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Ready, willing and able
A conceptualization of transitions to new behavioral forms

R. Lesthaeghe and C. Vanderhoeft

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VRIJE UNIVERSITEIT BRUSSEL

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Interface Demography, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium
Tel: 32-2-629.20.40 Fax: 32-2-629.24.20 E-mail: esvbalck@vub.ac.be
Website: http://www.vub.ac.be/DEMO
Vakgroep Bevolkingswetenschappen, Universiteit Gent, Sint-Pietersnieuwstraat 49, B-9000 Gent, Belgium
Tel: 32-9-264.42.41 Fax: 32-9-264.42.94 E-mail: sandy.vanlaer@rug.ac.be
Website: http://allserv.rug.ac.be/~jlievens

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1. Introduction

In the present paper we shall try to present a simple mathematical model for describing the adaptation to new forms of behavior and for studying the subsequent generalization of these forms among populations. Such transitions obviously involve processes of innovation and diffusion. In this conceptualization we shall make use of three basic concepts that correspond to three preconditions for the adaptation to a new mode of behavior. These three preconditions are "*readiness*", "*willingness*" and "*ability*". This formulation is taken directly from A.J. Coale (1973), who grouped the preconditions for a fertility transition under these headings. To the best of our knowledge, this simple conceptualization has not received any further attention in the 25 years following its introduction.

The notion of "readiness" refers to the fact that the new forms of behavior must be advantageous to the actor; i.e. its utility must be evident and outweigh its disutility. As such, the condition of "readiness" refers to the micro-economic cost-benefit calculus that actors utilize in decision processes.

The notion of "willingness" refers to considerations of legitimacy and normative (ethical, religious...) acceptability of the new pattern of action. Such an evaluation occurs against the backdrop of internalized normative structures existing in societies at any point in time. The basic question addressed by "willingness" is to what extent new forms of behavior run counter to established traditional beliefs and codes of conduct, and to what extent there is a willingness to overcome moral objections and fears.

The adoption of new forms of behavior may also depend on the availability of new techniques. The notion of ability then refers to the accessibility of these innovations. Also, this access may have a cost which reduces "ability", even if it is merely psychological. Obviously this third precondition disappears when the issue of accessibility to new facilitating factors does not arise.

The conceptual model built around "ready, willing and able" (R,W,A for short) may have many applications in a variety of fields. In general, the R and W conditions arise in all matters that have both an economic and a moral dimension.

The use of the RWA preconditions has also the advantage of creating links between the various social science disciplines, and particularly between economics concentrating on the R-condition, and the other social sciences that pay more attention to normative and cultural aspects, i.e. to the W-condition. The present conceptualization is therefore also meant as an overarching framework for the integration of hitherto segregated "narratives" existing in the various social science disciplines (cf. van de Kaa, 1996; Burch, 1996; Lesthaeghe, 1997).

Finally, the model will also attempt to build bridges to the literature dealing with processes of diffusion or contagion and with social learning (self-initiated) and social influence (other-initiated) (cf. Montgomery and Casterline, 1996).

The structure of the paper is as follows. First we shall revisit the RWA preconditions and their use in various "narratives" of the fertility transition. After all, this was the empirical field were this general formulation was initiated. Then we shall present transitions as a function of changing distributions of R, W and A. Here we shall adopt three beta-distributions and define the outcome variable S as the minimum of the R, W and A-scores. If success (S) with respect to the adoption of a new form of behavior is dependent on meeting the three preconditions *jointly*, i.e.

$$S = R \cap W \cap A \qquad [1]$$

and if R, W and A are distributions on a zero to unity scale, then for an individual i:

$$S_i = \text{Min}\ (R_i, W_i, A_i) \qquad [2]$$

which means that the weakest link (the smallest of the three scores) will determine the outcome.

In the next section we shall link the shape of the beta-distributions to the Montgomery-Casterline formulation of social learning and social influence, thereby introducing outside influences in the decision process and degrees of heterogeneity within a population with respect to all three preconditions.

In the last section we return to a demographic application by relating the RWA-concepts to actual data taken from the DHS-surveys in African countries. The purpose here is to establish where the bottleneck conditions are located.

2. RWA and fertility transition narratives

As indicated in the introduction, the RWA preconditions were introduced in 1973 by A.J. Coale in an article that attempted to summarize the findings of the Princeton "European Fertility Transition"-project (EFT for short). Coale clearly meant that the onset and the speed of European fertility transitions was contingent on the *joint* meeting of the three preconditions, i.e. $S = R \cap W \cap A$. But just like in the "nature-nurture" debate in psychology, the findings of the EFT-project were quickly converted by others into a "culture *versus* economics" debate despite the fact that $R \cap W$ specifies a "culture *and* economics"-model. This misinterpretation continues till to-day. In this paper we consider the "economics versus culture" formulation as a dead end street (see R. Lesthaeghe, 1997) and we shall not devote any more time to it. Rather, we shall give a short overview of the "subnarratives" attached to R, W and A.

First, the R-precondition has been extensively discussed and conceptually modeled in the economic literature dealing with demographic outcome variables. All schools of thought in the micro-economics of the family give a great weight to the classic cost-benefit calculus. The starting point is simple: the essence of the model is the presumption that families would balance utilities against disutilities ascribed to the *n*th child to determine whether a family wanted this child (Liebenstein, 1957). The neo-classic formulation that followed introduced the assumptions of fixed preferences, maximizing behavior and equilibrium solutions. In 1960 G. Becker introduced the concept of a household production function. The demand for children depends on the utility (economic, social and psychological) of offspring to the parents and on the costs of children (i.e. costs of parental time, labor and external inputs). Caldwell's "wealth flow reversal" (1982) equally states that a fertility decline starts when the "wealth flow" over a life time from children to parents changes into a "wealth flow" in the opposite direction.

So far, and this holds for Easterlin's, Caldwell's and the early neo-classical versions, the parental decisions are solely based on the parental interests. The much older theory of "social capillarity", formulated by Arsène Dumont in 1880, introduced the welfare of the children themselves and altruistic behavior of parents in favor of the children's future well-being. In Dumont's conceptualization all individuals aspire to upward social mobility, but when the parents cannot achieve this for themselves, they project this ambition onto their children and invest in children's health and especially education. This is an early formulation of Becker's "dynastic multi-generational model" that introduces a preference shift in favor of "higher quality"-children. From this a "quantity-quality swap" is being derived. In Arsène Dumont's version, industrialization, urbanization, and economic growth opened up new opportunities for the incoming generations and higher real wages allowed parents to invest more in the education of a smaller set of children, thereby maximizing the social mobility chances of their offspring. It is clear that in this version bequests and investments are added to parental time, labor and external inputs.

In Easterlin's version extra attention is being paid to several other crucial factors. First, a corrective response can also be generated by an increase in the supply of children. Such an increase can stem from a variety of factors, such as declining infant and childhood mortality (increasing the supply of surviving children), reduced birth-spacing (decreasing length of breast-feeding and postpartum abstinence), increased fecundity, etc. Even with a constant demand for children, an increase in the supply would produce excess fertility and generate a corrective response in the other direction. Furthermore, Easterlin (1985) pays considerable attention to factors associated with the costs of fertility regulation, which, in our framework, fall under the "ability" precondition. He also emphasizes that the key variables are reflecting the subjective perceptions and not the objective costs and benefits.

The advantage of economic theories dealing with the R-condition has been their conceptual richness and the predilection for formal specifications. The disadvantages are related to the facts that (i) many concepts (child utility, child quality....) are multi-dimensional and therefore difficult to measure, (ii) that the nature of motivations is very difficult to extract from respondents, and (iii) that the calculation of a balance between costs and benefits is not easy for actors, let alone observers (cf. Burch, 1997; Robinson, 1997). The outcome is that we have a set of theories that explain conceptually why fertility control may be advantageous, but that we are still far removed from reliable and valid measurements of the key ingredients. Incidentally, the studies that tried to measure the key concepts pertaining to child utility in a direct way, rather than through rough proxies, were fielded by social psychologists rather than by economists. The "Value of Children Project" by Fawcett, Arnold and Bulatao (1972, 1975, 1979) is a prominent example of such attempts.

The W-condition, by contrast, has received far less attention than the R-condition. The main reason for this is that "willingness" is taken to follow immediately in the wake of "readiness". In other words, there is no moral dilemma or "cultural lag". This may be true in problems of firms adopting a new technology, but not in the field of fertility transitions. Much of the discussion of the W-condition in narratives of fertility transition stems from the Princeton EFT-project and is therefore linked to the concept of secularization, meaning the reduced credibility given to religious prescriptions. Also the measurement of secularization in European historical settings was facilitated by the fact that secularism was often an overt element of the political-ideological dimension of social organization. This permitted operationalizations through voting behavior or through adherence to religious practices (e.g. Lesthaeghe and Wilson, 1986; Livi-Bacci, 1977; Lesthaeghe, 1991; Le Bras and Todd, 1981). But, the fact that the degree of secularization was readily measurable only in Western Europe does not mean that the W-condition is irrelevant elsewhere. Clearly, the W-condition refers to a much broader set of issues than Western-style secularization in relation to Christianity.

Secular political mobilization (e.g. Nag, 1989) and growing female empowerment in developing countries (e.g. Mason, 1985), all in relation to fertility control and health, show the relevance of the W-condition. First, the W-condition deals with the *legitimacy* of interfering with nature or with a "natural order" as a cultural construction. Second, it deals with the belief in the *power* that individuals have to alter this "natural order", and hence W depends, inter alia, on dimensions such as fatalism. Third, the W-condition depends on the degree of *internalization* of traditional beliefs and codes of conduct. And fourth, W depends on the *severity of sanctions* (even imaginary ones such as those stemming from avenging spirits) attached to transgressions of normative prescriptions. Much of this is not only dependent on individual psychological dispositions, but equally on institutional agency and on what Delumeau describes as the "politics of culpabilization" (1983).

Occasionally sociological studies conducted in other than Western countries have attempted to operationalize such dimensions of "control over nature" or of "fatalism versus self-directed destiny" (e.g. Inkeless and Smith, 1974, is a classic in this field), but these batteries of questions have never found their way into the large scale demographic surveys (WFS, DHS etc.). Generally speaking, the broader context of the W-condition has remained inadequately documented in the areas of fertility or health transitions.

