

Mothers' Transitions from Welfare to Work and the Well-Being of Preschoolers and Adolescents

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Results from a longitudinal study of 2402 low-income families during the recent unprecedented era of welfare reform suggest that mothers' transitions off welfare and into employment are not associated with negative outcomes for preschoolers (ages 2 to 4 years) or young adolescents (ages 10 to 14 years). Indeed, no significant associations with mothers' welfare and employment transitions were found for preschoolers, and the dominant pattern was also of few statistically significant associations for adolescents. The associations that did occur provided slight evidence that mothers' entry into the labor force was related to improvements in adolescents' mental health, whereas exits from employment were linked with teenagers' increased behavior problems.

The U.S. welfare system underwent sweeping reforms in the 1990s, culminating in the Personal Responsibility and Work Opportunity Reconciliation Act (PRWORA) of 1996. Several new components were introduced into the main cash welfare program for low-income, predominantly single-mother families, now known as Temporary Assistance for Needy Families (TANF): (i) stricter work requirements for virtually all welfare recipients; (ii) much tougher "sanction" policies, which reduce or terminate benefits to women for not complying with the rules; and (iii) the imposition of a federal 5-year lifetime maximum on the receipt of benefits. Since the mid-1990s, the welfare caseload has plummeted and hundreds of thousands of poor single mothers have entered the workforce. Experts concur that the caseload reduction is a consequence of welfare reform, the booming economy in the 1990s, and the expansion of work support programs such as the Earned Income Tax Credit (1).

Proponents of welfare reform argued that growing up on welfare was harmful to children because it fostered dependency and lack of initiative, thus lowering cognitive achievement and increasing behavior problems. Moving mothers from welfare to work would benefit children because it would increase their families' income, model disciplined work behavior, and better structure their family routines. Opponents of PRWORA countered that an original goal of welfare was to enable impoverished mothers to raise their children at home, a context viewed as especially important for young

children. The reforms were predicted to reduce the time mothers and children spend together, to increase parental stress and decrease responsive parenting, and to move children into low-quality childcare or unsupervised settings while their parents worked. Opponents also feared that families going off welfare would be driven deeper into poverty because they would not be able to earn sufficient incomes to make up for the loss of welfare benefits.

None of these claims had a strong research foundation at the time. Since then, a modest body of research on the impact of welfare and employment on children has emerged. The non-experimental research on welfare is sparse and contradictory. Some research has found no differences in social and cognitive development between children on welfare and children who are poor but not on welfare (2). One study of families who left welfare found no benefit or harm to children (3), while another suggested that transitions off welfare caused problems in child development (4). A more consistent finding indicates that higher family incomes lead to improvements in child well-being (5, 6). For adolescents, findings are also inconsistent, with some indication of negative impacts of welfare participation on adolescents' educational attainment (7), but other evidence of positive effects, especially for African-American adolescents (8, 9). In contrast, when mothers work outside the home, children's development is consistently unaffected (10), with the possible exception of modest decrements in cognitive development in non-Hispanic white children if their mothers had been employed during their children's infancy (11).

Recently, experimental research has been conducted in a series of demonstrations with random assignment methods (12, 13). The treatment groups in these experiments were given various combinations of work require-

ments, sanctions, time limits, earnings supplements, childcare assistance, and intensive case management. In general, preschoolers were neither harmed nor helped by the treatment programs, whereas elementary school children showed positive outcomes—higher levels of school achievement and less problem behavior—albeit mostly when the treatment group received income supplements. In contrast, adolescents of program mothers evidenced troubling developmental patterns, including poorer performance in school, even when family income improved.

This body of research has important limitations. Most of the nonexperimental studies on the effects of maternal employment and welfare participation on children have not focused on low-income, single mothers and by and large have not addressed post-1996 welfare reform. Similarly, most of the experiments were begun before 1996 and did not test the types of programs implemented after the 1996 legislation (e.g., most experiments did not have time limits, and many had income supports and childcare subsidies more generous than many of those currently in existence). In addition, random assignment experiments may not generalize to other populations at different times. Further, experiments by their nature cannot measure the mechanisms by which the treatment programs may affect child outcomes. For example, such studies cannot separate the effects on adults and children of going off welfare per se from the effects of going to work, which we find to be a critical distinction (14).

