMPLEMENTATION

The expansion of water-independent technologies such as wind power and efficiency measures that reduce energy consumption are suitable measures to reduce the cooling demand and to sustain the energy generating potential during heatwaves.

The following scenario assumptions are made to evaluate the subnational economic impacts of these adaptation measures, (see GIZ 2022, section 6.2.2.2):

- Investments of 2.9 trillion KZT in wind power in those regions[9] with the highest wind energy potential (South Kazakhstan, Jambyl, Almaty region, Akmola, Pavlodar, and Karaganda).

[9] https://www.asiawind.org/research-data/market-overview/kazakhstan/ (last accessed February 1st, 2023)

- Manufacturing sector and "professional, scientific and technical activities" are in particular affected by the production of wind power stations (O'Sullivan and Edler 2020). It is assumed that the respective regions have sufficient production capacities.
- Energy efficiency improvements in housing account for nine billion USD and result in a reduced energy demand of 11% in the residential sector by 2050.
- Related construction activities are expected to take place in all subnational regions as heat waves are a concern for the entire country.

### 6.2.2 SCENARIO RESULTS

These adaptation measures have positive impacts on the economy. Kazakhstan's GDP growth accelerates and results in a GDP which is up to 0.7% resp. 540 bn. KZT higher compared to a situation without adaptation and heatwaves (Figure 34). The GDP impacts for the subnational regions increase between 0.5% and 0.9% in 2047. South Kazakhstan, Jambyl, Almaty region, Akmola, Pavlodar, Atyrau and Karaganda are above national average.

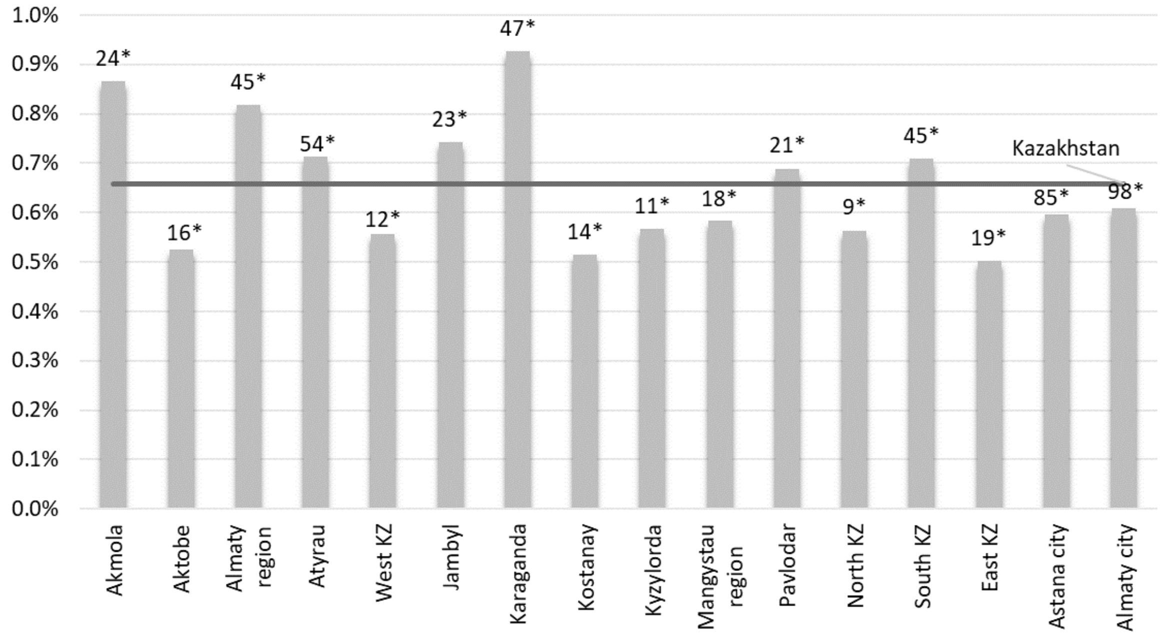



Figure 34: Effects of the "wind power deployment and housing energy efficiency improvement" scenario on real gross regional product, 2047, deviations from the "heat wave" scenario in percent

