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Science Technology Human Values 1996; 21; 54
DOI: 10.1177/016224399602100103

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Large differences in scientific productivity between male and female researchers have not yet been explained satisfactorily. This study finds that child care and lack of research collaboration are the two factors that cause significant gender differences in scientific publishing. Women with young children and women who do not collaborate in research with other scientists are clearly less productive than both their male and female colleagues.

Introduction

Even though a number of studies have attempted to explain the large differences in scientific productivity between male and female researchers, the puzzle is not yet solved (cf. Cole and Zuckerman 1984). A number of explanations have been proposed to account for this difference (Kyvik 1991). It has been claimed that women are less integrated into professional networks than are men and that they are accordingly less motivated or enjoy fewer opportunities to be productive. Women are said to have less access to resources and assistants for doing research. They use less time for research than do men, either because they are less motivated to engage in research or because they are not able to use as much time for research as are men. In addition, women often interrupt their research careers because of childbirth and have more caring responsibilities than do men. These different explanations have also been integrated into the "cumulative advantage theory" (Cole and Cole 1973). If women do less well than men on a number of such indicators, productivity differences are likely to reflect different cumulative

Science, Technology, & Human Values, Vol. 21 No. 1, Winter 1996 54-71

effects for men and women over time. Finally, this theory has been further developed into the "theory of limited differences" (Cole and Singer 1991).

In an earlier study, based on data from Norwegian universities, we suggested that child care is the most critical factor for women's scientific productivity (Kyvik 1990b, 1991). Whereas women with children younger than ten years of age published considerably less than did their male counterparts, women whose children were older were as productive as men in the same family situation and academic position.

This finding contradicted the conclusions drawn in other studies (Cole 1979; Cole and Zuckerman 1984), which indicated that women with children publish more than do childless women and thus suggested that women's lower productivity cannot be due to maternal responsibilities. We argued, however, that comparisons between women with children and those without children can be misleading. When children's age is introduced as a variable, child care turns out to be an important determinant for women's publishing activity.

The effect of having young versus older children on women's and men's publishing activity is, however, still not settled. A study by Fox and Faver (1985) reports that having small children is positively related to women's productivity, whereas our study came to the opposite conclusion. How can this be explained?

Both samples were confined to the rank of assistant professor or higher. The samples were therefore comparable except that Fox and Faver studied the American research population and we studied Norwegian scientists. In addition, our sample included men and women in twenty-seven different disciplines within the social, natural, and medical sciences and the humanities, whereas Fox and Faver's study was confined to faculty members in graduate social work programs. As the authors note, the high proportion of women in social work compared to other fields may restrict the generalizability of their findings, making them inapplicable to disciplines that are male dominated. It is, however, impossible to say whether these differences can explain the contradictory findings.

Against this background, we decided to repeat our study ten years later to see whether we would find any changes in men's and women's productivity. In addition, our earlier work generated a number of new questions that deserved further investigation.

First, the fact that women with young children were almost 50 percent less productive than their male colleagues in the same situation requires an explanation. Are interruptions in women's research careers due to childbirth the most important hindrance? Are arrangements for taking care of children

during the day or after school so unsatisfactory that they severely hinder women's research careers? The new study included questions on the importance of these factors for research activities.

Second, the most widely used explanation for gender differences in productivity is that women in male-dominated universities have problems in becoming integrated into important informal networks (Bernard 1964; Reskin 1978; Cole 1979; O'Leary and Mitchell 1990; Fox 1991). If women are excluded from important networks so that their opportunities for collaboration in research are thus restricted, their publishing activity and academic careers may be adversely affected (Cole 1981).

Evidence suggests that teamwork in itself stimulates productivity (Pelz and Andrews 1966; Price and Beaver 1966). Price and Beaver report that even when corrections are made for multiple authorship (by assigning $1/n$ of a point for the occurrence of a scientist's name among n authors of an article), those who publish most joint papers are still the most productive. Evidence also suggests that researchers who collaborate produce higher quality work than do those who work alone (Stephan and Levin 1987). Studies of editorial decisions in leading journals in physics (Zuckerman and Merton 1971), in astronomy (Gordon 1980), in social psychology (Presser 1980), and in cancer research (Lawani 1986) show that joint-authored papers have a higher acceptance rate than do single-authored papers.

