Policy Research Working Paper 8940

Where They Live

District-Level Measures of Poverty, Average Consumption, and the Middle Class in Central Asia

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WORLD BANK GROUP
Poverty and Equity Global Practice
July 2019

Abstract

Rapid economic growth over the past two decades lifted millions of people out of poverty in Central Asia. But the uneven spread of prosperity left many communities struggling to catch up. To support lagging regions within countries, each of the region's five national governments has made convergence a pillar of their development strategies. An imperfect patchwork of household surveys allows policy makers to monitor progress and identify some spatial disparities. But these share an important weakness: none of the official surveys in the region is representative when disaggregated to the level of districts. Islands of poverty and prosperity are thus lost in the averages—leading to targeting inaccuracies that can slow the pace of poverty reduction. This study partially addresses the challenge. The accuracy of key welfare indicators is sharpened well beyond what could be achieved for any country alone by: i) unifying survey data from across the region and ii) applying the techniques of small-area estimation. The results provide detailed measures of welfare that in turn can be disaggregated for each district in Central Asia. Comprehensive maps of where the poor and the middle class live are presented, for the entire region and individually for each country.

This paper is a product of the Poverty and Equity Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The author may be contacted at wseitz@worldbank.org.

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District-Level Measures of Poverty, Average Consumption, and the Middle Class in Central Asia

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Keywords: Poverty mapping. Fay-Herriot, Small Area Estimation, Central Asia, Regional Development

JEL Codes: I30, I32 R12

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ACKNOWLEDGMENTS

This report is a product of the World Bank Poverty and Equity Program for Central Asia, led by William Seitz (Economist, GPV03). Maps and data files were generated with assistance from Avralt-Od Purevjav (Consultant, GPV03). The approach used to derive the small area estimates in this report relies on a Stata command developed by Paul Andres Corral Rodas (Data Scientist, GPV03), William Seitz, Minh Cong Nguyen (Economist, GPV03) and Joao Pedro Azevedo (Lead Economist). Reviewers include: Bob Fay (Senior Scientist, Westat), Alexandru Cojocaru (Senior Economist, GPV03), Kenneth Simler (Senior Economist, GPV02), Kristen Himelein (Senior Economist, GPV02) and David Newhouse (Senior Economist, GPV07). Additional project support was provided by Alisher Rajabov (Economist, GPV03), and Saida Ismailakhunova (Senior Economist, GPV03). This task was completed under the guidance of Carlos Silva-Jauregui (Lead Economist and Acting Practice Manager, GPV03)

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I – Introduction

Measurement of poverty rates, average per capita consumption, the size of the middle class, and other welfare indicators is traditionally conducted using survey data. To allow for frequent monitoring and to contain the costs of gathering detailed information, such surveys usually visit only a small sample of the population. When this sample of the population is representative, welfare surveys provide reliable estimates of poverty incidence for the entire population at a small fraction of the cost that would be required to survey each person in the country.

However, this approach necessarily leads to sampling errors, and consequently, a typical household income or expenditure survey cannot produce statistically reliable welfare estimates for small geographic units. This study starts with nationally (and regionally) representative data from each of the four Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) for which they are available. The analysis then proceeds to sharpen the reliability of the survey estimates to allow reporting at a level below what is traditionally reported (moving from "oblast" level estimates, to "rayon" level estimates). Because no such survey data are available for Turkmenistan, the country is excluded from the analysis.

There are two survey types used in the approach described in this report. In Kazakhstan and the Kyrgyz Republic, welfare estimates are derived from the Household Budget Surveys (HBS) conducted by the national statistical agencies. In Tajikistan and Uzbekistan, HBS data were either inappropriate for this analysis, or unavailable. Instead, the welfare estimates for these countries are derived from the baseline surveys for two World Bank studies: Listening to Tajikistan (L2T) and Listening to the Citizens of Uzbekistan (L2CU).

Each of these four surveys are designed to be representative at the national level in the respective country, for rural and urban areas, and at the region (oblast) level. For this reason, the national official rates of poverty monitored in each country are not usually published for administrative units below the regional level (with some exceptions). However, many government administrative activities are undertaken at the district level, and regions are a relatively high level of spatial aggregation for targeting policies that are sensitive to the needs of poor and vulnerable people. Likewise, policies that are intended to grow the middle class and average income could benefit from greater disaggregation than is directly available.

Small area estimation (SAE) techniques sharpen the precision of welfare measures to enable reporting at highly disaggregated geographic units. Using statistical models for imputation, SAE approaches provide estimates of indicators for small areas that would be impossible to reliably construct with traditional survey data alone. The results are often used to target policies and assign resources to have greater poverty-reducing impact or are intended to address the concerns of specific welfare groups at the local level. In many countries and regions, poverty maps have been used to highlight geographic variations, simultaneously display different dimensions of well-being, understand income determinants, and to both design and select interventions.

A variety of such methods have been devised to overcome the increasing imprecision of welfare estimates as they are disaggregated. The standard approach to SAE, used by the World Bank and applied in most cases when enough data are available, is described in Elbers, Lanjouw, and Lanjouw

(2003) and is often referred to as the "ELL" poverty mapping method. The assumptions and data employed for ELL maps are further elaborated upon in Bedi, Coudouel, and Simler (2007). However, a pre-requisite for using the ELL approach is access to micro-level census data. In Central Asia, census data either do not exist (for instance, in Uzbekistan), are relatively dated (for instance, in the Kyrgyz Republic and Tajikistan), or are not made available for these purposes (for instance, in Kazakhstan). In such cases, the most common alternative approach is the Fay-Herriot (FH) method, which is adopted to generate the results described in this report.

The FH method allows estimation of indicators and rates using a combination of survey data and district-level indicators from available sources that are less subject to imprecision, such as administrative data or remote sensing. In this report, most of the publicly available sources used are derived from satellite imagery. The FH approach proceeds by matching accurate area-based information with indicators that are aggregated to the level of interest in the survey (the district, in this case). Starting from the relatively imprecise estimates from the survey, a statistical model is developed, which attempts to explain the variation of the welfare indicator at the district level (in this case, either the poverty rate, average consumption per capita, or the share of the middle class at the district level). Once the model is estimated, the direct survey estimates also enter into the final area-level results: the final estimated area-level poverty rate is a weighted average of the observed and model-based estimates for cases in which both estimates are present. For areas that do not appear in the survey data, the results rely entirely on estimates derived from the statistical model.

The report is structured as follows. The remainder of this section reviews the definitions of the key indicators to be estimated. Section II reviews the data used in the study (relying on both survey microdata, and complementary satellite/administrative data). The approach used for the maps described in this report is discussed in more detail in section III. Section IV includes the district-level maps for Central Asia. Section V briefly discusses the results and gives two examples of uses for the maps (comparing migration rates to poverty rates and locating program locations on maps). The annexes include detailed tables of the results at the level of districts (rayons) throughout Central Asia, validation and robustness exercises, and the regression models used.

I.I – Definitions of Poverty in Central Asia

The World Bank regularly produces internationally comparable estimates of poverty as part of its mandate. In 2017, the World Bank updated all such estimates to a new set of poverty lines, and at the same time, began applying up-to-date purchasing power parity (PPP) conversion factors for each country (based on estimates of price differences in 2011). The objective of calculating the World Bank's internationally comparable poverty estimates is to estimate the prevalence of poverty in terms of a single global standard. Measures created on this basis are in turn used to monitor progress towards development goals set by the World Bank, the member states of the United Nations, and other partners.

The World Bank poverty estimates contrast with national official poverty estimates in Central Asia in several ways. The most common official poverty approaches in the region consider local patterns of income or consumption and are often more appropriate for country-specific analysis. However, despite their many advantages, national official poverty measures are not comparable with the approaches used in other counties, in part because they are so tailored the specific country context. Thus, comparisons across countries (for instance, for the purposes of monitoring or benchmarking) require a harmonized approach, such as that conducted by the World Bank.

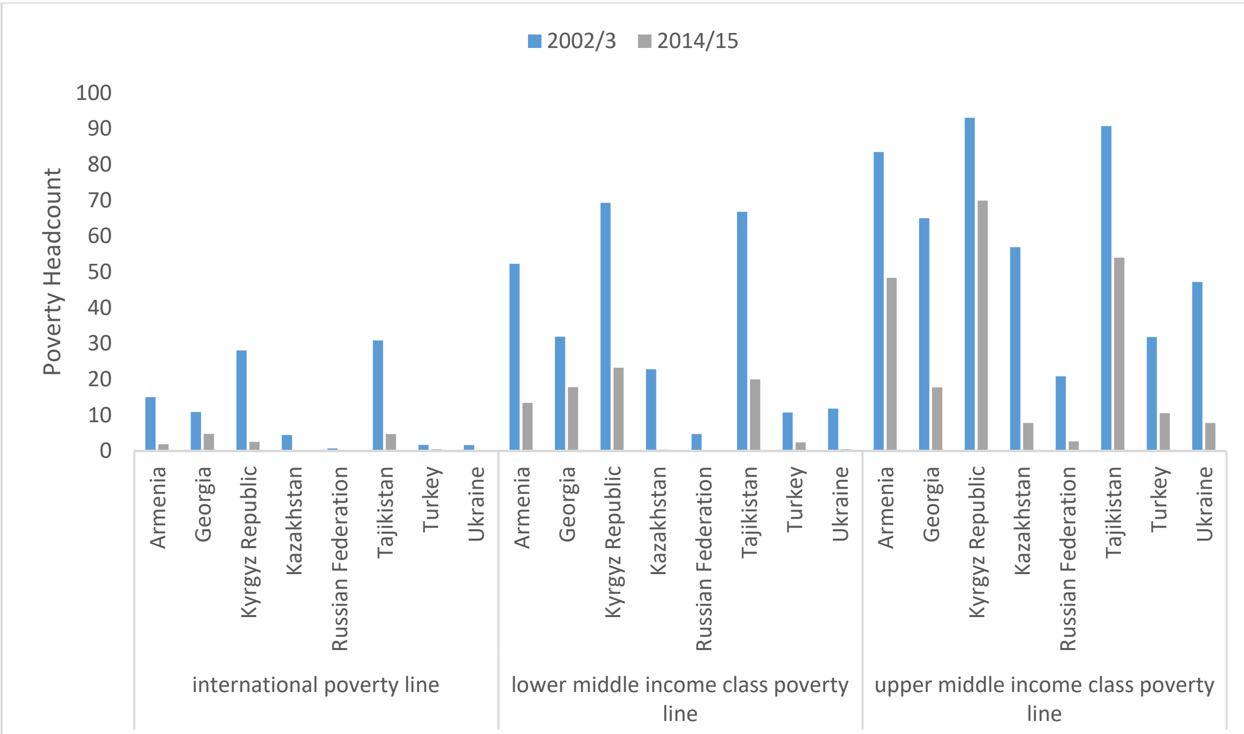
An additional reason that the World Bank uses a stand-alone approach to measure internationally comparable poverty rates is to account for differences in the cost of living between countries. To address this issue, the World Bank participates in the International Comparisons Program (ICP), a global effort to measure differences in the amount of goods and services a unit of one country's currency can purchase in another country. The ICP exercise was most recently completed in 2011, which led to important updates to previous PPP measures.

The original dollar-a-day line was created in 1991 using 1985 PPPs and was estimated by taking an average of the national poverty lines in the world's poorest countries. When a new set of PPPs was published in 1993, the line changed to $1.08 per day. PPPs were revised again in 2005, and the new line was estimated at $1.25.[2] For the most recent revision in 2011, the new line was estimated again using the national poverty lines of the poorest countries, as was the case in previous rounds. The result was a line set at $1.90 a-day. However, poverty by this measure is quite rare in Central Asia and is therefore excluded from the analysis that follows.

But in addition to the international "low income" poverty line, the World Bank also uses income class poverty lines which facilitate comparisons between countries at similar stages of development. The income class poverty lines are defined for the lower middle-income and upper middle-income countries and are based on the national poverty lines of the countries in each group. As such, they provide a more appropriate threshold to measure poverty for countries in each income class. The lines are defined at $3.2 (for lower middle-income countries) and $5.5 (for upper middle-income countries). The welfare measures of income or consumption used are the same as those used for the international poverty line. Cross-country comparisons of poverty measured at these lines are presented in Figure 1.

[2] For more details on the updated lines from Francisco Ferreira, Dean Joliffe and Espen Prydz, follow this link

Figure 1: Cross-Country Comparison of Income Class Poverty Rates

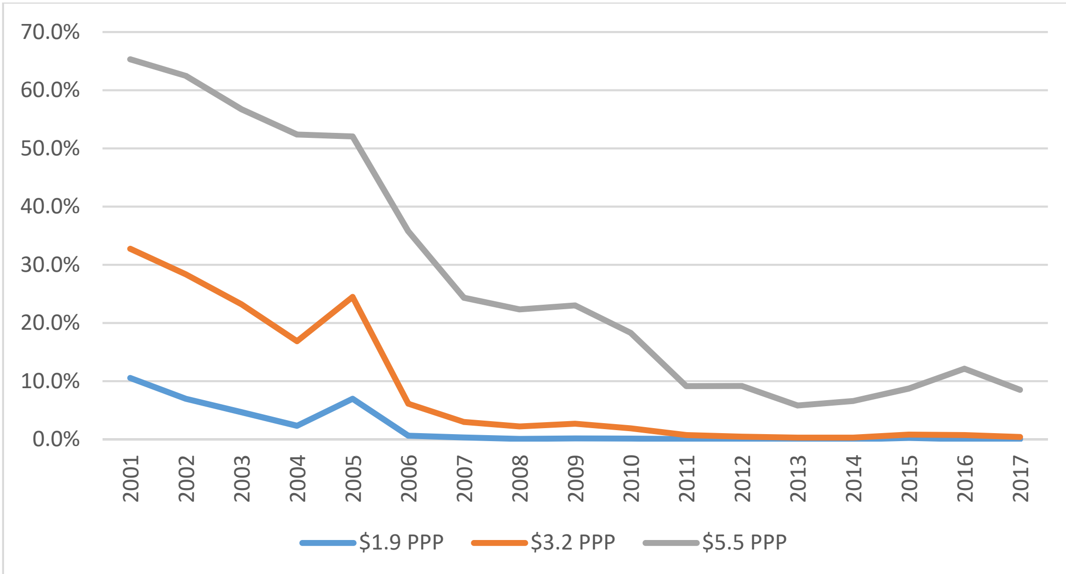


Source: Official Survey Data by Country, Author's calculations

Kazakhstan has achieved large and enduring reductions in poverty since independence. The rate of extreme poverty measured at the international poverty line of $1.9-a-day is now largely indistinguishable from zero. Despite setbacks in 2009 and 2015, poverty measured using all common lines indicate substantially improving welfare over the long-term. The most recent data available suggest that the poverty rate in Kazakhstan fell between 2016 and 2017. Measured against the highest poverty line the World Bank uses – which is usually reserved for upper middle-income countries like Kazakhstan – poverty has fallen from about 65 percent in 2011 down to about 8.5 percent in 2017. But many challenges remain, and Kazakhstan is vulnerable to economic shocks that periodically reverse the country's progress on poverty reduction. The two most notable cases of this were in 2005 and from about 2013 to 2016. During those spells of low growth or contraction, many people fell into poverty (though not often extreme poverty), and only a return to growth in the following years pulled the poverty rate down again. Indeed, measured at the highest poverty line, Kazakhstan has still yet to return to the low rate it achieved in 2013.

Even at the regional level, welfare and resilience to shocks have strong spatial dimensions in Kazakhstan. During the most recent economic downturn starting in late 2014 and continuing into 2015, regions with lower average incomes and histories of higher poverty rates experienced larger increases in poverty in 2015.

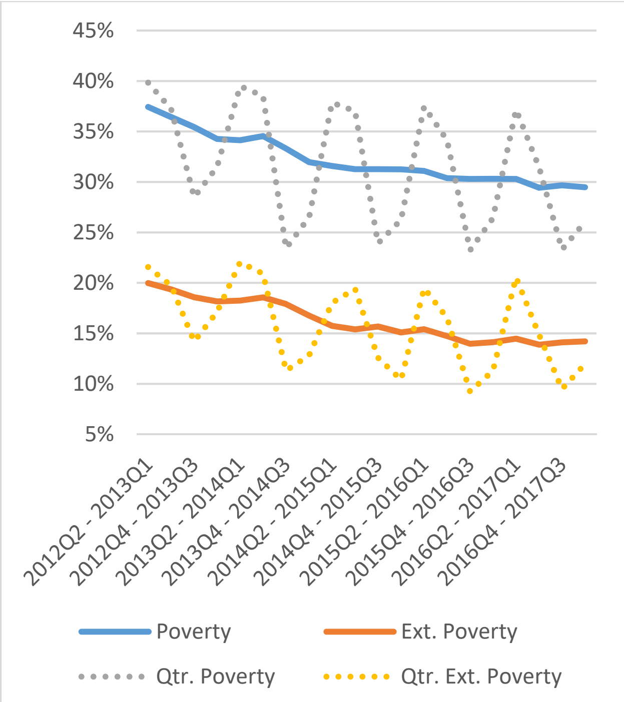
Figure 2: Poverty rates in Kazakhstan using international poverty lines

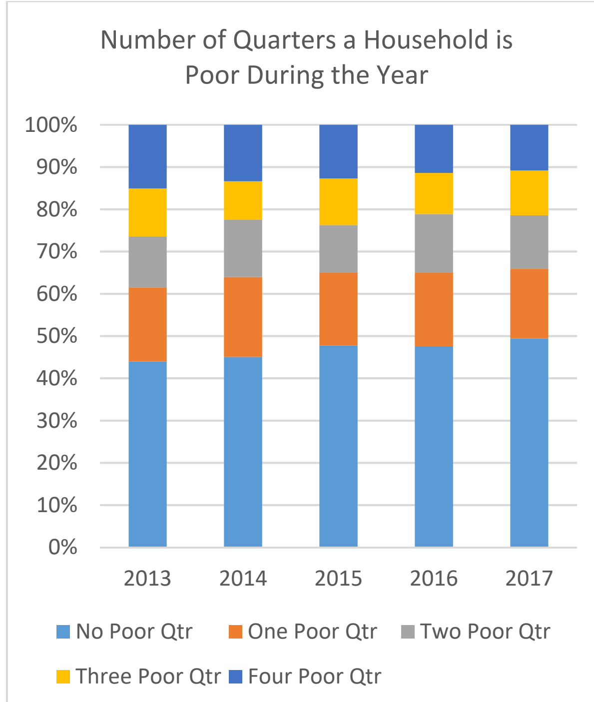


Source: the Kazakhstan HBS, Author's calculations

Among the Central Asian countries, **Tajikistan** traditionally has the highest rates of poverty, though in recent years the gap with Kyrgyzstan has been falling. As is the case with Kazakhstan, the country monitors poverty using a national official definition that is distinct from the World Bank's poverty line. According to the national series, the poverty rate fell from over 72 percent in 2003 to 47 percent in 2009. The rate of extreme poverty measured at the international poverty line of $1.9-a-day is below 2 percent. According to a different method of measuring national poverty which began in 2012, poverty continued to decline from 37.4 percent in 2012 to 29 percent in 2017. The poverty rate in Tajikistan fluctuates strongly between seasons and about half of the population falls into poverty (by the national definition) at least once during the year (figure 3).

Figure 3: National Poverty Rates in Tajikistan (left-note not comparable to international poverty estimates); Number of quarters in poverty (right)

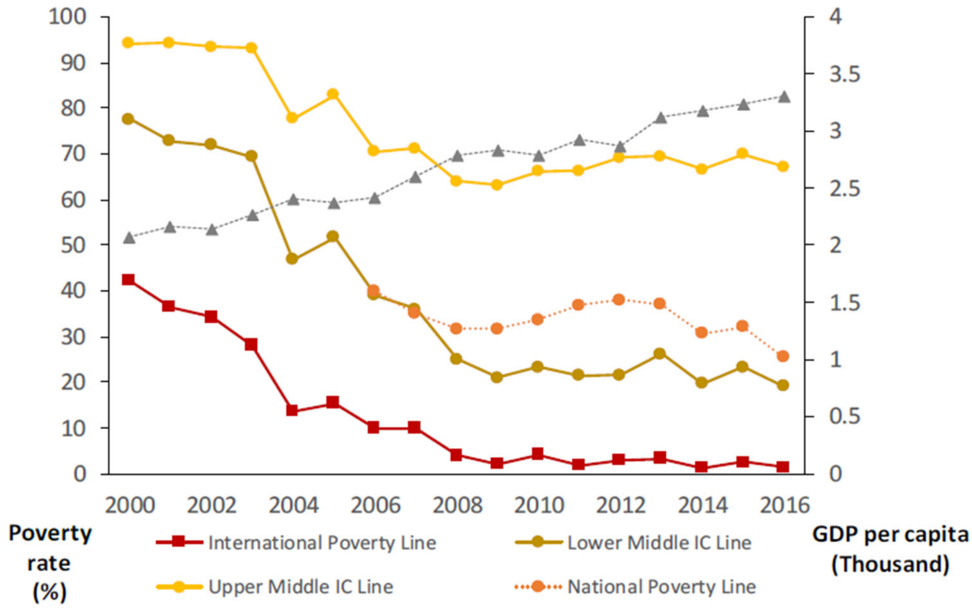




Source: the Tajikistan HBS, Author's calculations

Kyrgyzstan struggles with poverty rates nearly as high as those in Tajikistan, and in some cases higher. Although poverty fell rapidly for the first half of the past decade, progress stagnated thereafter. Measured at $3.2-a-day, the poverty rate fell from about 79 percent of the population in 2000 to 20 percent in 2008. However, the declining trend nearly halted at that point, and over the following years has remained nearly flat. Changes in the poverty rate are strongly associated with economic growth in the Kyrgyzstan, and recent slow economic growth has translated into little poverty reduction. The country is also relatively undiversified, and in the past, boom-bust cycles in economic activity have been closely linked to periods of progress and stagnation in poverty reduction.

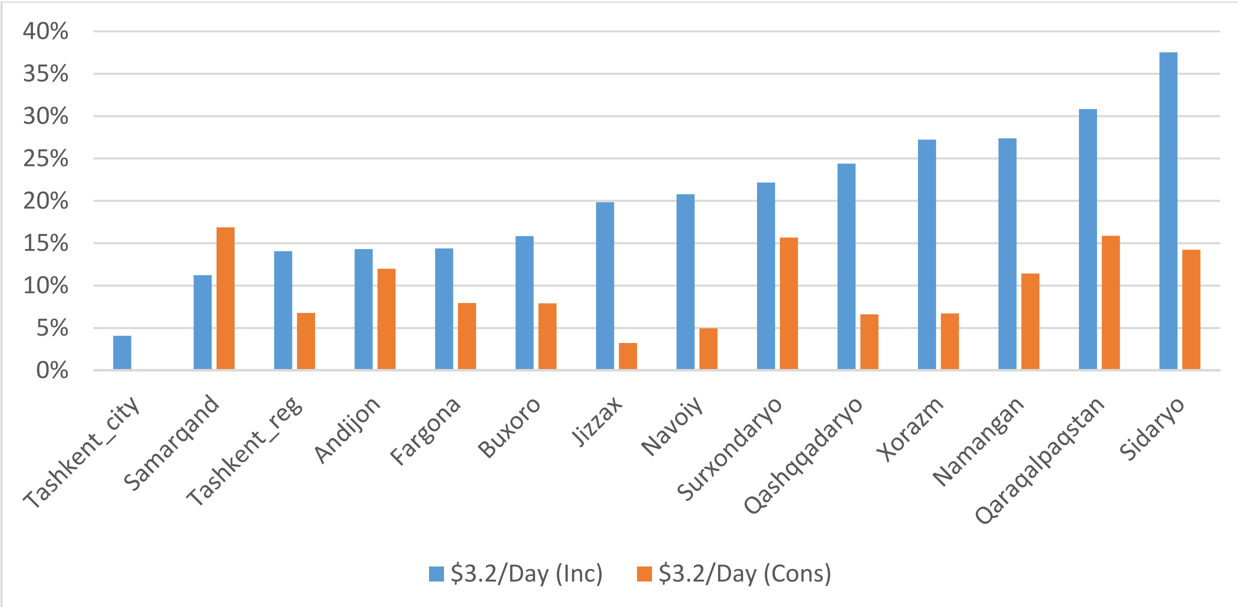
Figure 4: Poverty rates in the Kyrgyz Republic



Source: the Kyrgyzstan HBS, Official World Bank calculations

Until recently, **Uzbekistan** did not regularly provide the international community with the official data needed to estimate internationally comparable poverty rates. Consequently, the latest official and internationally comparable estimates date from the early 2000s. However, in 2018 a new study was launched by the World Bank in consultation with the National Statistical Agency of Uzbekistan and other partners called Listening to the Citizens of Uzbekistan. This study included a comprehensive baseline survey that can be used to estimate comparable poverty rates. These estimates suggest that in 2018 the poverty rate measured at the $3.2/day line stood at 9.6 percent of the population, and 36.6 percent at the $5.5-a day line.

Figure 5: Poverty Rates by Region of Uzbekistan (2018)

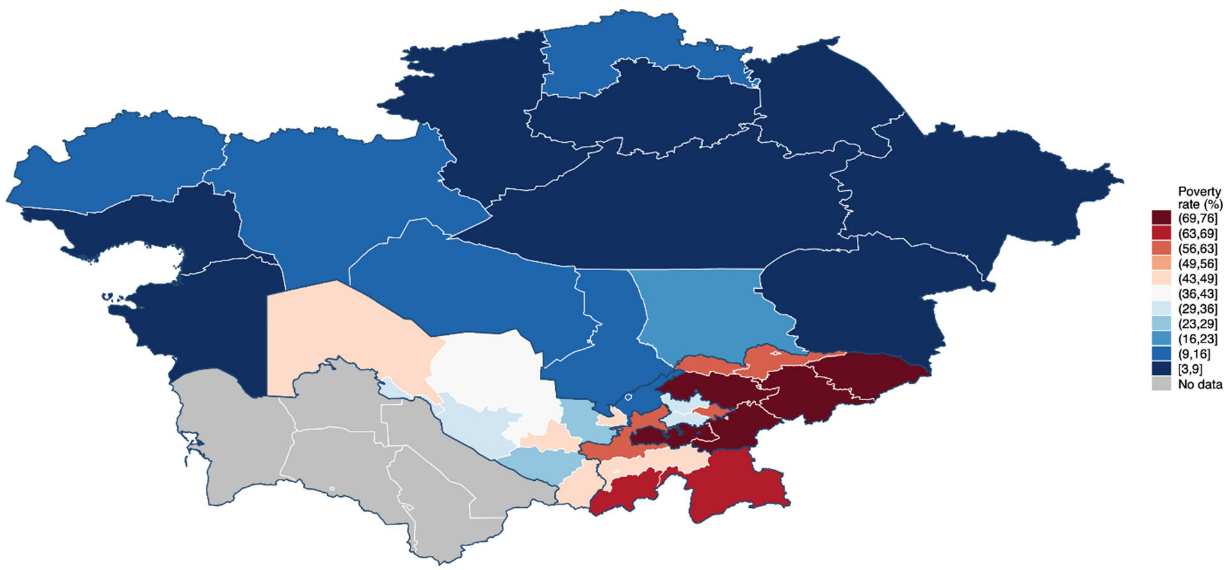


Source: The Listening to the Citizens of Uzbekistan baseline survey, Author's calculations

Turkmenistan alone has no data available at all to estimate internationally comparable estimates. For this reason, it is excluded from the analyses that follow.

In each of the four countries for which data are available, the survey data that are used to generate poverty estimates are usually considered to be representative at the level of regions (rayons) only. When disaggregated further, sampling errors are sufficiently large that confidence intervals substantially overlap. The resulting maps can potentially be misleading. Point estimates indeed suggest a specific value for the poverty rate in a given district, but if the precision of these estimates is ignored, it is easy to miss that the true value of the poverty rate may be much higher or lower. Such interpretations can lead to inappropriate policy decisions. Figure (6) presents harmonized poverty estimates for the four countries in which survey data are available at the level that the underlying surveys are usually considered to be representative. The task for the remainder of this report is to estimate and report welfare indicators, including poverty rates, that are representative at the district level, one step lower than those presented here.

