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International migration and city growth

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Mathias Lerch

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PREFACE

The world's current and future demographic growth is expected to be essentially concentrated in cities, particularly in those situated in less developed regions. The risks and opportunities of this population growth are in sharp contrast to the scarce evidence base on the demographic components. We combine the use of individual-level census data and indirect demographic estimation techniques to provide new and comparable estimates of the role of natural increase, internal and international migration in the process of population change in 23 city-regions across the world in the period 1990 to 2010. The results reveal a generally positive growth contribution of net international migration, which exceeds that of natural increase and internal migration in a number of city-regions. Given the importance, if not dominance, of international migration in the process of city growth, the evidence base about this component of population change needs to be developed in order to support better appropriate migration and integration policies.

The paper was written by Mathias Lerch (Independent Consultant) as background material for the report of the Secretary-General on sustainable cities, human mobility and international migration, to be considered under agenda item three of the fifty-first session of the Commission on Population and Development, 3 to 7 April 2017 in New York. The paper benefitted from ideas and suggestions provided by and has been revised taking into account helpful comments received from staff members of the Population Division.

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INTERNATIONAL MIGRATION AND CITY GROWTH

SUBSTANTIVE INPUTS FOR THE UNITED NATIONS SECRETARY-GENERAL'S REPORT ON "SUSTAINABLE CITIES, HUMAN MOBILITY AND INTERNATIONAL MIGRATION"

Mathias Lerch, Consultant[1]

SUMMARY

The world's current and future demographic growth is expected to be essentially concentrated in cities, particularly in those situated in the less developed regions. The risks and opportunities of this population growth are in sharp contrast to the scarce evidence base on the demographic components. We combine the use of individual-level census data and indirect demographic estimation techniques to provide new and comparable estimates of the role of natural increase, internal and international migration in the process of population change in 23 city-regions across the world in the period 1990 to 2010. The results reveal a generally positive growth contribution of net international migration, which exceeds that of natural increase and internal migration in a number of city-regions. Given the importance, if not dominance, of international migration in the process of city growth, the evidence base about this component of population change needs to be developed in order to support better appropriate migration and integration policies.

1. INTRODUCTION

Urbanization, as driven by higher population growth in urban than in rural areas, constitutes one of the most important transformations in contemporary population geography. Between 1990 and 2015, the share of the world population living in urban areas increased from 43 per cent to 54 per cent, with a particularly fast rise in less developed countries from 35 per cent to 49 per cent (United Nations, 2015). Even though the urban growth rate in less developed countries is declining (from 3.2 per cent to 2.6 per cent), the level remains high and outpaces by at least three times the rates observed in the rural areas, as well as in cities of more developed countries. The fast increase in the number of urban inhabitants in less developed regions constitutes a major challenge for achieving the United Nations' sustainable development goals (SDGs) for 2030 in a context of fast growing slum populations. Yet the concentration of population in cities is also accompanied by new opportunities related to the educational expansion and economic growth (Bloom, Canning and Fink, 2008).

The risks and opportunities of urban growth are in sharp contrast to the scarce evidence base on the demographic components of the process. This is especially the case at the city level, where more disaggregated demographic information can effectively support urban and development planning. In this paper, new and comparable estimates of the demographic sources of the recent city growth across the world were provided. The aim is to account for an underappreciated component: international migration. Given the concerns regarding the quality of the available data, two complementary methods were used to quantify the uncertainty of the derived estimates.

2. BACKGROUND

Repeated international assessments of the components of urban growth have suggested a dominant role for natural increase (i.e. more births than deaths), rather than for rural-to-urban migrations (Chen, Valente and Zlotnik, 1998; Dyson, 2011; Jedwab, Christiaensen and Gindelsky,

[1] Thank is hereby being expressed to the following colleagues for sharing data on the sex- and age-specific census counts for different cities-regions: Christophe Guilmoto, Pavel and Olga Grigoriev, Mathias Nathan, Peter McDonald, Antonio Lopez-Gray, Anna Oksuzyan, and Usha Rham.

2017; United Nations, 1980). Yet with the fast decline in urban fertility rates across all regions (Lerch, 2017b), one would expect a more diverse set of patterns of population growth. The intensity of migration should increase. When the number of children declines and the national populations start to age, the majority is concentrated in the working ages at which the rate of geographic mobility is the highest. In the very low urban fertility contexts of China and South-East Asia, net rural-to-urban migration recently became the main component of urban growth (Hugo, 2014; Zheng and Yang, 2016).

Moreover, the patterns of migration in urban areas change over the process of urbanization and economic development (Geyer and Kontuly, 1993). In the initial phase, rural-to-urban migration leads to population concentration in cities. With increasing diseconomies resulting from industrial agglomeration and congestion effects in central places, cities start to extend spatially through the delocalization of jobs; a process referred to as suburbanization. Later, with the shift from an industrial to a post-industrial economy, the significance of distance to the workplace as a residential determinant decreases as a result of the development of transport and communication technologies. These changes are accompanied by a second phase of urban sprawl, referred to as peri- or counter-urbanisation (Champion, 1989). Inhabitants from central areas move into formerly rural areas located on the more distant urban periphery as they are looking for environmental amenities in less congested and more natural settings.

Whereas in more developed countries, these stages of urbanization developed one after the other over a century, contemporary developing countries experience different patterns of migration at the same time. While rural populations continue to move to the cities' vicinities in order to find a livelihood, the affluent strata within cities started to move from the centers into gated communities which are also located in the periphery of the agglomerations. Intercity-migration is also on the rise, especially in Latin America (Rodriguez, 2007).

Eventually, the demographic potential for rural-to-urban migration will shrink, as the majority of populations is living in urban areas and fertility is low. In these contexts, international migration can be expected to dominate city growth for at least two reasons. First, cities are the engines of economic development and, therefore, compete with one another for both highly skilled and low skilled labour on a global scale (Sassen, 1994). Therefore, cities are the national gateways for international immigrants. In 2000-2005, Price and Short counted 20 cities across the globe with more than one million foreign-born residents. This immigrant population accounted for almost a fifth of the world' migrant stock (Price and Benton-Short, 2007). International migration not only compensates for the inner-cities' migratory losses to the peripheries of agglomerations. It is also believed to sustain the development of a new phase of population redistribution back to the city (i.e., a renewed concentration of the city's inhabitants; Kabisch and Haase (2011)).

The second reason for the relevance of international migration in the process of city growth is that cities are well connected to international transports system and concentrate the higher education infrastructure. Cities are thus also expected to be major sending areas of international migrants. More educated populations face lower barriers to mobility (in terms of costs, language skills, etc.) and their labour market tends to be more global than that of the lower skilled workers. Thus, positive net international migration can be expected for a given city in periods of economic development. The migration balance is likely to become negative in periods of crises, which motivate individuals to look for better economic opportunities in other countries (Skeldon, 2008).