The question of whether there are gender differences with respect to research collaboration and publishing activity has not been examined sufficiently. The "exclusion hypothesis" has received very little empirical attention despite some evidence that lack of research collaboration between graduate students and their mentors negatively influences women's publishing activity (Long 1990). Furthermore, Long reports that for female graduate students but not for males, opportunities for collaboration were decreased significantly by having young children. The relationship among having young children, collaboration in research, and publication needs to be investigated also for faculty members, and this study includes data on collaboration in research.

Data and Methodology

The data are drawn from a questionnaire study conducted in spring 1992 among all faculty members (except those in technology where the number of women faculty members is very low) of the rank of assistant professor or higher at Norway's four universities. The response rate was 70 percent for men ($N = 1,277$) and 68 percent for women ($N = 252$).

The questionnaire required that faculty members specify the number of publications during the three-year period 1989-91, dividing them into four categories:

— articles in scientific and scholarly journals;
— articles in research books, textbooks, and conference proceedings;
— research books and textbooks; and
— reports.

Faculty members were instructed not to include abstracts or book reviews and to include reports only if they were part of a publication series.

To adjust for the effect of multiple authorship on the output variable and to enable us to make comparisons of productivity patterns across fields of learning and between individual researchers, a productivity index that takes account of types of publication and co-authorship was developed. All publications have been transformed to article equivalents. An article in a journal or book or a report was given the value of 1 point, and a book was given the value of 4 points. This means that an article is regarded as one article equivalent and a book is regarded as four such equivalents. In cases of co-authorship, the number of points according to whether the publication was an article, a book, or a report was divided by 2, irrespective of the number of authors. To give full credit to all authors would have meant overestimating the productivity of researchers in those disciplines where joint authorship is normal and would have distorted the pure effect of teamwork on scientific output. The index thus measures the number of article equivalents produced during the three-year period 1989-91.

The empirical justification for this weighing procedure is given in Figure 1. It illustrates the relationship between real and adjusted publication counts in four major fields of learning: the humanities and the social, natural, and medical sciences. On average, each faculty member had 8.0 publications during the three-year period. The average was highest in the medical sciences and lowest in the humanities. However, when the productivity index is used, differences between the medical sciences, the social sciences, and the humanities disappear, whereas the average number of article equivalents is somewhat lower in the natural sciences. The reason for the latter result may be that the average natural scientist is less productive than the average colleague in the other fields. In natural sciences, for example, the average number of article equivalents per faculty member is lower among older researchers than it is among younger ones, indicating that natural scientists have problems in keeping up with the research front as they become older (Kyvik 1990a). Because publishing practices vary among disciplines, these

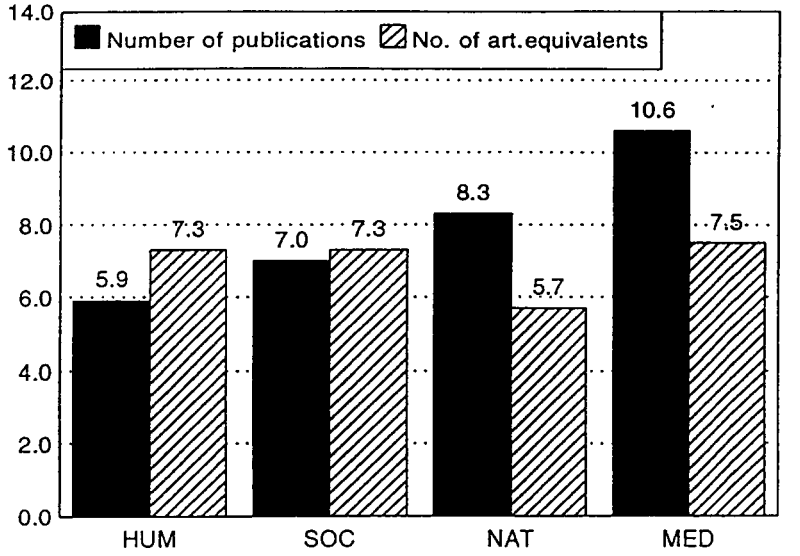

Figure 1. Average number of publications and article equivalents during the period 1989-91, by field of learning.

figures do not necessarily reflect real productivity differences; nevertheless, it appears that the choice of weights and fractional counts offers a rough but acceptable measure of productivity across fields of learning.