Figure 6: UMIC Poverty Rate by Regions (Oblasts) in Central Asia



Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

I.II – The Middle Class in Kazakhstan, and Average Per Capita Consumption

In Kazakhstan and in each country in Central Asia, growing the middle class is a central aspiration of the government, and one of the key commitments laid out in National Development Strategies. Although poverty has fallen, many people remain vulnerable to economic volatility. A large share of population has a consumption level just above the poverty line for upper middle-income countries and at significant risk of falling below it. As the recent economic downturn in Central Asia showed, there is substantial churning in and out of poverty among households during times of economic hardship, which points to a low degree of resilience. In the context of increased economic volatility, region-wide or idiosyncratic shocks easily translate to reduction in welfare.

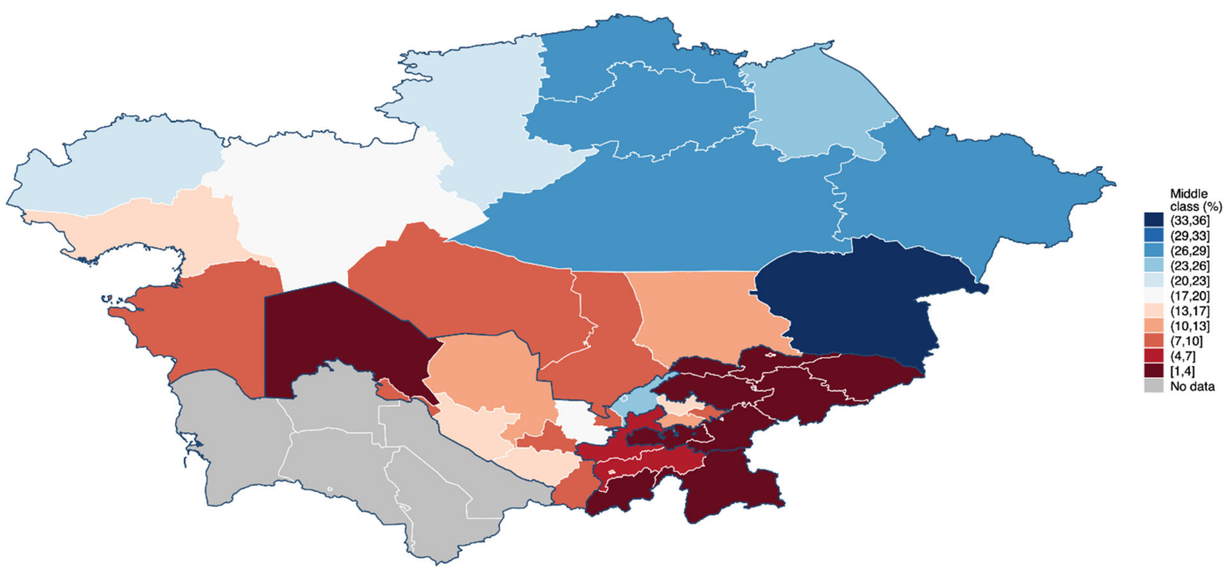
From an economic perspective, exiting that state of vulnerability could be viewed as a transition process to becoming a "middle class" society and highlights the process of reaching a threshold of economic stability associated with a low probability of falling back into poverty. There currently is no official measure of the middle class in Kazakhstan or in the other countries in the region, but in Pittau

& Zelli (2018), the World Bank together with other development partners recently recommended a strategy based on data from the official HBS.

Fixed thresholds are a common approach to measuring and monitoring the evolution of the middle class. But there is a wide variety of thresholds that have been used in varying contexts. One of the most replicated comes from Ferreira et al. (2013) who estimated per capita middle-class income lines of US$10 to US$50 a day in 2005 PPP terms in Latin America and the Caribbean. However, it is not clear that this range makes sense for Kazakhstan, which is quite removed from the context in which these lines were initially set. Thus, the method recommended by the World Bank, and adopted for this study, uses an empirically estimated line calibrated to the context of Kazakhstan using a module of self-reported class membership in the 2013 Kazakh HBS. The approach yields a lower income threshold of 474,000 tenge and an upper threshold of 1,772,000 tenge, which correspond to the 56th and the 99th percentiles of the weighted income distribution. These values in turn correspond to US$14.00 and US$52.20 per day in 2011 international dollars.

Because at this time there is no official middle-class line for the other countries in the region, and the line that has been developed in Kazakhstan is the most articulated definition in the region, this line is used throughout the region for the maps that follow.

Figure 7: The middle class share of the population, by regions (oblasts) of Central Asia

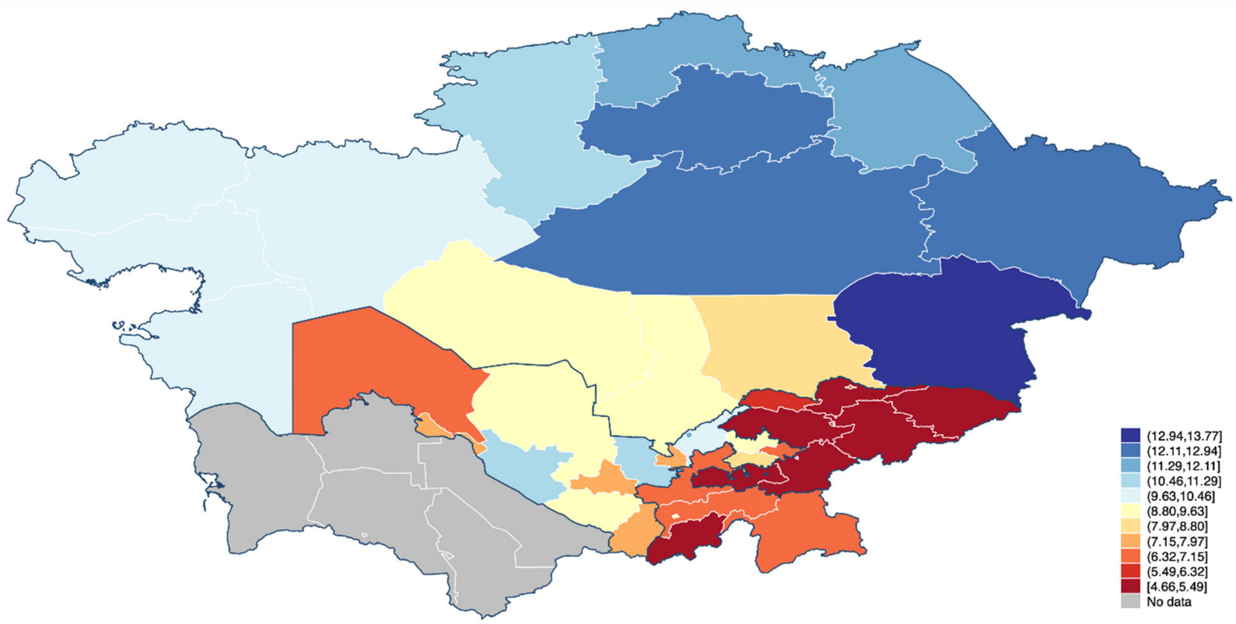


Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

Another important measure of welfare is average consumption, which is a strong proxy for income in countries with large informal and agriculture sectors. Average consumption focuses attention not only on the bottom of the distribution such as poverty indicators in this context. Average consumption can also be measured more precisely and is amenable to small-area estimates in ways that poverty is not in most applications. One drawback of the Fay-Herriot approach in the context of values close to zero (such as percentage values) is that they are more difficult to validate in terms of coefficients of variation (National Research Council, 2013). However, average consumption suffers from no such limitations.

To be comparable across countries, average consumption is adjusted using the PPP conversion factor for each country and expressed in 2011 terms. Figure (8) presents the direct estimates at the regional level.

Figure 8: Average Daily Per Capita Consumption in 2011 PPP



Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

II – Data

Data from two types of sources are generally required to conduct an SAE mapping exercise. The first source is a welfare survey, which is preferably the data with which poverty, consumption, and/or the size of middle class is monitored. The second source must permit disaggregation to the level for which the desired indicator will be estimated and, preferably, include the entire population, rather than a sample. Any sampling for the second source leads to additional error and should be avoided if possible. For the area-based estimates described in this report, publicly available satellite, station, and geographic data aggregated to the district-level are used, none of which suffers from additional constraints due to sampling.

To ensure that the definitions of key indicators defined in the microdata are as similar across countries as possible, the harmonization standard applied by the World Bank in its ECAPOV initiative in generating official World Bank estimates of poverty is used here.

II.I – Districts by Country

Presenting the results and matching the survey data to satellite imagery require identifying the cartography of each country at the district level. This was accomplished using standardized map shapefiles and matching each to the disaggregated location data available for each survey.

Table 1: Survey Data Used

Country	Year	Hhlds	Svy Dist.	Map Dist.	Impute
KAZ	2017	47445	178	202	24
KGZ	2016	19575	40	42	2
TJK	2015	2999	149	159	10
UZB	2018	4013	126	190	64
TKM	None	.	.	.	.

The analyses discussed in this report primarily use the data from the diary/list of food consumed, non-food expenditure, and household composition.

II.II – Kazakhstan HBS data for 2017

Poverty estimates and other welfare indicators for Kazakhstan rely on the 2017 round of the HBS, conducted by the Statistics Agency of the Republic of Kazakhstan. For household consumption and expenditure, the survey is usually considered nationally representative, representative at the oblast (region) level, and separately representative for rural and urban areas. The survey uses a stratified sample design with strata corresponding to 14 regions + 2 large cities crossed by their urban and rural areas (except for Almaty and Astana cities, which are entirely urban). A complete consumption module is gathered in the HBS, covering both food and non-food items. Information on household composition, income, employment, and related topics is also collected. All data for the HBS in Kazakhstan are collected in person, except for consumption, which is collected using a diary-type instrument. The survey is continuous, and representative quarterly within the year for most welfare indicators.

II.III – Uzbekistan L2CU Baseline Survey 2018

Official HBS data for Uzbekistan had not been made available by the National Statistical Agency to the World Bank until recently. However, the L2CU activity, which is conducted by a private firm on behalf of the World Bank and in cooperation with Ministries and the Statistical Agency, included a comprehensive baseline survey appropriate to the needs of poverty mapping. The survey design closely followed the Living Standards Measurement Study (LSMS) surveys and was conducted using a standard two-stage sampling design, in which 200 clusters (administrative territories called mahallas, in the case of Uzbekistan) were randomly selected with probability proportionate to size. The national sample was stratified by region and by urban areas.

Though a national household census would be a preferable sample frame for the first selection step; no such census has been conducted in Uzbekistan since independence from the Soviet Union (a census is currently scheduled for 2022). Instead, the universe of mahallas, the smallest official jurisdiction in Uzbekistan, was used. These data include official population statistics provided by the National Mahalla Committee from official registration data (current as of the first quarter of 2018). The data were re-weighted based on observed population totals within the mahallas at the time of the survey fieldwork. The second stage procedure was conducted using simple random selection with equal probability within selected mahallas. A separate stratification level for households that receive social assistance was included, totaling 4 households per mahalla. The final sample included 4,000 households in total (20 households per mahalla), 800 of which were social protection recipients by design.

The baseline survey included a full consumption and expenditure module using a list/recall approach. The resulting estimates are representative for 12 regions, 1 autonomous republic, and 1 independent city (Tashkent), crossed with their urban areas (except for the City of Tashkent, which is entirely urban). The survey was conducted entirely on tablet devices (CAPI), enabling validation using cross-referencing and other techniques to ensure accuracy. The survey was conducted over the course of a 1.5-month period in May/June 2018. Although the L2CU study collected data continuously, the baseline is the only source that provides a comprehensive consumption and expenditure module.

II.IV – Kyrgyz Republic HBS 2016

Poverty rates and other welfare estimates for Kyrgyzstan rely on the 2016 round of the Kyrgyzstan HBS, conducted by the National Statistical Agency. For household consumption, the survey is usually considered nationally representative, representative at the oblast (region) level, and separately representative for rural and urban areas. The survey uses a stratified sample design with strata corresponding to seven regions + 1 large city (Bishkek) crossed by their urban and rural areas. A complete consumption module (using a diary approach) is gathered in the HBS, covering both food and non-food items. Information on household composition, income, employment, and related topics is also collected. All data are collected in-person, and in most recent years using a CAPI system.

II.V – Tajikistan L2T Baseline Survey for 2015

Although the Tajikistan HBS survey is made available to the World Bank and other development partners, the sampling design used is not well-suited to the purposes of poverty mapping because the geographic coverage of the survey is limited in comparison to other options. Geographic coverage is crucial in the context of poverty mapping, and as an alternative, a survey with a more widely distributed sample was used. The baseline for the L2T Survey was selected because it: i) used the 2010 national census sample frame for the L2T baseline survey conducted by the national statistical agency, and ii) used a widely distributed traditional stratified two-stage clustered sample design. In the first stage, 150 clusters were selected, with a probability of selection proportional to size. In the second stage, 3,000 households were selected to participate in the survey.

The sample was designed to be nationally representative for consumption and expenditure. The survey was conducted over a two-month period beginning in March 2015. CAPI systems were used and all data were collected in person. As with the L2CU study, continuous data collection was conducted following the baseline survey, however, no comprehensive consumption or expenditure model was included in follow-up rounds. The interviews were implemented under the supervision of the Ministry of Health and Social Protection of Tajikistan and the World Bank.

II.VI – Satellite and Administrative Data

The main source of satellite and administrative data for this study is the AidData project at the college of William and Mary.[3] The spatially aggregated data available for Kazakhstan from this source include:

1) World Bank project locations
2) Yearly VIIRS day night band nighttime lights data (without stray light correction)
3) Version 4 DMSP-OLS Nighttime Lights composites. The lights from cities, towns, and other sites with persistent lighting, including gas flares. Ephemeral events, such as fires have been discarded. Calibrated across sensors and years using Elvidge 2014 coefficients
4) Average precipitation per year, created using UDel Precipitation data set (v4.01)
5) Average air temperature per year, created using UDel Air Temperature dataset (v4.01)
6) Global slope (in degrees) derived from Shuttle Radar Topography Mission (SRTM) data set (v4.1) at 500m resolution
7) Global elevation (in meters) from Shuttle Radar Topography Mission (SRTM) data set (v4.1) at 500m resolution
8) Binary indicating locations with deposits of known on-shore oil and gas deposits
9) Standard MODIS land cover type data product (MCD12Q1) in the IGBP Land Cover Type Classification
10) Yearly value for Normalized Difference Vegetation Index (NDVI). Created using the NASA Long Term Data Record (v4) AVHRR data

[3] Data available at http://geo.aiddata.org/query/#!/

11) Population density (UN Adjusted values) from Gridded Population of the World v4.GPWv4 depicts the density of human population across the globe; source data provided in 30 arc-second (~1 km) grid cells
12) Map of total economic activity, including both formal and informal economic activity for ~2006; created from nighttime lights and LandScan population grid
13) Distance to coast (on land only), measured in meters; derived using World Vector Shorelines
14) Distance to water, measured in meters; derived using World Vector Shorelines combined with rivers and lakes from World Data Bank 2 (via Natural Earth)
15) Distance to roads, measured in meters, based on the Global Roads Open Access Dataset (gRoads) version 1.0
16) Distance to country borders, measured in meters; derived using GADM 2.8 ADM0 (country) boundaries
17) Particulate matter (PM2.5) estimate, based on prediction model using combination of satellite-based estimate and TM5-FASST simulation
18) Estimated travel time (in minutes) to the nearest city of 50,000 or more people in year 2000.

III – Fay-Herriot Small Area Estimation Model

The basic area-level model setup is as follows. Let P_i be the true poverty or middle-class incidence in each geographic area *i*, and let the sampling model be defined by:

$$p_i = P_i + e_i,$$

where p_i is the observed survey direct estimate of poverty headcount ratio (or middle-class headcount ratio) P_i, and e_i is the sampling error associated with p_i, such that $e_i | P_i \sim N(0, \varphi_i)$ and φ_i are assumed to be known. The linking model is defined as:

$$P_i = X_i\beta + u_i,$$

where X_i denotes a vector of area characteristics, and u_i are independent and identically distributed random errors with $E(u_i) = 0$ and $Var(u_i) = \sigma_u^2$. The data on X_i are obtained from publicly available sources at the area-level, largely from administrative sources focusing on geography, and from continuous monitoring data from satellites or weather stations, and hence are free of sampling error. Combining the above sampling and linking models, it follows that the observed poverty or middle-class membership rates from the survey can be modeled as follows:

$$p_i = X_i\beta + u_i + e_i.$$

Given this setup, the best linear unbiased estimator of $P_i = X_i\beta + u_i$, one that minimizes the mean squared error $MSE(\tilde{P}_i) = E(\tilde{P}_i - P_i)^2$ is:

$$\tilde{P}_i^{BLUP} = X_i\beta + u_i,$$

where $u_i = \gamma_i(p_i - X_i\beta)$, and $\gamma_i = \frac{\sigma_u^2}{\varphi_i + \sigma_u^2}$ is referred to as a "shrinkage factor". Given that σ_u^2 is unknown, the Best Linear Unbiased Predictor (BLUP) is replaced with its empirical counterpart EBLUP: $\widehat{P}_i^{\,EBLUP} = \tilde{P}_i^{BLUP}(\hat{\sigma}_u^2)$, which can be rewritten as:

$$\widehat{P}_i^{\,EBLUP} = \widehat{\gamma}_i p_i + (1 - \widehat{\gamma}_i\,)X_i\tilde{\beta}\ ,$$

where $\tilde{\beta}$ is the Feasible GLS estimator for β and $\widehat{\gamma}_i = \frac{\hat{\sigma}_u^2}{\varphi_i + \hat{\sigma}_u^2}$. Thus, $\widehat{p}_i$ is a weighted average of the direct survey estimate p_i and the synthetic (model-based) estimate $X_i\tilde{\beta}$, and the weights are given by $\hat{\gamma}_i$. For p_i with smaller sampling variances φ_i the shrinkage factor gives higher weight to the direct estimate, while for p_i with higher sampling variances a higher weight is assigned to the synthetic estimate. In areas that are not part of the survey sample, the prediction is based on the synthetic estimate $X_i\hat{\beta}$, where $\hat{\beta} = \tilde{\beta}(\hat{\sigma}_u^2)$. The prediction error associated with $\hat{p}_i$ takes account of the sampling variance associated with p_i, as well as the uncertainty associated with the estimate of β and σ_u^2 (see Rao, 2003 for more details).

When calculating the term φ_i needed for the Fay-Herriot approach, there are several potential methods for considering the stratified and clustered two stage sample designs of the surveys used in this application. Perhaps the simplest approach is to use the Horvitz-Thompson (HT) estimator of P_i, which can be expressed as:

$$\sum_{i \in s_d} w_i p_i$$

The term s_d denotes the set of sampled units in domain *d*. However, the HT estimator is often not preferred in SAE applications (National Research Council, 2013; Eurostat, 2013). It is commonly unstable, especially for small domains with few survey observations (a common challenge in this context). To address this, there are various alternative direct estimators that may out-perform the HT estimator.

Common practice in the World Bank has been to obtain sampling variances associated with the district-level poverty rates by taking the variance estimate from the survey data source and dividing it by the sample size for each domain to obtain a set of "smoothed" sampling variance estimates. This ignores components of the clustered sample design; however, these smoothed sampling variances are commonly less volatile than simple weighted direct HT estimates.

A final approach is to compute variance and the associated root mean square error of the mean using the linearized variance estimator approach—based on a first-order Taylor series (Wolter 2007). In sensitivity analyses this was the most stable variance measure of the three described here, and the preferred approach for this application. Annex G reports comparisons and analysis of sensitivity to the choice of domain variance measure. Final results are quite similar when comparing the second ("smoothed") and third ("linearized") options described, though as expected, the HT approach yields results that are more distant from those of the remaining two options. For more detail on the trade-off between approaches for domain variance estimation, see Heeringa et. al., (2017); Molina and Rao (2010); Wolter (2007); and Kolenikov (2010).

The results of the SAE estimates are presented graphically in the following section. Separate modeling exercises are conducted for each welfare indicator. The model variables that are part of the X vector in the estimation procedure were chosen to maximize the ratio of explained variance to the total variance, as captured by the adjusted R^2.[4] There is no pre-set group of variables that are guaranteed to achieve that objective. Instead, automated variable selection using the stepwise approach was used. Sensitivity analysis comparing the results to alternative model development approaches (including several variations of the lasso approach) are described in annex I.

IV – Results

Summarizing poverty rates by region (at which the underlying surveys are themselves considered representative) yields a range of between 0 and 27.7 percent at the poverty line for lower middle-income countries ($3.2 PPP per person, per day), and between 0 and 76 percent for the line appropriate for upper middle-income countries ($5.5 PPP per person, per day). But this level of aggregation hides significant variation within regions. When disaggregated to the district level, the resulting poverty estimates for the LMIC line range from 0 percent to 70 percent, and many individual districts register nearly 100 percent poverty rates at the UMIC line, despite a lower average poverty rate in the surrounding region.[5]

Poverty rates at the LMIC line are relatively low throughout Kazakhstan and in much of Uzbekistan. However, pockets of high poverty rates remain in the Kyrgyz Republic and in Tajikistan. The parts of the Ferghana Valley within Uzbekistan's borders have relatively low rates of poverty but nearby districts in the Kyrgyz Republic and Tajikistan with somewhat higher rates of poverty.

Even stronger regional disparities are apparent when using the UMIC line. Poverty by this definition was still less than 10 percent in Kazakhstan in 2017, but this stands in contrast to much higher rates in the Kyrgyz Republic, Tajikistan, and to a lesser extent, Uzbekistan. In Tajikistan and the Kyrgyz Republic there are districts in which nearly all people are poor by the UMIC line, whereas the highest rate in Kazakhstan is 44 percent.

Throughout Central Asia, most of the poor live in the most populated districts, despite the higher poverty rates prevalent in some of the sparsely populated and mountainous regions. The density of the population below the poverty threshold (i.e. the absolute number of poor individuals, obtained as the product of the predicted poverty rate and population of the district) is concentrated in the more densely populated areas in each country. Rural areas are much poorer than urban areas on average, and remote areas have higher average poverty rates. Districts that border on Afghanistan also tend to be poorer. Figures 9-12 (and 17-31) in the following depict each of the welfare indicators derived using the Fay-Herriot approach in this application.

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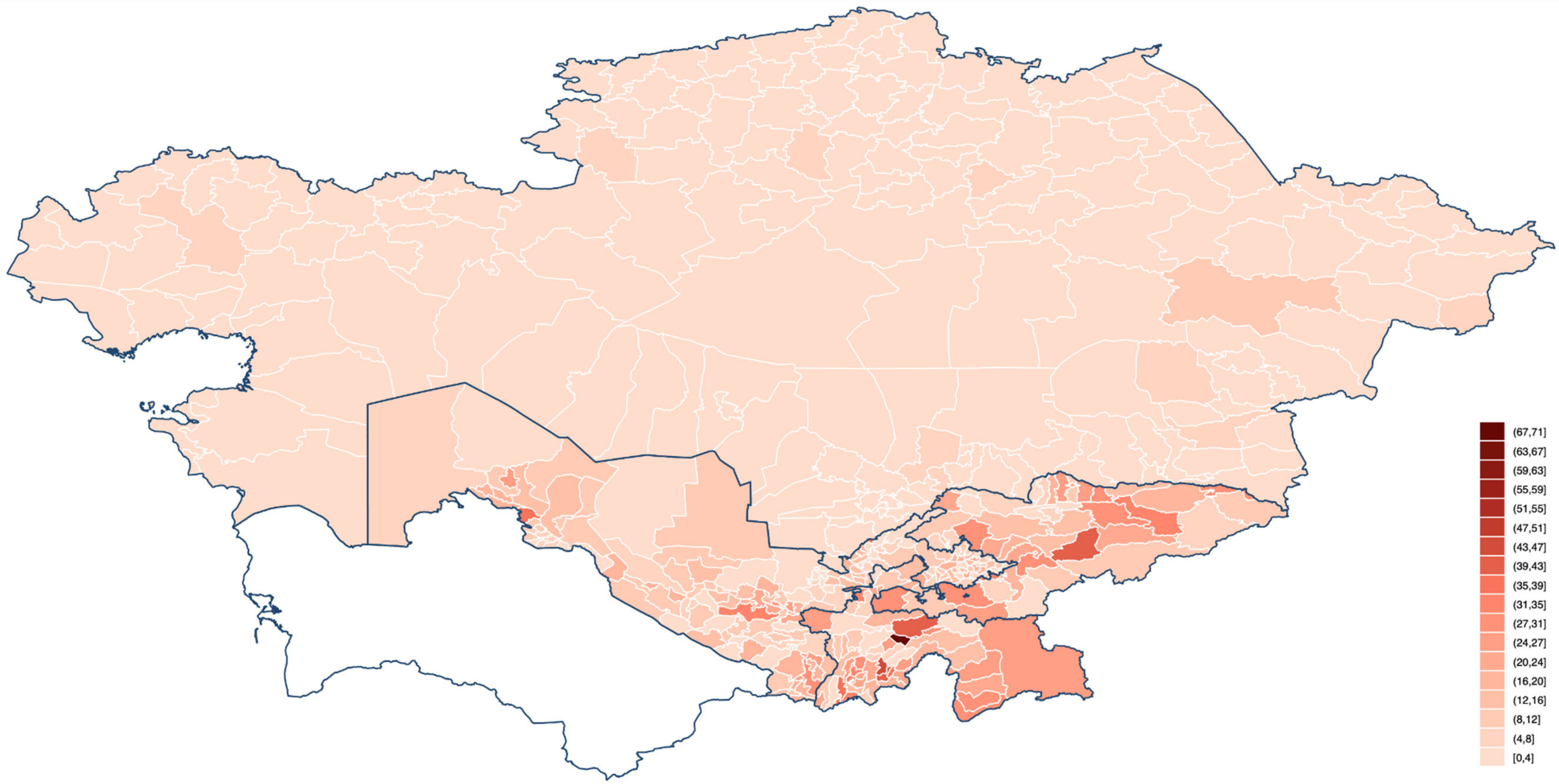
[4] Adjusted R is chosen instead of (unadjusted) R because the latter is non-decreasing in the number of explanatory variables in the model.

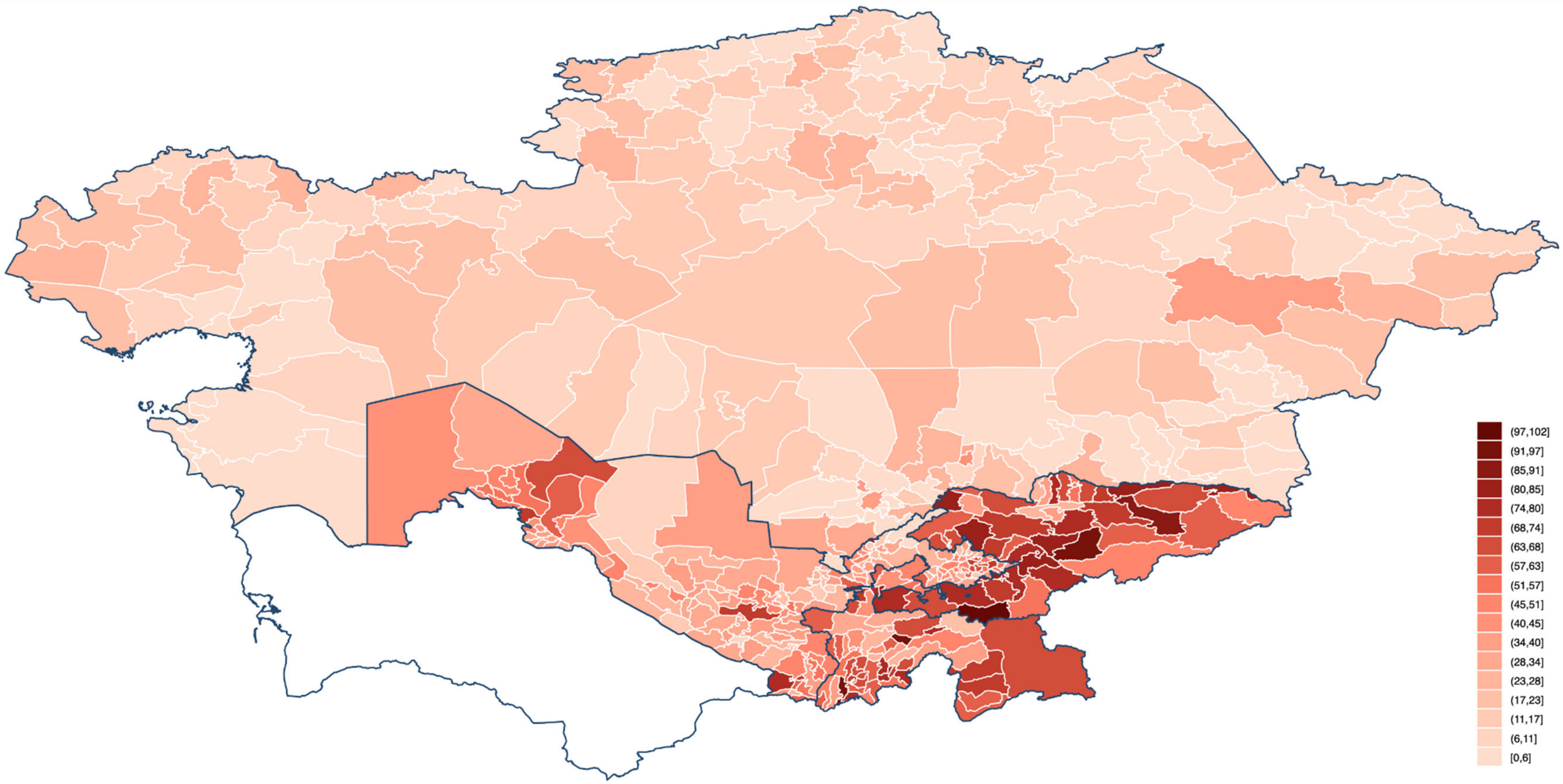
[5] The district-level estimates are reported in Annexes A-D.

