Population Replacement and Migration in Historical Perspective: Depopulation in Castile&Leon and Concentration in Madrid in the 20th century

Alberto del Rey (Universitat Autònoma de Barcelona)
Mar Cebrián (Universidad de Salamanca)

I. APPROACH:

Although population reproduction depends of fertility, mortality and migration, the concept of reproduction is a term of common usage in demographic literature to define the level of fertility required to ensure a population replaces itself in size[1]. Even though migration can be a significant factor in terms of reproduction, for long time it has been normally ignored in studies of population reproduction due to historically mortality and migration have been the main causes of population growth (Bongaarts, 1998).

Nowadays one of the main challenges is to incorporate the migratory component in demographic dynamics and to construct indicators that are sensitive to the effects of migration (Preston and Wang, 2007). Thus, in comparative analysis, the reproduction rates obtained may be similar while the evolution of births presents quite different behaviors due to the different impact of migration. Furthermore, in historical perspective, another main problem is the lacking of data, particularly migration data, to measure its impact on population reproduction.

Firstly, in this paper we use Calot's approach (1984) of Total Fertility Rate (TFR) as period replacement indicator to estimate a net migration constant of female population at reproductive ages. On the one hand, we estimate a weighted average of mother population exposures, weighted according the level of fertility. On the other hand, we estimate an "expected" population of mothers, according the cohort of mothers at birth, its exposition to the cohort mortality and weighted by its fertility level. The relation between present mothers and expected mothers gives us a migration constant.

Secondly, in order to analyse population reproduction, the most popular demographic indicators are, Total Fertility Rate (TFR) and Net Reproduction Rate (NRR), but they are valid only for closed and stable populations. The TFR indicates the number of children a woman will have in her lifetime if the fertility rates for a particular year remain constant. It assumes constant fertility rates and does not take into account neither mortality nor migration. The NRR refers to the number of female births that will replace their mothers if both mortality and fertility rates remain constant. Although mortality is incorporated, NRR takes into account the period or "synthetic" index instead of the cohort or "real" mortality, which means that it is an overestimated indicator for periods of declining of mortality. Nor do they incorporate the effect of migration.

There have been some attempts to reduce the impact of these shortcomings: the Social Replacement Rate has been proposed by Hyrenius (1951), a measure that includes the gains or losses due to migration in the net reproduction rate; Espenshade (1982) defined net reproduction rate in presence of emigration and modeled the impact of several hypothetical scenarios; Preston and Wang (2007) extended Espenshade's approach to immigration generating new measures such as intrinsic growth rates and net reproduction rates in the presence of migration; De Santis and Livi-Bacci (1998)

[1] Recently some authors have criticized the tendency to define the level of replacement fertility as 2.1 children per women, valid for all times and paces (Espendshade et al, 2003).

integrated a net migration factor in the net reproduction rate; Sardon (1991) proposed Reproduction Ratios at different ages; Ryder (1997) proposed Reproduction Ratios under different net migration scenarios. Smallwood and Chamberlain (2005) projected several scenarios of replacement (using cohort and period perspectives for England and Wales) under different assumptions of fertility, mortality and migration. However, none of these proposed indicators solve the problems mentioned because they take into account migration as a constant or propose hypothetical scenarios.

Under this perspective, the Birth Replacement Ratios –BRR- (Ortega, 2006; Ortega and del Rey, 2006 and 2008) is an indicator that also takes into account the effects of all three components of demographic dynamics. The BRR provides an important addition to the demographer´s toolkit since migration is becoming the main component of population growth in many countries and regions, and it is not explicitly considered in current reproduction indicators.

The BRR analyses the reproduction level of a population, according to whether the births of a particular year replace their parents ("previous generation"). BRR is a retrospective indicator that does not assume hypothetical scenarios. First it is affected by changes in fertility over time, which affects the number of births. Secondly, it incorporates the cohort mortality. The survival of more or less women at motherhood affects the number of births generated by this cohort of women. Lastly, emigration or immigration of female population from 0 to 49 years also affects the number of births generated by each cohort of mothers.

Another major merits of the new indicator are that it is easy to calculate (only births in the past and the information already available to calculate the TFR) and to interpret (comparison of births of mothers with the current number of births). Finally, we are not proposing with this new indicator to replace traditional indicators but also to complement them and to offer a new perspective.

Using the BRR indicator, our first objective is to study the impact of each demographic phenomenon in the evolution and process of reproduction, -depopulation in Castile&Leon against the concentration process in Madrid during the 20th century. Today, demographic dynamics in Spain and others developed countries are focused on the impact of international migration. Nevertheless, at a regional level, internal migration has been and continues to be in many cases, the most determinant factor from a reproductive standpoint. Secondly, we provide a decomposition of the BRR to measure the impact of each phenomenon (fertility, mortality, emigration and immigration) on replacement of births. Specifically, we measure the double effect on reproduction caused by this migration of women for a particular year: a direct effect due to the loss of women from emigration or gains from immigration and an indirect effect due to their implication in future births. The latter is an aspect not generally taken into consideration when analysing depopulation (or concentration) but one that aggravates the process.

II. METHOD AND DATA

A) Method: Estimation of net migration constant and Birth Replacement Ratios

1) Estimation of net migration constant of female population in reproductive ages (15-49 years): observed women or mothers (G_t) and survival women or mothers (G^{Surv}_t)

First, taking Calot's interpretation of TFR, we obtain the *observed women* (G_t)

[1]

$$TFR_t = B_t/G_t;\ \text{being}\ G_t = \Sigma[F_x(t)/TFR_t]\ .\ E_x(t)$$

Where B_t is the total number of births in years t and G_t is a weighted average of female population exposures, with the weights proportional to the fertility rate. $E_x(t)$ are the years-woman at risk of having children by age (between 15-49 years): and $F_x(t)$ is the age-specific fertility rate for age x in year t.