Although the picture of research productivity is altered substantially by the introduction of the index, the total number of publications and total number of article equivalents are strongly correlated (Pearson's $r = .86$). In the various fields, these relationships are even stronger (.92 in the humanities and the social sciences, .93 in the natural sciences, and .88 in the medical sciences).

We used regression analysis to test simultaneously the effects of young children and of research collaboration on published output. In addition to these two variables, a number of other factors may contribute to explaining gender differences in productivity and thus change the relative impact of child care and research collaboration on scientific publishing. We included the following variables that might be of some importance: rank, age, research funding, international contact, and number of children.

The independent variables have been operationalized in the following ways.

Rank

Several studies report that publication productivity tends to increase with academic rank (Trow and Fulton 1975; Blackburn, Behymer, and Hall 1978; Knorr et al. 1979; Kyvik 1991). In Norway, this cannot be due to differences in the time available for doing research because the universities have established norms that all faculty members should have about the same amount of time for this activity. The present study also finds that there are virtually no differences in the average time used for research by full, associate, and assistant professors as reported by individual staff members.

This variable is measured at an ordinal level, whereas regression analysis normally assumes that the variables are at an interval level. We have solved this problem by constructing a set of dummy variables where "full professor," "associate professor," and "assistant professor" are regarded as independent dichotomous variables with the values 1 and 0. "Assistant professor" is chosen as a reference category to study the effect of being a "full professor" or an "associate professor."

Age

This is a continuous variable.

Research Funding

This variable is constructed as a dichotomous variable. Faculty members who, during the course of the previous five years, received funding from outside the university are given the value 1; the rest are given the value 0.

Research Collaboration

Information on whether faculty members have collaborated with colleagues on research projects is used as one of two indicators on integration in the scientific community. The variable is operationalized on the basis of information about research collaboration (which does not necessarily include collaboration in publication) with other researchers during the period 1989-91. The variable is constructed as a dichotomous variable. Those who have had such collaboration are given the value 1; the rest are given the value 0.

International Contact

The other indicator of integration in the research community is degree of contact with colleagues in other countries. Some scientists have a wider contact network than do others, and it has been shown that these scientists also tend to be more productive than other researchers (Kyvik and Larsen 1994).

This variable is constructed as an additive index for international scientific communication. Those who participated in a conference or seminar in 1991 are given 1 point, those who participated in two conferences are given 2 points, and those who participated in three or more conferences are given 3 points. The same procedure is used for study or research visits, guest lectures, evaluation work, and research collaboration. Each of these forms of contact may receive a maximum of 3 points. In other words, it is possible to receive up to 15 points.

Young Children

This variable is constructed as a dichotomous variable. Faculty members with children under the age of eleven years are given the value 1; others are given the value 0. In this respect, we are following Long, Allison, and McGinnis (1993).

Number of Children

The bivariate relationship between the number of children and productivity is curvilinear, and the variable therefore cannot be directly used in the regression analysis. Accordingly, we have therefore constructed a set of dummy variables: "no children," "one child," "two children," and "more than two children," where "one child" is used as reference category.

Some of the independent variables refer to the year 1991, whereas the publication data are from the period 1989-91. This means that publications for that period cannot be the result of work in 1991. We assume, however, that the values of these variables are an expression of relatively stable activity levels, and the variables may thus be used as explanatory indicators for publishing activities during the period 1989-91.

Some researchers are highly productive in comparison to the average researcher. The values of the dependent variable are thus distributed unevenly. This can be important for the amount of explained variance in the regression analysis. We have therefore examined whether the results change if those sixty-six persons who have more than 20 article equivalents during the

three-year period studied are excluded from the analysis. The differences are insignificant, however, and the prolific researchers have therefore been included in the analysis.

To study the effects of child care and research collaboration on scientific publishing, we have chosen first to show the bivariate relationship between each of the two variables and productivity. Thereafter, the relative effects of these two variables and a number of other factors that may influence gender differences in scientific output are tested by means of regression analysis.

Results

Productivity Differences between Men and Women

On average, men published 6.9 article equivalents during the three-year period 1989-91, whereas women published 5.6 (i.e., 20 percent fewer articles). Corresponding figures for number of publications are 8.3 for men and 6.1 for women. In addition, 9 percent of the male faculty and 11 percent of the female faculty had not published anything during that period. Gender differences in productivity are therefore not due to a higher proportion of nonpublishing women, nor are these differences due to inequalities in coauthorship. Among male faculty, 42 percent of the publications were coauthored compared to 49 percent among female faculty. This latter result is also reported in other studies (Cole and Zuckerman 1984; Long 1992).

