Malthusian Checks: An Investigation into Sufficiency Conditions, Long-Term Dynamics and Implications for Inverse Projections

ALBERTO PALLONI

Center for Demography and Ecology, University of Wisconsin, 1180 Observatory Drive, Madison, Wisconsin 53706-1393, USA, e-mail: palloni@ssc.wisc.edu

1 Objective

This is a set of notes designed to invite discussion, awaken interest, and suggest a potentially fruitful research agenda, one that links different strands of research in historical demography. The document is quite informal and does not pursue many of the leads but leaves them as open area of inquiry.

2 Sufficiency of Malthusian Checks

A while back there was a controversy that I do not think was ever resolved satisfactorily. The core of the problem can be formulated thus: in pre-industrial societies Malthusian checks, of the positive and preventive variety, operated with some regularity; we know that, on the whole, these checks were quite efficient for natural rates of increase hovered around 0 for a long time, albeit with pronounced oscillations and, during a long period starting in 1400, may be even on a slight but sustained upward trend. But, were the positive checks sufficient or of any significance at all? And if so, what was the magnitude of the contribution toward the maintenance of the long term homeostatic equilibrium? [25, 17, 26, 8, 9]

My own calculations suggest that, in the long run, positive checks may have had more than trivial consequences, but my arguments were not quite convincing nor was I able to derive estimates of the contribution of positive checks to the total inhibiting effects of Malthusian checks. Menken and Watkins as well as Fogel and Weir are of the belief that mortality crises play only a minor role, if at all, and that most of the inhibiting forces falls surely within the realm of preventive checks. Positive checks are a historical nuisance with little consequence for the long run movement of populations.

To investigate the question with available empirical data would stack the cards against the null hypothesis of an efficient positive check. This is because we face a massive selection problem from the start: we only have information for communities, cities, countries that survived extinction altogether and were not wiped out by epidemics, wars or other unpleasant positive checks. The right way to pose the problem is via simulations. These simulations require four ingredients:

a) knowledge about the nature, frequency, and intensity of shocks associated with positive (and preventive) checks;
b) information about the short-term impact of these shocks on the levels and patterns of mortality, nuptiality and marital fertility. Migration is, of course, equally important but I will circumvent discussing it for the time being in order to keep the presentation within the confines of what I know best;
c) information of the underlying population regime, that is, the background patterns and levels of mortality, fertility and nuptiality;
d) existence of long lags in some responses: there are relations between fertility (mortality) experienced throughout life by a birth cohort and the levels of fertility (mortality) prevailing at the time of birth of that cohort.

With information on (a) through (d) one could conceivably postulate a generalized dynamic population model with changing vital rates, one that incorporates the fact that changes in vital rates at one point affect changes in vital rates several years later, and where the shocks that infuse energy into the system are randomly produced according to some well defined process. A Poisson process is a good candidate or, else, one could use a more complicated stochastic process, one retaining some memory, and even containing embedded variability in the intensity of the shock.

3 The Workings of Long-Run Dynamics: What Information Do We Need and What Do We Know?

The formal dynamics of some of these systems has already been investigated. For example, work on cyclical oscillations (Easterlin cycles and the like) has been done by several authors. See for example the work by Lee [13], Wachter [23], Tuljapurkar [22], Wachter and Lee [24], Frauenthal and Swick [10], Bonneuil [3] and Artzrouni and Komlos [1]. However, very little work has been done on the dynamics of populations subject to random changes. There are some exceptions. First, Joel Cohen [6, 7]; worked on applications of (random) projection matrices to understand long run dynamics of systems where vital rates varied randomly. Second, in his PAA (Population Association of

America) presidential address Ron Lee [15] pursued the problem by hinting that regimes of short-term responses had long run implications.

It is clear that combining cyclical oscillations of the Easterlin variety and short terms fluctuations poses a rather massive problem. I doubt very much that we will get too far ahead following the closed-form solution route. An alternative is to use microsimulations.

3.1 How Does the Long-Run Dynamic Work?

Completing the design of a microsimulation process that accomplishes what I desire is not very difficult. I present it here in a simplified form. Let us assume that there is a population regime characterized by a mortality pattern, $M(x)$, with level e_0 (life expectancy at birth), a marital fertility pattern, $MF(x)$, with level TMFR (Total Marital Fertility Rate), and a nuptiality pattern $N(x)$ with level SMAM (Singulate Mean Age at Marriage). Together, the nuptiality and marital fertility pattern imply a pattern of fertility rates, $F(x)$, with a level TFR (Total Fertility Rate). Imagine that a population shock with intensity $I = i$ and that such shock occurs following a Poisson process with rate λ_i. Suppose we know the mortality, fertility and nuptiality elasticity with respect to I are at lags $k = 1,2,3,...,K$. Let these be δM_k, δF_k and δN_k with corresponding total responses equal to the summation of the elasticities over the range of lags. Finally, assume we know the relation between the size of a cohort born Y years before an index time and the corresponding fertility levels, or the response $\delta TFR^{(cohort)}(B(t-Y))$. I assume we also know the relation between the mortality levels experienced by a cohort early in life and the mortality regime for the cohort later on in life, or the response $\delta e_0^{(cohort)}(e_0(t-Y))$. I have blurred a bit the distinction between marital and general fertility to simplify the exposition. However, it should be kept in mind throughout that the effects of shocks on fertility work mostly, though not completely, through effects on marriage and marital fertility.