We analyzed the association between children's developmental trajectories and their mothers' transitions into and out of employment and welfare, drawing upon data from a household-based, stratified random-sample, longitudinal survey of 2402 low-income children and their mothers in low-income neighborhoods of Boston, Chicago, and San Antonio (15, 16). Families with a preschool child (ages 2 to 4 years) or a young adolescent (ages 10 to 14 years) participated in 2.5-hour home interviews in 1999 and 16 months later on average in 2001 ($n = \sim 564$ for preschoolers and ~ 895 for adolescents, although samples were reduced further because of missing values for some covariates) (17). We chose early childhood and early adolescence because these are important developmental periods during which environmental influences may be particularly salient in shaping or altering children's trajectories (18, 19). About 46% of the children were African American, 48% were Hispanic, and 6% were non-Hispanic white and other ethnicities. At the first interview, most of the families were poor, with an average income that put them well below the federal poverty line (mean income-to-needs = 0.72), and $\sim 38\%$ were on welfare.

We focused on three domains of children's development—cognitive achievement, prob-

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lem behaviors, and psychological well-being—that are central to healthy functioning during childhood and adolescence and are also key predictors of successful adaptation in adulthood (18, 19). The Applied Problems and Letter-Word Identification scales from the Woodcock-Johnson Psycho-Educational Battery-Revised Edition directly assessed quantitative skills and reading skills, respectively. The Child Behavior Checklist (CBCL), a 100-item mother-report measure, assessed emotional and behavioral problems such as depression and anxiety (called “internalizing problems”), as well as aggression and delinquency (called “externalizing problems”). Adolescents self-reported their psychological distress (composed of subscales on depression, somatization, and anxiety; Brief Symptom Inventory) and their delinquent behaviors (with subscales on serious delinquency and drug and alcohol use; items modified from the National Longitudinal Study of Youth and the Youth Deviance Scale) (16).

We used ordinary least-squares regression to estimate the association of mothers’ employment and welfare transitions with changes in child outcomes. We defined four possible transitions that mothers made between the two interviews: (i) from on welfare to off welfare (“off welfare”); (ii) from off welfare onto welfare (“onto welfare”); (iii) from unemployment to employment (“into employment”); and (iv) from employment to unemployment (“out of employment”) (20). We also included variables for employment and welfare status at the first interview, implying that each of the four transition variables measured the effect of that transition relative to staying in the same employment or welfare status at the first and second interview and not making a transition (16). The welfare and employment variables are represented separately, because tests of their interaction were statistically insignificant.

For each equation, a child outcome from the first interview was included as an independent variable, and the same child outcome from the second interview constituted the dependent variable. Thus, the four welfare and employment transition coefficients measured the change in child outcomes associated with each transition (21). This also allowed us to control for unmeasured, time-invariant differences in children that were already present at the first interview (22). We termed this model 1. For model 2, we added important demographic variables that could influence children’s well-being, including city of residence, child age, race, gender, and mother’s age. Model 3 added human capital characteristics from wave 1 of the survey, including mother’s marital status, education, and household income-to-needs. We also included whether the mother was the biological mother of the child, whether English was her first language, the number of minors in the household, and whether the child lived with a different primary caregiver at the second interview (16).

A qualification to our method is that our statistical models cannot control for unmeasured characteristics of the mother that might be correlated with employment and welfare transitions as well as with changes in child outcomes. For example, if mothers who move from unemployment to employment have higher levels of motivation than mothers who stay unemployed, and if maternal motivation is linked with more positive developmental trajectories in children, then it is not the employment transition per se that is causing the change in child outcomes. Hence, we could be estimating a spurious correlation. Our models also cannot control for time-varying characteristics of children, such as personality characteristics that emerge during adolescence, which might be correlated with maternal employment and welfare transitions. Our results could thus be biased in part by the influence of these unmeasured factors and should be interpreted accordingly.