The A-condition has again received ample attention, predominantly in the family planning literature. In fact, the precursor of the World Fertility Survey (WFS) has been the series of KAP-surveys, dealing with the assessment of knowledge, attitudes and practice of contraception in developing countries. These studies were predominantly designed to show that there was a knowledge gap, i.e. it was essentially the lack of knowledge about contraception and the lack of accessibility to reliable contraception that formed the bottleneck. Others argued vividly that it was a lack of motivation which constituted the weakest link. Stronger still, if there was no "reversal of the wealth flow", family planning efforts would run against the interest of large segments of populations of developing nations. In short, we had a clear debate about the relative locations of the W and A-distributions. Also national politics in many countries got involved in both local and worldwide debates on the feasibility of promoting "ability", and the United Nations (World Population Conferences, UNFPA) assumed a leading role in promoting the legitimacy (W) and the accessibility (A) of family planning. More recently, academic interest in the issue of "ability" has taken the forms of studies in diffusion mechanisms and models (e.g. Rosero-Bixby and Casterline, 1993; Montgomery and Casterline, 1996). Several of these ideas will be used in this paper as well.

To sum up, the R and A-conditions for fertility transitions are extensively covered by the literature, but the W-precondition in Coale's formulation has been given much less attention. The various dimensions involved in cultural change in developing countries need to be given greater priority.

3. RWA-distributions and the weakest link model

In the following section we assume that the degree of fertility control (S) is an outcome variable with a continuous intensity ranging from 0 to 1. This outcome variable is, as in Coale's original verbal formulation, dependent on three preconditions, R, W and A, as shown in the Boolean expression:

$$S = R \cap W \cap A$$

i.e. all three conditions must be met jointly. However, for S to be a continuous variable, we must also assume that R, W and A are continuous and comprised between 0 and 1. In this new formulation a score of zero for R would mean that limiting fertility would have zero advantages and only entail disadvantages. A score of 0.5 would typify the situation where advantages and disadvantages are in perfect balance, and obviously a score of unity would mean that there are only advantages in adopting the new strategy. Similarly, a score of 0 on W means that fertility control is ethically or religiously totally unacceptable, a score of 0.5 identifies the point of undecidedness, and a score of unity implies that there are no moral or cultural obstructions to adopting the new form of behavior. Finally, a score of 0 on A means that the individual has no means whatsoever to control fertility, a score of 0.5 implies that there would only be ineffective traditional methods and a score of unity corresponds to complete ability to regulate fertility. An index of contraceptive use-efficiency would equally be appropriate. In this model one could convert these scores into a dichotomy (controller - no controller) if the score on the outcome variable is larger than a given cutting point, say 0.5. For each individual in a population a score is available on all three preconditions (R_i, W_i and A_i). In the weakest link model the outcome score for that individual, i.e. S_i, is the smallest value of the three R_i, W_i or A_i. Hence:

$$S_i = \text{Min}\,(R_i, W_i, A_i)$$

This means, for instance, that precondition A would be the bottleneck if A_i is the lowest score: the individual could be highly ready and willing, but has few means of controlling fertility (for instance: only abstinence).

This principle is readily generalizable to entire populations. In this instance we deal with three distributions for R, W and A respectively, and the weakest link rule gives the distributions of the outcome variable S as

$$S = \text{Min}\,(R, W, A)$$

These distributions need a particular shape. Here we have opted for a beta-distribution, because this distribution is contained between 0 and 1 and because it has the feature of bell-shaped distributions if its mean is 0.5 and if the variance is small. If the mean is lower than 0.5, the distribution is positively skewed, and if its larger than 0.5, the distribution is negatively skewed. On figure 1, we have produced three such beta-distributions, respectively with means = .1667 (var = .0106), .5 (var = .0357) and .7778 (var = .0173). The distribution to the left on figure 1 would show the population distribution at the onset of a R, W or A transition. The vast majority would see little economic advantage in controlling fertility, or would largely be unwilling or unable to do so. However, there would already be an upper tail of "innovators" for whom R, W or A would come closer to the 0.5 mark or even surpass it. Halfway during the transition of the three preconditions, the distribution would assume a classic bell-shape and half the population would be located beyond the 0.5 cutting point. Finally, near the end of the transition, only the lower tail of the skewed distribution would drag behind the majority of the population. Such a general movement of the distribution from left to right in figure 1 seems an attractive representation of a general transition since it does accommodate the features of "early initiators" and "late joiners".

As indicated, our problem consists of finding the distribution of the minimum of R_i, W_i and A_i. Assuming stochastic independence between the random variables R, W, and A (subscripts are dropped to simplify the notations), the distribution of $S = \min(R,W,A)$ can easily be obtained from the following probabilistic statement (which holds for any s between 0 and 1):

$$\begin{aligned}\Pr(S > s) &= \Pr((R > s) \cap (W > s) \cap (A > s)) \\ &= \Pr(S > s)\Pr(S > s)\Pr(S > s)\end{aligned}$$

which, in terms of the cumulative distribution functions of R, W and A, can also be written as:

$$1 - F_S(s) = (1 - F_R(s))(1 - F_W(s))(1 - F_A(s)).$$

Differentiating with respect to s gives the following expression for the probability density function (pdf) of S:

$$\begin{aligned}f_S(s) = \quad & f_R(s)(1 - F_W(s))(1 - F_A(s)) \\ & + f_W(s)(1 - F_R(s))(1 - F_A(s)) \\ & + f_A(s)(1 - F_R(s))(1 - F_W(s))\end{aligned}$$

Using the interpretation of a random variable's density in s as the probability that the random variable takes the value s, this formula becomes intuitively appealing and clear: the

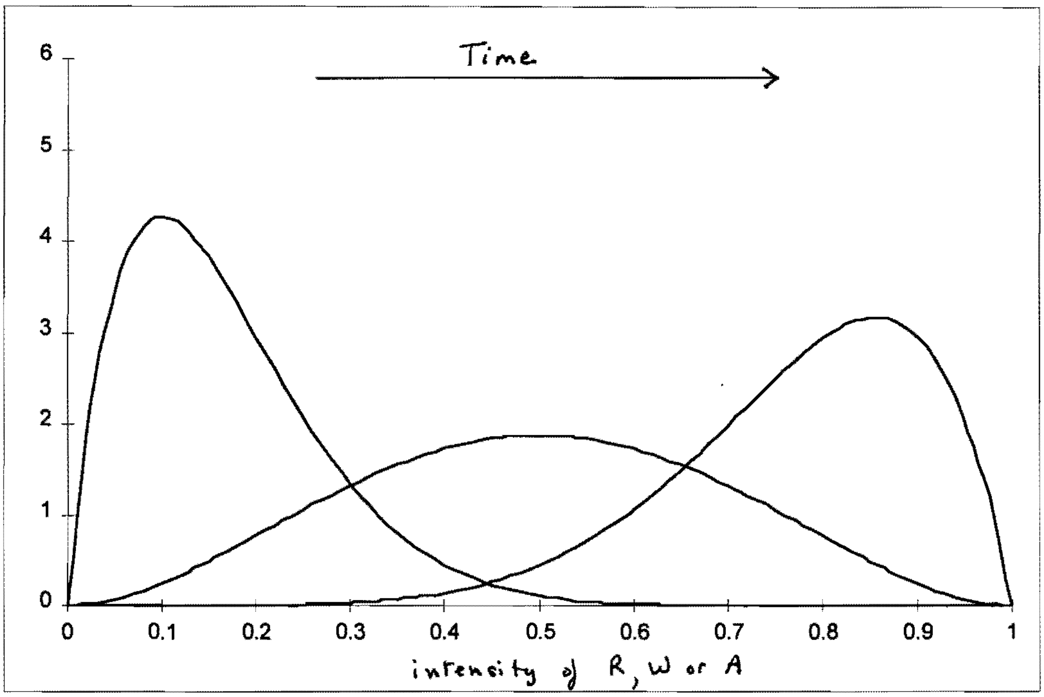


Figure 1

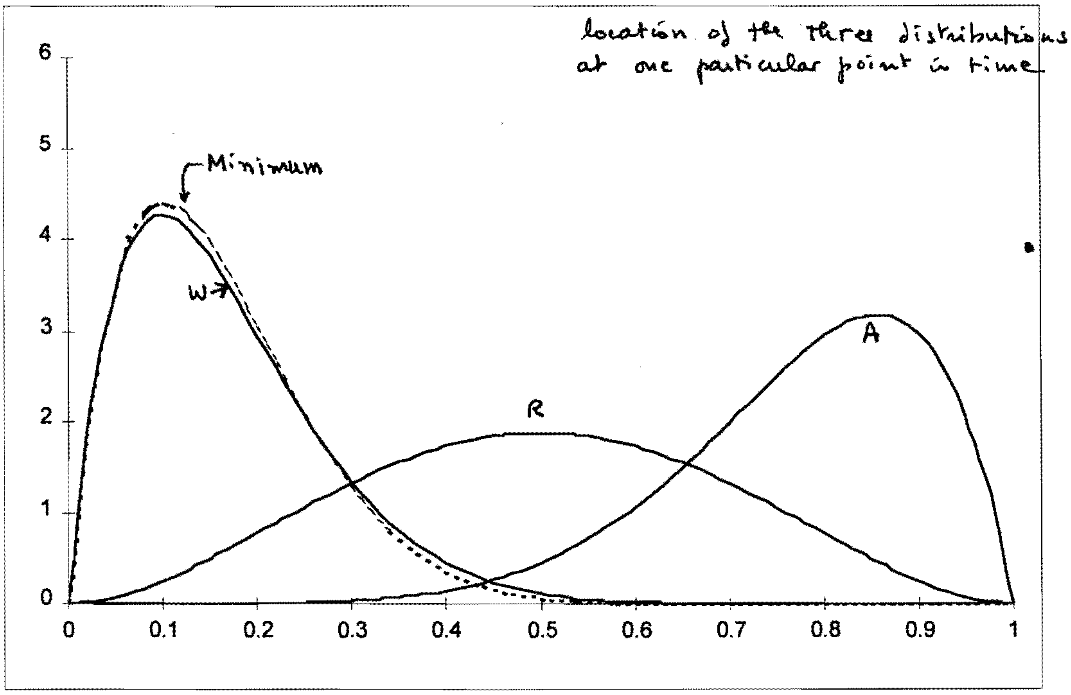


Figure 2

probability that the minimum S assumes the value s, is the probability that one of the three underlying variables assumes that value s, while the other two have at least that value s.

Moreover, if, for fixed s, both $1-F_W(s)$ and $1-F_A(s)$, for example, are large (i.e. close to 1), then $f_S(s)$ is close to $f_R(s)$. Thus, if two of the underlying random variables (e.g. W and A) are heavily right skewed, then the distribution of S is close to that of the third random variable (e.g. R).

We used the above formula to calculate and draw the pdf of S in figures 2 to 4, which will be discussed hereafter. Notice that, although R, W and A are assumed to be beta-distributed, S will generally not be beta-distributed. An explicit formula for the pdf of S, however, is not our concern here, and would not even be useful for our purposes, as it involves incomplete beta functions (which are to be evaluated by numerical integration).

