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ILLICIT DRUG USE AND HEALTH: ANALYSIS AND PROJECTIONS OF NEW YORK CITY BIRTH OUTCOMES USING A KALMAN FILTER MODEL

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ABSTRACT

Using monthly data from New York City that span the years 1978-1990 we investigate the relationship between the incidence of drug use during pregnancy and the rate of low birth weight. Estimation results indicate that the increase in pregnancies complicated by drug use accounts for 71 percent of the increase in the rate of Black low birth weight between 1983-84 and 1990. If the use of drugs among Black pregnant women is reduced to its 1978 level, this would reduce the number of Black low birth weight babies by 8% (40 births per month) with respect to the level that would have been observed in the absence of any intervention. This implies an annual $5.1 to $6.8 million (in 1990 dollars) savings in terms of avoided initial hospitalization and special education costs. We could not find a significant relationship between drug use and the rate of low birth weight for whites.

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INTRODUCTION

As the use of illicit drugs persists as a major social problem facing urban America, the clinical evidence linking prenatal exposure to illicit drugs, in particular cocaine, and adverse birth outcomes has been mounting rapidly (Zuckerman et al. 1989; McCalla et al. 1991; Feldman et al. 1992). Newborns exposed prenatally to cocaine appear to be more likely to suffer intrauterine growth retardation, low birthweight and preterm delivery than infants unexposed. All three outcomes are strongly linked to infant mortality and excess morbidity (Institute of Medicine 1985, Mc Cormick 1985). Furthermore, low birthweight infants who survive are more likely to experience serious developmental, health and learning problems later in life. The marginal costs of treating exposed as compared with unexposed infants has been estimated at between $8,450 and $12,000 in 1990 dollars for the initial hospitalization only (Phibbs, Bateman, and Schwartz 1991; Calhoun and Watson 1991).

The extent of the problem and its progression over time, however, are not well known. Estimates on the number of infants exposed to illicit substances in the United States range from 350,000 to 739,000 annually (Gomby and Shiono 1991). Determining the prevalence of illicit drug use in a free-living population is difficult and costly. The reporting biases inherent in surveys are substantial. More controlled studies based on urine toxicologies are limited in size as well as generalizability; and they provide little insight as to the changes over time (Chasnoff, Landress, and Barrett 1990).

Indirect evidence, however, suggests that the problem may be more widespread and more dynamic than anticipated. A univariate analysis of monthly time-series data from New York City birth certificates revealed a dramatic increase in the rate of low birthweight births among Blacks beginning in 1984. The rate of low birthweight rose from 10.6 percent in 1984 to 13.1 percent in 1988: an unprecedented rise which over four years reversed a 22-year decline (Joyce 1990). The upturn in low birthweight among Blacks in New York City was coincident with anecdotal evidence on the introduction of crack cocaine to the city. Without time-series data on prenatal drug use, however, the nexus between low birthweight and cocaine was speculative.

A more recent study based on New York City birth certificates addressed these shortcomings. The researchers used a pooled times-series, cross-sectional design to examine the link between illicit drug use and low birthweight (Joyce, Racine, and Mocan, 1992). The study, based on annual data from 1980 to 1989 across health districts in New York City, reported that prenatal drug use was the most plausible explanation for the upturn in low birthweight among Blacks in the mid-1980's after controlling for prenatal care, smoking, and out-of-wedlock childbearing.

Since early 1989, however, both prenatal drug use and low birthweight among Blacks have turned sharply downwards. The rate of low birth weight has fallen from a peak of 14.1 to approximately 12.2 percent in 1990; the observed rate of prenatal illicit drug use has fallen from 6.0 percent to 5.1 over same time span. The turnaround in both low birth weight and prenatal drug use is certainly encouraging and it raises several questions. What is the most likely trajectory of prenatal drug use and its impact on the rate of low birthweight in the near term? What are the short-term opportunity costs of not pursuing an aggressive policy that reduces the prevalence of prenatal drug use to its pre-crack epidemic level? What would be the consequences and costs of an unexpected upturn in prenatal illicit drug use?

To address these questions we fit a structural time-series model to race-specific monthly rates of low birthweight in New York City from 1963 through 1990. We first examine whether the upturn in 1984 is consistent with a structural shift in the long-term trend of low birthweight. We then project the rate of low birth weight that would have been observed had the upturn in 1984 not occurred. Finally, we add data on race-specific rates of prenatal illicit drug use, prenatal care and smoking that are available from 1978 to determine the relative contribution of each. With this model we provide answers to consequences and costs of various trajectories in illicit drug use and low birthweight.

ANALYTICAL FRAMEWORK

Economic models of infant health emphasize the distinction between the health production function and the input demand functions (Rosenzweig and Schultz 1983; 1988; Corman, Joyce, and Grossman 1987; Joyce and Mocan 1993). The former represents the technical relationship between the birth outcome and the health inputs, whereas the latter focuses on the factors which determine the use of the health inputs. To illustrate, let B represent infant health and let M be a health input such as prenatal care.

(1) $B = f_1(M,S)$

(2) $M = f_2(P,Y)$

(3) $S = f_3(P,Y)$

To complete the model, let S represent the consumption of deleterious substances such as tobacco and cocaine; let P stand for price and availability measures, and let Y represent income or command over resources. The aim of the paper is the estimation of equation (1), the infant health production function. In particular, we seek to determine the contribution of illicit drug use to the rise in the rate of low birth weight. Note that substitution of equations (2) and (3) into equation (1) would yield a reduced form production function, where the rate of low birth weight becomes a function of input prices and income. Although clearly of interest, estimation of the reduced form is problematic, mainly because of unavailability of the price of illicit drugs, especially on a monthly basis.

EMPIRICAL IMPLEMENTATION

The data include all singleton live births to Blacks and Whites residents of New York City between 1963 and 1990. Data on illicit drug use, however, are only available since 1978. New York City birth certificates are the *only* population based data source in the United States that has routinely reported information on prenatal illicit drug use for over a decade. The size of city, its racial diversity and the magnitude of the illicit drug problem make New York City a unique setting from which to address the time-series relationship between low birth weight (LBW) and illicit drug use.

Individual birth certificates have been aggregated by month and race. Our measure of infant health is the race-specific rate of LBW births. LBW is superior to infant mortality as a measure of health in time-series context, because there is less potential confounding in LBW due to technological change. The rapid decline in infant mortality in the United States over the past 20 years has been attributed to advances in management of newborn care. By contrast, the rate of LBW has shown only a slight improvement, which has been attributed to the increased utilization of appropriate prenatal care, better nutrition, and a declining proportion of births to adolescents (Kleinman and Kessel 1983; National Center for Health Statistics 1980). It is hypothesized that these favorable trends have been offset by the prenatal consumption of illicit drugs. Our measure of illicit drug use variable (DRUG) is the percentage of women whose pregnancies are complicated by the use of cocaine, heroin, methadone and barbiturates.[1] The production function estimated from 1978-1990 also includes the percentage of women who smoked during pregnancy (TOB) and the percentage of women

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[1] *We exclude marijuana because it was added specifically to the birth certificate in 1988.*

who started consuming prenatal care during the first trimester (CARE). In preliminary analyses we experimented with other correlates of low birth weight such as percentage of births out-of-wedlock, the percentage of births to women with a high school education, and the percentage of first births; but these added little explanatory power to our model and were thus excluded from further specifications.