Using mothers’ retrospective reports at each wave of the survey (monthly calendars for up to the previous 2 years), we estimated four variants of each of these models with different welfare and employment definitions: (i) short-term (2 out of the 3 months before each interview) welfare receipt and employment, with employment defined as 1 or more hours per week; (ii) short-term welfare receipt and employment, with employment defined as 40 or more hours per week; (iii) long-term (6 out of 11 months before each interview) welfare receipt and employment, with employment defined as 1 or more hours per week; and (iv) long-term welfare receipt and employment, with employment

defined as 40 or more hours per week. There was little change in any of the welfare and employment coefficients from models 1 through models 3, either with or without the demographic and human capital control variables in the model. Consequently, we present the relevant welfare and employment standardized coefficients from model 3 for each of the four transition definitions (16, 23).

For preschoolers, neither mothers’ employment transitions nor their welfare transitions appear to be problematic or beneficial for cognitive achievement or behavior problems. Table 1 presents the results of our four different specifications of welfare and employment transitions for each of five preschool outcomes, summarizing 20 separate regression models (16, 24). None of the 80 regression coefficients was significantly different from zero at the 0.05 level (25). Whether or not a mother left welfare, entered welfare, took a job, or left a job between the interviews had no discernable link with preschoolers’ development.

For adolescents, the dominant pattern was also one of few associations (Table 2) (26). But where findings did occur, the most consistent pattern was that mothers’ transitions into employment were related to improvements in adolescents’ mental health. Adolescents whose mothers began working—whether for 1 or more hours or 40 hours and whether short- or long-term—reported statistically significant declines in psychological distress. This pattern was strongest for their symptoms of anxiety. For these two outcomes the coefficients for moving into employment were significantly

Table 1. Summary of regression models testing the association between preschoolers’ developmental trajectories and mothers’ welfare and employment transitions. Standardized regression coefficients are presented, and none is statistically significant at the $P < 0.05$ level.

Preschoolers	Quantitative skills	Reading skills	Behavior problems (total)	Internalizing behavior problems (subscale)	Externalizing behavior problems (subscale)
I. Short-Term					
A. ≥ 1 hour					
Off welfare	0.03	−0.01	−0.04	−0.10	−0.09
Onto welfare	−0.03	0.00	−0.02	0.07	0.01
Into employment	0.05	0.02	0.03	0.01	0.05
Out of employment	0.04	0.05	0.02	−0.03	0.03
B. 40 hours					
Off welfare	0.02	−0.03	−0.02	−0.06	−0.09
Onto welfare	−0.03	0.01	0.01	0.08	0.01
Into employment	0.02	0.06	0.07	0.01	0.04
Out of employment	0.01	−0.02	0.06	0.08	−0.04
II. Long-term					
A. ≥ 1 hour					
Off welfare	0.02	0.08	0.02	−0.08	−0.05
Onto welfare	0.05	0.02	0.01	−0.05	0.04
Into employment	0.01	−0.03	−0.01	−0.08	−0.09
Out of employment	0.08	0.08	−0.00	0.04	−0.02
B. 40 hours					
Off welfare	0.01	0.04	0.04	−0.06	−0.09
Onto welfare	0.04	0.01	0.04	0.01	0.03
Into employment	0.00	0.03	−0.04	−0.08	−0.06
Out of employment	0.02	0.08	−0.05	−0.03	−0.04

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different from zero at the 0.05 level for seven out of eight separate models. In Fig. 1, the anxiety subscale patterns are illustrated across all four definitions of employment and welfare transitions. The magnitude of the significant reduction for the groups who made the transition into employment was modest, about 0.15 standard deviations.

No other pattern of statistically significant findings for adolescents was as robust to changes in definitions of welfare and employment. The following findings were significant in some models, but not in others. Transitions out of full-time employment were associated with increased internalizing and externalizing behavior problems in the short-term 40-hour models. Adolescents whose mothers left the welfare system increased their reading skills in the long-term models, and teenagers whose mothers went onto welfare had significant reductions in their reading skills in the short-term models. Mothers' exits from welfare for both short- and long-term definitions were also linked to significant decreases in teenagers' use of drugs and alcohol, but only in the models using the 1 or more hours per week definition of employment. For one definition, going onto welfare was significantly related to increased drug and alcohol use (27).

Explanatory mechanisms. To test the role of family income and mothers' time with child, we estimated equations of the same form as model 3 above, except that we replaced the dependent variable (child outcome) with variables for family income-to-needs and mother's time spent apart from the child at the second interview (16). These models explore whether employment and welfare transitions are linked

with changes in time apart and family income, thus providing some indication of whether time and money may be explanatory mechanisms for our child outcome findings (16).