However, large differences exist among individual scientists in publishing productivity. Relatively few scientists produce most of the publications, and large groups are typically low producers. These patterns are also shown to hold for both men and women (Cole 1979; Cole and Zuckerman 1984). Just as these studies found, we also find the productivity pattern to be as skewed among women as it is among men. About 20 percent of both male and female faculty account for half of the published works. These figures are exactly the same as those for the period 1979-81 (Kyvik 1991).

Productivity differences between men and women are shown in Figure 2. Few persons are prolific publishers, whereas the majority have a more "normal" publishing practice (i.e., 1 to 3 article equivalents per year). More men than women may be characterized as prolific researchers as 26 percent of the men, and only 18 percent of the women, published more than 3 article equivalents per year.

Several studies indicate that publishing activity varies by age (Dennis 1966; Bayer and Dutton 1977; Kyvik 1990a; Stephan and Levin 1992). In our study, the average productivity is highest in the forty- to forty-nine-year-

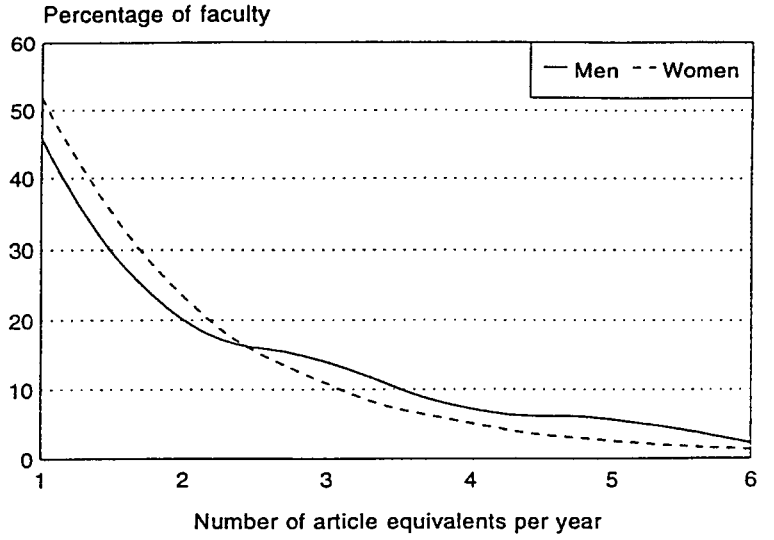

Figure 2. Distribution of number of article equivalents per year during the period 1989-91.

old age group (Figure 3). This relationship between age and productivity holds for men as well as for women. The most important result is that male faculty members under age 40 published twice as many article equivalents as did their female counterparts, whereas differences between men and women are small (10-15 percent) for faculty over age 40. However, gender differences in productivity cannot be explained by age differences. Even though female faculty members are on average two years younger than their male counterparts (47 vs. 49 years), there are no differences in mean age between men and women in the three age groups.

This tendency is also found in a longitudinal study of American biochemists. Long (1992) reports that whereas sex differences in publication increase over the first decade of a career, they diminish over the second decade. A significant proportion of females increase their productivity, whereas the average male's productivity levels off.

Children and Productivity

One explanation for the relationship between age and scientific productivity for women could be that women are behind their male colleagues in the development of their careers because of childbirth, maternity leave, and

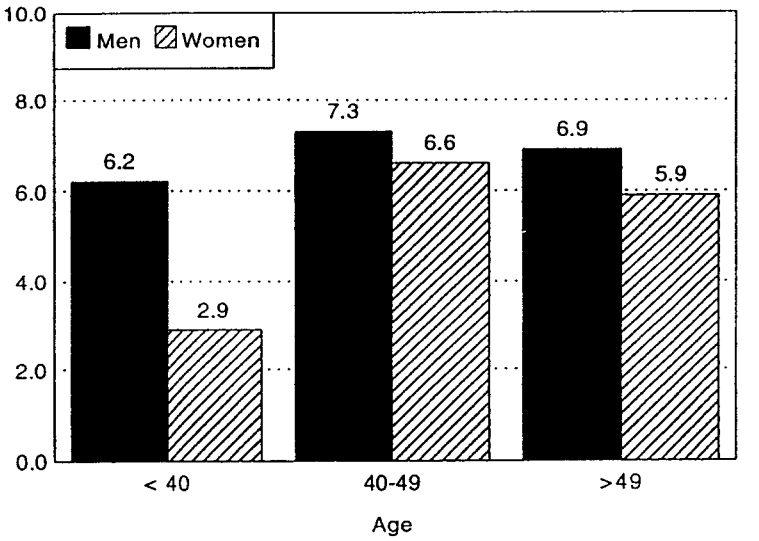

Figure 3. Average number of article equivalents during the period 1989-91, by age.