Source: Own illustration based on e3.kz results

For many economic sectors positive effects from adaptation can be recognized (Figure 35) compared to a situation without adaptation and heatwaves. Manufacturing (+0.7%), energy (+2.3%), and construction (+1.4%) sectors benefit directly and indirectly. Wind power expansion and insulation activities increase the demand for manufactured products, construction activities and professional, scientific, and technical activities. Furthermore, additional household spending due to increased income and freed-up money due to lower energy expenditures can be seen for example in service sectors such as accommodation and food service activities (+4.1%) and other supplying sectors such as agriculture (+0.8%). Mining & quarrying (-0.2%) suffers compared to a situation without adaptation and heat waves because renewable energy replaces fossil fuels in electricity generation.

If key sectors of a subnational region are affected by sectoral developments at national level, these regions show the greatest impact. Thus, Karaganda region benefits from increased e.g., manufacturing activities and energy production. The cities Almaty and Astana are facing in especially a higher service demand (Figure 35). All regions benefit from the higher construction activity to insulate residential buildings.

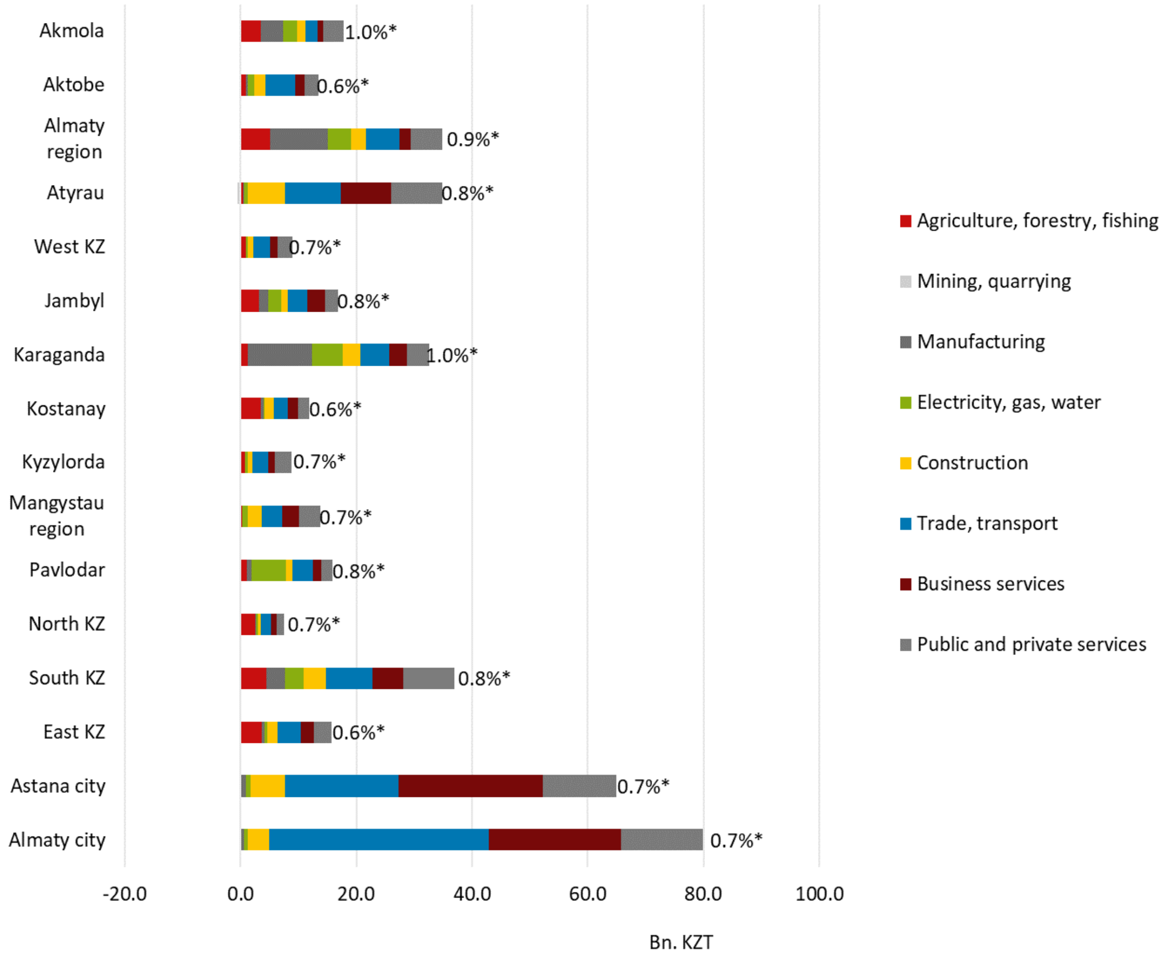



Figure 35: Effects of the "wind power deployment and housing energy efficiency improvement" scenario on regional value added in real values by economic sectors and subnational regions, 2047, deviations from the "heat wave" scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The impacts on subnational employment by economic sectors shows Figure 36. Service sectors show the greatest increase in jobs (22.5 thousand in 2047) compared to a situation without adaptation and heatwaves. Accommodation and food service activities (7.3 out of 11 thousand in public and private services) benefit the most as it is expected that households spend the freed-up money for such services. Also, in construction 4.6 thousand jobs are created due to refurbishment of houses. Subnational regions – such as South Kazakhstan, Almaty city and Astana city – with many inhabitants and thus houses to be insulated show a greater increase as sparsely populated areas.

The employment impacts for the subnational regions range between 0.2% and 0.6% (resp. 0.8 thousand and 5.2 thousand) higher in 2047 compared to the heatwave scenario without adaptation (Figure 36). Employment at national average accounts for additional 0.35% resp. 35 thousand employed persons.

