**Appendix: Methodology of Population Reconstruction**

**of the 1921-1923 famine and the Holodomor**

Estimation of famine losses requires yearly population reconstruction for a period between two censuses encompassing the famine period. It also requires the estimation of hypothetical yearly births and deaths for the famine period, had there been no famine. The basic steps for population reconstruction are as follows:

a) Gather all the necessary demographic data: censuses, yearly birth and death registration, migration data, urban-rural reclassification (if reconstruction is made for urban and rural areas).

b) Evaluate the data and make appropriate corrections: adjustment of censuses, adjustment of births and deaths, estimation of yearly net migration.

c) Calculation of yearly balances:

*population (t+1) = population (t) + births – deaths + net migration.*

d) Estimation of hypothetical yearly births and deaths for the famine period.

There is an extra step In the case of reconstructions at the subnational level. It is necessary to have the same administrative structure for all the years of the reconstruction. The administrative structure of Soviet Ukraine experienced frequent changes during the 1920s and 1930s. Thus, it is necessary to recalculate all the demographic parameters (census populations, births and deaths and migration) to this common structure. This is done by comparing different maps and estimating transition coefficients.

The methodology of the population reconstruction for the 1921-1923 famine is described in the text of the article. Here we provide a summary of the reconstruction for the Holodomor (more detailed descriptions can be found in Rudnytskyi et. al. 2015a and Wolowyna et al. 2016).

**Population reconstruction for the Holodomor**

***Census adjustments***

The reconstruction period is 1927-1939, anchored in the 1926 and 1939 censuses. Data from the 1937 census and the 1931 urban count were also used, as controls for the reconstruction. Only one adjustment, i.e., undercount of children under five year of age was made (Lorimer 1946; Andreev et al. 1990) and coefficients estimated by Korchak-Chepurkivskyi (1928) were applied: 0.6 and 0.8 percent for urban and rural areas, respectively. Another adjustment was the redistribution of military personnel. Military personnel were registered de facto, while the civilian population was registered de jure. It was necessary to redistribute them, as military garrisons were usually located in cities and this introduced a distortion in the urban male population. It was assumed that the proportion of the Soviet Army in Ukraine was the same as the proportion of the Ukrainian civilian male population in the Soviet Union, i.e., 19 percent.

The 1937 census was the first census conducted after the Great Famine and it documented large population losses in Ukraine. It was declared “defective” by the Soviet government and made inaccessible for many years. Only in the late 1980s did the data from the 1937 census become available (Poliakov 1992) andit was shown that the 1937 census was executed correctly (Tolts 1989; Volkov 1990; Livshits 1990). As total population by age and sex is not available for individual republics (Poliakov 2007), it was not possible to estimate undercount of children aged 0-4 years in Ukraine. Andreev et al. (1990) estimated the undercount for Russia in 0.43 percent, and we applied this factor to both urban and rural areas of Ukraine. Military personnel were redistributed using the same methodology as in the 1926 census. Persons with unreported age in the civilian population were distributed proportionally among persons with reported age in both 1926 and 1937 censuses, and the age structures were smoothed to eliminate age heaping.

The 1939 census once again documented a significantly smaller population than predicted by Stalin and was subject to a string of sophisticated falsifications (Zhiromskaya 1990). Undercount adjustments were inflated in regions most affected by forced collectivization and the famine. Census forms of subpopulations such as prisoners in forced labor camps (gulags) were reassigned to original areas of deportation, and addresses in census forms of military personnel were also changed. Archival documents show that addresses in 795,000 census forms of labor camp inmates were changed, and 383,000 of them were reallocated to specific areas in Ukraine (Simchenko 1990; Tolts 1995). Inflated factors for allocating control forms were also applied (as part of census procedure, a list of all residents in a household was compiled and adjustments were made for persons missed during the census count); disproportionate numbers of these forms were allocated to subpopulations and areas that suffered most from the famine, i.e., males and rural areas (Andreev et al. 1990; Maksudov 1995; Tolts 1995; Zhiromskaya 2001).

