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The effect of drug use on workplace accidents

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Abstract

In this paper, we examine the relationship between illicit drug use and workplace accidents among young adults in the United States in two complementary ways. The first, examines whether individuals who use drugs are more likely than their non-using counterparts to experience an accident on the job. The second focuses on the individual's consumption choices. The results are mixed. For young adult males, there is some evidence that drug use is significantly and positively related to workplace accidents, but for young adult females, the evidence suggests that there is no systematic relationship between drug use and workplace accidents.

JEL classification: J2S

Keywords: Drug use; Workplace safety; Accidents

1. Introduction

In the last thirty years, there has been a significant decrease in the growth rate of labor productivity in the United States and as a result of this experience the country is paying greater attention to workplace issues. Coinciding with the

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decline in productivity has been an increase in illicit drug use by the employed population. Not surprisingly, the two facts have been combined and it has now become conventional wisdom that drug use is a significant cause of declining productivity. Estimates of the dollar value of the productivity loss due to illicit drug use range from 8.6 to 33 billion dollars per year [1].

In response to these perceived losses, the government and private sector have undertaken an extensive campaign to reduce drug use in the workplace. Hundreds of companies in the United States have developed employee assistance programs alternately aimed at prevention, detection and treatment of employees who use illicit drugs. As of, 1990, 46 percent of all firms with 250 or more employees had a drug-testing program and 79 percent of these firms had a formal employee assistance plan (Hayghe, 1991). The federal government has also been quite active in its effort to control illicit drug use in the workplace. The Drug Free Workplace Act of 1988 requires federal government contractors to maintain drug free workplaces, and executive order 12 564 requires all federal agencies to establish drug free workplace policies. The Department of Defense and Department of Transportation have additional regulations that require their contractors to have drug-testing programs.

The widespread acceptance of a causal link between drug use and declining productivity is surprising given that most of the evidence on the issue is anecdotal in nature [2]. On the other hand, the limited amount of scrutiny of the problem is reasonable in light of documented evidence of the adverse physical and psychological consequences of drug use [3]. The purpose of this paper is to examine the relationship between drug use and productivity in a more systematic way than that found in prior studies. In particular, this paper will investigate the relationship between drug use and workplace accidents. Accidents on the job are often cited as an important consequence of drug use and a significant factor related to declining productivity.

In this paper, we examine the issue in two complementary ways. First, we examine whether individuals who use drugs are more likely than their non-using counterparts to experience an accident on the job. In this analysis, drug use is treated as an input into a job safety production function. Intuition suggests that drug users will be involved in more accidents than non-users. An alternative

[1] The 8.6 billion dollar figure comes from a study by Rice et al. (1990) and refers to the year 1985. The 33 billion dollar figure is from the Institute of Medicine (1990).

[2] See the Institute of Medicine (1994) publication Under the Influence? Drugs and the American Work Force for a review of previous studies examining drugs and productivity.

[3] Information regarding the physiological effects of marijuana and cocaine, the two drugs examined in this paper, can be found in the report of the Institute of Medicine (1990) on Marijuana and Health, and the NIDA monograph, Mechanisms of Cocaine Abuse and Toxicity edited by Clouet et al. (1991).

approach is to focus on an individual's consumption choices. Assuming that drug use affects the probability of having an accident, it can be shown that wages and workers' compensation benefits will have a significant impact on drug consumption levels. The logic underlying this hypothesis is relatively simple: an accident results in a loss of income the size of which is determined by the difference between wages and workers' compensation benefits. Thus, an examination of the effect of wages and workers' compensation benefits on drug use provides indirect evidence that drug use affects workplace accidents.

The results of the analyses are mixed. Among young adult males, estimates indicate that past year drug use is significantly and positively related to the probability of having a workplace accident in the past year. On the other hand, variation in wages and workers' compensation benefits had little effect on the probability that a young adult male would be a drug user. For young adult females, the results suggest that drug use had little effect on workplace accidents. Past year use was not significantly related to past year accidents, and wages and workers' compensation were not significant predictors of past year drug use.

2. Previous research

There have been few systematic studies of the effect of illicit drug use on workplace accidents, and none to our knowledge in the economics literature. Most of the information that makes it way into the public consciousness comes from the popular press. The most sensational reports are often based on the analysis of post-accident drug tests from the transportation industry. This type of information, however, is not useful because the prevalence rate of illicit drug use among employees who are not involved in an accident is unknown. Typically, post-accident drug tests reveal prevalence rates of illicit drug use of between one and 13 percent (Institute of Medicine, 1994). These figures, however, are similar to estimates of past 30-day use of illicit drugs from the National Household Survey of Drug Abuse (National Institute on Drug Abuse, 1988), that reports a prevalence of nine percent for males in 1988. This is the relevant comparison group since most of the jobs analyzed are in male dominated occupations and most of the reported tests occurred between the years 1985 and 1989. Given these figures, it is not obvious that drug use is a significant factor associated with workplace accidents.

In addition to the studies that examine post-accident drug tests, there have been several studies which compare the accident rate of drug users to that of non-users [4].

[4] See the studies of Hingson et al. (1985), Holcum et al. (forthcoming), Zwerling et al. (1990) and Normand et al. (1990).

In these studies, drug use in the past year tends to be positively correlated with an increase in the probability of experiencing an accident on the job, but the associations are usually not significant. Most of these studies use small, regional samples and/or focus on only one industry, so their findings may have limited applicability to other populations. Furthermore, these studies use a relatively limited set of control variables and fail to take into account the possibility that the drug use may be endogenous.

Our study represents a significant improvement over previous investigations of the relationship between drug use and workplace accidents. First, we use multivariate regression models to form non-experimental control groups. Therefore, our study goes beyond simply reporting the prevalence of drug use among individuals experiencing workplace accidents. Second, our study utilizes a nationally representative sample of young adults in the United States. Young adults are a particularly interesting group to examine since they have relatively high rates of both drug use and workplace accidents, and since the data are representative of the national population makes our findings more general than past studies. Third, our empirical analyses are based on a more complete specification of the behavioral relationships underlying drug use and workplace accidents. Therefore, our estimates of the effect of drug use on workplace accidents can be given a more causal interpretation than estimates from previous studies. Finally, we examine the effect of drug use on workplace accidents by focusing on individual consumption choices. This is a novel aspect of our paper, and one that provides indirect evidence of the effect of drug use on workplace accidents.