Figure 1 presents the behavior of the Black and White rates of low birth weight (BLBW and WLBW) between 1963 and 1990. To highlight the underlying secular trends, both series are exponentially smoothed. The Black rate of low birth weight exhibits a downward trend between 1967 and 1984: it goes down from a monthly average of 14.66 in 1967 to 10.59 in 1984. Starting in 1985, the downward trend of 1967-1984 is reversed, and the Black rate of low birth weight rises steadily until 1988, where the average reaches 12.95. The trend is reversed again in 1989, and the average BLBW becomes 12.20 in 1990. Even though the White rate of low birth weight exhibits similar trends, the magnitudes of the changes are not as significant as those pertaining to Blacks. The monthly average rate of low birth weight for Whites is 7.23 in 1967, and 5.99 in 1984. Average WLBW reaches 6.32 in 1988 and falls to

6.15 in 1990.

Figure 2 displays the percentage of pregnancies complicated by drug use for both races between 1978 and 1990. The percentage of Black pregnancies complicated by drugs (BDRUG) remains stationary between 1978 and 1983 (mean BDRUG is 2.35 in 1983-84), but we note an upswing starting with 1985, and a downturn in 1989 (the monthly average of 1988 is 6.67, and 4.87 in 1990). These dates coincide with the turning points of the Black rate of low birth weight series (BLBW). For Whites, the corresponding averages are 2.27 in 1983-84, 3.08 in 1988, and 2.69 in 1990.

Figure 3 shows the percentage of Black and White pregnancies complicated by tobacco use (BTOB and WTOB); figure 4 reports BCARE and WCARE (percentage of Black (White) pregnancies where the consumption of prenatal care started in the first trimester). BTOB and WTOB exhibit similar patterns, BTOB lying almost three percentage points above WTOB. In Figure 4 one observes that the average of BCARE is 29.47 during 1978. It rises steadily and levels off with an average of 36.36 in 1989-1990. WCARE smoothly rises from 48.38 percent in 1978 to 52.57 percent in 19884-85. It then starts declining where the 1990 average becomes 47.13.

ESTIMATION

It is vital to control accurately for the trend in health outcomes because it captures the underlying health technology and other unobservables. Failure to do so would contaminate the residuals and cause model misspecification. In this paper we estimate a structural time series model using the Kalman Filter which enables us to avoid the current debate surrounding the unit root testing issue. More precisely, the structural time series analysis described below obviates the need to specify whether the trends are deterministic or stochastic prior to the analysis, and enables us to capture the dynamics of the underlying trend more accurately. In fact, taking the first differences or regressing on a deterministic time trend are special cases of the flexible trend model we estimate. Thus, it becomes much less likely that spurious estimates will be obtained due to misspecification of the trend. The approach we employ in this paper formulates the series under investigation in terms of its trend, seasonal and irregular components and estimates it through the Kalman Filter. More precisely, following Harvey and Jaeger (1991), Harvey (1985) and Harvey and Todd (1983) we hypothesize that the dynamics of the rate of low birth weight can be formulated as

$$LBW_t = \mu_t + \psi_t + \varepsilon_t \tag{4}$$

where LBW_t is the natural logarithm of the rate of low birth weight at time t, and μ_t, ψ_t, and ϵ_t are the trend, seasonal and irregular components, respectively. Within this framework, one can specify a locally linear trend where the level and the slope of the series are governed by random walks as follows:

$$\begin{aligned} \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t \\ \beta_t &= \beta_{t-1} + \xi_t \end{aligned} \tag{5}$$

where η_t and ξ_t are white noise disturbance terms that are serially uncorrelated, and uncorrelated with each other with variances σ_η^2 and σ_ξ^2, respectively. Following Harvey and Durbin (1986) and Harvey (1989), seasonality is assumed to be generated by the following stochastic trigonometric process, which is allowed to evolve over time.

$$\psi_t = \sum_{j=1}^{s/2} \psi_{jt} \tag{6a}$$

$$\begin{aligned} \psi_{jt} &= \psi_{j,t-1} \cos\lambda_j + \psi^*_{j,t-1} \sin\lambda_j + \omega_{jt} \\ \psi^*_{jt} &= -\psi_{j,t-1} \sin\lambda_j + \psi^*_{j,t-1} \cos\lambda_j + \omega^*_{jt} \end{aligned} \tag{6b}$$

where $j=1,2,\ldots,[s/2]$, ω_{jt} and ω_{jt}^* are zero mean white noise disturbances which are uncorrelated with each other, and ψ_{jt}^* appears by construction (see Hannan, Terrel and Tuckwell 1970, and Harvey 1989, p.40-49).

The structural model depicted in (4) can be extended by adding exogenous explanatory variables x_t to the right hand side, which gives[2]

$$(7) \qquad LBW_t = \mu_t + \psi_t + \delta x_t + \varepsilon_t$$

RESULTS

We estimated the Black rate of low birth weight (BLBW) and the White rate of low birth weight (WLBW) using Kalman Filter for the years 1963 to 1980, and computed normalized recursive residuals from January 1981 through December 1990 as a means of diagnosing a structural change.[3] If the series has not undergone a structural change, then the recursive residuals should be randomly distributed around zero; thus, the cumulative sum (CUSUM) of the residuals should fluctuate around zero. If there emerges a secular

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[2] *For more on estimation, see the Appendix.*

[3] *To illustrate, we estimated the model for BLBW based on data from January 1963 through December 1980. We then predicted the BLBW for January 1981. The difference between the actual rate and predicted rate for that month divided by the standard deviation of the residuals is the normalized recursive residual for January 1981. The model was re-estimated with data from January 1963 through January 1981 and the recursive residual for February 1981 is calculated. The process of updating the series, re-estimating the model, and generating new predictions was repeated for each month through December 1990.*

pattern to the CUSUM residuals, it would imply a structural change, and the point where the change in CUSUM of residuals begins would suggest an approximate date. A plot of CUSUM residuals, therefore, is a means of diagnosing structural shift. It is particularly useful in the present context since the precise date of a specific intervention is not known.

Figure 5 displays the CUSUM residuals for Blacks and Whites between 1981-1990. For Blacks the CUSUM residuals start rising in 1985, and they decline after 1989. Thus, 1985 and 1989 seem to be the years in which some change took place which altered the dynamics of BLBW series. The pattern of CUSUM residuals is consistent with Figure 1, where we observe two turning points in BLBW series in 1985 and 1989. For Whites the CUSUM residuals exhibit an increase starting in 1986, and they decline after 1988. The magnitude of the increase in CUSUM residuals is bigger for Blacks than Whites, which is again consistent with Figure 1 which indicates that shifts in the Black series are more notable than those in Whites.