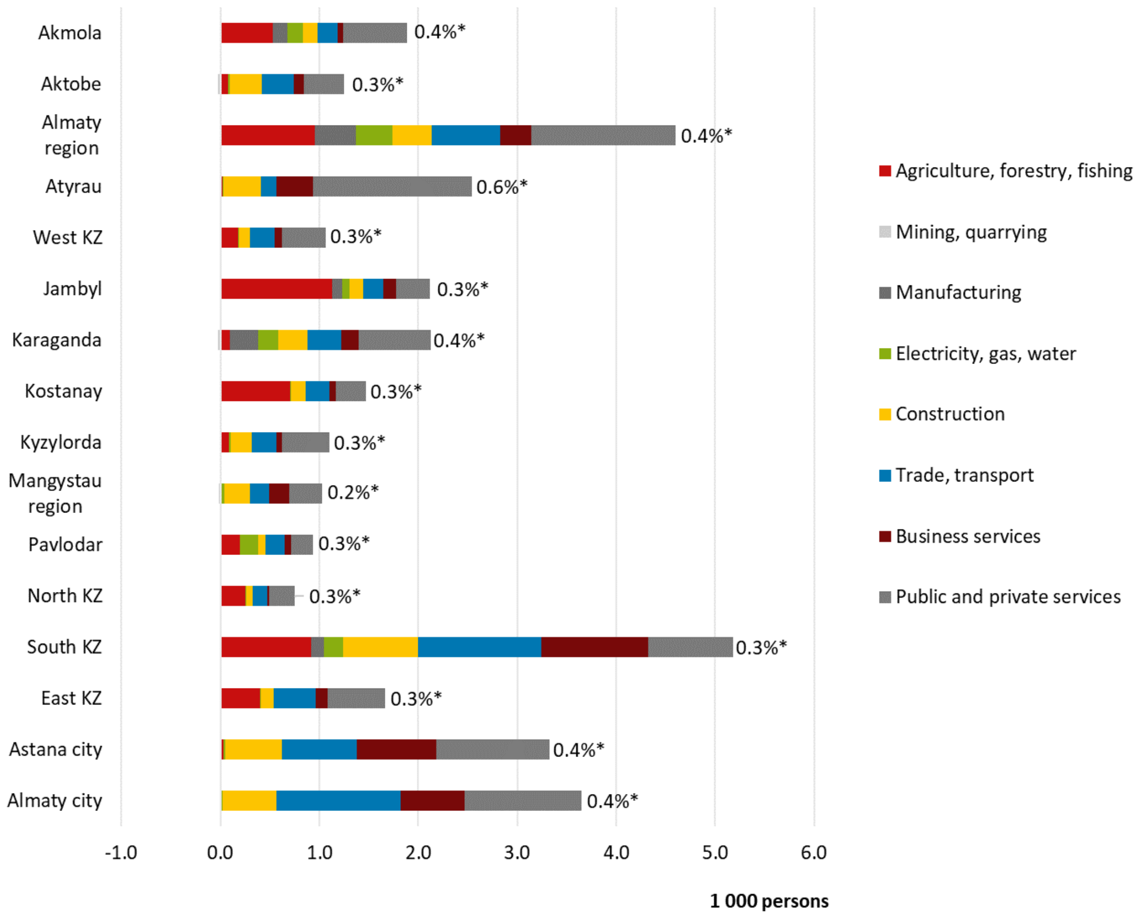



Figure 36: Effects of the “wind power deployment and housing energy efficiency improvement” scenario employment by economic sectors and subnational regions, 2047, deviations from the “heat wave” scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

# 6.3 ADAPTATION IN INFRASTRUCTURE: CLIMATE-RESILIENT ROADS

## 6.3.1 SCENARIO ASSUMPTIONS AND IMPLEMENTATION

Climate-resilient road infrastructure helps to reduce the damage from extreme precipitation and flooding which are expected to occur more frequently and more severely. Drainage and new pavement structures can be considered during regular construction and maintenance of roads which keeps the costs comparatively low and reduces the destruction of roads, bridges, and cars during such EWEs.

For the analysis of the subnational economic impacts the following assumptions are set (see GIZ 2022, section 6.2.3.3):

- 2,117 bn. KZT must be invested for climate-proofed roads which is 7-9% of regular road investments. The adaptation costs are fully financed by international donors.
- The adaptation measures are being implemented in West Kazakhstan, Aktobe, South Kazakhstan, Almaty region, and East Kazakhstan. It is expected that the respective construction activities can be carried out by the regions themselves.

- Road infrastructure damages are assumed to be reduced by 50%. Trade costs are expected to be 1% lower as transport is less disrupted and delayed.
- While the lower reconstruction costs (due to less damages) are observable in the affected regions, all regions can benefit from higher transport performances and other economic activities.

### 6.3.2 SCENARIO RESULTS

The macroeconomic effects of the investments in climate-resilient roads are positive resulting in 0.46% resp. 391 bn. KZT higher real GDP for Kazakhstan in 2050 compared to a situation without adaptation and extreme precipitation events (Figure 37). All subnational regions show positive impacts but with a different magnitude. The real GRP impacts range from +0.28% (Jambyl) to +0.53% (West Kazakhstan).