We obtain the *observed women* (G_t)

[2]

$$G_t = B_t/TFR_t;$$

Second, once we know the female births of the past (B^f_{t-x} or mothers in year t that were born between 15 and 49 years before) and the cohort mortality to which they have been exposed, we can estimate the *expected women* of childbearing age in year t in the absence of migration (G^{Surv}_t). Female births are weighted in G^{Surv}_t by their contribution to the number of births in year t, that is, by their fertility level (F_x).

[3]

$$G^{Surv}_t = \sum 0.5[L_{x}(t-x) + L_{x+1}(t-x)] \cdot [F_x(t)/TFR_t] \cdot B^f_{(t-x)}$$

Where $L_x(t-x)$ and $L_{x+1}(t-x)$ are the population of female survivors in the cohort mortality tables at ages x y x+1 respectively. We use the same weights to calculate the new mean size of the mother's generation (F_x).

The difference between the *observed mothers* (G_t) and the *expected mothers* (G^{Surv}_t) is the net migration constant (k^{NetMig}).

[4]

$$k^{NetMig}_t = [G_t / G^{Surv}_t] - 1$$

2) The Birth Replacement Ratios (BRR)

From Calot's interpretation of TFR we have obtained the Birth Replacement Ratios which compare births (B_t) with the size of the generation of mothers at birth (BG_t):

[5]

$$BG_t = \Sigma[F_x(t)/TFR_t] \,.\, B^f_{(t-x)}$$

Where BG_t is a weighted average of mothers at birth; and $B^f_{(t-x)}$ is the number of female births in period t-x. We use weights proportional to the fertility rates (F_x)[2].

The BRR is obtained from the comparison of this number of births of mothers with the current number of births, i.e.:

[6]

$$BRR_t = B_t / BG_t$$

The theoretical level of replacement is approximately 2.05, which means it replaces both births of mothers and births of fathers[3].

Taking into account only female births (B^f_t) we obtain the Net Birth Replacement Ratios (NBRR), which means that the replacement level would be 1 and which would allow comparisons with the NRR.

[7]

$$NBRR_t = B^f_t / BG_t$$

The decomposition of the Birth Replacement Ratios in its components of mortality, fertility, emigration and immigration are based on the relation between G and BG. In particular, in a closed population, where the only component that makes G different from BG is the mortality rate, i.e., in the absence of migrations, we would have the following number of women (G^{Surv}) and a new expected number of births (B^{exp}_t). With this component, we obtain the expected BRR in the absence of migration (BRR^{NoMig}):

[8]

$$BRR^{NoMig}_t = TFR_t \cdot G^{Surv}_t / BG_t = B^{exp}_t / BG_t$$

We assume that fertility rates for those who are missing-emigrated correspond to the average of the province or region of origin.

We can also calculate the loss or gain of births per woman (K^{BRR}_t) due to migration and the total number of "lost" or "gained" births ($VarBirth_t$).

[9]

$$K^{BRR}_t = BRR_t - BRR^{NoMig}_t$$

[10]

$$VarBirth_t = \sum[K^{BRR}_t * G^{Surv}_t] \text{ or } VarBirth_t = B_t - B^{exp}_t$$

Furthermore, if we have information regarding the female population by birth place, as occurred in the census years of 1981, 1991 and 2001, it is possible to separate the effects of immigration (internal and international) and of emigration.

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2 In our application t represents years from 1908 to 2005 and x represents ages from 15 to 49, which means we take female births -$B^f_{(t-x)}$- from 1858 to 1990.

3 The value 2.05 results from the *sex ratio* at birth, since for every 100 female births approximately 105 males were registered.

We decompose the observed women (G_t) from different origins:

$$G_t = G^{Nat}_t + G^{Spa}_t + G^{For}_t \quad [11]$$

Where *Nat* refers to regional or native women, *Spa* refers to women born in the rest of Spain and *For* refers to women born abroad. These sizes of mother's generation are obtained using Calot's interpretation of the TFR_t, where $G^i_t = B^i_t / TFR^i_t$, and i = {Nat, Spa, For}.

We assume the same fertility levels for natives-born mothers and born in the rest of Spain; and we have estimated the fertility level for foreigners mothers.

Likewise we can determine the proportion of native women who emigrated by comparing G^{Nat} with G^{Surv}. We refer to this proportion as k^{Emig}.

$$k^{Emig}_t = [G^{Nat}_t / G^{Surv}_t]-1 \quad [12]$$

A) Data

Births by province from 1858 to 2005. Sources: Vital Statistics from Spanish National Institute of Statistic (INE) (see appendix 2).