As a second exercise, we estimated the BLBW and the WLBW between 1978 and 1983, and obtained one-step-ahead forecasts. If the forecasts would capture the 1985 upswing and the

1989 downturn, this would support the hypothesis that there was no structural shift in 1985 or 1989. Put differently, it would imply that the own dynamics of the rate of Black and White low birth weight, rather than the influence of other factors was responsible for the observed behavior.

Figure 6A displays BLBW along with the forecasts for 1984-1990, which are based on the estimation using the sample 1978-1983. As can be seen neither the upswing in 1985, nor the downturn in 1989 is captured by the forecasts. In order to investigate how the inclusion of BTOB (percentage of Black pregnancies complicated by tobacco), BCARE (percentage of Black pregnancies where the consumption of prenatal care started in the first trimester), and BDRUG (the percentage of Black pregnancies complicated by drug use) improve the forecasts, we added each of these variables to the BLBW equation separately, estimated the models between 1978 and 1983, and obtained the forecasts for 1984-1990. Adding BTOB as a regressor did not improve the forecast accuracy. When we included BCARE we noticed an improvement in forecasts. In particular, both turning points were captured by the forecasts of that model. Inclusion of BDRUG as an explanatory variable did improve the forecasts more than that of BCARE.

Figure 6B presents the actual and predicted values of BLBW where the model includes BDRUG as a regressor.[4] A comparison of Figure 6B with Figure 6A demonstrates that inclusion of BDRUG improves the forecasts of BLBW and both turning points of BLBW are captured with precision. To sum, there is evidence that structural changes took place in 1985 and 1989 that altered the dynamics of Black the rate of low birth weight series. Consequently, one-step-ahead forecasts of BLBW are not precise and do not capture the turning points. Adding BDRUG to the model as a regressor increases the forecasts accuracy and enables the forecasts of the rate of Black low birth weight capture the turning points. Figures 7A and 7B display the same information for Whites. Unlike Blacks, however, modeling WLBW between 1978 and 1983 generates accurate forecasts for 1984-1990 (see figure 7A). A comparison of Figures 7A and 7B demonstrates that adding the rate of White pregnancies complicated by drugs (WDRUG) as an explanatory variable to the model does not improve the accuracy of the forecasts significantly.

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[4] *The signs of BTOB, BDRUG and BCARE were positive, positive, and negative, respectively, as expected. None of them, however, was significant.*

SIGNIFICANCE OF THE DRUG USE AND PROJECTIONS FOR 1991 AND 1992[5]

To more formally test the impact of the use of drugs, smoking and early initiation of prenatal care we estimated BLBW and WLBW using the Kalman Filter between 1978 and 1990 including TOB, DRUG and CARE as regressors. Table 1 reports the regression results for Blacks and Whites. To investigate the potential endogeneity of the regressors we performed a Wu-Hausman test as described by Nakamura and Nakamura (1981). We could not reject the null hypothesis that DRUG, TOBACCO and CARE were exogenous.[6]

Table 1 demonstrates that none of the explanatory variables have a statistically significant impact on the White rate of low birth weight. This outcome was expected given the ability of WLBW to predict the 1984-1990 values based on its dynamics only (Figure

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[5] *The 1991 vital statistics for New York City are not released as of December 1992.*

[6] *The Wu-Hausman test analyzes the correlation of the regressors with the residuals (Wu 1973). Instrumental variables were i) the maximum allowable benefits in constant dollars for a family of two under the Aid to Families with Dependent Children (AFDC) program in New York City, ii) the New York City unemployment rate, iii) the real minimum wage, iv) percentage of self financed births v) percentage of births financed by Medicaid.*

7A), and is consistent with the results reported by Joyce, Racine and Mocan (1992). The lack of a relationship between the inputs and the White rate of birth weight is not surprising because unlike Blacks, the White rate of low birth weight does not exhibit significant variation during the period studied (see Figure 1). Furthermore, Figures 2, 3 and 4 indicate that the explanatory variables for the White regressions do not have much variation over time either, which would tend to inflate the standard errors of the estimated coefficients. This result, however, does not imply that the use of drugs or smoking is not a risk factor for White pregnant women at the individual level. It merely highlights the lack of an important association at the aggregate level.

Table 1 also illustrates that early prenatal care is not a significant determinant of the Black rate of low birth weight (the t-statistic is 0.47). A one percent increase in the Black pregnancies complicated by illicit drugs generates a 0.10 percent increase in the Black rate of low birth weight holding constant the consumption of tobacco and medical care. The rate of Black pregnancies complicated by illicit drugs increased by 107 percent between 1983-84 and 1990 (see Figure 2). This implies that this particular rise in drug use generated a 10.4 percent increase in the rate of Black low birth weight keeping the influences of tobacco and prenatal care constant. As Figure 1 demonstrates, the rate of Black low birth weight increased by 14.7 percent between 1983-84 and 1990. Thus, the increased drug use among Black pregnant women in New York City between 1983-84 and 1990 accounts for 71 percent of the increase in the rate of low birth weight for Blacks.

We modeled BTOB (WTOB) and BCARE (WCARE) using the Kalman Filter as depicted by (4)-(6), and obtained their 1991 and 1992 projections. Figures 8 and 9 present the actual values (1978-90) and the 1991-92 projections of TOB and CARE. The same is done for BDRUG (WDRUG), and the forecasts of 1991 and 1992 are displayed in Figure 10 along with the actual values. For both BDRUG and WDRUG Figure 10 illustrates three separate paths for 1991-1992. The branches labeled *"pw"* and *"pb"* are the Kalman Filter projections of WDRUG and BDRUG, respectively. For Blacks, one observes another turning point in 1990. Put differently, the projection implies that the observed 1989 downturn in the rate of Black pregnancies complicated by drug use will be countered by another upturn in 1991, and the projected rate of Black pregnancies complicated by illicit drug use will reach 5.60 at the end of 1992. The Kalman Filter projection of the rate of White pregnancies complicated by illicit drug use (pw) demonstrates that it will remain steady during 1991-92 with an average of 2.76. The branches labeled "*h1*" and "*h3*" in Figure 10 portray hypothetical paths for WDRUG and BDRUG, respectively. They are constructed so that at the end of 1992 the values of BDRUG and WDRUG go down to their respective 1978 averages. In other words, they are representations of an imaginary scenario in which the rate of Black and White pregnancies are brought back to their 1978 levels. The branches labeled "*h2*" and "*h4*" demonstrate the scenario where WDRUG and BDRUG gradually increase to their respective 1989 levels.

