# Intergenerational transmission of fertility, review of up to date research and some new evidence from Bejsce parish register reconstitution study, 18th – 20th centuries, Poland.

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ABSTRACT - short
Paper aims at the review of up to date research concerning intergenerational transmission of fertility. It compares results obtained from various databases, periods, population and analytical methods in order to assess the differences and changes in magnitude of interrelation between fertility of generations within this same lineage.

The paper contains the analysis of fertility transmission patterns in historical population of Bejsce parish. For individuals born between 1740 and 1968 we have reconstructed the genealogies for three successive generations using the data based on the parish registers.

Results reveal major differences in fertility transmission of fathers vs. sons and mothers vs. daughters. The relation between fertility of women from this same lineage is much stronger than for males. There is also important cohort effect: the fertility of relatives from the two consecutive generations born after the fertility transition (beginning of the 20th century) reveals stronger interrelation than for the earlier cohorts.

ABSTRACT - extended
The paper aims at the review of up to date research on the issue of intergenerational transmission of fertility. It the results obtained from various data, periods, population and analytical methods in order to assess the differences and changes in magnitude of interrelation between fertility of parents and children. Although the environmental and genetic factors cannot be separated in a satisfactory way, the general conclusion from the reviewed literature is that the interrelation between fertility of parents and children becomes important for periods after the fertility transition. Moreover the interrelation between fertility of female members of this same lineage is much stronger than for the male members.

The review is supplemented with the original analysis of fertility transmission patterns in historical population of Bejsce parish, Poland. The models are based on reconstruction of the genealogies for three successive generations from the parish registers of Bejsce. The analysis compares fertility of grandparents, parents and grandchildren born between 1740 and 1968. The results reveal major differences in fertility transmission with respect to sex (fertility of fathers vs. sons and mothers vs. daughters) and with respect to birth cohort. The results confirm that the relation between fertility of women from this same lineage is much stronger than for males. Also two consecutive generations exhibit much stronger correlation in the reproductive performance. Moreover, the strength of the relation seems to be associated with the birth cohort of the generation. The fertility of relatives from two consecutive generations born after the fertility transition (turn of the in 20th century) reveals much stronger interrelation than in the earlier birth cohorts.

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## INTRODUCTION

The motivation for this paper came from the earlier analyses of the effect of relatives on the individual reproductive performance (Tymicki, 2004). Earlier analyses pointed out that this research problem might be framed as the relation between number of helpers and their contribution to the reproduction of a particular sibling. However, the sibling's group necessarily constitutes the offspring of the previous generation. Therefore, the relation between the number of the siblings and individual reproductive performance might also be framed as the relation between fertility of "older" generation and the fertility of the descendants. This takes us directly to the issue of intergenerational transmission of fertility.

This research issue was puzzling the researchers for over one century now. Pearson and Lee (1899) were the first who tried to investigate the correlation between fertility of parents and children using historical data on British peerage. From that time number of researches devoted to the investigation of the intergenerational transmission of fertility is growing rapidly (Anderton et al., 1987; Bocquet-Appel and Jakobi, 1993; Huestis and Maxwell, 1932; Imazumi, Nei, and Furuscho, 1970; Johnson and Stokes, 1976; Kohler, Rodgers, and Christensen, 1999; Langford and Wilson, 1985; Murphy, 1999). These various studies tried to answer a question about the sources of variation in human reproductive outcome. This question seems to be important since it cannot be argued that the number of offspring among humans varies only by chance and follows the Poisson distribution with equal mean and variance. It is well know that the variance in the number of human progeny is much larger than the mean, which reflects one of the basic forces of natural selection - the differential reproduction. Therefore what could be the sources of this variation? The following sections aims at the explanation of the sources of this variation by disentangle between genetic and environmental component.

## THEORETICAL BACKGROUND: GENES OR ENVIRONMENT?

The positive association between fertility outcomes of individuals from this same population might be attributed to the shared environmental and genetic background. The latter is of course restricted only to relatives whereas the first mentioned is independent from the degree of genetic relatedness. Like in the case of human life expectancy there might be a share of life expectance attributable to genetic endowment and to the other non-genetic determinants. It is estimated that around 20% of variation in the human life expectancy could be attributed to the genetic endowment (Wachter and Finch, 1997). Therefore, fact of having long-lived parents would affect our life expectancy only in 20%. The rest could be attributed to our life style, habits etc. We may wonder whether we can estimate somehow the extent to which our fertility behavior is determined by genes and what is the strength of this influence. Of course it could be said that our reproductive behavior does not have anything to do with genes and is completely under our volitional or at most is controlled by social norms. However recent evidence suggest that genetic influence might be helpful in explaining variation in human fertility (Rodgers et al., 2001).

The perspective that genes could be responsible for the variation in fertility has been neglected since Fisher has introduced the fundamental theorem of natural selection (Fisher, 1930). This theorem states that, in the long run, traits which have a strong effect on reproductive success will have no genetic variation. This comes from the situation where individuals with high reproductive success will squeeze out those with low reproductive success which, results in no genetic variance. However, as noted by many researchers (Rodgers and Huges et al., 2001; Rodgers and Kholer et al., 2001; Rodgers and Kohler, 2003), this theorem has been consistently misinterpreted. In fact it does not apply to individual level components of reproductive success like survival or fertility and moreover there are *"perturbing forces"* which may maintain the genetic variance within a population. Such *"perturbing forces"* include contraception, changes in the social norms associated with reproduction, changes on the marriage market (mating) etc. All those forces associated with reproductive behavior, which are present also today, create a space for genetic variation without contradicting with the Fisher's theorem (Rodgers and Kohler, 2003).

