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Interpreting UN Urbanization Projections Using a Multi-state Model

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Abstract

The United Nations provides the most comprehensive and widely used projections of urbanization at the national level, based on a method that projects differences in urban and rural growth rates over time. Taking the case of China as an illustration, we use a multi-state model to explore the implications of this projection for rural-urban migration, its plausibility, and the uncertainty associated with it. We find net that the UN urbanization projection implies a net rural-urban migration path of just over 10 million per year for the next 20 years, followed by a substantial decline over the 2020s. We also find that alternative migration scenarios can produce a wide range of outcomes for urbanization and for the age structures of rural and urban populations, suggesting that urbanization projections that reflect a full range of uncertainty are desirable. Given the range of possible outcomes for rural and urban age structures – some of which are unlikely or infeasible – it appears advisable that urbanization projections should explicitly model these populations and the age structure of migration.

Acknowledgments

We thank Gui-Ying Cao at IIASA and Leiwen Jiang at Brown University for helpful conversations and assistance with data, and the participants of the workshop on "Rethinking the Estimation and Projection of Urban and City Populations" at Columbia University in January, 2006, for useful feedback that improved this manuscript.

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Background

Urbanization projections serve as key components of many types of analyses in demography, economics, and environmental studies (National Research Council 2003). The principal source of national urbanization projections is the United Nations, which publishes a bi-annual series of projections extending to the year 2030. The UN projection methodology takes an extrapolative approach based on projecting the future evolution of the difference between urban and rural growth rates in a given country. This projection is based, in turn, on a regression model relating the urban-rural growth rate difference to the urbanization level; individual countries are assumed to steadily approach a single hypothetical relationship between these two variables. The U.N. method has the benefit of being relatively simple and transparent, requiring no detailed data to carry out, and being easy to apply to large numbers of countries. In addition, the approach is grounded in past experience in that it is based on an empirical regularity that can be observed in historical data between the level of urbanization and growth rate differences.

However the method has been criticized on grounds that it is unrealistic for countries near either the beginning or the end of the urbanization transition, that it implicitly assumes all countries will follow historical paths of urbanization, and that it can be inconsistent with current rates of urbanization in some countries (National Research Council 2003; Cohen 2004; Bocquier 2005). We highlight a number of additional shortcomings of the approach:

- It is unclear what combinations of time paths of fertility and mortality (in both urban and rural areas) and net rural-urban migration would lead to the projected urbanization outcome. As a result, it is difficult to judge the plausibility of any given scenario.
- It is unclear whether the projected level of urbanization is equally plausible regardless of the population scenario to which it is applied.
- It is difficult to define a plausible range of uncertainty using this method (i.e., to define urbanization paths that would be considered exceptionally slow or exceptionally fast for a given country).
- No separate urban and rural age structure is produced. Knowing the age structure implied by particular urbanization scenarios can be useful in applied

research, and can also help judge the plausibility of a given scenario. For example, a scenario might imply implausibly drastic changes to rural age structure even if it does not appear to be implausible in terms of total rural population size.

To address these weaknesses, we explore the potential benefits of multi-state projections that explicitly model urban and rural populations. We develop multi-state population and urbanization projections for China and compare them to UN projections. Multi-state projections include explicit assumptions about fertility and mortality in urban and rural areas and rural-urban migration rates. Such projections also produce explicit age structures in both urban and rural areas, and allow clear distinctions to be made between the effects of natural increase and migration on urban (or rural) population.

We develop two types of projections, discussed in more detail in the following sections. First, we perform a back-projection exercise that takes a UN urbanization, population, and components-of-change scenario for China as input, and solves for the implied net rural-urban migration rate over time. This allows us to interpret the results of the UN projection methodology for the case of China in a new way, by examining the migration necessary to produce the UN outcome. Second, we develop a set of forward projections that take alternative rural-urban migration scenarios as input to develop a range of urbanization outcomes. This allows us to begin to explore a plausible range of uncertainty in future urbanization and compare it to the UN projection.

Before presenting these analyses, we first briefly discuss two methodological issues. First, our urbanization projections assume that the current definition of urban vs. rural in China remains the same into the future. The problem of changing definitions of urban and rural in Chinese statistics is well known; over the past five censuses, no single definition of urban has been used twice in a row (Zhou and Ma 2003). The 2000 Census introduced a new definition of urban, intended to correct for undercounting in the 1990 Census, that implied an urban proportion in 2000 of about 36%; according to the 1990 definition this percentage would have been about 31%. The definition of urban population in 2000 has two components: defining geographical areas classified as urban, and defining which people within those areas to count as urban. The latter definition is the simplest to state: people who have been residing in an urban geographical area for at least six months as of the census date are counted as urban. The definition that identifies geographical areas is complex, and depends on the administrative unit to which the area belongs (city, town, township, etc.), its population density, and whether it is the seat of local government, or contiguous to an areas that is a seat (Chan and Ying 2003; Zhou and Ma 2003). Here we assume no further definitional changes in the urban population; thus the 2000 definition implicitly remains in place.

The second issue is reclassification. In general, urban areas grow by natural increase, migration, and reclassification – i.e., the reclassification of areas defined as rural to areas defined as urban. This reclassification can occur for a variety of reasons depending on how urban areas are defined. For example, if population density or city size increases due to in-migration or natural increase, an area may become designated as urban. This reclassification therefore can reflect the cumulative effects of past migration, but that migration was not (yet) defined as rural-urban, but rather as rural-

rural (after the reclassification, the continuation of this migration becomes rural-urban). If reclassification is quantitatively significant, distinguishing between it and rural-urban migration in a projection is important for two reasons. First, it affects the interpretation of scenarios. A migration scenario that appears to be implausibly high may not be implausible if a substantial portion of it actually consists of reclassification. Second, reclassification has a different age profile than migration – it reflects the age structure of entire settlements, not of the migration flow *per se* – and therefore would be expected to have substantially different effects on age structure or rural and urban areas.

