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When is a tempo effect a tempo distortion?

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Abstract

Our aim is to clarify the fundamental conceptual difference between a tempo *effect* and a tempo *distortion* and to answer the question of which uses of quantum and tempo measures lead to distortions. We conclude that tempo effects are widespread in period measures, but that the need for adjustment depends on the purpose of the indicator. When the objective is to measure current conditions, as is usually the case, two approaches exist. In the classical approach, current age specific event rates are assumed to reflect fully current conditions. In contrast, we argue that current rates and the tempo effects in measures derived from them do not in general reflect current conditions. When changes in the timing of demographic events shift rates schedules to higher or lower ages, constant conditions may imply changing rates. In that case, tempo effects are distortions that need to be corrected in order to get an accurate measurement of current conditions.

The measurement of the quantum and tempo of life cycle events is one of the oldest and most important topics in demography. Quantum is defined as the average number of events over the course of the life cycle, tempo as the mean age at the event. For example, completed cohort fertility is a quantum measure, and life expectancy at birth in a cohort (generation) life table is a tempo measure of mortality.

There are three problems with cohort measures of quantum and tempo. First, they do not provide information on behavior during specific years or other short time period, which is often what we are most interested in. Second, cohort measures can be calculated only for cohorts whose life cycle event experience is complete. This means that cohort measures necessarily refer to behavior in the more or less distant past, sometimes many decades in the past. Third, the calculation of cohort measures requires data for all years in which life cycle events to the cohort occur. Often this data is unavailable, even for fertility and nuptiality, which require roughly three decades of data. In the case of mortality, data is required for as much as 100 years, a severe limitation.

"Period" measures were invented to overcome these problems. The period version of any cohort measure is defined for any time period as *the value of the measure in an hypothetical cohort that experiences, throughout its lifetime, the conditions observed in the reference time period.* Demographers have generally assumed that "conditions" during the reference time period are represented by age-specific rates observed during this period.

However, for more than half a century it has been known there are situations in which rates do not adequately represent conditions. Hajnal (1947) and Ryder (1956) both observed that period measures of fertility quantum may be distorted when women advance or postpone births.

This note aims to clarify the conceptual difference between a tempo *effect* and a tempo *distortion* and to answer the question of when tempo effects should be regarded as distortions. The heart of the issue—whether or not tempo effects are distortions that require a correction — lies in the precise meaning of "conditions" and what it means to hold them constant.

Background

The terms "tempo effect" and "tempo distortion" were first introduced in the demographic literature by Norman Ryder, who made a series of fundamental contributions to the study of quantum and tempo measures in fertility (Ryder 1956, 1959, 1964, 1980). His most important finding was that a change in the timing of childbearing results in a discrepancy between the period total fertility rate (*TFR*) and the cohort completed fertility rate (*CFR*). He considered the period *TFR* to contain a tempo distortion when the timing of childbearing changed.

Ryder's work was highly influential and for most of the last half century the idea of tempo effects in fertility has been widely accepted. Empirical assessment of tempo effects, however, was problematic and rarely attempted. This changed in 1998, when we provided a reformulation that lead to a simple equation for assessing period tempo effects, an equation that made relatively modest demands on data (Bongaarts and Feeney 1998). Our analysis led to considerable discussion over approaches to measuring fertility tempo effects (Bongaarts and Feeney 2000;

Van Imhoff and Keilman 2000; Kohler and Ortega 2002, 2004; Kim and Schoen 2000; Sobotka 2004)

Controversy ensued when we proposed that mortality measures—in particular the conventional life expectancy—are also affected by tempo effects. A substantial, highly technical literature surrounding this issue has accumulated in recent years, much of it summarized in Barbi, Bongaarts and Vaupel (2008)

Tempo effects

If age-specific birth rates are constant for a sufficiently long period of time, both period total fertility rates and cohort total fertility rates will be constant and have the same value. One might infer from this that period total fertility rates and cohort total fertility rates will be equal if both of these rates are constant for a sufficiently longer period of time. The latter proposition is false, as shown by Ryder. The period total fertility rate and the cohort fertility rate can be constant for any length of time, while at the same time be different from each other, if the mean age at childbearing is changing. Ryder referred to this difference between the period and cohort indicators as a "tempo" effect.