In order to account for the genetic influence researchers use the heritability coefficient denoted as $h^2$. This coefficient *"measures the percentage of overall variance (often referred to as phenotypic variance) in some physical trait or behavioral characteristic that is related to genetic process.* (Rodgers and Huges et al., 2001: 185)*."*

The range of values of $h^2$ could potentially vary from zero to unity and in fact the misinterpretation of Fisher's theorem implies that the heritability of fertility and other reproductive traits will be around zero. However, even Fisher (Fisher, 1930) himself has estimated the heritability of completed family sizes for the British peerage to be different from zero ($h^2$=0.4). As we shall see in the next section, there were conducted a lot of research supporting the finding that there is a consistent and significant pattern of heritability of human fertility. It means that some proportion of the observed phenotypic variance in fertility and other characteristics related to the process of reproduction could be attributed to genetic influence.

The observed fact that there is some degree of genetic influence on human fertility behaviour does not mean that there is specific fertility gene. It rather means that there is a set of genes, which by interaction with environment manifest themselves on the level of phenotypes (behavioural level). Therefore, any research focused on the estimation of heritability of human fertility tackles the issue quantitatively. In other words, *"determines the sum of heritable genetic influence on behaviour, regardless of the complexity genetic modes of action or the number of genes involved, (…) quantitative genetics does not tell us which genes are responsible for genetic influence."* (Plomin, 1990: 184).

In the research focused on quantitative genetics of human behaviour, there are no powerful methods, like those of experimental research used in the animal studies. Therefore, researchers have to rely on the family studies, adoption studies and twin design studies. The family studies assess the resemblance for the genetically related individuals, although it is not possible to disentangle the non-genetically (environmental) sources of resemblance. This is exactly the point where the research area can benefit from the adoption studies. Taking the advantage of the fact that adopted individuals are not genetically related to their new families, it is possible to estimate the share of resemblance, which is not due to inherited characteristics.

Finally the twin studies take the advantage of the fact that monozygotic twins are genetically identical therefore the coefficient of relatedness equals unity. Therefore twins constitute a sort of natural experiment where genetically identical individuals can be compared to fraternal twins, whose coefficient of genetic relatedness equals 0.5. Therefore, if inheritance affects behaviour monozygotic twins should be more resemble with respect to behavioural characteristics than fraternal twins do.

In the research focused on heritability on human fertility two analytical approaches are predominant. First one uses simple correlation approach in order to account for the intergenerational transmission of fertility. The origins of this approach could be traced back to the research conducted by Pearson and Lee (1899). They have used correlation approach in order to infer about heritability of fertility between generations. This approach, closest to the above-described family studies, is not free form distortions mainly due to lack of control for the environmental effects. Many researchers interested in the heritability issue followed this analytical path (extensive review will be presented in the next section) however accuracy of their estimates was frequently questionable (compare critique of Fisher's analysis by Williams and Williams, 1974).

Much promising approach is offered by the twin design studies. As noted above in such studies it is possible to control for shared genetic endowment vs. shared environment. Moreover recent developments in the twin research methodology like DF analysis and structural equation modelling allow for efficient and accurate estimation of heritability (Kohler and Rodgers, 2001; Rodgers et al., 2001). These researches focus not only on the heritability of completed fertility but also on the fertility precursors indirectly influencing individual reproductive outcomes like age at first marriage, age at first sexual intercourse, first attempt to have a child (for instance: Miller, 1994; Rodgers et al., 2001). These studies have found moderate heritabilities associated with behaviours and traits related to direct fertility measures and strong heritability of fertility precursors like, for instance, age at first proception i.e. first attempt to have a child (Rodgers et al., 2001).

## TRANSMISSION OF FERTILITY BEHAVIOR: REVIEW OF UP TO DATE RESEARCH

As already noted, from the very beginning of the studies of the transmission of fertility behavior the scholars were puzzled by the question about the extent to which variation in human could be attributed to the genetic factors (nurture) and to the environmental factors (nature). Even Pearson, who was strongly biologically oriented, had to acknowledge that there might be some distortions in the process of heritability due to substantial degree of heterogeneity between individuals in the population.

Due to the lack of suitable research methods, for many years researchers interested in the investigation of this issue were unable to disentangle between genetic and environmental component. Therefore they have focused on some approximations using pair correlations between parents and children which stood for the heritability of fertility ($h^2$). In an excellent review paper, Murphy provides a comprehensive survey of these studies (Murphy, 1999). The estimates of the relationship between fertility of parents and children (male and female pairs) show rather moderate level of association between fertility of parents and children. The earliest study of British peerage by Pearson and Lee (1899) on the intergenerational transmission of fertility shows considerable variation in the estimates with respect to the social class of individuals. However, some more general pattern of stronger correlation between fertility of mothers and daughters than fathers and sons emerges. The estimates for mother and daughters varied around 0.2 and the estimates for fathers and sons varied between 0.05 and 0.11.

Other studies of historical populations prior to 19$^{th}$ century did no seem to confirm such strong relationship (Bocquet-Appel and Jakobi, 1993; Imazumi, Nei, and Furuscho, 1970;

Langford and Wilson, 1985). The coefficients estimated in these studies (using similar methodology) were small and statistically not significant.

The two existing studies of 19th century populations provided once again positive and significant correlation between fertility of parents and children (Anderton et al., 1987; Wise and Condie, 1975). Using similar databases of Mormon population from the 19th century the researchers have estimated the correlation coefficient between fertility of pairs of consecutive generations. In the case of the study by Wise and Condie (1975), the estimates for the first and second generations varied between 0.213 and 0.234, for the second and third between 0.171 and 0.242 and surprisingly for the third and fourth generations between –0.028 and –0.147. Such a negative relationship has been also found by Imazumi et al. (1970). They have found negative correlation coefficient (-0.272) between fertility of mothers and daughters for the birth cohort 1891-1900.

Anderton et al. (1987) used similar database as study quoted above. They have also found a positive relation between fertility of mother and daughters (approximately 0.1) and moreover they have found a clear time pattern of this relationship, showing that the relationship became stronger over the time.

Analyses covering later period (first half of the 20th century) show constant increase in the strength of the relationship between fertility of two successive generations. As reported by Murphy (1999) the coefficients of correlation were relatively high ranging between 0.15 and 0.26 depending on the population and study.