3. Economic models of workplace accidents

There is a sizable literature concerning the determination of the number of workplace accidents and injuries [5]. Most of the previous work in this area is empirical in nature and based on models that relate the number of accidents to the level of workers' compensation benefits, the employee's wage, firm size and other state and industry characteristics [6]. The reasons for including these variables in the model are straightforward. Wages and workers compensation benefits determine the employee's financial loss associated with a workplace accident or injury. Higher benefits reduce the cost of an injury and provide an incentive for the

[5] See for example Chelius (1974, 1982), Butler and Worrall (1983), Ruser (1985, 1991) and Moore and Viscusi (1989).

[6] Ruser (1985) develops a simple theoretical model that rationalizes the past empirical work, particularly as it relates to the inclusion of workers' compensation benefits in the empirical model.

worker to take less precaution against accidents or to file more claims. Therefore, more injuries will occur as a result of higher benefits. Higher wages increase the cost of an injury to the worker and the worker should take greater precaution against injury. Therefore, we would expect wages to be negatively related to the number of injuries and accidents.

The level of workers' compensation benefits, however, also affects the firm's behavior. Higher benefits increase workers' compensation insurance premiums and provide an incentive for the firm to invest in injury reducing production processes. Therefore, higher benefits may reduce the number of injuries. On average, it appears that the net effect of an increase in benefits is an increase in accidents and injuries [7]. Finally, as Ruser (1985) demonstrates, the size of the firm is an important determinant of injury rates because of the way workers' compensation insurance is priced. In large firms, the insurance payments are more likely to reflect the true marginal cost of an accident or injury because these firms are experience rated with respect to accident histories, and the firm will undertake the optimal amount of investment in job safety (i.e., marginal benefit). Ruser (1985, 1991) and others do in fact find that large firms have a lower injury rate.

Recently, Durbin (1992) has incorporated the consumption of alcohol into the standard model of workplace accident determination. In his model, there is an accident production function that includes alcohol consumption, other worker chosen safety producing inputs, and firm safety producing inputs. In addition to the accident safety production function, Durbin (1992) specifies a utility function that depends on alcohol use and the probability of experiencing an accident on the job. The solution to the consumer's problem yields an accident probability model that depends on wages, workers compensation benefits and alcohol use. Empirically, Durbin (1992) tests his model using state-level aggregate data and finds that greater alcohol consumption leads to an increase in workplace accidents.

4. A model of drug consumption

An obvious way to examine the effects of drug use on workplace accidents is to follow Durbin (1992) and incorporate illicit drug use into the model of workplace accidents. This method is straightforward and one that is pursued in this paper. An alternative approach, however, is to focus on the individual's consumption choices. Assuming that drug use affects the probability of having an accident, it can be shown that changes in wages and workers' compensation benefits will alter drug

[7] For evidence on this point see Chelius (1974, 1982), Butler (1983), Ruser (1985, 1991), and Moore and Viscusi (1989). Moore and Viscusi (1989) present evidence indicating that higher benefits reduce the risk of job related fatalities.

consumption levels. Thus, an examination of the effect of wages and workers' compensation benefits on drug use provides indirect evidence that drug use affects job safety.

The structural relationships between drug use, wages and workers' compensation benefits can be derived from a simple model of inter-temporal consumer choice. Assume that there are two periods, $(i = 1, 2)$, and that utility in each period is a function of drug use (D_i) and other consumption (X_i). Furthermore, assume that utility is inter-temporally separable, and within each period, separable with respect to drug use and other consumption.

Accidents occur in period two, and the probability of an accident (π) depends on first period drug use. We assume that an increase in period one drug use increases the probability of an accident in period two. In period two, the consumer finds himself in one of two states, healthy $(j = 1)$ or injured $(j = 2)$, depending on whether an accident has occurred. Accordingly, we specify a state dependent utility function for period two since the marginal utility of consumption is expected to be lower in the injured state relative to the healthy state.

Under these conditions the individuals expected utility $[E(U)]$ may be written as

$$E(U) = U(D_1) + V(X_1) + [1 - \pi(D_1)]U^1(D_{21}) + \pi(D_1)U^2(D_{22}) + [1 - \pi(D_1)]V^1(X_{21}) + \pi(D_1)V^2(X_{22}) \quad (1)$$

Note, that due to the separability assumption, there are different utility functions for drug use $(U$ and $U^i)$ and other consumption $(V$ and $V^i)$. The model specified by Eq. (1) is applicable to a class of individuals with identical tastes for risk. The variation in risk of injury on the job is solely a function of differences in drug use.

Assuming that the consumer has no ability to borrow or lend, the relevant budget constraint for period one is the following [8]:

$$X_1 = W - pD_1 \quad (2)$$

where W is the wage rate, which is assumed to be time invariant, p is the price of drugs, which is also assumed to be fixed over time, and the price of other consumption has been normalized to one. The second period budget constraint

[8] One of the items in the composite good X includes a worker chosen safety input into the accident production function. Substituting the determinants of the demand for this safety input into the model results in an accident production function that includes wages and workers' compensation benefits (Durbin, 1992).

may be written in two parts corresponding to the two states of the world that may occur:

$$X_{21} = W(D_1) - pD_{21} \tag{3}$$

and

$$X_{22} = bW(D_1) - pD_{22} \tag{4}$$

All variables in Eqs. (3) and (4) have been previously defined except for b which is the proportion of earnings replaced by workers' compensation insurance. Specifying workers' compensation benefits in this matter is consistent with the way in which workers' compensation benefits are commonly established. In most states b is equal to two-thirds of weekly wages for injuries that are categorized as a temporary total disability (the most common). Finally, note that drug use in period one is allowed to have an impact on the second period wage with the expectation being that an increase in drug use lowers the wage.

