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The Joint Estimation of Rates of Pregnancy, Foetal Death and Induced Abortion - Japan and U.S.A.

THE purpose of this paper is to derive the combination of the estimates of pregnancy rate, live births, foetal deaths and induced abortions with internal consistency. In theory, if any three of the preceding four elements are known, the fourth one can easily be estimated. But what can we do if only two elements, such as live births and foetal deaths, are known and we want to estimate the remaining two elements ? The solution obviously depends upon how much other information we have about the population in question.

Disregarding details for the moment, let us assume that we possess estimates for live births and foetal deaths but not for pregnancy rate and induced abortions. We can start with some arbitrary value of the pregnancy rate and estimate the corresponding level of induced abortions. In this way we can produce a series of estimates for induced abortions corresponding to different values of the pregnancy rate. As we shall describe later one outcome of this exercise would be our ability to pinpoint the minimum level of the pregnancy rate. The minimum level would correspond to the case of zero abortion. The remaining part of our exercise, i.e. to indicate the probable levels of pregnancy rate and induced abortions, depends upon how much else is known about the population under consideration. We shall illustrate our approach by considering the populations of Japan and the United States, Let us denote the proportions of conceptions resulting in live births, foetal deaths (of all gestation periods) and induced abortions by x, y and z respectively. Then,

$$x + y + z = l. \qquad (1)$$

The pregnancy rate and the general fertility rate can be related by the following identity

$$G = \frac{Rx}{100 + bR}, \qquad (2)$$

where

G =General fertility rate, i.e. the number of live births per female of childbearing age per year.

R =Pregnancy rate, i.e. the number of conceptions per 100 years of exposure to the risk of conception.

x = Proportion of conceptions resulting in live births.

b = Average number of years of non-exposure following a conception, i.e. the sum of the gestation period and post-partum sterility.

The above identity can easily be established.

In order to use equation (2) we need, among other things, an estimate of *'U*, the average number of years of non-exposure following a conception. The 'b', can be computed as the weighted average of mean lengths of non-exposure time following a live birth, a foetal death', and an induced abortion. The weights would be the distribution of outcome of conceptions in terms of live births, foetal deaths and induced abortions. In symbols,

$$b = 1_1, x + 1_2 y + 1_3 z, \qquad (3)$$

where 1_1, 1_2 and 1_3 are the average number of years of non-exposure following, respectively, a live birth, a foetal death and an induced abortion.

1. The computation of *'b'* can be refined by assigning different values for lengths of the non-exposure time associated with different groups of foetal deaths by gestation period. Since our objective is geared more towards the methodology than the perfection of underlying assumptions, we are treating foetal deaths of all gestation periods as one group.

To start with we do not know the distribution of outcome of the conceptions *(x, y* and z) we therefore, cannot compute *'b** by using equation (3). An iterative procedure to estimate '£' will be explained in our illustrative examples of Japan and the United States.

Regarding the lengths of the non-exposure periods (1,, 1_2 and 1_3); we make use of the estimates provided by Potter. These are reproduced in Table 1. Since induced abortions are functionally equivalent to miscarriages, the non-exposure period for induced abortion would be the same as for miscarriages, i.e. four months. We also assume that the average period of non-exposure for a foetal death (of all gestation periods) is six months. This is due to the fact that approximately one-half of the foetal deaths occur before 12 weeks of gestation—as miscarriages. Therefore the average period would be much closer to four months (corresponding to miscarriages) rather than to 11 months (corresponding to stillbirths). Then an estimate of *'b'* for a population practising no lactation would be :

$$b = \frac{13}{12}x + \frac{6}{12}y + \frac{4}{12}z. \qquad (4)$$

Japan 1955

Yoshio Koya estimated that there were 1,755,000 induced abortions in Japan during 1955[2]. This estimate is about 50 per cent greater than the reported number. The estimation procedure was : "The reported number of induced abortions per married women was obtained for each perfectufe. The highest of these rates was assumed to be the minimum applicable to all perfectures."[3] Koya's estimate of induced abortions compares well with the one developed by Muramatsu. Muramatsu's high, medium and low estimates of the number of induced abortions in 1955 were 2,259,000, 1,889,000 and 1,517,000. He favoured the medium estimate.[4]