caring responsibilities. As expected, the results of the current study are similar to those of our earlier research. Women with children younger than eleven years of age published 41 percent fewer article equivalents than did their male counterparts, whereas for women and men all of whose children were over age ten years old this difference was reduced to 8 percent.

Other data support this finding. For example, women with children under age eleven worked 5.5 hours less per week than did their male colleagues in the same situation, but there were no differences between men and women all of whose children were over age ten.

It is difficult to disentangle the effects of disruption in a research career resulting from childbirth and maternity leave from the effects of caring responsibilities. The number of women in this study is too low to undertake detailed analyses. We can address the question indirectly by distinguishing between women with children under six years of age (preschool age) and those with children ages six to ten at the time the survey was undertaken (spring 1992). The first group has children born in 1987 or later, and the publication data were collected for the years 1989-1991. Possible effects of childbirth and maternity leave should thus be seen by comparing the average publishing level during this period to corresponding publication data for

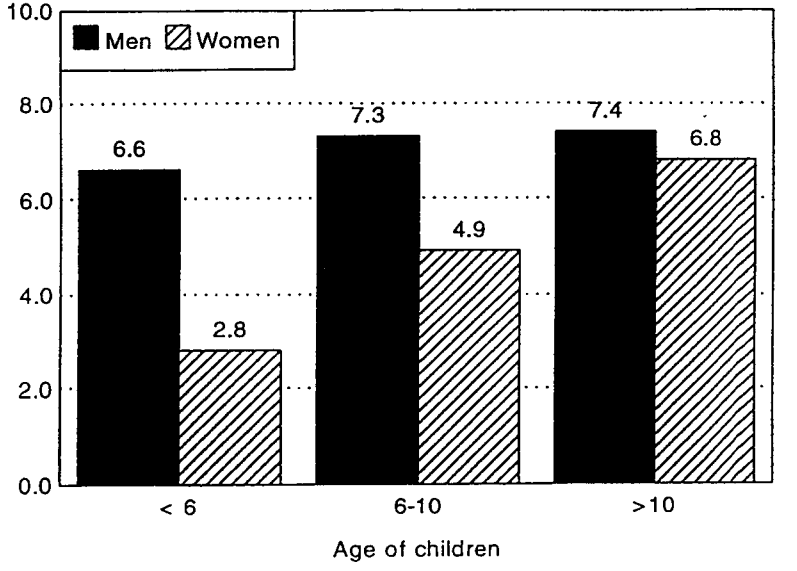

Figure 4. Average number of article equivalents during the period 1989-91, by age of children.

women with children ages six to ten in 1992. Whether having children in the latter age group will affect publishing activities may be studied by comparing men in the same situation and women with children over age ten.

The results, shown in Figure 4, indicate clearly that the age of children does not play any role for the productivity of men. However, women with children under age six were almost 60 percent less productive than were their male counterparts during the three-year period, and women with children ages six to ten published 30 percent fewer article equivalents than did men in the same situation.

This indicates that maternity leave greatly reduces women's scientific productivity, but child care in itself also affects the publishing activity of women.

Faculty members were also asked to assess the degree to which caring responsibilities affected their ability to engage in research. The majority of women (71 percent) and men (60 percent) replied that caring responsibilities resulted in "great" or "some" problems regarding research. More women (18 percent) than men (7 percent) replied that caring responsibilities resulted in

"great" problems in relation to research. However, the differences between men and women in this area increase if we distinguish between caring for children in different age groups. Among women with children under age six, 40 percent replied that caring responsibilities caused "great" problems for their research compared to 26 percent of the women with children ages six to ten and 7 percent of the women whose children all were older than age ten. The corresponding figures for men are 13, 15, and 2 percent.

Having suitable day care arrangements for young children is presumably decisive for the peace of mind necessary for doing research. We attempted to survey the kind of child care provisions for university researchers with children under age eleven and how satisfied they are with these. We distinguished between children of school age under age eleven and children younger than school age.