Figure 9: Poverty headcount ratio at $3.2-a-day PPP per person, rates for Central Asia



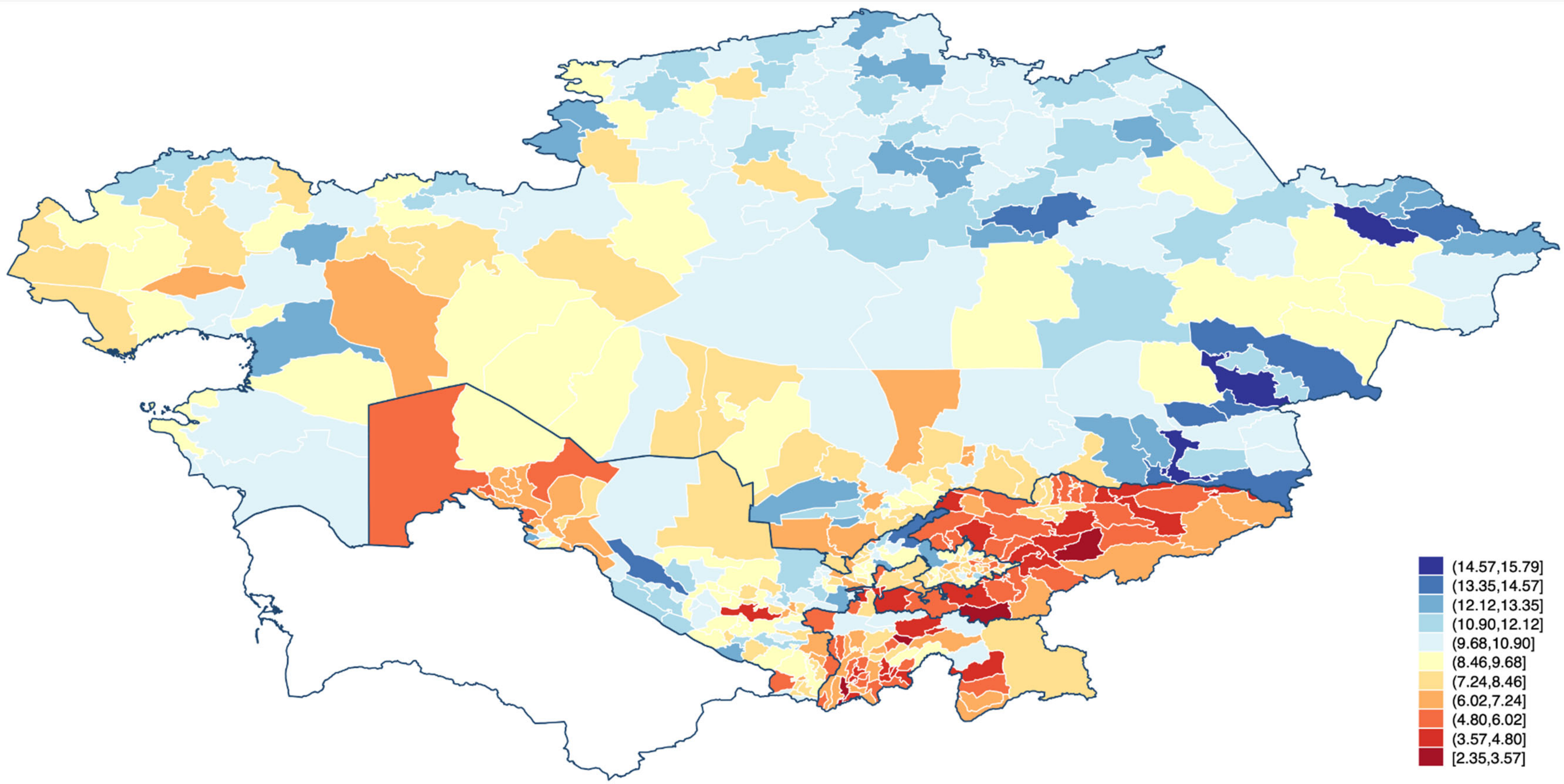
Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

Figure 10: Poverty at $5.5-a-day PPP per person, rates for Central Asia



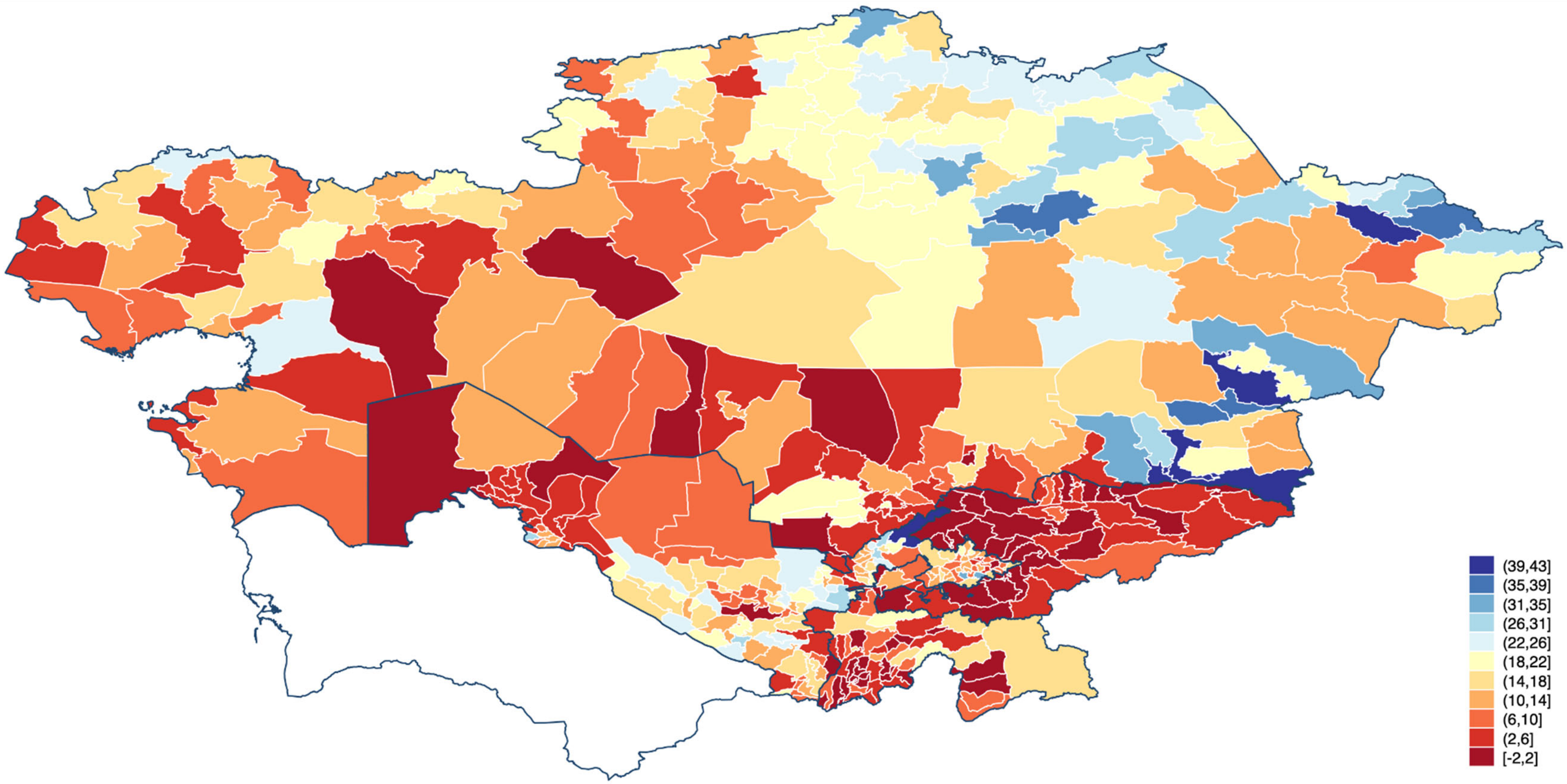
Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

Figure 11: Average Per Capita Consumption 2011 PPP



Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

Figure 12: Share of Population in the Middle Class in Central Asia



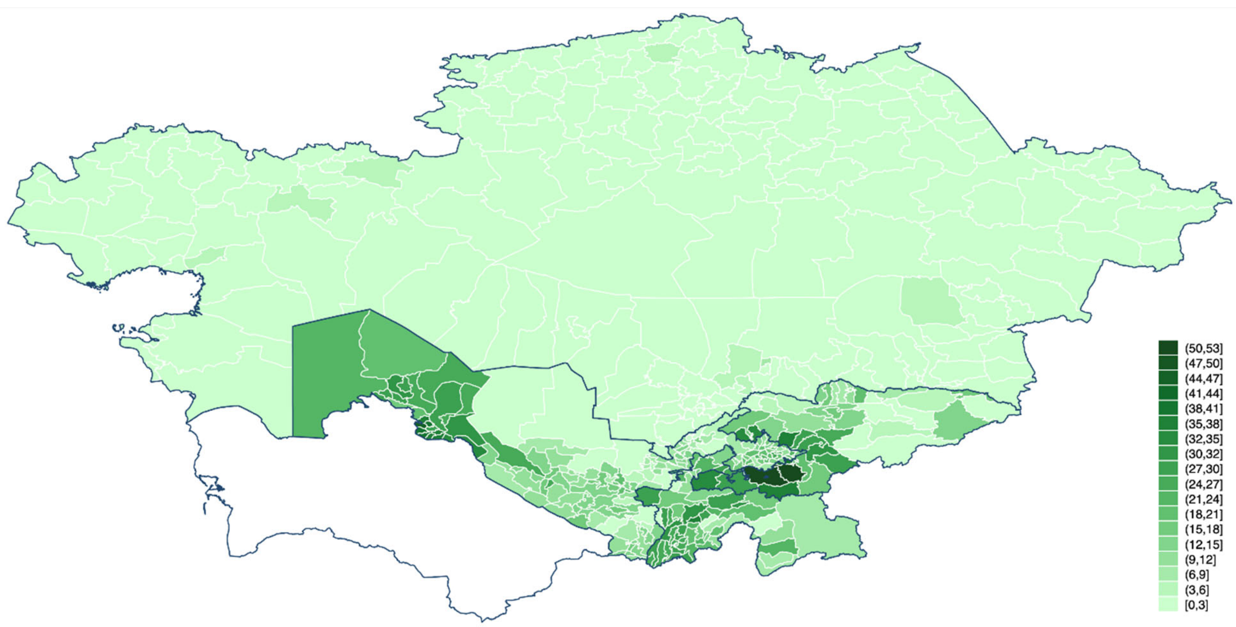
Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016). All welfare measures are reported in real PPP terms. Welfare data are spatially deflated within country.

V – Concluding Remarks and Example Applications

Millions of people have left poverty in Central Asia over the past two decades. But some areas are improving more quickly than others. Insufficient sample sizes in most standard surveys are a barrier to better understanding the dynamics of economic convergence in Central Asia. This study partially addresses the challenge. Key welfare indicators are improved upon by unifying survey data from across the region and applying the techniques of small-area estimation.

These maps have many potential practical uses. Given the high rates of migration and remittance-dependence in the region, one important example is to compare rates of migration to poverty rates at the district level. Figure (13) provides the share of households with at least one migrant member by district.

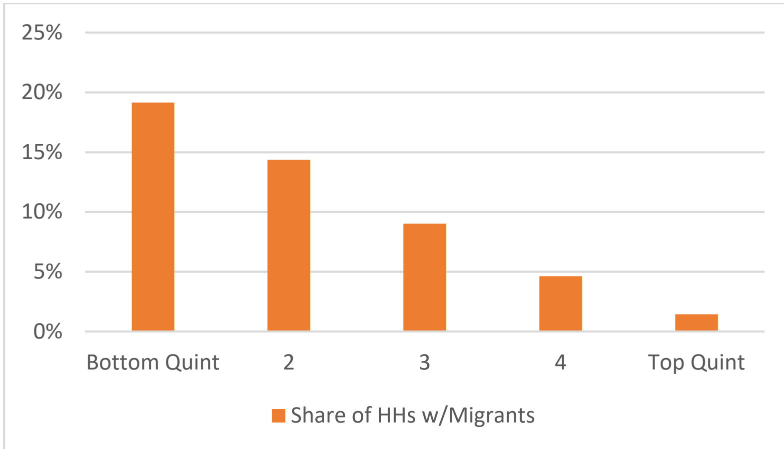
Figure 13: Share of Households with at Least One Member Abroad for Work



Notes: Sources include the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016).

Comparing these estimates highlights how labor migrants from Central Asia disproportionally originate in some of the poorest districts in the region. The correspondence suggests that migrants significantly contribute to the region's poorest areas through both remittances and investment. About 19 percent of households in bottom quintile districts have at least one migrant abroad, compared to less than 2 percent in top quintile districts.

Figure 14: District Share of HHs with Migrants by District Per Capita Consumption Quintile

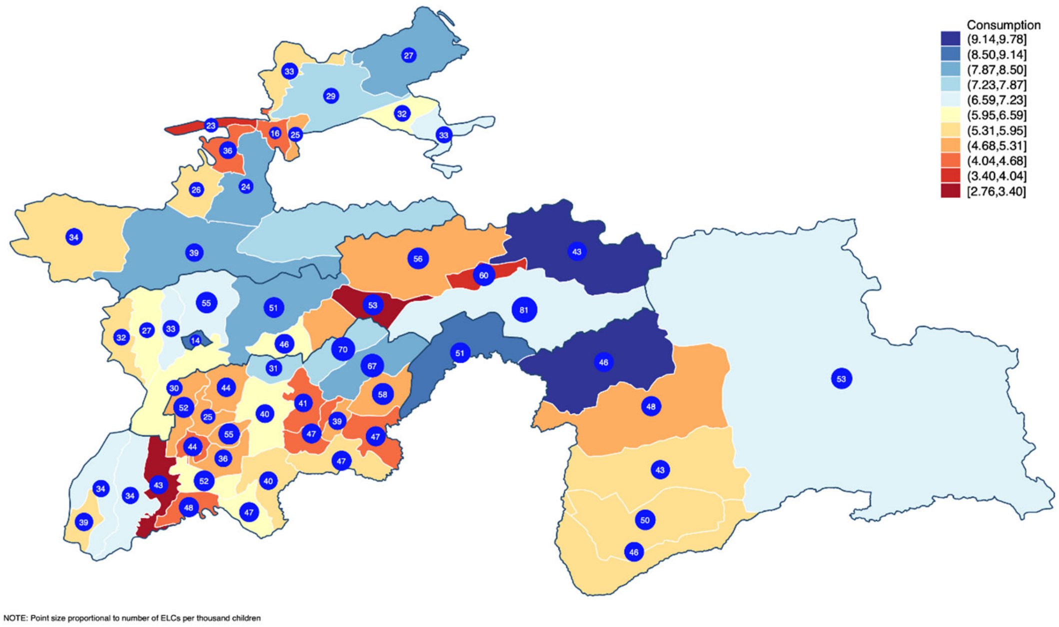


Source: Author's calculations on the basis of the baseline survey for Listening to the Citizens of Uzbekistan (2018), the baseline survey for Listening to Tajikistan (2015), the household budget survey of Kazakhstan (2017), and the household budget survey for Kyrgyzstan (2016).

These results complement other analyses that focus on migration; providing useful regional context to this analysis. Where household-level determinants of migration have been analyzed in more detail, there is a strong relationship between migration and local economic challenges, including low labor force participation, household welfare shocks, and living in an area with greater dependence on social protection benefits. Absent financial support from migrants, poverty rates and unemployment rates in struggling regions would be significantly higher, while average incomes would be much lower.

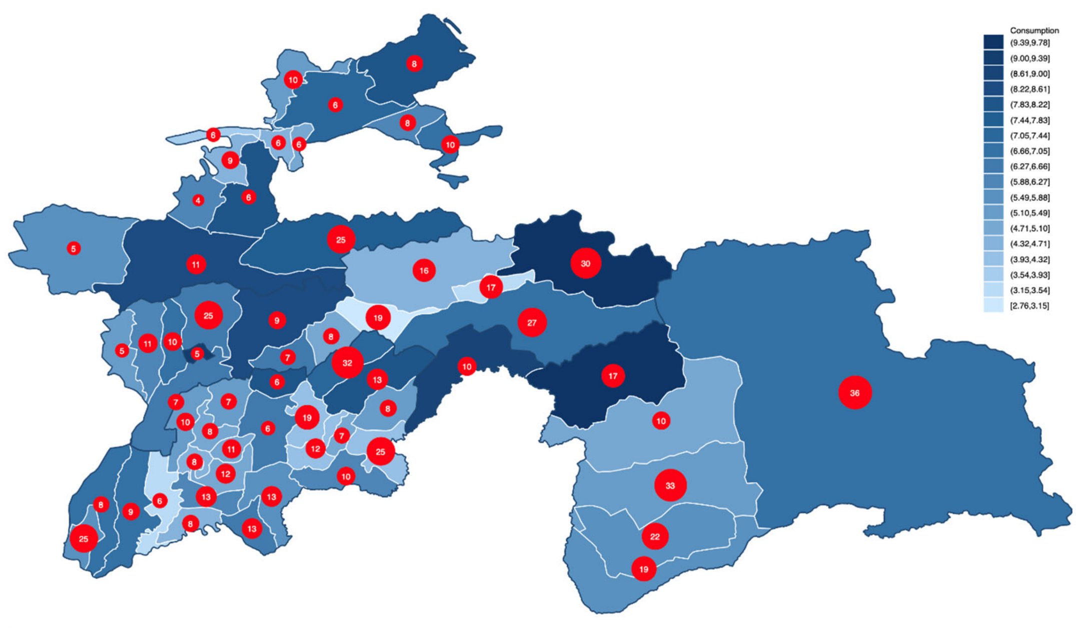
Another example is country specific: in Tajikistan, the government and World Bank are in advanced discussions of expanding the number of kindergartens and early childhood learning centers. But what areas need more assistance? The following figures (15-16) overlay the poverty maps for the country with details on the number of educational facilities per 1,000 children, highlighting areas with significant co-incidence of high poverty rates and low coverage.

Figure 15: Number of Early Learning Centers per 1000 Children



Source: Author's calculations based on administrative data from the Ministry of Education in Tajikistan and the baseline survey for Listening to Tajikistan (2015)

Figure 16: Number of Kindergartens per 1000 Children



Source: Author's calculations based on administrative data from the Ministry of Education in Tajikistan and the baseline survey for Listening to Tajikistan (2015)

These results thus provide detailed measures of welfare that in turn can be disaggregated for each district in Central Asia. The results highlight the heterogeneity of progress in the region. Poverty estimates range from 0 to nearly 100 percent by both the LMIC poverty line and the UMIC line. The results are robust to many separate validation approaches.

The maps created with these data can be used to identify areas where progress is being achieved most rapidly, as well as those areas that are lagging. With better and more detailed information at the ready, policies and interventions can be better targeted to support people in need where they live.

VI – References

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VII – Annexes

Annex A – Kazakhstan District-level Results 2017

Table 2: Kazakhstan District-level Results 2017

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Almaty	Aksuskiy		0.000	0.000	0.056	0.021	0.571	0.039	14.896	0.643
Almaty	Alakolskiy		0.000	0.000	0.132	0.035	0.657	0.043	13.741	0.838
Almaty	Almaty (Alma-Ata)		0.001	0.001	0.020	0.004	0.574	0.013	14.828	0.221
Almaty	Balkhashskiy	*	0.000	0.083	0.143	0.144	0.846	0.077	9.897	1.832
Almaty	Enbekshikazakhskiy		0.000	0.000	0.092	0.013	0.777	0.018	11.332	0.303
Almaty	Iliyskiy		0.000	0.000	0.020	0.010	0.728	0.029	12.578	0.722
Almaty	Karasayskiy		0.000	0.000	0.048	0.009	0.610	0.019	14.202	0.338
Almaty	Karatal`Skiy	*	0.053	0.081	0.201	0.141	0.871	0.075	9.595	1.794
Almaty	Kerbulakskiy	*	0.044	0.082	0.125	0.142	0.821	0.076	10.706	1.801
Almaty	Koksuskiy		0.000	0.000	0.024	0.015	0.639	0.043	14.114	0.915
Almaty	Panfilovskiy		0.000	0.000	0.039	0.013	0.881	0.020	9.824	0.276
Almaty	Raiymbekskiy		0.000	0.000	0.000	0.000	0.594	0.038	14.369	0.350
Almaty	Sarkandskiy		0.000	0.082	0.043	0.142	0.784	0.076	11.538	1.811
Almaty	Taldyqorghan		0.000	0.000	0.013	0.007	0.620	0.027	14.151	0.483
Almaty	Talgarskiy		0.000	0.000	0.026	0.011	0.570	0.032	15.789	0.698
Almaty	Uygurskiy		0.000	0.000	0.016	0.011	0.862	0.028	10.246	0.396
Almaty	Zhambylskiy		0.000	0.000	0.020	0.011	0.680	0.033	12.491	0.511
Aqmola	Akkol`Skiy		0.008	0.008	0.111	0.027	0.810	0.031	10.340	0.456
Aqmola	Arshalynskiy		0.049	0.034	0.153	0.054	0.842	0.047	9.804	0.855
Aqmola	Astrakhansiy		0.000	0.000	0.019	0.024	0.749	0.062	12.307	0.857
Aqmola	Atbasarskiy		0.020	0.017	0.236	0.050	0.787	0.043	10.093	0.689
Aqmola	Bulandynskiy		0.000	0.000	0.066	0.043	0.778	0.058	11.137	0.943

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Aqmola	Egindykol`Skiy	*	0.022	0.082	0.193	0.141	0.811	0.079	9.715	1.790
Aqmola	Enbekshil`Derskiy	*	0.019	0.081	0.123	0.141	0.823	0.079	10.239	1.792
Aqmola	Ereymengauskiy		0.022	0.018	0.116	0.038	0.798	0.042	10.584	0.651
Aqmola	Esil`Skiy		0.000	0.000	0.058	0.041	0.782	0.059	11.156	0.941
Aqmola	Korgalzhynskiy	*	0.008	0.082	0.175	0.141	0.783	0.080	9.842	1.791
Aqmola	Sandyktauskiy		0.000	0.000	0.106	0.043	0.788	0.050	10.505	0.665
Aqmola	Shortandinskiy		0.000	0.000	0.000	0.000	0.760	0.061	12.406	1.044
Aqmola	Shuchinskiy		0.010	0.008	0.134	0.029	0.827	0.030	10.104	0.467
Aqmola	Tselinogradskiy		0.000	0.000	0.015	0.004	0.681	0.014	12.983	0.166
Aqmola	Zerendinskiy		0.010	0.007	0.111	0.023	0.739	0.030	11.893	0.514
Aqmola	Zhaksynskiy		0.048	0.035	0.228	0.065	0.808	0.052	10.163	1.022
Aqmola	Zharkainskiy		0.000	0.000	0.126	0.059	0.884	0.046	8.444	0.612
AqtöBe	Alginskiy		0.000	0.000	0.084	0.053	0.891	0.052	9.661	0.761
AqtöBe	Aqtobe		0.002	0.002	0.072	0.011	0.791	0.017	10.940	0.235
AqtöBe	Aytekebiyskiy		0.007	0.012	0.107	0.043	0.868	0.044	10.050	0.887
AqtöBe	Bayganinskiy		0.014	0.021	0.191	0.068	0.986	0.019	7.216	0.399
AqtöBe	Irgizskiy		0.018	0.026	0.225	0.071	0.986	0.017	7.460	0.476
AqtöBe	Kargalinskiy		0.000	0.000	0.000	0.000	0.812	0.065	12.026	1.072
AqtöBe	Khobdinskiy		0.000	0.000	0.068	0.038	0.837	0.049	10.658	1.254
AqtöBe	Khromtauskiy		0.000	0.000	0.090	0.039	0.852	0.042	10.173	0.645
AqtöBe	Martukskiy		0.000	0.000	0.275	0.083	0.881	0.052	9.308	1.077
AqtöBe	Mugalzharskiy		0.018	0.013	0.186	0.039	0.947	0.021	7.563	0.320
AqtöBe	Shalkarskiy		0.000	0.000	0.133	0.043	0.878	0.038	9.500	0.536
AqtöBe	Temirskiy		0.000	0.000	0.176	0.072	0.942	0.038	8.237	0.607
AqtöBe	Uilskiy		0.000	0.000	0.000	0.000	0.792	0.062	12.295	1.017
Atyrau	Atyrau		0.000	0.000	0.044	0.011	0.861	0.018	10.118	0.245
Atyrau	Inderskiy		0.000	0.000	0.137	0.047	0.978	0.019	7.207	0.287
Atyrau	Isatayskiy		0.000	0.000	0.078	0.036	0.910	0.035	8.853	0.513

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Atyrau	Kurmangazinskiy		0.000	0.000	0.182	0.037	0.935	0.022	8.339	0.346
Atyrau	Kzylkoginskiy		0.000	0.000	0.012	0.016	0.851	0.045	10.426	0.605
Atyrau	Makatskiy	*	0.022	0.081	0.146	0.141	0.921	0.076	9.540	1.800
Atyrau	Makhambetskiy		0.000	0.000	0.049	0.033	0.842	0.047	10.796	0.643
Atyrau	Zhylyoyskiy		0.000	0.000	0.000	0.000	0.759	0.040	12.393	0.538
East Ka	Abayskiy	*	0.010	0.081	0.143	0.141	0.888	0.076	10.045	1.794
East Kaz	Ayagozskiy		0.098	0.040	0.344	0.062	0.873	0.041	8.913	0.933
East Kaz	Beskaragayskiy	*	0.006	0.081	0.143	0.141	0.873	0.075	10.074	1.790
East Kaz	Borodulikhinskiy		0.000	0.000	0.109	0.035	0.818	0.040	10.704	0.637
East Kaz	Glubokovskiy		0.000	0.000	0.044	0.026	0.704	0.046	12.924	0.904
East Kaz	Katon-Karagayskiy		0.000	0.000	0.066	0.034	0.699	0.051	12.409	1.470
East Kaz	Kokpektinskiy		0.000	0.000	0.048	0.031	0.908	0.035	9.349	0.461
East Kaz	Kurchumskiy		0.013	0.016	0.201	0.057	0.811	0.047	10.762	0.920
East Kaz	Leninogorsk		0.000	0.000	0.036	0.021	0.679	0.045	12.968	0.681
East Kaz	Semipalatinskiy		0.003	0.003	0.050	0.011	0.721	0.021	12.106	0.313
East Kaz	Shemonaikhinskiy		0.047	0.019	0.153	0.032	0.753	0.035	11.659	0.684
East Kaz	Tarbagatayskiy		0.000	0.000	0.235	0.061	0.870	0.041	9.030	0.585
East Kaz	Ulanskiy		0.004	0.003	0.045	0.010	0.577	0.023	15.149	0.500
East Kaz	Urdzharskiy		0.008	0.010	0.192	0.042	0.895	0.029	8.548	0.404
East Kaz	Zaysanskiy	*	0.040	0.081	0.128	0.141	0.825	0.076	10.270	1.802
East Kaz	Zharminskiy		0.000	0.000	0.026	0.021	0.895	0.038	9.180	0.550
East Kaz	Zyryanovsk		0.000	0.000	0.019	0.014	0.644	0.042	13.886	0.793
Mangghystau	Aqtau		0.000	0.000	0.012	0.007	0.901	0.019	10.202	0.200
Mangghystau	Beyneuskiy		0.000	0.000	0.086	0.029	0.982	0.013	8.478	0.233
Mangghystau	Karakiyanskiy		0.000	0.000	0.033	0.012	0.916	0.018	10.036	0.217
Mangghystau	Manghystauskiy		0.000	0.000	0.015	0.012	0.900	0.029	10.194	0.337
Mangghystau	Tupkaraganskiy		0.000	0.000	0.024	0.016	0.969	0.016	8.760	0.187
North Kaz	Akzharskiy	*	0.000	0.082	0.108	0.141	0.775	0.081	10.602	1.793