Koya also gives an estimate of 'R' (pregnancy rate) as about 17 during 1955. His estimate is based on married women covered under various family planning guidance programs[5]. Since *'R'* is based on married

2. Koya, Yashio, *Pioneering in Family Planning,* Tokyo ; Japan Medical Publishers, Inc., 1963, p. 26.

3. Koya, Yoshio, *op. cit.,* p. 26.

4. Muramatsu, Minoru, Effect of Induced Abortions on the Reduction of Births in Japan, *Milbank Memorial Fund Quarterly,* 38, April 1960, pp. MO-164.

5. Koya, Yoshio, *op. cit.,* p. 38, 59, 78, etc.

TABLE 1—MEAN LENGTHS OF NON-EXPOSURE PERIODS CORRESPONDING TO MISCARRIAGE, STILLBIRTH AND LIVE BIRTH

Component	*Mean Length (in months)*			
	Miscarriage	*Stillbirth*	*Live Birth No Lactation*	*Prolonged Lactation*
Pregnancy	3	8	9	9
Post-partum Amenorrhoea	1	2	2	11
Anovulatory Cycles	—	1	2	2
Total Non-Exposure Period	4	11	13	22

SOURCE : Robert G. Potter, Jr., Birth Intervals : structure and change, *Population Studies*, 17 (2), November, 1963, pp. 156-157.

women, we shall compute the general fertility rate *(G)* on the basis of legitimate births and married women. The relevant statistics for Japan (1955) are as follows :

No. of married women (15-44)	=11,624,905
No. of legitimate births	= 1,701,674
General fertility rate, *G*	= 0.1464
Estimated no. of induced abortions among married women	= 1,755,000
Pregnancy rate	= 17

Since the number of live births and induced abortions were about the same in 1955 (1.7 million), we assume, for the sake of simplicity of computations, that the proportions of conceptions resulting in live births and those resulting in induced abortions are equal, i.e. $x=z$. (This implies no growth in the female population of childbearing age during 1954-55.)

The next step is to estimate *'b'*, the average number of years of non-exposure following a conception. To estimate 'b' we need, among other things, an estimate of the average length of breast-feeding in Japan. I am not aware of any Japanese study that reports the length of lactation and other related factors. However, rny Japanese colleague at the University of Michigan, Professor John Takeshita, maintains that the average period of lactation in Japan during the period we are discussing was less than in a country like Taiwan and greater than in Europe or America, but much closer to the level of Taiwan. In Taiwan, the average length of amenorrhoea is estimated to have been about 10 months during 1965-67[6]. Lacking any other information, we assume that the average length of postpartum amenorrhoea in Japan, was seven months in 1954-55. The equation (4) will be modified as :

$$b = \frac{18}{12}x + \frac{6}{12}y + \frac{4}{12}z. \qquad (5)$$

Let us assume arbitrarily that 40% of all conceptions result in live births. Then

$$x = z = 0.4, \quad \text{so } y = 0.2.$$

Substituting these values into equation (5), 'b' would be 0.83 years. Now substituting $G = 0.1464$, R — 17 into equation (2), the proportions of conceptions resulting in live births *(x)* would be as follows :

x = 98.2 % when b = 0.83 years

x = 97.1 % when b = 0.75 years

x = 95.6 % when b = 0.65 years.

So the proportion 'x' is relatively insensitive to the magnitudes of *'b'*. Since, in general, about one-half of all conceptions terminate in live births (with a non-exposure period of approximately 13 months), the average period of non-exposure for a country like Japan would be in the neighbourhood of 0.75 years. In any case, our procedure contains a re-estimation of 'b' on the basis of a probable distribution of the outcome of conception. Therefore, we start our computations with an assumed value of 0.75 years for 'b'. So Table 2 is prepared by using equation (2) for different values of pregnancy rate *(R)* and the following parameters for Japan in 1955 :

b = 0.75 years (assumed)

G = 0.1464

$x = z$

$y = 1 — x — z.$

6. Jain, Anrudh K., *et al.*, Demographic Aspects of Lactation and Postpartum Amenorrhoea, *Demography*, *7*, May 1970, p. 259.