We estimated BLBW (WLBW) between 1978 and 1990, including BTOB (WTOB), BCARE (WCARE) and BDRUG (WDRUG) as regressors. Using the estimated coefficients and the 1991-1992 projections of TOB, DRUG and CARE we obtained the forecasts of BLBW (WLBW) for 1991 and 1992. Figure 11 reports the three projections for each race. The projections "*pw*" and "*pb*" are obtained by using the 1991-92 Kalman Filter forecasts of TOB, CARE, and DRUG displayed in Figures 8-10. *h1-h4* of Figure 11 are the simulated paths for the White and Black rate of low birth weight, which are obtained by employing the same projected values of TOB and CARE, but using *the hypothetical paths of DRUG (h1 through h4 in Figure 10)*. Therefore, the difference between projections *pb and h3* of Figure 11 represents the decline in the rate of Black low birth weight that would have occurred, had the rate of Black pregnancies complicated by drug use gone down to its 1978 level instead of following its normal path, keeping the paths of the use of tobacco and prenatal care intact. Similarly, the difference between projections *pb and h4* illustrates the increase in the rate of Black low birth weight that would have taken place, had the rate of Black pregnancies complicated by drug use gone up to its 1989 level by the end of 1992. For Whites we notice that the branches *"pw"* *"h1"* and "*h2*" are virtually the same in Figure 11. This means that the decrease of the rate of White pregnancies complicated by drug use to its 1978 level or its increase to the level prevailed in 1989 would not have an impact on the behavior of the White rate of low birth weight during 1991-1992.[7]

According to Figure 11, employing the Kalman Filter projections of BTOB, BCARE, and BDRUG for 1991-92, the predicted 1992 average of BLBW becomes 12.10 (branch *"pb"*).

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[7] *Once again, this result is not surprising given the lack of a relationship between the rate of White low Birth weight and the health inputs. Nevertheless, we kept Whites in the exercise for completeness.*

Using the same model and the same projections of BTOB and BCARE, but forcing BDRUG to go down to its 1978 level generates a reduction in BLBW, where the 1992 average becomes 11.36 (branch *"h3"*). This implies that if the drug use among Black pregnant women in 1992 went down to the level prevailed in 1978, the Black rate of low birth weight would be 0.74 percentage points less than the one to be observed in 1992. On the other hand, all else being constant, if the rate of Black pregnancies complicated by drugs goes up to its 1989 level (branch *"h4"* in Figure 10), this would generate the simulated path *"h4"* of Figure 11 for the Black rate of low birth weight, where the 1992 average becomes 12.39.

We modeled the monthly number of Black and White births using the procedure discussed earlier and obtained their 1991-1992 projections which are displayed in Figure 12. Multiplying the 1991-92 projections of the number of births by the projected rate of low birth weight rates yields the projected number of low birth weight births for the period 1991-92. Using this algorithm we find that the projected total number of low birth weight births between January 1991 and December 1992 is 11,289 for Blacks and 9,068 for Whites. If by the end of 1992 the rate of Black pregnancies complicated by drug use could be pulled down to its level prevailed in 1978 (path *h3* of Figure 10), the resultant outcome would be a total of 10,845 low birth weight Black births for the period 1991-92. Thus, 444 Black low birth weight births would be averted during the period of 1991-1992 by reducing the maternal drug use to its 1978 level.

It should be noted that this amount is the result of a gradual decline in the drug use over a period of two years. As Figure 11 demonstrates, the decline in BLBW increases as the drug use variable approaches to its pre-crack epidemic level. The average monthly number of low birth weight births during the period of October 1992-December 1992 is 447 given that the drug use reaches its pre-epidemic level in these months. The projected monthly average Black low birth weight for the same period is 487 given that the drug use follows its normal (status quo) path. Thus, an average of 40 Black low birth weight births would be averted per month with the drug use being reduced and kept at its 1978 level. This implies that the monthly number of averted Black low birth weight births would approximately be 8% of total Black low birth weight births (40/487).

The marginal cost of treating infants who are exposed to drugs is between $8,450 and $12,000 in 1990 dollars for the initial hospitalization (Phibbs, Bateman, and Schwartz 1991; Calhoun and Watson 1991). This implies that in the first two years $3.7 to $5.3 million in initial hospitalization cost could be saved in New York City by lowering the drug use among Black pregnant women to its 1978 level. After the first two years, where the intervention has pulled the Black pregnancies complicated by drug use to the level prevailed in 1978, annual savings in initial hospitalization costs would be between $4.06 and $5.8 million.

The total social cost of low birth weight births is higher than portrayed by the ones associated with initial hospitalization. For example, Chaikind and Corman (1991) show that low birth weight babies have a higher probability of needing special education because of learning disabilities and emotional problems. More precisely, they show that low birth weight babies are almost fifty percent more likely to be enrolled in any type of special education than babies who are of normal weight at birth, controlling for the individual, family and regional characteristics. This implies that 222 Black children who are born in 1991-1992 and an additional 240 every year after that could avoid special education if the maternal drug use went down to its pre-crack epidemic level. Chaikind and Corman cite a study by Moore at al.(1988) where excess cost of special education (the total cost required to educate a special education student minus the costs to educate a regular student) are estimated as $4,350 per pupil in 1989-90 dollars. Thus, an additional $966,000 in terms of avoided special education costs could have been saved by decreasing the maternal drug use to its 1978 level. Therefore, $4.7 to $6.3 million in 1990 dollars could have been saved in terms of avoided initial hospitalization and special education costs pertaining to Black low birth weight babies born in New York City between 1991-1992 if an intervention program could bring the maternal drug use among Black pregnant down to its level prevailed in 1978. After the prevalence of prenatal illicit substance use reached and remained at its 1978 level, the initial hospitalization and special education savings would amount to $5.1 to $6.8 million annually (in 1990 dollars) with respect to status quo.

CONCLUSION

Using monthly data from New York City that span the years 1978-1990 we investigate the relationship between the incidence of drug use during pregnancy and the rate of low birth weight.
Using Kalman Filter we model the dynamics of the White and Black rate of low birth weight between

1963 and 1980, and obtain CUSUM residuals which signal structural shift in 1984 and 1989. When we estimate the model between 1978 and 1983, and obtain dynamic forecasts for 1984-1990, we get accurate forecasts for Whites, but inaccurate ones for Blacks. Including the percentage of pregnancies complicated by the use of illicit drugs as a regressor to the model increases the forecast accuracy significantly. More precisely, the upturn in the Black rate of low birth weight that took place in 1984 and the downturn of 1989 are captured. Estimating the models between 1978 and 1990 reveals that smoking during pregnancy, early initiation of prenatal care or the use of drugs during pregnancy have no impact on the rate of White low birth. This result does not imply that the weight of White babies is not influenced by the use of deleterious substances during pregnancy. It indicates that the variations in maternal drug use, smoking and the use prenatal care are not serious enough to generate a change in the White rate of low birth weight. On the other hand, smoking and drug use are significant determinants of low birth weight for Blacks at the aggregate level. We find that the rise in pregnancies complicated by drugs accounts for 71 percent of the increase in the rate of Black low birth that took place between 1983-84 and 1990. Furthermore, our simulations reveal that given the projected paths of smoking and prenatal care, if drug use among Black pregnant women is reduced back to its 1978 level between January 1991 and December 1992, we would have had 444 less Black low birth weight babies during the same period. This implies that between $4.7 and $6.3 million in 1990 dollars would have been saved in initial hospitalization and special education costs for that period. Furthermore, after the first two years if the level of maternal drug use is kept at its pre-crack epidemic level, this reduces the number of Black low birth babies by 8%, or 40 births per month with respect to the level that would have observed in the absence of any intervention. Thus, $5.1 to $6.8 million (in 1990 dollars) per year would be saved in terms of initial hospitalization and special education costs as a result of reducing the prevalence of prenatal illicit substance use to its pre-crack epidemic level.