To illustrate this point, see Figure 1 in which the dots represent the density and distribution of some demographic event by period (vertical lines) and cohort (diagonals). The sum of the age specific rates in a given year gives the period "Total Event Rate," or *TER*. The sum of rates over the life cycle of a cohort gives the cohort total event rate, which we denote as *CER*. If the distribution of events is the same in each year, the period and cohort quantum are constant and equal, $TER=CER$.

Figure 2 introduces tempo changes by shifting the age distributions of events in cohorts by a fixed amount r each year holding the shape constant. In this scenario the *TER*, *CER* and r are all constant but $TER<CER$ when $r>0$ (as shown) and $TER>CER$ when $r<0$ (not shown). A rising mean age at the event deflates the period indicator relative to the cohort level. A declining mean age has the opposite effect. As suggested by the general terminology used in this illustration, tempo effects are not limited to fertility; they may occur for any demographic event.

This brief examination of cohort and period indicators clearly documents the existence of tempo effects, but it does not provide a direct way to measure this effect when cohort and period fertility are not constant, as is generally the case. We addressed this issue in 1998 when we introduced a procedure for estimating the tempo effect in a period as the difference between (a) the observed value of a period measure at time t and (b) the value that would have been observed if the period mean age at the event at time t had been constant (Bongaarts and Feeney 1998, 2003, 2006). A *TFR* tempo effect, for example, is the difference between the observed *TFR* for a given year and the value that would have been observed if the period mean age at childbearing had remained constant at the value observed during the year. Note that there is no reference to any cohort measures in this definition.

The concept of delayed childbearing for cohorts is straightforward, but a period delay in childbearing is less clear-cut. To clarify our analysis of the impact of period delays in demographic events on period event rates it is useful to make a distinction between three types of period delay (for simplicity we will use birth delays, but the following discussion applies also to other demographic events):

- *Temporary delay*: Births may be delayed in certain years on account of war, economic conditions or cultural beliefs, without any long term trend in the age at childbearing. For example, suppose that postponement occurs only in one year Y and that all postponed births occur in the following year. Let *B* denote the number of births that occur each year in the absence of postponement and x the number of births postponed from year *Y* to year *Y+1*. In this scenario the annual number of births will decline from *B* to *B-x* between year *Y-1* and year *Y*, increase from *B-x* to *B+x* between year *Y* and year *Y+1*, and decline from *B+x* to *B* between year *Y+1*and year *Y+2*. Period fertility as measured by age-specific birth rates will accordingly fall in year *Y*, rise in year *Y+1*, and fall again in year *Y+2* , and remain constant thereafter. The postponement of births from year *Y* to year *Y+1* is accompanied by a rise in mean age at childbearing between year *Y* and year *Y+1* and a fall between year *Y+1* and year *Y+2*. These changes result in a negative tempo effect in year Y and an offsetting positive tempo effect in year *Y+1*.
- *A permanent shift* occurs when period changes in conditions, such as increases in women's education and labor force participation, result in a permanent rise in the age at childbearing. Suppose that the period mean age at childbearing rises during year *Y* because of a change in such conditions. The number of births will decline from *B* to *B-x* between year *Y-1* and year *Y*, as before. Between year *Y* and year *Y+1*, however, births will rise from *B-x* to *B* (and not to *B+x*) and thereafter will remain constant. There is a one-time negative tempo effect in year *Y*.
- *Continuous rising mean age*. This scenario occurs when the one time permanent shift described in the preceding case is repeated year after year. Instead of a deficit in births in one year the deficit occurs year after year as long as the mean age at childbearing keeps rising. This is equivalent to the scenario depicted in Figure 1 with a negative tempo effect that persists year after year.