We note in Table 2 that the proportion '*y'* and 'z' are marked as inadmissible values corresponding to the pregnancy rates of 17, 25 and 30. This is because of the fact that the sum of the three proportions cannot be more than 100. Since the proportions *'x'* and V are assumed equal for Japan, the estimated proportion V should be, at most, 50%. According to this criterion, the minimum level of the pregnancy rate in 1955 would be 37.5. At this level there would be no foetal deaths—an impossible event.

TABLE 2—A MODEL FOR OUTCOME OF 100 CONCEPTIONS, JAPAN, 1955

Pregnancy Rate R	*Percentage of Conceptions Resulting in*			
	Births X	*Foetal Deaths* y	*Abortions* z	*Total No. of Conceptions*
17	97.1	-	—	
25	69.5	-	-	
30	59.8	-	-	
37.5	50.0	0.0	50.0	100.0
40	47.6	4.8	47.6	100.0
45	43.5	13.0	43.5	100.0
50	40.3	19.4	40.3	100.0
55	37.6	24.8	37.6	100.0
60	35.4	29.2	35.4	100.0

'—'=Inadmissible values.

What is the likely level of the pregnancy rate in view of Table 2 ? To answer this question, we should have some notion about the level of foetal deaths in Japan. Generally we are accustomed to the foetal death ratio (the ratio of number of foetal deaths to live births in a year) rather than to the proportion *y'* as a measure of the level of foetal deaths. The foetal death ratios derived from Table 2 are as follows.

Pregnancy Rate *R*	*Foetal Death Ratio* (as percentage) (y/x)100
40	10.1
45	29.9
50	48.1
55	66.0
60	82.5

The number of registered foetal deaths of 12 + weeks gestation in Japan was 183,265 in 1955[7]. The New York study on foetal deaths showed that 50% of all foetal deaths occur before 12 weeks of gestation[8]. Applying this ratio to Japan, the estimate of total number of foetal deaths of all gestations would be 366,530. This estimate yields a ratio of 21.5

foetal deaths per 100 live births (= 366,530/1,701,674 x 100) If this estimate of

the level of foetal deaths is correct, the above tabulation shows that the pregnancy rate in 1955 would be between 40 and 45. However the registration of foetal deaths is likely to be incomplete. This means that the pregnancy rate in Japan would be closer to 45 than to 40.

Now, from Table 2, for $R = 45$ we have $x = 43.5$, $y = 13.0$ and $z = 43.5$. The corresponding estimate for 'b' yielded by equations, would then be 0.861 years. Thus we have re-estimated the value of *'b'* — a kind of iterative procedure. Using this estimate of *'b'*, equation (2) yields :

R	*Outcome of 100 Conceptions*			*(ylx)100*
	x	*y*	*z*	
45	45.1	9.8	45.1	21.7
50	41-9	16.2	41.9	38.7

Now, corresponding to *'R'* of 45, we get a foetal death ratio of 21.7. This is, incidentally, the same ratio as was estimated on the basis of registered foetal deaths. As mentioned earlier, the foetal death ratio of 21.5 is likely to be an underestimate for Japan. Furthermore, the foetal death ratio of 38.7, which corresponds to the pregnancy rate of 50, seems to be too high for the conditions of Japanese mortality prevailing in 1955. Thus the pregnancy rate in Japan is likely to be around 45-47. Our conclusion is supported by the survey results provided by Koya. He reports that the pregnancy rate was between 40 and 50 among his various survey populations before the introduction of family planning guidance programs[9]. So, we can say that the pregnancy rate in Japan was around 47 in 1955 and that out of every 100 conceptions,

7. United Nations, *Demographic Year Book 1961*, New York, p. 212.

8. Shapiro, Sam, *et al.*, A Life Table of Pregnancy Terminations and Correlates of Fetal Loss, *Mllbank Memorial Fund Quarterly*, 40, January 1962, p. 14.