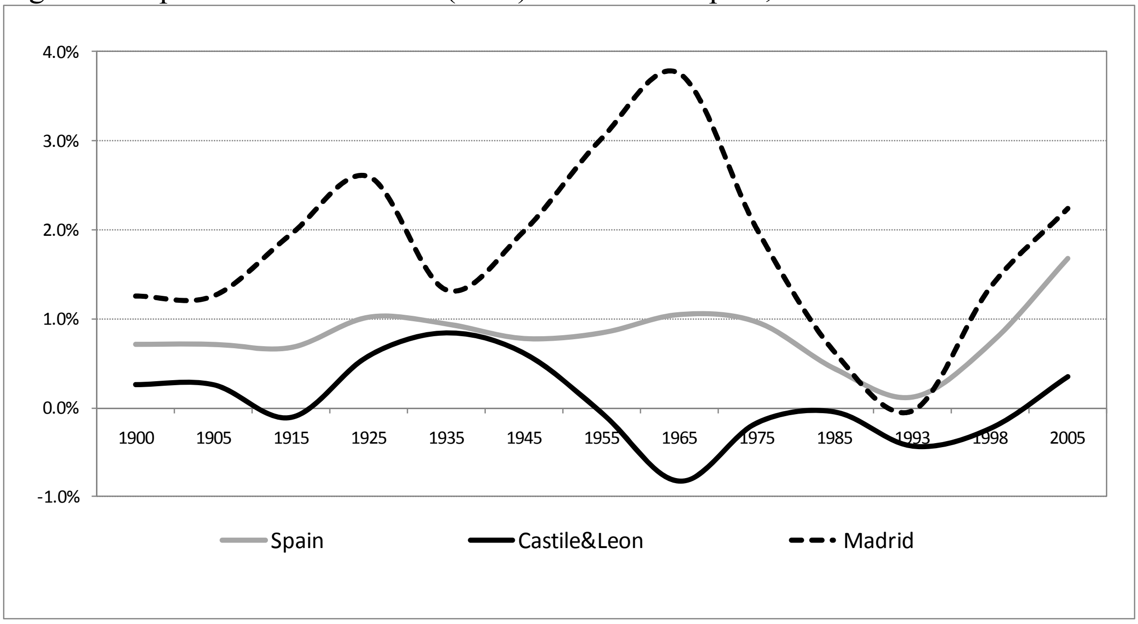
Total Fertility Rate and Fertility Rate by age. Sources: Data for each province from INE between 1975-2005. For the period between 1908-1975 the provincial fertility rate has been estimated using the Calot's interpretation of the TFR (see appendix 3).

Period life tables. Sources: provincial tables from Dopico and Reher (1998) 1900, 1910, 1920 and 1930; provincial tables from Blanes (2007) from 1960-62, 1965-67, 1970-72, 1975-77, 1980-82, 1985-87, 1990-92, 1995-1997 and 2000-2002. Using the mortality rate for the period, we have estimated the cohort mortality rate (see appendix 4).

III. POPULATION REPLACEMENT IN CASTILE&LEON AND MADRID

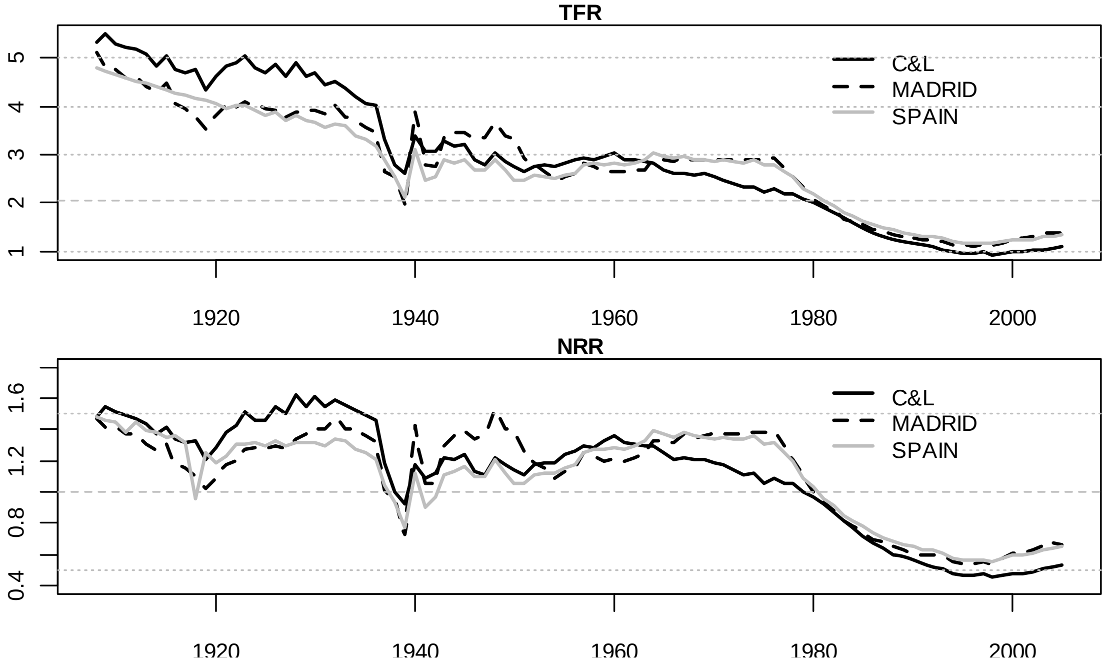
During the past century Castile&Leon and Madrid have experienced the demographic transition in the same way that the rest of Spain. Fertility rates have suffered a drastic decline (Muñoz-Pérez, 1989; Delgado and Livi-Bacci, 1992; Kohler, Billari et al., 2002). Mortality rates have also registered a marked decline in all age groups, doubling life expectancy at birth from 40 years to 80 years (Reher and Sanz-Gimeno, 2000; Ramiro and Sanz-Gimeno, 2000; Blanes, 2007). Nevertheless, while the Spanish population has been multiplied by 2.4 and Madrid by almost 8, the population of Castile&Leon has increased by less than 10% (figure 1).