These studies yields quite consistent results, however, the interpretation of the results varied considerably from purely genetic explanations (Imazumi, Nei, and Furuscho, 1970) to some more socially and culturally oriented perspectives (Johnson and Stokes, 1976). This was mostly due to the fact that the researchers were not able to answer the question about the differential effect of genes and environment since the nature of used data and methodology unable them to do so.

The recent studies, which successfully attempt to provide genetic models of human fertility, are based on the twin data and twin research methodology (Kohler, Rodgers, and Christensen, 1999; Kohler, Rodgers, and Christensen, 2003; Rodgers et al., 2001). The twin databases seem to be particularly well suited for answering the question about the degree in which human fertility is determined by genes. The fact that monozygotic twins are genetically identical allows controlling for the shared genetic background and isolate respective environmental factors. The results of these studies reveal that around one-quarter of the variance in the completed fertility is attributable to genetic influence (Rodgers et al., 2001).

There is also a differential genetic for cohorts characterized by high and low fertility levels (presumably natural and controlled fertility). The theoretical considerations presented in these studies lead to the conclusion that genetic influence on fertility outcomes appear to operate through volitional fertility motivations and desires as well as through biological process such as fecundity.

These studies also suggest that there is a shift in the relative importance of shared environmental and genetic effects over time (Kohler, Rodgers, and Christensen, 2003). The genetic influences seem to be of particular importance among post-transitional populations whereas the environmental influences among pre-transitional populations. This is in accordance with the theoretical predictions (Fisher, 1930). As demographic transition progress the social restrictions concerning the reproduction relax and the socioeconomic conditions in general facilitate a wider choice of demographic behavior that includes the conscious control of marital fertility. This changing context of fertility decisions apparently leads to a fading of shared environmental influences, and emergence of strong genetic influences on fertility behavior.

The results of all up to date, researches on the intergenerational transmission of fertility pooled by Murphy (1999) provide an excellent overview on the patterns of fertility transmission process. The FIGURE 1 present the pooled results from the paper of Murphy along with some new results of recent studies.

This figure shows quite clear time pattern of no or weak relationship at so-called natural fertility regimes (or pre-transitional societies) and relatively stronger genetic influences in post-transitional populations or birth cohorts. These pooled results indeed suggest that there was a constant shift towards greater importance of genetic effects in comparison to environmental effects.

[FIGURE 1 ABOUT HERE]

Although the results show a great degree of variation ranging between 0.1 and 0.5, on average they converge to the value around 0.2-0.3 which usually obtained in various studies concerning intergenerational transmission of fertility. This figure gives only a general overview of the trends and there are other, more detailed aspects of the topic that are worth mentioning.

One of the important dimensions of the intergenerational transmission of the fertility behavior is the differential effect with respect to sex and generation. The results suggests that there is much stronger intergenerational transmission of fertility between females than between males (Murphy, 1999). That is, daughter's fertility correlates much stronger with fertility of her mother that fertility of son with fertility of his father. This is of course related to the fact that female fertility is dependent on many biological or physiological characteristics which are genetically inherited. Thus, genetically transmitted individual fecundity, among other factors, predetermines the fertility outcomes of females. On the other hand male fertility seems to be rather related to the social position and to less extent to genetically inherited traits.

Another important difference in the magnitude of the genetic effects is related to the time distance between studied generations. Apparently, two successive generations should exhibit higher correlation of fertility outcomes than the correlation between fertility of grandparents and grandchildren. This is of course related to the coefficient to genetic relatedness which is higher between two successive generations than between grandparents and grandchildren. Also the environmental effects which partially shape the reproductive outcomes are much more similar in the case of the two successive generations. That is the external socioeconomic conditions which shape the fertility of a given generation are much resemble in the case of parents and children, which in turn might translate into higher correlation of the fertility outcomes.

## FERTYLITY TRANSMISSION: THE CASE OF BESJCE PARISH

This paper do not stand only for the review of up to date research but also adds some new evidence on intergenerational transmission of fertility. The new evidence comes from the historical population of Bejsce parish, Poland. The data from the reconstitution study of Bejsce parish do not allow for sophisticated analysis that would accurately capture the inheritance of fertility behavior. Therefore as in the case of most studies of intergenerational transmission of fertility the analyses are based on a simple correlation approach in order to assess the relationship between fertility outcomes of two successive generations. Although, such an approach is far from being ideal solution if one want to capture the inheritance schedule, however it allows for approximation of such a relation and enables the comparison with other studies.

### Sample selection and preparation

The data from the parish registers from Bejsce were collected by the research team led by professor Edmund Piasecki from Institute of Anthropology of Polish Academy of Science. Research team has chosen Bejsce parish located in south central part of Poland (100 kilometers north from Cracow). The selection criteria restricted possible choices to big rural parishes, located on fertile soils, with long and continuous settlement and well-preserved parish registers from 17th to 20th century. Bejsce parish fulfilled each of these criterions and moreover, this site was homogenous with respect to nationality and religion of inhabitants and was not exposed to any dramatic depressions like wars or plaque. The whole parish, founded in year 1313, consists of eight villages. Although there are eight villages within the parish, there were quite closely located so there is no risk that the population could be heterogeneous with respect to the place of residence. Throughout all its' history inhabitants were dealing with agriculture but the information on size of owned land in the parish registers were missing or incomplete. However the primary goal of the research team was to reconstruct also anthropometric data, finally the data base contains only information about deaths, births and marriages of all inhabitants registered in the parish books.

The parish books were relatively well preserved. The oldest among parish books is the book of marriages. The first record in this book has been made in the year 1586. Second oldest is the book of births (established in the year 1606) and finally the book of burials was introduced in the year 1679. The whole database consists of almost 40 thousands of inhabitants linked in families by individual numbers attached to each unit of observation (more details on the database construction and preparation process see: Piasecki, 1990; Tymicki 2004).