Though very different, these three types of delay render birth rates problematic as indicators of current fertility conditions and similar problems arise in period measures of other demographic events. Tempo effects in period nuptiality measures have been demonstrated by Winkler-Dworak and Engelhardt (2004). Bongaarts and Feeney (2003, 2003, 2006); Guillot (2006) and Rodriguez (2006); Vaupel (2002, 2005) and Wachter (2006) discuss tempo effects for mortality.

Tempo distortions

Whether a tempo effect in an indicator is a distortion that requires an adjustment depends on the use to which the indicator is put. Guillot (2006; see also Vaupel 2002) notes that period indicators have three distinct uses in demography:

(1) To summarize period age-specific rates. The results may be given a synthetic cohort interpretation, but the aim is purely descriptive.

(2) As proxies for cohort indicators where the data necessary for the calculation of cohort indicators is not available, e.g., because some of the cohort experience lies in the future.

(3) As estimates of the cohort indicators implied by the continuation of *current conditions*. As noted above, "conditions" have generally been identified with age-specific rates, despite problems with this identification that have been know for more than half a century.

On the first use, we agree with Guillot (2006) that even when tempo effects exist, they are not relevant to period indicators as summary measures and hence are not distortions. On the second use we also agree that tempo effects in period measures clearly result in a distorted estimate of cohort measures. Moreover, cohort indicators cannot, in general, be derived from a single period indicator. This derivation is possible only if period and cohort quantum are constant while tempo changes linearly. These conclusions regarding the first two uses are straightforward.

Our primary concern here is therefore with the third use of period indicators, as measures of current conditions. In this case the intention is to obtain a period indicator that equals the quantum or tempo that would be observed in the cohort born in year *t* if no further changes in conditions occur after year *t* (see Vaupel and Guillot 2006 for similar definitions). The heart of the debate over tempo effects—whether they are distortions that should be corrected for, or merely effects—lies in the precise meaning of "conditions" and what it means to hold them constant.

There are two perspectives on this issue (Bongaarts and Feeney 2008; Guillot 2006; Rodriguez 2006; Vaupel 2002). The classical approach assumes a model for which period conditions generate a set of age specific rates that faithfully reflect these conditions. The central assumption is that demographic events occur randomly, that they are not influenced by past events, and that they do not influence future events, though their incidence may depend on demographic and socioeconomic characteristics such as age, education etc. As conditions change event rates rise or fall and any resulting changes in tempo are considered secondary. According to this model, period indicators derived from rates are undistorted indicators of period conditions. Tempo effects exist, but they are not distortions and there is no need for a tempo adjustment. An analysis of trends in the force of mortality by Rodrigues (2006), for example, concludes that "This is clearly a tempo effect …. I don't believe, however, that it is a distortion."

The classical model clearly captures an essential aspect of the occurrence of demographic events, but Ryder's analysis of fertility tempo effects shows that it fails to capture another important aspect: the delays that give rise to the fertility tempo effects that most demographers now regard as distortions. The Bongaarts-Feeney (BF) approach to general tempo effects differs from the classical view because we make a fundamental distinction between changes in age-specific rates that reflect changes in quantum and changes in age-specific rates that reflect tempo change. Tempo changes result in *shifts* of the event rate schedules to either higher or lower ages, as conditions change.

This distinction implies an important conclusion: continuation of *constant* conditions may be associated with *changing* age-specific rates. This is inconsistent with classical thinking, according to which age-specific rates can change only if conditions change because conditions are fully reflected in rates.

To illustrate, suppose that socioeconomic conditions influencing the age childbearing are changing before year *t* (e.g., a rise in women's level of education or labor force participation) and that this leads to a tempo change, i.e., a rise in the mean age at birth. Assume further that the quantum of fertility is constant. The shifting age schedule of childbearing results in a tempo effect that depresses the total fertility rate up to time *t*.

Next, suppose that the socioeconomic conditions are held constant from time *t* onward and that the new, higher age at birth prevails as long as the new socioeconomic conditions continue. Continuation of current *conditions* after time *t* means a movement from a rising to a constant mean age at birth. The disappearance of the tempo effect after *t* leads to a rise in age-specific birth rates and in the total fertility rate even though the quantum of fertility is assumed to be unaffected by the changing conditions. Constant conditions here does *not* mean a continuation of the corresponding age-specific birth rates. On the contrary, constant conditions *imply a change* in age-specific rates.