In families with either preschoolers or adolescents, mothers' entry into employment was related to a significant increase in family income across every model specification. For example, teenagers' mothers who went to work had household income-to-needs ratios that rose from 0.65 to 1.26 on average, bringing the majority of families above the poverty line. In contrast, exits from employment were generally related to decreases in income. However, income did not change when mothers went onto or left the welfare rolls. Thus, increased income may explain why adolescents' mental health improved when mothers went to work, consistent with other studies showing that employment combined with higher income is linked to positive outcomes for children (12). On the other hand, the fact that improvements were not seen in other preschool and adolescent outcomes implies that higher family income from maternal employment may not benefit children uniformly and is not the only explanatory factor.

Using information from a time diary of the day before the interview, we calculated two measures of the time mothers spent apart from their children: hours apart while working and hours apart while not working. As expected, mothers' hours apart from adolescents increased significantly by an average of 3.7 hours per day when mothers went to work. However, mothers' hours apart from adolescents while not working decreased by an average of 2.8 hours a day. Thus, it appears that when mothers of adoles-

cents entered the labor force, they compensated for time away from their young teenagers by cutting down on time apart when they were not on the job. The net result is that adolescents in our study did not experience much additional separation from their mothers due to employment (~45 min each day). This is consonant with time-diary studies of national samples in 1965 and 1998 which showed that the net time mothers spend with children has been relatively stable over time despite the movement of mothers into the workforce (10). Preschoolers in our sample, however, experienced a significant decline in time spent with their mothers. When mothers moved into employment, they decreased total time with their preschoolers by an average of 2.1 hours per day.

Thus, for preschoolers, there was a trade-off between time and money when mothers went to work. Family income increased and mothers' time with children decreased, so these two effects may have offset each other, leading to the extensive lack of findings for preschoolers' outcomes (28). For adolescents, we did not find a trade-off between time and money. Family income increased, but mothers did not substantially reduce their time with their adolescents even though they entered the labor market. There is some evidence in the literature showing that mothers are able to compensate for time away from children due to employment by cutting down on sleep, leisure, or volunteer activities (10), and our time-use data suggest that when mothers went to work, they cut back on personal, social, and educational activities that did not involve their children (29). We also found that the quality of mothers' parenting

Table 2. Summary of regression models testing the association between adolescents' developmental trajectories and mothers' welfare and employment transitions. Standardized regression coefficients are presented. ** $P < 0.01$, * $P < 0.05$.

Adolescents	Quantitative skills	Reading skills	Behavior problems (total)	Internalizing behavior problems (subscale)	Externalizing behavior problems (subscale)	Psychological distress (total)	Anxiety (subscale)	Delinquent behaviors (total)	Drug and alcohol use (subscale)
I. Short-term									
A. ≥ 1 hour									
Off welfare	-0.02	0.08	0.04	-0.06	0.04	0.02	0.03	-0.14	-0.17*
Onto welfare	0.03	-0.06*	0.04	0.06	0.07	0.02	0.00	0.04	0.07
Into employment	0.03	-0.08	-0.03	-0.03	-0.03	-0.10*	-0.15**	-0.07	-0.03
Out of employment	-0.00	0.05	-0.04	0.03	0.01	0.02	0.04	-0.03	-0.05
B. 40 hours									
Off welfare	0.05	0.05	0.04	-0.02	0.01	-0.02	-0.00	-0.11	-0.07
Onto welfare	0.01	-0.05*	0.06	0.07	0.07	0.02	0.01	0.05	0.06
Into employment	-0.01	-0.05	-0.01	-0.06	-0.01	-0.07	-0.12**	-0.01	-0.07
Out of employment	-0.02	-0.02	0.07	0.12*	0.07*	0.09	0.11	-0.01	-0.04
II. Long-term									
A. ≥ 1 hour									
Off welfare	0.00	0.10*	0.03	-0.06	0.04	-0.01	0.02	-0.13	-0.15**
Onto welfare	-0.00	-0.04	0.03	0.06	0.08	0.04	0.04	0.09	0.10*
Into employment	0.04	-0.08	-0.05	-0.03	-0.07	-0.12**	-0.15**	-0.06	-0.04
Out of employment	0.05	0.03	-0.02	-0.02	-0.02	0.00	0.02	-0.03	-0.08
B. 40 hours									
Off welfare	0.07	0.08*	-0.01	-0.02	-0.02	-0.02	0.00	-0.11	-0.10
Onto welfare	0.02	-0.02	0.04	0.04	0.10	0.04	0.03	0.09	0.08
Into employment	0.01	-0.04	-0.02	-0.05	-0.03	-0.10*	-0.14**	-0.02	-0.02
Out of employment	-0.03	0.03	0.04	0.09	0.07	-0.06	-0.05	0.03	0.02

