Human Fertility Declines with Higher Population Density

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FIRST DRAFT – PLEASE DO NOT QUOTE WITHOUT PERMISSION

Reproduction has been found to decline with increasing population density in a wide variety of species, yet demographers have not given systematic attention to density as a relevant factor in human reproduction. If human fertility also depends on population density, then this has important implications for population projections, which conventionally assume universal convergence of fertility rates (ref UN). Here we examine the relationship between population density and fertility in 143 countries since 1960, controlling for important social and economic variables, and also study regional differentials in fertility preferences. In all cases, we find consistently strong and significant negative associations between density and family size. We also found fertility preferences (ideal family size) decline with increased density across X countries. It is unclear how population density affects human fertility, though a variety of mechanisms could play a role, including endocrine responses to crowding, psychological mechanisms to adjust fertility according to perceived costs and benefits of reproduction, and differential access

to modern contraception. These findings alter how we should think about future fertility and human population growth.

(B – Global Population Trends) Over the past decades human fertility rates have been falling in both developed and developing countries. This has altered the global population outlook from a vision of continued rapid growth to one of moderate further growth and a high probability that the world population will peak at around 9 billion during the second half of this century. This additional population growth will be heavily concentrated in the developing world and is due to a combination of still high fertility rates (above the replacement level of two surviving children per woman) and the very young age structure that results in increasing cohorts of women entering reproductive age (the momentum of population growth) (2 Bongaarts 94 Science). In Europe, on the other hand, below replacement fertility has already resulted in an age structure with fewer children and therefore fewer women entering reproductive age in the future ("negative momentum") (3 Lutz Science). In combination with increasing life expectancy and limited immigration this low fertility is resulting in significant population ageing, posing serious challenges to existing systems of old age security and care for the elderly. (WC 186)

(C – Demographic Transition) In the long run, human population dynamics (growth and of changing age structures) will be dominated by the future level of fertility. The paradigm of demographic transition has been a powerful tool in explaining the remarkable fertility changes that took place in all countries of the world over the past century. It assumes that after an initial decline in death rates birth rates also start to fall after a certain lag. It also assumes that once under way, this transition from pre-modern high fertility to low and controlled fertility is irreversible and will eventually lead to fertility levels around or below replacement. While this paradigm has shown astonishing predictive power in anticipating the fertility declines in most populations of the world (REF? I would also cite a critique or too to be balanced), it is not very helpful with respect to anticipating the likely level of post-transition fertility. It used to be assumed that the demographic transition ends with reaching replacement fertility but the empirical evidence shows that in the vast majority of countries the fertility decline did not stop at replacement but continued below that level (REF?). The social sciences have not yet come up with a useful theory to predict the future fertility level of advanced societies. The notion of a "second demographic transition" emphasising value changes with respect to marriage and sexuality also cannot tell us to what fertility levels such changes will lead and which societies are likely to have higher fertility levels than others. In a broad assessment of the state of our knowledge on post transition fertility levels a study by the American National Research Council only concludes that the future fertility of today's high fertility countries is likely to be in the same range as that of today's low fertility countries. (WC 291)

(D – Fertility and Density for Animals) In their search for explanations for fertility differentials among populations social scientists have given surprisingly little attention to ecological factors, such as population density. This is surprising because "the negative relationship between population density and population growth rate is at the heart of population biology." (Sibly & Hone). A wide range of species – from microbes, mussels, and fruit flies to elephants and other large mammals – show density-dependent effects on reproduction, as well as survival Ricklefs 1996, p.344.fig 15.13. Domestic animals have long known to show reduced fertility at high population densities, and an increasing number of studies also report evidence for density-dependent reproduction (and mortality) with wild animals. Population density affects fecundity in most large mammal species studied (Sibly & Hone table 2.1) (Fowler 1981;1987). For example, density affects fecundity in red deer (*Cervus elaphas)* (Clutton-Brock & Albon 1989; Clutton-Brock et al. 1997a) and soay sheep (*Ovis aries*; Clutton-Brock et al. 1997a; Milner et al. 1999). **)** Food resource limitation is suspected to be an important ecological mechanism behind density-dependent reproduction (Klein 1970, Clutton-Brock *et al*. 1983, 1985, 1987, Skogland 1983, 1985, 1990, Sand *et al*. 1996), though neuro-endocrine changes induced from crowding are also known to inhibit reproduction in primates and other mammals (Sapolsky, In Crews). It is not difficult to understand why such responses have evolved. When offspring survival is density-dependent, density-dependent reproduction will provide a selective advantage. Indeed, one study on birds (Great tits, *Parus major)* found that individuals adaptively adjust their clutch size according to population density (Both, C. 1998, J. Anim. Ecol.67, 667-674). Pearl & Reed (1920) suggested that density affects population growth in the U.S., but with only few exceptions, density-dependent reproduction has been generally ignored for humans (except Edwards and Fuller 1992; Johnson and Booth 1976Paydarfar 1995; Lutz & Qiang).