This can also be understood intuitively. On figure 2 we have reproduced the same three beta-distributions as those of figure 1. Assume that the left hand distribution now represents the individuals' scores for one of the preconditions, say W, and that the other two are representing R and A. From the "weakest link" rule S = Min (R, W, A) it follows that the outcome for S would closely resemble the distribution of the weakest link, i.e. of W. In fact, an overwhelming majority of individuals have scores W_i that would be the lowest of the three, and only for a few persons, mostly located at the upper tail of W, one would find scores of R_i and A_i that could be smaller than their W_i. Hence, the distribution of S must always be slightly to the left of the distribution of the weakest link condition (here W). Hence, the upper tail of W will be pulled in, S would have a slightly higher peak than W, and consequently the mean of S must be smaller than the mean of W. Similarly, the variance of S will also be reduced compared to the variance of W. As expected, the calculation of the S-distribution (see dotted line on figure 2) shows exactly these features.

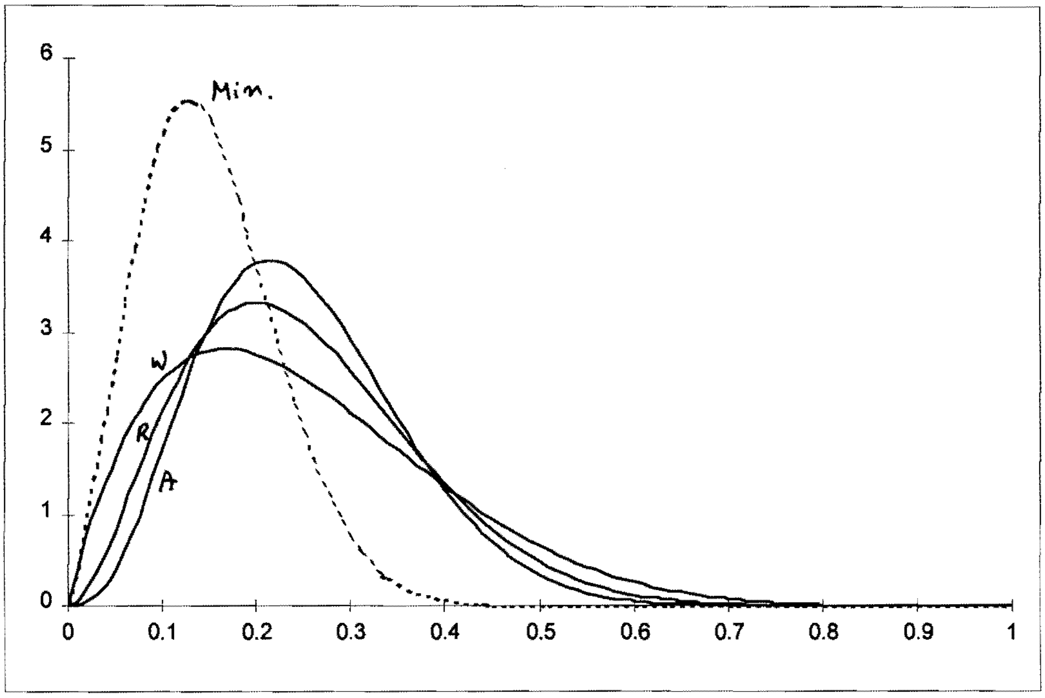


Figure 3

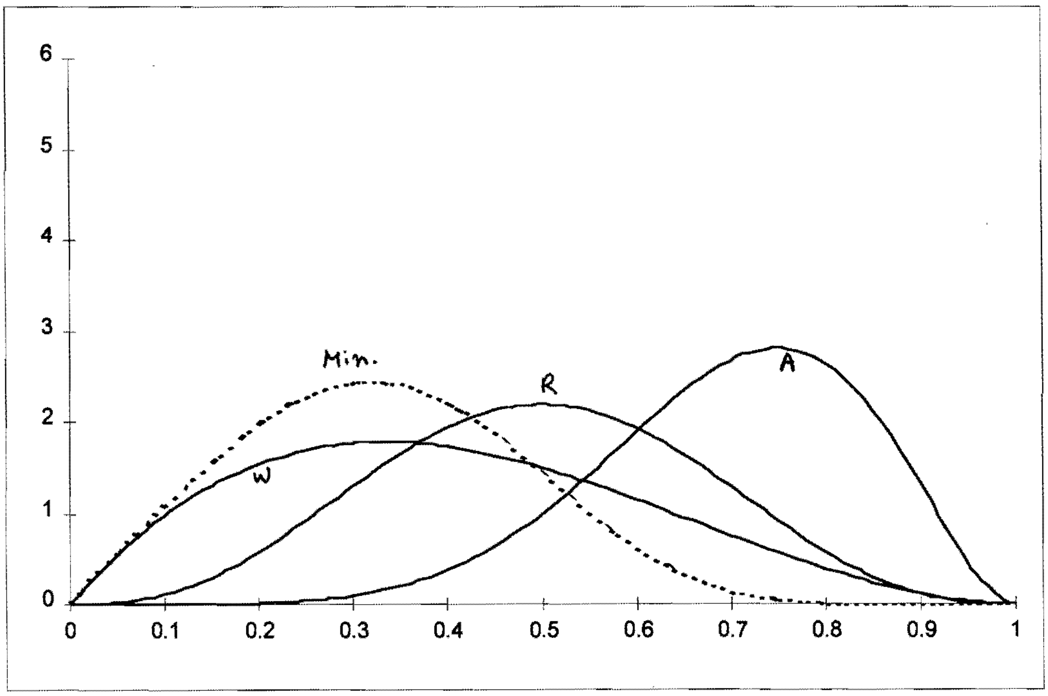


Figure 4

Two other examples will bring this out in a more striking way. On figure 3 we have plotted (full lines) three beta-distributions with the same mean (= 0.25) but a different variance (respectively .0208; .0144 and .0110). The distribution of their minimum (dotted line) has a mean of 0.14 only, and also a variance which is much smaller, i.e. .0052. This example furthermore illustrates that each of the three beta-distributions for R, W and A may have an upper tail (innovators) larger than the "indecision"-cutting point of 0.5, but that such an upper tail for the distribution of the minima would virtually be inexistant.

In the third example (figure 4) we present a situation in which the distributions have again different means (0.4, 0.5 and 0.7) and different variances (.04, .0278 and .0191). Suppose that we are dealing with a situation in which the vast majority of the population is already quite ready to control fertility (right hand distribution), that willingness is following in the wake of readiness (middle distribution), but that availability and accessibility to efficient contraception would be lagging (left hand distribution). In this instance, the distribution of the minima of scores (dotted line) would typically be situated further to the left than the distribution of the weakest link and a much smaller proportion would have S_i-scores greater than 0.5 than in any of the other three distributions. In this example the mean of the S-distribution is only 0.33 and the variance is again smaller than that of the weakest link distribution (.022 compared to .04). (In the next section we shall see that figure 4 very closely resembles the situation found in Niger)

This section has illustrated the rules of the game. We shall now take up the issue of diffusion and shifting distributions.

4. The meaning of the RWA-model for social learning and social influence

Montgomery and Casterline have recently presented (1996) a simple formulation of the impact of social environment factors. They assume that an outcome variable Y at time t would be a function of two components: first, a set of individual characteristics $X_{i,t}$ and second , a weighted set of social influences Z_{t-1}.

This equation is as follows:

$$Y_{i,t} = \beta X_{i,t} + \delta_i \sum_{j \in N} \omega_{i,j} Z_{j,t-1} + E_{i,t}$$

The greek letters identify coefficients and roman capitals are variables. The social influence component is made up as follows: $Z_{j,t-1}$ is the opinion or behavior of another individual j observed by the actor i at an earlier point in time, given that individual j belongs to the network N of individual i. The latter will give a weight $\omega_{i,j}$ to the influence of j, and will furthermore do so for all other members of his network. The coefficients $\omega_{i,j}$ illustrates which network co-members will be more or less influential. To this package of outside influences, individual i will also give a general "influence" or "credibility"-weight in the form of coefficient δ_i. This coefficient will be high for an impressionable learner or quick follower and low for someone with a conservative "mindscape". Finally, E is a vector of residuals.

Obviously one can include a variety of actors into the relevant network. The subscript j can stand for husbands, kin, friends etc., but also for institutional influences operating via media, religious groups, political parties etc. This distinction is a crucial one since the underlying models of diffusion are distinct. If information, and more crucially, messages about intentions (cf. Kohler, 1977) stem from individuals in the actor's own primary group environment (kin, close friends), the growth curve of adoption of new behavior is likely to follow a logistic S-curve. In other words, it may take some time before adoptive behavior reaches momentum. This feature is obviously caused by the fact that the adoption has to start from a restricted group of early innovators who can only reach their immediate environment. By contrast, messages initiated by the mass media through mobilization immediately reach a broad audience, so that the rate of increase of adoptive behavior is likely to reach a maximum right from the onset. (cf. Lave and March, 1975, chapter 7). However, diffusion via individual contact may be less ephemeral and more convincing than that via media, so that the ultimate proportions in a population who alter behavior can be higher.

One can also make a distinction, as Montgomery and Casterline have done, between social learning which is actor-initiated or social influence which is initiated by others. In the case of institutional actors one would then refer to processes of "mobilization" or "propagation". In the European historical experience, we know that such institutional actors played a significant role in the process of fostering or obstructing secularism in the various regions, and that this had a non-redundant extra effect on the pace of the marital fertility decline. The same can be said for contemporaneous countries with a strong propagation, if not a coercive form of family limitation. Furthermore, we know that people are willing to listen to those in their immediate, trusted environment, but that such interaction density circles are not completely impermeable. Permeability across social classes for instance often results in a "trickle down" effect with the behavior or attitudes of the lower classes following those of the higher ones (cultural mobility, reference group behavior, bandwagon effects).

In the model of three preconditions, we need to specify the Montgomery-Casterline expression not just for social learning and social influence with respect to family planning (i.e. ability) alone, but for *all three* preconditions:

$$R_{i,t} = \beta X^{R}_{i,t} + \delta_i \sum \omega_{i,j} Z^{R}_{j,t-1} + E_R$$

$$W_{i,t} = \beta' X^{W}_{i,t} + \delta'_i \sum \omega_{i,j} Z^{W}_{j,t-1} + E_W$$

$$A_{i,t} = \beta^* X^{A}_{i,t} + \delta^*_i \sum \omega_{i,j} Z^{A}_{j,t-1} + E_A$$

With this specification, a number of new features emerge.