While the global rate of international migration has remained rather stable over the last decades (at around 0.65 per cent over 5-year periods), the phenomenon has concerned a growing number of developing countries and has increasingly been taking place within the less developed regions (Abel, 2016; Abel and Sander, 2014; Czaika and de Haas, 2014), from less to more urbanized countries (Özden and Parsons, 2015). In a number of low-income countries, which experienced sustained levels of natural increase and intense rural-to-urban movements, a surplus of rural migrants still moved abroad (Berry and Kim, 1994).

Yet the role of international migration in the process of city growth remains under-appreciated and crucially under-documented in less developed countries. Not accounting for international migration may lead to the wrong conclusion about the dominance of natural increase in city growth. Case studies in developing contexts—such as on urban areas of post-communist Albania, and the city of Zurich during its industrial revolution—indeed reveal a major role for international migration losses or gains in the cities' demographic fortunes (Lerch, 2014, 2017a). City growth in highly developed and urbanized countries is virtually dependent on international migration (Strozza, Benassi, Ferrara and Gallo, 2015).

The intensity of migration and its spatial focus (domestic versus international) has important implications for human development. In sending countries, sustained international emigration that bypass domestic cities may deplete the labour force potential for development (Skeldon, 2008), even though migrant remittances may compensate for the losses (DeHaas, 2010). Large- scale rural-to-urban migration and the resulting process of urbanization, however, are commonly associated with economic growth (Bloom and others, 2008; IOM, 2015; World Bank, 2009).

3. DATA AND METHODS

The demographic information for the period 1990 to 2010 in order to indirectly estimate the components of population change in 22 city-regions, distinguishing natural increase, net internal migration and net international migration.

A. Data

Any analysis of demographic change in cities faces two main challenges. First, the city borders extend over time as the population sprawls into formerly rural areas situated in the city's vicinity (Bloom, Canning, Fink, Khanna and Salyer, 2010; Montgomery, Stren, Cohen and Reed, 2003). This rural-to-urban reclassification of municipalities is seldom documented and usually confounds indirect estimates of the demographic components of population change. We therefore defined city-regions based on subnational administrative boundaries (states, prefectures or provinces[2]), which can be expected to remain unchanged for a longer time period, when compared to actual city borders. On the one hand, this spatial approach allows us to focus on the demographic dynamics within constant geographic areas. On the other hand, the analysis will not cover the components of demographic change in the recently formed agglomeration belt areas of a number of cities, in which the metropolitan area extended (far) beyond administrative borders.

The second challenge in the estimation of the components of city growth is related to the scarcity of official demographic statistics disaggregated by type of place of residence or city. Although this concerns all components of demographic change, the lack of data is particularly acute when it comes to (international) migration (Willekens, Massey, Raymer and Beauchemin, 2016). We have put a particular effort in addressing this challenge by compiling alternative data sources that have been ignored until recently (Montgomery and Balk, 2011). We have assembled public use samples of individual-level records from national censuses compiled by IPUMS (Minnesota Population Center, 2017) in order to estimate internal out- and in-migration of cities. Information on the current residence and the individuals' responses to the question about residence at a prior date was used. To estimate urban deaths, the United Nations (2017) death rates and estimates of the at-risk populations was relied on. For the latter figures, we relied on official

[2] Our mapping of the IPUMS data revealed that the information on previous place of residence is only available at the first subnational level (states, prefectures or provinces) in the large majority of countries.

census statistics by age and sex whenever this information was available. When this was not the case, we estimated the census counts using the IPUMS (self-weighted or probability-weighted) samples. Although the IPUMS data may be affected by sampling biases, their main advantage is that the geographic information has been harmonized and made consistent across different census rounds in each country. The numbers of births and international migrations are then indirectly estimated (see further down).

Our mapping of the available statistical information identified 15 countries with IPUMS census-samples that meet the data requirement for our estimation procedure. For the city of Delhi, official census tables on migration, based on the exhaustive enumeration in 2001 (D-series tables; available at the Indian Office of the Registrar General and Census Commissioner) were relied on. In the majority of these countries, our spatial approach allows us to identify only the capital cities. To increase our sample of cities, we also relied on register data from the city of Zürich (as defined at the municipality level, with internal migration being defined as the migratory movements of the Swiss, and international migration as those of the foreigners). We also included the United Nations (2017) estimates of the components of demographic growth in the city-states Hong Kong Special Administrative Region (SAR) of China, Macao Special Administrative Region (SAR) of China and Singapore. Table 1 reports the city-regions covered, the period of observation, as well as information about the data used.

B. Method

Given the concerns about the quality of the data, two complementary methods for the estimation of the components of city growth were applied to quantified the uncertainty of the estimates.

C. Estimation at the aggregate level

The components of demographic change are estimated at the aggregate population level, using the demographic balancing equation method. Population change is measured based on counts by age and sex at two censuses (*N1* and *N2* in equ. 1). The number of deaths (*D*) during the interval is estimated by multiplying the United Nations' annual sex- and age-specific mortality rates with the person-years lived in each age group, as approximated by the average of the population at the start and end of the period multiplied by the length of the interval. Net internal migration (*NMinternal*) is computed based on the number of in- and out-migrations: the person-years lived during the interval is multiplied with the annual average migration rates at the ages 5 and over, as estimated based on the IPUMS census samples that close the period. Only a few countries enable to estimate the internal migration rates for the entire intercensal period (see table 1). Question about place of residence five years ago were mainly rely on, and it was assumed that the annualized rates of migration prevailed throughout the whole intercensal period.

TABLE 1. REGIONS COVERED AND INFORMATION ABOUT THE DATA USED, BY REGION, 1990 TO 2010

Region	*Country*	*Period*	*Source of population data (by age)*	*Region*	*Spatial definition*	*Reference period for internal migration*
AFR	Botswana	2001-11	IPUMS (self- wgt)	Gaborone	District	2006-11
	Morocco	1994-2004	IPUMS (self- wgt)	Casablanca	Provinces Casablanca, Mediouna, Nouaceur	1999-2004
	Morocco	1994-2004	IPUMS (self- wgt)	Rabat	Provinces Rabat, Salé, Skhirate- Temara	1999-2004
	Morocco	1994-2004	IPUMS (self- wgt)	Tanger	Provinces Fahs-Anjra-Tanger- Assilah, Larache, Tetouan	1999-2004
	Mozambique	1997-2007	IPUMS (self- wgt)	Maputo	City-province Maputo and city- district Matola	2002-07
	Senegal	1988-2002	IPUMS (self- wgt)	Dakar city and Dakar region	Region; city- province	1997-2002
ASIA	Indonesia	2000-10	IPUMS (wgt)	Jakarta	City-province of Jakarta	2005-10
	Philippines	1990-2000	IPUMS (wgt)	Manila	Metropolitan region (3 provinces)	1990-2000
	India	1991-2001	Stat. office	Delhi	State	1991-2001
	Viet Nam	1999-2009	IPUMS (wgt)	Ho Chi Min	City-district of Ho Chi Min	2004-09
	Hong Kong SAR of China	2005-10	...		Nation	...
	Macao SAR of China	2005-10	...		Nation	...
	Indonesia	2005-10	...		Nation	...
LAC	Mexico	2000-10	Stat. office	Mexico-city	Distrito Federal	2005-10
	Brazil	2000-10	IPUMS (wgt)	Brasilia	Distrito Federal	2005-10
	Bolivia	1992-2001	IPUMS (self- wgt)	Cochabamba	Province	1996-2001
	Uruguay	2004-11	Stat. office	Montevideo	Department	2007-11
US	United States	1990-2000	IPUMS (wgt)	Washington, D.C.	State	1995-2000
EU	Belarus	1999-2009	Stat. office	Minsk	Minsk city region	2004-09
	Armenia	2001-11	Stat. office	Yerevan	Yerevan city region	2001-11
	Spain	2001-11	IPUMS (wgt)	Madrid	Autonomous region	2001-11
	Switzerland	2000-10		Zurich	City of Zurich	register