(E – Measurement issues) Human population density is typically measured by dividing the total surface area of a country or a region by its total population size. This definition does not reflect differences in the quality of the land including the climatic conditions which are highly relevant when it comes to the potential agricultural output of a given piece of land. From a theoretical point of view it is not entirely clear, which aspects of the land should be considered when studying the fertility-density relationship. In predominantly agrarian societies the agricultural potential can be expected to play a major role, in highly industrialized modern settings this is less relevant and it may be more space itself and average distance to the neighbours that matters for perceived density. Extensive sensitivity analyses with different possible definitions of density have shown that the resulting correlations are very robust. For this reason only results with density data are presented that refer to total land area. Population density is used in logarithmic form which corresponds to the plausible assumption of diminishing effects at very high levels of density.

(Box on Methods)

Table 1 reports the estimation results based on data for 145 countries from 1960 to 2000 pooled to a single data set. The first column shows the between country estimation which is a regression on the time-averaged equation (e.g., on the average values of the independent and dependent variables over time), that discards the time series information in the data set and uses only the variation between countries. The second column shows the results of the pooled ordinary least squares estimation with fixed country effects (approximated with a dummy variable for each country) that uses the time variation within each cross section unit. The country effects may be interpreted as unobserved time-constant variables capturing features of the countries that are given and roughly constant over time and may be arbitrarily correlated to the other explanatory variables. The third column depicts the results of the pooled ordinary least squares estimation with fixed country effects allowing for different density slopes from area to area, in order to account for the heterogeneity in the time series association between total fertility rate and density in different regions of the world. We allowed for the possibility of fixed time effects approximated with a dummy variable for each decade. Robust variance estimators are used in the fixed effects models due to the presence of serial correlation in the composite error.

(F – Regression Results) Table 1 gives the results for multiple regressions for time series of 143 countries since 1960 with the Total Fertility Rate (TFR) as the dependent variable and population density, infant mortality, GDP per capita, female labour force participation, female literacy and proportion urban as independent variables. The latter ones are indicators of social and economic development that are widely used as key covariates in explaining fertility differentials in a huge body of literature. The estimated effects of these independent variables on fertility are largely consistent with those given in this literature. What is new about the models presented here is the additional inclusion of population density. In all models this additional effect of population density on fertility (five years later) after controlling for the social and economic variables is negative and statistically significant.

(G – ideal family size) While this analysis reveals a negative association between population density and actual fertility it does not give information about the nature the causation. To test whether effect of density on fertility works through changing individual fertility preferences, we analyze recently collected data from the Eurobarometer (Ref). To capture more regional variation Figure 1 plots the average personal ideal family sizes of 54 NUTS2 regional of the EU against population density of these regions. Since the relevant survey question asked for the personal fertility preferences under hypothetical ideal conditions it is the best broadly available indicator for preferences independent of financial or other constraints. The figure shows a strong negative relationship with rural Northern European regions in the upper left corner and urbanized Central European regions in the lower right corner. The Pearson correlation is –0.44. It is also interesting to look at the outliers: the regions of Ireland tend to have higher family size ideals than suggested by their density and the regions of German and Austria tend to have lower ideals (Ref to recent article on this).

(H) Conclusions and outlook.

Here are some points that I think are important, though it is up to you two, which ones we include.

1. Our findings indicate that fertility declines with population density; and therefore, density should be considered in future analyses/projections of human fertility and population growth (especially since it is as important as GDP). Say how incorporating density might change population projections?

2. Of course, it may not be population density that affects fertility, but rather some other factor correlated with density (we have intercorrelation problems!), and therefore, additional tests are needed.

3. Other approaches are needed to examine possible mechanisms that can inhibit fertility, such as nuero-endocrine changes with crowding or pollution, and especially the availability or interest in modern contraception.

4. In particular, we expect that the economic costs of rearing children (housing, education, etc.) is higher at higher population densities (REF?), and this explains why individuals have reduced fertility preferences at higher densities. The social stress of living in evolutionarily novel (large, anonymous) societies may also play a role.

5. It is important to note that theoretical work indicates that most density-dependent changes in fertility at population levels are expected to occur quite close to a population's carrying capacity (Fowler 1981)

TABLES AND FIGURES:

Table 1. Regression of Total Fertility Rate on Demographic and Socio Economic Indicators (1960-2000).

X-Standardized coefficients. Quinquennial data. Unbalanced panel. Corrected standard errors.