In our analysis, reclassification is not explicitly separated from urban-rural migration; rather, it can be thought of as implicitly included as a component of migration. We make this simplifying assumption based on the assessment that reclassification is probably not quantitatively significant compared to net migration, although the extent to which this is true remains an open question. For example, Hsu (1994) concludes that in national urban population totals, new city designations do not substantially affect urbanization rates since most are small cities, although this process can be important in individual provinces. Similarly, Chan and Ying (2003) estimate that only about 22% of urban population growth in the 1990s was due to reclassification. On the other hand, Chan (personal communication) argues that new data indicate this figure should be revised substantially upward. Finally, we note that in all these cases, it appears that the urbanization time series used to make these estimates does not correct the urbanization estimates from the 1990 Census to be consistent with the 2000 Census definition. Thus, these figures include the effects of definitional change rather than reclassification *per se*, and may be biased high as a result.

Back-projections of UN urbanization

To understand the implications of the UN urbanization projection for rural-urban migration, we begin by taking as given the UN projection of urbanization in China to 2030 (United Nations 2002). We also take as given the national population, TFR, and life expectancy projections for China from the UN 2002 Revision (United Nations 2003) medium scenario, and the base-year age and sex profile of the population. The UN projections assume that fertility remains constant at about 1.85, life expectancy rises from 71 in 2000 to about 74 years in 2030, and that urbanization will increase from 35.8% to 59.5%, while total population will grow from 1.28 billion to 1.45 billion.

To calculate implied rural-urban net migration in this scenario, we use a multi-state model with states defined by urban or rural residence. This model requires separate estimates of rural and urban age structure in the base year, age profiles of fertility and mortality in both regions, separate assumptions about TFR and life expectancy changes over time in both regions, and an assumed age- and sex-profile for rural-urban migration. We use 2000 census data to define age profiles of mortality and fertility in rural and urban areas, age profiles of migration for each sex, and the proportion of the national population that is urban by age and sex. These proportions urban are then used to define base-year age and sex profiles for urban and rural regions separately consistent with the national profiles from the UN.

The back projection is carried out by solving for the time path of total net rural-urban migration that minimizes differences between our projection and the UN outcomes for total population, proportion urban, and national level fertility (see appendix for details). In this way, we produce a projection that closely replicates UN national level assumptions and outcomes, while also producing consistent migration paths and urban and rural age structures over time.

To do this, some assumption must be made about differences between rural and urban fertility. The UN projection assumes only a national TFR path, but differences in fertility between rural and urban areas might have important effects on implied migration. For example, if fertility is much higher in rural areas than in urban areas over the course of the projection, rural population will have a large rate of natural increase (and urban areas a low rate of natural increase) requiring higher migration to match a given UN urbanization scenario.

We address this issue by producing a number of scenarios with different assumptions about rural-urban fertility differentials, in order to test the sensitivity of the results. In our base case, we do not specify the difference but treat it as a choice (control variable) in the optimization problem. We define the rural-urban fertility difference as a piece-wise linear function that begins in 2000, changes linearly to a value in 2015, and remains constant thereafter. The values in 2000 and 2015 are free parameters, chosen so that the best fit to the UN projection is produced. At the same time, the total migration path is also specified as a piece-wise linear function with free parameters representing total migration in 2000, 2010, 2020, and 2030. The optimization proceeds by finding values for all these parameters such that the best fit to the UN projection is produced.

Figure 1 shows the results for implied net migration. The UN projection implies that rural-urban migration must be 10-12 million per year until 2020, and then decline sharply to less than 4 million by 2030. Our multi-state projections reproduce very closely the UN outcomes for total population, urban proportion, and total fertility at the national level, but are produced with jointly modeled urban and rural populations. Our confidence that the optimization procedure is producing reasonable results is increased by the fact that the migration in 2000 (a free parameter) compares well with a separate estimate of average annual net migration over the period 1995-2000 of 9 million per year, based on 2000 census data (L. Jiang, personal communication).

The results are not sensitive to the assumed rural-urban fertility differences. In our base case scenario, the best fit to the UN projection occurs when the fertility difference begins at 0.76 in 2000, declines to 0.33 in 2015, and remains constant thereafter. We defined three additional scenarios in which the fertility difference is not treated as a choice but rather is assumed to be constant over the entire period at 0.76, 0.5, or 0.3, and results are shown in Figure 1. Cumulative migration over the 30-year period ranges from 279 to 301 million across the four scenarios, with our base case amounting to 291 million (at the center of the range). Differences in migration in any given year across these scenarios do not exceed 1 million.

Figure 2 shows results for urban and rural age structure in our base case scenario. Because of the distinctive age profile of rural-urban migration (see Figure 3), migration has a strong effect on age structure. That effect is already present in the base year; the rural population has a noticeable deficit of people in their early 20s, and the urban population a noticeable surplus in the 20-40 year age group, due in part to the concentration of out-migration at these ages. By 2030, the rural population is smaller overall, has aged considerably, and the deficit in the age profile has now grown larger and shifted to those in their late 40s and early 50s, exacerbated by continuing out-migration (albeit at a lesser rate after people age beyond their mid-20s). The urban population grows at all ages over this period, particularly above age 40, due to the effect of sustained high in-migration.

Our conclusion then is that the back-projection indicates that the UN urbanization projection for China implies steady migration of 10-12 million per year for 20 years followed by a sharp decline. It also implies a substantial aging of the rural population – e.g., the proportion age 65+ increases from 0.07 to 0.20 over the period 2000-2030, a substantially larger shift than the increase from 0.06 to 0.13 that occurs in urban areas – and identifies distinctive characteristics of the age structures of urban and rural populations that would result from this urbanization scenario, assuming that the age profile of migration remains constant.

Alternative urbanization scenarios for China

Next, we explore a range of possible urbanization outcomes, both to quantify the uncertainty that might be associated with the UN projection and to help interpret it by identifying where in this range it lies. Few other multi-state projections of China's urban and rural populations exist. Shen (1998) uses an economic-demographic model with a multi-state demographic component and presents projections for future population growth and age structure in urban and rural areas, but does not report the migration assumptions used.

Here, we develop two types of forward urbanization projections: relatively low and relatively high scenarios. We carry out projections beyond the 2030 time horizon to 2050 in order to explore more fully the longer-term consequences of migration assumptions. To establish a longer-term benchmark, we first extend to the year 2050 our base case "implied UN" scenario described in the previous section. This scenario reproduces the UN population and urbanization outcomes over the period 2000-2030; beyond 2030, we assume that migration and urban and rural fertility remain constant at their 2030 levels, and that mortality follows the UN scenario. This "extended UN" projection provides our reference case against which to measure lower and higher migration scenarios.