Figure 1. Population Growth Rate (PGR) 1900-2005: Spain, Castile&Leon and Madrid



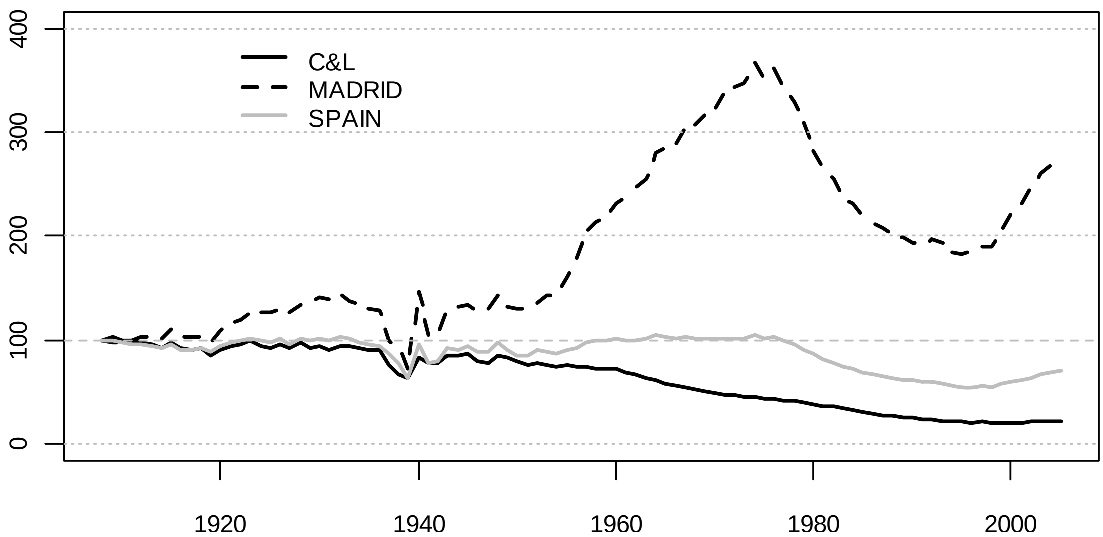
Sources: Censuses. Various years (INE). Own elaboration.

Figure 2. Total Fertility Rate and Net Reproduction Rate: Castile&Leon, Madrid and Spain 1908-2005



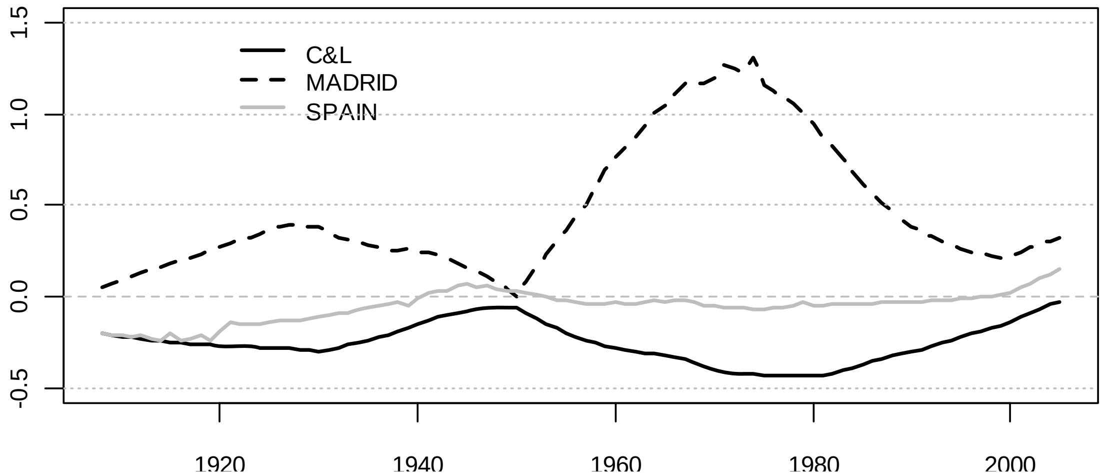
There are two aspects to highlight according to the level and trend of the NRR in Castile&Leon and Madrid (figure 2): first, the replacement registered until eighties was higher than the theoretical replacement level (with the exception of the Spanish Civil War); second, the evolution and level of NRR in both regions have been very similar, however the evolution of the number of births has been very different (figure 3): Madrid has multiplied by almost 3 the number of births and Castile&Leon has divided its births by 4.

Figure 3. Number of Births (1908=100): Castile&Leon (C&L), Madrid and Spain 1908-2005



The different trend between NRR and number of births is explained by the impact of migration (figure 4). Madrid registered a high positive migration constant of women in reproductive ages, while Castile&Leon registered a pronounced negative constant during the 20th century. This situation shows the weakness of NRR as reproduction indicator in contexts of high incidence of migration. However, the NBRR shows very different replacement levels and trends in Castile&Leon and Madrid (figure 5).

Figure 4. Net Migration Constant of female population in reproductive ages: Castile&Leon, Madrid and Spain 1908-2005



The differences between NRR and NBRR are result both the impact of migration and mortality (figure 5): the NRR does not take into account migration and it is affected by the period mortality instead of cohort mortality; by contrast, NBRR is affected by cohort mortality and female migration. For periods of mortality declining, period mortality is an overestimated indicator as we can observe in figure 6.