	Between country effects model WLS	Fixed time and country effects models	
		additive model	density-region interactions
population density (log)	-0.37***	-1.85***	-5.43***
infant mortality	0.23*	0.40*	0.12
GDP per capita (log)	-0.32*	-0.08	0.26
female labour force participation	-0.33***	-0.64***	-0.36*
female literacy	-0.94***	-1.07**	-1.51***
proportion urban	-0.38**	0.30	0.11
Time reference: 1960-65			
1970/1975		-0.12	-0.13**
1980/1985		-0.11	-0.15**
1990/1995		-0.04	-0.07*

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Table 1. (Continued) Regression of Total Fertility Rate on Demographic and Socio Economic Indicators (1960-2000).

X-Standardized coefficients. Quinquennial data. Unbalanced panel. Corrected standard errors.

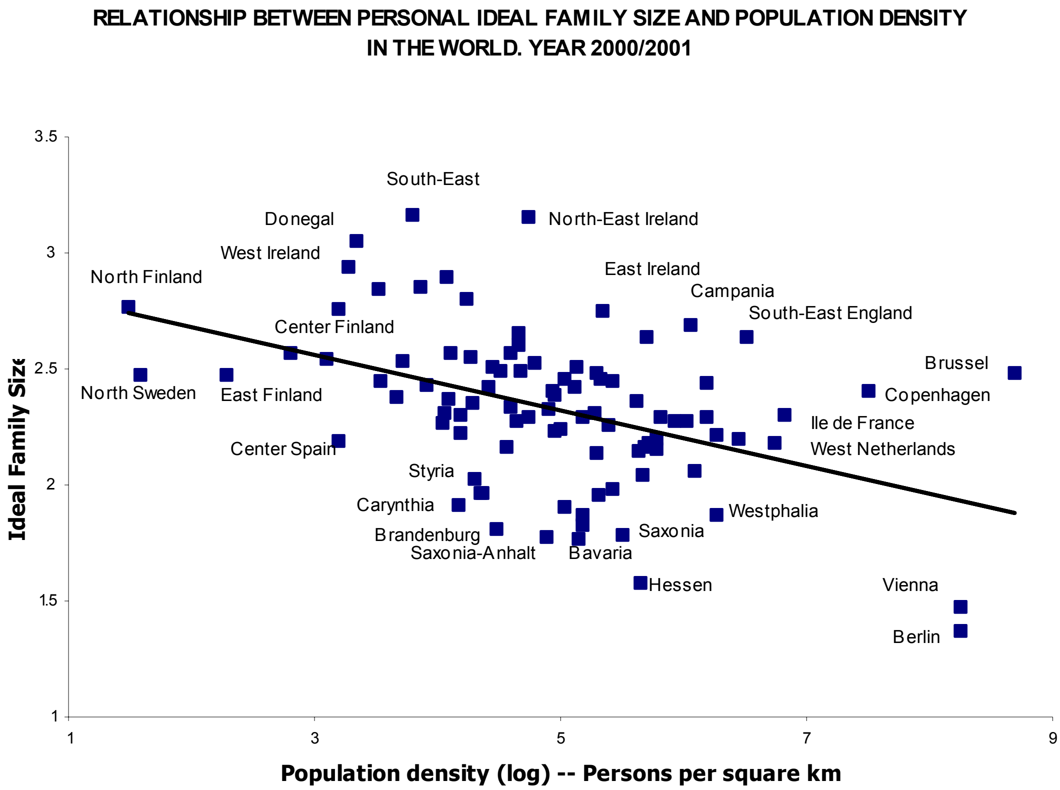
			DENSITY- REGION INTERACTIONS
population density (log)*			
Eastern Africa			4.70**
Middle Africa			8.21***
Northern Africa			0.41
Western Africa			4.77**
Southern Africa			2.61
Eastern Asia			-1.18
South-Central Asia			2.73
South-Eastern Asia			2.26
Western Asia			4.63**
Eastern Europe			0.14
Northern Europe			0.16
Southern Europe			2.06
Caribbean			1.54
Central America			1.66
South America			1.74
Northern America			5.19***
Australia & New Zealand			2.47
Melanesia			3.79**
# observations	145	895	895

Notes.

* p<0.05; ** p<0.01; ***p<0.001

Composition of macro regions according to the United Nations Demographic Yearbook

Figure 1


RELATIONSHIP BETWEEN PERSONAL IDEAL FAMILY SIZE AND POPULATION DENSITY
IN THE WORLD. YEAR 2000/2001
3.5
3
2.5
2
1.5
1
1
3
5
7
9
Ideal Family Size
Population density (log) -- Persons per square km
South-East
Donegal
North-East Ireland
West Ireland
North Finland
East Ireland
Campania
South-East England
Center Finland
Brussel
North Sweden
East Finland
Copenhagen
Ile de France
West Netherlands
Center Spain
Styria
Carynthia
Westphalia
Brandenburg
Saxonia
Saxonia-Anhalt
Bavaria
Hessen
Vienna
Berlin