Substituting Eqs. (2)–(4) into Eq. (1) yields the following expression for expected utility

$$\begin{aligned} E(U) = {} & U(D_1) + V(W - pD_1) + [1 - \pi(D_1)]U^1(D_{21}) \\ & + \pi(D_1)U^2(D_{22}) + [1 - \pi(D_1)]V^1(W(D_1) - pD_{21}) \\ & + \pi(D_1)V^2(bW(D_1) - pD_{22}) \end{aligned} \tag{1a}$$

The consumer's problem is consequently to choose a level of first period (current) drug use to maximize expected utility (Eq. (1a)). The first order condition for this problem is,

$$\frac{U_D}{V_X} = p + Z_1 + Z_2 \tag{5}$$

where,

$$Z_1 = \frac{\pi_D}{V_X}\{[U^1(D_{21}) - U^2(D_{22})] + [V^1(X_{21}) - V^2(X_{22})]\} > 0$$

and

$$Z_2 = \frac{W_D}{V_X}\{[1 - \pi(D_1)]V_X^1 + \pi b V_X^2\} > 0$$

Eq. (5) is the familiar consumer equilibrium condition. U_D and V_X are the marginal utility of current drug use and other consumption respectively, U_D^j and V_X^j are the marginal utility of period two drug use and other consumption in the healthy $(j=1)$ and injured $(j=2)$ state, π_D is the partial derivative of the accident probability with respect to a change in drug use, and W_D the partial derivative of the wage with respect to drug use. The right-hand-side of Eq. (5) represents the ‘full’ price of drug use which includes the market price (p) and two additional costs of drug use associated with: (1) An increase in the probability of having an accident (Z_1), and (2) a decrease in consumption in the period two healthy state due to a lower second period wage (Z_2).

5. Wages, workers’ compensation benefits and drug use

The effect of wages and workers’ compensation benefits on drug consumption can be derived from Eq. (5), and details of the derivation are contained in Appendix A. The results indicate that workers’ compensation benefits and drug use should be positively related. An increase in benefits increases consumption in the period two injured state, and the difference in the level of utility between the healthy and injured states will decrease. Thus, the ‘full’ price of drug use will decrease as Z_1 in Eq. (5) becomes smaller. The reduction in price will increase consumption. These results suggest that drug use should be greater among individuals receiving more generous workers’ compensation benefits. In addition to this effect, however, a change in benefits has a second order effect on the ‘full price’ of drugs that works through the expression Z_2. An increase in benefits increases the level of consumption in the period two injured state, and increases the negative effect of a lower second period wage. This acts to increase the ‘full’ price of drugs and reduce consumption. This latter effect, however, should be small and so it is expected that an increase in benefits should lead to an increase in current drug use. This last statement would be particularly true if drug use did not have an adverse impact on wages since in this case Z_2 is equal to zero. Recent studies that have investigated the impact of drug use on wages have found that drug use has a positive or insignificant effect on wages (Gill and Michaels, 1990; Register and Williams, 1990; Kaestner, 1991, 1994). Given this evidence, it is expected that benefit levels will have a positive effect on drug use.

The relationship between the wage and current drug use is expected to be negative, although as was the case with workers’s compensation benefits this prediction is subject to some qualification [9]. A change in the wage will affect both components of the ‘full’ price of drugs, and it is possible to determine the sign of

[9] The model neglects the fact that one of the goods that make up the composite commodity, X, is leisure, and that the wage is the price of leisure. Thus, in addition to the effects of the wage on drug use described in the text, the wage would expected to effect druguse negatively (positively) if leisure and drug use were complements (substitutes) in consumption. Our intuition is that drugs and leisure should be complements in consumption, and thus the wage and drug use should be negatively related.

the effect of wages only for the component Z_1. An increase in the wage will increase the costs of drug use as the difference between period two consumption in the healthy and injured state increases. This should lead to a decrease in drug use. The wage, however, also affects Z_2 but it is not possible to specify a priori the sign on this partial derivative. Therefore, it is an empirical question as to how wages and drug use will be related. If, however, drug use does not have an adverse effect on the wage, the expected relationship between wages and drug use is negative. Note that this is an income compensated effect, since in addition to this price effect a change in the wage will alter income, and consequently the level of drug use.

6. The effect of drug use on workplace accidents

6.1. Empirical model

The relationship between drug use and workplace accidents is examined from two perspectives. The first is a direct examination of the effect of drug use on probability of being involved in an accident. This analysis builds on the previous empirical literature related to workplace accidents and is most similar to the work of Durbin (1992), who examined the effect of alcohol consumption on the injury rate using state-level aggregate data. The typical empirical model found in previous studies specifies workplace accidents or injuries to be a function of the wage, workers' compensation benefits, and other state or industry characteristics. We refer to this as the structural model.

In this paper, we use individual-level data, and specify a reduced form model of workplace accidents in which the probability of accident depends on the level workers' compensation benefits, personal characteristics and job characteristics. The model is a reduced form because we replace the potentially endogenous wage with its exogenous determinants. The wage is likely to be endogenous since workers' receive a wage premium on jobs that have a high degree of risk of injury. Therefore, it is likely that those who experience a workplace accident will have higher wages.

The reduced form estimate measures the direct and indirect effects of drug use on workplace accidents. For example, drug use may have a direct effect on the probability of a workplace accident if drug use impairs a worker's mental and physical abilities. Drug use, however, may also have an indirect effect on workplace accidents that works through the wage. Drug use may lower a person's wage and, all else equal, increase the probability of an accident on the job because the financial loss associated with an accident has been reduced.

The current specification of the workplace accident model is as follows:

$$A_{nt}^{*} = X_{nt}\beta + \alpha D_{nt} + \varepsilon_{nt} \quad A_{nt} = 1 \text{ if } A_{nt}^{*} \geq 0 \quad A_{nt} = 0 \text{ if } A_{nt}^{*} < 0 \qquad (6)$$

where A^* is an unobserved index of the likelihood of having an accident, A is an indicator of whether an accident occurred in the past twelve months, X_{nt} is a vector of explanatory variables, D_{nt} is a measure of past year drug use, β and α are parameters to be estimated, ϵ is an error term, $n=1$ to N is an index of individual observations, and $t=1$ to 2 is an index of time.

An important point to note about Eq. (6), is that drug use is potentially endogenous. The level of drug consumption is dependent on the ex-ante risk of accident on the job as can be seen in Eq. (5). All else being equal, those with higher risk of accident or injury on the job should have lower drug use because for these individuals, the 'full' price of drugs is higher than for individuals on jobs with less risk. In light of this consideration, we test whether drug use is endogenous and report on the results of those tests below.

6.2. Data

The data used in the analysis come from the National Longitudinal Survey of Youth (NLSY) which is a longitudinal survey of the labor market experiences of young adults who were between the ages of 14 and 21 in 1979 (Center for Human Resource Research, 1993). The data contain detailed information on a respondent's labor market experience, family and personal background, involvement in workplace accidents and illicit drug use. Respondents have been interviewed on a yearly basis since 1979.