Table 1

Estimated Low Birth Weight Equations 1978-1990

	Dependent Variable	
Explanatory Variables	The Rate of Black Low Birth Weight (BLBW)	The Rate of White Low Birth Weight (WLBW)
TOBACCO	0.1074 (3.2236)	0.0012 (0.0414)
MEDICAL CARE	0.0450 (0.4716)	-0.0435 (-0.2420)
DRUG	0.0972 (3.7241)	0.0309 (0.7952)
$\sigma^2_\eta x10^3$	0.0000	0.6840
$\sigma^2_\xi x10^3$	0.0001	0.0000
$\sigma^2_\omega x10^3$	0.0002	0.0017
$\sigma^2_\epsilon x10^3$	2.5750	2.7700
N	3.576	3.746
H(47)	0.858	0.845
Q(13)	9.773	9.190
R^2	0.588	0.268
Wu-Hausman $F_{3,123}$	1.129	1.839

$R^2 = 1-[T^*p^2/\Sigma(y_t-y_m)^2]$, where $T^*=T-d$, d is the degree of differencing, p^2 is the estimated one step ahead prediction error variance, and y_m is the mean of y_t.

Normality$=(T^*/6)b_1+(T^*/24)(b_2-3)^2$, where b_1 is the square of the *third moment of the standardized residuals about the mean, b_2 is the fourth moment.*

H(h) is a test for heteroscedasticity defined as

$$H(h) = \sum_{t=T-h+1}^{T} \upsilon_t^2 \,/\, \sum_{t=d+1}^{d+1+h} \upsilon_t^2$$

where $h = T^{*}/3$, and ν_t is the standardized residuals. H(h) has an F(h,h) distribution.

Q is Box-Ljung Q-statistic for the joint significance of the first fifteen residuals. It is distributed Chi-square with the degrees of freedom in parentheses.

The numbers in parentheses are the asymptotic t-ratios.

Figure 1

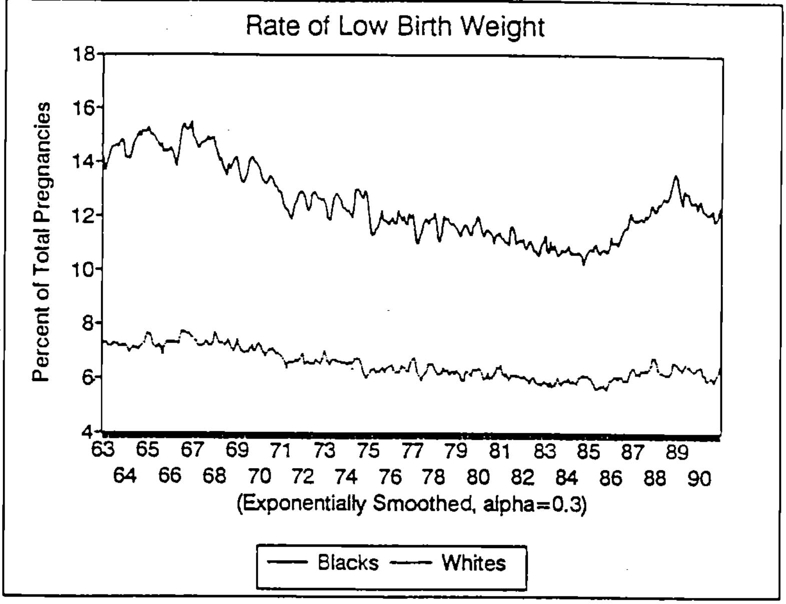


Figure 2

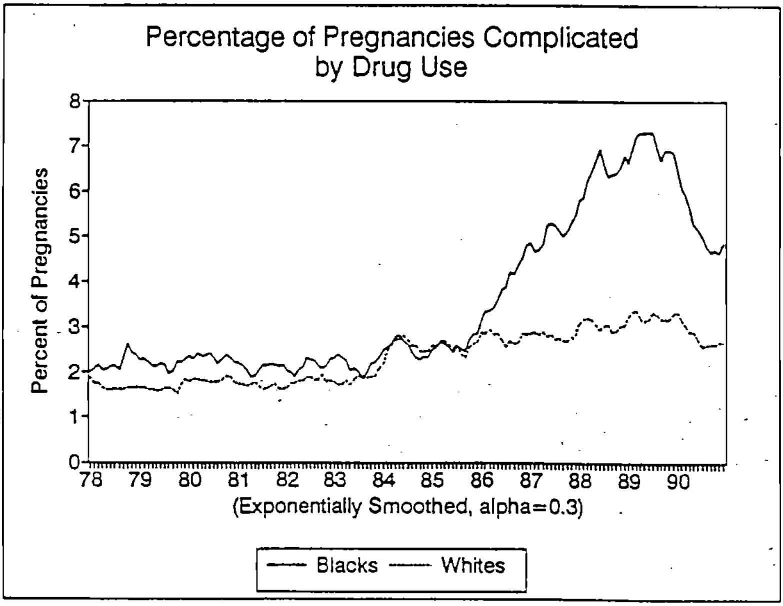
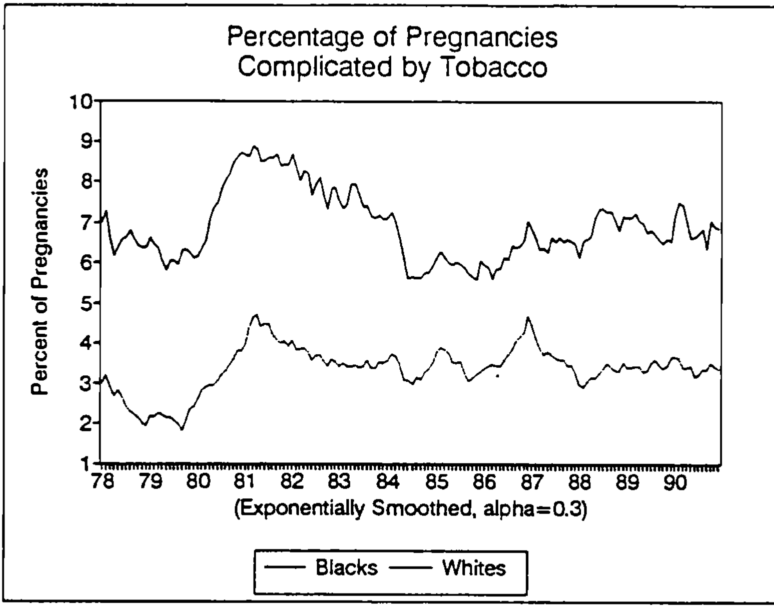