9. Koya, Yoshio, *op. cit.*, p. 46, 59, 78, etc.

about 43 resulted in live births, 14 in foetal deaths and 43 in induced abortions.

U.S.A. 1960

Now we shall present a similar exercise concerning the United States. In the case of the United States we can estimate the level of foetal deaths but we have little knowledge of extent of induced abortions. The registered foetal deaths in the U. S. pertain to the gestation period of 20 + weeks. It is well known that the accuracy of this registration varies among the states and that the over-all registration of foetal deaths is incomplete. In 1960 the highest value of the foetal death ratio among the states was observed in New York—23.2 foetal deaths of 20 + weeks gestation per 1000 live births were registered as compared with 16.1 in the United States[10]. This does not imply that New York is the worst state in the U.S. so far as level of foetal mortality is concerned. Rather this situation testifies to the well-known fact that New York has the best system for the registration of foetal deaths in the United States. In recent years the highest value of the foetal death ratio observed in New York state was 27.2 in 1964[11]. Even this level would be less than the actual level of foetal deaths because the registration system could not be 100 per cent complete in New York. Since the levels of foetal and infant mortality are highly correlated (positively) and the infant mortality rate in New York is little less than the national average[12] we can safely assume that the over-all foetal death ratio in the U.S. would at least correspond to that observed in New York, i.e., 27.3. Even this level may be an under-estimation for the United States. So, for our present purpose, we shall place the level in U.S. at 30.0 foetal deaths of 20+ weeks gestation per 1000 live births in 1960.

The New York study on foetal deaths shows that 18% of all foetal deaths occur after 20 weeks of gestation[13]. Applying this proportion,

10. U.S. Department of Health, Education and Welfare, *Vital Statistics of the United States 1960,* Vol. II - *Mortality,* Washington, D.C., 1963, Table 9-2.

11. U.S. Department of Health, Education and Welfare. *Vital Statistics of the United States, 1964,* Vol. II - *Mortality,* Washington, D. C., 1966, Table 7-2.

12. In 1954 the infant mortality rate in New York state was 24.1 as against the national average of 24.8 — *Vital Statistics of the United States 1964, op. cit.*, Table 7-2.

13. Shapiro, Sam., *op. cit.*

the estimate of the level of foetal deaths of all gestation periods is 167 foetal deaths per 1000 live births (= 30.00/0.18) or *16.7 foetal deaths per 100 live births.*

The relevant statistics needed for our exercise concerning the United States (1960) are as follows :

No. of legitimate births	=	4,033,550
No. of married females (15-44)	=	24,979,509
General fertility rate for married women	=	0.1615
b (assumed value)	=	0.75
Foetal deaths per 100 live births	=	16.7

The Family Growth Study reveals the pregnancy rate of 25.5 after marriage and 20.4 after the birth of the first child[14]. Therefore we shall start our computations with a pregnancy rate of 20. The results are shown in Table 3. It is clear from Table 3 that, under the given conditions, the minimum pregnancy rate application to the U.S. in 1960 would be 22. Table 3 was prepared by using the assumed value of *'b'* as 0.75 years. Let us estimate the value of *'b'* by using the distribution of conceptions corresponding to the pregnancy rate of 25 in Table 3. Thus, substituting two months for period of post-partum amenorrhoea for the U.S. (negligible lactation—Table 1) in equation (4), we get

$$b = \frac{13}{12} \times (.767) + \frac{6}{12} \times (.128) \times \frac{4}{12} + (.105)$$

$$= 0.9292 \text{ years}$$

Table 4 is prepared by using the above estimate of *'b'* and other relevant parameters. This table shows that the minimum level of the pregnancy rate in the United States would be 23 or 24, corresponding to insignificant number of induced abortions. Let us compute the absolute number of induced abortions implied in the proportions of conceptions resulting in induced abortions *(z)* shown in Table 4. The results are presented in Table 5.

14. Westoff, Charles F., *et al., Family Growth in Metropolitan America,* Princeton, N. J.: Princeton University Press, 1961, p. 85.