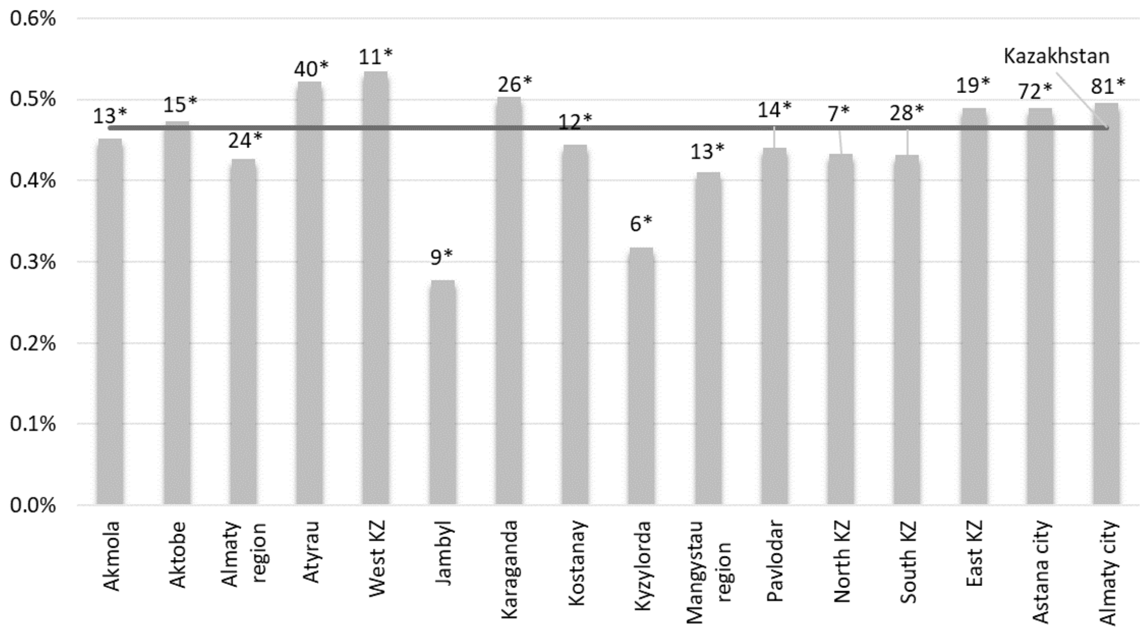



Figure 37: Effects of the "(re-)construction of climate resilient roads" scenario on gross regional product in real values, 2050, deviations from the "extreme precipitation" scenario in percent and in bn. KZT (*)

Source: Own illustration based on e3.kz results

Trade & transport, manufacturing and construction show an increased economic activity. The (re-) construction of climate-resilient roads support construction activities and manufacturing of concrete, for example. With the ongoing road works, trade and transport activities can be accelerated. Other indirect and induced effects have a positive effect on other business services. Also, the mining & quarrying sector show a greater activity as the demand for energy products increases e.g., in the transport and manufacturing sector.

Relative deviations of real value added by region range between +0.1% (Jambyl) and +0.4% (West Kazakhstan) compared to a situation without adaptation and extreme precipitation events. In absolute terms, the cities Astana and Almaty benefit the most in especially from additional service and trade & transport activities. Although Atyrau region is not directly affected from the adaptation measure, the region profits indirectly from a greater demand in mining and quarrying products.