Figure 5. Net Birth Replacement Ratios and Net Reproduction Rate: Castile&Leon, Madrid and Spain, 1908-2005

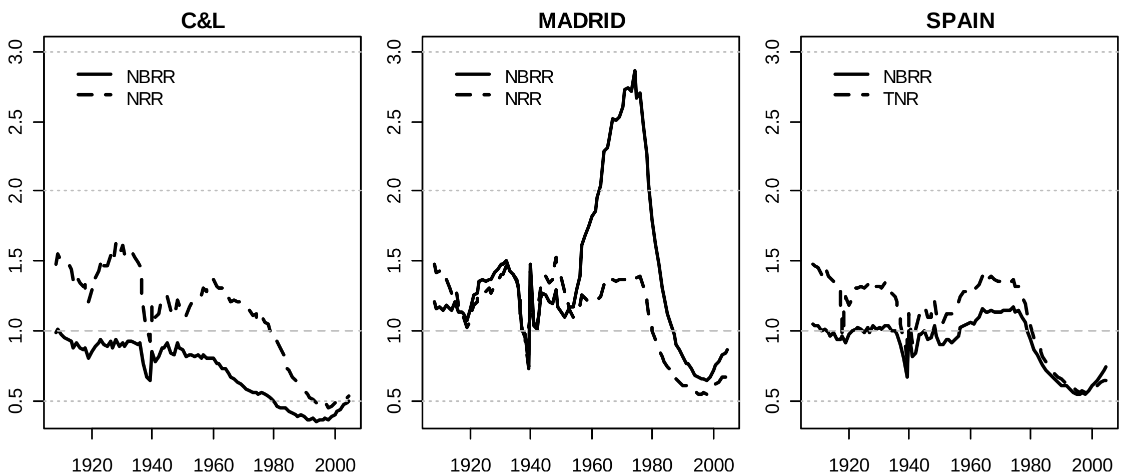
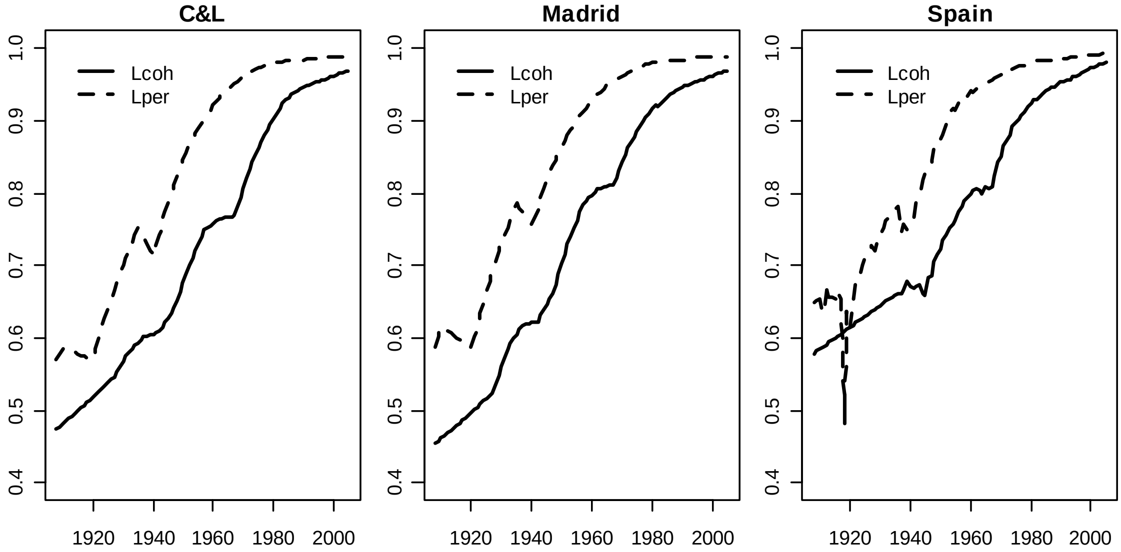
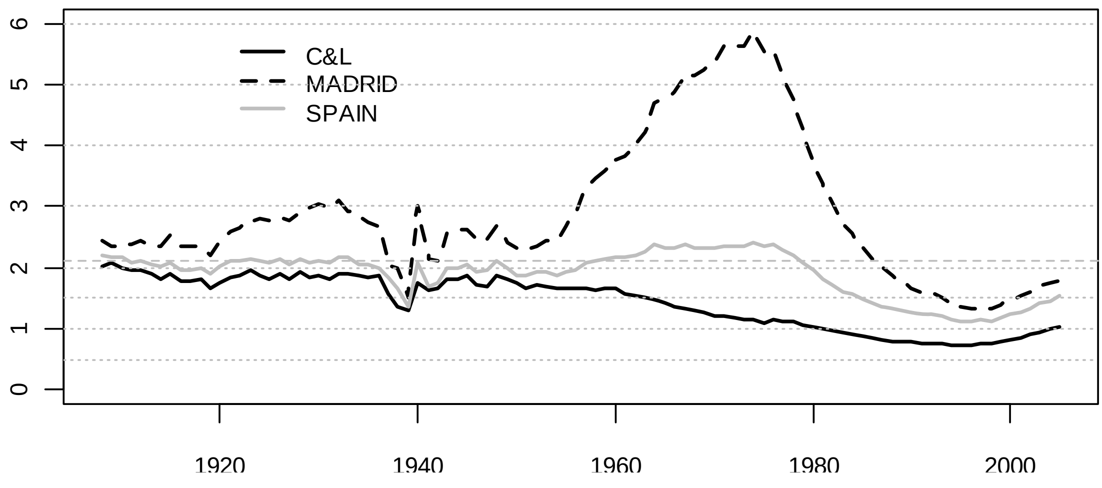


Figure 6. Suvival at mean age at motherhood: Cohort $–L^{coh}$- and period $–L^{per}$- indicator by Castile&Leon, Madrid and Spain, 1908-2005.