In a survey conducted in North Carolina, the following frequencies of induced abortions were estimated[15].

Group	*Estimates of the Proportions of Women (15-44) having Abortions During the Preceding Year*
All Women	0.0342
Never Married	0.0796
Ever Married	0.0237

Applying the abortion rate of ever-married women, we get the estimated number of induced abortions in the United States as :

= 24,979,000 x (.0237)

= 592,014.

This estimate of induced abortions corresponds to the pregnancy rate of about 26.5 (Table 5). We expect that the abortion rate in the more

TABLE 3-A MODEL FOR OUTCOME OF 100 CONCEPTIONS, U.S.A., I960

Pregnancy Rate R	*Percentage of Conceptions*		*Resulting in*	*Total No. of Conceptions*
	Births X^1	*Foetal Deaths* Y^2	*Abortions* z^3	
20	93.7	15.6	-	
21	89.0	14.9	-	
22	85.5	14.3	0.2	100.0
23	82.3	13.7	4.0	100.0
24	79.4	13.3	7.3	100.0
25	76.7	12.8	10.5	100.0
26	74.2	12.4	13.4	100.0
27	71.9	12.0	16.1	100.0

'—' = Inadmissible values.

1. The proportion *x* is obtained by using equation (2).

2. The proportion *y* is obtained by applying the foetal death ratio to the proportion *x*, i. e. by multiplying *'x'* with 0.167.

3. The proportion *z* is obtained by subtraction, i.e., z = 100 — *x* — *y*.

15. Abernathy, James R., *et al.*, Estimates of Induced Abortions in Urban North Carolina, *Demography*, *7*, 1970, p. 23.

populous and industrialized states of the North-East and West would be higher than the one observed in North Carolina. Therefore one could say that the prgenancy rate in 1960 would be around 28 and the total number of induced abortions around one million. In the subsequent extension of the Family Growth Study—a pregnancy rate of 24.7 was estimated with the truncation of exposure period at 12 months and a pregnancy rate of 25.1 with the trunctation at 6 months[16]. Our estimate of a pregnancy rate of 28 implies that out of every 100 conceptions, 72.7 result in live births, 12.1 in foetal deaths and 15.2 in induced abortions. (Table 4).

TABLE :4-A MODEL FOR THE OUTCOME OF 100 CONCEPTIONS U.S.A., 1960.

(b = 0.9292)

	Percentage of Conception Resulting in			
Preanancv Rate R	*Births* x^1	*Foetal Deaths* y^2	*Abortions* z^3	*Total No. of 'Conceptions*
20	95.7	16.0	—	
22	88.4	14.8	—	
24	82.3	13.7	4.0	100.0
25	79.6	13.3	7.1	100.0
26	77.1	12.9	10.0	100.0
27	74.8	125	12.7	100.0
28	72.7	12.1	15.2	100.0
30	68.8	11.5	19.7	100.0
35	61.1	10.2	28.7	100.0

•—* = Inadmissible values.

1. The proportion x is obtained by using equation (2).

2. The proportion y is obtained by applying the foetal death ratio to the propotion x, i.e. by multiplying 'x' with 0.167.

3. The proportion z is obtained by subtraction, i.e., $z = 100 - x - y$.

16. Westoff, Charles F., *el al., The Third Child Study,* Princeton, N. J. : Princeton University Press, 1963, p. 285.

TABLE 5-ESTIMATED NUMBER OF INDUCED ABORTIONS CORRESPONDING TO DIFFERENT LEVELS OF PREGNANCY RATES

Pregnancy Rate	*Ratio of Aboritions to Live Births*	*Estimated Number of*
R	*(z/x)* x *100*[1]	*Abortions*[2]
24	4.86	196,030
25	8.92	359,793
26	12.97	523,151
27	16.98	684,897
28	20.91	843,415
30	28.63	1,154,805
35	46.97	1,894,558

[1]. Computed from columns (2) and (4) of Table 4.

[2]. Computed by multiplying column (2) with the number of legitimate births in 1960, i.e., 4,033,550.