(e.g., structured family routines, cognitive stimulation) rarely changed with employment at a statistically significant level, so parenting may not be an explanatory mechanism (16, 30).

Discussion. Within the limitations of our nonexperimental design where there are possible alternative explanations, this study suggests that mothers' welfare and employment transitions during this unprecedented era of welfare reform are not associated with negative outcomes for preschoolers or young adolescents. A few positive associations were tenuously indicated for adolescents. Mothers' entry into employment was related to improvements in teenagers' mental health. Similarly, mothers' exits from employment sometimes were associated with increases in adolescents' depressive and aggressive behavior problems. In addition, we found modest evidence that mothers' exits from the welfare system were related to enhanced cognitive achievement and reduced drug and alcohol use among adolescents. Entrances onto welfare showed the opposite pattern. The well-being of children of most concern to some observers of welfare reform—preschoolers—appeared to be unrelated to their mothers' leaving welfare or entering employment, at least as indexed in measures of cognitive achievement and behavior problems.

The absence of statistically significant findings for preschoolers is consonant with both the nonexperimental and experimental literatures on maternal employment, especially because we focused on maternal employment during the preschool years, and not during infancy when children are more vulnerable. However, our findings for adolescents are at odds with the experimental studies (13). There are three possible reasons why we found no negative effects

of maternal employment on adolescents, whereas the experimental studies did. First, in the experimental studies the treatment groups experienced mandatory work requirements, whereas our sample includes both mothers on welfare facing work requirements and unemployed mothers not on welfare who also chose to join the labor force. Second, the measurement of child outcomes in the present study is more in-depth and extensive than that in the experimental literature and covers additional developmental domains. Our individual, direct assessments of children's reading and math skills may be more valid and reliable than teacher or mother reports of school progress. Our assessments of adolescents' mental health used a self-reported scale of psychological distress with strong psychometric properties, whereas adolescents' psychological distress was not measured in the experimental studies. Finally, the teenagers in the experimental studies were older than those in the present study at the time of measurement: 12 to 18 years versus 11.5 to 15.5 years, respectively. As adolescents in the present study reach their later teenage years, some negative findings could emerge.

We emphasize that our findings only pertain to children's development within a 16-month interval. Whether harmful or more positive effects will arise after a longer interval is a question that must await further study of the post-welfare reform environment. Moreover, the first two waves of our study were conducted during the recent economic boom that sharply lowered unemployment and elevated wages among low-skilled workers. We do not know whether our findings would be replicated if there were a prolonged period of economic stagnation.

We have presented evidence that income and time provide a partial explanation for how employment and welfare transitions are related to children's development. Psychological and family processes are undoubtedly also at work. For example, the self-esteem of mothers of adolescents often significantly increased when those mothers went to work and often significantly decreased when they left work, suggesting that a more positive self-concept may be important in linking maternal employment and teenager outcomes, perhaps through role modeling (16). Alternatively, adolescents are perceptive and sensitive to the pressures of poverty and economic hardship in their families (8, 31), so their anxiety levels may decrease as they see their mothers going to work each day. Similarly, our findings suggest that teenagers may express their feelings of disappointment or worry about finances as depression or anger when their mothers leave employment. A more detailed psychological model, taking into account multiple aspects of the family system, would be necessary to explore further the processes underlying the results of this study (32).