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
North Kaz	Ayyrtauskiy		0.006	0.011	0.138	0.048	0.817	0.045	9.967	0.684
North Kaz	Bulaevskiy		0.000	0.000	0.000	0.000	0.853	0.047	10.210	0.507
North Kaz	Esil`Skiy		0.027	0.030	0.194	0.068	0.788	0.056	10.422	0.993
North Kaz	Kyzylzharskiy		0.018	0.008	0.109	0.018	0.671	0.026	12.500	0.388
North Kaz	Mamlyutskiy	*	0.000	0.082	0.128	0.141	0.777	0.081	10.380	1.794
North Kaz	Shal Akyna		0.009	0.011	0.236	0.048	0.779	0.042	10.346	0.745
North Kaz	Sovetskiy		0.025	0.028	0.144	0.058	0.788	0.054	10.565	0.903
North Kaz	Taiynshinskiy		0.000	0.000	0.000	0.000	0.744	0.058	12.593	0.645
North Kaz	Timiryazevskiy		0.000	0.000	0.075	0.042	0.760	0.056	11.553	0.886
North Kaz	Tselinniy		0.000	0.000	0.110	0.043	0.814	0.046	10.038	0.638
North Kaz	Ualikhanovskiy	*	0.000	0.082	0.098	0.141	0.764	0.082	10.502	1.794
North Kaz	Zhambylskiy		0.000	0.000	0.019	0.023	0.788	0.055	11.125	0.804
Pavlodar	Aksuskiy		0.000	0.000	0.030	0.016	0.722	0.038	12.534	0.530
Pavlodar	Aktogayskiy	*	0.000	0.082	0.131	0.141	0.808	0.081	10.092	1.793
Pavlodar	Bayanaul`Skiy		0.000	0.000	0.080	0.043	0.804	0.052	10.150	0.657
Pavlodar	Ekibastuz		0.000	0.000	0.061	0.019	0.716	0.032	11.743	0.414
Pavlodar	Irtyshskiy		0.000	0.000	0.000	0.000	0.748	0.066	11.877	0.994
Pavlodar	Kachirskiy		0.011	0.025	0.152	0.074	0.803	0.060	10.242	1.061
Pavlodar	Lebyazhinskiy		0.000	0.000	0.176	0.078	0.809	0.062	10.180	1.073
Pavlodar	Mayskiy		0.000	0.000	0.032	0.036	0.899	0.045	8.921	0.621
Pavlodar	Pavlodarskiy		0.001	0.001	0.044	0.010	0.764	0.020	11.590	0.305
Pavlodar	Sherbaktinskiy		0.000	0.000	0.041	0.035	0.800	0.057	10.568	0.837
Pavlodar	Uspenskiy		0.014	0.030	0.116	0.069	0.723	0.069	11.141	1.546
Pavlodar	Zhelezinskiy		0.007	0.015	0.081	0.045	0.733	0.059	11.939	0.844
Qaraghandy	Abayskiy		0.007	0.006	0.095	0.022	0.671	0.033	13.244	0.607
Qaraghandy	Aktogayskiy		0.000	0.000	0.075	0.030	0.775	0.041	11.383	0.618
Qaraghandy	Bukhar-Zhyrauskiy		0.001	0.001	0.055	0.008	0.652	0.016	13.576	0.278
Qaraghandy	Karkaralinskiy		0.000	0.000	0.081	0.046	0.839	0.049	9.695	0.706

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Qaraghandy	Nurinskiy		0.010	0.020	0.104	0.058	0.777	0.062	11.091	1.346
Qaraghandy	Osakarovskiy		0.000	0.000	0.137	0.046	0.732	0.052	11.835	0.872
Qaraghandy	Shetskiy		0.011	0.012	0.179	0.044	0.878	0.033	8.692	0.446
Qaraghandy	Ulytauskiy		0.018	0.008	0.152	0.021	0.833	0.022	10.363	0.592
Qaraghandy	Zhanaarkinskiy		0.023	0.025	0.171	0.059	0.810	0.050	9.690	0.709
Qostanay	Altynsarinskiy		0.013	0.022	0.161	0.062	0.842	0.051	9.348	0.728
Qostanay	Amangel`Dinskiy	*	0.000	0.081	0.127	0.141	0.912	0.076	9.746	1.798
Qostanay	Arkalyk		0.000	0.000	0.000	0.000	0.897	0.037	10.732	0.377
Qostanay	Auliekol`Skiy		0.000	0.000	0.145	0.042	0.853	0.038	9.792	0.588
Qostanay	Denisovskiy		0.000	0.000	0.063	0.038	0.793	0.055	12.289	1.023
Qostanay	Dzhangil`Dinskiy	*	0.000	0.081	0.128	0.141	0.915	0.076	9.445	1.808
Qostanay	Fyodorovskiy		0.000	0.000	0.198	0.070	0.828	0.055	10.047	0.941
Qostanay	Kamystinskiy		0.053	0.036	0.237	0.065	0.915	0.039	8.195	0.579
Qostanay	Karabalykskiy		0.037	0.031	0.184	0.060	0.929	0.034	8.596	0.698
Qostanay	Karasuskiy		0.000	0.000	0.000	0.000	0.887	0.044	10.149	0.573
Qostanay	Mendykarinskiy		0.000	0.000	0.102	0.039	0.807	0.045	11.066	0.718
Qostanay	Naurzumskiy	*	0.000	0.081	0.128	0.141	0.896	0.075	10.052	1.792
Qostanay	Qostanay		0.000	0.000	0.030	0.008	0.757	0.019	11.501	0.259
Qostanay	Sarykol`Skiy		0.000	0.000	0.124	0.050	0.962	0.024	8.185	0.399
Qostanay	Taranovskiy		0.000	0.000	0.190	0.043	0.904	0.029	8.755	0.450
Qostanay	Uzunkol`Skiy		0.000	0.000	0.000	0.000	0.863	0.048	10.605	0.557
Qostanay	Zhitikarinskiy		0.000	0.000	0.000	0.000	0.783	0.052	12.712	0.763
Qyzylorda	Aral`Skiy		0.000	0.000	0.080	0.025	0.884	0.026	9.547	0.480
Qyzylorda	Karmakchinskiy		0.000	0.000	0.000	0.000	0.907	0.042	9.823	0.543
Qyzylorda	Kazalinskiy		0.000	0.000	0.162	0.039	0.903	0.031	8.920	0.441
Qyzylorda	Qyzylorda		0.002	0.003	0.166	0.020	0.881	0.017	9.558	0.360
Qyzylorda	Shieliyskiy		0.000	0.000	0.164	0.039	0.889	0.031	8.916	0.486
Qyzylorda	Terenozekskiy		0.000	0.000	0.160	0.040	0.962	0.020	7.819	0.299

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Qyzylorda	Zhalagashskiy		0.000	0.000	0.100	0.041	0.984	0.016	7.784	0.314
Qyzylorda	Zhanakorganskiy		0.000	0.000	0.126	0.032	0.956	0.020	7.889	0.325
South Kaz	Arysskiy		0.000	0.000	0.000	0.000	0.817	0.029	11.340	0.325
South Kaz	Baydibekskiy		0.000	0.000	0.016	0.012	0.866	0.032	10.730	0.353
South Kaz	Chardarinskiy		0.000	0.000	0.311	0.045	1.000	0.000	7.146	0.224
South Kaz	Kazygurtskiy		0.000	0.000	0.043	0.019	0.981	0.012	8.289	0.212
South Kaz	Maktaaral`Skiy		0.000	0.000	0.056	0.014	0.968	0.011	8.212	0.171
South Kaz	Ordabasynskiy		0.015	0.011	0.388	0.042	0.968	0.015	6.722	0.296
South Kaz	Otrarskiy		0.000	0.000	0.000	0.000	0.781	0.041	12.435	0.501
South Kaz	Saryagashskiy		0.014	0.006	0.332	0.024	0.981	0.007	6.859	0.144
South Kaz	Sayramskiy		0.000	0.000	0.033	0.009	0.964	0.010	8.558	0.135
South Kaz	Shymkent		0.000	0.000	0.016	0.005	0.783	0.015	11.774	0.151
South Kaz	Suzakskiy	*	0.000	0.085	0.000	0.147	1.014	0.079	9.984	1.813
South Kaz	Tolebiyskiy		0.000	0.000	0.272	0.027	0.943	0.014	7.338	0.193
South Kaz	Turkestan		0.000	0.000	0.061	0.010	0.950	0.009	8.447	0.106
South Kaz	Tyul`Kubaskiy		0.000	0.000	0.132	0.034	0.926	0.025	8.841	0.340
West Kaz	Akzhaikskiy		0.045	0.026	0.226	0.050	0.945	0.025	8.044	0.435
West Kaz	Burlinskiy		0.025	0.018	0.091	0.033	0.823	0.040	10.478	0.552
West Kaz	Chingirlauskiy		0.000	0.000	0.232	0.072	0.924	0.039	8.168	0.547
West Kaz	Dzhangalinskiy	*	0.009	0.081	0.143	0.141	0.897	0.075	9.563	1.794
West Kaz	Dzhanybekskiy		0.000	0.000	0.209	0.065	0.953	0.029	7.578	0.468
West Kaz	Karatobinskiy		0.000	0.000	0.104	0.052	0.880	0.048	9.280	0.643
West Kaz	Kaztalovskiy		0.011	0.018	0.202	0.067	0.858	0.051	9.062	0.772
West Kaz	Syrymskiy	*	0.014	0.081	0.140	0.141	0.883	0.075	9.890	1.791
West Kaz	Taskalinskiy		0.000	0.000	0.092	0.058	0.827	0.061	11.160	1.263
West Kaz	Terektinskiy		0.034	0.025	0.253	0.059	0.909	0.034	8.028	0.651
West Kaz	Urdinskiy		0.031	0.030	0.266	0.074	0.966	0.026	7.481	0.559
West Kaz	Zelenovskiy		0.000	0.000	0.079	0.013	0.760	0.021	11.343	0.305

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Zhambyl	Bayzakskiy		0.000	0.000	0.079	0.012	0.844	0.017	9.874	0.220
Zhambyl	Kordayskiy		0.036	0.017	0.267	0.040	0.955	0.018	7.385	0.292
Zhambyl	Lugovskoy		0.006	0.007	0.215	0.037	0.956	0.018	7.767	0.272
Zhambyl	Merkenskiy		0.025	0.015	0.162	0.035	0.921	0.025	8.382	0.373
Zhambyl	Moyynkumskiy		0.000	0.000	0.042	0.030	0.850	0.051	10.315	0.695
Zhambyl	Sarysuskiy		0.029	0.021	0.268	0.052	0.973	0.020	6.744	0.340
Zhambyl	Shuskiy		0.000	0.000	0.031	0.013	0.878	0.025	9.710	0.372
Zhambyl	Talasskiy	*	0.049	0.086	0.249	0.141	0.935	0.079	8.062	1.887
Zhambyl	Zhamb.		0.033	0.016	0.443	0.042	0.994	0.007	6.188	0.194
Zhambyl	Zhambylskiy	*	0.062	0.086	0.231	0.142	0.905	0.079	8.108	1.885
Zhambyl	Zhualy	*	0.039	0.086	0.310	0.141	0.980	0.080	7.159	1.888
Zhambyl	Zhualynskiy		0.000	0.000	0.032	0.016	0.956	0.018	8.663	0.261

Annex B – Uzbekistan District-level Results 2018

Table 3:Uzbekistan District-level Results 2018

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Andijon	Andijon		0.126	0.015	0.688	0.021	0.984	0.005	5.645	0.150
Andijon	Asaka		0.160	0.014	0.559	0.019	0.960	0.007	6.290	0.150
Andijon	Baliqchi		0.127	0.015	0.689	0.021	0.945	0.011	5.673	0.159
Andijon	Bo'Zsuv	*	0.105	0.087	0.640	0.150	0.935	0.078	6.731	1.837
Andijon	Buloqboshi	*	0.140	0.087	0.566	0.144	0.906	0.076	7.109	1.813
Andijon	Izboskan	*	0.108	0.087	0.523	0.146	0.912	0.077	7.099	1.834
Andijon	Jalolquduq		0.095	0.011	0.559	0.019	0.902	0.011	7.192	0.218
Andijon	Marhamat	*	0.013	0.091	0.368	0.142	0.858	0.076	8.045	1.797
Andijon	Oltinko'L	*	0.129	0.087	0.692	0.157	0.935	0.078	6.664	1.861
Andijon	Paxtaobod		0.057	0.011	0.482	0.023	0.949	0.010	8.387	0.475
Andijon	Qo'Rg'Ontepa	*	0.032	0.091	0.385	0.142	0.834	0.076	8.602	1.804
Andijon	Shahrixon		0.175	0.018	0.645	0.022	0.882	0.015	7.724	0.456
Andijon	Ulug'Nor	*	0.016	0.090	0.455	0.145	0.890	0.076	7.622	1.798
Andijon	Xo'Jaobod		0.048	0.014	0.513	0.032	0.942	0.015	7.389	0.287
Bukhoro	Buxoro		0.065	0.009	0.328	0.017	0.872	0.012	8.816	0.252
Bukhoro	G'Ijduvon	*	0.126	0.082	0.297	0.142	0.859	0.081	10.581	1.942
Bukhoro	Jondor	*	0.085	0.082	0.275	0.142	0.829	0.081	10.953	1.941
Bukhoro	Kogon		0.055	0.014	0.318	0.030	0.817	0.024	10.174	0.630
Bukhoro	Olot		0.024	0.013	0.162	0.032	0.737	0.037	11.651	1.565
Bukhoro	Peshku		0.043	0.013	0.158	0.023	0.773	0.026	13.428	0.842
Bukhoro	Qorako'L	*	0.088	0.082	0.255	0.142	0.832	0.081	10.949	1.943
Bukhoro	Qorovulbozor	*	0.117	0.082	0.304	0.142	0.830	0.081	10.592	1.940
Bukhoro	Romitan		0.158	0.032	0.496	0.043	0.800	0.033	10.814	1.028
Bukhoro	Shofirkon		0.106	0.019	0.342	0.030	0.828	0.023	11.649	0.808
Bukhoro	Vobkent		0.110	0.014	0.345	0.021	0.851	0.016	9.248	0.367

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Ferghana	Beshariq		0.231	0.026	0.574	0.031	0.905	0.018	7.450	0.373
Ferghana	Bog'Dod		0.107	0.010	0.431	0.016	0.882	0.010	7.923	0.175
Ferghana	Buvayda		0.092	0.018	0.439	0.032	0.883	0.020	8.144	0.551
Ferghana	Dang'Ara		0.064	0.009	0.293	0.018	0.884	0.012	8.895	0.229
Ferghana	Farg'Ona		0.066	0.010	0.304	0.018	0.858	0.013	9.612	0.274
Ferghana	Furqat	*	0.124	0.082	0.337	0.142	0.865	0.076	8.002	1.800
Ferghana	O'Zbekiston		0.048	0.008	0.303	0.017	0.867	0.013	8.558	0.178
Ferghana	Oltiariq		0.134	0.021	0.351	0.030	0.912	0.018	8.314	0.302
Ferghana	Oxunboboev		0.000	0.000	0.281	0.028	0.660	0.029	10.205	0.368
Ferghana	Quva		0.004	0.004	0.170	0.024	0.693	0.028	11.834	0.448
Ferghana	Rishton	*	0.145	0.082	0.353	0.142	0.873	0.075	7.945	1.798
Ferghana	So'X	*	0.076	0.082	0.234	0.142	0.889	0.075	9.312	1.825
Ferghana	Toshloq	*	0.218	0.084	0.584	0.149	0.902	0.077	7.211	1.821
Ferghana	Uchko'Prik	*	0.121	0.082	0.436	0.151	0.848	0.076	8.333	1.798
Ferghana	Yozyovon	*	0.139	0.082	0.485	0.150	0.867	0.076	7.788	1.798
Jizzakh	Arnasoy	*	0.009	0.089	0.254	0.154	0.796	0.083	10.417	1.964
Jizzakh	Baxmal	*	0.093	0.089	0.353	0.155	0.772	0.083	9.719	1.976
Jizzakh	Do'Stlik	*	0.009	0.089	0.253	0.154	0.797	0.083	10.406	1.964
Jizzakh	Forish		0.000	0.000	0.324	0.033	0.768	0.029	11.639	0.667
Jizzakh	G'Allaorol	*	0.033	0.089	0.257	0.154	0.785	0.083	10.616	1.966
Jizzakh	Jizzax		0.045	0.009	0.152	0.015	0.756	0.018	11.013	0.264
Jizzakh	Mirzacho'L	*	0.010	0.089	0.254	0.154	0.806	0.083	10.230	1.964
Jizzakh	Paxtakor		0.030	0.012	0.211	0.029	0.870	0.023	9.430	0.330
Jizzakh	Yangiobod	*	0.000	0.089	0.233	0.154	0.812	0.083	10.510	1.966
Jizzakh	Zafarobod	*	0.051	0.089	0.273	0.154	0.799	0.083	10.209	1.965
Jizzakh	Zarbdor		0.000	0.000	0.149	0.025	0.776	0.029	9.280	0.273
Jizzakh	Zomin		0.051	0.016	0.235	0.030	0.729	0.030	12.476	0.755
Karakalpakstan	Amudaryo		0.376	0.043	0.689	0.044	0.952	0.021	5.839	0.533
Karakalpakstan	Beruniy		0.135	0.032	0.586	0.047	0.952	0.021	6.176	0.317

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Karakalpakstan	Chimboy		0.273	0.025	0.494	0.029	0.947	0.013	7.196	0.432
Karakalpakstan	Ellikqala	*	0.099	0.087	0.460	0.151	0.946	0.081	7.467	1.924
Karakalpakstan	Kegeyli		0.104	0.021	0.494	0.035	0.981	0.010	6.741	0.299
Karakalpakstan	Mo'Ynoq	*	0.001	0.091	0.334	0.158	0.880	0.086	8.739	2.038
Karakalpakstan	Nukus	*	0.185	0.086	0.555	0.149	0.957	0.079	6.032	1.885
Karakalpakstan	Qanliko'L	*	0.180	0.086	0.568	0.149	0.958	0.079	6.009	1.882
Karakalpakstan	Qo'Ng'Irot		0.055	0.021	0.434	0.047	1.000	0.000	5.981	0.224
Karakalpakstan	Qorao'Zak	*	0.147	0.086	0.517	0.149	0.968	0.079	6.713	1.886
Karakalpakstan	Shumanay		0.146	0.032	0.415	0.047	1.000	0.000	6.314	0.263
Karakalpakstan	Taxtako'Pir		0.117	0.031	0.682	0.044	1.000	0.000	5.152	0.219
Karakalpakstan	To'Rtko'L		0.085	0.014	0.453	0.025	0.953	0.011	7.085	0.244
Karakalpakstan	Xo'Jayli		0.192	0.016	0.517	0.021	0.962	0.008	6.252	0.147
Kashkadarya	Chiroqchi	*	0.096	0.085	0.369	0.142	0.848	0.075	8.831	1.802
Kashkadarya	Dehqonobod		0.000	0.000	0.257	0.031	0.865	0.023	9.192	0.449
Kashkadarya	G'Uzor		0.174	0.027	0.371	0.034	0.895	0.021	7.487	0.423
Kashkadarya	Kasbi		0.109	0.013	0.329	0.019	0.800	0.016	8.608	0.204
Kashkadarya	Kitob	*	0.081	0.085	0.385	0.142	0.879	0.075	7.893	1.799
Kashkadarya	Koson		0.032	0.009	0.371	0.024	0.830	0.019	10.298	0.498
Kashkadarya	Muborak	*	0.030	0.085	0.295	0.141	0.887	0.076	8.802	1.795
Kashkadarya	Nishon		0.032	0.009	0.286	0.023	0.771	0.021	12.201	0.622
Kashkadarya	Qamashi		0.055	0.010	0.241	0.018	0.772	0.017	11.096	0.349
Kashkadarya	Qarshi		0.008	0.004	0.114	0.013	0.726	0.017	11.498	0.279
Kashkadarya	Shahrisabz		0.087	0.020	0.382	0.034	0.960	0.013	7.575	0.288
Kashkadarya	Usmon Yusupov		0.144	0.025	0.309	0.033	0.778	0.029	9.466	0.381
Kashkadarya	Yakkabog'		0.103	0.016	0.358	0.025	0.773	0.021	10.554	0.483
Khorezm	Bog'Ot	*	0.059	0.087	0.385	0.150	0.893	0.075	8.587	1.796
Khorezm	Gurlan		0.110	0.018	0.417	0.028	0.965	0.010	6.795	0.195
Khorezm	Hazorasp		0.030	0.008	0.341	0.022	0.972	0.008	7.053	0.146
Khorezm	Qo'Shko'Pir		0.086	0.022	0.309	0.036	0.727	0.034	12.658	0.959

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Khorezm	Shovot		0.046	0.012	0.475	0.028	0.944	0.013	6.463	0.203
Khorezm	Urganch		0.075	0.009	0.361	0.017	0.885	0.011	9.767	0.366
Khorezm	Xiva		0.000	0.000	0.353	0.040	0.921	0.022	7.088	0.264
Khorezm	Xonqa	*	0.066	0.087	0.397	0.150	0.897	0.076	8.468	1.797
Khorezm	Yangiariq	*	0.065	0.087	0.395	0.150	0.894	0.076	8.492	1.796
Khorezm	Yangibozor		0.091	0.023	0.448	0.039	0.929	0.020	7.587	0.585
Namangan	Chortoq		0.076	0.011	0.213	0.017	0.777	0.017	12.201	0.598
Namangan	Chust		0.093	0.015	0.372	0.025	0.839	0.018	9.445	0.426
Namangan	Kosonsoy		0.006	0.005	0.184	0.027	0.811	0.027	9.361	0.313
Namangan	Mingbuloq		0.157	0.025	0.473	0.035	0.909	0.020	7.183	0.356
Namangan	Namangan		0.191	0.014	0.434	0.017	0.872	0.012	8.271	0.252
Namangan	Norin	*	0.273	0.091	0.647	0.150	0.949	0.080	6.457	1.887
Namangan	Pop		0.113	0.022	0.255	0.031	0.838	0.025	12.802	0.963
Namangan	To'Raqo'Rg'On	*	0.193	0.084	0.500	0.145	0.904	0.076	7.754	1.814
Namangan	Uchqo'Rg'On		0.000	0.000	0.251	0.031	0.890	0.022	9.144	0.353
Namangan	Uychi		0.124	0.023	0.322	0.033	0.873	0.023	9.521	0.797
Namangan	Yagiqo'Rg'On		0.114	0.016	0.376	0.025	0.868	0.017	7.673	0.221
Navoi	Karmana	*	0.149	0.082	0.309	0.142	0.907	0.076	8.486	1.791
Navoi	Konimex	*	0.115	0.082	0.269	0.142	0.939	0.077	8.726	1.792
Navoi	Navbahor	*	0.096	0.082	0.265	0.142	0.840	0.076	8.850	1.799
Navoi	Nurota		0.030	0.007	0.300	0.019	0.857	0.015	9.306	0.335
Navoi	Qiziltepa		0.029	0.011	0.276	0.029	0.754	0.028	10.507	1.606
Navoi	Tomdi		0.094	0.018	0.352	0.030	0.924	0.016	7.939	0.449
Navoi	Uchquduq	*	0.000	0.083	0.094	0.144	0.916	0.077	9.760	1.840
Navoi	Xatirchi		0.138	0.018	0.486	0.026	0.918	0.014	7.579	0.471
Samarkand	Bulung'Ur	*	0.181	0.082	0.424	0.142	0.826	0.076	8.012	1.804
Samarkand	Ishtixon		0.144	0.011	0.374	0.015	0.848	0.011	10.228	0.311
Samarkand	Jomboy	*	0.258	0.084	0.558	0.144	0.883	0.076	6.894	1.819
Samarkand	Kattaqo'Rg'On		0.230	0.023	0.483	0.028	0.915	0.015	8.686	0.696

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Samarkand	Narpay	*	0.190	0.082	0.440	0.142	0.900	0.075	7.998	1.797
Samarkand	Nurobod		0.352	0.028	0.716	0.027	1.000	0.000	4.643	0.140
Samarkand	Oqdaryo		0.246	0.024	0.348	0.027	0.794	0.023	10.520	0.547
Samarkand	Pastdarg'Om		0.080	0.012	0.226	0.018	0.744	0.019	10.954	0.416
Samarkand	Paxtachi	*	0.147	0.082	0.343	0.142	0.907	0.076	8.550	1.792
Samarkand	Payariq	*	0.213	0.082	0.469	0.143	0.869	0.075	7.874	1.806
Samarkand	Qo'Shrabot	*	0.182	0.082	0.414	0.142	0.877	0.075	8.291	1.792
Samarkand	Samarqand		0.098	0.018	0.450	0.030	0.906	0.017	7.208	0.250
Samarkand	Toyloq		0.165	0.010	0.470	0.014	0.901	0.008	7.525	0.185
Samarkand	Urgut	*	0.200	0.082	0.387	0.142	0.850	0.075	8.469	1.797
Sirdaryo	Boyovut		0.134	0.024	0.417	0.035	0.847	0.025	7.723	0.388
Sirdaryo	Guliston	*	0.124	0.082	0.348	0.142	0.871	0.076	8.579	1.794
Sirdaryo	Mirzaobod		0.087	0.020	0.317	0.033	0.944	0.016	7.457	0.344
Sirdaryo	Oqoltin		0.117	0.016	0.464	0.025	0.980	0.007	6.899	0.190
Sirdaryo	Sayxunobod	*	0.141	0.082	0.361	0.142	0.887	0.075	8.172	1.795
Sirdaryo	Sharof Rashidov	*	0.125	0.082	0.360	0.142	0.865	0.076	8.553	1.793
Sirdaryo	Sirdaryo		0.162	0.026	0.498	0.035	0.955	0.014	6.361	0.264
Sirdaryo	Xovos		0.134	0.024	0.623	0.034	0.967	0.012	6.071	0.264
Surkhandarya	Angor		0.079	0.015	0.278	0.026	0.926	0.015	7.286	0.213
Surkhandarya	Bandixon	*	0.240	0.085	0.688	0.152	0.927	0.076	6.827	1.820
Surkhandarya	Boysun	*	0.162	0.082	0.464	0.150	0.858	0.075	9.433	1.796
Surkhandarya	Denov		0.260	0.024	0.488	0.028	0.915	0.015	6.344	0.254
Surkhandarya	Jarqo'Rg'On	*	0.168	0.082	0.533	0.149	0.890	0.075	7.980	1.798
Surkhandarya	Muzrabot		0.154	0.014	0.427	0.020	0.792	0.016	9.724	0.351
Surkhandarya	Oltinsoy	*	0.171	0.082	0.542	0.150	0.845	0.075	8.315	1.805
Surkhandarya	Qiziriq	*	0.178	0.082	0.579	0.149	0.906	0.075	7.624	1.804
Surkhandarya	Qumqo'Rg'On		0.281	0.025	0.371	0.027	0.821	0.021	8.914	0.472
Surkhandarya	Sariosiyo		0.077	0.015	0.474	0.028	0.947	0.012	6.193	0.159
Surkhandarya	Sherobod		0.107	0.017	0.743	0.025	0.963	0.011	5.862	0.196