We start a conventional cohort population projection and for each year of the projection draw a random number to determine the type of population shock that will apply during that year (if any). One can then use the estimated elasticities $\delta TFR^{(cohort)}(B(t-Y))$ and $\delta e_0^{(cohort)}(e_0(t-Y))$ to generate levels of mortality and fertility that will prevail in years following the shocks. When a cohort arrives at marriage and childbearing ages, their background levels of marriage and nuptiality will depend on the ones calculated at birth but modified by period effects prevailing at time t (when the cohort is aged Y). These period effects are calculated from elasticities δM_k, δF_k and δN_k. There is, of course, some slippage here since most population shocks may last more than one year.

This projection can be run repeatedly for a large number of periods and, at each time, a number of outcomes can be evaluated: (a) the overall natural rate of increase within a period of T years and the total deviation from the background natural rate of increase; (b) the actual magnitude of the contribution of positive and preventive checks; (c) the variance in the quantities described before. Finally, we could also investigate if and when the population attains a steady state of oscillations. To investigate the importance of either Malthusian check one can simply run the projections but shutting down completely the operation of the other check.

Note that it is not difficult to write the integral equation for births subject to the above described dynamics. In the absence of migration, the number of births at time t is given by:

$$B(t) = (1+g(t)) \int B(t-x)\, \varphi_c(x,t-x)\, dx$$

where $g(t)$ is a term representing the proportional change in the period fertility caused by the shock in year t as well as any lagged effects of previous shocks, $\varphi_c(x,t-x)$ is a cohort net fertility function, one that reflects past mortality effects experienced by each cohort, as well as marriage postponement (effects on nuptiality) and delays in childbearing (effects on marital fertility).

The nature of the function $g(t)$ is complex as it depends on the random variable I as well as on the estimated short-term elasticities of fertility and nuptiality. I am not sure what the solution to this integral equation is although a search procedure could be employed following the work of Tuljapurkar [21] and Boulanger and Yashin [4].

3.2 Background Regime

Specifying a background population regime is relatively unproblematic. We should define age patterns of mortality, fertility and nuptiality as well as levels for a particular period. It is important to make sure that we define a marital fertility schedule that can be modified by a marriage pattern to convert it into conventional fertility rates and net maternity rates. One could also allow for secular changes in both levels and age patterns of all three vital events.

3.3 Short-Term Responses

There is a large literature on demographic effects of short-term economic oscillations. This literature focuses on effects of short-term deviations from a secular trend of changes in some proxy of wealth or ability to access resources, such as real wages and prices, or total real output of an economy.

A number of studies have used data from pre-industrial Europe [14, 11, 20], Latin America [18, 12, 5, 19], and parts of Asia [16] to estimate distributed lag models involving total births, total number of marriages and total number of deaths, as well as the total number of births to married women and the total number of deaths by age and causes. These estimates provide a remarkably consistent picture indicating that the marriage and birth elasticities with respect to real wages are in the range 0.5-1.0 whereas those of number of deaths are not larger than 0.25. These estimates alone should be a basis to judge the importance of the positive check. However, they are opaque pieces of information when it comes to answer the questions posed at the outset, namely, those related to the nature and magnitude of the mortality response and long-term dynamic of the system.

An important issue that arises here is that of the selective effects on mortality by age and by causes. The studies where elasticities for age and cause-specific mortality were estimated suggest great variability in the mortality response by age. Since these studies were carried out in countries of Latin America during the period 1950-1990, they cannot be used as a basis for making retrospective inferences to the pre-industrial period. But it should serve as a warning that the generally accepted assumption that mortality crises preserved the age pattern of mortality is probably incorrect. As I will argue later this is a source of stochastic variability in inverse projection that has not been given adequate importance.

3.4 Easterlin-Like Cycles in Fertility and Mortality

Easterlin-type responses have been estimated for contemporary populations and have been shown to be of reasonable strength and influence. I confess to not knowing much about research on the operation of similar types of feedback mechanisms in pre-industrial societies, but it surely must not be very difficult to investigate. However, it is not clear to me what kind of dynamics evolves if we superimpose a stochastic process that effectively amplifies or shrinks the response to the operation of Easterlin type of cycles.