In this illustration, the *TFR* before *t* is clearly affected by a tempo effect and this effect is a distortion because the *TFR* does not measure the fertility quantum implied by the prevailing conditions up to time *t*. This view of tempo effects and distortions is now widely accepted and corrections for tempo distortions are now commonly used in the analysis of fertility trends (Lutz and Sobotka 2008).

We argue that the same phenomenon applies to adult mortality in high life expectancy countries. Changes in mortality conditions are assumed to lead to *shifts* of the schedule of mortality rates to higher ages, strictly reflecting tempo change (the quantum of mortality can of course not change because everyone dies eventually). "Current conditions" includes the availability and use of immunizations and other public health practices; the availability of medical devices, such as pace-makers, dialysis machines, and portable and inexpensive devices to measure blood sugar level; screening programs for early detection of different kinds of cancers; drugs that prolong life by reducing the incidence of particular life-threatening diseases, such as antibiotics and anti-cholesterol drugs; and surgical procedures, such as open heart surgery, that prolong life; and behavioral changes, such as changes in diet and exercise, that improve health and prolong life. Just as in the case of childbearing, when new conditions come into being to raise the age at death, they tend to persist because they shift the age schedule of rates to different ages.

Constant conditions thus refers to the absence of changes in the many medical, public health, behavioral and other circumstances that influence length of life. Just as in the case of fertility, constant conditions may imply changes in age-specific rates. “Conditions” refers to mortality-relevant behaviors, treatments and technologies—not to age-specific rates as such.

We therefore argue that period indicators of mortality are subject to tempo effects which are distortions for the same reasons that period indicators of fertility are subject to these effects and contain distortions. Current rates do not necessarily reflect current conditions. When conditions change in such a way as to increase length of life by shifting rates to higher ages, tempo effects come into play, and age-specific death rates are distorted indicators of current conditions. This is the rationale for the mortality tempo adjustment we have proposed. Whenever current conditions are changing , mortality measures derived from period age-specific death rates need to be adjusted for tempo distortions.

Discussion

(1) Tempo effects can be measured, and appropriate corrections can be made, only by imposing simplifying assumptions. The most important of these in our analysis is that there are no cohort effects, i.e. all cohorts respond to changing period conditions in the same way. We have argued elsewhere that this assumption holds approximately for fertility and adult mortality in most contemporary populations.

(2) The preceding discussion focuses on indicators derived from rates of the “second kind”, but indicators derived from rates of the “first kind” (hazards) are also subject to tempo effects and distortions. This is because tempo changes operate on the numerators of rates, and hence affect rates of both the first and second kind. In particular, life table measures are subject to tempo effects (see Kohler and Ortega 2002, 2004)

(3) The BF correction for tempo distortions does not necessarily apply to all ages and types of events. In the case of mortality, for example, the classical interpretation of rates applies to child mortality and to accidental or crisis mortality, while the BF interpretation of tempo effects applies to senescent mortality (see Bongaarts and Feeney 2008).

(4) Tempo adjusted period indicators are not projections of future levels any more than unadjusted period indicators are projections of future levels. In making projections, however, it is useful to be able to assess tempo effects. Consider for example a projection of the TFR in a population with a rising mean age at childbearing, which creates a negative tempo effect. Forecasting the quantum and tempo components separately may be more appropriate than forecasting unadjusted total fertility rates directly. One might assume that both components remain constant, implying a continuation of the trend in the mean age at birth.