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Surkhandarya	Sho'Rchi	*	0.159	0.082	0.531	0.149	0.891	0.075	8.372	1.796
Surkhandarya	Termiz		0.162	0.017	0.605	0.022	0.904	0.013	9.731	1.367
Surkhandarya	Uzun		0.120	0.018	0.480	0.028	0.997	0.003	5.912	0.152
Tashkent	Bekobod		0.102	0.020	0.288	0.029	0.798	0.025	8.585	0.304
Tashkent	Bo'Ka	*	0.062	0.087	0.343	0.142	0.857	0.076	8.602	1.793
Tashkent	Bo'Stonliq		0.020	0.009	0.034	0.012	0.610	0.030	14.101	0.384
Tashkent	Chinoz	*	0.138	0.087	0.435	0.144	0.891	0.076	7.830	1.812
Tashkent	O'Rtachirchiq		0.000	0.000	0.209	0.026	0.699	0.029	10.584	0.354
Tashkent	Ohangaron		0.079	0.013	0.228	0.021	0.914	0.013	8.870	0.211
Tashkent	Oqqo'Rg'On		0.000	0.000	0.254	0.028	0.883	0.020	8.595	0.365
Tashkent	Parkent	*	0.045	0.087	0.288	0.142	0.791	0.076	10.377	1.809
Tashkent	Piskent		0.050	0.008	0.310	0.018	0.758	0.016	12.693	0.622
Tashkent	Qibray		0.025	0.004	0.144	0.009	0.697	0.012	11.555	0.187
Tashkent	Quyichirchiq	*	0.137	0.087	0.471	0.143	0.897	0.076	7.801	1.815
Tashkent	Toshkent		0.390	0.031	0.832	0.024	0.979	0.009	4.871	0.297
Tashkent	Yangiyo'L	*	0.129	0.087	0.427	0.143	0.885	0.076	7.975	1.808
Tashkent	Yuqorichirchiq	*	0.068	0.087	0.364	0.142	0.820	0.076	9.076	1.802
Tashkent	Zangiota	*	0.162	0.088	0.487	0.146	0.887	0.077	7.549	1.833
Tashkent City	Tashkent City		0.000	0.000	0.165	0.007	0.736	0.009	11.953	0.172

Annex C – Kyrgyz Republic District-level Results 2016

Table 4: Kyrgyz Republic District-level Results 2016

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Batken	Batken		0.089	0.025	0.669	0.044	0.982	0.012	5.664	0.376
Batken	Kadamjai		0.297	0.029	0.785	0.027	0.995	0.005	4.385	0.150
Batken	Lailak		0.310	0.033	0.787	0.030	0.994	0.006	4.388	0.159
BišKek	BišKek		0.165	0.011	0.516	0.015	0.958	0.006	6.392	0.110
ChüY	AlamüDüN		0.102	0.019	0.567	0.032	0.980	0.009	5.712	0.183
ChüY	Chui		0.279	0.040	0.725	0.043	0.995	0.007	4.607	0.227
ChüY	Jaiyl		0.069	0.021	0.367	0.041	0.940	0.021	7.410	0.394
ChüY	Kemin		0.136	0.037	0.823	0.042	0.999	0.004	4.435	0.169
ChüY	Moskovsky		0.186	0.035	0.765	0.038	0.974	0.015	4.807	0.283
ChüY	Panfilov		0.000	0.000	0.237	0.061	0.968	0.032	7.705	0.651
ChüY	Sokuluk		0.270	0.028	0.630	0.031	0.987	0.007	5.156	0.194
ChüY	Ysyk-Ata		0.245	0.034	0.641	0.039	0.987	0.009	5.147	0.242
Jalal-Abad	Aksyi		0.301	0.030	0.833	0.025	1.000	0.001	4.156	0.107
Jalal-Abad	Ala-Buka		0.048	0.018	0.676	0.042	0.992	0.009	5.299	0.189
Jalal-Abad	Bazar-Korgon		0.164	0.027	0.599	0.037	0.995	0.005	5.138	0.143
Jalal-Abad	Chatkal		0.079	0.024	0.593	0.044	0.997	0.005	5.581	0.201
Jalal-Abad	Nooken		0.229	0.031	0.729	0.033	0.986	0.009	5.027	0.396
Jalal-Abad	Suzak		0.226	0.019	0.781	0.019	0.993	0.004	4.614	0.105
Jalal-Abad	Togus-Toro	*	.	.	.	.	.	.	.	.
Jalal-Abad	Toktogul		0.141	0.029	0.716	0.039	0.996	0.005	4.809	0.166
Naryn	Ak-Talaa		0.421	0.054	0.912	0.033	0.997	0.006	3.253	0.229
Naryn	At-Bashi		0.107	0.037	0.481	0.067	0.941	0.028	6.868	0.768
Naryn	Jumgal		0.150	0.038	0.795	0.042	0.995	0.007	4.560	0.244
Naryn	Kochkor		0.313	0.047	0.718	0.049	0.952	0.021	5.166	0.442
Naryn	Naryn		0.210	0.038	0.624	0.047	0.971	0.015	5.558	0.361
Osh	Alai		0.036	0.015	0.543	0.042	0.975	0.014	6.236	0.253

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Osh	Aravan		0.333	0.034	0.837	0.028	0.995	0.006	4.189	0.156
Osh	Chong-Alay	*	.	.	.	.	.	.	.	.
Osh	Kara-Kuldja		0.093	0.026	0.775	0.040	0.973	0.016	4.941	0.275
Osh	Kara-Suu		0.174	0.017	0.745	0.020	0.986	0.005	4.833	0.106
Osh	Nookat		0.064	0.014	0.716	0.025	0.991	0.005	5.264	0.125
Osh	Uzgen		0.278	0.025	0.812	0.022	0.996	0.003	4.331	0.117
Osh (City)	Osh		0.171	0.021	0.704	0.025	0.978	0.008	5.318	0.176
Talas	Bakai-Ata		0.018	0.016	0.351	0.057	0.991	0.013	7.025	0.322
Talas	Kara-Buura		0.231	0.043	0.826	0.039	0.995	0.007	4.208	0.195
Talas	Manas		0.012	0.015	0.583	0.070	0.996	0.011	5.645	0.335
Talas	Talas		0.053	0.019	0.668	0.042	0.994	0.007	5.379	0.226
Ysyk-KöL	Ak-Suu		0.090	0.021	0.499	0.038	0.953	0.016	6.678	0.310
Ysyk-KöL	Djety-Oguz		0.047	0.019	0.582	0.047	0.970	0.017	6.135	0.338
Ysyk-KöL	Ton		0.350	0.049	0.884	0.036	0.999	0.005	3.732	0.185
Ysyk-KöL	TüP		0.296	0.050	0.825	0.047	0.997	0.006	4.297	0.242
Ysyk-KöL	Ysyk-KöL		0.170	0.028	0.632	0.037	0.973	0.013	5.587	0.289

Annex D – Tajikistan District-level Results 2015

Table 5:Tajikistan District-level Results 2015

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Dushanbe	Rudaki		0.053	0.008	0.305	0.016	0.841	0.013	9.121	0.212
GBAO	Darvoz	*	0.188	0.082	0.369	0.142	0.816	0.076	9.096	1.808
GBAO	Ishkoshim	*	0.296	0.085	0.577	0.152	0.923	0.077	6.435	1.960
GBAO	Murghob	*	0.245	0.091	0.632	0.161	0.835	0.080	7.530	2.052
GBAO	Roshtqala	*	0.294	0.085	0.575	0.151	0.927	0.077	6.455	1.958
GBAO	Rushon		0.246	0.034	0.707	0.036	1.000	0.000	4.641	0.166
GBAO	Shughnon		0.199	0.035	0.685	0.044	0.989	0.010	5.470	0.284
GBAO	Vanj	*	0.153	0.083	0.348	0.145	0.854	0.080	10.010	1.849
Khatlon	Baljuvon		0.070	0.028	0.347	0.055	0.935	0.030	7.610	0.461
Khatlon	Bokhtar		0.339	0.020	0.702	0.020	0.996	0.003	4.644	0.108
Khatlon	Danghara	*	0.199	0.082	0.592	0.144	0.954	0.077	6.322	1.837
Khatlon	Farkhor		0.174	0.027	0.609	0.036	0.971	0.013	5.599	0.238
Khatlon	Jilikul		0.375	0.051	0.956	0.023	1.000	0.000	3.330	0.150
Khatlon	Jomi		0.327	0.033	0.641	0.035	0.995	0.005	4.777	0.243
Khatlon	Khovaling		0.000	0.000	0.253	0.037	0.845	0.032	9.152	0.745
Khatlon	Khuroson		0.258	0.037	0.633	0.043	1.000	0.000	5.130	0.272
Khatlon	Kolkhozobod		0.137	0.029	0.593	0.043	0.941	0.022	6.325	0.392
Khatlon	Kulob		0.375	0.025	0.728	0.023	0.979	0.007	4.687	0.177
Khatlon	Moskva	*	0.168	0.082	0.552	0.144	0.955	0.077	5.965	1.831
Khatlon	Muminobod	*	.	.	.	.	.	.	.	.
Khatlon	Norak		0.048	0.017	0.236	0.036	0.892	0.028	8.091	0.378
Khatlon	Nosir Khusrav		0.212	0.046	0.625	0.058	0.986	0.016	5.954	0.440
Khatlon	Panj		0.058	0.016	0.504	0.037	0.963	0.014	6.452	0.250
Khatlon	Qabodiyon		0.000	0.000	0.358	0.056	1.000	0.000	7.107	0.309
Khatlon	Qumsangir		0.335	0.029	0.763	0.027	0.974	0.010	4.658	0.236

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
Khatlon	Sarband	*	.	.	.	.	.	.	.	.
Khatlon	Shahrituz		0.089	0.020	0.473	0.036	0.928	0.019	6.832	0.298
Khatlon	Shurobod		0.222	0.046	0.770	0.049	1.000	0.000	4.249	0.205
Khatlon	Sovet		0.434	0.034	0.793	0.030	1.000	0.000	4.062	0.162
Khatlon	Vakhsh	*	.	.	.	.	.	.	.	.
Khatlon	Vose		0.406	0.034	0.768	0.031	0.996	0.005	4.042	0.144
Khatlon	Yovon		0.298	0.032	0.634	0.035	0.987	0.008	5.071	0.212
Sogd	Asht		0.132	0.025	0.474	0.036	0.940	0.017	7.743	0.573
Sogd	Ayni		0.000	0.000	0.285	0.052	0.824	0.045	9.771	0.951
Sogd	Ghafurov		0.111	0.010	0.451	0.017	0.896	0.010	7.423	0.171
Sogd	Ghonchi	*	0.049	0.082	0.404	0.148	0.933	0.078	7.912	1.875
Sogd	Isfara		0.080	0.023	0.472	0.044	0.953	0.019	6.861	0.403
Sogd	Istaravshan		0.328	0.020	0.724	0.019	0.977	0.006	4.635	0.125
Sogd	Jabor Rasulov		0.211	0.048	0.852	0.040	1.000	0.000	4.664	0.328
Sogd	Konibodom		0.167	0.032	0.547	0.044	0.964	0.017	6.117	0.301
Sogd	Kuhistoni Mastchoh		0.184	0.041	0.311	0.052	0.800	0.047	9.967	0.903
Sogd	Matchin		0.029	0.014	0.605	0.043	1.000	0.000	5.359	0.176
Sogd	Pandjakent		0.250	0.024	0.617	0.028	0.953	0.012	5.547	0.228
Sogd	Shahriston		0.101	0.036	0.641	0.057	0.971	0.020	5.768	0.412
Sogd	Spitamen		0.228	0.048	0.747	0.051	1.000	0.000	4.552	0.249
Sogd	Zafarobod		0.266	0.049	0.801	0.047	1.000	0.000	3.762	0.178
RRS	Fayzobod		0.049	0.015	0.450	0.037	0.974	0.012	6.481	0.209
RRS	Hissor		0.149	0.020	0.444	0.029	0.922	0.016	6.862	0.258
RRS	Jirgatol		0.000	0.000	0.197	0.035	0.833	0.034	9.882	0.483
RRS	Nurobod		0.707	0.034	0.933	0.022	0.997	0.005	2.725	0.157
RRS	Rasht		0.431	0.031	0.666	0.030	0.982	0.009	4.697	0.243
RRS	Roghun	*	.	.	.	.	.	.	.	.
RRS	Rudaki		0.153	0.023	0.522	0.032	0.961	0.013	6.581	0.271

Province	District	Not Precise	Rate ($3.2)	S.E.	Rate ($5.5)	S.E.	Below MClass	S.E.	Mean Cons.	S.E.
RRS	Shahrinav		0.114	0.037	0.596	0.060	0.973	0.020	5.858	0.443
RRS	Tavildara	*	0.148	0.083	0.508	0.149	0.960	0.080	6.925	1.890
RRS	Tojikobod	*	.	.	.	.	.	.	.	.
RRS	Tursunzoda		0.140	0.022	0.594	0.032	0.982	0.009	5.430	0.172
RRS	Vahdat		0.036	0.008	0.241	0.019	0.925	0.011	8.299	0.192
RRS	Varzob		0.115	0.038	0.423	0.060	1.000	0.000	6.525	0.434

Annex E – Country-Level Maps

Figure 17: Poverty headcount ratio at $5.5-a-day PPP per person, rates for Kazakhstan 2017

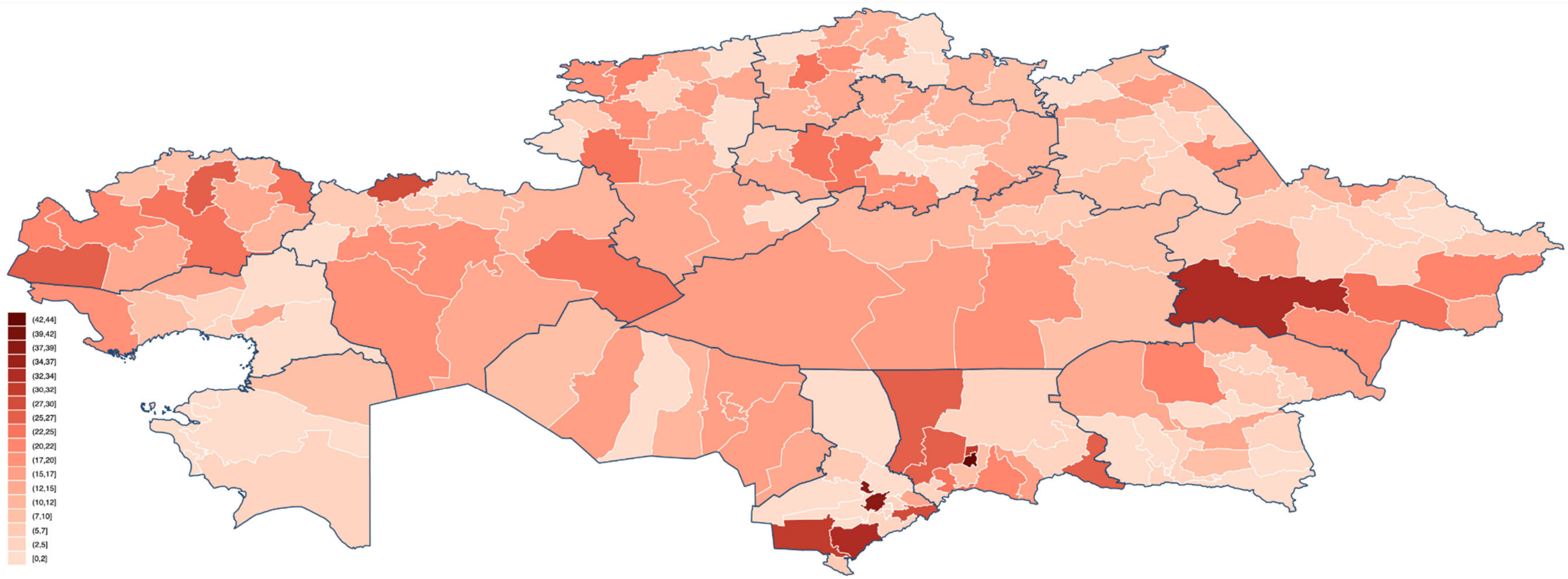


Figure 18: Share of the population in the middle class, rates for Kazakhstan 2017

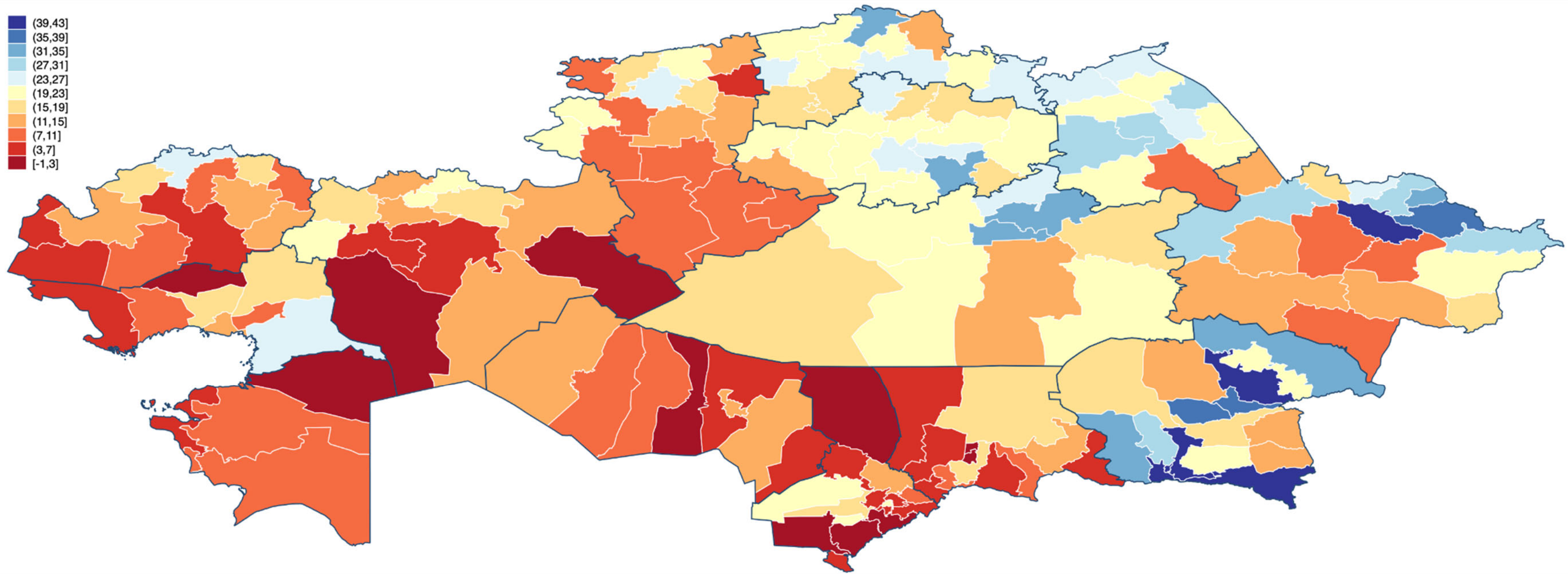


Figure 19: Average Per Capita Daily Consumption in 2011 PPP for Kazakhstan 2017

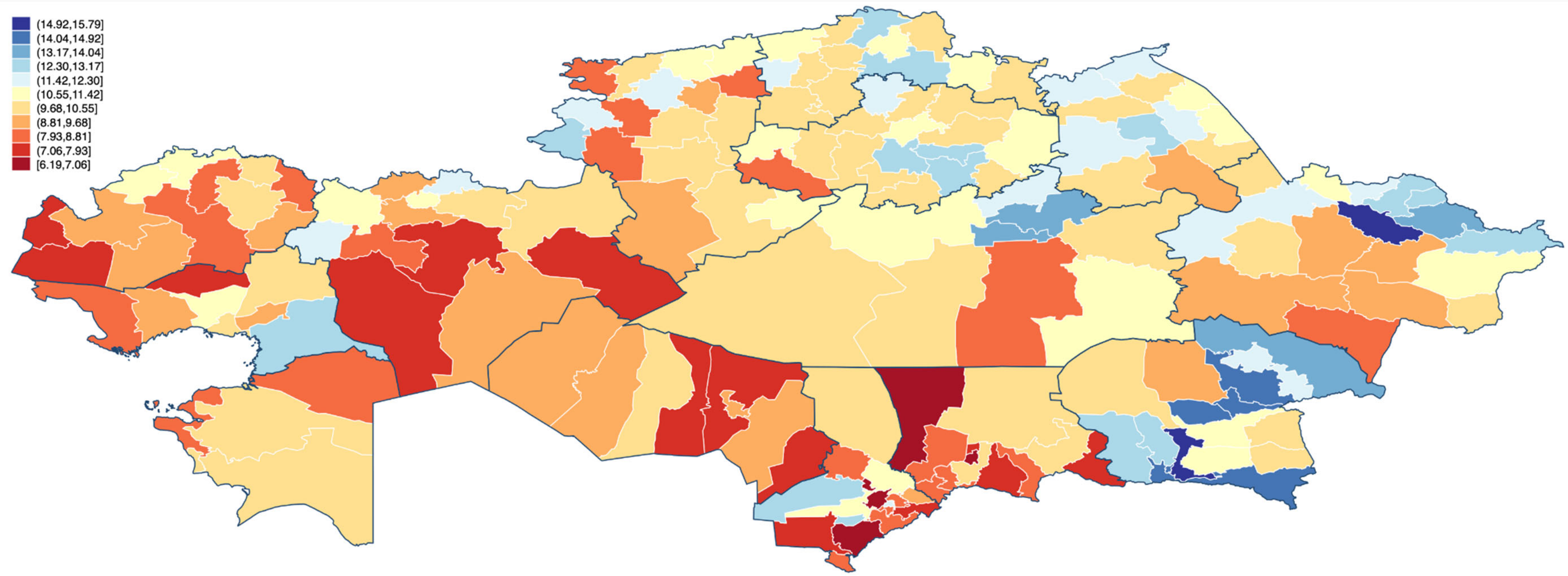


Figure 20: Poverty headcount ratio at $3.2-a-day PPP per person, rates for Uzbekistan 2018

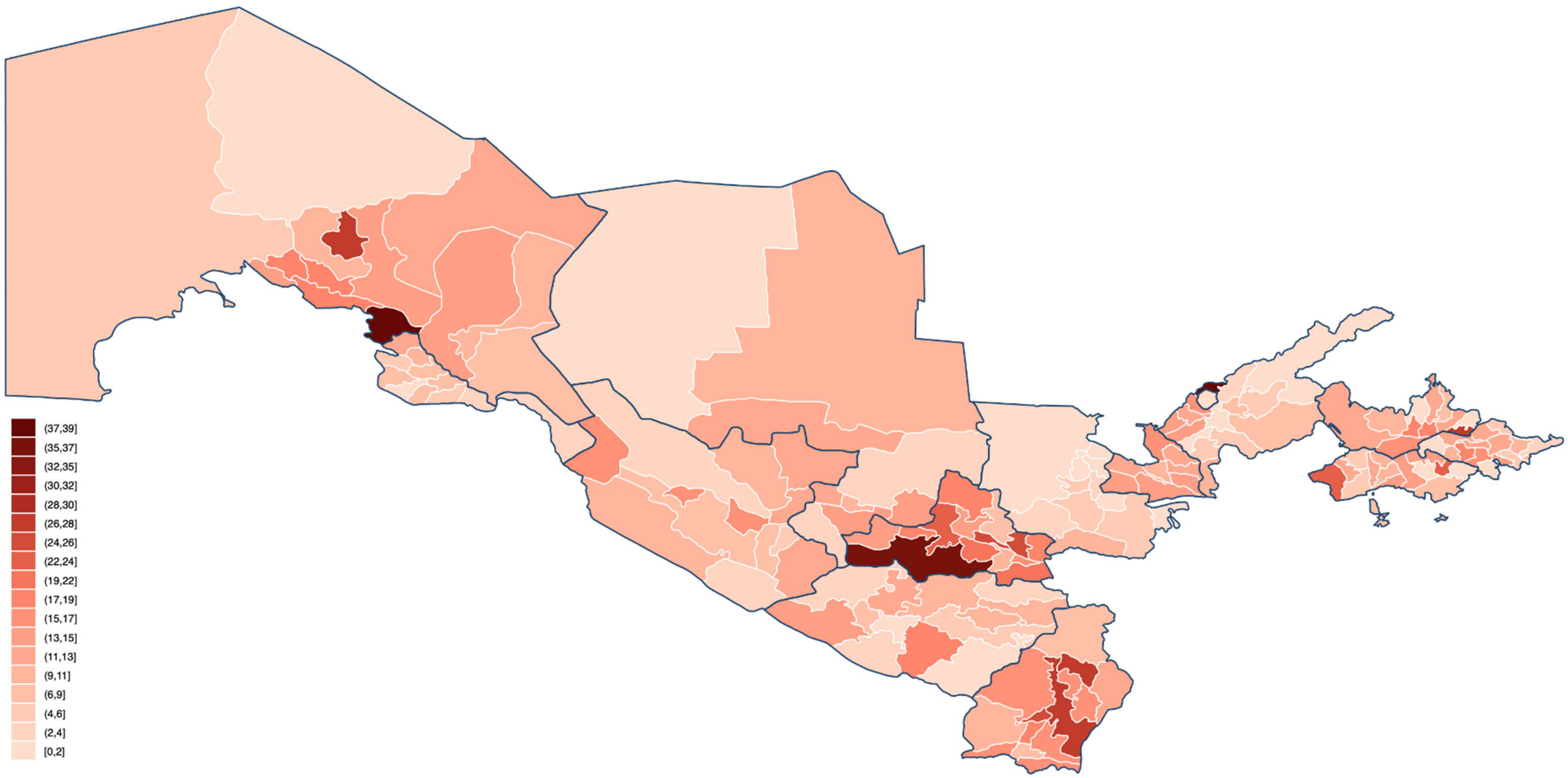


Figure 21: Poverty headcount ratio at $5.5-a-day PPP per person, rates for Uzbekistan 2018