For the region of Castile&Leon, what it is first observed is that the BRR (and also NBRR) for the whole period, except that for 1909, is below the replacement level (2.05), despite the fact that until the 1980s, the TFR is above 2.1 children per woman and the NRR is above 1 (figure 7). That is, throughout the 20th century and for the beginning of the 21st century, yearly registered births were not enough to replace the births of parents' generations. However, in Madrid, a traditionally immigrant region, the BRR was well above the theoretical replacement level until the mid-1980s (with the exception of 1938-1939, years of the Spanish Civil War). Even with much lower fertility levels during the second half of the 20th century, the BRR for Madrid has been much higher than the replacement level and has even doubled the fertility level due to the impact of migration.

Figure 7. Birth Replacement Ratios: Castile&Leon, Madrid and Spain, 1908-2005



In the first half of the 20th century the high mortality rates together with a negative migration constant, as a consequence of internal emigration and international emigration to America (Sanchez-Alonso, 2000; Silvestre, 2005), explain the low replacement level in Castile&Leon. Until 1915, the average survival to motherhood was below 50%, i.e., less than 1 of every 2 girls born in the region survived to the average

age at motherhood[4]. The loss of women-mothers in this period was increased by the emigration of a large part of survivors: until the beginning of the Spanish Civil War, the migration constant was less than -20%, with minimums of -30% between 1928 and 1931. Therefore, despite the fertility in this first half of the 20th century was above 4 children per woman, the BRR was less than 2, and therefore it did not reach the replacement levels.

In Madrid, (the main destination for emigrants from Castile&Leon), even when fertility rates were slightly lower than for Castile&Leon and mortality rates higher between 1910-1935, the BRR exceeded the theoretical replacement level registered due to the contributions of immigrants.

In the second half of the 20th century, the replacement in Castile&Leon was marked by a strong decrease in fertility and by a strong emigration, again, internal and international, but now to other European countries (Cabré, Moreno, et al., 1985; Rodríguez Osuna, 1985; Delgado and Garcia-Barbancho, 1988). This caused a permanent decline in BRR despite the increase in survival. Castile&Leon registered a BRR of 1, which means that births of those years only replaced half of the births from the generation of their parents. In practice this means a reduction to half the amount of births from previous generations[5]. In Madrid, and despite the fertility decline, replacement increased after 1950 until it reached values close to 6 by the mid-1970s due to an intense internal immigration. Thus, while in the 1970s the number of births dropped to half in Castile&Leon in relation to previous generations, they doubled in Madrid (figure 3).

Emigration from Castile&Leon gradually increased after 1950 (Cabré, Moreno, et al., 1985; Recaño, 2006). This is clearly reflected in the female migration constant until the 1980s, when losses began to slow down. Between 1971 and 1983 the K^{MigNet} exceeded -40%, i.e., 2 of every 5 women with ages between 15 and 49 had emigrated.

Yet again, Madrid, unlike Castile&Leon, registered migration constants higher than 1 in the 1970s, while the rest of the country had losses due to emigrations to Europe (figure 4). In other words, Madrid had more than double of expected women according to previous female births and mortality conditions. The contribution from immigrants in the first half of the 1980s allowed the BRR to maintain itself above the replacement level, despite fertility levels were below 2.1 children per woman.

In the last period, and after the mid-1990s, a slight recuperation in fertility and replacement began both in Castile&Leon and in Madrid, due to a large extent to foreign immigration (Roig and Castro, 2007). In the first place, fertility rates in Castile&Leon increased from 0.94 children per woman in 1998 to 1.03 in 2005. This increase was result of both the recovery of native fertility and the arrival of foreign women with higher fertility rates. In second place, the negative migration constant lowered, due to a decrease in internal emigrations and to an increase of women arriving from outside the region. In 2001, compared to previous census, there was a greater presence of women at motherhood that were not born in the region (table 1) and especially women born outside Spain (5%). This percentage has continued to increase in following years in step with the increase in the international flow (Muñoz-Pérez and A. Izquierdo, 1989; Blanco, 1993; Arango and Martin, 2005). In Madrid, the decrease of internal immigration since 1980s has been balanced by international immigration since 1990s.

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[4] It is worth noting the importance of taking the cohort mortality instead of that of the period of mortality drop phases. For example for 1930 the $L^{coh27.5}$= 0.57 while $L^{per27.5}$= 0.70.

[5] Births for 1980 were 33,000 while those for 1950 were 68,000.

Table 1. Decomposition of mothers (G_t) by place of birth (native, born in other parts of Spain and abroad) in the census years of 1981, 1991 and 2001: Castile&Leon, Madrid and Spain

	Castile&Leon			**Madrid**			**Spain**		
	1981	**1991**	**2001**	**1981**	**1991**	**2001**	**1981**	**1991**	**2001**
G_t	16337	18107	17656	35155	39649	47474	258043	293850	327320
Total	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
P^{Nat}	0.89	0.87	0.82	0.44	0.60	0.66	0.68	0.74	0.75
P^{Spa}	0.10	0.11	0.13	0.53	0.36	0.20	0.30	0.23	0.17
P^{For}	0.01	0.02	0.05	0.03	0.04	0.14	0.02	0.03	0.08

Sources: Population Census 1981, 1991 and 2001 (INE). Own elaboration.