(i) R, W and A are likely to be correlated. This is so because the sets of individual attributes relevant for R, W and A respectively (i.e. X^R, X^W and X^A) are overlapping. Education, urban residence, income etc. are indeed likely to have an impact, be it each time with a different coefficient, on R, W and A. Furthermore, the same holds for the impact of the social environment, since people largely maintain a fairly well circumscribed social network.

(ii) In this social network, the messages tend to have some consistency. This may be particularly true for institutional agents who propagate a coherent "total attitude". If they favor family planning, they will also propagate the economic advantages of a smaller family and send out ethical messages about responsibility, foresight, etc. This means that action on A, for instance, will also have an impact on R and on W. The mere fact of showing that family planning is safe, also alters one's views on nature, self-directedness, secular values etc.

(iii) The correlations between R, W and A can vary substantially across contexts (countries, neighborhoods, social groups ...) and the assumption of complete endogeneity of W is not likely to hold. For instance, counterpropagation or gossip about the physical effects or comfort of contraception can reduce willingness considerably, even if R and A would be high. Hence, the chain model $R \rightarrow W \rightarrow A$ needs not be general either. In a good family planning message the chain is reversed: $A \rightarrow W \rightarrow R$.

(iv) The empirical task therefore consists of locating members of a population along a RWA-classification, from all three conditions being met (RWA) to none being met (rwa). This yields information about the bottleneck conditions (see next section) and about the factors that are responsible for it (see equations above).

(v) The three equations simultaneously determine the outcome $S_{t,i}$ via the weakest link rule, and hence all too exclusive stress on A could result in one of the other two distributions lagging behind. Examples of negative effects of A on R and W are the cases of coercive or poor quality family planning programs. Actually, W and R can be adversely affected at a considerable speed through the network part in the Montgomery-Casterline equations.

(vi) The Montgomery-Casterline equation may also inform us about the variance of the R, W and A distributions as related to the rapidity of shifts in their means. In the beta-distributions that we have proposed, a small group of "innovators" is capable of pulling the rest of the population with them. This assumes permeability between social networks in an area. The greater the degree of permeability, the smaller the variance can be expected to be as the mean moves to the right. However, impermeable and distinct networks are likely to be formed on the principle that the like-minded also assemble. In such instances the overall variance is likely to remain substantial. If this holds for the weakest condition, this lower tail will pull the distribution of S towards the left and the transition of S will be slowed down. If one has reasons to believe that a society has important social cleavages that cause impermeability, messages about R, W and A need to be tailor-made as to suit each of these segregated networks.

The bottom line from this discussion is that the sole application of social learning and social influence models to the factors affecting the ability condition may lead to lopsided policy inputs. If the two other conditions, and predominantly the W-condition is overlooked, the final S-distribution may show a surprising lag as a result of the weakest link rule.

5. RWA as seen through the African DHS-surveys

A conceptual model should also derive some credibility from an application. In this section we shall try to locate the proportions of women of reproductive age in African countries in eight categories, ranging from obviously ready, willing and able (RWA) to none of these three (rwa). In this application the conditions are seen as discrete, i.e. satisfied or not, and this will be denoted by upper case or lower case letters. The following eight categories can obviously be established:

1. R W A
2. R W a
3. R w A
4. R w a
5. r W A
6. r W a
7. r w A
8. r w a

We shall apply this classification to all women who are currently married, fecund and exposed to risk of becoming pregnant (i.e. excluding those who are amenorrheic, or already pregnant). Among such women, those who are current users of contraception plainly fall in category 1, i.e. RWA. The others are non-users and they must be distributed over the remaining seven slots. Those among them who are non-users in order to conceive ("want another child soon") are obviously members of categories 5 through 8, and have the attribute r, meaning not ready to delay the next pregnancy. Those non-users who want to delay the next birth or to avoid it altogether are ready to control, but do not do so, either because they are not willing and/or not able. They must therefore belong to categories 2, 3 or 4.

The three-way classification can now be abbreviated as follows:

*RWA: current users

* r..: non-users who want their next pregnancy soon

*R-RWA: all other non-users who want to delay the next pregnancy (2+ years) or avoid it altogether (i.e. RWa + RwA + Rwa).

Such a three-way classification can be obtained from the African DHS-surveys for all currently married, fecund and exposed women, and the results are presented in table 1. Before going into the details of this table, we shall first establish a link with the theoretical distributions presented in figure 4.

Suppose that the beta distributions of figure 4 would represent, from left to right, the distributions of willingness (mean = 0.4), readiness (mean = 0.5) and ability (mean = 0.7). Assume, furthermore, that we use a cutting point value of 0.5 for dichotomizing these distributions. The proportions in each of the eight discrete categories are then:

RWA:	0.142	rWA:	0.142
RWa:	0.014	rWa:	0.014
RwA:	0.313	rwA:	0.313
Rwa:	0.031	rwa:	0.031
R..:	0.500	r..:	0.500

Given that the mean for readiness in this example has been set at 0.5, the population would obviously be split equally over the R.. and r.. slots. Furthermore, since willingness is defined as the weakest link, each of these halves must contain much smaller proportions satisfying W than A. Using the three-way classification adopted in table 1 for real population, the above example corresponding to figure 4 would yield the following outcomes:

RWA: 0.142

r..: 0.500

R-RWA: 0.358

This can be compared to the values observed for Niger 1992 (see table 1):

RWA: 0.140

r..: 0.520

R-RWA: 0.340

Hence, figure 4 can be taken as a fairly close representation of the Niger situation. Roughly half the population of married, fecund and exposed women would not be ready to postpone or avoid the next pregnancy (r = 0.520) at any rate, and of the other half, more than two thirds (R-RWA = 0.340) would either be unwilling, unable or both. The bottleneck condition is, furthermore, especially a lack of willingness (left hand distribution on figure 4), and hence we would expect that ethical or religious objections, health fears and beliefs, or social pressure from others would be the key factors in pulling the S-curve for Niger to the left, thereby preventing a contraceptive breakthrough.

In their study of "unmet need", Westoff and Bankole (1995) present a table (nr. 4.1, p. 5) which allows us to establish this first three-way division for many other African countries. Those classified as RwA, RWa or Rwa in this paper differ from the Westoff-Bankole women with "unmet need" in a number of ways. First, our denominator only contains exposed women, whereas theirs also includes currently pregnant or amenorrheic women. Second, our numerator only contains the non-users with a desire to postpone or avoid the *next* pregnancy, whereas theirs also uses the non-exposed women who report a mistimed or unwanted *previous* birth. The classification we adopt has the advantage of concentrating exclusively on the next birth (which we need conceptually to assess R or r), but it has the disadvantage of excluding substantial numbers of women who are pregnant or amenorrheic. Information on their future intentions rather than past experience would have helped. The proportions that we derive for Rwa + RWa + RwA are often larger than the figures derived by Westoff and Bankole for "unmet need", not only because of the smaller denominators used in our computation, but also because we suspect that the number of mistimed or unwanted last or current pregnancies is likely to be underreported in African populations. In other words, we suspect that Westoff-Bankole "unmet need" is underestimated (which, in fact, makes their argument for countries with large unmet need even more powerful). The other distinction is that Westoff and Bankole imply, by virtue of the label "unmet need" (we assume: need for family planning), that the bottleneck condition is non-ability (a). In our conceptualization, the bottleneck can equally be non-willingness (w) or non-willingness and non-ability jointly (wa).

Finally, a short note on the calculations is required. The results in table 1 stem from the Westoff-Bankole table 4.1 for all DHS-surveys prior to 1994. The percentages

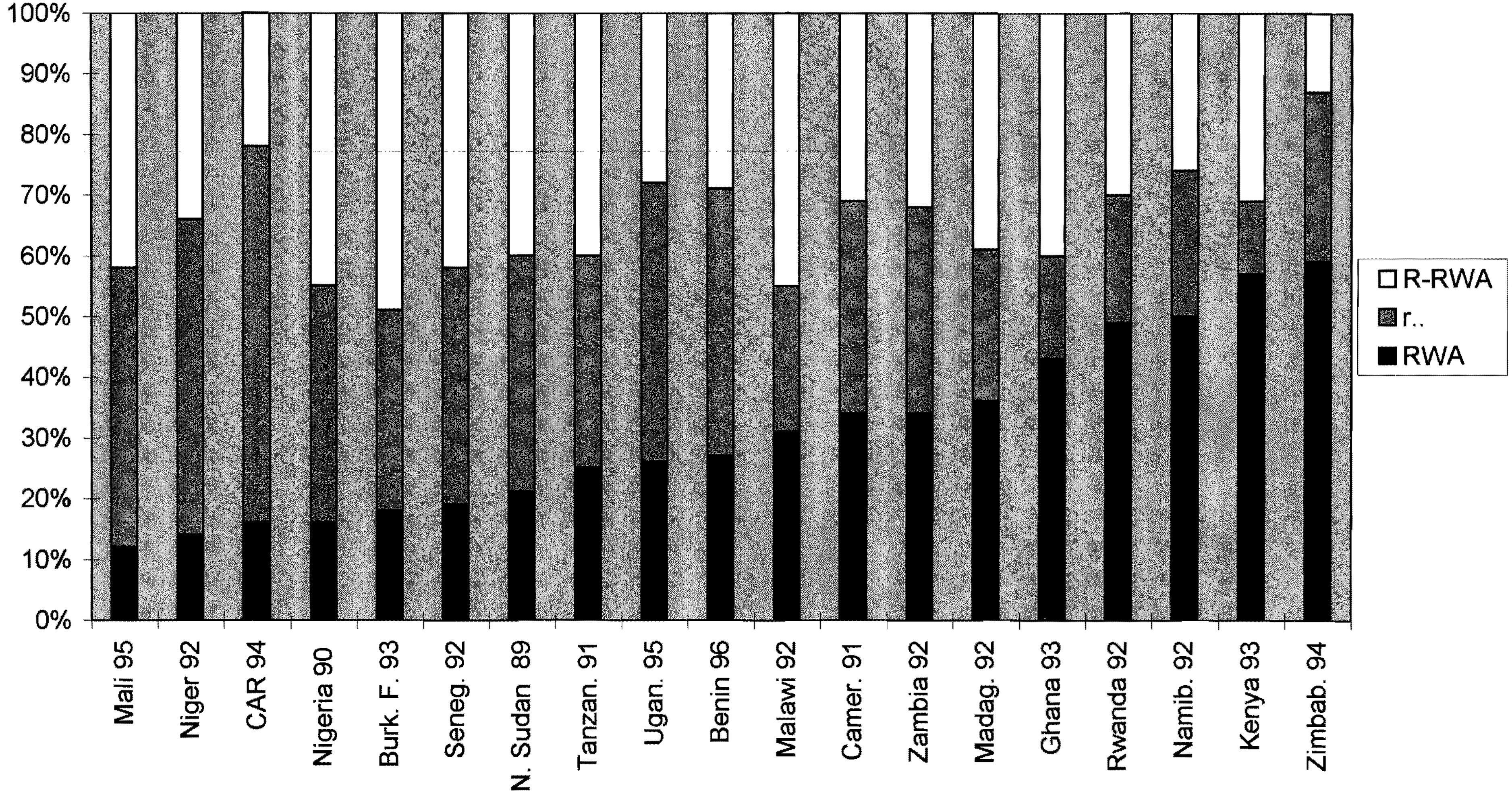
Table 1: Distribution of currently married, fecond and exposed women according to their planning status of the next birth; African DHS surveys.