It was estimated that the inflation factor for Ukraine was 2.6 per cent, with 1.2 per cent for urban and 3.4 per cent for rural populations. A more detailed description of this adjustment can be found in Rudnytskyi et al. 2015a.

Two adjustments were made to the urban 1931 population data (CSA UkrSSR 1933): a) undercount of children aged 0-4 years; b) estimation of urban population by single year of age and sex (the age structure in official reports is presented in age groups). Both adjustments were taken from estimates made by Korchak-Chepurkivskyi (n.d., personal papers).

***Adjustments of registered births and deaths***

Different adjustment methods of births and deaths were used for crisis (1932-1934) and non-crisis (1927-1931 and 1935-1939) years, and separately for three components: births, death under one year of age and deaths one year or older. Adjustments were done in three major steps: a) adjustment of the three components for urban and total populations during non-crisis years and urban populations during crisis years; b) adjustment of births and infant deaths for the total populations during crisis years; c) adjustment of deaths of one year or more for rural populations during crisis years. During the first step infant deaths were adjusted first, while adjustments of births and deaths of one or more years are based on adjusted infant deaths. As part of the first step, the three adjusted components for rural populations for non-crisis years were calculated as the difference between total and urban estimates. At step two, once adjustments for total population births for crisis years are estimated, respective infant deaths adjustments are a function of the birth adjustment factors. As part of the second step, adjusted infant deaths and births for rural populations are calculated as the difference between respective adjusted components for total and urban populations. In step three, once rural deaths of one year or more are estimated for the crisis years, adjusted deaths of one year or more for the total populations are calculated as the sum of respective urban and rural estimates.

Average adjustments are: a) deaths: 10 percent for non-famine years and 122 percent for 1933; births: three percent for non-famine years and 36 percent for 1933. A detailed description of the technical aspects of these adjustments is presented in Rudnytskyi et al. 2015a.

***Estimation of migration***

***a) Urban migration***

A migration registration system was in place in major cities and some industrial centers during the intercensal period, and it was improved in 1932 with the introduction of registration cards for all arrivals and departures in these cities (Popov 1995). However, the system was not implemented in medium and small cities, and the quality of the data is problematic. Thus a mixed strategy was used for estimating urban net migration for the intercensal period: estimation of total net migration for periods defined by the three censuses and the 1931 urban count using the demographic balance equation, and use of data from the urban registration system to disaggregate net migration for these periods by year and estimating their age-sex structure.

Taking as basis adjusted numbers of urban populations in 1927, 1931, and 1939 by single year of age and sex, and of total populations by sex for 1937, net migration is estimated for three periods: 1927-1930, 1931-1936 and 1937-1938. The difference between the final and initial points of each period is equal to the natural growth plus net migration for the period, and net migration is estimated for each period by subtracting natural growth.

Yearly disaggregation of these net migrations in each of the three periods was done proportionally to the yearly numbers of registered net migrants. The yearly age-sex structure of net migrants for the 1927-1930 period was derived from detailed reconstructed populations as the difference between the total growth and natural growth in each year, whereas the age structure of net migrants for the other years was taken from the urban migration registry (RGAE).

***b) Rural migration***

As there was no migration registration system in rural areas, the demographic balancing equation was used to calculate the number of net rural migrants for 1927-1928, i.e., difference between the total rural population at the beginning and end of each year and the natural growth for that year. It is not possible to estimate yearly net migration for the 1929-1934 period the same way because adjusted deaths for 1932-1934 have not been calculated at this point. The approach used is based on a comprehensive analysis of all available data sources for rural-to-urban migration within Ukraine, and out- and in-migration to and from other Soviet republics for these years (Table A).

With one exception, data for all out-migration streams were estimated directly from archival sources and publications. The emigration stream of Jews was estimated using the ethno-demographic balance method, which assumes very little assimilation among members of a nationality between censuses, i.e., the same nationality is reported by a person from one census to another. The two in-migration streams listed in Table A are: resettlement of peasants from Russia and Belarus to villages decimated by the famine, and resettlement of kurkuls from Central Asia to rural areas of Ukraine (“kurkuls” were relatively well-off farmers considered to be class enemies by the Soviet regime and subject to repressions).