Similar cycles in mortality are justifiable to the extent that cohort mortality changes operate in the way envisioned, for example, by those who argue for increased (decreased) heterogeneity of within-cohort frailty in response to lower (higher) mortality or, alternatively, by arguments that directly pose a relation between risks later in life and conditions near birth.

3.5 Stochastic Shocks Regimes

Perhaps the most difficult part of this exercise is to justify a regime of population shocks. If one is interested only on the occurrence of economic shocks, we may find some comfort in research on long-term oscillation of prices and wages. But this is unlikely to be sufficient. As the record of most pre-industrial populations show, population crises were associated with a number of conditions, all of which ended up having some sort of effects on the economy and thus on production and wages.

A possibility is to investigate the historical record of the frequency and intensity of shocks in the past, fit alternative models, and then utilize the estimated parameters associated with these models in the simulation. This type of solution faces two problems. The first is that we are not likely to get enough information for one society to produce robust estimates. The solution is to pool the experience of several societies but with consequent losses of specificity or increase in variance. Second, we are confined to proceed as if there were no feedback mechanisms, that is, we must assume that the occurrence of shocks is completely exogenous to population changes. This is plainly incorrect as we know that some crises are associated with transient relative overpopulation or excess labor supply. Indeed, the Easterlin type mechanism that we promote as an important part of the model rests on the idea that such associations are important. A similar veil of unreality permeates the model since it is difficult to integrate the fact that populations located in different regional spaces are related to each other, and that the occurrence of a crisis in a place will affect the probability of a crisis somewhere else.

4 Implications for Inverse Projections

These considerations are of relevance to the procedures used to implement inverse projections of the forward type. In fact, the stock of births and deaths in populations regimes such as those described above will be subject to oscillations reflecting both the random impact of population shocks of intensity I and lagged effects of Easterlin-like cycles. To the extent that changes in age patterns of fertility (possibly induced by postponement of marriage or delayed childbearing) does not have an impact on other aspects of the population (mortality, for example), its oscillations and their association with shocks can be safely ignored. Well, not quite: there is the fact that estimates of TFR or TMFR are calculated assuming a particular pattern of births by age of mother and, therefore, can be distorted by assuming incorrect patterns.

This is not so for the case of mortality. If the age distribution of ages at death at time t changes as a consequence of the shocks, then inverse projections that rely on a standard age pattern of mortality will be in error. Thus, for example, if the bulk of all deaths in a crisis year, say t, is associated with infant deaths, the forward projection will attribute too many deaths to older ages and will distort the age distribution of the estimated population at time

$t+1$. These errors will propagate forward and will eventually disappear. But, age specific rates as well as measures of levels will be incorrect for a number of years following year t.

The above considerations are strongly supported by the fact that, in cases where differentials in age-specific mortality responsiveness to shocks can be tested for, the evidence suggests that these are strong and durable. Since the shocks occur at random and they introduce a stochastic component to population dynamics, it is worth asking what is its magnitude of its influence compared to the impact of other random components, such as those that concern a study by Bertino and Sonnino [2]. It also presents us with the issue of determining the timing of a shock as well as the associated period within which lagged responses occur.

Lest I give the impression that changes in age patterns of mortality can only change due to short-term fluctuations, it is important to note that to the extent that cohort effects of mortality do take place, they too will distort the age distribution of ages at death at a given point in time.

To test the influence that these kinds of effects may have on estimates from inverse projections, one could run the simulations in tandem with a number of scenarios for implementing forward inverse projection (regarding number of censuses or exogenous estimates of migration available). Since the simulations will be performed multiple times, so will inverse projection and the results will generate measures of average errors and variance of the errors which could then be used to test significance in empirical cases.

5 Conclusions

The vexing problem of the efficiency of Malthusian positive checks can be addressed via microsimulations that do not require strict closed solutions. Similarly, the selection problem caused by population extinction and the dynamics of steady states can be thoroughly investigated. The research program suggested in this paper is not overwhelming since at least half of what is required by it, knowledge of population response to economic shocks, has already been accomplished. It does require, however, that we understand better the realization of economic cycles, their spatial diffusion, and the nature of endogenous feedback mechanisms.

The solution to the conundrum has unanticipated spill-over effects. The most important one is that it will enable to understand better the sensitivity of estimates derived from forward inverse projection, and to assess more rigorously the robustness of these estimates to violations of assumptions on which the procedure relies. These violations are common occurrence for that is the nature of the beast: pre-industrial societies did experience recurrent crises that not only altered levels of mortality and fertility but obfuscated age patterns as well. Thus the program of research suggested here not only serves the narrow interests of a small constituency of researchers obsessed with concerns about steady states or chaotic responses, but also with a much wider audience of historical demographers concerned about the estimation of basic demographic parameters.