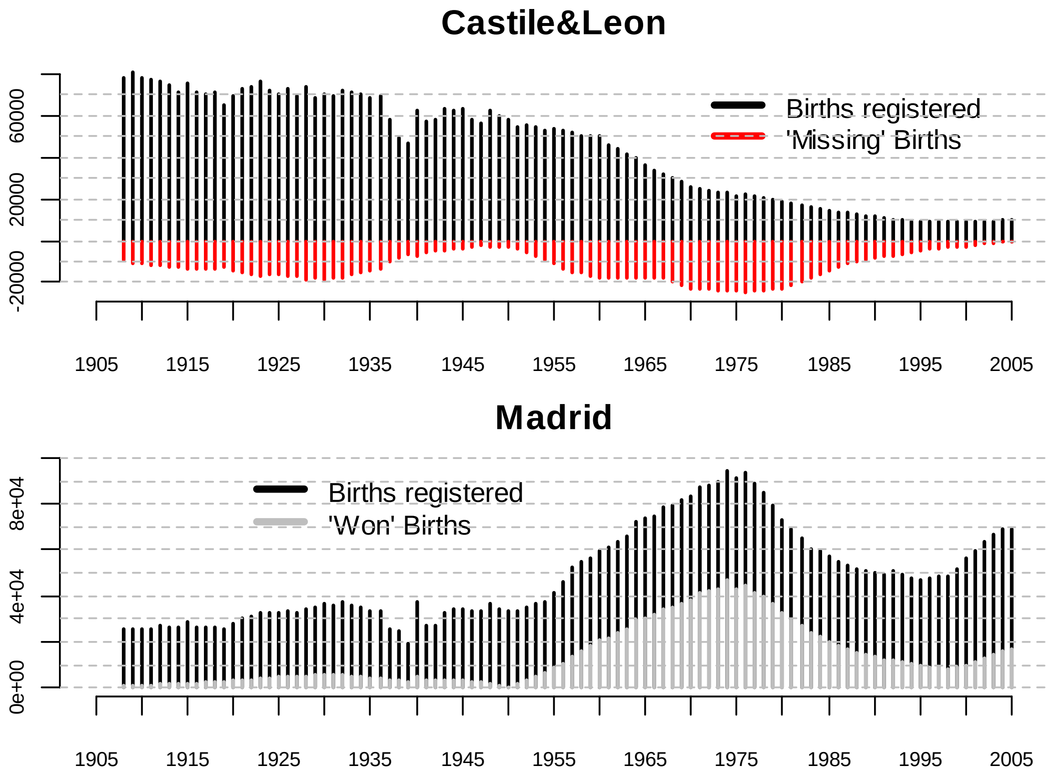
Nowadays, in conditions of very low fertility and very high survival rates, the migration component is the main determinant of the replacement process in Castile&Leon and Madrid.

We have calculated "lost" or "gained" births taking into account the impact of migration in each regional area (VarBirth). This is an "indirect" effect not generally taken into consideration but that aggravates the depopulation processes in some cases and the concentration one in others.

Castile&Leon registered little over 4,300,000 births between 1908 and 2005, but more than 1,200,000 births from the emigration of the female population have not been accounted for; i.e., 27% of births have been lost for this period (figure 8). In Madrid the number of registered births was 4,774,781, 28% of which (1,333,056) were due to immigration of women. In the mid-1970s, Castile-Leon registered a number of births equal to the number of births lost as a consequence of female migration. The opposite happened in Madrid: half the registered births were by immigrant women.

The result is that births registered as from 1900 in Castile&Leon have drastically reduced, reaching their maximum in 1910 with over 85,153 while today they are less than 20,000. In Madrid, births have increased from 25,000 to almost 70,000 although this was exceeded in the seventies by over 90,000.

Figure 8. Births registered, and births “lost” and “gained” from migration in Castile&Leon and Madrid, 1908-2005.



IV. CONCLUSIONS

Migration is becoming the main component of population dynamic in many countries and regions and it is not explicitly considered in the principal current reproduction indicators. In this paper we have seen that the Birth Replacement Ratios provide a very interesting alternative to former replacement indicators like the NRR, particularly in contexts where migration plays a major role. We have applied the Birth Replacement methodology in the context of Castile&Leon and Madrid during the 20th century in order to show the different impact of migration in population replacement.

Firstly, we would like to emphasise the importance of the replacement indicator and its decomposition to describe the demographic dynamics of a population. The BRR is a replacement indicator that explains the replacement of births according to demographic dynamics both in the present (fertility levels) and past (impact of mortality and migration). Its decomposition allows us to evaluate at any given moment the impact of changes in fertility, mortality and to know the impact of migration on replacement.

Castile&Leon and Madrid have experienced the same transition in fertility and mortality –similar NRR- but the evolution of their births has been very different. However, the BRR clearly shows that the demographic dynamics of Castile&Leon and Madrid have been very different throughout the 20th century when the migration effect is taken into account. Castile&Leon has registered replacement levels below the theoretical replacement level while in Madrid, independently of the fertility and mortality trends, births have risen sharply until quite recently and have easily replaced births corresponding to previous generations.

The result is that while Castile&Leon has suffered an intense depopulation and aging process due to the constant outflow of young population, Madrid has registered the opposite effect: concentration and rejuvenation.

Secondly, the departure or arrival of populations at motherhood generates a double effect in the depopulation or concentration process: on the one hand, we observe direct effects derived from the migration of the population and, on the other hand, there is an indirect effect due to future outcomes on births of those migrated women. The migration of women at motherhood means the future gain or loss of births for the region affected.

In Castile&Leon the population leaving the region was mainly young, at working age and from a demographic standpoint, in reproductive ages. This has meant that together with direct losses from those who left (1,175,307 according to the 2001 census only by internal emigration) indirect losses from births that will not be registered in the region (1,200,000) are added, which is totally the opposite for Madrid. Births have dropped sharply and presently represent less than a quarter of births registered at the beginning of the 20th century. The decline in births implies the inability to renovate past generations and this affects the future.