DHS-country and date	N of women	Non-users (proportion)		Users (proportion) RWA
		Pregnancy wanted r..	Next pregnancy to be delayed (2+ years) or no more wanted R-RWA	
CAR 94-95	2306	.62	.22	.16
Niger 92	1840	.52	.34	.14
Mali 95_96	4160	.46	.42	.12
Uganda 95	2382	.46	.28	.26
Benin 96	2041	.44	.29	.27
Nigeria 90	2478	.39	.45	.16
Senegal 92-93	1722	.39	..42	.19
N. Sudan 89-90	2187	.39	.40	.21
Tanzania 91-92	2543	.35	.40	.25
Cameroon 91	1337	.35	.31	.34
Zambia 92	2006	.34	.32	.34
Burkina F. 93	2338	.33	.49	.18
Zimbabwe 94	2331	.28	.13	.59
Madagascar 92	1727	.25	.39	.36
Malawi 92	1471	.24	.45	.31
Namibia 92	1308	.24	.26	.50
Rwanda 92	1627	.21	.30	.49
Ghana 93	1502	.16	.41	.43
Morocco 92	3129	.14	.20	.66
Kenya 93	2657	.12	.31	.57
Egypt 92	6370	.11	.21	.68

<u>Source</u>: before 1994: computed from Westoff & Bankole (1995) table 4.1 p. 5; 1994-96: computed from special output prepared by Macro International, personal communication Dr. M. Vaessen.

<u>Note</u>: exposed = not amenorrheic or pregnant; also women reporting not having sex, infrequent sex, menopausal/hysterectomy, subfecund & infecund, in pp. Abstinence are eliminated from N.

Fig 5 - Distribution of curr. married fecond & exposed women (%) according to planning status of next pregnancy - African DHS.



were recalculated by eliminating the infecund women and the pregnant or amenorrhoeic women from the N's used in Westoff and Bankole table. For DHS-surveys with dates 1994 or later, the results were obtained from special tabulations provided by Macro International starting from the raw data tapes. In these tables, although produced for fecond, married and exposed women, a number of respondents still give reasons for not using contraception pertaining to not being married, having no or infrequent sex, being infecund or subfecund, or having reached menopause. These women were also eliminated from the analysis.

We can now turn to table 1 itself or to the graphical representation in figure 5. Also the outcomes for Morocco and Egypt were added to table 1 for comparison. In our logic we start with a first dichotomy pertaining to readiness, i.e. to r.. or R... Two countries have more than half the population of married, fecond and exposed women who are not ready to postpone or avoid the next pregnancy (r..): Niger and the CAR; and another three have proportions for r.. in excess of 40%: Mali, Uganda and Benin (see column 2). However, Uganda and Benin must have distributions of W and A that have shifted further to the right than in the other three countries, since their values of RWA are already larger than 0.25.

The next group of countries has values for r.. comprised between 30 and 39%, indicating that a larger part of the R-distribution has moved to the right. This group contains Senegal, Nigeria, Burkina Faso, Northern Sudan, Cameroon, Tanzania and Zambia. But, in addition, Cameroon and Zambia have significantly higher proportions in RWA, meaning that they must have more favourable locations of the W and A-distributions as well.

In the third group of countries, the subpopulation with r.. is already smaller than 30%; and some, such as Ghana and Kenya, have proportions lower than 20%, which is already typical for Northern Africa. Yet, in this group, the A or W-distributions seem to act as a stronger brake in Malawi or Madagascar, since proportions in RWA are still below 40%. To a lesser extent, this also holds for Ghana, especially when compared to Kenya, Rwanda, Namibia and Zimbabwe with proportions in RWA close to or in excess of 50%.

The analysis conducted so far illustrates that the planning status of the next birth sheds already some light on the approximate locations of the R, W and A distributions. The three-way classification can, however, be refined a bit further for women falling in the

R-RWA category (column 3 in table 1) since more information is available that helps clarifying the respective roles of W and A.

The DHS-surveys of the late 1980s probed for reasons for not using contraception among married, fecund and exposed women who also stated that they would "be unhappy to have the next pregnancy soon" or for whom "such a pregnancy would cause problems". The results are also published in the DHS-country reports for these years (chapters 4). Among the answers, some categories are indicative of in- or subfecundity or non-exposure, and we have eliminated such respondents from our analysis. The recalculated percentages are reproduced in table 2.

The DHS-country reports for the 1990s either do not have such tables or do not publish them for married, fecund and exposed women. However, Macro International could produce tabulations at our request for five surveys between 1994 and 1996 that satisfy our needs. Again, women who want to postpone the next pregnancy (2+ years) but were not using contraception for reasons of infecundity or non-exposure were eliminated. These results for the later five surveys should be comparable to those published for the late 1980s, and they are reproduced in table 3.

In both tables we have regrouped the response categories in two large classes. First, the reasons for not using contraception, despite a manifest need for postponing or altogether avoiding a next pregnancy, pertaining to a lack of knowledge about methods of contraception, to a lack of knowledge about FP-services, difficulty of access to FP or pertaining to costs are grouped in the category "non ability" (i.e. condition a). Reasons related to personal opposition to FP, to opposition from others, to religious objections, related to fatalistic attitudes or to fears for health are regrouped in the category "non willingness" (i.e. condition w). Only one response item could be specified, so that no information is available for the proportion satisfying both conditions, i.e. aw. Finally, in some countries the frequencies for "other reasons" without further specification and/or the non-response are fairly high – sometimes in excess of 30% - so that extra caution is needed in interpreting the outcomes.

The first question that can be addressed with this additional information is whether, for those in R-RWA, the dominant bottleneck is either a or w. A ratio a/w is therefore calculated in tables 2 and 3. In the late 1980s the a/w ratio is larger than unity in all but three countries. The first of these is Senegal, but this is unfortunately a case with more than 30% of unspecified or missing answers. The other two are Zimbabwe (a/w = .77) and Botswana (.37), which are countries with high proportions in RWA and low proportions in R-RWA. By 1994 the a/w-ratio for Zimbabwe (see table 2) further declines to 0.10 only, and also in Mali, the ratio diminishes from 1.72 in 1987 to 1.10 in 1995-96. This suggests that a/w-ratios decline when proportions users (RWA) increase. In such circumstances, the bottleneck condition at the onset would be primarily the A-distribution, which is logical for most of sub-Saharan Africa given the lower knowledge levels and the much weaker FP organization during the 1980s. But, when overall need for contraception increases over time, i.e. when the R-distribution shifts to the right, it is increasingly the W-distribution rather than the A-distribution which becomes the weakest link. Hence, one can expect for the future that the reasons for not using contraception among those with a spacing or stopping need will increasingly be associated with non-willingness rather than non-ability, as was already the case in Botswana and Zimbabwe in the 1980s. This does not imply that the W-distribution remains static – in fact, it too shifts to the right – but that in the course of the transition the distributions for R and A are moving faster. At this later stage, despite greater willingness than before, willingness becomes the bottleneck condition.

Finally, tables 2 and 3 also lend more support to the hypothesis that reasons for non-willingness may be increasingly associated with health fears (bad for health, side-effects, inconvenient to use) rather than with social opposition to fertility control in general. The items concerning health fears already had the highest frequencies in the 1980s in Togo, Ghana, Liberia, Kenya, Zimbabwe and Botswana (table 2) and in the 1990s in Mali, Uganda and Zimbabwe (table 3). Moreover, these items were more frequently cited in the 1990s than in the late 1980s in the three countries for which we have two observations: an increase in Mali from 4.6 to 21.8%, in Uganda from 10.5 to 21.3% and in Zimbabwe from 20.2 to 47.1%.

Admittedly, the evidence from tables 2 and 3 is not yet conclusive and needs to be checked out for more countries with at least two observations tabulated for the R-RWA subpopulations. But, it does at least advance two new hypotheses:

Table 2: Breakdown of reasons for not using contraception among fecond and exposed women who want to delay or avoid the next pregnancy (condition R), but who are also non-users (conditions a, w or aw); various DHS sub-Saharan countries in the late 1980s

	Mali 1987	Senegal 1986	Togo 1988	Liberia 1986	Ghana 1988	Burundi 1987	Uganda 88-89	Kenya 1989	Zimbabwe 1988	Botswana 1988
A. Bottleneck = non-ability (a)	N=835	264	610	331	786	486	1388	1818	400	697
- Lack of information	48.3	30.3	38.9	11.8	32.1	39.7	37.6	25.8	8.0	6.5
- Access difficult	2.3	1.1	2.6	12.7	2.5	3.3	9.9	13.9	23.2	0.1
- Too expensive	na	na	4.4	15.1	2.8	2.3	1.8	2.2	4.5	12.9
	50.6	31.4	45.9	39.6	37.4	45.3	49.3	41.9	35.7	19.5
B. Bottleneck = non-willingness (w)										
- Religion opposed	10.1	20.4	5.4	2.7	4.4	1.0	22.0	5.7	5.8	1.4
- Others opposed, social control	2.0	na	na	na	0.9	0.2	0.6	0.9	1.2	3.9
- Husband opposed	12.7	8.0	na	9.4	5.1	4.3	4.3	11.2	11.3	8.0
- Opposition to Family Planning	na	na	14.3	6.3	4.8	4.8	5.5	4.2	6.2	18.2
- Fatalistic	na	na	na	na	0.6	3.3	0.9	1.4	1.8	0.9
- Inconvenient, bad for health	4.6	8.0	15.7	20.8	15.0	4.3	10.5	11.4	20.3	20.2
	29.4	36.4	35.4	39.2	30.8	17.9	43.8	34.8	46.6	52.6
ratio a/w	1.72	.86	1.30	1.01	1.21	2.53	1.13	1.20	.77	.37
C. Bottleneck: not specified										
- Other reason	15.0	21.6	17.9	21.1	17.6	28.3	5.8	16.0	13.8	3.7
- Don't know	4.8	10.6	na	na	13.4	8.2	na	6.2	3.5	23.0
- No answer	0.2	na	0.8	na	0.8	0.2	0.9	1.0	0.5	1.1
	20.0	32.2	18.7	21.1	31.8	36.7	6.7	23.2	17.8	27.8

Excluded from the calculations are: breastfeeding or amenorrhoeic women, women with "infrequent sex", and for Togo, Senegal and Mali also women who want a birth soon (in the other countries, such women were already eliminated from the published analysis)
na = response category not used in published table
Source: DHS individual country report, chapter 4

Tabel 3: Breakdown of reasons for not currently using contraception among fecond and exposed married women who have indicated that they want to postpone (2+ years) or avoid the next pregnancy (R); selected DHS-countries in the 1990s.