We define a low scenario in a simple manner by assuming that migration is 50% of the level in our extended UN scenario, but with otherwise identical assumptions in urban and rural regions. We make no claim about the plausibility of this scenario; rather we use it strictly as a sensitivity analysis. The aim in this case is simply to get a sense of how much the urbanization outcome changes as a result of this substantial and mathematically convenient change in the migration assumption.

Figure 4 shows that the effect is significant: By 2050, the extended UN scenario has reached about 65% urban, while the scenario with half the migration has already stabilized at about 47% urban. Differences are substantial even by 2030, when the UN projects a 60% urbanization level while the half-migration scenario produces a level of only 46%. Another way of interpreting these results is that reducing migration by half results in less than half the increase in urbanization levels: in the UN case the urbanization level increases by 24 percentage points between 2000 and 2030 (from 36% to 60%), while with half the migration the increase is only 10 percentage points (to 46%).

The high end presents a more difficult case. For example, developing a similar sensitivity analysis by multiplying the migration in the extended UN projection by a particular factor larger than 1.0 quickly leads to infeasible results, because population in particular rural age groups becomes negative; i.e., some age groups simply run out of people to support the assumed migration flows. We therefore take a different approach in which, rather than specifying migration in advance, we solve for the maximum amount of migration possible over the period 2000-2030 such that over the full period 2000-2050 population in all age groups in rural areas is non-negative. The aim here is to explore how high migration might *feasibly* be, before considering the *plausibility* of such scenarios. If the feasible upper limit to migration is not much higher than the implied migration in the UN scenario, it will be a strong indication that the UN projection may itself be near the upper end of the plausible range.

We begin with the simplest possible assumption about the time path of future migration: constant migration. We then relax that assumption in a number of ways, first by allowing changing patterns of migration over time, and then also by allowing the age profile of migration to change.

In the constant migration scenario, we find that annual migration can be no more than 9.8 million per year over the period 2000-2050 without leading to negative population in some rural age groups. As shown in Figure 5, in this scenario, the out-migration leads to a population age structure which comes very close to zero in the early 40s age group in the year 2050. This is the cohort born in the first decade of the century, which then steadily loses people to migration (in addition to mortality), particularly (but not only) when the cohort is in its early 20s. By the time this cohort is in its early 40s there is essentially no one left to migrate. Note that the constant level of migration that produces this result is actually less than the implied migration in the UN scenario over the first 20 years (10-12 million per year). Another means of comparison is in terms of cumulative migration over the period of the UN projections, 2000-2030. The maximum constant migration scenario implies 303 million cumulative migrants over this period, only marginally higher than in the UN scenario, which implies 279-301 million. Similarly, the maximum constant migration scenario produces the same urbanization level in 2030 as the UN scenario, although by 2050 it is higher than our extended UN scenario (77% vs. 65%, see Table 1) given the higher levels of migration beyond 2030.

Based on these comparisons, one might be tempted to conclude that the UN scenario is very near the upper limit of feasible migration and migration. However, this would not yet be a fair conclusion because, of course, beyond 2020 migration in the UN scenario declines sharply, while it is constrained to remain constant here. It is the sustained high migration level that causes the problem. Therefore, as a next step, we allow the maximum migration path to be piecewise linear, so that the migration level in 2000, 2010, 2020, and 2030 are all free parameters (and beyond 2030 migration remains constant). Table 1 summarizes results: this scenario allows substantially more migration over the period 2000-2030 than the implied UN scenario (466 million versus 291 million), and it produces substantially higher urbanization in both 2030 and 2050 (74% and 78% versus 60% and 65%). It does so by concentrating migration in the period before 2030 – in this case rising from around 9 million/year in 2000 to over 25 million/year in 2020 – and assuming essentially zero migration thereafter (Figure 6). This is a qualitatively similar shape to the implied migration in the UN scenario, but quantitatively more extreme. In the maximum migration scenario it is a consequence of the formulation of the problem, which maximizes migration over the first 30 years but applies a constraint to the effects on rural population out to 2050. Achieving these goals simultaneously means that migration should be as high as possible in the first few decades, and then decline immediately to zero to minimize the degree to which the effect of this migration on rural age structure will be exacerbated by further migration thereafter.

Table 1. Cumulative migration and urbanization levels in high urbanization scenarios, compared to the UN extended scenario.

Migration Scenario	Cumulative Migration 2000-2030, millions	Urbanization 2030	Urbanization 2050
Implied UN extended	291	0.60	0.65
Low			
½ Implied UN	145	0.46	0.47
High			
Max. Constant	303	0.60	0.77
Max. Piece-wise Linear	466	0.74	0.78
PW Linear + Shift	470	0.74	0.79
PW Linear + Flatten	598	0.77	0.75
PW Linear + Opt. Profile	616	0.76	0.71
PW Linear + All	649	0.78	0.73

Figure 5 shows the implications for age structure. The constraint is reached by 2030 in this case: the very high migration levels drive the rural population in the 30-year-old age group nearly to zero by this time. This cohort – born in the first decade of the century – is not substantially reduced any further over the following 20 years, since there is little migration after this point.

It is possible that even this very high migration and urbanization outcome could be artificially low because of the assumption of a fixed age profile of migration, which drives population down in very particular age groups, when in reality the age profile could change over time. We test the sensitivity of the results to this assumption in three ways: by allowing a shift of the profile along the age axis, by allowing the profile to flatten over time so that it is not as concentrated in a narrow age range, and finally by finding an optimal age profile that does not impose any particular structure at all.

Results (Table 1) show that allowing the age profile of migration to shift at a constant rate over the time period makes little difference to maximum migration (and urbanization); the optimal solution is essentially to leave the current age profile fixed. In contrast, adding the possibility of flattening the age profile has a substantial effect, increasing maximum cumulative migration from 466 million to nearly 600 million. Figure 6 shows the large degree of flattening that produces this result: by 2030, the migration profile is almost completely flat up to age 80 (beyond which age we assume migration is zero). This is a rather extreme and probably unrealistic outcome, but it is interesting to note that it is the one that produces the highest feasible amount of migration.