In this indirect estimation procedure, the number of births (B) is estimated first by reverse-survival of the numbers of children aged less than 10 years at the second census (Moultrie et al.,

2013). The number of net international migrations (*NMabroad*) is obtained in a second step as the residual of the demographic balancing equation of the total population:

$$NMabroad = N2 - N1 + D - B - NMinternal \quad (1)$$

Based on these counts of the aggregate components of demographic change, we estimated annual crude rates (relative to the person-years lived during the interval) for the total and the sex-specific populations (after redistribution of the number of births by sex according to a standard sex-ratio of 105 boys for 100 girls).

The indirect estimates of the number of births and net international migration may be significantly affected by differential levels of enumeration completeness of the two censuses. We therefore provide lower and higher confidence intervals of our point estimates by replicating the procedure outlined above after adjustment of the population counts at the second census for a hypothetical rate of under- and over-enumeration of three percent, respectively.

D. Estimation by age group

As young children are frequently undercounted in censuses, our estimate of natural increase may be particularly under-estimated. The residual net international migration would then be over-estimated. Yet, natural increase may also be overestimated, as it is computed based on the age structure at the second census, which includes the immigrants during the interval. In this case, the residual international migration would be under-estimated. In order to cross-validate the results based on the aggregate method, we therefore applied an alternative procedure of indirect estimation, in which the number of net international migration is obtained as the first residual and the number of births as the second residual.

To obtain estimates of international migration, we used and adapted Hill's (1987) method which applies the demographic balancing equation to age groups; see also Hill and Wong (2005). This not only provides more disaggregated information on the age profile of migration. The inspection of the indirectly estimated age profiles also helps to understand better the quality of the data.

Hill proposed to estimate (overall) net migration at age x to $x+5$ ($_5NM_x$ in Equation 2) between two dates as the residual of, on the one hand, the change in the age-specific population counts ($_5N2_x - {}_5N1_x$), and on the other hand, the sum of the numbers of deaths ($_5D_x$) and the transitions in and out of a given age group (B_x and B_{x+5}, respectively) due to the ageing of the population:

$$5NMx = (5N2x - 5N1x) + 5Dx - Bx + Bx+5 \quad (2)$$

The number of birthdays in and out of an age group can be approximated from the age-specific population numbers at the start and the end of the period[3]. The number of deaths during the interval is computed in the same way as in the aggregate method (see above). The main advantages of Hill's method, when compared with the conventional cohort-survival method of estimating migration by age (Siegel and Swanson, 2004), is that it directly provides estimates for age-groups (rather than age-cohorts), and that it is able to accommodate intercensal intervals that are not exactly ten years.

In order to obtain net international migration as a residual, we subtracted from the estimated

[3] $B_X = (t/5)^* ({}_5N1_{X-5} * {}_5N2_X)^{1/2}$. This equation approximates the number of entries into age group x to $x+5$ by accounting also for mortality: ${}_5N1_{X-5}$ includes individuals that will die before moving in the next age group during the period of length t, whereas ${}_5N2_X$ only includes the survivors of those who entered the age group in the period.

number of net migrations (by age group, $_5NM_x$) the number of net *internal* migrations over the period. The latter numbers are estimated in multiplying the age-specific numbers of person-years lived during the interval with the annual average net migration rates, as computed based on the IPUMS data for the age groups 5 to 9 years up to the group aged 75 years and over. The numbers of internal and international migration in the first age-group (aged 0 to 4 years) are estimated by multiplying the number of female migrants at the ages 20 to 44 with the child-women ratio observed in the population at the end of the interval.

The total number of births in the intercensal period is then obtained as a second residual, between total population change and the sum of the age-specific deaths and internal and international migrations over age:

$$B = N2 - N1 + D - NMinternal - NMabroad \quad (3)$$

As in the aggregate-level procedure, we computed lower and higher confidence intervals, assuming respectively a three percent under- and over-enumeration at the second census.

4. RESULTS

A. The role of international migration in city growth

Figure 1 shows the relevance of international migration as a component of city growth. All city-regions according to the annual crude rates of international migration on the vertical axis and the rate of natural increase on the horizontal axis were plotted by region. The results were combined based on the aggregate and the age-specific methods, and plot the maximal confidence intervals by using dots connected through a solid line. The intersection of these lines and the city-labels indicate the average point estimates. In the city-regions that are situated inside of the two gray-shaded areas, international migration is the primary component of (positive or negative) population change. Outside of these areas, city growth is determined mainly by natural increase.