	Mali '95-96	**Benin '96**	**Centr. Afr. Rep.'94-95**	**Uganda '95**	**Zimbabwe '94**
A. Non-ability (a)					
- lack of information	42.5	47.4	36.1	41.2	3.7
- Access difficult	0.6	0.4	0.3	2.2	3.9
- Too expensive	1.0	3.0	0.4	4.0	1.3
Total a	44.0	50.8	36.8	47.4	8.9
B. Non willingness (w)					
- Religion opposed	2.6	3.3	5.4	2.9	10.6
- Husband opposed	4.8	4.8	6.4	13.9	12.4
- Others opposed	0.2	0.2	0.2	0.2	0.7
- Opposition to FP	10.8	18.1	10.6	4.2	14.3
- Health fears	19.2	14.5	8.1	19.9	45.5
- Inconvenient to use	2.6	0.8	Na	1.4	1.6
Total w	40.2	41.7	30.7	42.5	85.1
C. Not-specified					
- Other reasons	2.2	4.5	6.0	8.2	3.3
- Don't know	13.5	3.0	1.4	1.8	2.6
- No answer	Na	Na	25.2	Na	Na
Total unspecified	15.7	7.5	32.6	10.0	5.9
a/w ratio	1.10	1.22	1.20	1.12	0.10

Source : DHS data files – personal communication Dr. M. Vaessen, Macro International

i) The take-over hypothesis: as the three distributions for R, W and A shift to the right, the A-distribution is likely to move faster than the W-distribution, leading to a situation in which increasing willingness still becomes the bottleneck condition.

ii) The shifting objections hypothesis: as the W-distribution moves to the right, non-willingness becomes increasingly associated with beliefs about the health impact of contraception and less with general ethical, religious or social opposition.

Nevertheless, country specific features associated with differences in culture, social organization and FP-program implementation are likely to exert their influence as well.

6. Conclusions

The reintroduction of the triple concepts of readiness R, willingness W and ability A in social demography has a set of advantages:

i) It allows us to integrate economic and non-economic paradigms of transitions to new forms of behavior, which is a crucial requirement for the study of fertility transitions in particular.

ii) It avoids dead end streets such as the "economics versus culture" debate.

iii) It sharpens awareness of the fact that transitions can take many forms depending on the shapes of the R, W and A distributions and the speed at which they move.

The model presented here hinges on the *weakest link principle*, i.e. it is the minimum of either R, W or A which determines the final speed of the adoption of fertility regulation (either for spacing or stopping). Such a bottleneck model elucidates the role of leads and lags and recognizes that, during the course of a transition, different factors may be responsible for slower change or for barrier effects in diffusion. With respect to the latter effects, models should not only be constructed with respect to diffusion of contraceptive knowledge and availability (i.e. ability) but equally pay attention to the diffusion of readiness or perceptions of economic advantage and of willingness or perceptions of cultural, social and psychological obstacles.

The R,W,A-model furthermore allows for the *detection of bottleneck conditions*. The application to the data from African DHS-surveys illustrates that a simple three-way classification of the fecund and exposed population according to the planning status of the next pregnancy can already shed light on the approximate locations of the R, W and A-distributions in each of the countries concerned. As such, the application is a variant of the "unmet need"-concept, but it fully recognizes that such "unmet needs" can be also associated with a lack of willingness, and not solely with a lack of ability. The heterogeneity of the sub-Saharan populations with respect to the planning status of the next birth (i.e. the distribution over the categories r.., R-RWA and RWA) testifies to this effect. This heterogeneity indicates that factors associated with low readiness and ability tend to be responsible for the bottleneck at the onset but that the willingness condition is likely to become the weakest link at a later stage. In other words, as the distributions of R, W and A move to the right, the shift in the W-distribution may be slower than that of the other two. In such circumstances policies become necessary that confront cultural, social and psychological barriers to the use of contraception, in addition to policies that further facilitate access to FP. Finally, a closer inspection of the reasons given for not using contraception among fecund and exposed women who manifestly want to delay or avoid their next pregnancy (i.e. those in the R-RWA category) reveals that a shift may be occurring in the nature of non-willingness. More specifically, as the distribution of W also shifts to the right, the remaining obstacles seem to be increasingly associated with health-related fears rather than with more general ethical, religious or social objections. This equally implies that public messages related to FP should be increasingly attentive to such fears, particularly in countries that have to pull in the tail of "late joiners".

Further research starting from Coale's three preconditions can easily be imagined. First, locations and shapes of beta-distributions for the R, W and A conditions can easily be constructed, and the location of S determined. As was done for the case of Niger, the actual proportions in the categories RWA, r.., R-RWA can be obtained from the DHS data and these can be compared to a set of model situations to infer the approximate locations of R, W and A distributions. Second, the DHS data on reasons for not using contraception among the R-RWA subpopulation of fecund and exposed women should be produced systematically and in a comparable fashion. In order to estimate Rwa, the questionnaire should also allow for the specification of multiple reasons rather than just one. The breakdown of the fecund and exposed female population in the categories r.., RWA, RwA, RWa and Rwa would further facilitate the estimation of the location of the R, W and A distribution in each country and their subgroups, thereby shedding more light on the prevailing weakest link at various points in time.

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References

Becker, G. (1960): "An economic analysis of fertility" in: National Bureau of Economic Research: Demographic and economic changes in developed countries, Princeton.

Becker, G. (1981): A treatise on the family, Harvard University Press, Cambridge Mass.

Bulatao, R. (1979): On the nature of the transition in the value of children, East-West Center, EWPI-paper 60-A, Honolulu.

Burch, T.K. (1996): "Icons, straw men and precision: reflections on demographic theories and fertility decline", The Sociological Quarterly, 37 (1): 59-81.

Burch, T.K. (1997): "Fertility decline: toward a synthetic model", paper for the International Conference on Computer Simulation and the Social Sciences, Cortona, Sept. '97, mimeo.

Caldwell, J.C. (1982): Theory of fertility decline, Academic Press, New York.

Coale, A.J. (1973): "The demographic transition reconsidered", IUSSP – Proceedings of the International Population Conference, Liège: Eds. Ordina.

Delumeau, J. (1983): Le péché et la peur – La culpabilisation en Occident, Fayard, Paris.

Dumont, A. (1880): Dépopulation et civilisation – Etude démographique, Eds Lecrosnier et Babé, Paris.

Easterlin, R. (1976): "The conflict between aspirations and resources", Population and Development Review 2(3): 417-426.

Easterlin, R., Crimmins, E. (1985): The fertility revolution: a supply-demand analysis, Chicago: University of Chicago Press.

Fawcett, J. (ed) (1972): The satisfactions and costs of children: theories, concepts and methods, East-West Population Institute, Honolulu.

Fawcett, J., Arnold, F. (1975): "The value of children: theory and method", Representative Research in Psychology, 4(1): 23-26.

Inkeless, A., Smith, D.H. (1974): Becoming modern: individual change in six developing countries, Harvard University Press, Cambridge Mass.

Lave, C., March, J.G. (1975): An introduction to models in the social sciences, Harper & Row, New York (ch. 7: diffusion).

Le Bras, H., Todd, E. (1981): L'invention de la France, Hachette, Paris.

Kohler, H.-P. (1997): Fertility and social interaction – An economic approach. PhD-thesis, University of California, Berkeley.

Lesthaeghe, R., Wilson, C. (1986): "Modes of production, secularization and the pace of the fertility decline in Western Europe, 1879-1930", in: A.J. Coale & S.C. Watkins (eds): The decline of fertility in Europe, Princeton: Princeton University Press: 261-292.

Lesthaeghe, R. (1997): "Imre Lakatos' views on theory development: applications to the field of fertility theories", IPD-Working Papers 97-1, Vrije Universiteit, Brussels.

Liebenstein, H. (1957): Economic backwardness and economic growth, Wiley & Sons, New York.

Liebenstein, H. (1975): "The economic theory of fertility decline", Quarterly Journal of Economics, 89: 1-31.

Livi-Bacci, M. (1977): A history of Italian fertility during the last two centuries, Princeton University Press, Princeton N.J.

Montgomery, M., Casterline, J. (1996): "Social learning, social influence, and new models of fertility", Population and Development Review, vol. 22 supplement (Fertility theories in the US: new patterns, new theories): 151-175.

Mason, K.O. (1985): The status of women, Rockefeller Foundation, New York.

Nag, M. (1989): "Political awareness as a factor in accessibility of health services", Economic and Political Weekly (Bombay), 24, 8: 417-426.

Robinson, W.C. (1997): "The economic theory of fertility over three decades", Population Studies, 51: 63-74.

Rosero-Bixby, L.; J. Casterline (1993): "Modeling diffusion effects in fertility transition", Population Studies, 47: 147-167.

van de Kaa, D.J. (1996): "Anchored narratives: the story and findings of half a century of research into the determinants of fertility", Population Studies 50: 389-432.

Westoff, C., Bankole, A. (1995): "Unmet need: 1990-1994", Demographic & Health Surveys, Comparative Studies no. 16, Macro International Inc., Calverton, MD.