In order to account for the intergenerational transmission of fertility it was necessary to select the sub-sample of men and women and link them into successive generations. The criteria which were used to select the sub-sample for the analysis were quite similar with respect to males and females. They are also resemble to the criteria used in the other studies devoted to the issue of intergenerational transmission of fertility (compare: Imazumi, Nei, and Furuscho, 1970; Murphy, 1999).

For both sexes it has been assumed that it is crucial to be at risk of experiencing a birth of a child through the whole reproductive period. In the historical population, like those of Bejsce parish, being in the union was critical with respect to be at risk of experiencing a birth. Therefore, pre-processing procedure excluded individuals who stayed out of the union (single and widowed persons) and people who have terminated the unions before reaching the limit of reproductive ages. However, the procedure has not excluded persons who have terminated unions (due to for instance death of a spouse) but have remarried. It has to be noted that remarriage was much more frequent for males than for females.

In order to properly analyse transmission of fertility it is necessary to account only for completed fertility. Therefore, both for males and females, the age of 45 has been chosen to be the point where the individuals have relatively low chances for increasing their fertility outcome. In other words, the selection criterion was that individual has to survive (in union) at least to age of 45. This assumption seems to be quite reasonable in the case of females since age of 45 usually marks the onset of permanent sterility. Therefore when woman dies at age of 45 the probability that her reproductive outcome could be higher if she would survive is negligibly low.

However, this assumption is much less straightforward in the case of males. It could be argued that when man dies at the age of 45, number of his children at that time is far from being a proxy for his completed fertility if he would survive. Thus, when man dies at the age of 45 he is loosing some part of his reproductive span and his completed fertility could be higher if he would survive. That is true however the choice was dictated by the fact that individuals from youngest generation born between 1900 and 1923, have reached the age of 45 in the year 1968 which was the ending year of the reconstitution. Therefore the problem of relatively short reproductive span was limited only to some small fraction of the sample. There is no such a problem among older cohorts or generations.

The aim was to calculate the intergenerational transmission of fertility. Therefore it was necessary to link individuals in to families (lineages). It was possible to trace three successive generations. The youngest generation (third) was born in following cohorts: 1800-1850, 1851-1875, 1875-1900 and 1900-1923. This was the generation of sons and daughters, second was the generation of mothers and fathers and the first one was the generation of grandfathers and grandmothers. The birth cohorts of the three studied generations are given in the TABLE 1.

[TABLE 1 ABOUT HERE]

**Variables considered in the analysis**

The variables of a special interest in the analysis are intergenerational correlation of completed fertility and the number of surviving children. These two variables are usually used to measure the relationship between the fertility of parents and children (Murphy, 1999). The number of survivors is usually understood as the number of children who manage to survive until the maturity. In the case of the current study we have assumed the age at maturity to be 15 years old. Choice of this age limit was dictated by the fact that in the population of Bejsce parish children who has reached age of 15 very frequently were migrating to work in another parish or village. Such migration from parental household actually meant the gaining the independence from parents[1].

However, the strength of intergenerational correlation of completed fertility and the number of survivors could presumably refer to different underlying processes. The correlation between completed fertility of two generations refers rather to the individual biological ability to conceive, whereas the correlation between the number of survivors, besides the biological factors (woman's health status) refers also to an external conditions surrounding the process of childbearing. What is meant here by external conditions is overall infant mortality for given generation and birth cohort caused by such factors like good or bad nutrition (good or bad harvest) or epidemics.

Using the assumptions concerning the sample selection procedure described above, completed fertility has been calculated for both males and females. However, the number of survivors up to the age of 15 was computed only for females. This is due to the fact that considerable share of infant mortality in natural fertility populations was concentrated within few days and months after delivery. Among factors influencing neonatal mortality dominate factors associated with woman's health status, like infant's birthweight or susceptibility for infections. Therefore we should expect, if any, correlation between number of woman's surviving children rather than those of men.

**Correlation approach**

Taking into account methodology used in the research papers, which focus on the intergenerational transmission of fertility behavior of the inheritance of fertility one can roughly divide between sophisticated methods allowing to estimate the heritability measures derived from genetics, biometry and twin research methodology (Bocquet-Appel and Jakobi, 1993; Christensen et al., 2003; Kohler, Rodgers, and Christensen, 1999; Kohler, Rodgers, and Christensen, 2003) and simple correlation approach rooted in the paper by Pearson and Lee (1899), which was subsequently used by many researchers (for instance: Imazumi, Nei, and Furuscho, 1970; Langford and Wilson, 1985; Murphy and Knudsen, 2002).

Apparently the correlation approach is far from being the best solution if we want to estimate the heritability of human fertility. It gives rather a crude estimate of the strength of the relation between fertility of two generations of genetically related individuals. Since we cannot control for the shared environmental influences it is not possible to isolate the effect of genetic factors. The choice of the method is determined by the nature of the data. The

[1] Compare similar assumptions in (Tymicki, 2004).

methodology, which enables us to isolate genetic effects, requires specific data sets, preferably twin data and there is no restriction posed on the data set in the correlation approach. Thus most of the researchers working with the historical data use the correlation approach.

Current paper contributes to the "correlation branch" of the intergenerational fertility transmission studies, which is of course dictated by the nature of the data. Therefore, all interpretations of the correlation coefficients referring to genetics of the fertility transmission are unjustifiable. It could be only assumed that there is a genetic mechanism behind expected positive correlation of fertility outcomes between two successive generations. The only justified inference based on the correlation coefficients is that there is (or there is no) relation between fertility of the two successive generations and we can refer these results to some hypothetical explanations.