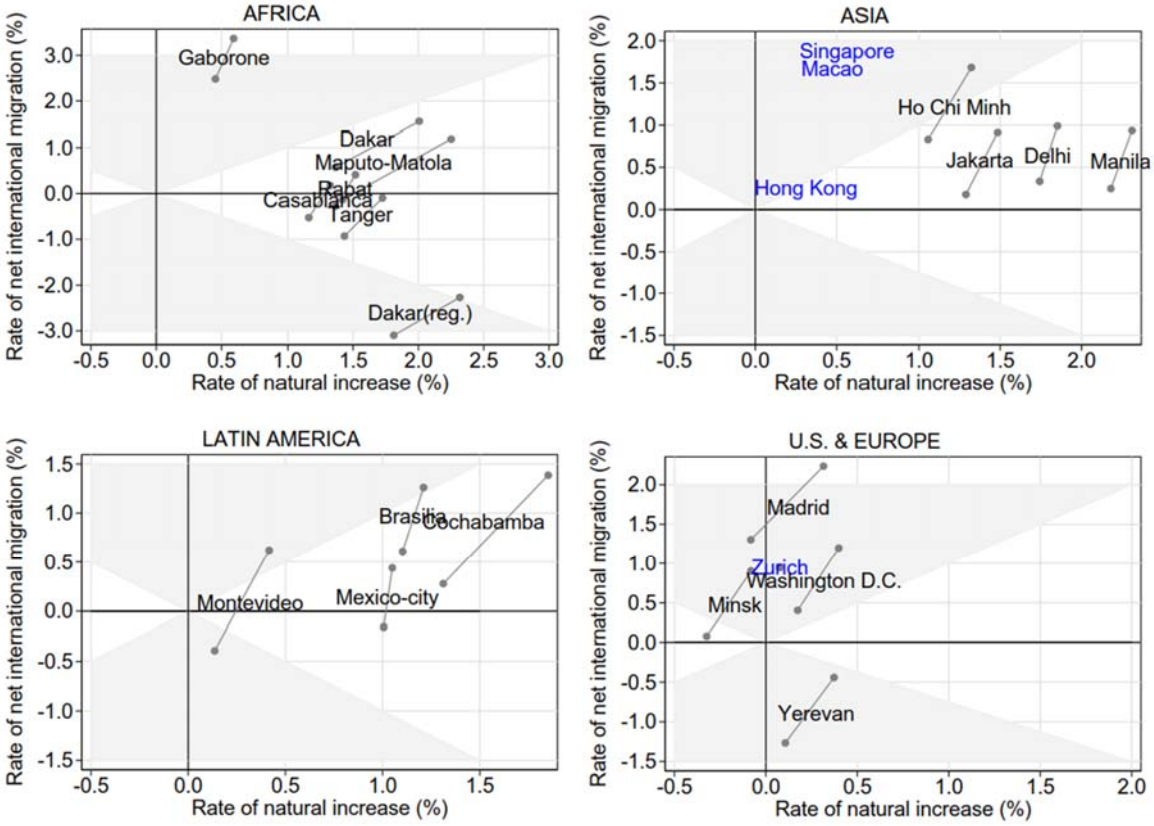
The first general observation is that net international migration was positive in almost all city-regions in 1990-2010. The average annual rates ranged from slightly positive in Montevideo and Rabat to about 2 per cent annually in Singapore—with a strong outlier constituted by Botswana's capital Gaborone. Although the confidence intervals are large, they are situated above zero in the majority of city-regions. Net international migration was negative only in Yerevan (Armenia), the region of Dakar (Senegal) and, to a lesser extent, Casablanca and Tanger (Morocco).

The range of international migration rates is largest in Africa. Following decades of net emigration from Botswana, the migration balance shifted as the economy started to develop and highly skilled migrants from other African countries were attracted. The levels of net international migration in the capital Gaborone was 3 per cent per year. At the other end of the spectrum is the region of Dakar. As a traditional point of departure of the migration routes towards the European continent and elsewhere within Africa, this city-region experienced large scale emigration (-2.7 per cent). Our indirect estimation appears to be over-estimated, when compared to a recent survey (-1 per cent among adults aged 18 to 44 years, according to the MAFE 2006; Willekens and others (2017)), but surveys do not observe the departure of entire households. It is also interesting to note that the international migration balance of the city-province of Dakar (i.e. the core of the agglomeration) is positive (see figure 1). This discrepancy in the estimates reminds us that the spatial definition of urban agglomerations matters for the analysis of the growth components. While the disadvantaged populations situated in the outer-ring of the agglomeration of Dakar may move abroad, the central city is a regional hub in the economic geography of Africa and, thus, attracts many (skilled) migrants from neighboring countries. Cities in Morocco

also experienced net emigration—especially Tanger, which is situated closest to the main destination countries in Europe.

All city-regions in Asia, the United States of America and Europe experienced positive net international migration (except Yerevan). Even though the Asian continent is characterized by low levels of international migration in comparison with other world regions, the capital cities attract a large number of migrants from other countries.

Figure 1: Annual average crude rates of natural increase and net international migration, city-regions across the world, 1990-2010.



Source: IPUMS, UN (2017), National Statistical Offices.

NOTES: The gray-colored dots correspond to the lower and higher confidence intervals, which are connected by solid gray-colored lines. The intersection of these lines with the city-labels indicates the average point estimates (as obtained based on the aggregate and age-specific method). For Zurich register data was relied on, and for Singapore, Macao SAR of China and Hong Kong SAR of China, United Nations estimations (no confidence intervals available) was relied on.

The exception Yerevan is characterized by a similarly large-scale emigration (1 per cent per year) when compared to that observed at the national-level since the onset of the economic and political crisis after the fall of communist rule in 1992. These important population losses of the capital may be explained by the fact that rural migrants move first from peripheral areas to the country's central places in order to develop their skills and access migrant networks, thereby increasing their opportunities to move abroad. A negative international migration balance for Minsk was also expected, but this is not confirmed by our results. A closer inspection of the age-specific results reveals a highly implausible age-pattern of international migration (see further down). The estimates for this city-region therefore, have to be taken with a high degree of caution. The discrepancies between the point estimates based on the aggregate and the age- specific methods are the largest in Minsk, Yerevan, Cochabamba, and in a number of city-regions of Africa (see Annex Table).

In Latin America, the cities' international migration regimes are mixed. Immigration to Brasilia and Cochabamba was sustained, while Montevideo and Mexico-city had only a slightly positive migration balance (with the lower confidence intervals being situated below zero). The negligible role of international migration in Mexico City may be explained by a major shift in terms of the geographical source of international emigrants—from mainly rural to predominantly urban origins—as the country developed and urbanized over the last four decades (Garip, 2012). The departure of a new wave of skilled workers to the United States of America may have compensated in part for the arrivals of migrants from other Latin American countries, as well as for the increasing return migrations from the United States of America.

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A second general observation in figure 1 is that the growth contribution of international migration exceeds that of natural increase in a number of city-regions. International migration indeed dominates in the low-fertility contexts of Asia (Singapore, Macao SAR of China, Hong Kong SAR of China, and Ho Chi Minh), the United States of America and Europe. In Yerevan, the limited natural increase was entirely annihilated by large-scale international emigration. In the Asian countries with total fertility rates still situated above the generational replacement level (Indonesia, India and the Philippines), however, international migration represented less than half of the contribution of natural increase to the growth of capital cities. If fertility continues to decline in these countries, external migration can be expected to dominate city growth in the future.

International migration also dominates city growth in Botswana's capital, which is leading the fertility transition in sub-Saharan Africa. In the region of Dakar, the large-scale emigration leveled out the relatively high level of natural increase. In the other African cities, international migration was a secondary source of population change.

The situation is similarly mixed in Latin America. The relative growth contribution of international migration is at par with that of natural increase in Brasilia and Montevideo and represents two thirds of the natural increase in Cochabamba—even though fertility remains relatively high in Bolivia due to a late onset of fertility decline.