Central to the purposes of this paper is the questions related to respondent's illicit drug use and workplace accident experience. In 1984, 1988 and, 1992 the respondent was asked questions about their lifetime and recent use of marijuana and cocaine. The drug use measures included in the NLSY are relatively crude and measure the frequency of lifetime and past 30 day use, and whether the person used marijuana or cocaine in the past year. The empirical analysis focuses on the measure of past year use, since relatively few individuals report past 30 day use and lifetime use is not relevant to past year accidents [10]. Thus, all results pertaining to past year measures of drug use need to be interpreted in a context consistent with what this variable measures. The past year use variable distinguishes users from non-users, but makes no distinction between heavy users and recreational users.

In addition to the drug use questions, in 1988 and, 1992 the respondents were asked to report whether they had been involved in a workplace incident that

[10] To differentiate potentially heavy past year users from light users, we interacted past year use with lifetime use. We assumed that individuals with past year use and a high lifetime frequency of use are relatively heavy users. The results, not reported, were very similar to those that used only past year use. The estimate of the effect of past year use did not differ significantly by lifetime frequency of use.

resulted in an injury or illness in the past twelve months. Given the timing of the drug use and accident information, only the years 1988 and, 1992 can be used for this analysis. The sample used in the analysis was restricted in two ways depending on the race, and employment status of the respondent. To be included in the sample, respondents had to be non-black, employed at some time during the year prior to the interview, and have no missing data. These restrictions resulted in a male sample of approximately 1600 to 2200 depending on the year and specification of the model, and a female sample of approximately 1500 to 2100, again depending on the year and model. The use of race as a selection criterion was in response to concerns over differences in the accuracy of self-reports of drug use. Mensch and Kandel (1988) suggest that there is under-reporting of drug use by minorities in the NLSY [11]. Restricting the sample to those who were employed during the year is necessary because the question pertaining to the probability of accident refers to the last year. A respondent had to work at least some portion of the year to be at risk of accident.

Besides drug use, the other independent variables used in the analysis consist of person specific characteristics, job attributes, and the level of workers' compensation benefits. The person specific variables include age, score on the Armed forces qualifications test (AFQT), education, past month alcohol use and past labor market experience; the job characteristics include usual hours of work per week, tenure, union status, industry and occupation. All of the personal characteristics, except labor market experience, will be measured at the time interview, and labor market experience will be measured as of one year prior to the interview. The job characteristics are a weighted average of the characteristics of all the jobs held in the prior year. The weight used was the proportion of annual hours worked on that job [12].

In addition to those variables just noted, a measure of workers' compensation benefits is included in the analysis. The workers' compensation benefit data comes from the US Chamber of Commerce (various years). As a proxy for the generosity of benefits in the state, the state specific maximum and minimum income benefit for total temporary disability were included in the model, as were interactions between these two variables and the level of education. Table 1 provides descriptive statistics for some of the variables used in the analysis.

[11] Other researchers have defended the accuracy of the self reports of drug use in the NLSY. Sickles and Taubman (1991) report on an unpublished study that purports to find no under-reporting, and Kaestner (1994) indicates that the 1988 NLSY drug figures are comparable to those of the National Household Survey on Drug Use (National Institute on Drug Abuse, 1988). Mensch and Kandel (1988) also suggest that females under-report, and thus they are treated separately.

[12] For individuals who were injured on the job and missed work, the annual hours of work were adjusted by multiplying the usual hours of work per week on the job by the amount of weeks the respondent missed due to injury.

Table 1
Personal characteristics of young adults in NLSY data by whether injured on job in last year

	Males		Females	
	Injured on job	No job injury	Injured on job	No job injury
1988				
Percentage of respondents who used marijuana in past year	*36.9	28.2	*27.4	19.4
Percentage of respondents who used cocaine in past year	*18.8	13.0	*15.3	8.2
Number of alcoholic drinks in past month	30.3	26.3	*17.9	10.2
Age	27.4	27.6	27.7	27.7
Number of years of completed schooling	*12.1	13.2	*12.8	13.3
Number of years of experience	6.9	6.8	6.0	6.4
Score on armed forces qualifications test	*67.9	74.2	73.7	76.1
Number of observations	309 (13.7%)	1947 (86.3%)	157 (7.22%)	2016 (92.78%)
1992				
Percentage of respondents who used marijuana in past year	*24.6	17.8	10.1	11.8
Percentage of respondents who used cocaine in past year	6.9	4.8	3.4	2.9
Number of alcoholic drinks in past month	51.4	54.2	37.1	35.5
Age	31.2	31.4	31.5	31.5
Number of years of completed schooling	*12.5	13.6	*13.1	13.7
Number of years of experience	10.2	10.4	9.1	9.6
Score on armed forces qualifications test	*70.8	76.0	*72.4	77.1
Number of observations	175 (10.13%)	1552 (89.87%)	89 (5.71%)	1470 (94.29%)

* Indicates significant difference ($p < 0.05$) between injured and non-injured.

6.3. Estimation and results

The first question that we address is whether drug use is exogenous. To test this proposition, we estimate Eq. (6) using a two stage least squares (IV) procedure for binary dependent variables proposed by Heckman and MaCurdy (1985). We then test the exogeneity hypothesis using a Wu–Hausman test (Wu, 1973; Hausman, 1978). We estimate Eq. (6) separately by year (1988 and, 1992), gender and type of drug (marijuana and cocaine). The first stage regressions are used to create a predicted measure of past year drug use to include in the second stage accident probability model. Instruments used to create the first stage predicted value include family background variables (e.g., religious affiliation), respondent personality traits (e.g., locus of control scale, self esteem scale) measured as of 1980 and area-specific measures (e.g., region, degree of urbanization, local crime rate, local poverty rate). First, we tested whether the excluded instruments were significantly different from zero in the first stage regressions. The associated Wald-statistics were always significant at the 0.05 level or less [13]. Therefore, the excluded instruments are sufficiently correlated with the potential endogenous drug variables to be considered reasonable. In addition, tests of overidentifying restrictions could not be rejected in six of the eight cases [14]. Only for the 1992 female sample did the overidentification tests reject the null hypothesis. Finally, results from the Wu–Hausman tests of exogeneity could not reject the null hypothesis in any case. The typical p-value associated with these tests was in the 0.5 range. Based on the results of these exogeneity tests, we treated drug use as exogenous in the accident probability model.