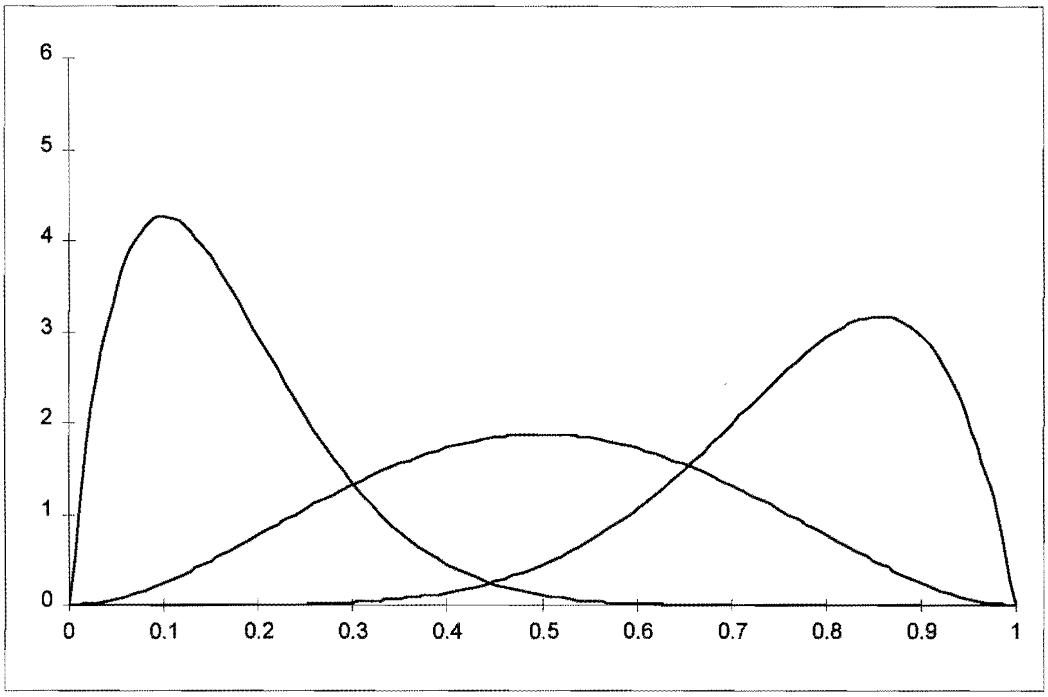


Figure 1

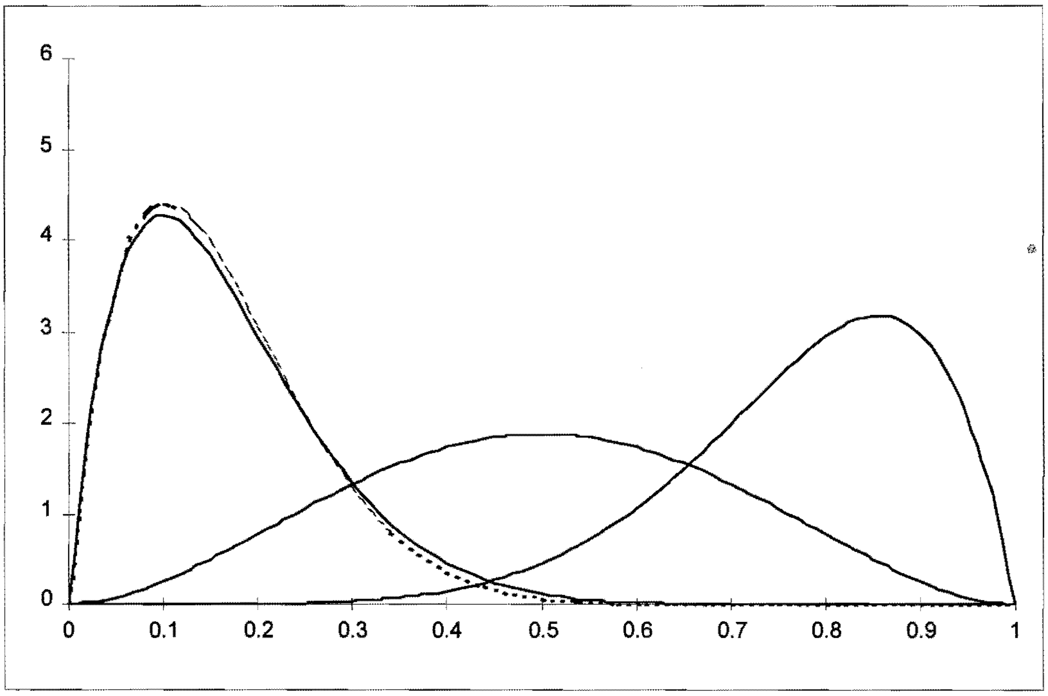


Figure 2

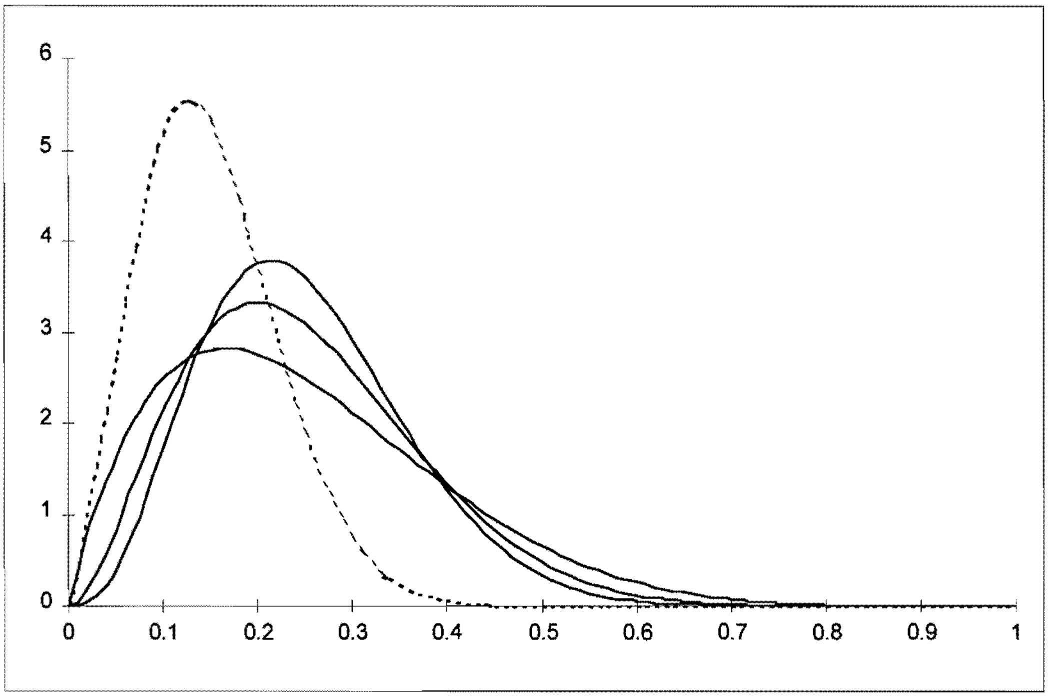


Figure 3

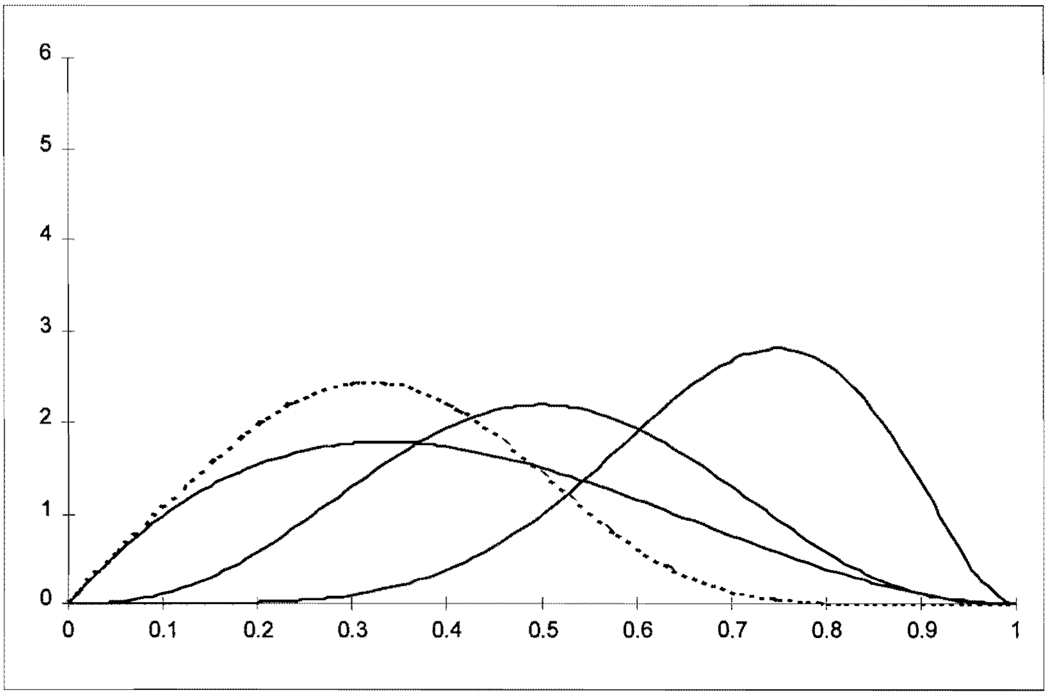


Figure 4

Assuming stochastic independence between the random variables R, W, and A (subscripts are dropped to simplify the notations), the distribution of $S = \min(R,W,A)$ can easily be obtained from the following probabilistic statement (which holds for any s between 0 and 1):

$$\begin{aligned}\Pr(S > s) &= \Pr((R > s) \cap (W > s) \cap (A > s)) \\ &= \Pr(S > s)\Pr(S > s)\Pr(S > s)\end{aligned}$$

which, in terms of the cumulative distribution functions of R, W and A, can also be written as:

$$1 - F_S(s) = (1 - F_R(s))(1 - F_W(s))(1 - F_A(s)).$$

Differentiating with respect to s gives the following expression for the probability density function (pdf) of S:

$$\begin{aligned}f_S(s) = \quad & f_R(s)(1 - F_W(s))(1 - F_A(s)) \\ & + f_W(s)(1 - F_R(s))(1 - F_A(s)) \\ & + f_A(s)(1 - F_R(s))(1 - F_W(s))\end{aligned}$$

Using the interpretation of a random variable's density in s as the probability that the random variable takes the value s, this formula becomes intuitively appealing and clear: the probability that the minimum S assumes the value s, is the probability that one of the three underlying variables assumes that value s, while the other two have at least that value s.

Moreover, if, for fixed s, both $1 - F_W(s)$ and $1 - F_A(s)$, for example, are large (i.e. close to 1), then $f_S(s)$ is close to $f_R(s)$. Thus, if two of the underlying random variables (e.g. W and A) are heavily right skewed, then the distribution of S is close to that of the third random variable (e.g. R).

(Voor de hazard functies geldt de eenvoudige relatie: $\lambda_S(s) = \lambda_R(s) + \lambda_W(s) + \lambda_A(s)$*; cf. competing risks models. Kan je hier iets mee doen, Ron?)*

We used the above formula to calculate and draw the pdf of S in figures 2 to 4, which will be discussed hereafter. Notice that, although R, W and A are assumed to be beta-distributed, S will generally not be beta-distributed. An explicit formula for the pdf of S, however, is not our concern here, and would even not be useful for our purposes, as it involves incomplete beta functions (which are to be evaluated by numerical integration!).