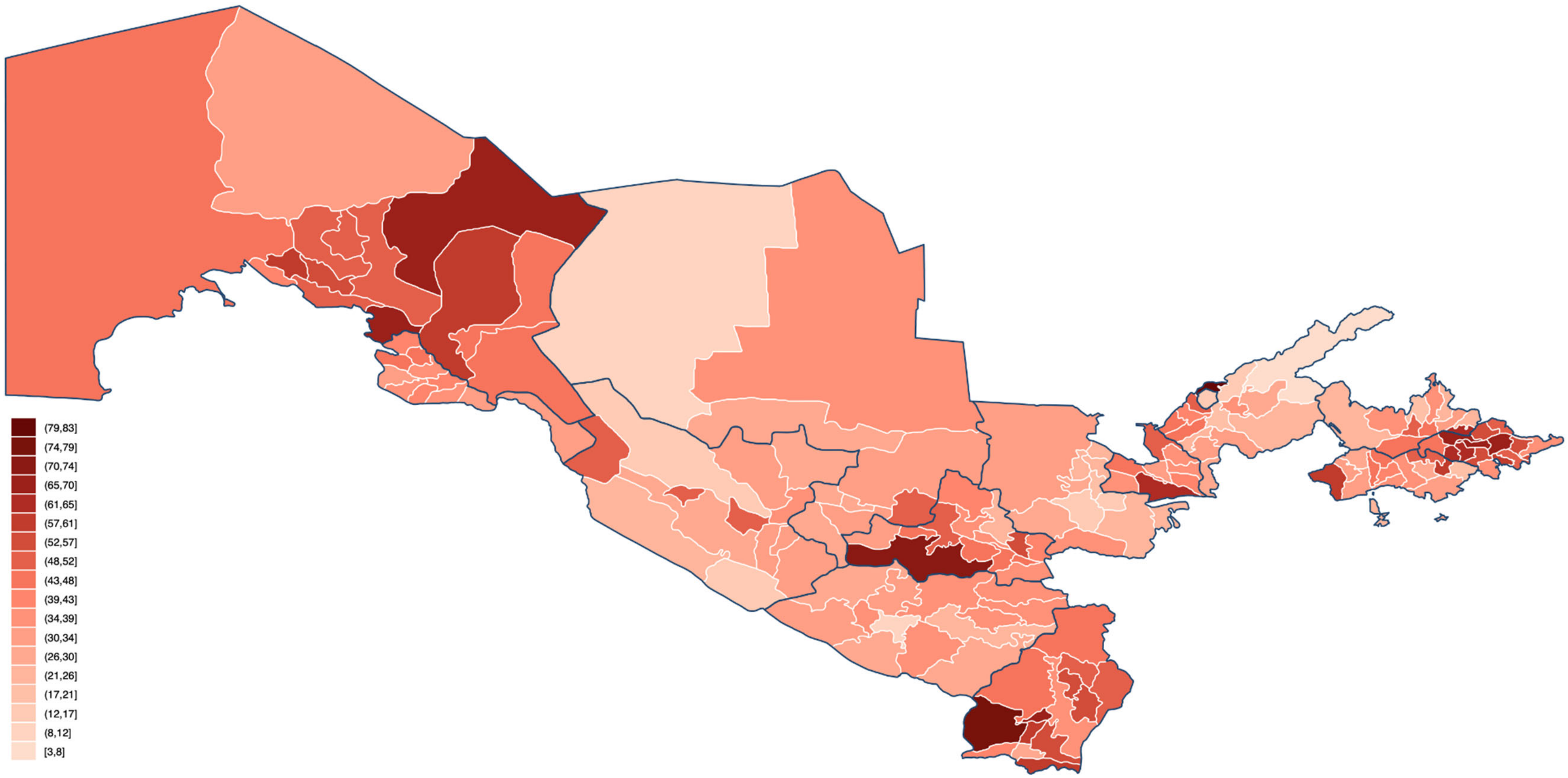


Figure 22: Share of population in the middle class, rates for Uzbekistan 2018

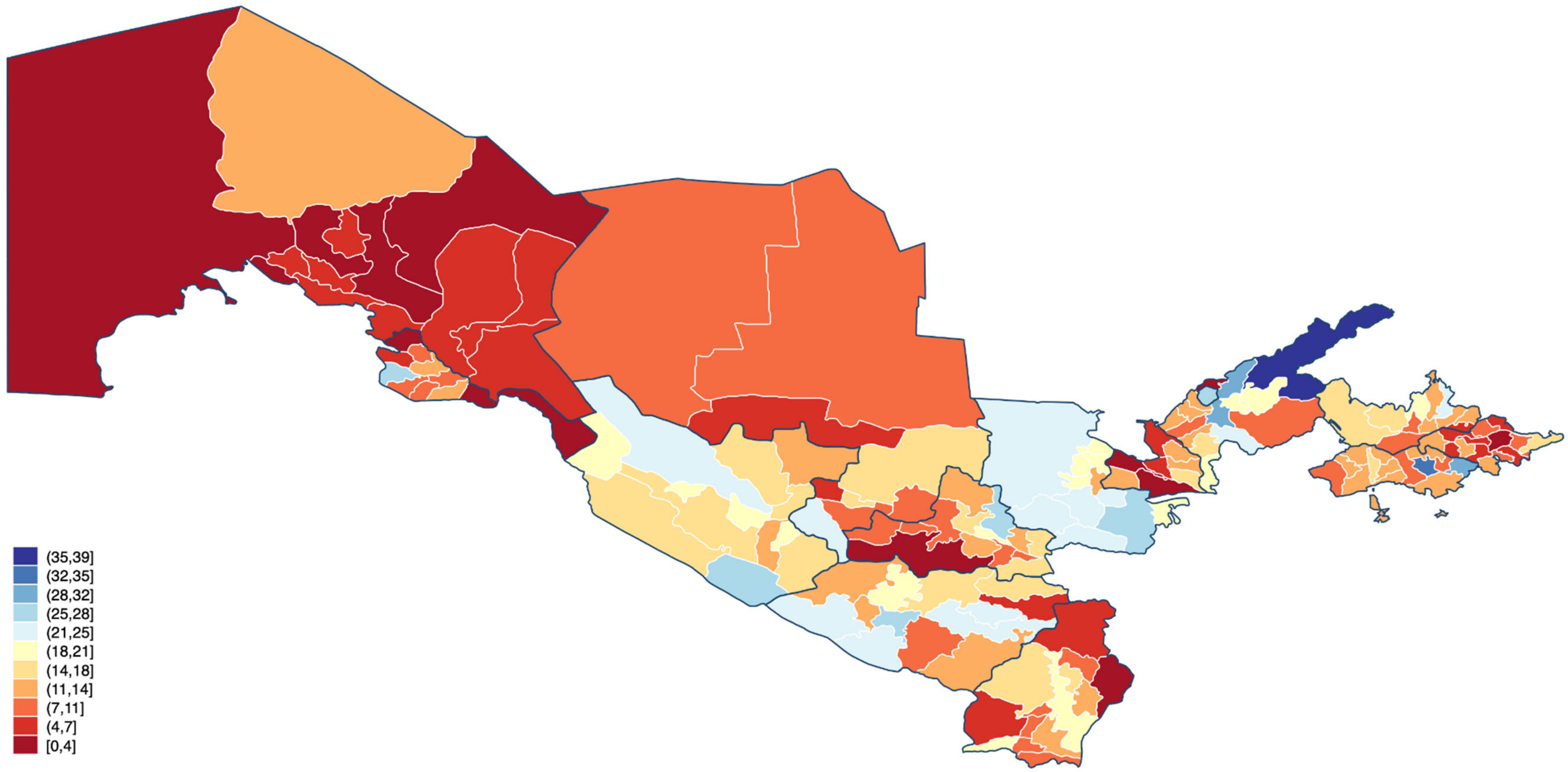


Figure 23: Average Per Capita Daily Consumption in 2011 PPP for Uzbekistan 2018

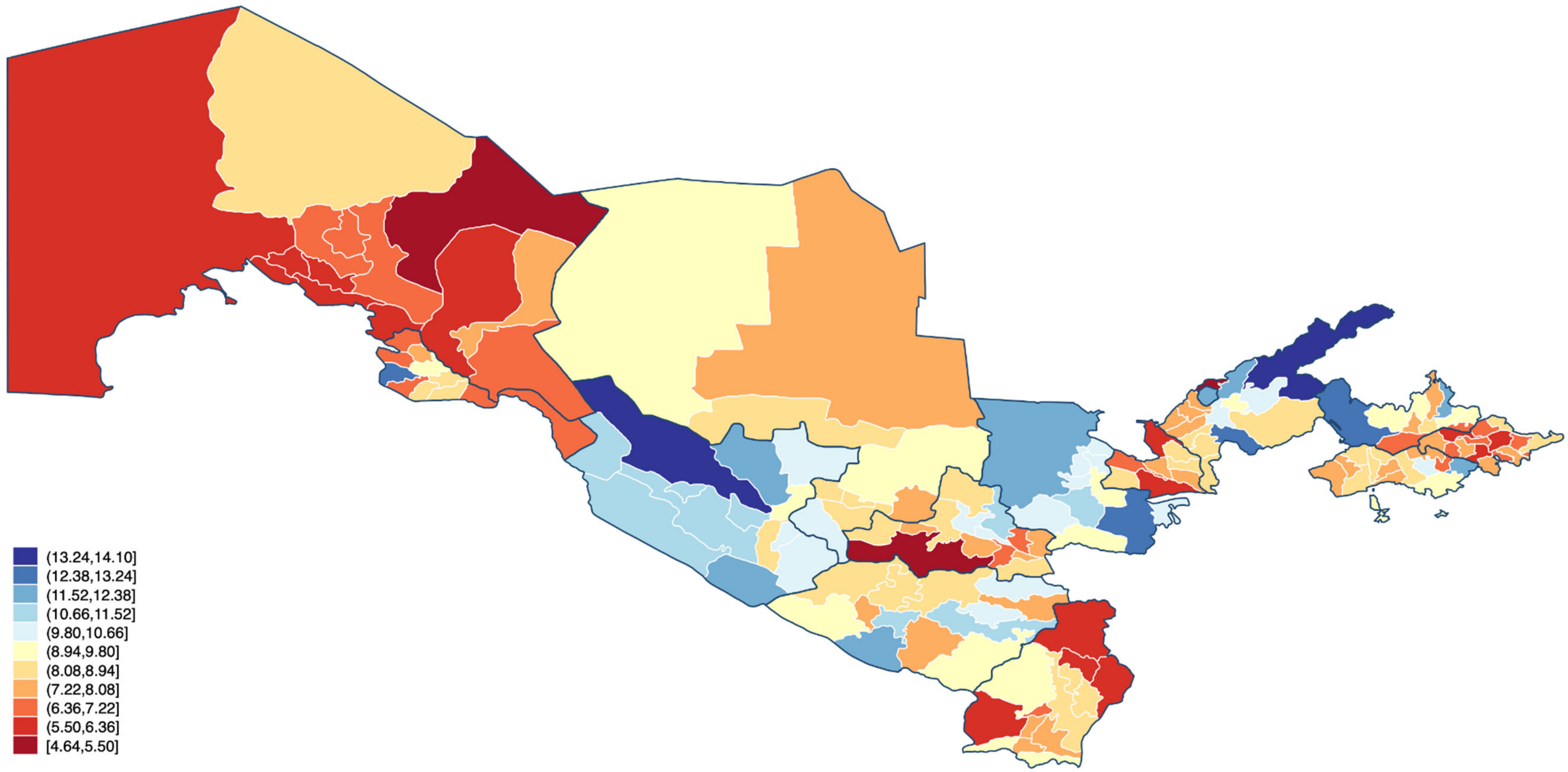


Figure 24: Poverty headcount ratio at $3.2-a-day PPP per person, rates for Kyrgyzstan 2016

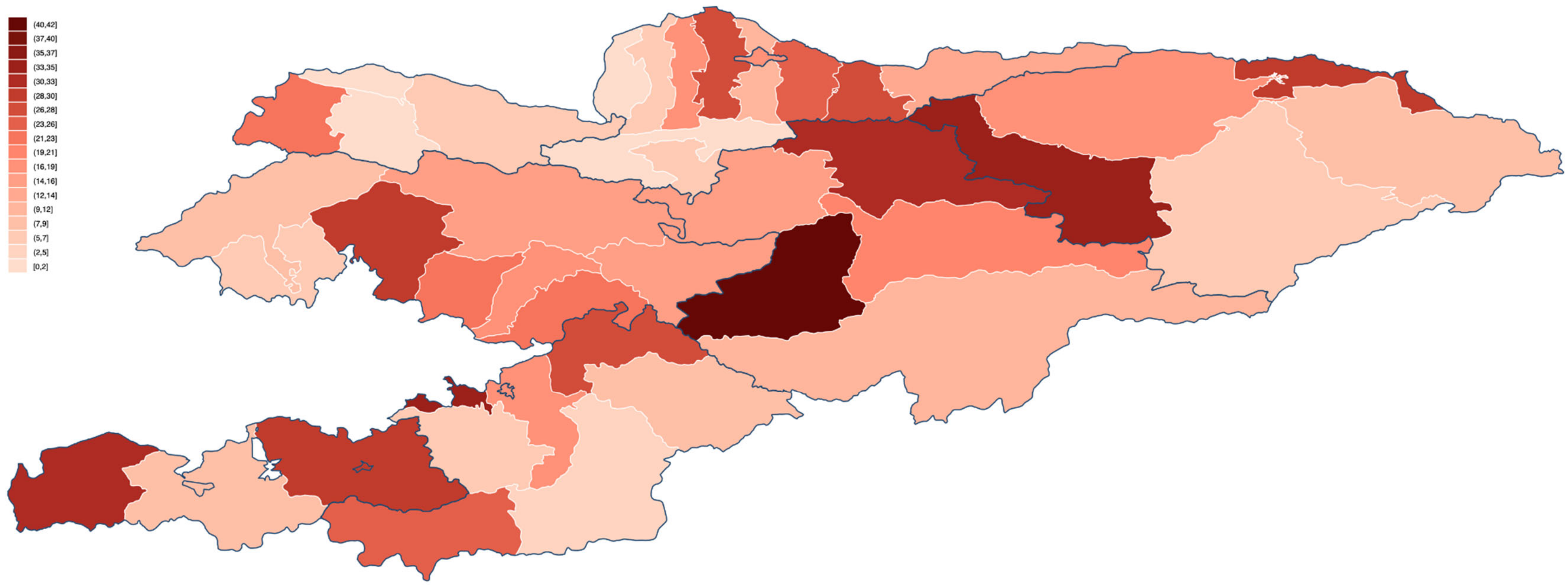


Figure 25: Poverty headcount ratio at $5.5-a-day PPP per person, rates for Kyrgyzstan 2016

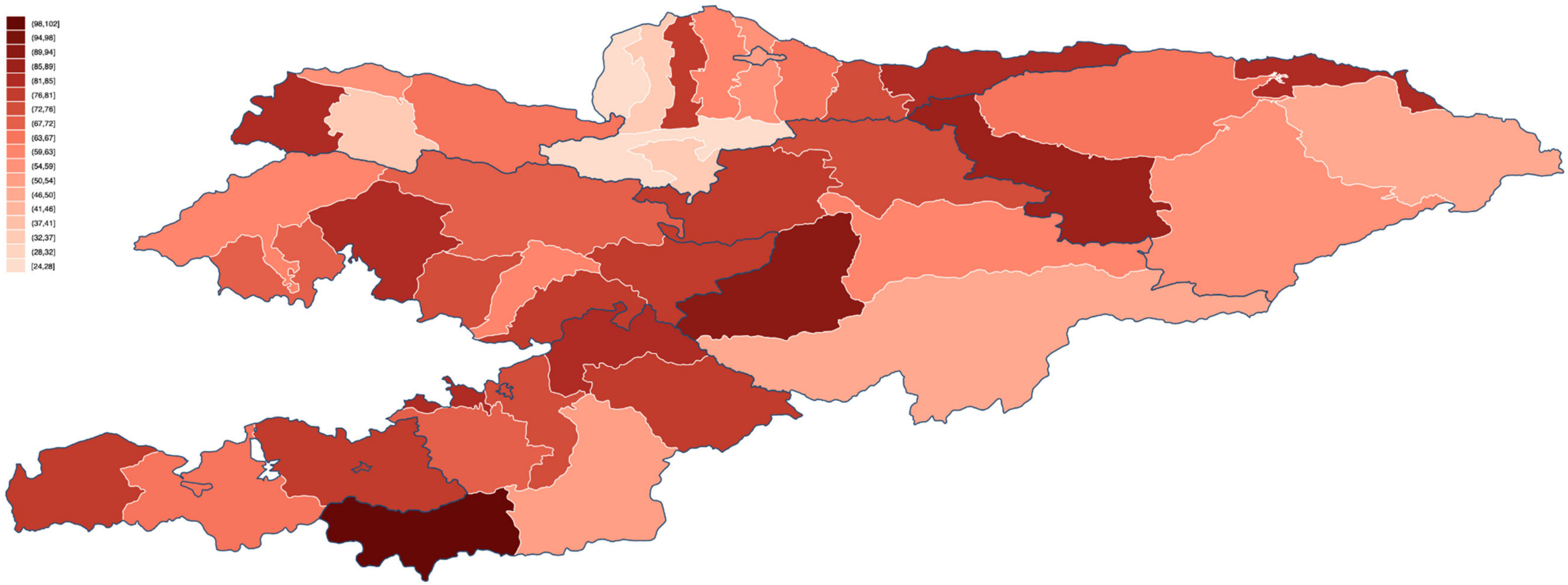


Figure 26: Share of the population in the middle class, rates for Kyrgyzstan 2016

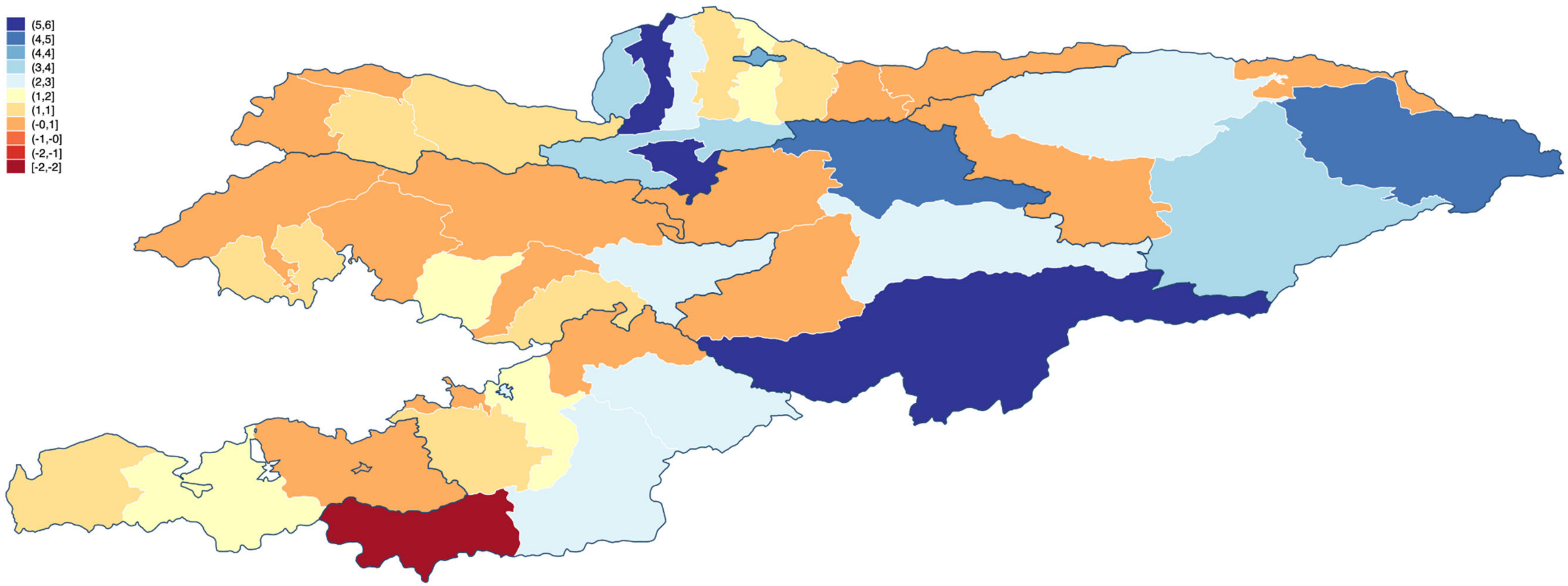


Figure 27: Average Per Capita Daily Consumption in 2011 PPP for Kyrgyzstan 2016

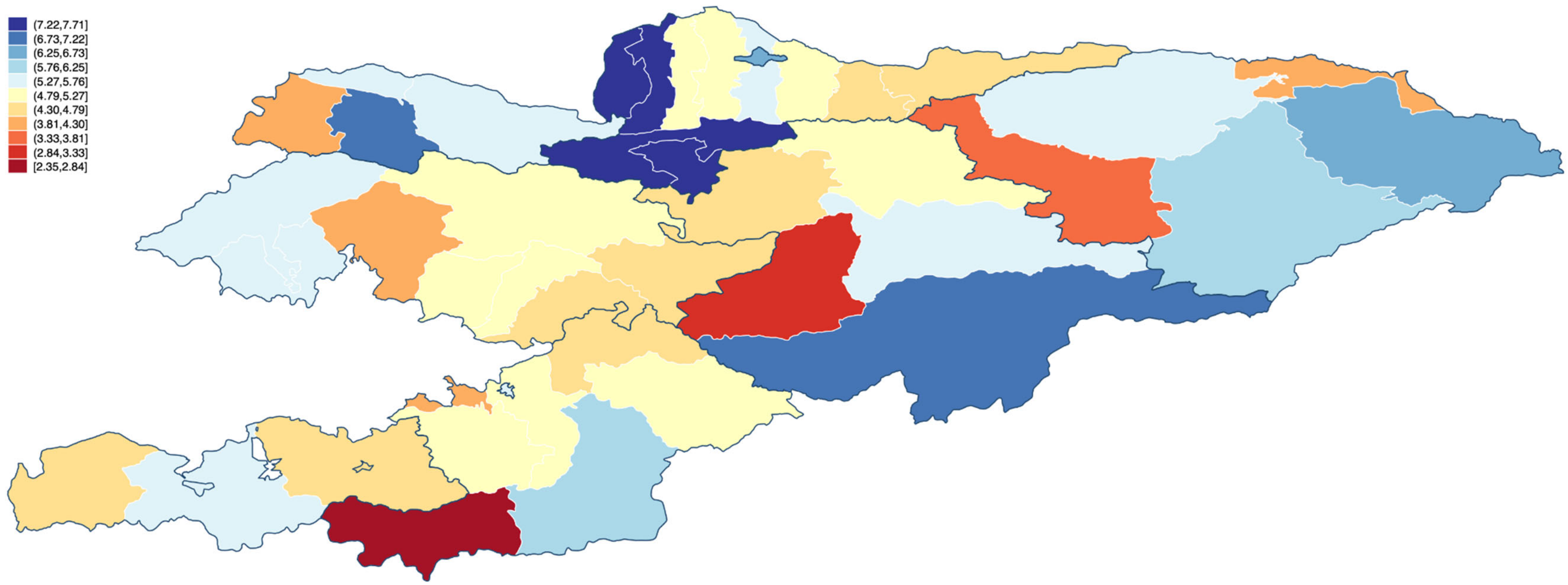


Figure 28: Poverty headcount ratio at $3.2-a-day PPP per person, rates for Tajikistan 2015

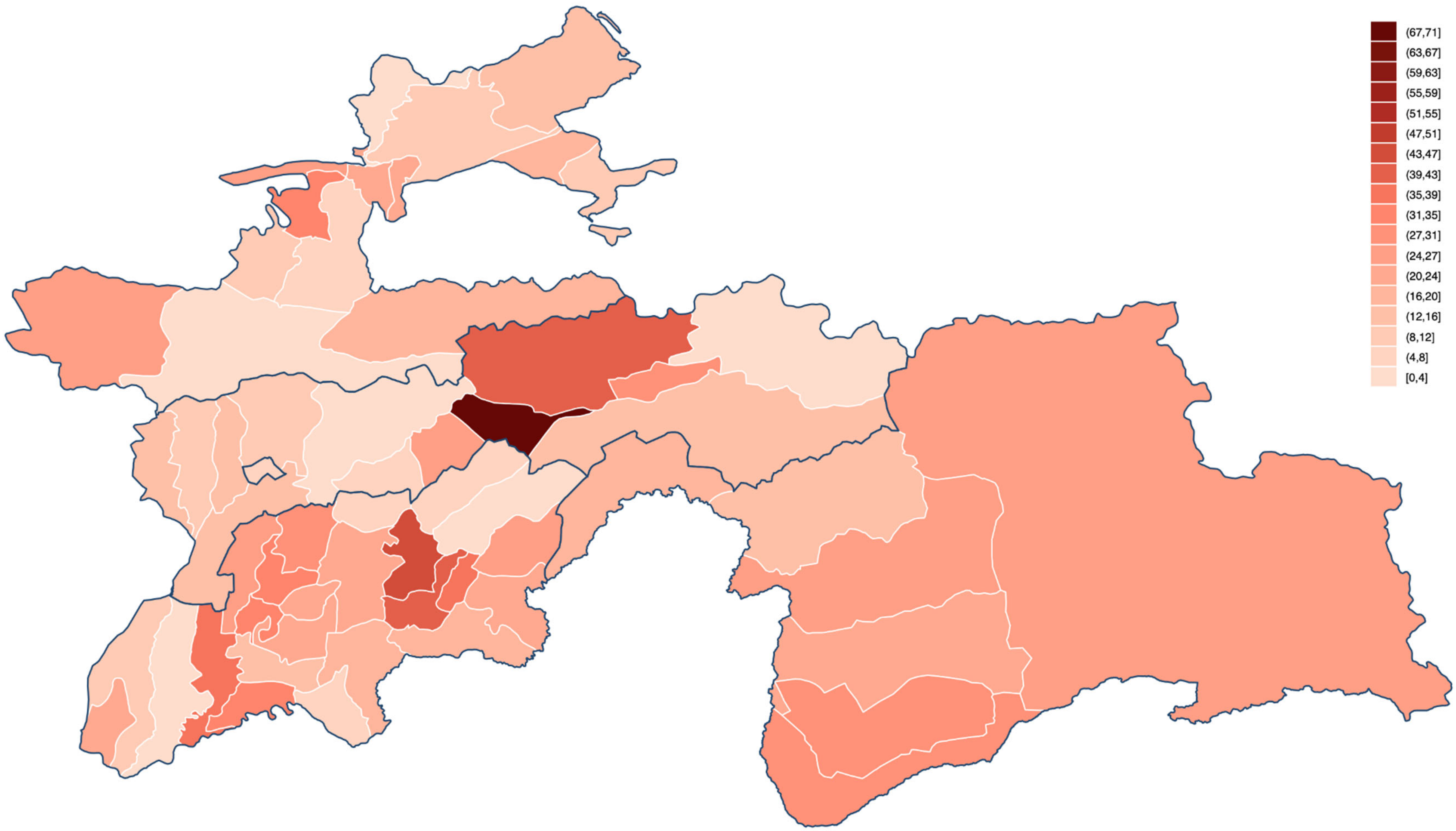


Figure 29: Poverty headcount ratio at $5.5-a-day PPP per person, rates for Tajikistan 2015

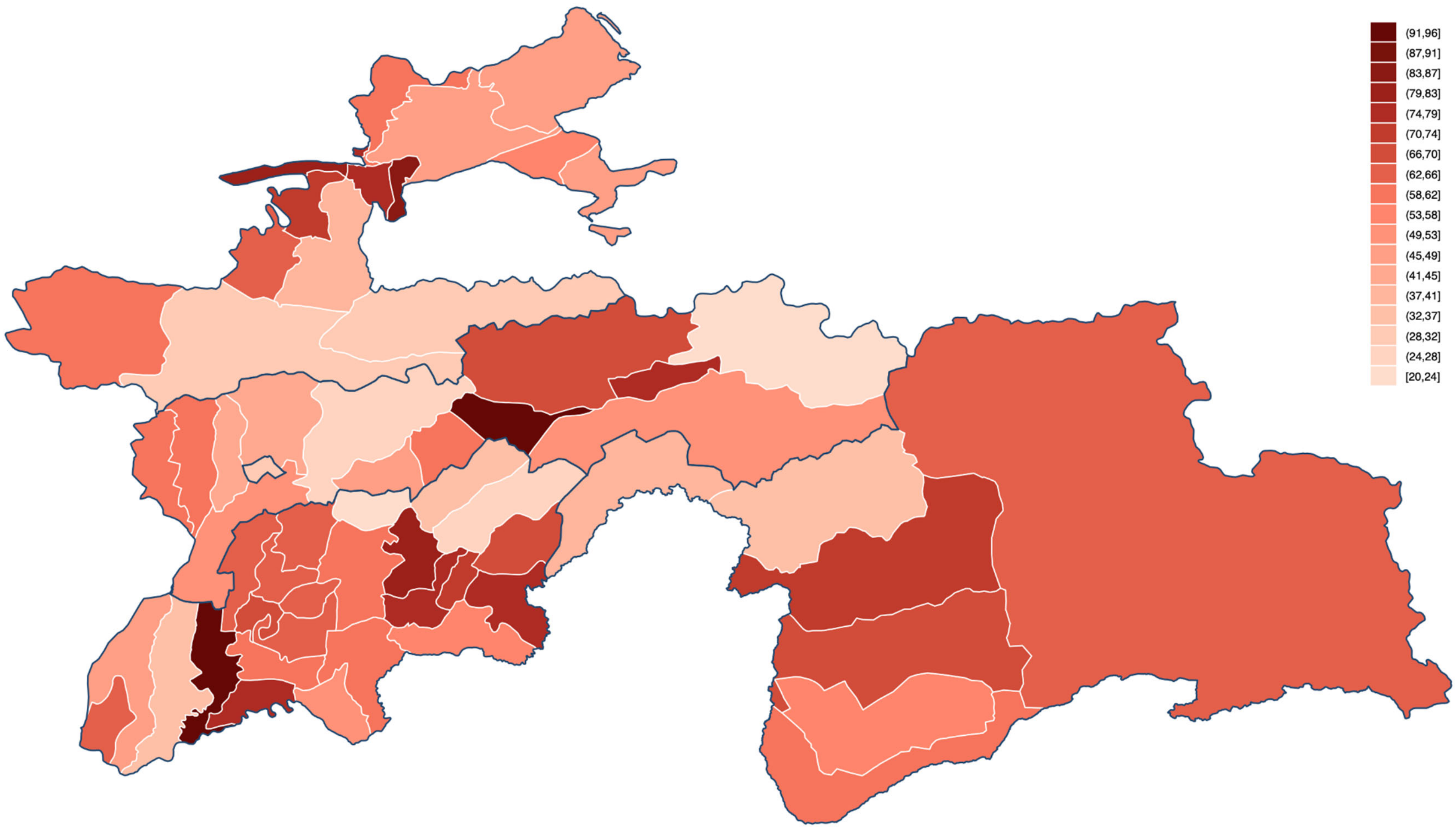


Figure 30: Share of the population in the middle class, rates for Tajikistan 2015