RESULTS

The analysis reports the intergenerational correlation between fertility of 3$^{rd}$ and 2$^{nd}$ generation (sons/daughters vs. fathers/mothers) and 3$^{rd}$ and 1$^{st}$ generation sons/daughters vs. grandfathers/grandmothers) with respect to the birth cohort of a youngest generation (third generation). Additionally, it gives the correlation measures of the outcome variables between the generation 2$^{nd}$ and 1$^{st}$. Taking into account the degree of genetic relatedness is basically the replication of correlation between the generation 3$^{rd}$ and 2$^{nd}$. The only difference is with respect to the birth cohort of the studied generations. The summary results of these calculations, separately for males and females, are given in the TABLE 2a and 2b. As mentioned above, second outcome variable is the number of survivors, which was created only for women from the Bejsce parish. Similarly, the correlation coefficients were calculated for all possible combinations of selected generations.

**Intergenerational correlation of completed fertility**

Firstly, the analysis focuses on the correlation between completed fertility across three generations: i.e. between 3rd and 1st generation. The comparison of the coefficients for males and females presented in the middle row of the TABLES 2a and 2b reveal quite different patterns. In the case of males (TABLE 2a) there is no correlation between completed fertility of sons and grandfathers (3$^{rd}$ and 1$^{st}$ generations). Such pattern of no relationship among males from relatively distant generations has been reported in many studies see comprehensive review by (Murphy, 1999).

[TABLES 2a, 2b, 2c ABOUT HERE]

However, the results for females reveals that there is also a lack of relationship with except for the cohort born between 1851 and 1875, for which there is a strong positive and significant correlation between completed fertility of daughters ($3^{rd}$ generation) and grandmothers ($1^{st}$ generation). Since there is no benchmark study, which allows for the comparison, it is difficult to hypothesize about the explanations for this result. It is however plausible to assume that this strong relationship might result from the sample selection bias since other results from this same birth cohort show different pattern. This is particularly obvious if we take look at the graphical presentation of the coefficients given at the mid-panel of the FIGURE 2.

The analysis of correlation between completed fertility of the successive generations ($1^{st}$ - $2^{nd}$ and $2^{nd}$ - $3^{rd}$) brings more predictable results (compare first rows of the TABLES 2a and 2b and FIGURE 2). As predicted on the basis of reviewed studies there is a strong positive and significant relationship between fertility of parents and children. Especially, the correlation between fertility of mothers and daughters ($2^{nd}$ vs. $3^{rd}$ generation) show clear time dependent pattern, with relatively high and significant coefficient for the youngest cohort. There is no such an effect between completed fertility of $1^{st}$ and $2^{nd}$ generation. It has to be noted that these generation were during their reproductive ages much earlier than $3^{rd}$ generation (compare TABLE 7-1) which may also reflect the fact that the correlation is strongly time dependent.

The results for males are less clear. There is a positive relationship for the youngest cohort of the 3rd generation (born 1800-1850) and slightly negative for the birth cohort 1851-1875, although the significances for both figures are weak. Therefore, it could be assumed that the level of variation in completed fertility of males from the Bejsce parish is much stronger than for females. Additionally, we have calculated the intergenerational correlation with respect to the number of survivors (compare TABLE 2c and bottom panel of FIGURE 2). This was done in order to answer the question about the possible intergenerational relationships between the number of woman’s surviving children. The results are quite coherent showing rather negative relationship. In principle, the larger surviving sibship size of and individual the lower is the correlation with the individual’s number of surviving children. The only exception is the positive correlation between the number of surviving children for daughter’s from the youngest birth cohort which might be associated with overall decrease in the infant mortality rate.

[FIGURE 2 ABOUT HERE]

## DISCUSSION

The issue of intergenerational transmission of fertility has been analyzed so far mostly from the perspective of inheritance of reproductive behaviour. However, non-adequate methodology did not allowed isolating purely genetic effects. Recent methodological improvements and use of twin design studies made possible to estimate the genetic effects on human fertility more precisely (Kohler, Rodgers, and Christensen, 1999; Rodgers et al., 2001). In order to achieve that it was necessary to resign from traditional studies of correlation between fertility outcomes of successive generations. Using the data from Bejsce parish it was not possible to use mentioned methodological improvements, therefore standard correlation approach was applied. From such an approach it is not possible to infer about the genetic effects. It is only possible to give a very crude account for the strength of relationship between fertility of parents and children and grandparents.

If we look at the results of current analysis we can think about them not only as the measure of relationship between fertility of parents and children but also as a measure of relationship between the number of children born to individual from generation *x* and the individual's sibship size. This perspective adds a new possible explanation, which reach beyond the genetic reasoning. As argued in one of the previous papers (Tymicki, 2004), in traditional populations siblings played a major role in the individual reproductive performance measured both by the completed fertility and by the risk of parity transition. This is associated with so-called *helpers-at-the-nest* hypothesis, which predicts that siblings constitute an important source of help that may alter individual reproductive performance. This might partially explain the positive relationship between number of siblings and individual fertility. One may expect that such a relationship will be strongly dependent on individual birth rank. As shown elsewhere (Tymicki, 2004), individuals with low birth rank (first born children) enjoy higher rates of reproduction then their later born siblings.

Indeed, recent advances in the field of intergenerational fertility transmission studies tried to explore the relation between individual birth rank and strength of relationship between fertility of parents and children (Murphy and Knudsen, 2002). This path of research seems natural, since it is difficult to isolate the genetic effects.

[FIGURE 3 ABOUT HERE]

Therefore if we are not able to isolate the genetic effect we should try to control for as much as possible of the environmental effects (Anderton et al., 1987;compare studies by: Johnson and Stokes, 1976).

Although the inference based on the results of the present chapter is limited because of used methodology, it is however possible to compare the results with the results of the previous studies. Such a comparison is presented on the FIGURE 3. The only study that covers similar period was conducted by Imaizumi et al. for the Japanese population of Uto community (Imazumi, Nei, and Furuscho, 1970). Interestingly the results obtained for the population of Bejsce parish follow quite closely the estimates for the Japanese population. The increase in the correlation at the beginning of the 20$^{th}$ century is preceded by negative relationship at the end of 19$^{th}$ century. After that point the correlation between reproductive outcomes of two successive generations is increasing.