B. The interactions of internal and international migration

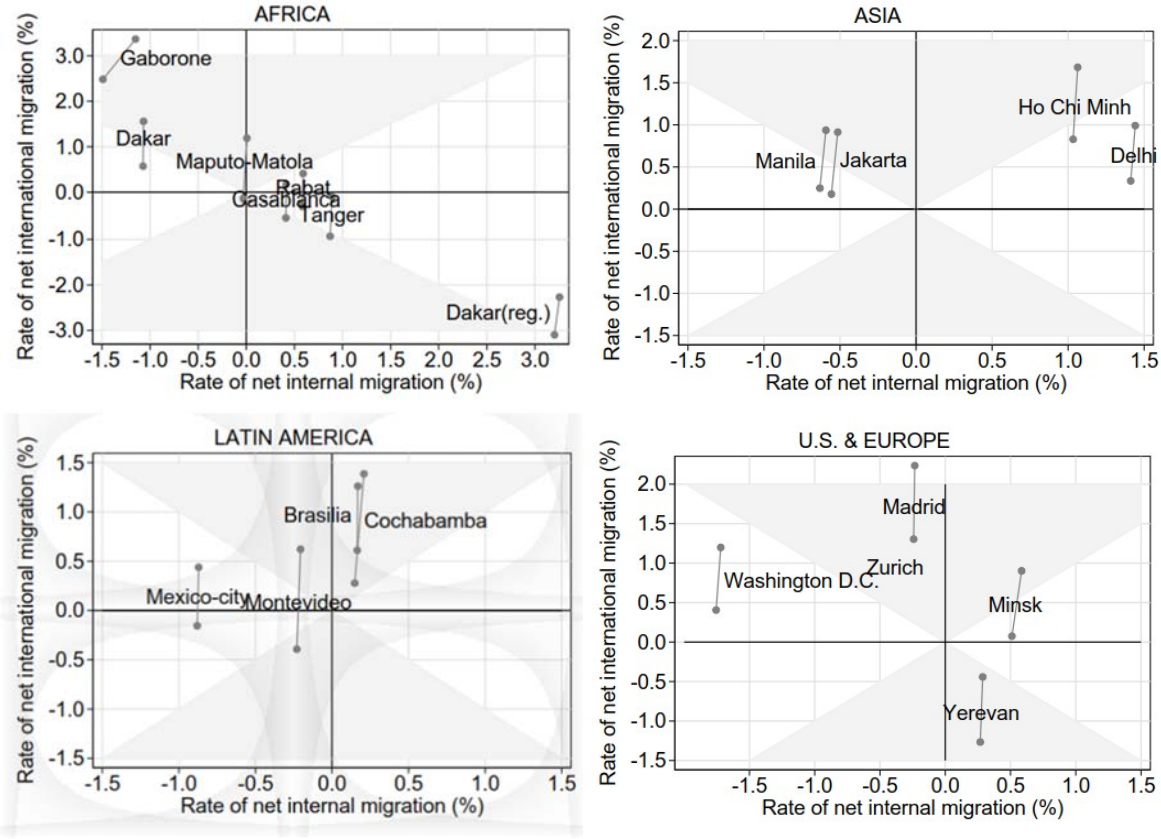
In Figure 2, we evaluate the importance of international migration relative to domestic mobility in the process of city growth. We plotted the annual crude rate of net international migration on the vertical axis and that of net internal migration on the horizontal axis (the city-states are excluded, as all migrants originate from foreign countries). As before, we combined the point estimates and confidence intervals from the aggregate and age-specific methods. In the city- regions situated within the two gray-shaded areas, net international migration had a stronger (negative or positive) growth impact when compared to net internal migration. The inverse is the case in city-regions situated outside of these areas.

The main message in figure 2 is that international movements slightly or clearly dominate the migration component of city growth, especially in Europe and Asia, but also in a number of Latin American and African countries. The picture is biased to some extend because in a number of cities we do not observe the inhabitants of the most peripheral areas of the agglomeration belt. Indeed, two different patterns of the interplay between net internal and international migration are observed.

First, net immigration from abroad compensated partially or totally for the population losses due to internal mobility in the city of Dakar, Gaborone, Jakarta, Manila, Mexico-city, Washington, D.C. and Zürich. In all of these cities, the metropolitan regions extend far beyond the administrative boundaries (i.e. more than half of the population of Jakarta is living in areas bordering the city-province; Jones and others (2016)). Our measure of net internal migration is thus underestimated due to two problems. On the one hand, the number of out-flows is overestimated because our measure includes movements from the observed core areas of the city to the unobserved

peri-urban belt areas. On the other hand, in-migration is underestimated as the bulk of rural-to-urban migrants settle in the unobserved vicinities of the cities. In addition to this measurement problem, internal migration of the capital cities may also be negative because the national city system tends to deconcentrate in advanced phases of urbanization—especially in Latin America. In Mexico, inhabitants move more and more from the congested megacities to intermediary-sized cities (Rodriguez, 2007).

Figure 2: Annual average crude rate of net international and net internal migration, city-regions across the world, 1990-2010.



Source: IPUMS, UN (2017), National Statistical Offices.

Notes: The gray-colored dots correspond to the lower and higher confidence intervals, which are connected by solid gray-colored lines. The intersection of these lines and the city-labels indicates the average point estimates (as obtained based on the aggregate and age-specific method). For Zurich, we relied on direct estimation (no confidence intervals shown).

Second, the internal and international migration balances were both positive in Ho Chi Minh, Delhi, Brasilia, Cochabamba and Minsk. Our spatial approach effectively covers the whole territory of these cities. Positive net internal migration can be related to the progress of higher level education, the process of economic development and the concentration of the national and international administrative functions in these cities. Internal movements towards Minsk were essentially driven by education (with an isolated peak in migration rates at the ages 15-19; see next section). Only a slightly higher international migration rate for men was found when compared to women, whereas the inverse is observed when it comes to internal migration (not shown).

C. Age patterns of migration as a validation of the indirect estimates

Although the purpose of this work was not to assess the quality of the estimates of the components of city growth based on different methods, a validation of the results is important to

inform about the limitations of this analysis. Figure 3 shows the age-patterns of the net international migration rates for men and women in four illustrative city-regions (black lines). These rates have been estimated as the residuals from the age-specific balancing equations. The internal migration rates derived from the IPUMS data are also shown for comparison (gray lines). The results highlight interesting generalizations with regards to internal migration, but also indicate major problems in the data used for estimating international migration as a residual.