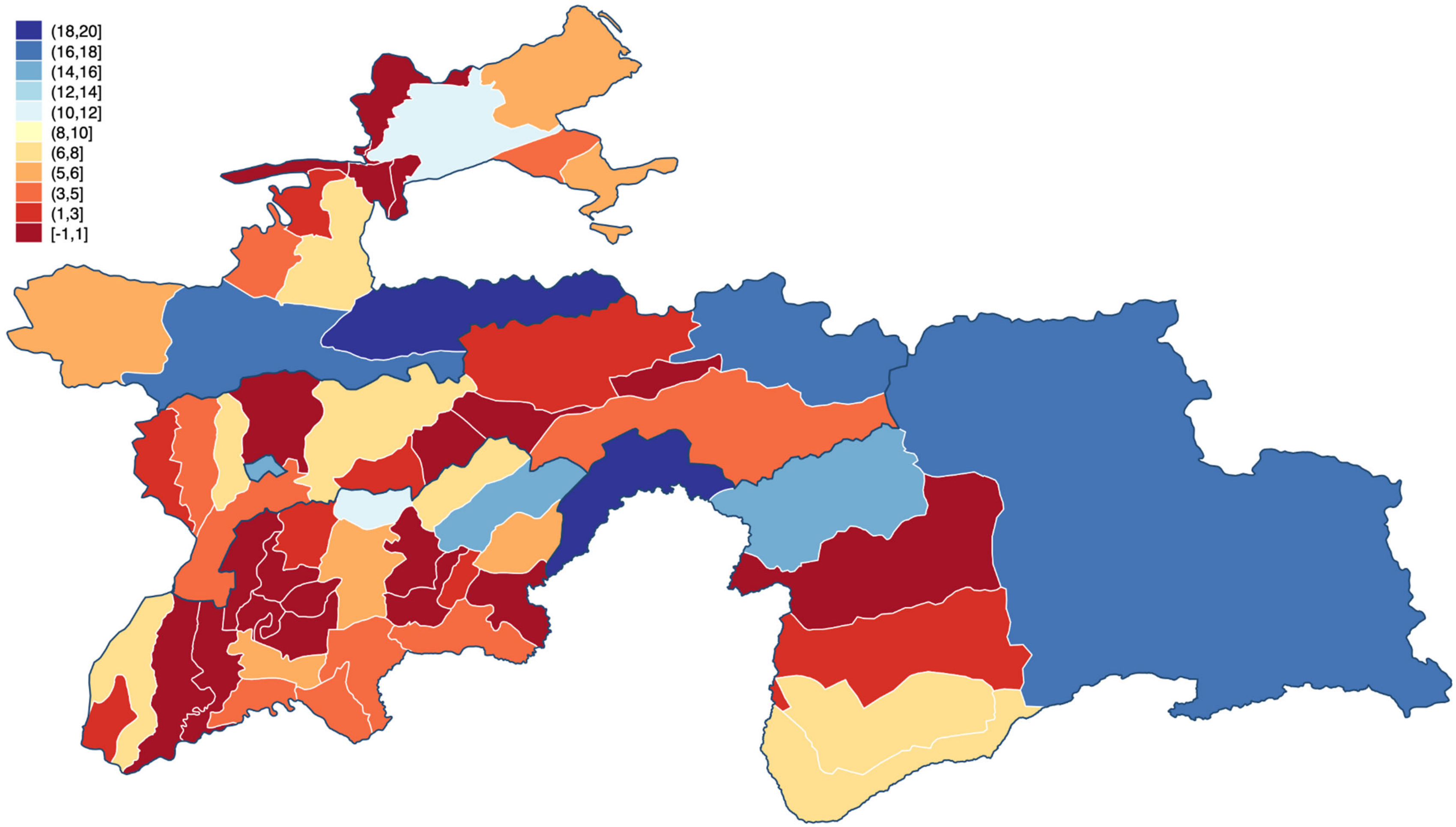
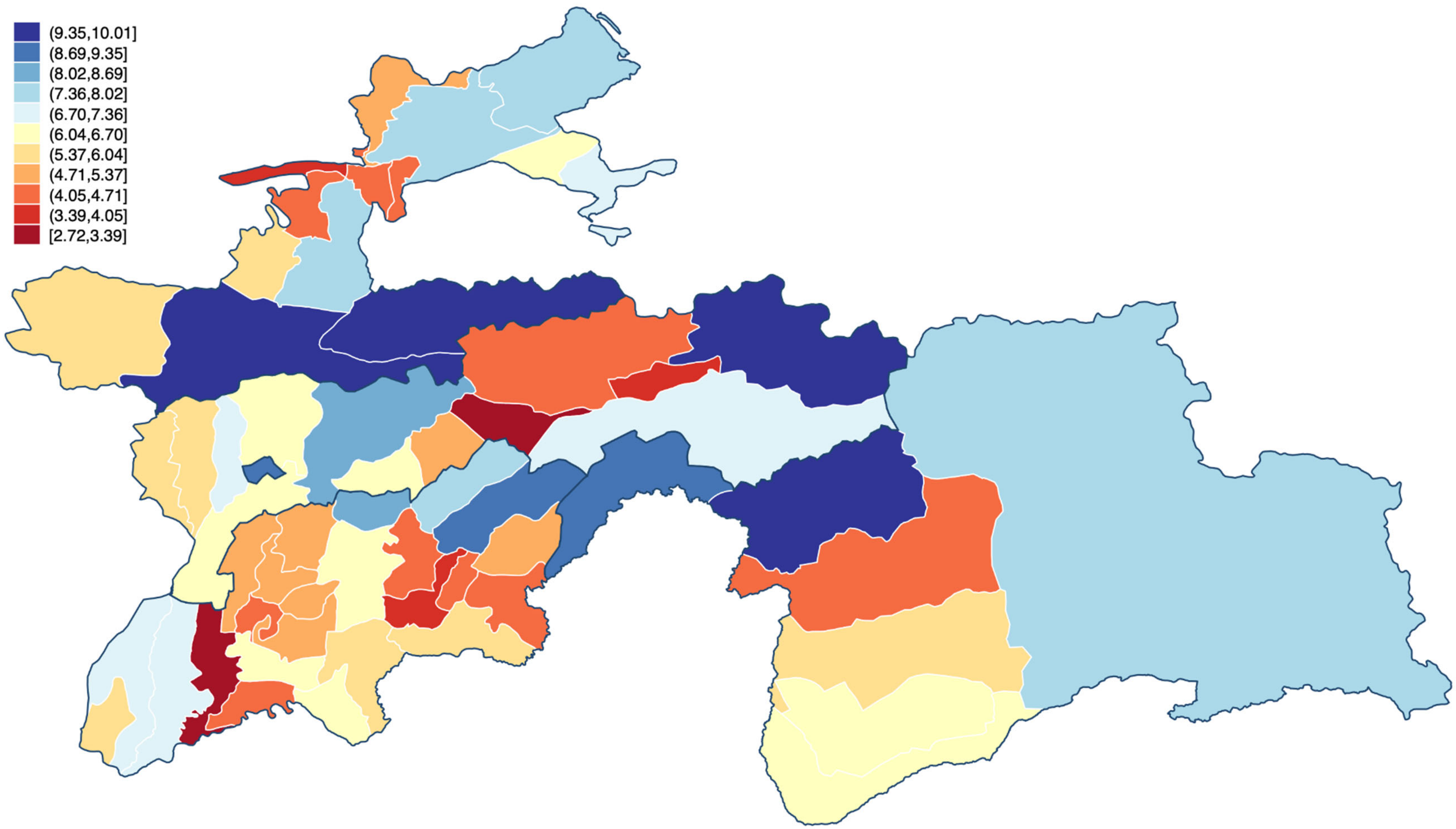


Figure 31: Average Per Capita Daily Consumption in 2011 PPP for Tajikistan 2015

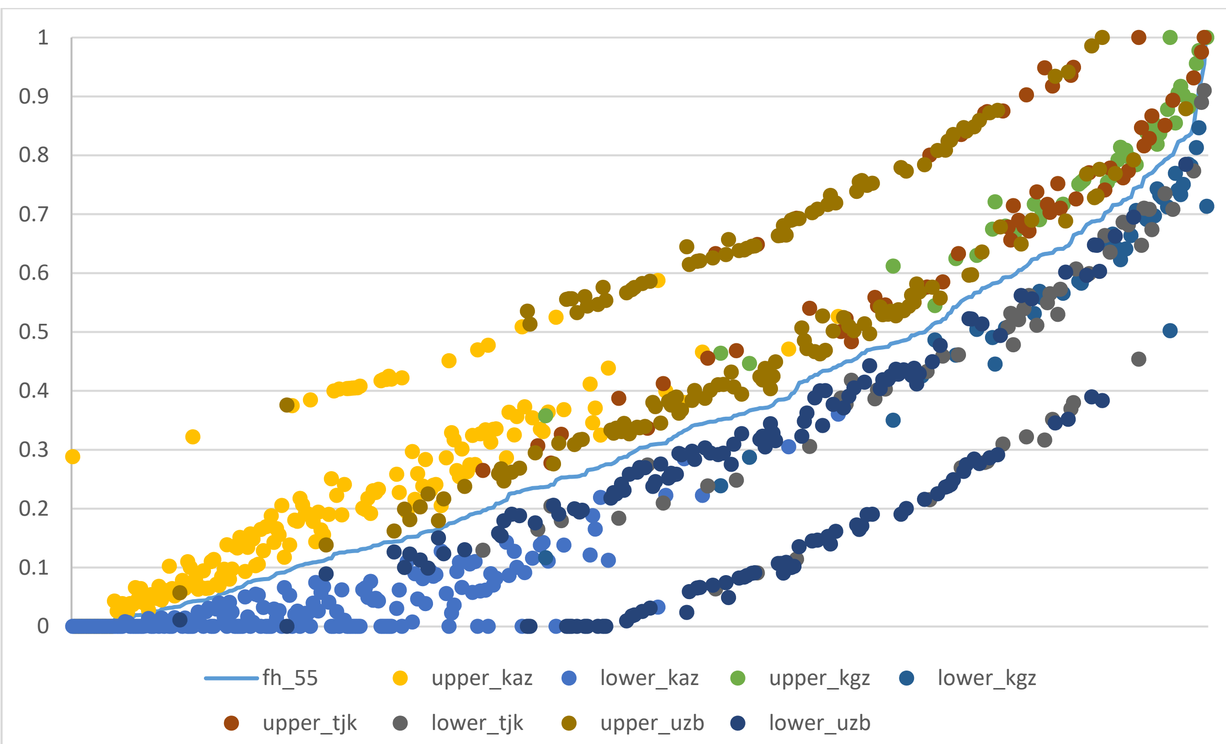


Annex F – Validation and Precision

One concern often raised regarding poverty map results is that the poverty estimates may not be precise enough for the purposes to which they are put. One way to assess this is to measure whether there are clear and statistically significant differences between the resulting poverty rates at the district level that can be usefully integrated into the work of the World Bank, counterparts, and other partners. This can be demonstrated graphically by reporting the poverty rates with the associated 95% confidence interval.

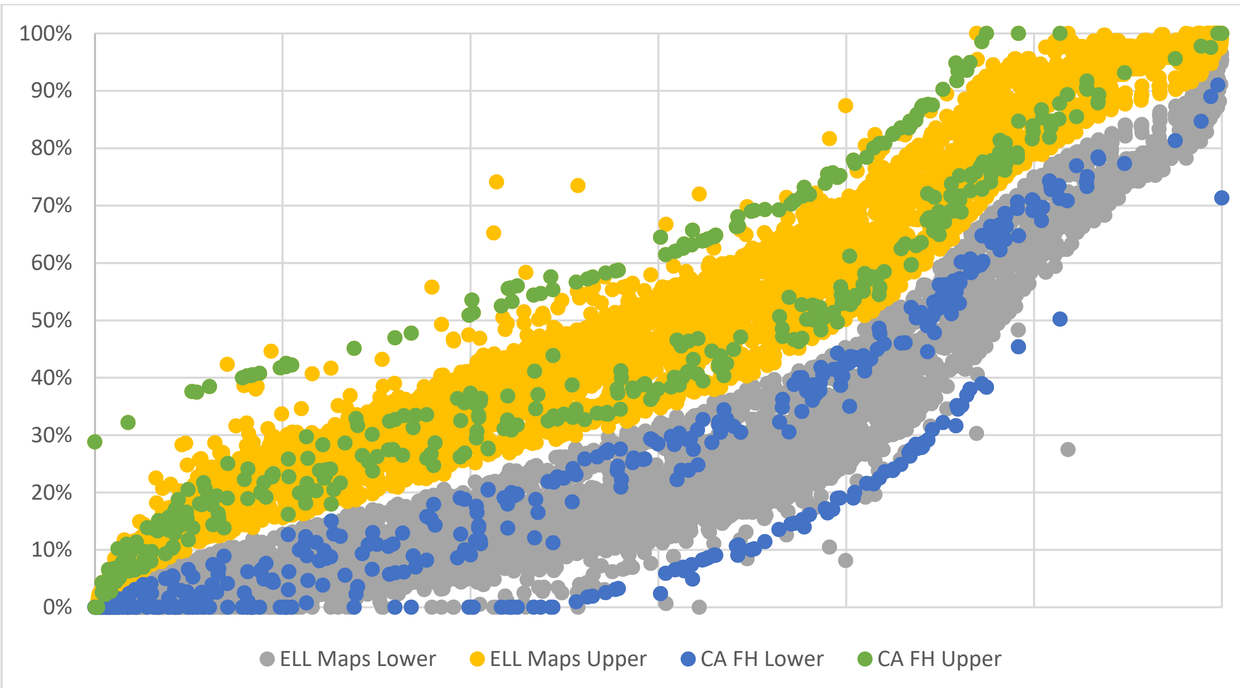
Because there are some districts in which there are no survey observations, these must be imputed out of sample when using the FH approach. In this minority of cases, the root mean square errors are larger than average, and should be used with caution. These cases of relatively high imprecision are noted in the district level tables with red stars (*). However, it is also important to note that most cases in this application are in sample do not suffer from this limitation of the FH approach.

Figure 32: Upper and Lower-bound Confidence Intervals, Including Out-of-Sample Predictions



Another way to demonstrate performance is to benchmark against "gold standard" results using the Elbers, Lanjouw, and Lanjouw (ELL) method previously published by the World Bank. The following graph demonstrates the comparison visually for 17 previously published maps that used the ELL approach. The results from the Central Asia poverty map perform quite well in this comparison for those cases that are in-sample. The 95% confidence intervals are usually well within those of other published results. However, there are notable exceptions for cases in which the estimates are derived entirely from the FH model (i.e. those districts in which there were no observations in the underlying survey). The root mean square errors for these cases are higher than in the case for most ELL maps and this is one of the key advantages of the ELL approach (because such analyses use census microdata, there are no missing districts that need to be estimated out-of-sample). However, unfortunately, in this application the ELL approach is not possible.

Figure 33: Comparison between ELL and FH

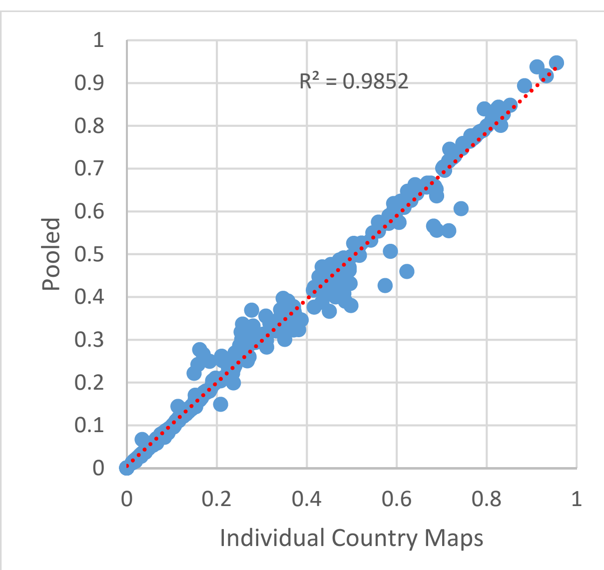


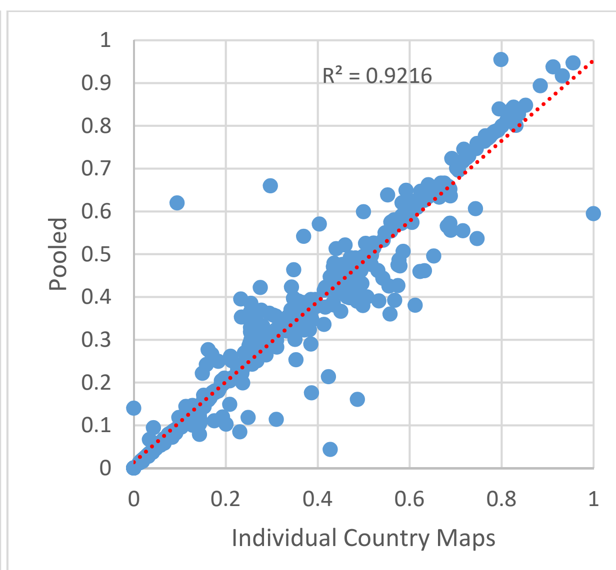
The improvements in precision (as measured by root mean square error) over direct survey estimates from the Fay Herriot approach are also substantial. Improvements are concentrated in those locations that had the least precise estimates before the exercise. The following figure (34) illustrates the improvement in terms of the root mean square error of the mean for poverty at $5.5/day.

Figure 34: Root Mean Square Error Before and After FH Approach (Poverty Headcount Ratio $5.5/day - Left; Average per-capita consumption 2011 PPP – Right)

An additional robustness check estimates FH models for each country individually, comparing the results with those using pooled data across countries. The results presented in figure (35) show that this makes little substantive difference in either the point estimates or in the root mean square error for within-sample districts. There is a very strong relationship between the estimates regardless of the pooled vs. individual approach. The relationship remains strong but weakens somewhat with respect to out-of-sample districts (figure 35 - right). Using the pooled approach likely improves on the out-of-sample prediction: this method improves the training of the model with more data than is available at the national level.

Figure 35: Comparison of Individual Models vs. Pooled Model (Only in sample - Left; Including out of sample - Right)

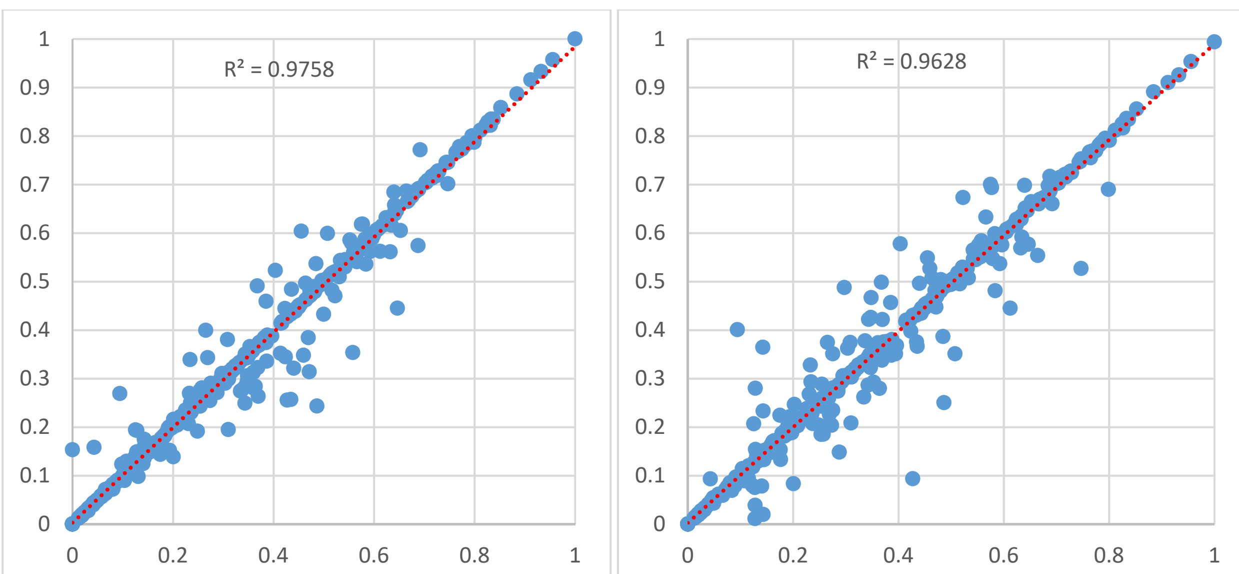




These results suggest that there is little concern that country-specific idiosyncratic relationships between y and the explanatory variables are contaminating the results for other countries. Because the right-hand side variables in the model are almost entirely based on remote-sensing data, and are not country-specific in nature, the approach is more amenable for such cross-country modeling than other potential methods that are more sensitive to these concerns. None of the explanatory variables that are used in the modeling stage (reviewed in annex H) in the final regression models would be expected to vary directly with policy regimes in the countries under study.

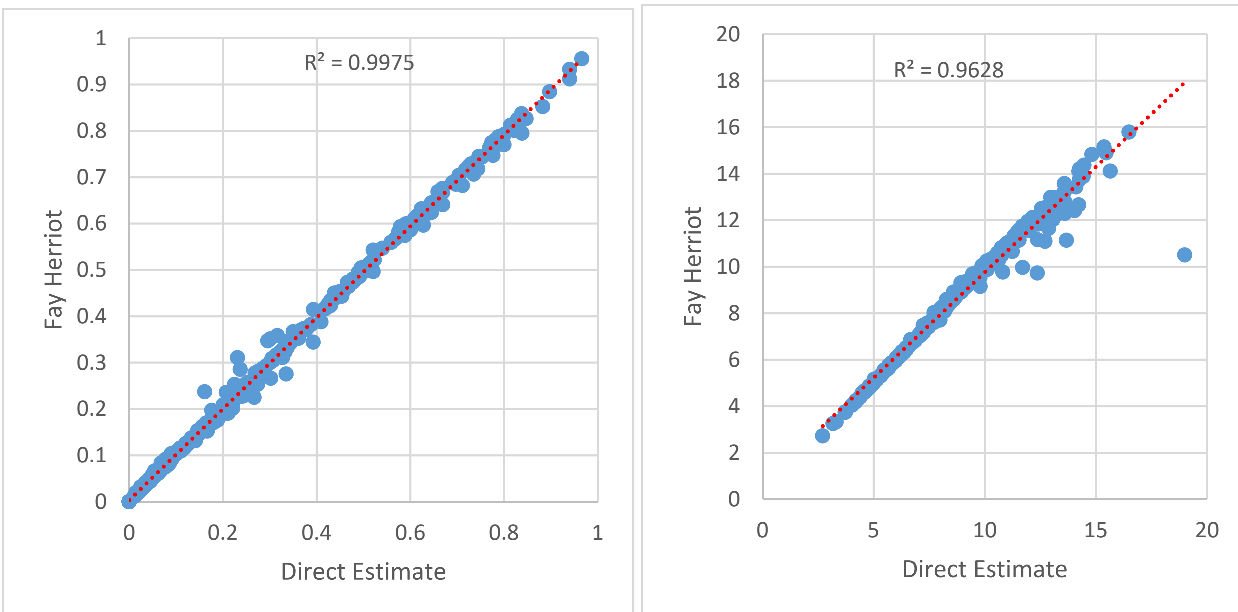
The model selection adopted in this approach uses the stepwise approach, which is vulnerable to the inclusion of variables with high variance inflation factors. Comparing a model that screens for high VIFs is reported in figure (36). The results show that limiting the variance inflation factor (VIF) of the variables included in the stepwise selection approach to standard levels has some small effect on the model and consequently the estimated results, and a reduction in the adjusted R2 (for the $5.5/day line, down from .72 to .67, when estimated over all Central Asia). Though this change leads to only small differences in terms of the point estimates or the root mean square error of the estimation results, the VIF minimizing strategy is clearly superior, and adopted in this report.

Figure 36: Left: Strict VIF Threshold (5) vs. Adopted Threshold (10); Right: No VIF Threshold vs. Adopted Threshold (1))



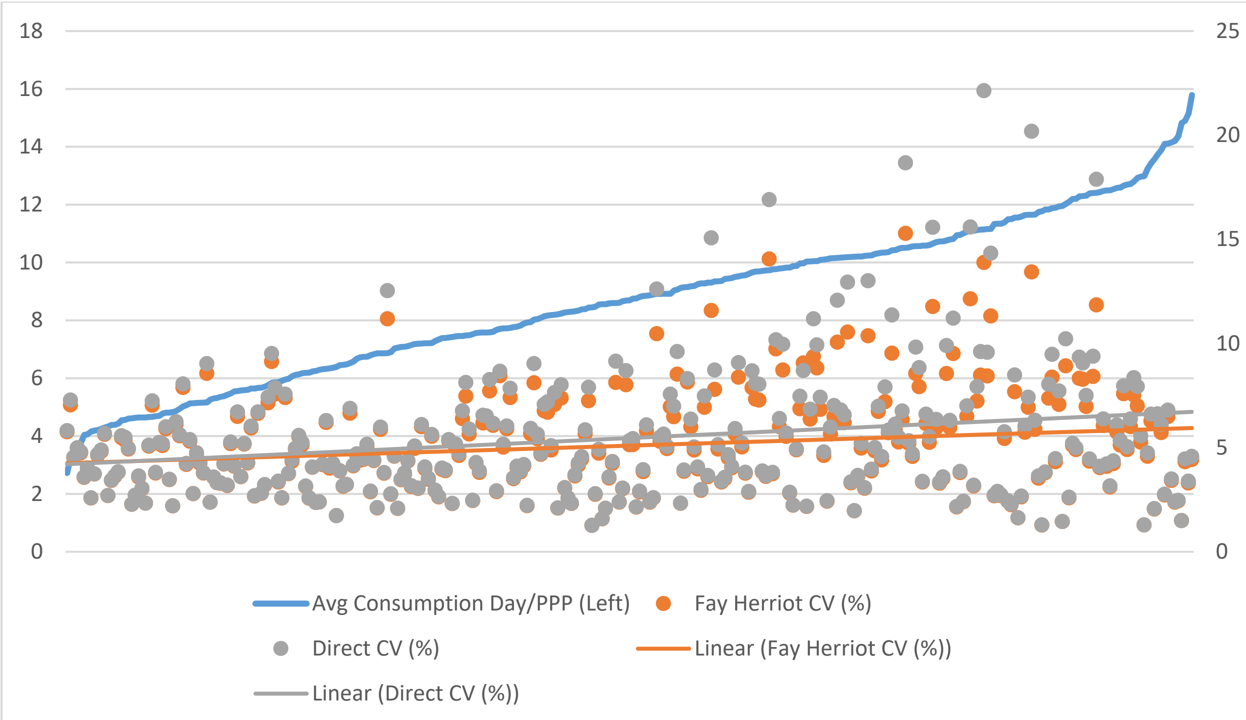
To ensure that the map faithfully represents the underlying poverty dynamics of the country, it is important to ensure that the results are internally consistent. One method of assessing the stability of the estimates and the robustness of the results is to compare the relationship between the direct and adjusted estimates. This relationshipcan be presented visually as a scatter plot, with direct survey estimates along the x-axis, and model estimates along the y-axis. With perfect correlation, the estimates would lie along the 45˚ line, and as figure (37) shows, there is indeed a strong relationship between the model predictions and those of the observed values in the survey data. The cases in which the FH most differs from the direct estimate, the direct estimate was relatively imprecise, and the synthetic result thus relies more on the model-based estimate of the indicator. The overall strong correspondence suggests that the model-based estimates improve the precision of estimates without dramatically changing the point estimates derived from the survey. In some cases, the estimate lies exactly on the 45° which signifies that the model-based estimates did not provide additional information enough to revise the direct estimates.