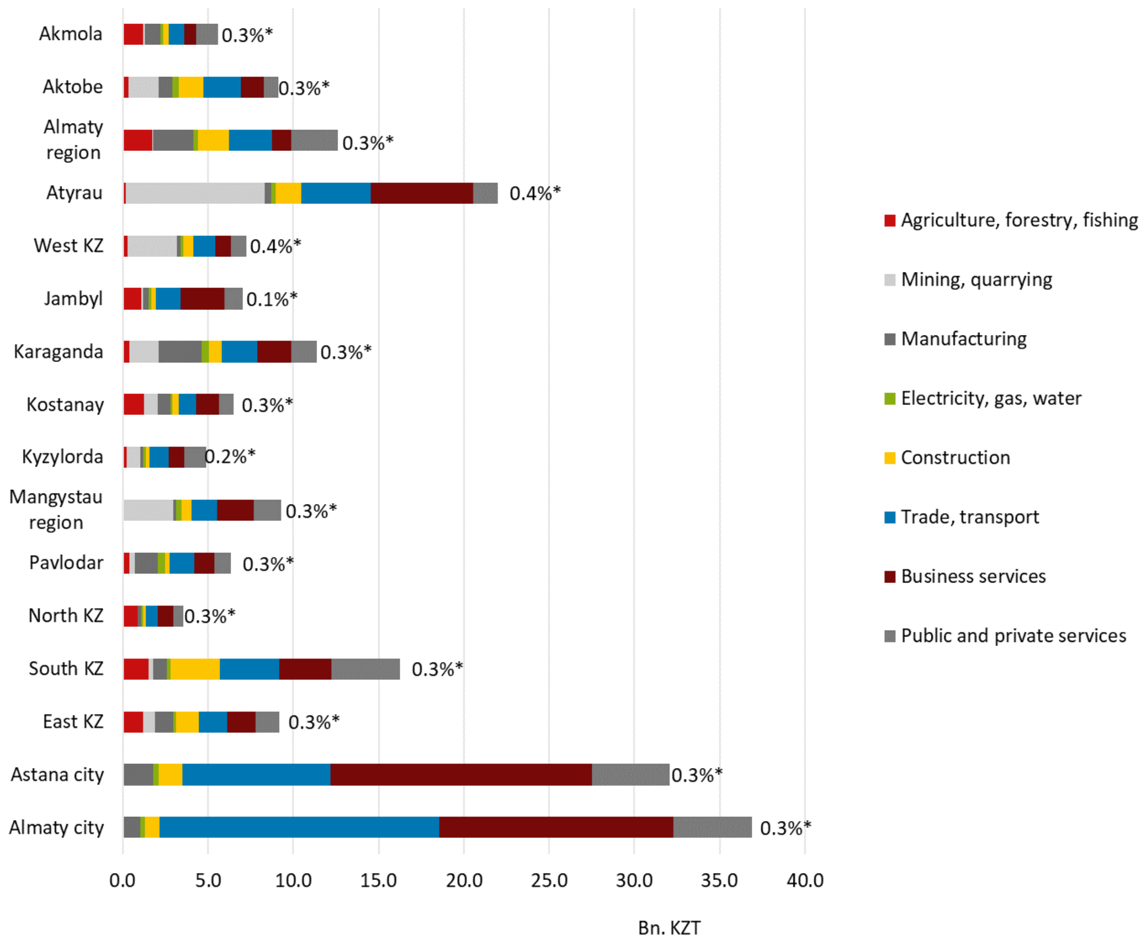



Figure 38: Effects of the "(re-)construction of climate resilient roads" scenario on regional value added in real values by economic sectors and subnational regions, 2050, deviations from the "extreme precipitation" scenario in Bn. KZT (x-axis) and percent for total regional value added (*)

Source: Own illustration based on e3.kz results

The impacts on regional employment by economic activities shows Figure 39. (Re-)construction of climate-proofed roads creates additional jobs in the construction sector of in total 1.4 thousand persons of which the most are expected in South Kazakhstan, Aktobe and Almaty region. Additionally, the trade & transport sector in all regions benefits in terms of employment (+3.8 thousand employed persons). Overall, employment is up to 7.7 thousand persons per year higher in 2050 compared to an extreme precipitation scenario without adaptation.