The exogeneity of drug use enables us to use single equation estimation methods. Accordingly, estimates of the parameters of Eq. (6) are obtained using maximum likelihood methods based on the assumption that the error term follows a logistic distribution (i.e., a logit model). The parameter estimates of the effect of drug use on the probability of having an accident are presented in Table 2. Appendix A contains a complete set of estimates for a representative model. Table 2 presents the results separately by sex of the respondent and by year [15]. Twelve separate models were estimated for each gender in each year. The twelve models

[13] A Wald test was used to test the linear restrictions since the linear probability model of past year drug use is characterized by heteroscedasticity. White's (White, 1982) correction was used to obtain a consistent estimate of the variance–covariance matrix.

[14] We used a test suggested by Hausman in which the second stage residuals are regressed on all of the exogenous variables in the model (Greene, 1993). The test statistic is formed by calculating $T(R2)$, where T is the number of observations and $R2$ is the unadjusted R-square statistic from the regression. This statistic is distributed as chi-square.

[15] A fixed effect model could not be estimated because of the small number of individuals that experienced an accident in 1988 (1992), but not in, 1992 (1988). For example, among males, only about 200 individuals changed their accident status between the two years.

Table 2
Logit estimates of the effects of drug use of workplace accidents (standard errors in parentheses)

	1988				1992			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Males								
Model 1: Past year cocaine use	0.354^{*} (0.168)	0.319^{+} (0.173)	0.335^{+} (0.190)	−0.013 (0.143)	0.324 (0.331)	0.466 (0.338)	0.528 (0.350)	0.901^{*} (0.402)
Model 2: Past year marijuana use	0.291^{*} (0.134)	0.269^{*} (0.137)	0.280^{+} (0.148)	0.008 (0.106)	0.316 (0.197)	0.313 (0.202)	0.389^{+} (0.214)	0.592^{*} (0.269)
Model 3: Past year cocaine or marijuana	0.320^{*} (0.153)	0.323^{*} (0.155)	0.333^{*} (0.168)	0.013 (0.120)	0.229 (0.217)	0.207 (0.222)	0.291 (0.237)	0.301 (0.312)
Past year cocaine and marijuana	0.385^{*} (0.188)	0.334^{+} (0.194)	0.347 (0.214)	−0.008 (0.159)	0.491 (0.351)	0.611^{+} (0.358)	0.668^{+} (0.370)	1.165^{*} (0.415)
Personal attributes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job characteristics		Yes	Yes	Yes		Yes	Yes	Yes
Industry and occupation			Yes	Yes			Yes	Yes
Observations	2256	2197	2017	2015	1727	1702	1564	1564
Females								
Model 1: Past year cocaine use	0.471^{+} (0.260)	0.454^{+} (0.267)	0.517^{+} (0.286)	0.422^{*} (0.175)	0.140 (0.614)	−0.355 (0.753)	−0.099 (0.776)	0.064 (1.077)
Model 2: Past year marijuana use	0.250 (0.201)	0.213 (0.206)	0.144 (0.224)	−0.086 (0.149)	−0.228 (0.369)	−0.221 (0.395)	−0.118 (0.416)	0.502 (0.530)
Model 3: Past year cocaine or marijuana	0.015 (0.235)	−0.042 (0.242)	−0.114 (0.264)	-0.441^{*} (0.204)	−0.197 (0.388)	−0.061 (0.397)	0.025 (0.421)	0.403 (0.579)
Past year cocaine and marijuana	0.619^{*} (0.284)	0.598^{*} (0.291)	0.603^{+} (0.314)	0.421^{*} (0.194)	−0.041 (0.746)	−0.779 (1.046)	−0.506 (1.067)	0.462 (1.100)
Personal attributes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Job characteristics		Yes	Yes	Yes		Yes	Yes	Yes
Industry and occupation			Yes	Yes			Yes	Yes
Observations	2173	2100	1913	1912	1559	1518	1381	1381

Notes: $^{+}p<0.10$, $^{*}p<0.05$.
In columns labeled (1), (2), or (3) the dependent variables is an indicator of whether the person had any type of accident on the job in the last year. In columns labeled (4) the dependent variable is an indicator of whether the person had an accident that resulted in lost work days. Personal attributed include: Age, education, AFQT score, past labor market experience, and alcohol use. Job characteristics include: Tenure, union status, usual hours worked per week, hourly wage and workers compensation benefits.

differ according to the specification of drug use and which set of explanatory variables are included in the model. We estimate four separate models for each of three measures of drug use. We were concerned about the possibility that past year marijuana use and past year cocaine use would be highly collinear, so we estimated separate models (four) for each of these two measures. We also, however, estimated another model that included both marijuana and cocaine use. In this case, we specify two dummy variables for drug use: Past year use of cocaine or marijuana, and past year use of cocaine and marijuana. For each of the three measures of drug use, four models were estimated. The models in columns labeled (1), (2) and (3) differ depending on which set of explanatory variables are included, and the models in columns labeled (4) use as the dependent variable an indicator of whether the respondent had an accident that resulted in lost work days.

Examining the estimates for the 1988 male sample first, it can be seen that both past year marijuana and cocaine use have a positive and significant effect on the probability of having an accident on the job in the past 12 months. The magnitudes of the effects are substantial. Evaluated at the sample mean probability of 0.137, a coefficient estimate of 0.3 implies a change in the accident probability of approximately 3.5 percentage points, which represents a 25 percent relative change in the accident probability. The estimates of the effect of drug use are not sensitive to the inclusion of a large set of control variables, as evidenced by the similarity of the estimates between columns 1, 2 and 3. The estimates in column 4, however, differ markedly from those in the first three columns. These estimates imply that drug use does not have a significant effect on the probability of having an accident that results in lost workdays. One interpretation of the differences between the estimates in column 4 and those in columns 1 through 3 is that drug users have a different perception of what constitutes an accident, and therefore report more accidents than non-drug users. Alternatively, drug use may cause more minor accidents that result in less serious injuries, but not affect the rate of serious accidents.

The estimates of the effect of drug use on the probability of an accident for the, 1992 male sample are positive, but usually not significant. The magnitudes of the effects, however, are similar to the 1988 estimates. A coefficient of 0.3 implies a change in the accident probability of 2.7 percentage points, which is approximately a 25 percent relative change in the accident probability. The lack of statistical significance of the estimates may be due to the fewer number of past year drug users in, 1992 relative to 1988, and the lower mean accident probability. The estimates in column 4 for the, 1992 male sample, however, are very significant and quite large. Contrary to the 1988 estimates, past year drug use is positively and significantly related to the probability of having an accident that results in lost workdays in, 1992.