The resulting age structure of the rural population shows the effect of the flattening: zero population is approached not in the cohort born in the current decade, but rather the cohort currently in its late teens and early 20s. The flattening of the migration profile spreads the impact across cohorts, lessening the cumulative impact on the cohort born in 2000-2010, but exacerbating it on cohorts that are already in or past the peak of the current migration profile. Thus, the population around age 20 in 2000 experiences greater migration than it otherwise would have as the peak flattens, and it is this cohort that ends up with near-zero population.

Finally, we allow even more flexibility in the shape of the profile by specifying it as an interpolating spline with several points that are treated as free parameters (see appendix for details). The optimal shape, which is held fixed over time, is shown in Figure 7. It too is largely flat, with somewhat of a peak in the early 40s. With this profile the rural population can sustain 616 million in out-migration over the period 2000-2030, although it produces slightly less urbanization

We also test the effect of combining these possibilities: an optimal profile that can flatten and shift over time. This boosts urbanization and migration marginally higher (Table 1, Figure 4). However, it is clear from the full set of results that the shape of the age distribution is the most important factor and that it can have a substantial effect on allowable migration, urbanization, and the rural and urban age structures that result.

Conclusions

The UN urbanization projection for China implies a rural-urban migration path of just over 10 million per year for the next 20 years, followed by a substantial decline over the 2020s. Assuming the age profile of migration remains constant, this projection would result in substantial changes in the age structures of rural and urban populations, including a near tripling of the proportion of the rural population age 65 or above. These results do not suggest that the UN projection is implausible; to the contrary, the UN urbanization path represents a continuation of current levels of migration for two decades into the future. The utility of carrying out the multi-state back projection is that it allows this plausibility to be verified, it quantifies the specific nature of the migration scenario inherent in the UN projections, and it provides urban and rural age structures over time consistent with the UN urbanization outcome.

The range of forward urbanization projections produced here indicates that migration and urbanization could be substantially higher or lower than in the UN scenario. The current set of results do not indicate upper and lower plausible bounds, but do give insight into the sensitivity of outcomes and provide some benchmark values for comparison. For example, we find that with no adjustment in the age profile of migration, the maximum constant migration rate over the next 30 years is approximately 10 million per year before negative population occurs in some age groups in rural areas. This result emphasizes that unchecked assumptions about future migration cannot be made lightly; serious consideration must be given to the possibility of infeasible outcomes. We also find that alternative migration scenarios can produce a wide range of outcomes for urbanization in the year 2030 (0.45 – 0.60), suggesting that urbanization projections that reflect a full range of uncertainty are desirable. So far, we conclude that multi-state projections offer a useful means of defining such ranges, given their explicit use of scenarios for migration, fertility, and mortality, and their explicit consideration of urban and rural age structure.

A possible weakness of the forward projections is their reliance on migration assumptions expressed in terms of absolute values of net migration. While modeling migration in terms of absolute numbers of people is attractive from an economic point of view, in that labor demands in urban areas are probably best thought of in terms of numbers, an approach based on migration rates might allow a more flexible means of specifying migration assumptions that would automatically adjust migration flows so as not to lead to negative population outcomes. Furthermore, stronger empirical regularities may exist for age- and sex-specific migration rates than for net migration profiles, allowing for scenarios that are more strongly grounded in past experience, and more directly relatable to migration theory (Raymer, Bonaguidi et al. 2005).

Appendix: Methodological Details

Back projections

Back projections were carried out as optimization problems, in which the following objective function was minimized:

$$Min\sum_{i,t}\left(1-\frac{F_{i,t,\text{model}}}{F_{i,t,\text{obs}}}\right)^2 \qquad \text{(A1)}$$

where i is an index of three variables (total population, national TFR, and proportion urban), t is an index of three points in time (2010, 2020, and 2030), $F_{i,\text{model}}$ is the modeled value, and $F_{i,\text{obs}}$ is the observed (in this case, UN-projected) value. The control variables were parameters describing net rural-urban migration over time, and in some cases rural-urban fertility differences. The parameters and functional forms for migration and fertility differed depending on the particular scenario analyzed, as described in the text.

Optimum shape of migration profile

Let f(x) be the profile of migration at age x as a proportion of total migration, with f(x) constant over time. An optimum profile for migration was derived by defining f(x) as an interpolating spline. Free parameters in the spline function were the value of f(x) at four ages, including age zero and three ages that were also free parameters. Migration was assumed to be zero at (and beyond) age 80.

Procedure for flattening of migration profile

Let f(x,t) be the profile of migration at age x and time t as a proportion of total migration at time t. Flattening of the base year profile was achieved by adding a constant value to f(x) for all x, and renormalizing:

$$f(x,t)=\frac{f(x,t_0)+\alpha(t-t_0)}{\sum_x f(x,t_0)+\alpha(t-t_0)}$$

where t_0 is the base year (taken to be 2000) and α is a parameter.

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Figure 1. Net annual rural-urban migration implied by UN projection for China.