Among those faculty members with children under school age, the majority had kindergarten places for their children. This pertained to more women (84 percent) than it did to men (60 percent). The majority were very or generally pleased with the provisions for day care for children under school age, as 80 percent of both women and men were very pleased.

Different kinds of after-school provisions were normal for those faculty members who had children age ten or younger. More women (69 percent) than men (40 percent) replied that either recreation centers or family, relatives, or neighbors took care of their children. More men (28 percent) than women (6 percent) replied that their spouses took care of the children or that they did not have any special arrangements. Most university teachers with school-age children under age eleven were either generally or very satisfied with day care provisions. Burdens connected to dissatisfaction with day care provisions for children alone cannot explain why female researchers with children under age eleven are less productive than other women or their male colleagues in the same situation.

Research Collaboration and Productivity

The bivariate relationship between research collaboration and publishing activity is shown in Figure 5. More women (20 percent) than men (12 percent) did not collaborate on research projects with colleagues during the period 1989-91. Faculty members who did not collaborate were less productive than those who worked together with colleagues, and this tendency is much stronger for women than it is for men.

This raises the question of whether women are more dependent than men on collaboration with colleagues when performing research and writing up the results. To get an indication of possible gender differences in this respect,

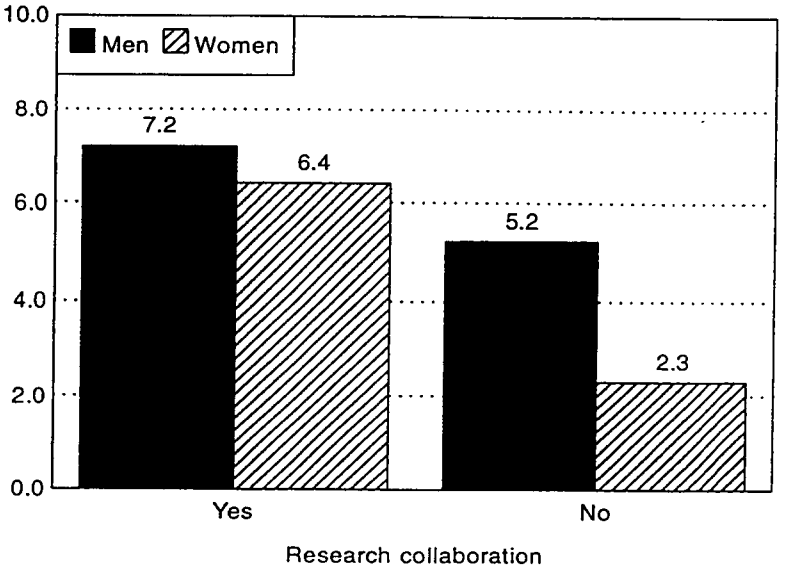

Figure 5. Average number of article equivalents during the period 1989-91, by research collaboration.

faculty members were asked to assess the extent to which a number of different measures might improve the research environment at their department. Questions related to size of the department, management, collaboration, and the psychosocial environment. Four reply alternatives were given: "to a large extent," "to some extent," "no effect," and "don't know." Differences between men and women were largest with respect to the following measures: "more internal collaboration on research," "more support and encouragement from colleagues," and "better psychosocial environment." About 40 percent of female faculty members compared to about 20 percent of their male colleagues replied that such measures might improve the research environment at their departments "to a large extent."

Determinants of Productivity Differences

The results of the regression analysis are presented in Table 1. The two variables that have the greatest effect on productivity differences between men and women are "research collaboration" and "young children." In both of these cases, the differences between men and women are 2 article equiva-

Table 1. Determinants of individual productivity differences

	Men	*Women*
Full professor	3.31*	2.58*
	(.25)	(.20)
Associate professor	1.66*	1.99*
	(.12)	(.17)
Age	−.19	−.08
	(−.05)	(−.02)
Research funding	.39	.17
	(.02)	(.01)
Research collaboration	.15	1.92*
	(.01)	(−.13)
International contact	.79*	.75*
	(.29)	(.24)
Young children	−.06	−2.07*
	(−.00)	(−.16)
No children	.02	−1.11
	(.01)	(−.09)
Two children	.85	−.51
	(.06)	(−.04)
More than two children	1.33*	−1.13
	(.10)	(−.08)
R^2	.16	.22
N	1,122	192

NOTE: Multiple regression analysis with unstandardized and standardized coefficients. Standardized coefficients are in parentheses.
*Significant at the .10 level.

lents during the three-year period. These are also the only two variables for which the coefficients for males are significantly different (at the .10 level) from those for females. Women with young children and women who do not collaborate with other colleagues in research are clearly less productive than both their male and female colleagues. The regression analysis confirms the results of the bivariate analyses presented in Figures 4 and 5.