References

1. Artzrouni M. and Komlos J. (1985), Population growth through history and the escape from the Malthusian Trap: A homostatic simulation model. *Genus* 41(3-4), 21–39.
2. Bertino S. and Sonnino E. (2003), The Stochastic Inverse Projection and the Population of Velletri (1590-1870). *Mathematical Population Studies* 10(1), 41–73.
3. Bonneuil N. (1997), *Transformation of the French Demographic Landscape 1806-1906*. Oxford University Press, Oxford.
4. Boulanger E. N. and Yashin A. I. (1992), Self-regulation in age-structural populations. *Working Paper*, IIASA, 92–83.
5. Bravo J. (1997), Demographic Consequences of Structural Adjustment in Chile. In Tapinos G., Mason A. and Bravo J. (Eds.), *Demographic Responses to Economic Adjustment Program*, Clarendon Press, New York.
6. Cohen J. (1977a), Ergodicity of age structure in populations with Markovian vital rates, II: General States. *Advances in Applied Probability* 9, 19–37.
7. Cohen J. (1977b), Ergodicity of age structure in populations with Markovian vital rates, III: Finite-state moments and growth rates, an illustration. *Advances in Applied Probability* 9, 462–475.
8. Fogel R. W. (1986), Nutrition and the Decline of Mortality Since 1700: Some Preliminary Findings. In Engerman S. L. and Gallman R. E. (Eds.), *Long-Term Factors in American Economic Growth*, University of Chicago Press, Chicago.
9. Fogel R. W. (1989), Second Thoughts on the European Escape from Hunger: Famines, Price Elasticities, Entitlements, Chronic Malnutrition, and Mortality Rates. *Working Paper Series on Historical Factors in Long Run Growth* 1, National Bureau of Economic Research, Cambridge, MA.
10. Frauenthal J. C. and Swick K. E. (1983), Limit cycle oscillation of the human population. *Demography* 20, 285–298.
11. Galloway P. (1988), Basic patterns of annual variations in fertility, nuptiality, mortality and prices in pre-industrial Europe. *Population Studies* 42(2), 275–302.
12. Hill K. and Palloni A. (1992), Demographic responses to economic shocks: The case of Latin America. In *The Peopling of the Americas*, Vol. 3, International Union for the Scienitifc Study of Population, Liegi, 411-438.

13. Lee R. D. (1974), The formal dynamics of controlled populations and the echo, the boom and the bust. *Demography* 11, 563–585.
14. Lee R. D. (1981), Short-Term Variation: Vital Rates, Prices and Weather. In Wrigley E. A. and Schofield R. S. (Eds.), *The Population History of England, 1541-1871*, Harvard University Press, Cambridge, MA.
15. Lee R. D. (1987), Population dynamics of humans and other animals. *Demography* 24(4), 443–465.
16. Lee R. D. (1990), The demographic response to economic crisis in historical and contemporary populations. *Population Bulletin of the United Nations* 29.
17. Palloni A. (1988), On the Role of Crises in Historical Perspectives: An Exchange. *Population and Development Review* 14, 145–158.
18. Palloni A., Hill K. and Pinto G. (1996), Economic swings and demographic changes in the history of Latin America. *Population Studies* 50(1), 105–132.
19. Reher D. and Ortega J. A. (1997), Short Run Economic Fluctuations and Demographic Behavior: Some Examples from Twentieth Century South America. In Tapinos G., Mason A. and Bravo J. (Eds.), *Demographic Responses to Economic Adjustment Program*, Clarendon Press, New York.
20. Richards T. (1984), Weather, Nutrition, and the Economy: The Analysis of Short-Run Fluctuation in Births, Deaths, and Marriages, France 1740-1909. In Bengtsson T. et al. (Eds.), *Pre-Industrial Population Change*, Almquist and Wiksell, Stockholm.
21. Tuljapurkar S. (1986), Demographic Models of Population Cycles: Dynamic Analysis. Paper presented at the Annual Meeting of the Population Association of America, San Francisco.
22. Tuljapurkar S. (1987), Cycles in nonlinear age-structured models I: renewal equations. *Theoretical Population Biology* 32, 26–41.
23. Wachter K. W. (1991), Elusive cycles: Are there dynamically possible Lee-Easterlin models for US births? *Population Studies* 45, 109–135.
24. Wachter K. W. and Lee R. D. (1989), U.S. births and limit cycle models. *Demography* 26, 99–115.
25. Watkins S. C. and Menken J. (1985), Famines in historical perspective. *Population and Development Review* 11(4), 647–676.
26. Weir D. (1984), Life under pressure: France and England, 1670-1870. *Journal of Economic History* 44, 27–47.