The estimates of the effect of drug use on workplace accidents among the female sample are usually not significant. Only for the 1988 sample, and only in the case of past year cocaine use, are the parameter estimates significant. In this case, the estimates indicate that past year cocaine use raises the probability of having an accident on the job. The point estimate implies a change in the accident probability of 2.6 percentage points, which translates into a 36 percent relative change.

The estimates regarding the effect of drug use in Table 2 imply a mixed conclusion. For males, drug use tends to have a positive effect on the probability of having an accident on the job, but for females, drug use tends to be unrelated to workplace accidents. These conclusions may not be surprising. Male occupations tend to be more risky than female occupations and men have higher rates of drug use than women.

A representative set of estimates of the effect of other variables is contained in Appendix A. For the male sample, the personal characteristics tended to be significant predictors of workplace accidents. Job characteristics were less significant, although belonging to a union had a large positive effect. The positive effect of union status may be due to reporting differences between union and non-union workers, as opposed to true differences in the rate of accidents. Unionized work settings may have more formal and less threatening procedures to report accidents and this may influence the individual self-reports. For the females, the personal characteristics were usually not significant, but the job characteristics were. Tenure on the job and hours worked per week were significantly related to the probability of having an accident. Similar to men, belonging to a union raised the probability of a workplace accident.

7. The effect of wages and workers' compensation benefits on drug use

7.1. Empirical model

An alternative strategy to investigate the impact of drug use on workplace accidents is to examine whether wages and workers' compensation benefits have an effect on drug use. As previously described, this procedure is an indirect test of the effect of drug use on workplace accidents. The hypothesis being tested in this part of the paper is whether workers' compensation benefits and wages have a significant effect on a person's drug consumption choices. There is an expectation that benefits and drug use will be positively related, and that wages and drug use will be negatively related.

Empirically, a drug demand function needs to be estimated, and we specify it as follows:

$$D_{nt} = Z_{nt}\Gamma + \gamma W_{nt} + \delta B_{nt} + \upsilon_{nt} \quad (7)$$

where D_{nt} is a measure of past year drug use, Z_{nt} is a vector of exogenous variables that determine the level of drug use, W_{nt} is the wage, and B_{nt} is the workers' compensation benefit, Γ, γ and δ are parameters, υ is an error term, and $t = 1$ to 2 is an index of calendar time.

An important empirical issue related to Eq. (7), is the possible endogeneity of the wage. Past research by Kaestner (1991, 1994) and others have shown that wages depend on drug use. Thus, wages may be endogenous. Furthermore, the level of workers' compensation benefits may also be endogenous because it is a function of the wage. In light of these possibilities, we test whether wages and workers' compensation benefits are endogenous. We report the results below.

7.2. Data

The data used in this analysis will be drawn from the NLSY survey years of 1984 and 1988. These two years were chosen because the sample sizes were larger than in, 1992. A significant part of the NLSY sample was dropped after the, 1990 survey year. The sample for this analysis was restricted to white respondents who are employed at the time of interview. The resulting sample sizes were approximately 1800 males and 1600 females.

The vector of explanatory variables in Eq. (7) contains an extensive set of variables that proxy for individual differences in preferences, incomes and prices. Variables that proxy for taste differences include the respondent's age, AFQT score, education, mother's education, whether the respondent lives with his parents, and several family background measures and personal traits measured when the respondent was younger (see Appendix B). A measure of non-earned income is included in the model to measure income differences. Age, education and family background measures will also reflect income differences, as will the wage that is also included in the model. As a proxy for the market price of drugs, several geographic (e.g., region, population density) and area specific measures (e.g., local crime and poverty rates) are included in the model. Finally, industry and occupation dummy variables are used to control for differences in the risk of injury on the job.

The main variables of interest in this analysis are the respondent's wage, and the workers' compensation benefit level. The benefit measure used is the income replacement rate, and it is calculated by dividing the expected weekly workers' compensation benefit for temporary total disability by the actual weekly earnings of the respondent (Viscusi and Moore, 1987). Significant differences in the replacement ratio can arise due to differences in the maximum and minimum benefit levels across states, although for this sample of young adults there is less variation than usual because many of the respondents are not constrained by the minimum and maximum [16].

[16] An alternative benefit measure was also used, and this was the state specific average employer workers' compensation insurance payment expressed as a percent of payroll. The findings were not qualitatively different when this benefit measure was used.

7.3. Estimation and results

Eq. (7) was estimated by a two stage least squares procedure suggested by Heckman and MaCurdy (1985) in the case of binary dependent variables. Both the wage and the workers' compensation benefit measure were treated as endogenous. In order to identify the model, the respondent's past labor market experience, the workers' compensation statutory maximum and minimum benefit level, and the local unemployment rate were used as instruments to predict the wage and workers' compensation replacement rate, but were excluded from the drug demand equation. These were reasonably chosen instruments. Wald tests of their significance in the first stage regressions were always significant at the 0.05 level or less, and tests of overidentifying restrictions could not reject the null hypothesis in six out of eight cases (two drug types, two genders, two years). The rejected overidentification restrictions occurred in regard to the female sample, and models of past year cocaine use. Finally, a Wu–Hausman test of the exogeneity of wages and workers' compensation replacement rate rejected the exogeneity hypothesis in five out of eight cases. Based on the results of the exogeneity tests, we treated the wage and workers' compensation replacement rate as endogenous.

Table 3 lists the parameter estimates of the effect of wages and workers' compensation benefits on drug use. Our expectation is that workers' compensation benefits and drug use will be positively related, and that wages and drug use will be negatively related. The models were estimated separately by gender and year [17]. A complete representative set of results can be found in Appendix B.

The estimates in Table 3 are for the most part not supportive of the hypothesis that drug use affects the probability of having a workplace accident. In contrast to expectations, the estimates of the effect of workers' compensation benefits on drug use are usually negative, although rarely significant. Similarly, only half of the estimates of the effect of the wage on drug use are significant, although all are negative as predicted. The wage has the largest and most significant effects with respect to past year marijuana use. Those individuals with higher wages are significantly less likely to have used marijuana in the past year. For example, using the 1984 estimates, a one dollar increase in the wage rate is expected to lower the probability of being a past year marijuana user by almost nine percentage points for women. This is a large effect given a mean probability of past year marijuana use of approximately 20 percent.