Figure 3



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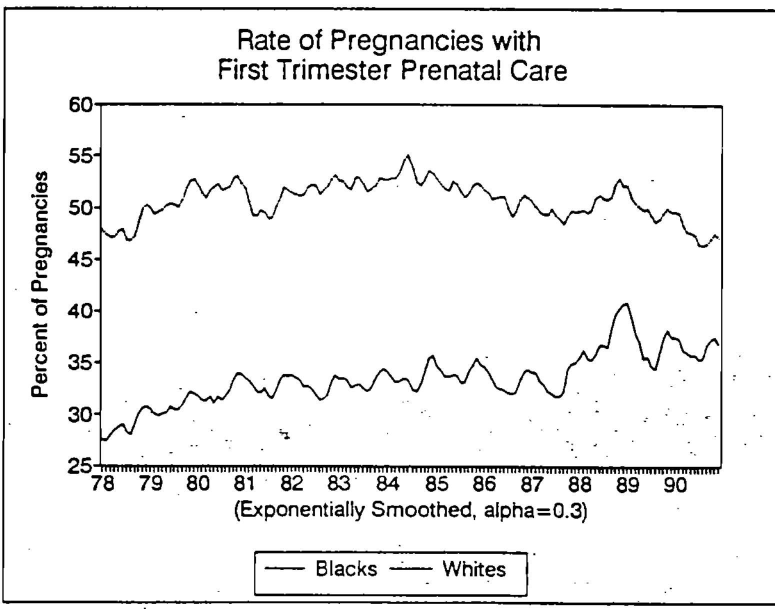