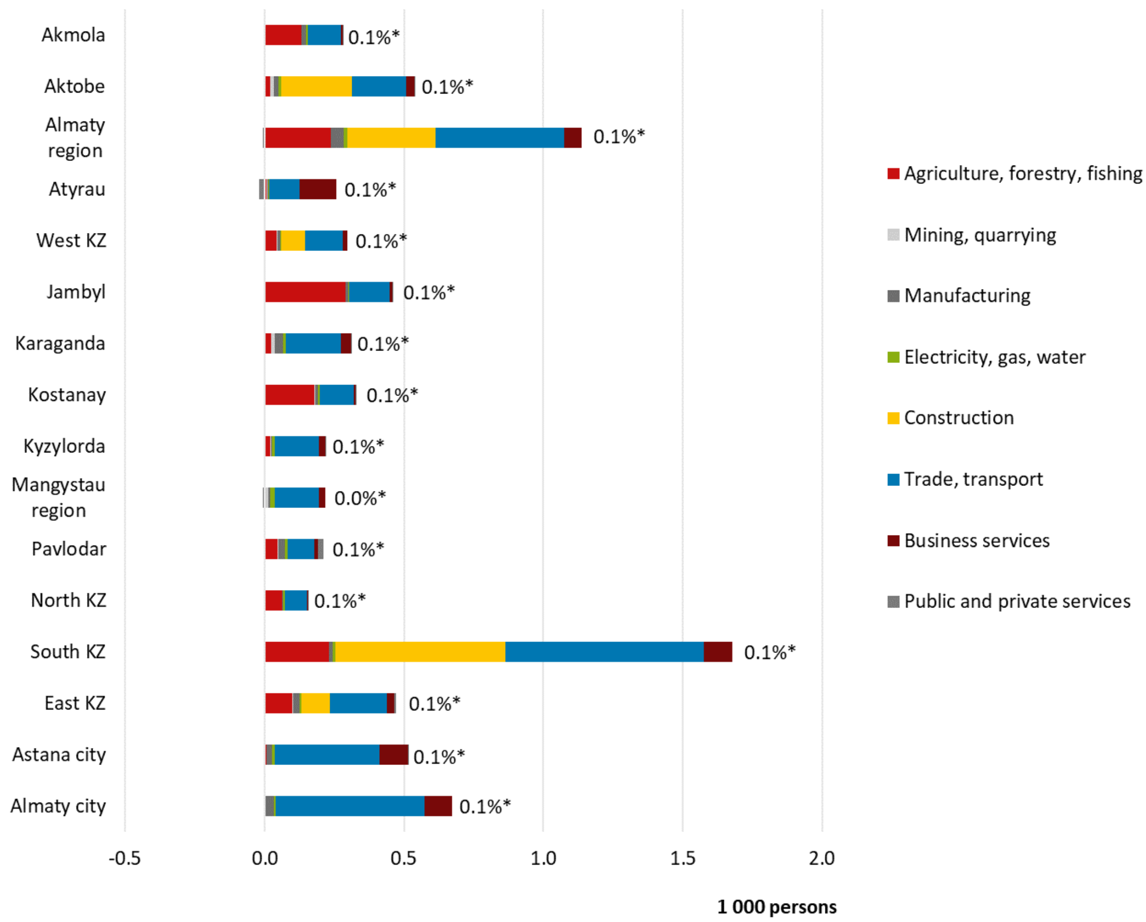



Figure 39: Effects of the "(re-)construction of climate resilient roads" scenario employment by economic sectors and subnational regions, 2050, deviations from the "extreme precipitation" scenario in 1,000 persons (x-axis) and percent for total regional employment (*)

Source: Own illustration based on e3.kz results

# 7 SUMMARY AND OUTLOOK

Climate change impacts occur nationally (e.g., drought, heatwave), regionally (e.g., storm) and locally (e.g., heavy rainfall). Responding adaptation measures tend to take place at the subnational or even local level. This calls for subnational evidence that is supported by using the substantial extension of the existing climate-sensitive macroeconomic model that has been developed in the CRED project for supporting adaptation action in Kazakhstan.

The starting point for the macroeconomic analysis of climate impacts and adaptation measures can be national and region-specific information. These are compiled and quantified in scenarios, simulated with the e3.kz model. The macroeconomic effects were initially quantified without subnational effects.

However, climate change is affecting the regions of Kazakhstan in different ways. The north is more affected by droughts, while the south is more confronted with floods. The regions also have a different economic focus and adaptation priorities. In the north of Kazakhstan, agriculture - especially rainfed wheat cultivation - is prominent, which increases vulnerability to droughts. The south-east is comparatively densely populated and is characterised by economic centres such as Almaty City. Due to its location, the region is more vulnerable to flooding.

Thus, the subnational extension of the e3.kz model to 16 regions (NUTS1 level) was performed. A simplified regionalisation approach was preferred, which considers the data situation at subnational level, reduces the modelling effort and is not at the expense of the user-friendliness of the tool. With the extended e3.kz model, selected climate change and adaptation scenarios already analysed at national level were evaluated regarding the regional economic effects.

It turned out that all regions in Kazakhstan are affected from the impacts of climate change and adaptation but at different scales. Regions with a significant sector-specific focus are exposed to a higher economic risk if climate change negatively affects that economic sector. Then, adaptation to climate change is in particular relevant for that region. Diversification and strategic reorientation of the economic structure may reduce this risk. In contrary, regions with a focus on economic sectors that profit from climate change adaptation such as construction and “green” industries, which e.g. support deployment of renewable energy, profit the most from climate-resilient strategies.

The advantage of embedding this subnational modelling approach in the macroeconomic projection is the consistent coverage of the regional, sectoral effects of climate change and adaptation scenarios. The comparison of regional, sectoral climate damage and regional economic structure shows the need for adaptation measures even more clearly than at the national level.

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