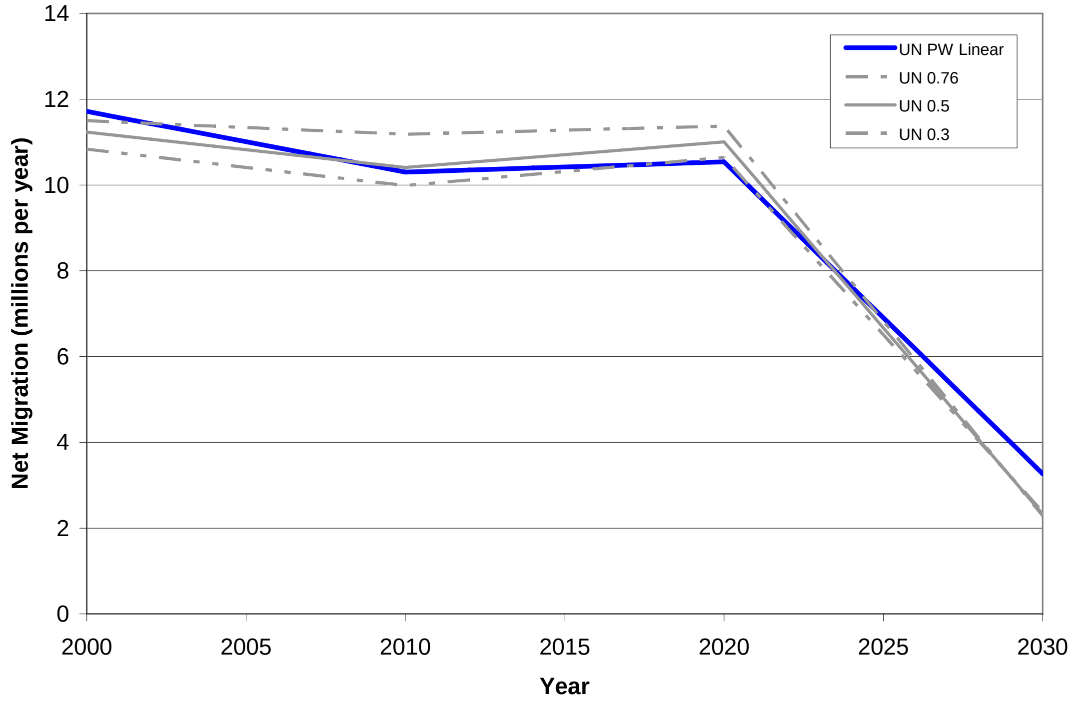


Figure 2. Urban and rural age structure for 2000 and 2030 in the base case projection consistent with the UN scenario.

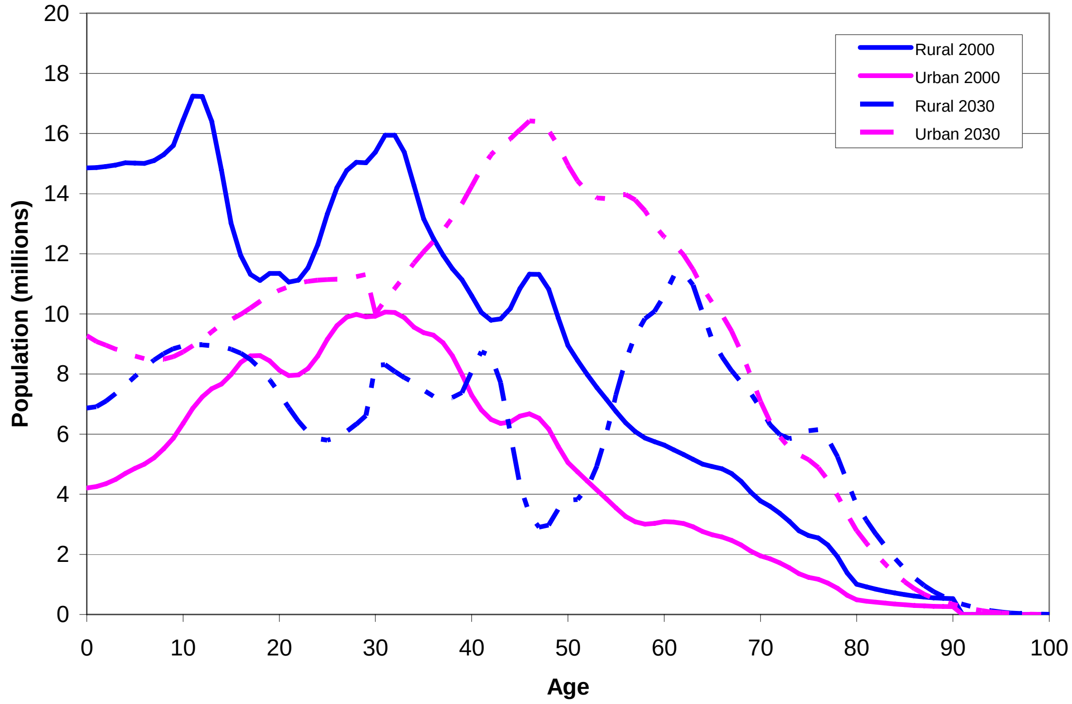


Figure 3. Age profile of rural-urban migration, males and females combined, based on 2000 census data. Units are proportion of total migration within each single year of age.

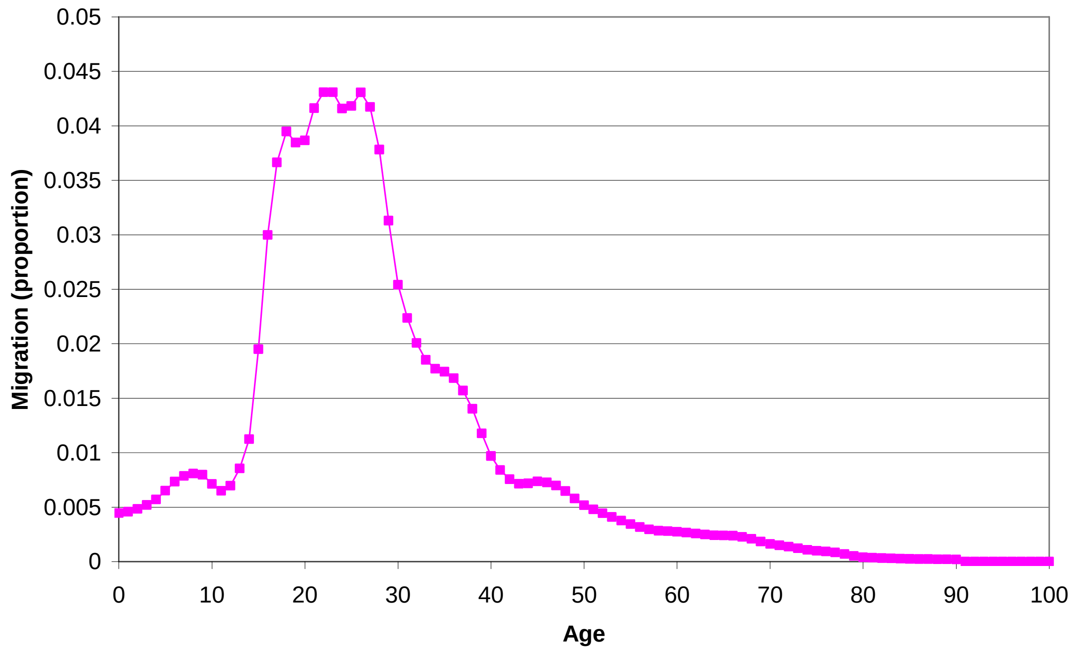


Figure 4. Urbanization according to our extended UN scenario and to additional high or low migration scenarios.