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15. The other components include an ethnography and an embedded developmental study. See Winston et al., *Welfare, Children, and Families: A Three-City Study, Overview and Design Report* (Johns Hopkins University, Baltimore, MD, 1999), available at www.jhu.edu/~welfare. That document also describes the welfare policies of the three states, which ranged

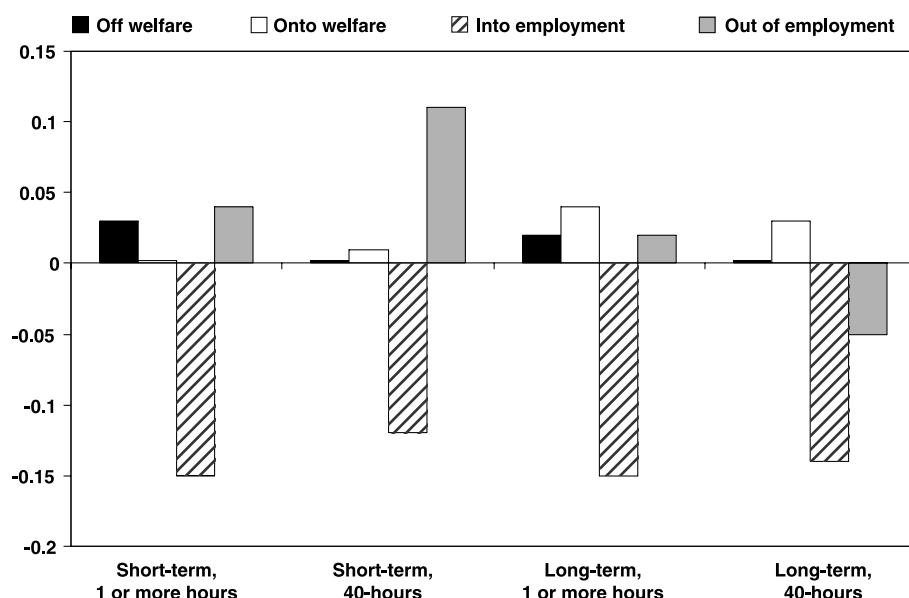


Fig. 1. Changes in anxiety for 10- to 14-year-olds according to mothers' employment and welfare transitions between the two interviews, for four different definitions of welfare receipt and employment. The height of the bar shows the increase or decrease, in standard deviations, between the two interviews.

- considerably in their time limits, work requirements, diversion policies, earnings disregards, and benefit levels.
16. Materials and methods are available as supporting material on *Science Online*.
 17. Data on 430 infants and toddlers are not included here, owing to different measurement.
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 20. In our data, just under 10% of women were working while on welfare, as should be expected in the period after 1996 when many women have combined welfare and employment. But when we disaggregated by child age group and omitted the infants and toddlers as described in (17), the absolute number of women making transitions into and out of this category was too small for analysis. Therefore, we omitted women in this category.
 21. An alternative regression formulation to measure change is the fixed effects model, which is similar to our model except that the dependent variable is measured as the change in child outcomes. We do not use that model because of its assumption that changes in child outcomes are the same regardless of their initial values, which also implies that welfare and employment transitions have instantaneous effects on child outcomes. To the contrary, changes in child outcomes are very likely to depend on the starting point, and to adjust gradually and with a lag.
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 23. Our data indicate that there was very little short-term cycling on and off welfare or employment before the two interviews [e.g., R. Moffitt, J. Roff, *The Diversity of Welfare Leavers*, Working paper 00-01, *Welfare, Children, and Families: A Three-City Study* (Johns Hopkins University, Baltimore, MD, 2000)]. Therefore, we did not test directly for the effects of such cycling.
 24. The weighted mean total sample size across our four model specifications in Table 1 is 493. The sample sizes for each of the four estimated transition effects in Table 1—each of which represents a comparison of outcomes for those who made a transition and those who did not—are as follows: for the into employment transition, $n = 83$ moved into employment and $n = 279$ stayed unemployed; for the out of employment transition, $n = 33$ moved out of employment and $n = 99$ stayed employed; for the onto welfare transition, $n = 30$ moved onto welfare and $n = 301$ stayed off welfare; and for the off welfare transition, $n = 83$ moved off welfare and $n = 80$ stayed on welfare.
 25. The probability of obtaining 80 insignificant coefficients at the 5% level is quite low if all 80 are independent. However, the tests are positively correlated to some degree, both across columns because different outcome measures often move together, and across rows because the four different panels shown in Table 1 are estimated on almost the same sample and with very similar specifications. Determining the exact probability of observing no significant coefficients in these 80 tests would be difficult, but that probability is higher than it would be if all of the tests were fully independent.
 26. The weighted mean total sample size across our four model specifications in Table 2 is 800. The sample sizes for each of the four estimated transition effects—each of which represents a comparison of outcomes for those who made a transition and those who did not—are as follows: for the into employment transition, $n = 32$ moved into employment and $n = 402$ stayed unemployed; for the out of employment transition, $n = 63$ moved out of employment and $n = 204$ stayed employed; for the onto welfare transition, $n = 32$ moved onto welfare and $n = 572$ stayed off welfare; and for the off welfare transition, $n = 102$ moved off welfare and $n = 94$ stayed on welfare.
 27. As with Table 1, it is possible that the 16 significant coefficients could have occurred by chance at the 5% level. Although the 16 coefficients represent more than 10% of all the effects estimated, the tests are correlated, and this raises the probability of a chance occurrence.
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 32. We gratefully acknowledge the support of the National Institute of Child Health and Human Development, Office of the Assistant Secretary for Planning and Evaluation, Administration on Developmental Disabilities, Administration for Children and Families, Social Security Administration, National Institute of Mental Health, Boston Foundation, Annie E. Casey Foundation, Edna McConnell Clark Foundation, Lloyd A. Fry Foundation, Hogg Foundation for Mental Health, Robert Wood Johnson Foundation, Joyce Foundation, Henry J. Kaiser Family Foundation, W. K. Kellogg Foundation, Kronosky Charitable Foundation, John D. and Catherine T. MacArthur Foundation, Charles Stewart Mott Foundation, David and Lucile Packard Foundation, Searle Fund for Policy Research, and Woods Fund of Chicago. We thank the other principal investigators of the Three-City Study, R. Angel, L. Burton, and W. J. Wilson, as well as J. Quane, C. O'Muircheartaigh, and the members of the MacArthur Foundation Network on the Family and the Economy, for their helpful insights.