Other variables in the model had the effect that one would intuitively expect. For example, more educated individuals and those who previously attended religious services frequently had a lower probability of being a past year drug user,

[17] As was the case in the analysis of workplace accidents, a fixed effect model was not feasible due to the small number of individuals that changed drug use status between 1984 and 1988.

Table 3
Estimates of the effects of wages and workers' compensation benefits on drug use parameter estimates from 2SLS linear probability model (standard errors in parentheses)

	1984		1988	
	Past year cocaine	Past year marijuana	Past year cocaine	Past year marijuana
Males				
Hourly wage (predicted)	-0.027^{+} (0.016)	-0.117^{*} (0.028)	−0.025 (0.018)	-0.068^{*} (0.029)
Workers compensation (predicted)	−0.048 (0.046)	−0.007 (0.073)	−0.116 (0.191)	−0.437 (0.321)
Observations	1783		1868	
Females				
Hourly wage (predicted)	−0.028 (0.026)	-0.080^{*} (0.040)	−0.014 (0.013)	-0.049^{*} (0.023)
Workers compensation (predicted)	-0.073^{+} (0.038)	-0.108^{+} (0.064)	−0.083 (0.068)	−0.147 (0.103)
Observations	1628		1609	

$^{+}p < 0.10$, $^{*}p < 0.05$.
Notes: Other variables included in the model are: Occupation, age, education, experience, unearned income, personal characteristics, mother's education, geographic location, density of location, crime rate, and poverty rate (See Appendix A for list of variables).

while those respondents who engaged in illegal activities when young and who live in areas with a high crime rate have a greater probability of being a drug user.

8. Conclusion

The purpose of this paper has been to investigate whether illicit drug use is significantly related to workplace accidents. Toward this end, we presented two complementary analyses of the issue using a nationally representative sample of young adults in the United States. The first examined the effect of drug use on workplace accidents directly by testing whether drug use was significantly correlated with workplace accidents. The second analysis was less straightforward and focused on individual consumption choices. Specifically, we tested whether workers' compensation benefits and wages, the determinants of the financial loss associated with a workplace accident, were significantly related to drug use.

The results are mixed. For the female sample, the evidence supports the conclusion that on average, drug use is not significantly related to the incidence of workplace accidents. This result is not surprising for two reasons. First, women work predominantly in occupations that are less hazardous, and where on-the-job accidents are less frequent. Second, women have relatively low levels of drug use and are less likely to be impaired by such use. Both of these facts may explain the absence of a significant effect of drug use on workplace accidents for the female sample. Among males, however, direct estimates of the effect of drug use on workplace accidents indicate that drug use raises the probability of having a workplace accident by approximately 25 percent. This is a large and significant effect. The indirect evidence of such a relationship, however, was somewhat weak: higher wages were associated with less drug use as predicted by our theoretical model, but workers' compensation benefits had no effect on drug use.

We place less weight on the results from the indirect analysis because of the demands this analysis makes on our data. The theoretical basis of the indirect test is the hypothesis that drug use is affected by factors such as wages and workers' compensation benefits that determine the size of the expected personal financial loss resulting from a drug related workplace accident. Since the probability of having an accident is relatively low, however, and the personal financial loss associated with an accident potentially not that great given the levels of wages and workers' compensation benefits, the expected financial loss resulting from a drug related accident may be small. More importantly, there may not be enough variation in the expected financial loss to identify a systematic effect of wages and workers' compensation on drug use. Given the relatively large direct evidence of a significant effect of drug use on workplace accidents, we tend to give less weight to the results of the indirect analysis. Therefore, we conclude that drug use does have a significant effect on workplace accidents among males.

The results of this analysis are important. Firms and the government dedicate a significant amount of resources to eradicate drug use by their employees, and part of that spending is justified by a belief that drugs are a significant cause of employment related accidents. While we cannot provide a full cost–benefit analysis of workplace drug policies, we can use our results to document the benefits of anti-drug policies on workplace accidents. For example, in, 1992, approximately 25 percent of our male sample used drugs in the past year and ten percent were involved in a workplace accident. If drug use was reduced to zero among this group, our estimates indicate that the incidence of workplace accidents would decline approximately one percentage point, or about ten percent. This appears to be a modest effect given that a program that reduced drug use to zero would presumably be quite costly. Thus, the beneficial effects of drug use on workplace accidents can justify only a small part of total spending on programs aimed at reducing drug use.

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Appendix A

Eq. (5) in the text is reproduced here for reference:

$$\frac{U_D}{V_X} = p + Z_1 + Z_2$$

where,

$$Z_1 = \frac{\pi_D}{V_X}\left\{\left[U^1(D_{21}) - U^2(D_{22})\right] + \left[V^1(X_{21}) = V^2(X_{22})\right]\right\} > 0$$

and,

$$Z_2 = \frac{W_D}{V_X}\left\{\left[1 - \pi(D_1)\right]V_X^1 + \pi b V_X^2\right\} > 0$$

The right hand side of Eq. (5) consists of the market price of drugs and the additional components of the ‘full’ price of drugs that are related to the adverse

Table 4
Parameter estimates from drug demand model corresponding to Table 2, column 3

Variable	Female, past year marijuana use (1988)		Males, past year cocaine use (1992)	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Intercept	−23.345	15.974	−34.820^{+}	19.708
Past year cocaine/marijuana use	0.144	0.224	0.528	0.350
Age	1.160	1.144	1.942	1.247
Age squared	−0.204	0.206	−0.313	0.197
AFQT score	0.057	0.045	−0.003	0.029
AFQT squared	−0.034	0.032	0.006	0.022
High school	−0.386	0.921	0.011	0.957
Some college	−0.267	1.074	−0.017	1.342
Bachelors	−0.441	1.261	−1.987	1.615
Postgraduate	−0.568	0.590	−0.799	0.541
Experience	0.181	0.216	0.422^{+}	0.246
Experience squared	−0.020	0.019	−0.026*	0.013
Unemployment rate	−0.053	0.041	0.063^{+}	0.038
Alcohol	0.005	0.003	−0.003*	0.001
Maximum benefit	0.000	0.002	0.001	0.002
Max. benefit × high school	0.002	0.003	−0.001	0.002
Max. benefit × some college	0.000	0.003	−0.002	0.003
Max. benefit × bachelors	−0.001	0.004	0.002	0.004
Minimum benefit	0.002	0.005	−0.006	0.004
Min. benefit × High School	0.001	0.005	0.005	0.004