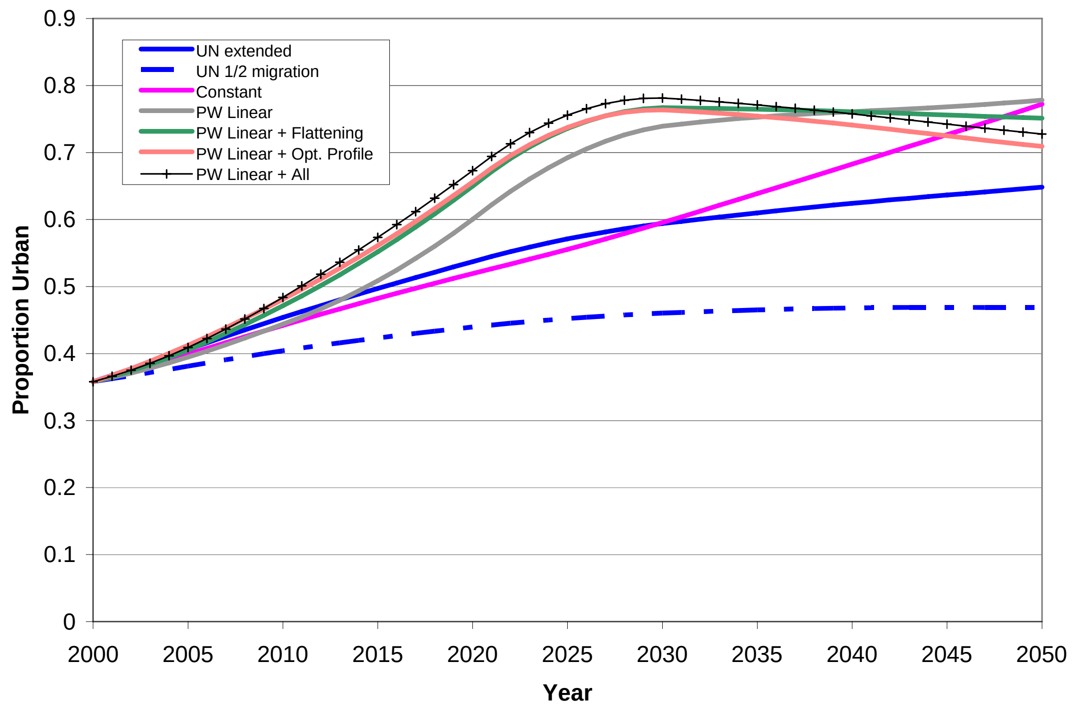
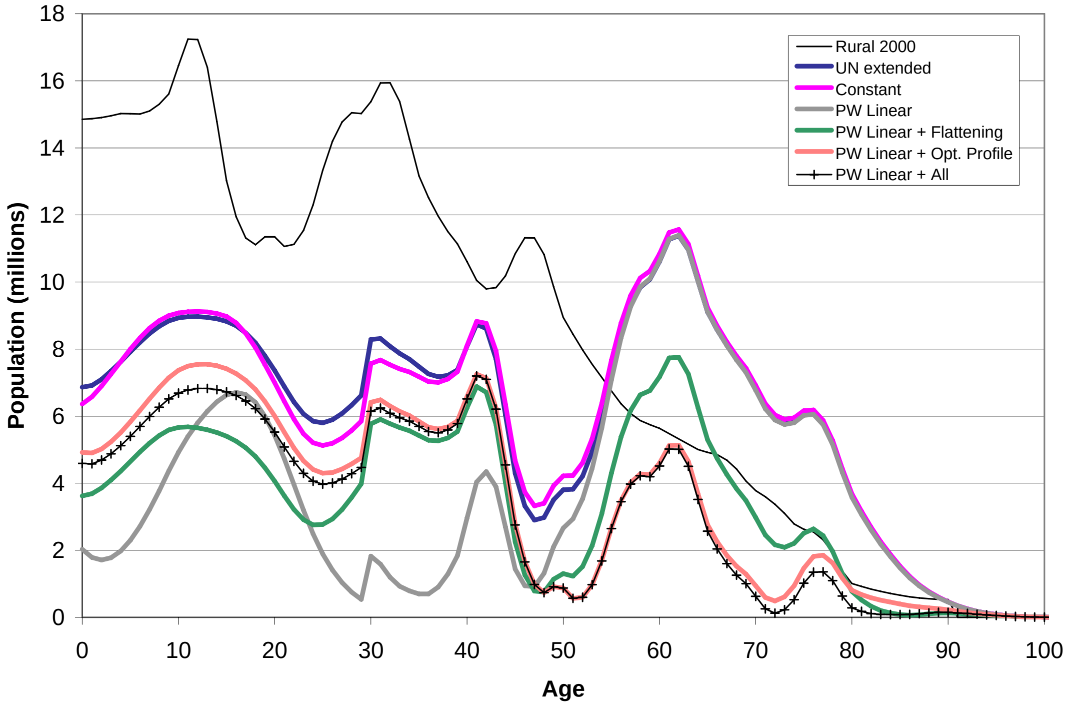


Figure 5. Rural age structure in various urbanization scenarios in 2030 (a) and 2050 (b).