This shape of time dependency seems to be quite standard finding for all populations. The increased strength of relationship between fertility of parents and children at the turn of the 20$^{th}$ century with comparison to previous decades has been tried to explain by growing importance genetic factors in fertility behaviour during changes associated with so-called fertility transitions (Kohler, Rodgers, and Christensen, 2003). However one may think about the alternative explanation which attributes the increase in the strength of relationship to the lower variance in the reproductive outcome during and after the fertility transition. Since fertility transition is, among others, associated with increase in the predictability of environment (for instance lower infant mortality) the fertility rates drop as a response to such a change. In the natural fertility populations, where there was no relationship between fertility outcomes of parents and children, the variation in the fertility was much higher due to possible irregularities in the reproductive process caused by the proximate determinants of natural fertility. These factors like: length of breast-feeding, nutrition, good or bad harvest etc. could cause intergenerational variation and made the fertility outcomes less predictable. On the other hand, during and after the fertility transition the number of produced children and their survival were much more predictable and uniform for the whole population which led to increase in the correlation between fertility of parents and children. Therefore, nowadays due to these changes fertility of parents seems to be by far better predictor for fertility of children than it was 200 hundreds years ago.

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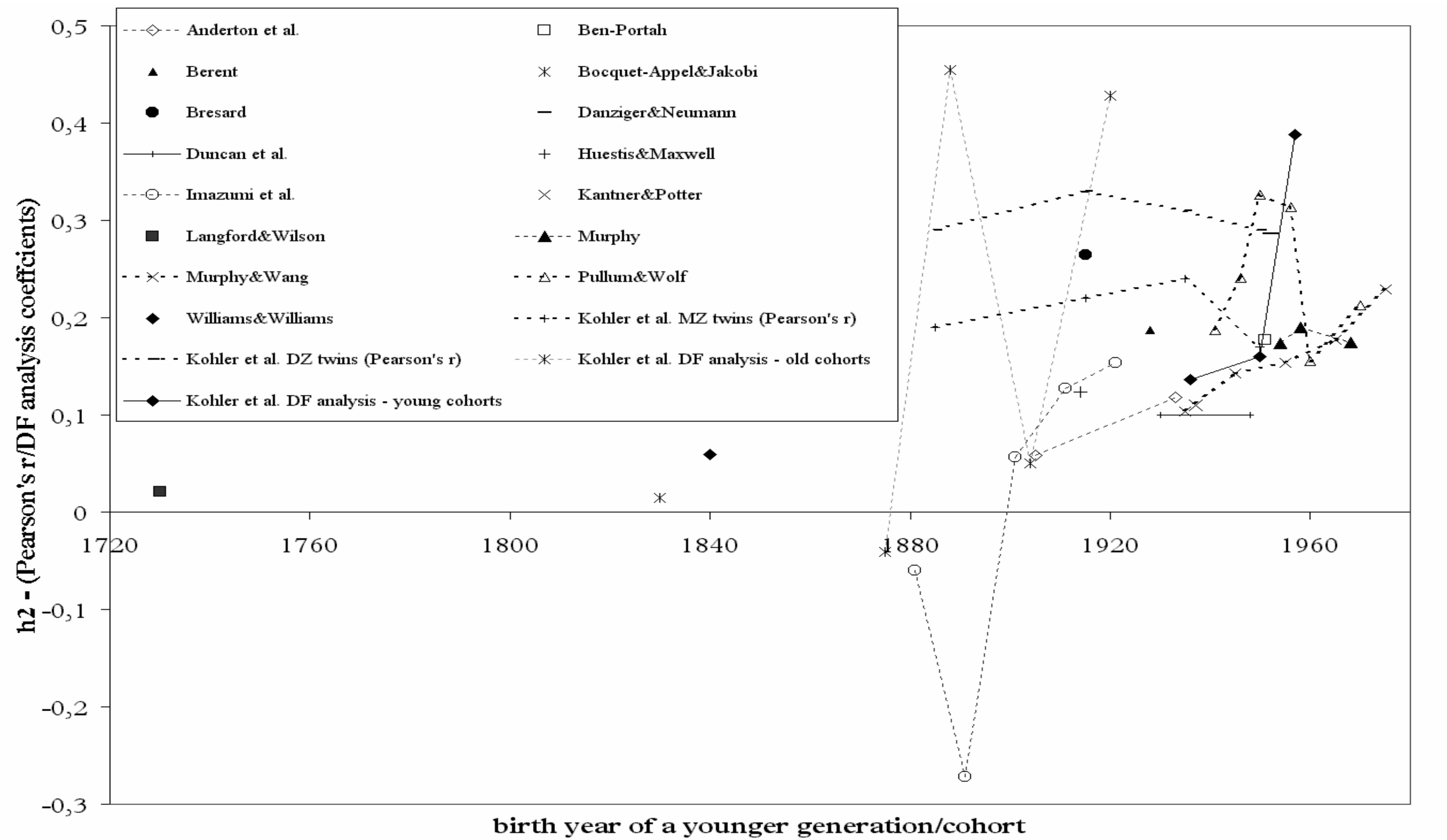
FIGURE 1. Pooled results of studies on intergenerational transmission of fertility and heritability of fertility between twins by birth year of younger generation/birth cohort




Source: modified from (Murphy, 1999); (Bocquet-Appel and Jakobi, 1993;Imazumi, Nei, and Furuscho, 1970;Kohler, Rodgers, and Christensen, 2003)

TABLE 1. Birth cohorts of the three successive male and female generations under analysis.

| | BIRTH COHORT | | | |
|---|---|---|---|---|
| **Third generation (sons\daughters)** | **1800-1850** | **1851-1875** | **1875-1900** | **1900-1923** |
| | MALES | | | |
| Second generation (fathers) | 1773-1828 | 1796-1850 | 1822-1877 | 1850-1900 |
| First generation (grandfathers) | 1741-1797 | 1752-1825 | 1766-1845 | 1806-1869 |
| | FEMALES | | | |
| Second generation (mothers) | 1767-1830 | 1811-1852 | 1834-1880 | 1858-1903 |
| First generation (grandmothers) | 1740-1805 | 1779-1825 | 1802-1856 | 1816-1880 |