We also tested whether there are any interaction effects between two pairs of variables in the analysis. The combination of having young children and at the same time many children may result in low publishing activity, especially for women. Furthermore, the combination of having young children and not collaborating with colleagues may negatively influence publishing activities for women. However, no significant interaction effects can be shown. This does not mean that these conditions might not be important. The number of women falling into these two categories is so low that reliable effects cannot be measured.

With respect to the relationship between child care and research collaboration, our data show that 20 percent of the women with young children (under age eleven) and the same proportion of women with older children had not collaborated with fellow colleagues during the three-year period. This indicates that lack of research collaboration can only to a small extent be due to maternal responsibilities.

For faculty with more than two children, male staff members on average published 2 more article equivalents during the three-year period than did their female counterparts. However, in this case, the coefficients for men and women are not significantly different from each other. These women are, in addition, not significantly less productive than their female colleagues with no children or with one or two children. Thus having many children cannot be the reason why male researchers are productive. The results suggest that men, in contrast to women, manage to be productive in spite of their family situation.

Discussion

Our earlier finding that child care is a critical factor for publishing activity among female faculty but not among male faculty is supported by the present survey. This study also indicates that interruptions in women's careers due to childbirth temporarily reduce their publication rates and that women, in spite of equity principles, take more responsibility than their male colleagues for preschool and early school-age children. There were no significant differences of opinion between male and female staff with regard to their satisfaction with their arrangements for taking care of children during the day or after school.

The evidence of a negative relationship between women's, but not men's, publishing activity and their family situation appears solid. The differences between our two studies and the American studies referred to earlier are surprising and can probably be explained only by differences in the social structure or culture or by incomparable data sets.

A sociocultural explanation might be that Norwegian women spend more time with their children during the first year after birth than do their American counterparts. The social security system in Norway provides for full-wage compensation for forty-two weeks parental leave or fifty-two weeks with 80 percent wage compensation. The leave may be shared between a mother and a father, but fathers very seldom use this opportunity. An additional explanation might be that the majority of female faculty members at Norwegian

universities have kindergarten places for their children, an arrangement that implies taking the children out of the house and picking them up. Their American female counterparts rely to a larger extent on day care mothers. This latter arrangement is probably less time consuming for the parents, and day care mothers may also do some of the housework, giving mothers more time for scientific work.

These sociocultural differences between the two nations might to some extent account for the differences in results. But if this is so, then why do American women not publish at the same rate as their male colleagues? In Norway, in both our 1982 and 1992 investigations, female faculty members were virtually as productive as their male colleagues when they passed the period of having young children. How can this be explained?

Incomparable data sets might therefore provide a better explanation for these differences. Whereas we used cross-sectional data, the two most important American studies in this respect used longitudinal data. However, because they compared men and women not over their whole life courses but only during the first 12 years (Cole and Zuckerman 1984) and 17 years (Long 1992) after graduation, the majority of women who passed the period of having small children were not included in these two studies. This means that the effect of having passed this period has not been properly taken into consideration. More detailed comparative work is required to settle this question.

In addition, we have found that lack of research collaboration with colleagues, inside or outside a university department, has a significant negative impact on women's productivity but not on men's productivity. We also found that women, more so than men, want more collaboration with other researchers and more support and encouragement from colleagues. Are female scientists more dependent than men on collaboration with colleagues? Reskin (1978) argued that women are less confident professionally and therefore more dependent on support from their working environments than are their male colleagues. A study of research groups in the natural sciences and technology in six European countries may support this hypothesis. The women were as satisfied as men with the work atmosphere in their groups. The same number of women and men had frequent contact with their group leader, but many more women than men thought this contact was important for their own work (Stolte-Heiskanen 1983). However, all things considered, the empirical evidence for women's larger degree of dependence on the environment is so far weak. Further studies are necessary to illuminate this issue before any conclusions can be drawn.

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