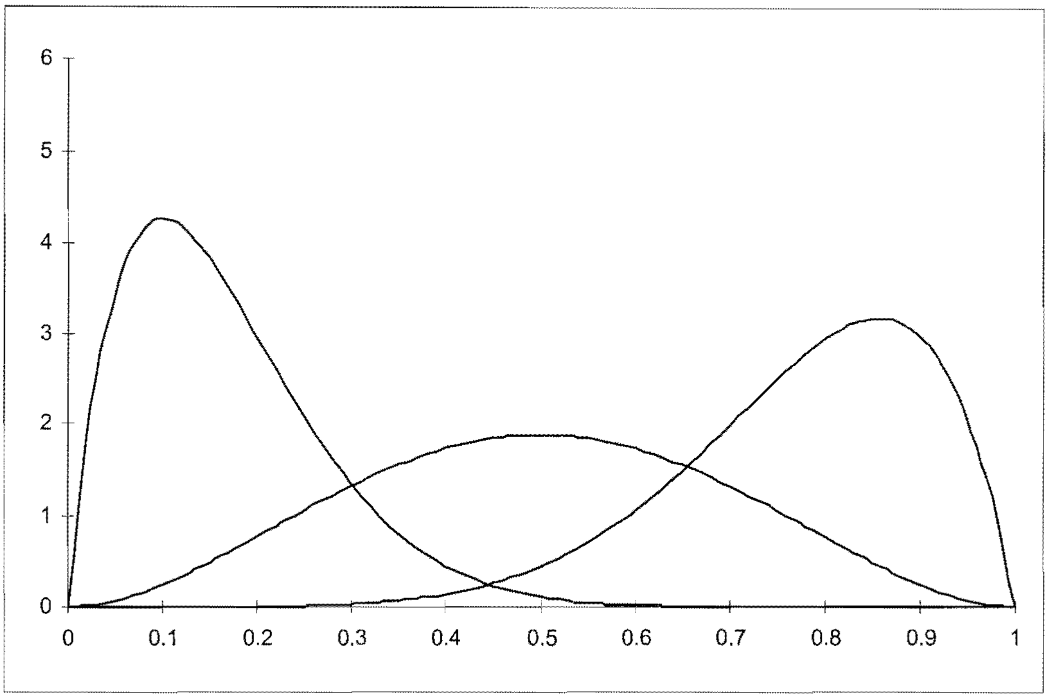
Ready, willing and able
A conceptualization of transitions to new behavioral forms

R. Lesthaeghe and C. Vanderhoeft

Interface Demography and Center for Statistics and Operations Research

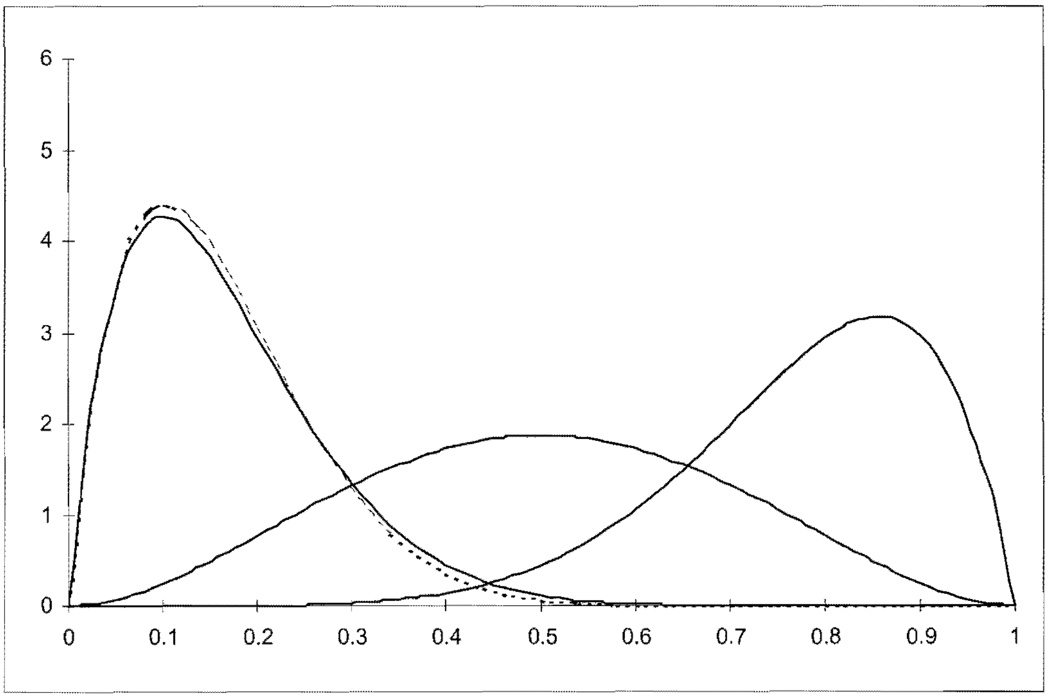
VRIJE UNIVERSITEIT, BRUSSELS

Paper prepared for the National Academy of Sciences meeting on the "Social Dynamics of Fertility Change in Developing Countries" to be held in Washington DC, January 29-30, 1998



Intensity of R, W or A (0=low, 1=high, 0.5=undecided)

Figure 1: Shift over time of the beta distribution of the intensity of either R, W or A from low (less than 0.5) to high (greater than 0.5)



Intensity of R, W or A

Figure 2: Location of W (left), R (middle) and A (right) at one point in time (example) and location of the distribution of the minimum (R_i, W_i, A_i) (=dotted line)

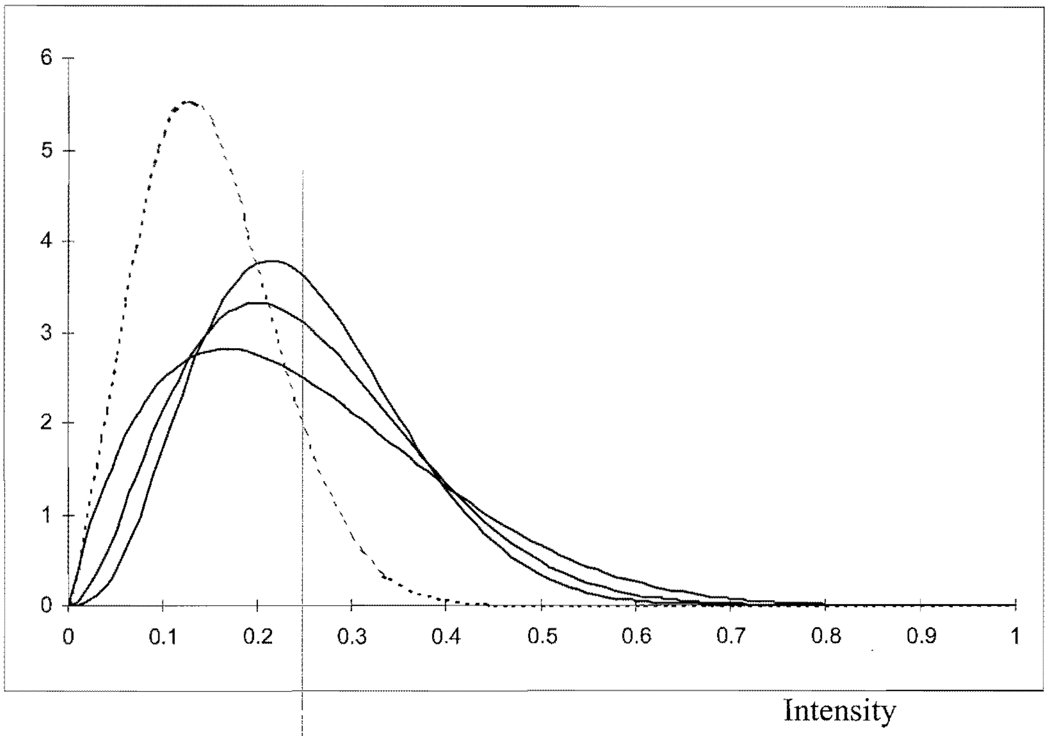


Figure 3: Location of W (left), R (middle) and A (right) at one point in time (second example) and location of the distribution of the minimum (R_i, W_i, A_i) (=dotted line)

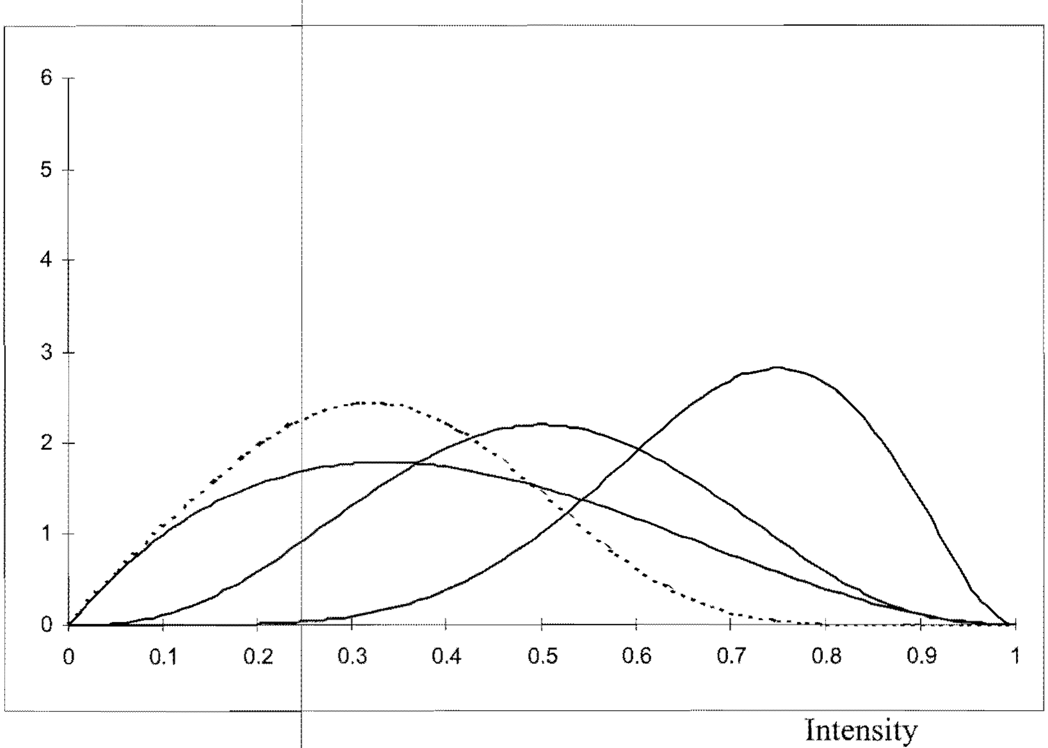


Figure 4: Location of W (left), R (middle) and A (right) at one point in time (third example) and location of the distribution of the minimum (R_i, W_i, A_i) (=dotted line)