TABLE 2a. Pearson correlation coefficients between completed fertility of men from this same lineage by birth cohort of the youngest generation (sons), Bejsce parish.

| | 1800-1850 | | 1851-1875 | | 1876-1900 | | 1901-1923 | |
|---|---|---|---|---|---|---|---|---|
| Son vs. father | 0,174** | *(p=0,022 n=173)* | -0,129* | *(p=0,051, n=231)* | 0,042 | *(p=0,554 n=199)* | 0,092 | *(p=0,163 n=231)* |
| Son vs. grandfather | -0,049 | *(p=0,524 n=173)* | -0,086 | *(p=0,193 n=231)* | 0,019 | *(p=0,786 n=199)* | -0,043 | *(p=0,514 n=231)* |
| Father vs. grandfather | 0,139* | *(p=0,069 n=173)* | 0,016 | *(p=0,804 n=231)* | 0,008 | *(p=0,910 n=199)* | -0,078 | *(p=0,239 n=231)* |

Note: significance level and number of cases in the parentheses. Significance: '*'=10%; '**'=5%; '***'=1%.

TABLE 2b. Pearson correlation coefficients between completed fertility of women from this same lineage by birth cohort of the youngest generation (daughters), Bejsce parish.

| | 1800-1850 | | 1851-1875 | | 1876-1900 | | 1901-1923 | |
|---|---|---|---|---|---|---|---|---|
| Daughter vs. mother | 0,114 | *(p=0,14 n=168)* | -0,012 | *(p=0,879 n=158)* | 0,007 | *(p=0,921 n=202)* | 0,205*** | *(p=0,002 n=237)* |
| Daughter vs. grandmother | 0,016 | *(p=0,841 n=168)* | 0,208*** | *(p=0,009 n=158)* | 0,037 | *(p=0,600 n=202)* | -0,008 | *(p=0,903 n=237)* |
| Mother vs. grandmother | -0,102 | *(p=0,182 n=172)* | 0,019 | *(p=0,810 n=171)* | 0,034 | *(p=0,632 n=206)* | -0,024 | *(p=0,701 n=257)* |

Note: significance level and number of cases in the parentheses. Significance: '*'=10%; '**'=5%; '***'=1%.

TABLE 2c. Pearson correlation coefficients between number of surviving children for women from this same lineage by birth cohort of the youngest generation (daughters), Bejsce parish.

| | 1800-1850 | | 1851-1875 | | 1876-1900 | | 1901-1923 | |
|---|---|---|---|---|---|---|---|---|
| Daughter vs. mother | -0,114 | *(p=0,142 n=168)* | -0,038 | *(p=0,640 n=157)* | -0,179** | *(p=0,011 n=202)* | 0,136** | *(p=0,037 n=237)* |
| Daughter vs. grandmother | 0,067 | *(p=0,389 n=167)* | -0,031 | *(p=0,700 n=157)* | 0,091 | *(p=0,2 n=202)* | -0,002 | *(p=0,972 n=233)* |
| Mother vs. grandmother | -0,185** | *(p=0,016 n=171)* | -0,127 | *(p=0,097 n=171)* | -0,073 | *(p=0,3 n=206)* | -0,168*** | *(p=0,008 n=253)* |

Note: significance level and number of cases in the parentheses. Significance: '*'=10%; '**'=5%; '***'=1%.

FIGURE 2. Graphical presentation of correlation coefficients from the TABLE 2a. Top: males; Middle: females; Bottom; females (number of survivors).