(a)



(b)

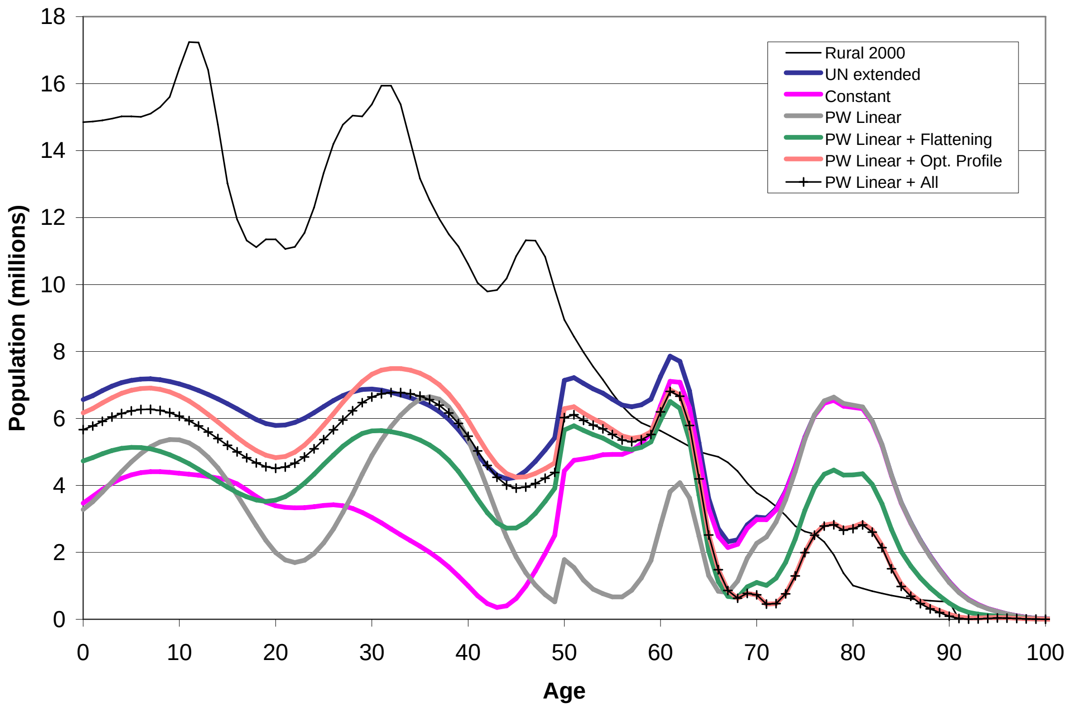
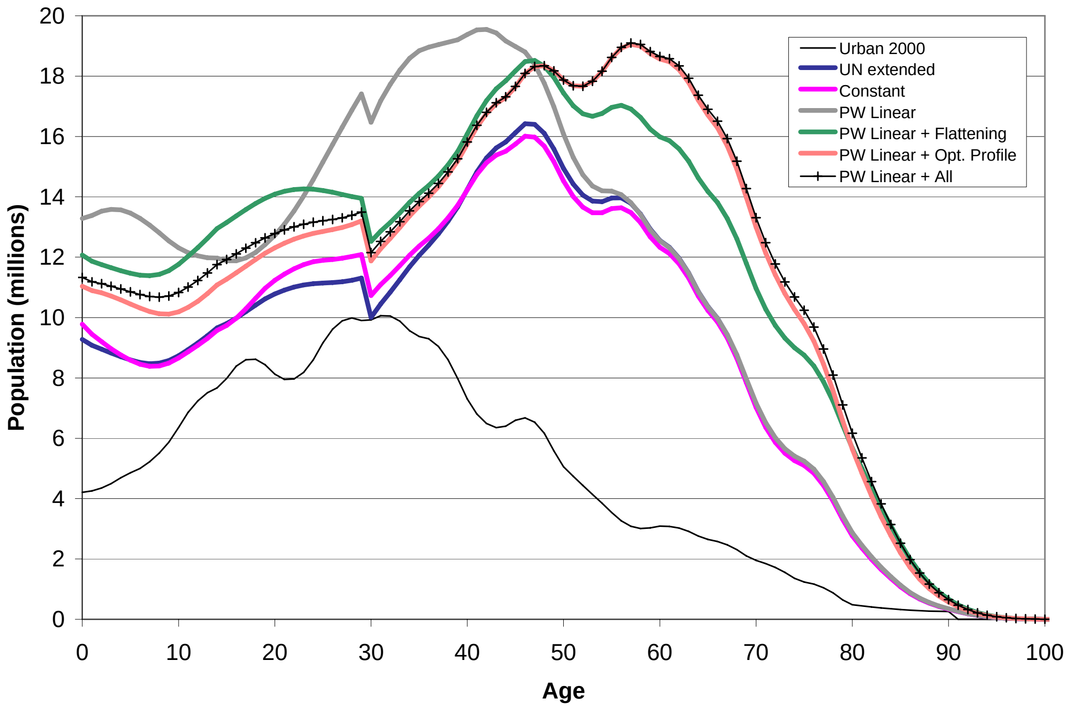


Figure 6. Urban age structure in various urbanization scenarios in 2030 (a) and 2050 (b).

(a)



(b)