V. APPENDIX

Appendix 1.
Replacement index, several years

Table 2. Replacement index in Castile&Leon, several years

year	BRR	TFR	L^{per}	L^{coh}	BRR^{NoMig}	K^{NetMig}	Births	VarBirth
1910	2.00	5.28	0.584	0.481	2.54	-0.21	85153	-11062
1920	1.76	4.61	0.571	0.519	2.39	-0.26	76547	-14217
1930	1.87	4.69	0.701	0.567	2.66	-0.30	80074	-19152
1940	1.74	3.37	0.713	0.606	2.04	-0.15	71010	-7400
1950	1.76	2.75	0.847	0.676	1.86	-0.05	68303	-2630
1960	1.65	3.02	0.922	0.758	2.29	-0.28	61338	-18074
1970	1.22	2.53	0.961	0.807	2.04	-0.40	41815	-22655
1980	1.04	2.03	0.980	0.902	1.83	-0.43	33168	-22755
1990	0.78	1.17	0.984	0.946	1.11	-0.30	21324	-8572
2000	0.83	1.00	0.989	0.962	0.96	-0.14	17874	-2702
2005	1.03	1.09	0.990	0.969	1.06	-0.03	19425	-548

Sources: INE. Own elaboration.

Table 3. Replacement index in Madrid, several years

year	BRR	TFR	L^{per}	L^{coh}	BRR^{NoMig}	K^{NetMig}	Births	VarBirth
1910	2.39	4.75	0.615	0.462	2.19	0.09	25729	+992
1920	2.41	3.80	0.587	0.498	1.89	0.27	27923	+2984
1930	3.04	3.92	0.732	0.561	2.20	0.38	36373	+5618
1940	3.00	3.88	0.756	0.621	2.41	0.25	37633	+4625
1950	2.33	3.30	0.865	0.702	2.31	0.01	33479	+163
1960	3.76	2.66	0.928	0.797	2.12	0.77	59807	+20726
1970	5.39	2.91	0.962	0.842	2.45	1.20	83442	+38311
1980	3.72	2.09	0.980	0.916	1.91	0.94	72841	+32384
1990	1.67	1.27	0.984	0.946	1.20	0.39	50065	+13258
2000	1.47	1.25	0.989	0.962	1.21	0.22	56623	+9915
2005	1.77	1.38	0.989	0.969	1.33	0.33	69367	+16524

Sources: INE. Own elaboration.

Appendix 2.
Estimate of births and correction of sub-register 1858-2005.

Sources:

1. 1858-1946. Provisional data. Vital Statistics (www.ine.es). For particular years:

- *Births in 1885*. Taken from: Gaceta de Madrid, 1891 N.19. Ministerio de Fomento. Dirección General del Instituto Geográfico y Estadístico (births by province and capital 1878-1888).
- *Births between 1871 and 1877:* linear interpolation.

- *Births between 1893-1899*. Taken from the Natural Migration of the Spanish Population. Year 1900. Dirección General del Instituto Geográfico y Estadístico. Total provincial data.
- *Births between 1920 and 1930*. Calculated using birth rates per capital and province.

2. 1946-2005. Definitive data. Vital Statistics (www.ine.es).

Corrections:

The records until 1950 have been corrected by using the residue calculated by Viciana (1998) and Blanes (2006). Both authors detect a sub-register in 1900 for 6% which practically disappears in 1950 after crossing registered births with censual populations and according to existing mortality conditions. The series of female births, given that they show a higher sub-register according to these authors, have been corrected by using a sex ratio at birth of 106 boys for every 100 girls.

Appendix 3.

Estimate of the Total Fertility Rate (TFR) from 1908 to 1975 for Castile&Leon and Madrid provinces.

The calculation has been made by using the Calot's (1984) interpretation of TFR as period replacement indicator: the number of women at motherhood, 15-49, has been taken from the census from 1910-1981 for each province. The female population exposure to motherhood (G_t) has been calculated by using as weighted rates the existing fertility rates (F_x) for Spain in Eurostat (1971-1974) and from Festy (1979) before 1970.

Using:

$$TFR_t = B_t/G_t$$

We have calculated:

$$G_t = \Sigma[F_x(t)/TFR_t] \,.\, E_x(t)$$

The female population exposure between census periods has then been interpolated. Once the number of women at motherhood (G_t) and the number of births (B_t) for the period between 1908-1981 was known, we obtained the TFR for each province and region.

Appendix 4.

Estimate of cohort mortality rates and period mortality rates for the provinces of Castile&Leon and Madrid, 1900-2005.

Sources:

- *Mortality tables by province* from Dopico y Reher (1998). Years: 1900-01, 1910-11, 1920-21, 1930-31.
- *Mortality tables by province* from Blanes (2007). Years: 1960-62, 1965-67, 1970-72, 1975-77, 1980-82, 1985-87, 1990-92, 1995-1997 y 2000-2002

1. *Period mortality*:

With the tables from Dopico and Reher, the mortality rates have been obtained by logarithmic interpolation between 1900 and 1935 by year.

With Blanes' tables we have estimated the mortality rates by logarithmic interpolation between 1960 and 2005 by year.

For the period 1935-1960, they have been obtained by logarithm interpolation using previous tables.

1935-1940, affected by the Spanish Civil War: the variation in series of female mortality has been taken into account for this period (total deaths, less than 1 years old and less than 5 years from INE, Vital statistics) to correct the interpolated provincial series from 1935-1940.

2. *Cohort mortality*:

The series of cohort mortality has been obtained from the period tables using the distribution of rates in the Lexis diagram area. Keeping in mind that the first period table is from 1900, the average survival to mortality of the cohort for 1927 has been estimated (born in 1900). A logarithmic interpolation of survival until 1908 has been made using this series.

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