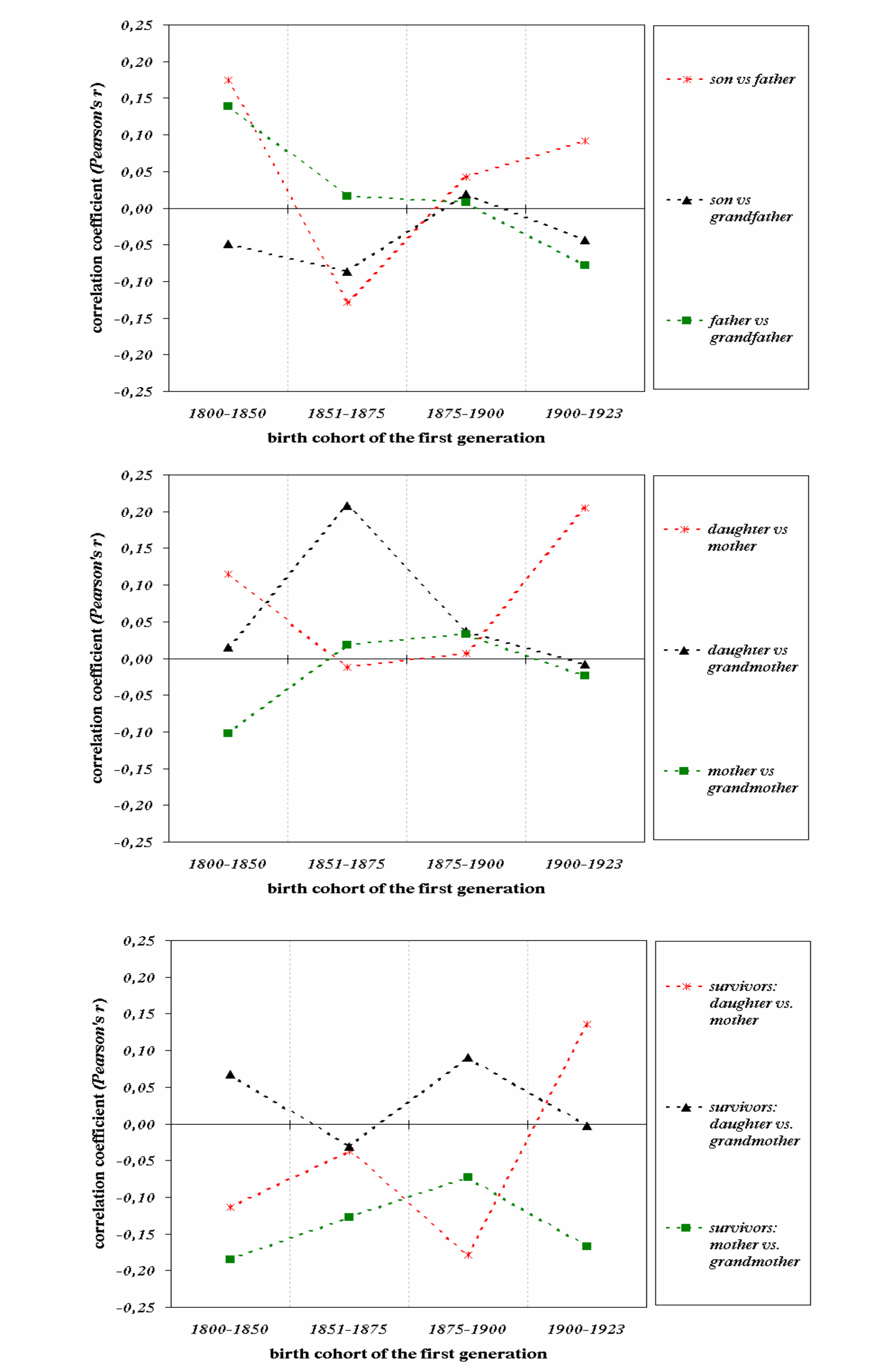
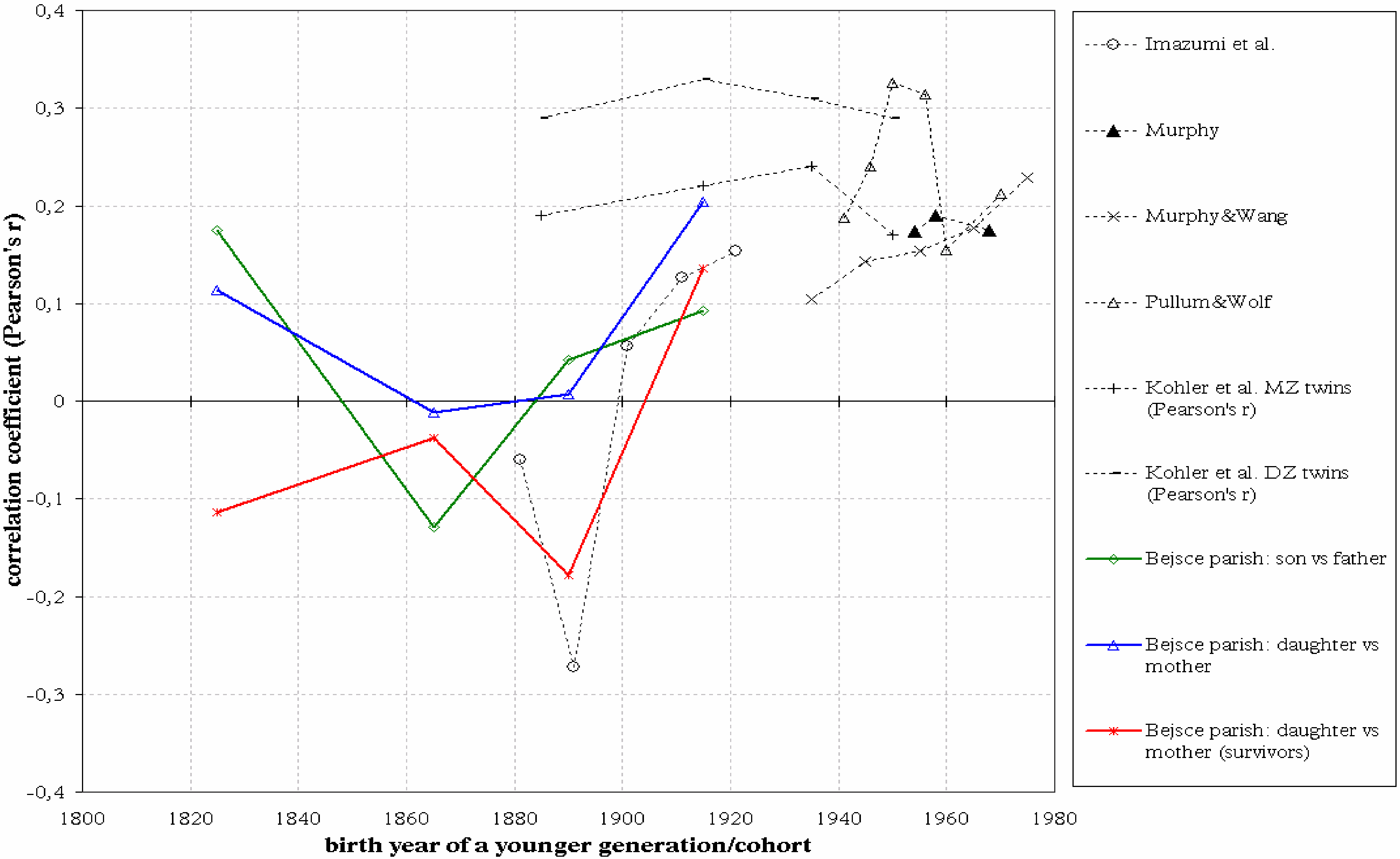


FIGURE 3. Compared results of the intergenerational (twin pair) correlation between fertility based on pooled results of selected past studies and the study of the Bejsce parish.




Source: modified from (Imazumi, Nei, and Furuscho, 1970;Kohler, Rodgers, and Christensen, 2003;Murphy, 1999) and own calculations