Figure 5

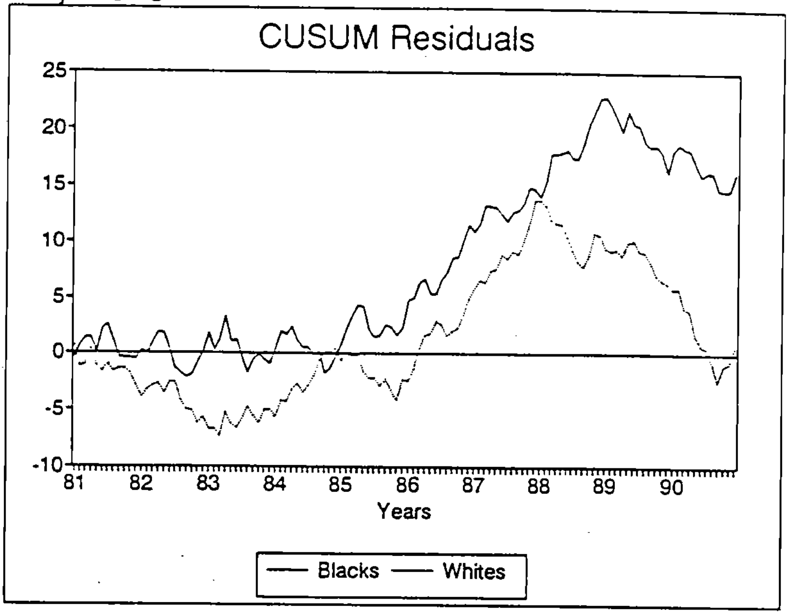


Figure 6A

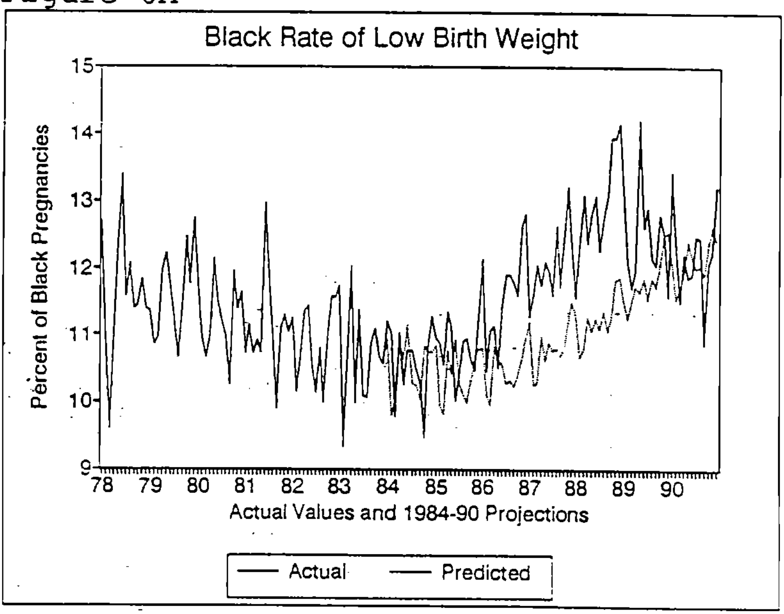


Figure 6B

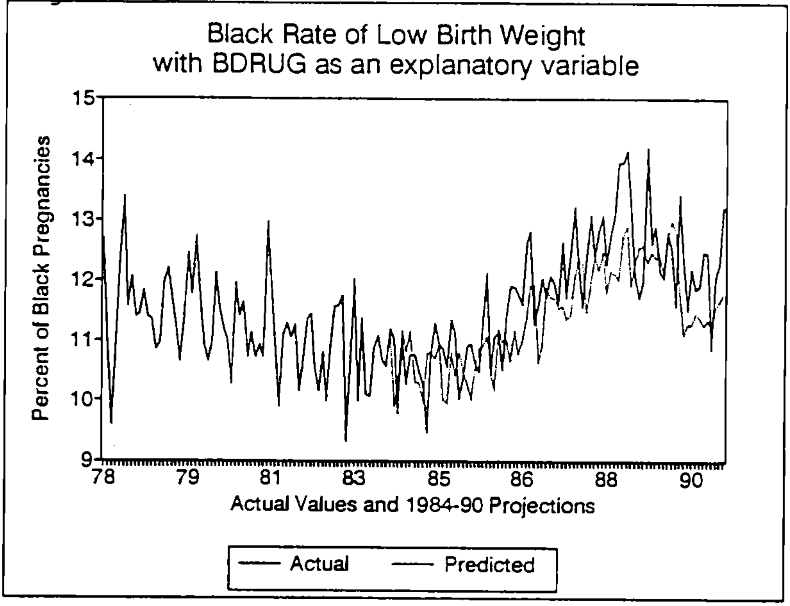


Figure 7A

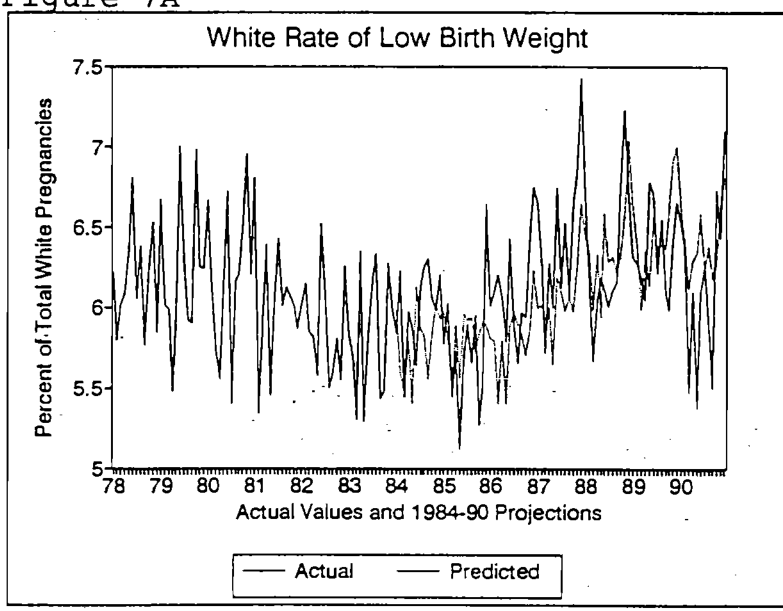


Figure 7B

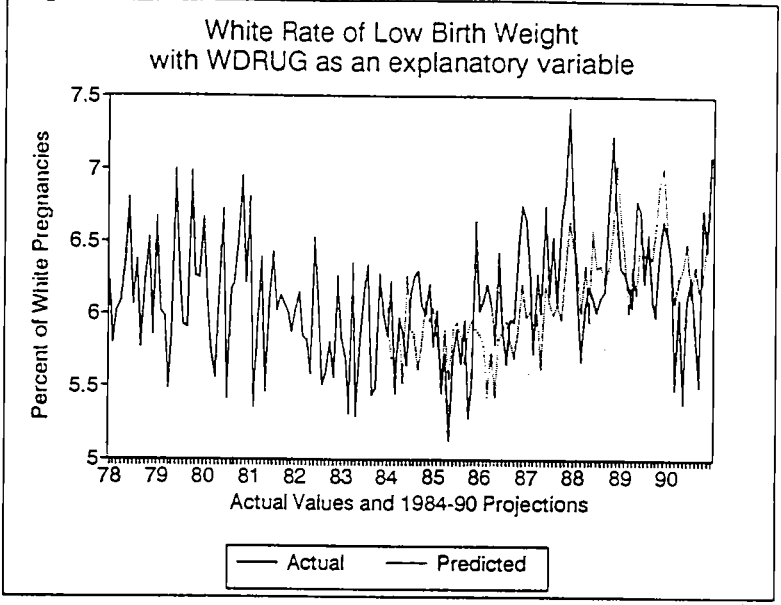


Figure 8

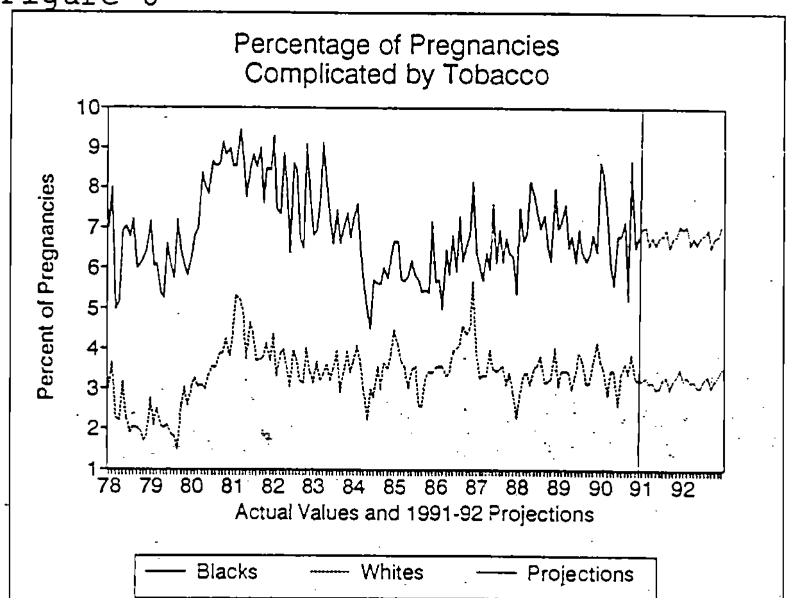


Figure 9

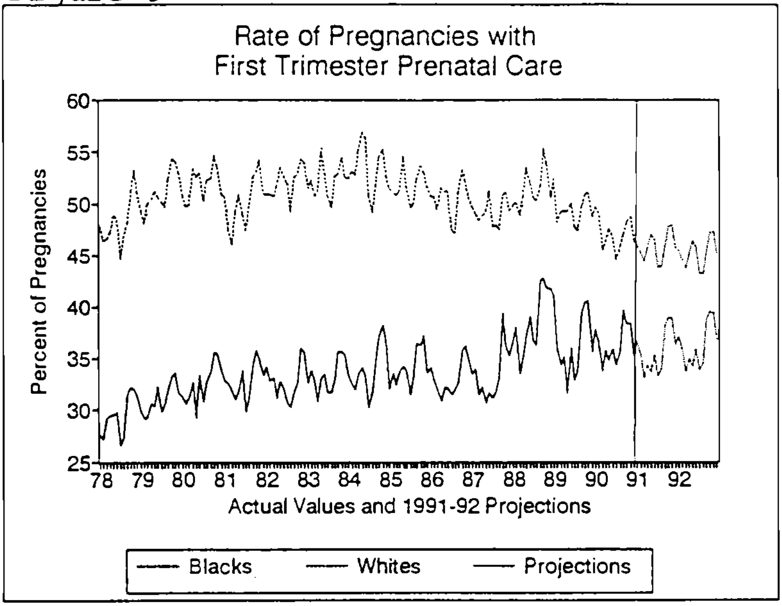


Figure 10

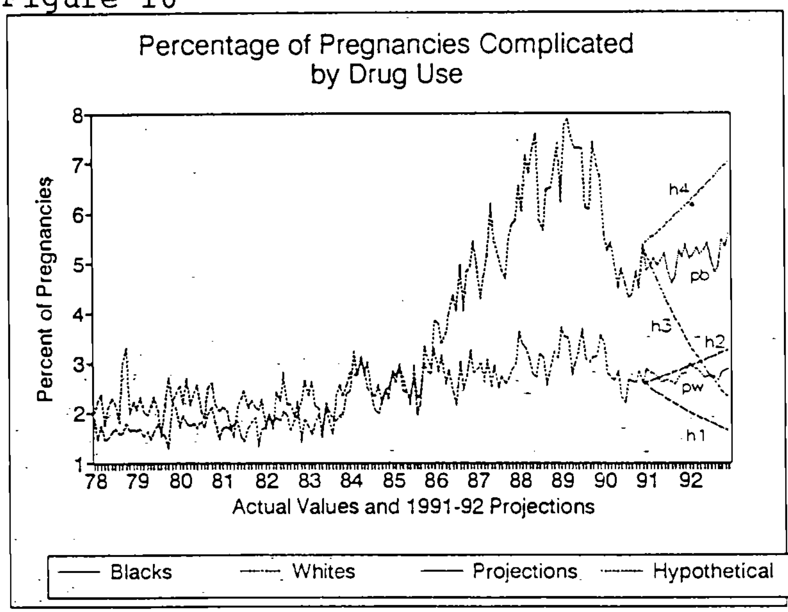


Figure 11

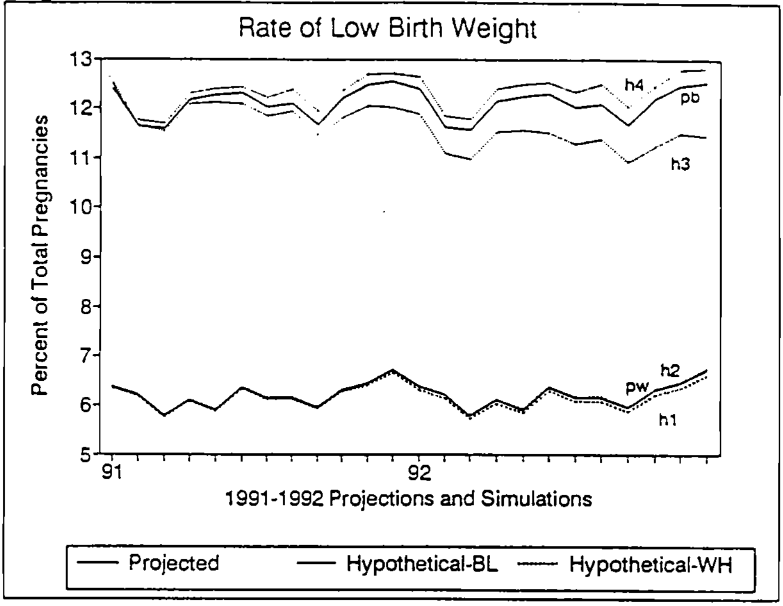
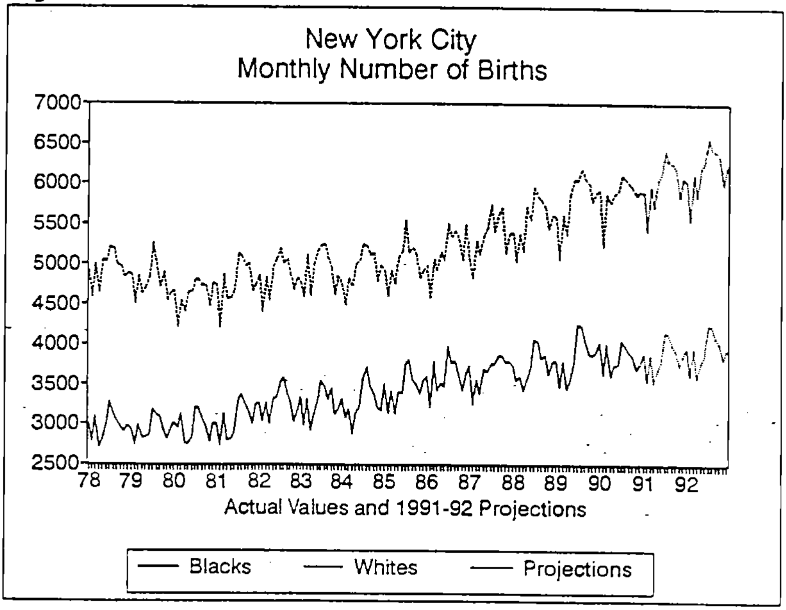


Figure 12



APPENDIX

The trend in (5) is equivalent to an ARIMA(0,2,1) process. If $\sigma_\xi^2=0$, the trend reduces to a random walk with a drift; i.e. w_t is stationary in first differences, (integrated of order one). If $\sigma_\eta^2=0$, but $\sigma_\xi^2>0$, the trend is still integrated of order two as the original case. If $\sigma_\eta^2=\sigma_\xi^2=0$, the model collapses to a standard regression model with a deterministic trend; i.e. $\mu_t=\mu_0+\beta t$.

The model described by equations (5), (6) and (7) can be put into state space form which consists of the following equations.

(8*a*) $$LBW_t = z_t' \alpha_t + e_t \quad t=1,...,T$$

(8*b*) $$\alpha_t = A_t \alpha_{t-1} + \nu_t \quad t=1,...,T$$

Equations (8a) and (8b) are the observation and transition equations, respectively. α_t is an (mx1) unobservable state vector, Z_t is an (mx1) fixed vector, A_t is a non-stochastic (mxm) matrix, ϵ_t is a serially independent, normally distributed irregular component with mean zero and variance σ_ϵ^2. Equation (8b) demonstrates that the state vector is updated each period, but it is also subject to some serially uncorrelated random distortions with zero mean and covariance matrix $\mathbf{\Omega}_t$, represented by the mx1 vector ν_t.