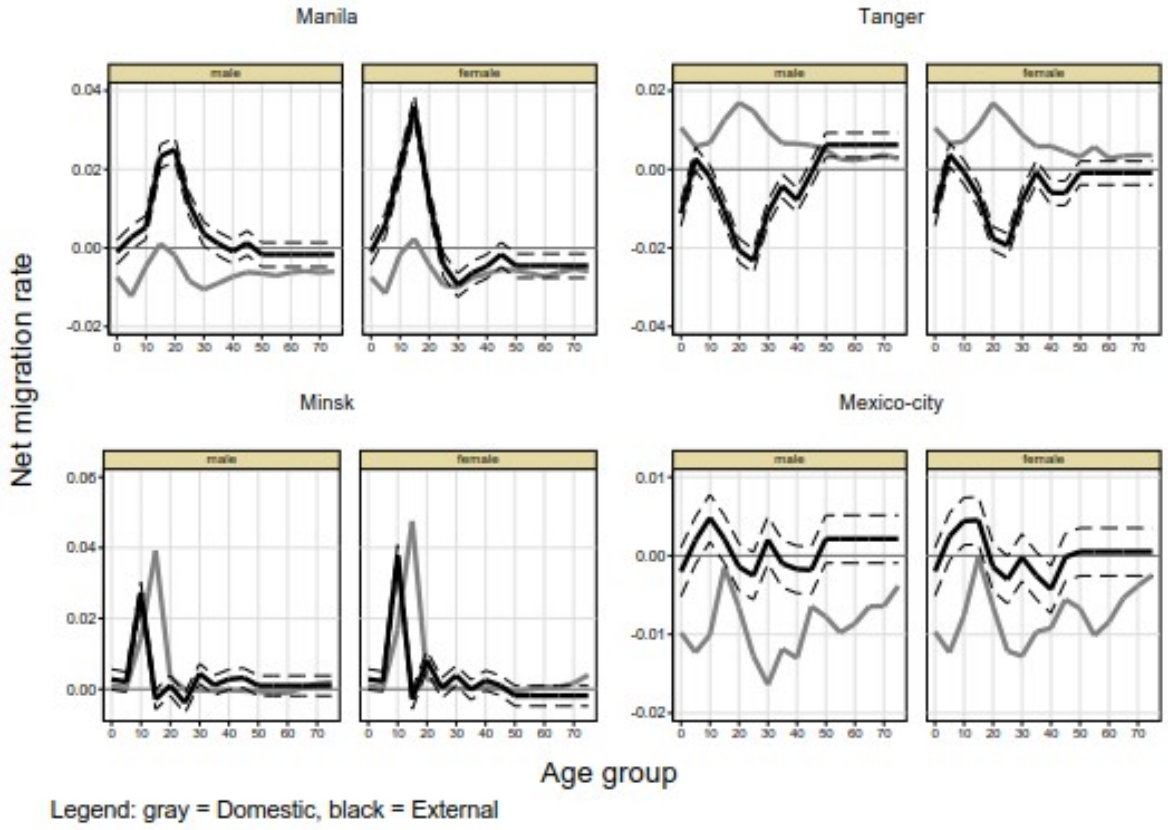
Internal migration peaked in the age group 15 to 19 years in all countries. The peak tended to be stronger for women than for men. In some countries, the rates are positive only at younger ages (i.e. between 15 and 24 years). This reveals the paramount role of the educational infrastructure in attracting students from all over the nation towards the capital cities. At the ages 25 to 50, however, internal migration tends to be the lowest—especially in those cities where the metropolitan area extended significantly beyond the administrative regions we observe. Young adults tend to move to the periphery of cities as they start building a family. At higher ages, we observe a renewed increase in net internal migration in a number of city-regions, especially among women. This can be explained by amenity seeking mobility at older ages and by the reunification of the frail or widowed parents with younger family members who are already established in cities.

The residual estimates of international migration are more problematic. The peaks at young working ages (15-29) in Manila and Tanger are plausible. The negative net migration among women aged 25 to 39 in Manila is also in line with the export of domestic maids from the Philippines. In a number of countries, however, the rates follow an implausible age-pattern—as shown for Minsk and Mexico-city. In particular, the rates are very high (or very low) in the age groups 5-9 years and 10-14 years. Although net migration rates can theoretically follow an irregular age-pattern (if they result from very different age-schedules of immigration and emigration), several issues with the quality of the data may bias the indirect estimates.

On the one hand, there may be problems either with the enumeration of children in urban areas or with the representativeness of the IPUMS samples disaggregated by sex, age and the sub-national level of residence. These two biases would distort the estimates of age-specific population growth and of the number of birthdays in and out of each age group. On the other hand, there may be problems with the individuals' declaration of their migrant status at the censuses. This would lead to a wrong classification of the internal migrant children as coming from abroad. Our hypothesis, according to which the intensity and pattern of internal migration as observed in the second 5-year period of the intercensal interval also prevailed in the firstperiod, may introduce additional biases in the results. Adjustments of the national-level death rates to derive more plausible estimates for the city contexts do not significantly affect the results.

These observations highlight the important limitations of the available data for estimating international migration as a residual of the demographic balancing equation by sex and age-group at the sub-national level. The analysis suggests a need for a more thorough validation and adjustment of the population age-structures that goes beyond the work undertaken in the context of this technical paper. The results of this analysis should be taken with a high degree of caution.

Figure 3: Annual average sex- and age-specific rates of net internal and international migration, city-regions across the world, 1990-2010.



Sources: IPUMS, UN (2017), National Statistical Offices.

5. CONCLUSION

This study provided the first comparative set of estimates of net international migration for a number of city-regions, by combining the use of individual-level census data with indirect demographic estimation techniques. We relied on administrative boundaries to define city-regions that can be compared over time in order to eliminate the bias of reclassification and to focus on the components of population change.

The results revealed a significant role for international migration in recent city growth. In the majority of cities, the recent migration balance with foreign countries is positive and equal to, or larger than, the contribution of natural increase to population growth. This conclusion challenges previous assessment of the demographic sources of urban growth in less developed countries that highlighted a major role for natural increase. As the present study focused on a limited set of predominantly capital cities, more research is needed to investigate whether the new demographic growth pattern also concerns other types of cities in less developed countries, in particular the larger ones or those situated close to national borders. If the factors susceptible to explain the importance of international migration in recent city growth are commonly found in cities, they are indeed particularly marked in capitals: the pioneering role in the spatial diffusion of the universal process towards low fertility and the major attractiveness as national gateways for international immigrants. In the city-regions that experienced a deep economic crisis (such as in the post-communist countries), however, international migration is a major factor of population decrease because the out-flows developed their own inertia over time (Lerch, 2016). Given the fast ageing of the population, the loss

of labour force and human capital will have major implications for future economic development.

The growth contribution of international migration also tends to be larger than that of net internal migration in the majority of city-regions. Net immigration from abroad supplemented the positive internal migration balance in those city-populations that were observed entirely based on the administrative area approach. In the core areas of cities, however, international migration compensates for the departure of residents to the peri-urban areas or to smaller and less congested cities.

These substantive conclusions, drawn at the international level, call for a more differentiated policy attention towards migration patterns of cities. As fertility reach low levels and the majority of populations already live in cities, further urbanization of countries will rest on the international redistribution of urban populations and on the attraction of rural inhabitants from less developed areas. In order to meet the demand for labour and to spur innovation, cities have to ensure that they remain attractive to foreigners. This demographic regime brings about new social challenges related to the integration of the foreign-born population and the social cohesion of the local society.

In order to appropriately support migration and integration policies in cities, however, the information base of the demographic components of city growth should be improved. Basic population statistics by age and sex at the sub-national level are often not publicly available—in both less and more developed countries. There is also a high degree of uncertainty in the quality of these data and, consequently, of the residual estimates of net international migration. Although these issues do not invalidate the main conclusions drawn above, more efforts need to be invested in the compilation, validation and adjustment of the available data. This would enable to draw important conclusions about the dynamics of international migration at more disaggregated levels of city populations.