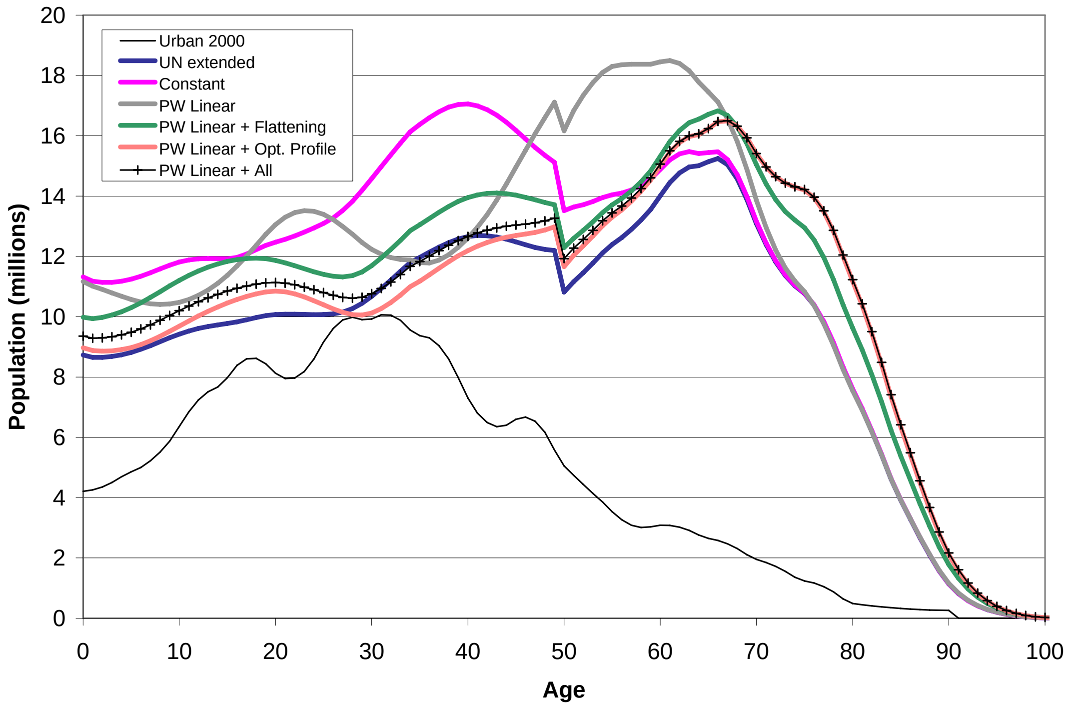


Figure 7. Age profiles of migration for various urbanization scenarios. Units are proportion of total migration by single year of age.

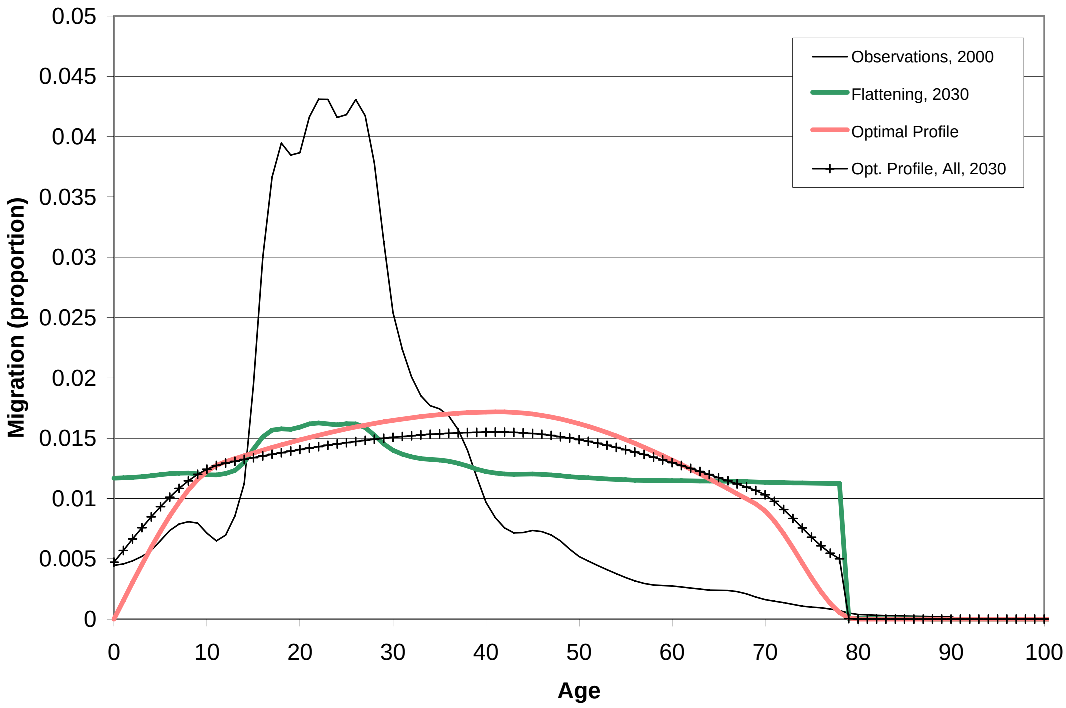


Figure 8. Total population in various urbanization scenarios.

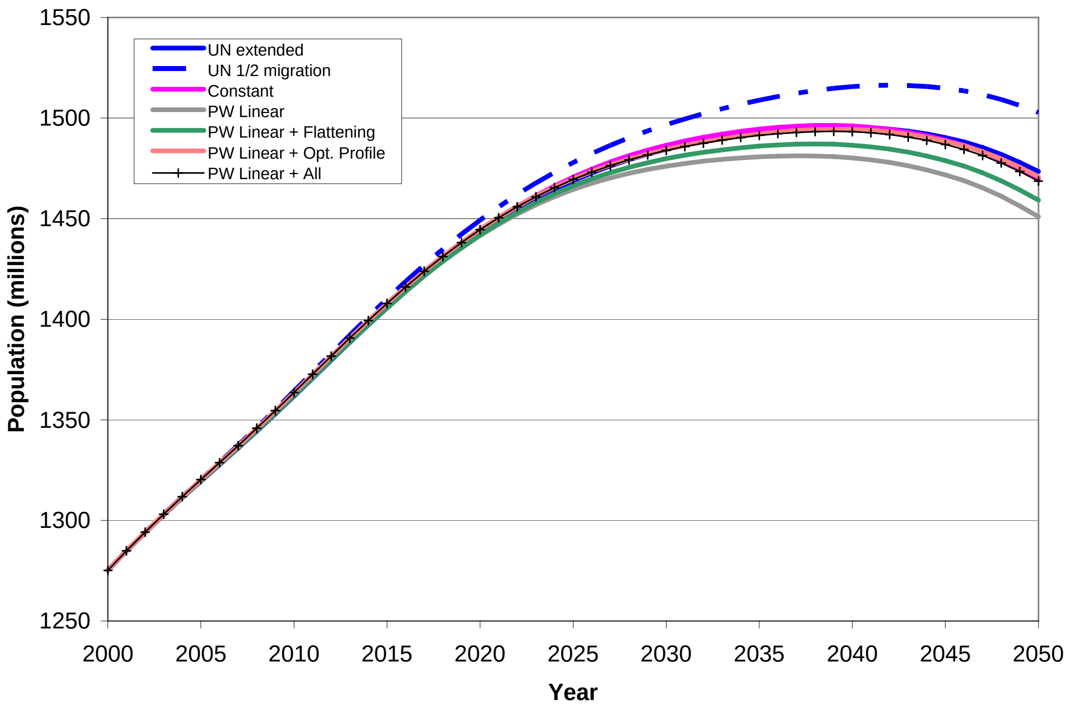


Figure 9. Total net rural-urban migration in various scenarios.