After expressing the model in terms of state space representation [Equations(8a) and (8b)], maximum likelihood estimates of the parameters of the structural model are obtained in the time domain and the Kalman filter is used for updating the unobserved components. If $\mathbf{a}_{t-1}$ is an estimate of α_{t-1}, and $\mathbf{P}_{t-1}$ is its covariance matrix, then the optimal (minimum mean square error) linear projections of $\mathbf{a}_t$ and $\mathbf{P}_t$ at time *t-1* are

$$(9) \quad a_{t|t-1} = A a_{t-1}$$

$$(10) \quad P_{t|t-1} = A P_{t-1} A + \Omega_t$$

The Kalman filter updates the already available optimal predictor $\mathbf{a}_{t|t-1}$ with the new information contained in LBW_t as follows (for details see Harvey 1981):

$$(11) \quad a_t = a_{t|t-1} + P_{t|t-1} Z_t (LBW_t - Z_t' a_{t|t-1}) / f_t$$

$$(12) \quad P_t = P_{t|t-1} - P_{t|t-1} Z_t Z_t' P_{t|t-1} / f_t$$

$$where \quad f_t = Z_t' P_{t|t-1} Z_t + \sigma_\epsilon^2$$

Note that the term in the parenthesis in equation (11) is the prediction error. Thus, equation (11) demonstrates that the predictor $a_{t|t-1}$ is updated by incorporating the prediction error, weighted by $P_{t|t1} Z_t / f_t$, which is the Kalman gain. Similarly, the new covariance matrix P_t in equation (12) is equal to the prior covariance matrix minus $Z_t' P_{t|t-1}$ weighted by the Kalman gain.

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