ANNEX TABLE

APPENDIX TABLE: ESTIMATES OF THE ANNUAL RATES OF THE COMPONENTS OF POPULATION GROWTH BASED ON THE AGE-SPECIFIC AND THE AGGREGATE DEMOGRAPHIC BALANCING EQUATION METHODS (WITH CONFIDENCE INTERVALS, ASSUMING DIFFERENT LEVELS OF RELATIVE ENUMERATION COMPLETENESS), CITY- REGIONS ACROSS THE WORLD, 1990-2010.

Country	*City*	*Period*	*Method*	*Scenario of relative completeness of 2nd census (%)*	*CRNM internal*	*CRNM external*	**r**
Armenia	Yerevan	2001-2011	Age-spec	97	0.003	-0.010	-0.006
Armenia	**Yerevan**	**2001-2011**	**Age-spec**	**100**	**0.003**	**-0.007**	**-0.003**
Armenia	Yerevan	2001-2011	Age-spec	103	0.003	-0.004	0.000
Armenia	Yerevan	2001-2011	Aggregate	97	0.003	-0.013	-0.006
Armenia	**Yerevan**	**2001-2011**	**Aggregate**	**100**	**0.003**	**-0.010**	**-0.003**
Armenia	Yerevan	2001-2011	Aggregate	103	0.003	-0.007	0.000
Belarus	Minsk	1999-2009	Age-spec	97	0.005	0.004	0.005
Belarus	**Minsk**	**1999-2009**	**Age-spec**	**100**	**0.005**	**0.006**	**0.008**
Belarus	Minsk	1999-2009	Age-spec	103	0.005	0.009	0.011
Belarus	Minsk	1999-2009	Aggregate	97	0.006	0.001	0.005
Belarus	**Minsk**	**1999-2009**	**Aggregate**	**100**	**0.006**	**0.003**	**0.008**
Belarus	Minsk	1999-2009	Aggregate	103	0.006	0.006	0.011
Bolivia	Cochabamba	1992-2001	Age-spec	97	0.001	0.003	0.023
Bolivia	**Cochabamba**	**1992-2001**	**Age-spec**	**100**	**0.001**	**0.006**	**0.026**
Bolivia	Cochabamba	1992-2001	Age-spec	103	0.001	0.009	0.029
Bolivia	Cochabamba	1992-2001	Aggregate	97	0.002	0.007	0.023
Bolivia	**Cochabamba**	**1992-2001**	**Aggregate**	**100**	**0.002**	**0.010**	**0.026**
Bolivia	Cochabamba	1992-2001	Aggregate	103	0.002	0.013	0.029
Botswana	Gaborone	2001-2011	Age-spec	97	-0.015	0.027	0.018
Botswana	**Gaborone**	**2001-2011**	**Age-spec**	**100**	**-0.015**	**0.030**	**0.021**
Botswana	Gaborone	2001-	Age-spec	103	-0.015	0.033	0.024
Botswana	Gaborone	2001-2011	Aggregate	97	-0.012	0.025	0.018
Botswana	**Gaborone**	**2001-2011**	**Aggregate**	**100**	**-0.012**	**0.028**	**0.021**
Botswana	Gaborone	2001-2011	Aggregate	103	-0.012	0.030	0.024
Brazil	Brasilia	2000-2010	Age-spec	97	0.002	0.006	0.020
Brazil	**Brasilia**	**2000-2010**	**Age-spec**	**100**	**0.002**	**0.009**	**0.023**
Brazil	Brasilia	2000-2010	Age-spec	103	0.002	0.012	0.026
Brazil	Brasilia	2000-2010	Aggregate	97	0.002	0.007	0.020
Brazil	**Brasilia**	**2000-2010**	**Aggregate**	**100**	**0.002**	**0.010**	**0.023**
Brazil	Brasilia	2000-2010	Aggregate	103	0.002	0.013	0.026
China	**Hong Kong SAR**	**2005-2010**	**...**	**100**	**...**	**0.003**	**0.001**
China	**Macao SAR**	**2005-2010**	**...**	**100**	**...**	**0.017**	**0.002**
India	Delhi	1990-2000	Age-spec	97	0.014	0.004	0.035
India	**Delhi**	**1990-2000**	**Age-spec**	**100**	**0.014**	**0.007**	**0.039**
India	Delhi	1990-2000	Age-spec	103	0.014	0.010	0.041
India	Delhi	1990-2000	Aggregate	97	0.014	0.004	0.035
India	**Delhi**	**1990-2000**	**Aggregate**	**100**	**0.014**	**0.006**	**0.039**
India	Delhi	1990-2000	Aggregate	103	0.014	0.009	0.041
Indonesia	Jakarta	2000-2010	Age-spec	97	-0.006	0.002	0.011
Indonesia	**Jakarta**	**2000-2010**	**Age-spec**	**100**	**-0.006**	**0.005**	**0.014**
Indonesia	Jakarta	2000-2010	Age-spec	103	-0.006	0.008	0.017
Indonesia	Jakarta	2000-2010	Aggregate	97	-0.005	0.003	0.011