Figure 37: Direct vs. Fay Herriot Estimates for in-sample Poverty $5.5day (left) and average consumption (right)



Coefficients of variation (CVs) are a useful guideline with respect to precision when estimates are far away from zero, and when the sample size is small (for instance, the surveys in UZB and TJK are much smaller than for the other two countries). In the case of per-capita consumption, no resulting in-sample estimates are above the 20% threshold that some statistical agencies adopt for reporting (Eurostat, 2013). Furthermore, the R2 between district poverty rates at $5.5/day and average consumption is very high (.74) suggesting that the estimates of poverty and average consumption are very consistent. This strong accordance should give greater credence to the poverty estimates.

Figure 38: Improvement of Coefficient of Variation in average consumption



Annex G – Comparison of Domain Variance Estimation Alternatives

The preceding results use the linearized variance estimator approach—based on a first-order Taylor series. The two other options are contrasted with this approach in figures (39) and (40) for average consumption and the poverty rate at $5.5/day respectively. Figure (41) provides comparisons of poverty rate results comparing across methods of variance estimation, highlighting the relatively small differences between the adopted approach (though the largest differences are present for the HT-based approach).

Figure 39 comparison of variance estimates for average consumption

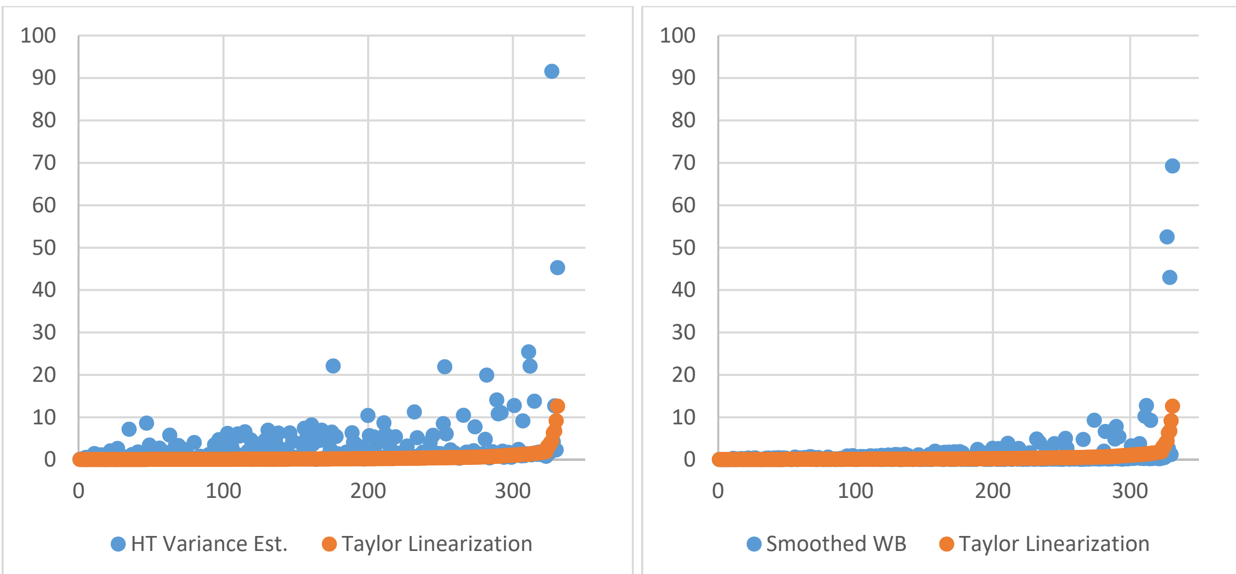


Figure 40: Comparison of variance estimates for poverty at $5.5/day

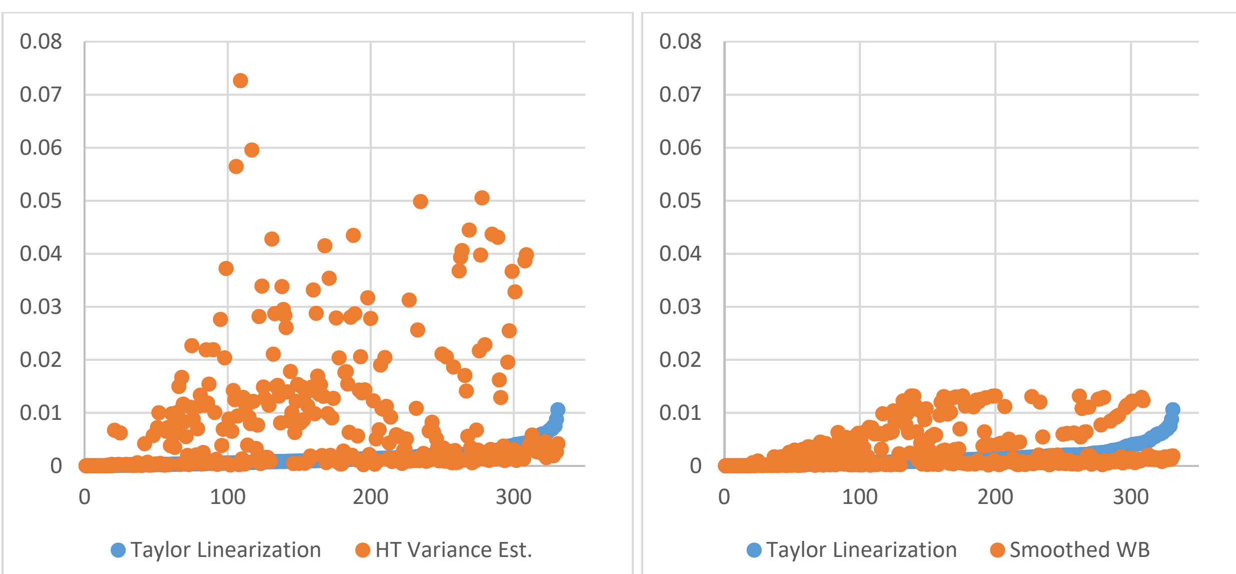
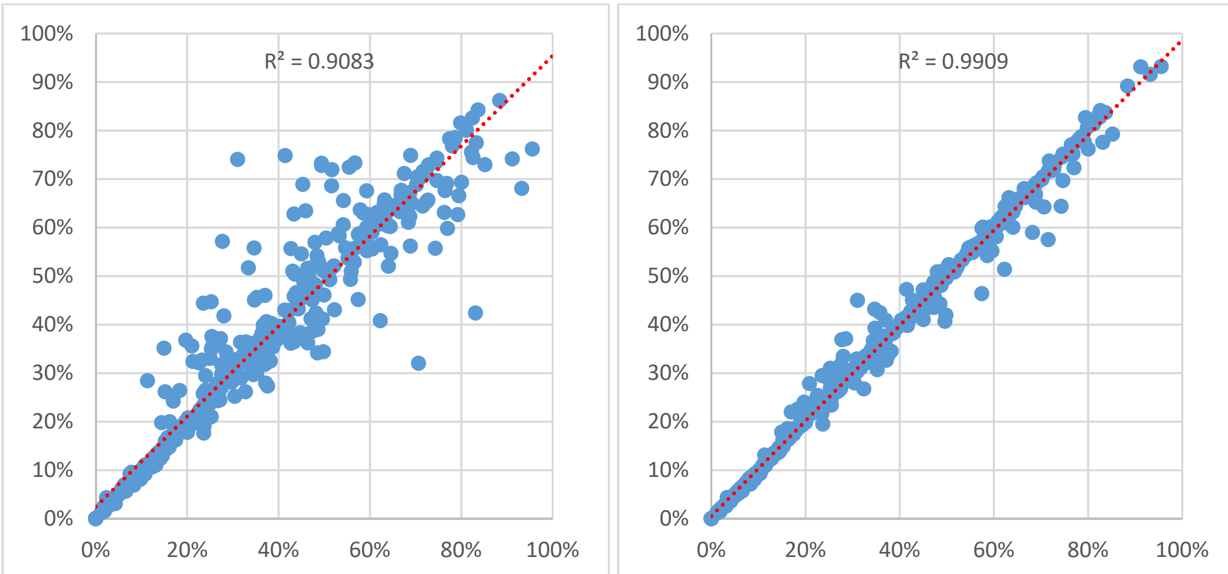


Figure 41: Poverty Headcount Ratio (5.5/day) for Taylor Linearized Method vs. HT Method (Left), Taylor Liberalized Method vs. Smoothed (Right)



Annex H – Regression Model Details

Table 6: Fay-Herriot Model for Poverty Rate at $5.5/day and $3.2/day

	Poor $5.5/day
	(1)
No local service road max value	1.0000***
	(0.0000)
Grid Mean GDP	0.9559***
	(0.0103)
Grid Mean Max	0.9981***
	(0.0005)
Air temperature max	1.0115***
	(0.0017)
Grid Minimum GDP	1.7417***
	(0.3025)
Minimum population count	1.0002**
	(0.0001)
500m Elevation	1.0003***
	(0.0001)
Constant	1.1588***
	(0.0373)
Observations	331
R-squared	0.6984

*** p<0.01, ** p<0.05, * p<0.1; selected country/region dummy variables not shown

	Poor $3.2/day
	(2)
No local service road max value	1.0000***
	(0.0000)
Minimum air temperature	1.0088***
	(0.0012)
Maximum elevation slope	1.0024***
	(0.0006)
Grid minimum GDP	1.4635***
	(0.1916)
500m Elevation	1.0001***
	(0.0000)
Grid mean GDP	0.9702***
	(0.0083)
Constant	1.0155
	(0.0155)
Observations	331
R-squared	0.4538

*** p<0.01, ** p<0.05, * p<0.1; selected country/region dummy variables not shown

Table 7: Fay-Herriot Model for share below middle-class line, and average consumption in 2011 PPP

	Below Middle Class
	(1)
Population count	1.0000**
	(0.0000)
Grid Sum GDP	1.0000***
	(0.0000)
Grid GDP Min	1.2266***
	(0.0940)
Vegetation Index max	1.0000**
	(0.0000)
Max precipitation	0.9987***
	(0.0004)
Vegetation Index average	0.9999***
	(0.0000)
No local service road max	1.0000***
	(0.0000)
Constant	2.8220***
	(0.1133)
Observations	331
R-squared	0.4902

*** p<0.01, ** p<0.05, * p<0.1; selected country/region dummy variables not shown

	Average Cons.
	(2)
Air temperature max	0.9071***
	(0.0270)
Max precipitation	1.0278***
	(0.0104)
Nighttime lights	1.0000***
	(0.0000)
Grid GDP Min	0.0142***
	(0.0225)
No local service road max value	1.0000***
	(0.0000)
Grid GDP Mean	1.5187***
	(0.1485)
Population count	1.0000**
	(0.0000)
Grid GDP Sum	1.0002***
	(0.0001)
500m Elevation	0.9977***
	(0.0006)
Constant	9,759***
	(5755)
Observations	331
R-squared	0.5593

*** p<0.01, ** p<0.05, * p<0.1; selected country/region dummy variables not shown

Annex I – Sensitivity to Model Selection Technique

Sensitivity analysis was conducted with respect to the method of automated model selection used in the FH application. The main alternative assessed was the lasso technique implemented using the *lassopack* suite of commands in Stata (Ahrens et al., 2018). In contrast to stepwise approaches which iteratively add variables to the model and assess the p-value of the indicator (keeping the variable in the model if it is below a certain threshold), the lasso approach minimizes the residual sum of squares subject to a constraint on the absolute size of coefficient estimates. There are thought to be two major advantages of lasso approaches over least squares. First the lasso tends to produce sparse solutions and thus facilitates model interpretation. Secondly, lasso can at times outperform least squares in terms of prediction due to lower variance. However, the stepwise models adopted in this paper were already quite sparse, and there were no great advantages observed in terms of minimizing the variance.

Each of three lasso options are contrasted with simple step-wise selection. In no case are the differences remarkable. In this context, stepwise was maintained as the preferred approach due to its greater replication simplicity and ease of explanation to non-expert audiences.

Figure 42: Lasso AIC vs. Stepwise

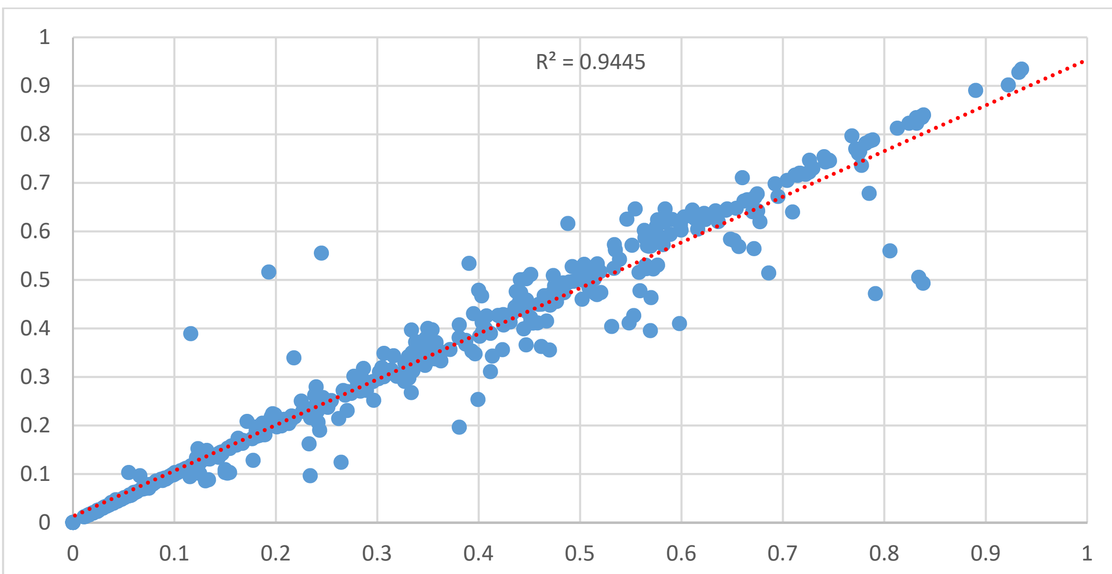


Figure 43: Lasso EBIC vs. Stepwise

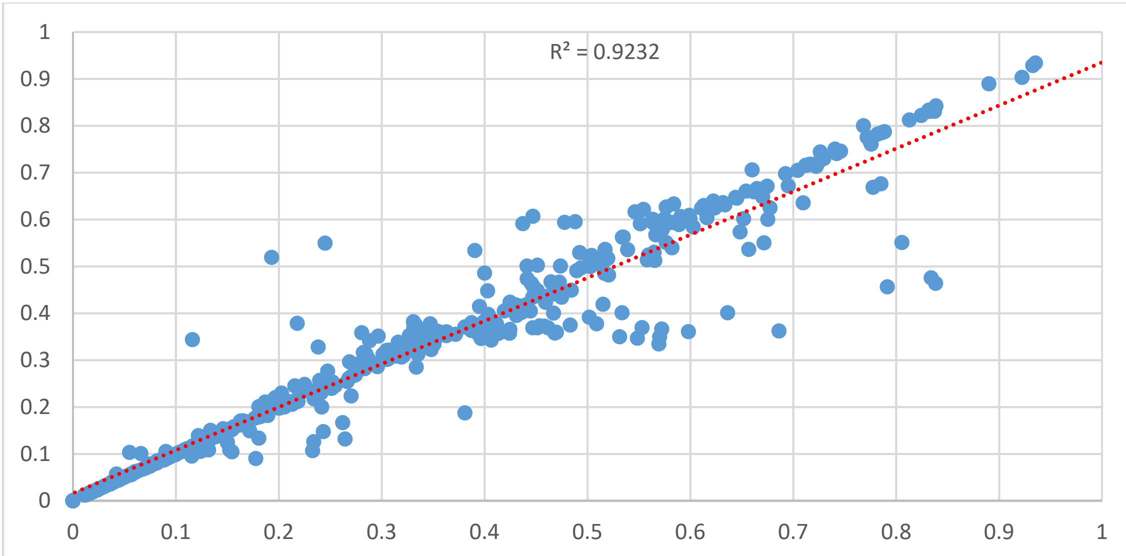
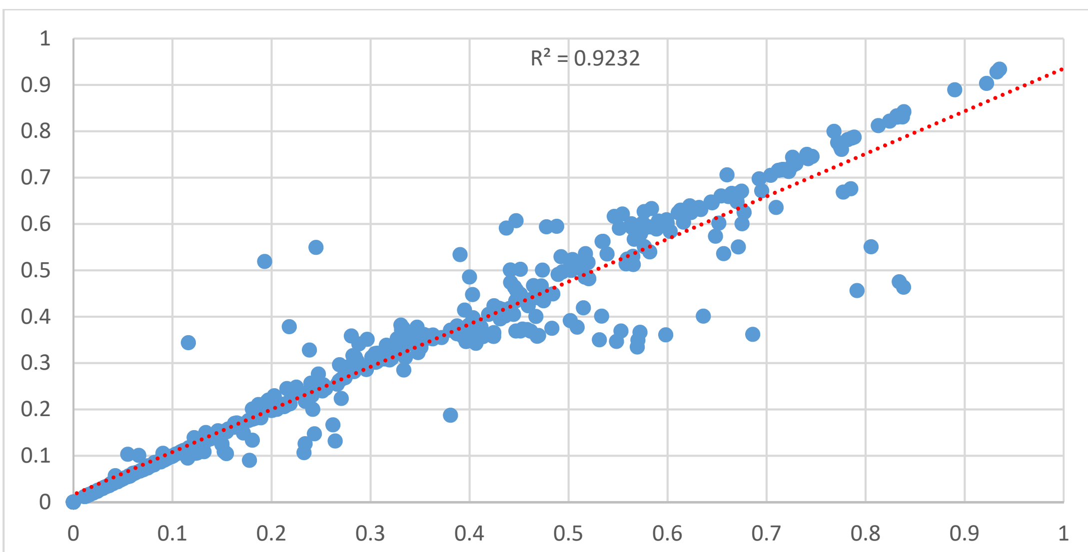


Figure 44: Lasso BIC vs. Stepwise



Annex J – K-fold Model Selection Sensitivity Analysis

An additional concern of automated variable selection techniques is that overfitting will generate spurious models that perform poorly in out-of-sample prediction. One method of assessing the risk of overfitting is to train models while withholding a portion of the data and checking that the automated model development technique performs similarly well despite the missing data. This assessment is described in this annex (J), and the results (presented graphically in figures 45-49) show that there is little change in the estimates of interest when withholding a subset of data to validate performance and the presence of overfitting.

In practice, this assessment was conducted by splitting the sample into 5 randomly assigned groups (called "folds"), and using 4 folds to develop the model, imputing by using the FH model to adjust the missing observations.

Figure 45: Fold A Full Sample (Left); Withheld Sample (Right)

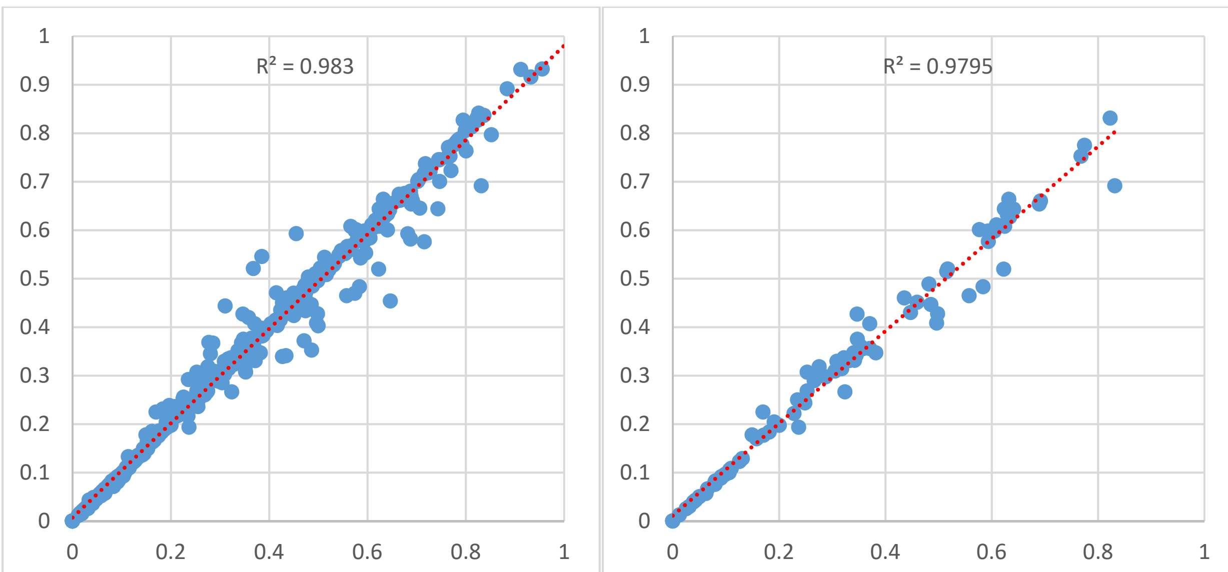


Figure 46: Fold B Full Sample (Left); Withheld Sample (Right)

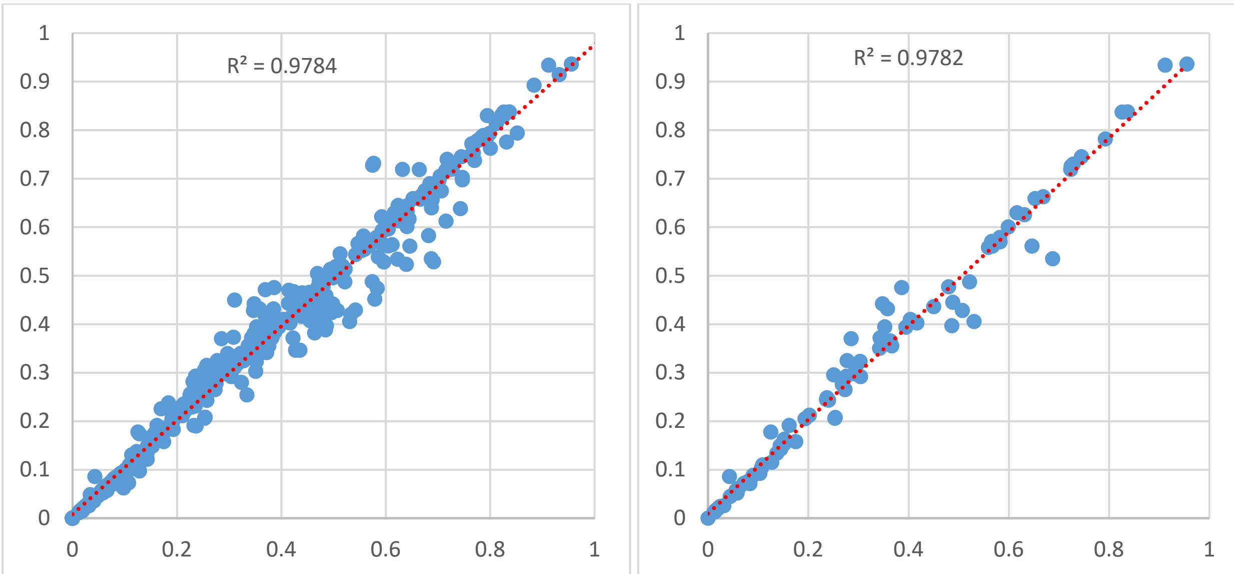


Figure 47: Fold C Full Sample (Left); Withheld Sample (Right)

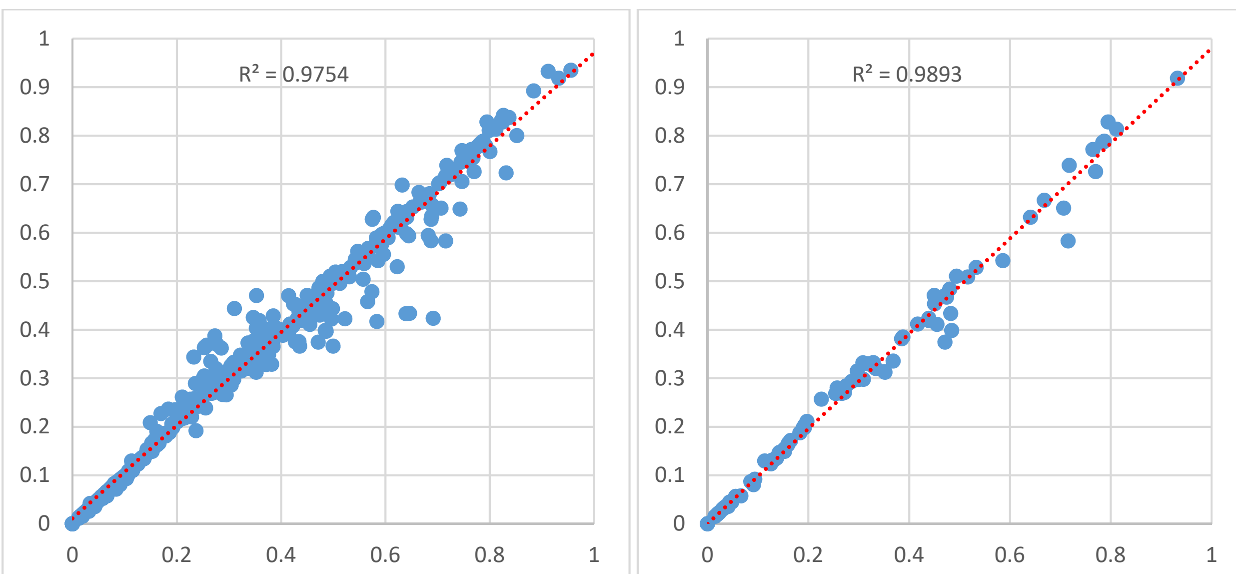


Figure 48: Fold D Full Sample (Left); Withheld Sample (Right)

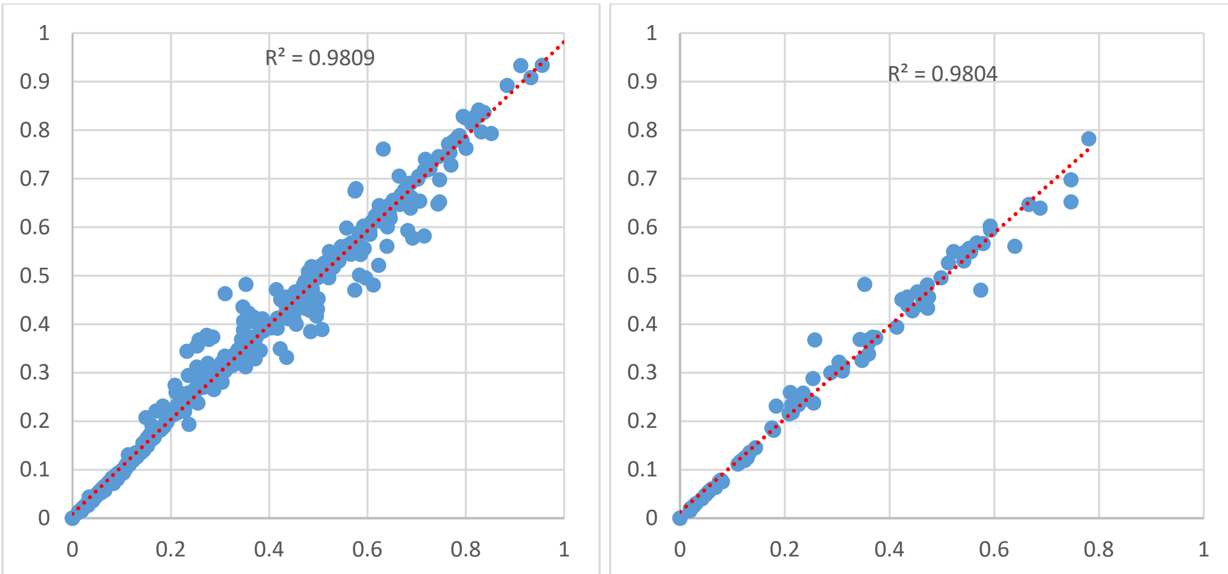


Figure 49: Fold E Full Sample (Left); Withheld Sample (Right)