Supporting Online Material

www.sciencemag.org/cgi/content/full/299/5612/1548/DC1

Materials and Methods

References and Notes

Tables S1 to S16

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REPORTS

The Cosmic Production of Helium

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We estimate the cosmic production rate of helium relative to metals ($\Delta Y/\Delta Z$) using K dwarf stars in the Hipparcos catalog with accurate spectroscopic metallicities. The best fitting value is $\Delta Y/\Delta Z = 2.1 \pm 0.4$ at the 68% confidence level. Our derived value agrees with determinations from H II regions and with theoretical predictions from stellar yields with standard assumptions for the initial mass function. The amount of helium in stars determines how long they live and therefore how fast they will enrich the interstellar medium with fresh material.

The amount of helium divided by the amount of heavier elements produced in stars ($\Delta Y/\Delta Z$) is of great interest to astrophysics and cosmology. The ratio governs the stellar clock and thus how long stars will live. Therefore, age determinations of both resolved and integrated stellar populations rely on knowing how helium concentration changes as a function of metallicity. Because ages of galaxies can help to determine the nature of dark energy (1), an accurate deter-

mination of $\Delta Y/\Delta Z$ is needed. This ratio also has an impact on the determination of primordial helium abundance by use of extragalactic H II regions (2). In addition to its cosmological interest, the ratio is also a test of theoretical predictions of stellar yields, because given an initial mass function for stars, $\Delta Y/\Delta Z$ is a predicted quantity of stellar evolution.

Helium lines can be observed only in stars with an effective temperature greater than 20,000 K; it is not possible to measure helium

abundances directly in cooler stars, which live more than 10^8 years. There are two methods to determine observationally the value of $\Delta Y/\Delta Z$ (where Y and Z are the fractional abundances of helium and all metals heavier than helium, respectively). One is through the use of H II extragalactic regions to measure helium's primordial abundance, which then is compared to that of the Sun to deduce $\Delta Y/\Delta Z$. This is done either by extrapolation of correlations of $Y - (O/H)$ with $Y - (N/H)$ to $O/H = N/H = 0$ [e.g., (3–5) and references therein], where O , N , and H are the fractional abundances of oxygen, nitrogen, and hydrogen, or by measuring Y in ultralow-metallicity blue compact dwarf galaxies and assuming that no chemical evolution has taken place [e.g.,

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Mothers' Transitions from Welfare to Work and the Well-Being of Preschoolers and Adolescents

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