Alternatively, if the mean age is already high, it might be assumed that the mean age would rise slower in the future and will eventually stop rising. Under this scenario the tempo distortion would disappear over time thus putting upward pressure in the TFR. It would then be reasonable to assume a small rise in period fertility if the quantum remains the same. This is why the UN projections for developed countries assume a rise in the TFR over coming decades. (UN 2007)

(5) The existence of tempo effects/distortions in period tempo indicators (i.e. in the mean age of events) is a complex issue. Here we note only that the above conclusions regarding the presence of tempo effects and distortions in quantum indicators also applies to tempo indicators

derived from rates of the first kind. This follows from the fact that tempo indicators are derived from the same age specific rates used to calculate quantum indicators. For example, Bongaarts and Feeney (2006) demonstrate tempo effects in the period mean ages at first birth derived with life tables when the timing of childbearing is changing. Tempo indicators of mortality such as the life expectancy at birth also contain tempo effects, and as discussed above, these effects are distortions. Evidence in support of this assertion includes the observation that the conventionally calculated life expectancy at a given time differs from the mean age at death of the cohort which is at its mean age at death at this time (Bongaarts and Feeney 2006, Rodriguez 2006; Goldstein 2006). The magnitude of this difference varies with the rate of increase in the mean age at death, as one would expect if the difference is caused by a tempo effect.

Conclusion

The discussion of tempo distortions is of wide interest because they can result in erroneous analysis and interpretation of past levels and trends in the quantum and tempo of life-cycle events. This in turn may result in inappropriate projections or the adoption of sub-optimal policies.

Our intent here is to clarify the terms “tempo effect” and “tempo distortion” and to identify the uses of quantum and tempo measures that in our view lead to distortions. We conclude that tempo effects are widespread in period measures. When the objective is to measure current conditions, as is usually the case, two views exist. In the classical approach, current event rates are assumed to reflect fully current conditions. We instead argue that current age-specific event rates do not in general reflect current conditions. When timing of demographic events shift rates schedules to higher or lower ages, constant conditions may imply changing rates. Age-specific rates fully describe conditions only when such shifts to higher or lower ages are absent.

When shifts to higher or lower ages are present, tempo distortions exist and need to be corrected, in order to get an accurate measurement of current conditions. These shifts are not limited to fertility. They may occur for nuptiality, mortality, and other events as well. We believe that our approach is a more realistic reflection of actual behavior in contemporary populations. Further research is needed to confirm this view.

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Figure 1: Density of events by period and cohort, constant tempo

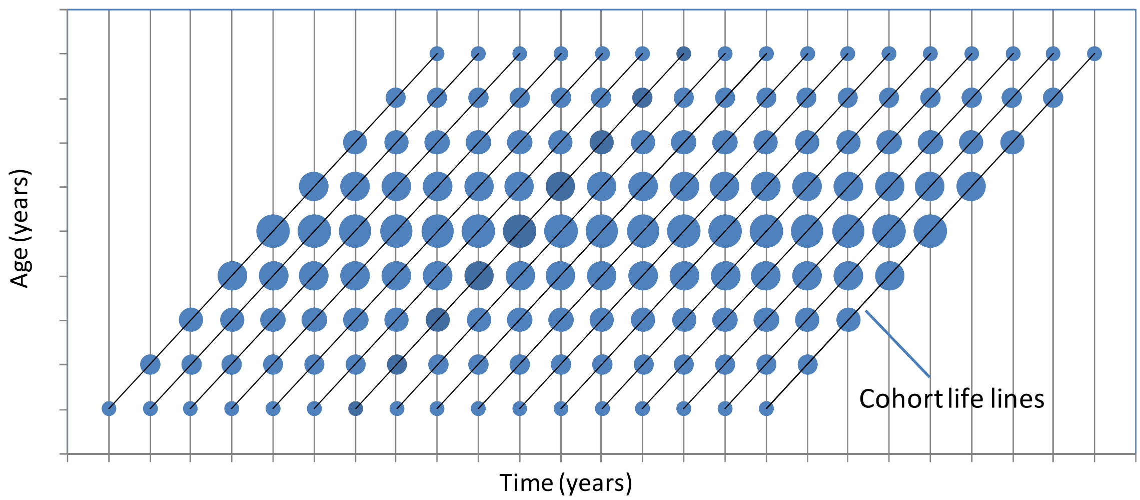

Figure 2: Density of events by period and cohort, increasing tempo