Country	*City*	*Period*	*Method*	*Scenario of relative completeness of 2nd census (%)*	*CRNM internal*	*CRNM external*	**r**
Indonesia	**Jakarta**	**2000-2010**	**Aggregate**	**100**	**-0.005**	**0.006**	**0.014**
Indonesia	Jakarta	2000-2010	Aggregate	103	-0.005	0.009	0.017
Mexico	Mexico-City	2000-2010	Age-spec	97	-0.009	-0.001	0.000
Mexico	**Mexico-City**	**2000-2010**	**Age-spec**	**100**	**-0.009**	**0.002**	**0.003**
Mexico	Mexico-City	2000-2010	Age-spec	103	-0.009	0.004	0.006
Mexico	Mexico-City	2000-2010	Aggregate	97	-0.009	-0.002	0.000
Mexico	**Mexico-City**	**2000-2010**	**Aggregate**	**100**	**-0.009**	**0.001**	**0.003**
Mexico	Mexico-City	2000-2010	Aggregate	103	-0.009	0.004	0.006
Morocco	Casablanca	1994-2004	Age-spec	97	0.004	-0.005	0.012
Morocco	**Casablanca**	**1994-2004**	**Age-spec**	**100**	**0.004**	**-0.002**	**0.015**
Morocco	Casablanca	1994-2004	Age-spec	103	0.004	0.001	0.018
Morocco	Casablanca	1994-2004	Aggregate	97	0.004	-0.004	0.012
Morocco	**Casablanca**	**1994-2004**	**Aggregate**	**100**	**0.004**	**-0.001**	**0.015**
Morocco	Casablanca	1994-2004	Aggregate	103	0.004	0.002	0.018
Morocco	Rabat	1994-2004	Age-spec	97	0.006	-0.003	0.018
Morocco	**Rabat**	**1994-2004**	**Age-spec**	**100**	**0.006**	**0.000**	**0.021**
Morocco	Rabat	1994-2004	Age-spec	103	0.006	0.003	0.024
Morocco	Rabat	1994-2004	Aggregate	97	0.006	-0.001	0.018
Morocco	**Rabat**	**1994-2004**	**Aggregate**	**100**	**0.006**	**0.001**	**0.021**
Morocco	Rabat	1994-2004	Aggregate	103	0.006	0.004	0.024
Morocco	Tanger	1994-2004	Age-spec	97	0.009	-0.009	0.017
Morocco	**Tanger**	**1994-2004**	**Age-spec**	**100**	**0.009**	**-0.006**	**0.020**
Morocco	Tanger	1994-2004	Age-spec	103	0.009	-0.003	0.023
Morocco	Tanger	1994-2004	Aggregate	97	0.009	-0.006	0.017
Morocco	**Tanger**	**1994-2004**	**Aggregate**	**100**	**0.009**	**-0.004**	**0.020**
Morocco	Tanger	1994-2004	Aggregate	103	0.009	-0.001	0.023
Mozambique	Maputo	1997-2007	Age-spec	97	0.000	-0.001	0.021
Mozambique	**Maputo**	**1997-2007**	**Age-spec**	**100**	**0.000**	**0.002**	**0.024**
Mozambique	Maputo	1997-2007	Age-spec	103	0.000	0.005	0.027
Mozambique	Maputo	1997-2007	Aggregate	97	0.000	0.007	0.021
Mozambique	**Maputo**	**1997-2007**	**Aggregate**	**100**	**0.000**	**0.009**	**0.024**
Mozambique	Maputo	1997-2007	Aggregate	103	0.000	0.012	0.027
Philippines	Manila	1990-2000	Age-spec	97	-0.006	0.003	0.019
Philippines	**Manila**	**1990-2000**	**Age-spec**	**100**	**-0.006**	**0.006**	**0.022**
Philippines	Manila	1990-2000	Age-spec	103	-0.006	0.009	0.025
Philippines	Manila	1990-2000	Aggregate	97	-0.006	0.002	0.019
Philippines	**Manila**	**1990-2000**	**Aggregate**	**100**	**-0.006**	**0.005**	**0.022**
Philippines	Manila	1990-2000	Aggregate	103	-0.006	0.008	0.025
Senegal	Dakar	1988-2002	Age-spec	97	-0.011	0.006	0.015
Senegal	**Dakar**	**1988-2002**	**Age-spec**	**100**	**-0.011**	**0.008**	**0.017**
Senegal	Dakar	1988-2002	Age-spec	103	-0.011	0.010	0.019
Senegal	Dakar	1988-2002	Aggregate	97	-0.011	0.012	0.015
Senegal	**Dakar**	**1988-2002**	**Aggregate**	**100**	**-0.011**	**0.014**	**0.017**
Senegal	Dakar	1988-2002	Aggregate	103	-0.011	0.016	0.019
Senegal	Dakar(reg.)	1988-2002	Age-spec	97	0.032	-0.031	0.024
Senegal	**Dakar(reg.)**	**1988-2002**	**Age-spec**	**100**	**0.032**	**-0.029**	**0.026**
Senegal	Dakar(reg.)	1988-2002	Age-spec	103	0.032	-0.027	0.028

Country	*City*	*Period*	*Method*	*Scenario of relative completeness of 2nd census (%)*	*CRNM internal*	*CRNM external*	**r**
Senegal	Dakar(reg.)	1988-2002	Aggregate	97	0.033	-0.027	0.024
Senegal	**Dakar(reg.)**	**1988-2002**	**Aggregate**	**100**	**0.033**	**-0.025**	**0.026**
Senegal	Dakar(reg.)	1988-2002	Aggregate	103	0.033	-0.023	0.028
Singapore	**Singapore**	**2005-2010**	**...**	**100**	**...**	**0.019**	**0.002**
Spain	Madrid	2001-2011	Age-spec	97	-0.002	0.017	0.013
Spain	**Madrid**	**2001-2011**	**Age-spec**	**100**	**-0.002**	**0.020**	**0.017**
Spain	Madrid	2001-2011	Age-spec	103	-0.002	0.022	0.019
Spain	Madrid	2001-2011	Aggregate	97	-0.002	0.013	0.013
Spain	**Madrid**	**2001-2011**	**Aggregate**	**100**	**-0.002**	**0.016**	**0.017**
Spain	Madrid	2001-2011	Aggregate	103	-0.002	0.019	0.019
Switzerland	**Zurich**	**2000-2010**	**...**	**100**	**-0.004**	**0.009**	**0.010**
United States	Washington, D.C.	1990-2000	Age-spec	97	-0.018	0.006	-0.009
United States	**Washington**, **D.C.**	**1990-2000**	**Age-spec**	**100**	**-0.018**	**0.009**	**-0.006**
United States	Washington, D.C.	1990-2000	Age-spec	103	-0.018	0.012	-0.003
United States	Washington, D.C.	1990-2000	Aggregate	97	-0.017	0.004	-0.009
United States	**Washington**, **D.C.**	**1990-2000**	**Aggregate**	**100**	**-0.017**	**0.007**	**-0.006**
United States	Washington, D.C.	1990-2000	Aggregate	103	-0.017	0.010	-0.003
Uruguay	Montevideo	2004-2011	Age-spec	97	-0.002	-0.001	-0.002
Uruguay	**Montevideo**	**2004-2011**	**Age-spec**	**100**	**-0.002**	**0.003**	**0.002**
Uruguay	Montevideo	2004-2011	Age-spec	103	-0.002	0.006	0.006
Uruguay	Montevideo	2004-2011	Aggregate	97	-0.002	-0.004	-0.002
Uruguay	**Montevideo**	**2004-2011**	**Aggregate**	**100**	**-0.002**	**0.000**	**0.002**
Uruguay	Montevideo	2004-2011	Aggregate	103	-0.002	0.004	0.006
Viet Nam	Ho Chi Minh	1999-2009	Age-spec	97	0.010	0.011	0.032
Viet Nam	**Ho Chi Minh**	**1999-2009**	**Age-spec**	**100**	**0.010**	**0.014**	**0.035**
Viet Nam	Ho Chi Minh	1999-2009	Age-spec	103	0.010	0.017	0.038
Viet Nam	Ho Chi Minh	1999-2009	Aggregate	97	0.011	0.008	0.032
Viet Nam	**Ho Chi Minh**	**1999-2009**	**Aggregate**	**100**	**0.011**	**0.011**	**0.035**
Viet Nam	Ho Chi Minh	1999-2009	Aggregate	103	0.011	0.014	0.038

Note: Figures in bold refer to point estimates based on the intercensal aggregate and age- specific demographic balancing equation method; other results are lower and higher confidence intervals, assuming respectively an under- and over enumeration of three percent of the population at the second relative to the first census; CRNI = crude rate of natural increase, CRNM = crude rate of net migration, r = total growth rate.

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