Min. benefit × some college	0.001	10.007	0.001	10.006
Min. benefit × bachelors	0.005	0.007	0.001	0.007
Union	0.542*	0.266	0.773*	0.212
Tenure	−0.003	0.003	−0.002	0.002
Tenure squared	0.001	0.001	0.000	0.000
Hours per week	0.069*	0.031	0.040	0.033
Hours squared	−0.046	0.034	−0.034	0.031
Professional	−0.281	0.629	−0.728	0.445
Managerial	−0.755	0.642	−1.506*	0.462
Sales	−1.335	0.831	−1.960*	0.851
Clerical	−1.089+	0.609	−0.635	0.491
Craft	0.130	0.731	−0.242	0.312
Operative	−0.200	0.628	−0.260	0.329
Service	0.297	0.597	0.161	0.404
Construction	−0.096	1.195	0.263	0.415
Manufacturing	0.808	0.729	0.652+	0.393
Transportation	0.281	0.873	0.507	0.460
Trade	0.702	0.721	0.678+	0.410
Finance/insurance	−0.030	0.851	−0.823	1.105
Government	0.617	0.858	0.603	0.499
Service	0.416	0.724	0.010	0.433

Females, past year marijuana use (1988) and males, past year cocaine use (1992).
$^{+}$ $p < 0.10$, * $p < 0.05$.

Table 5
Parameter estimates from drug demand model corresponding to Table 3

Variable	Female, past year marijuana use (1984)		Males, past year cocaine use (1988)	
	Parameter estimates	Standard errors	Parameter estimates	Standard errors
Intercept	0.775	1.618	1.201	0.984
Hourly wage (predicted)	−0.080*	0.040	−0.025	0.018
Workers compensation (predicted)	−0.108^{+}	0.064	−0.116	0.191
Professional	0.108	0.093	0.039	0.058
Managerial	0.144^{+}	0.090	0.085	0.056
Sales	−0.012	0.096	0.159	0.111
Clerical	0.044	0.077	0.024	0.043
Craft	0.193^{+}	0.107	0.083^{+}	0.044
Operative	0.143^{+}	0.089	0.041	0.042
Service	0.099	0.080	0.083	0.055
Construction	−0.019	0.162	0.055	0.053
Manufacturing	0.057	0.110	−0.004	0.056
Transportation	0.027	0.141	−0.015	0.059
Trade	0.011	0.107	−0.066	0.077
Finance/insurance	0.057	0.114	−0.029	0.067
Service	0.013	0.107	−0.067	0.067
Government	0.023	0.130	−0.041	0.064
AFQT	0.001	0.001	0.002*	0.001
Age	−0.003	0.138	−0.084	0.082
Age squared	−0.001	0.029	0.016	0.017
High school	0.056	0.053	0.044	0.032
Some college	0.100^{+}	0.063	0.015	0.048
Bachelors	0.105	0.078	−0.009	0.050
Postgraduate	0.189^{+}	0.118	0.026	0.071
Non-earned income	−0.003*	0.001	0.001	0.001
Missing income	−0.047	0.052	0.018	0.032
Lives with parent	0.009	0.040	0.007	0.039
Religiosity	−0.027*	0.008	−0.018*	0.005

Rotter scale	−0.006	0.006	0.001	0.004
Self esteem scale	−0.003	0.003	0.003	0.003
Number of illegal acts	0.002*	0.001	0.001*	0.003
Two parents age 14	0.026	0.037	−0.012	0.026
Mother's education	0.010+	0.006	0.007+	0.004
Missing mother's ed.	0.142	0.100	0.108+	0.058
North East	0.036	0.055	0.048	0.042
North Central	−0.067	0.058	−0.067+	0.040
South	−0.010	0.060	−0.005	0.038
Population density	−0.015	0.044	0.056	0.036
Pop. density sq.	0.003	0.004	−0.003	0.003
North East × density	0.029	0.045	−0.052	0.036
North Central × density	0.128*	0.062	0.014	0.053
South × density	−0.039	0.066	−0.064	0.054
North East × Density sq.	−0.003	0.004	0.003	0.003
North Central × density sq.	−0.178*	0.008	−0.003	0.007
South × density sq.	0.004	0.007	0.002	0.005
Local crime rate	0.025*	0.006	0.012*	0.004
Local poverty rate	−0.010*	0.004	−0.000	0.003

Females, past year marijuana use (1984) and males, past year cocaine use (1988).
+ $p < 0.10$, * $p < 0.05$.

affects of drug use on the probability of accident and wages. The effect wages and workers' compensation benefits on the 'full price' of drugs can be obtained by differentiating Z_1 and Z_2 with respect to wages and benefits. The following assumptions about marginal utility will be made: $V_x,\ V_X,\ V_X^2 > 0$; $V_{XX},\ V_{XX}^1,\ V_{XX}^2 < 0$; $U_D,\ U_D^1,\ U_D^2 > 0$. In addition, the period/state specific budget constraints may be written as follows:

$$D_{21} = W/p - 1/pX_{21}$$

$$D_{22} = (bW)/p - 1/pX_{22}$$

$$X_{21} = W - pD_{21}$$

$$X_{22} = (bW) - pD_{22}$$

Finally, it is assumed that: $W_{DW} < 0,\ p_{DD} > 0,\ p_b = 0,\ p_w = 0$. Given the above assumptions and definitions, the following results are derived for a change in benefits:

$$Z_{1b} = -\frac{\pi_D}{V_X}\left[U_D^2 W(1-p) + V_X^2 W\right] < 0$$

and

$$Z_{2b} = -\frac{W_D \pi(D_1)}{V_X}\left[V_X^2 + V_{XX}^2 b\right] > 0$$

For a change in the wage, the effect on full price is the following:

$$Z_{1W} = \frac{V_X \pi_D}{(V_X)^2}\left\{\left[U_D^1(1/p) - U_D^2(b/p)\right] + \left[V_X^1 - V_X^2 b\right]\right\} - \left\{V_{XX}(Z_1)V_X\right\} > 0$$

and Z_{2W} is a complex function with indeterminate sign.

Appendix B

Tables 4 and 5

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