Incarceration and Labor Markets: A Macroeconomic Analysis

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Abstract

Between 1980 and 2005, the incarceration rate in the United States increased fourfold. At this level, 6.6% of the population will be imprisoned for a year or more during their lifetime. We provide a comprehensive analysis of the effects of increased incarceration rates on all actors in labor markets: criminals, non-criminals, and employers. To do so, we expand a search and matching model to include incarceration. Incarceration has two direct effects: (1) it interrupts employment relationships; and (2) it deteriorates human capital. We estimate the model by indirect inference using variation in incarceration rates across demographic groups. Simulating our model will allow us to measure the effect incarceration has had on broad labor market trends and to predict future effects for different policy scenarios.
1 Introduction

At any given time, two to three percent of the working age population of the United States is imprisoned.\(^1\) The cumulative effect is that, at 2001 incarceration rates, 6.6% of U.S. residents will be incarcerated for a year or more during their lifetime. This includes 1 in 3 black males and 1 in 17 white males, (Bonczar (2003)). In light of the magnitude of these statistics, Sociologists and Microeconomists have provided estimates of the impact of an incarceration experience on individuals’ labor market outcomes. Unsurprisingly, the evidence shows incarceration dramatically worsens an individual’s employment and wage prospects.\(^2\) While these concentrated short term effects are well understood, the broader and long-run effects remain open questions. We have not yet observed a cohort pass through life under the higher rates of incarceration. Nor has the aggregate effects of an increase in incarceration rates on labor markets been well-studied. In this paper, we provide some answers to these questions and argue that, if unchanged, incarceration will play a significant role in the evolution of labor markets and inequality in the decades to come.

Incarceration is an experience similar to other social trends economists have analyzed to understand labor markets. For instance, child birth, disability, and incarceration all interrupt labor market experience. Several studies have shown that even a brief exit from the labor force has permanent effects on wages and employment patterns. For instance, Lundberg and Rose (2000) find a wage penalty of 23% for women who exit the labor force upon the birth of their child\(^3\). This has led to studies showing the introduction of oral contraceptives gave women greater control over the timing of fertility and labor market exit, potentially raising women’s labor force participation by 14% (Bailey (2006)). The rising trends in incarceration incidence and duration do the opposite. They lead to a more volatile and sparse labor market experience amongst the criminal population, potentially leading to wage penalties and lower

\(^1\)2000-2010 data including all adults confined in Federal or State prisons (Sourcebook of Criminal Justice Statistics) or local jails (Annual Survey of Jails). Working age population from Current Population Survey Estimates.


\(^3\)They find no penalty for women who remain continuously employed.
labor force participation.

Quantitatively, incarceration has become increasingly relevant for understanding labor markets. The aggregate incidence is large. By 2000, over two percent of the working age population (16-64) was imprisoned on any given day.\(^4\) Compare this to 5.3% of adults aged 25-64 receiving disability insurance (\textit{Autor and Duggan (2001)}) or less than one percent of working women with a new child birth each year.\(^5\) A more important statistic than the population imprisoned on a given day is the amount of people experiencing incarceration during their lifetime. At 2001 rates, 6.6% of the population and 17% of men will be incarcerated in State or Federal prison during their lives, (\textit{Bonczar (2003)}). Time served in these prisons is typically more than one year. The full magnitude of the impact of rising incarceration rates has yet to hit labor markets. This is because the majority of the current working-age population reached adolescence at a time when incarceration rates were five times lower. Therefore the true impact cannot be measured in current data.

Incarceration complements other factors in our understanding of labor markets because it is concentrated in an unique demographic group. Incarceration disproportionately affects males under 35, African Americans, and the low educated. In this sense, incarceration is part of the story of cross sectional inequality. Yet, to address cross-sectional inequality we must not only measure the negative effect on the criminal population but also a potential positive effect on the non-criminal population that compete with criminals for jobs. For instance, the deterioration and African American male’s outcomes may have played a role in the large improvement in African American women’s outcomes in the past few decades.

In this paper, we provide a comprehensive analysis of the effects of increased incarceration rates on all actors in labor markets: criminals, non-criminals, and employers. To achieve this goal, we build a four-state search theoretical framework featuring employment, unemployment, labor force participation, and incarceration. Workers are born criminals or non-criminals. Criminals face a probability of being incarcerated. We focus on two effects

\(^4\)Includes all adults confined in Federal or State prisons (Sourcebook of Criminal Justice Statistics) or local jails (Annual Survey of Jails).

of incarceration on individuals. First, incarceration cuts employment relationships short and second, it prohibits the incarcerated from building human capital through labor market experience.

The key choice workers make is labor force participation. This allows incarceration to affect the labor market through the channel of labor supply. Incarceration directly reduces labor supply and skills of the criminal and ex-criminal population through forgone labor market experience while incarcerated. Out of prison, criminals may also choose not to participate in the labor market, even if there are jobs available, if their low skills earn a low wage or employment is likely to be interrupted by incarceration. As in all search models, a reduction in labor supply of one demographic group reduces the congestion externality on others. When fewer people are searching, unemployed find jobs more quickly. This raises the value of search and thus raises labor supply of non-criminal workers. The net effect on aggregate labor supply is a quantitative issue. It depends on how much the labor supply of criminals falls versus how much the labor supply of non-criminals increases.

The key choice employers make is whether to create a new job. This allows incarceration to affect the labor market through the channel of labor demand. One one hand, if there are fewer criminals in the pool of unemployed, employers face less risk in creating a new job. They are more likely to hire a non-criminal and not to have the match disrupted by the incarceration of the employee. On the other hand, non-criminals may have a better outside option and higher bargaining power. This could mean lower expected profits from hiring a new worker. Again, the effect on labor demand is a quantitative question.

Our approach provides both a theoretic and a quantitative contribution. First, we contribute to theory by developing a labor market model of incarceration that allows us to measure the externalities criminals and incarceration provide on unemployment, labor force participation, and wages of all participants. The Macroeconomic literature on the impact of incarceration focuses on theories of efficient labor markets that preclude externalities on non-criminals, (Burdett et al. (2004) and Engelhardt et al. (2008)). Additionally, incarceration in our model is a source of “turbulence” of the type proposed by Sargent and Ljungqvist to understand the nature of unemployment persistence. In their papers a turbulent economy

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6See Ljungqvist and Sargent (2005, 2007) and den Haan et al. (2005).
is one with a high employment separation rate and a high probability of skill deterioration when unemployed. In our model, incarceration affects the economy through exactly these two channels. In that way our analysis is both a theoretical exploration of heterogeneity of turbulence across individuals (higher for criminals) and a quantitative analysis of how much incarceration adds to the aggregate turbulence of labor markets.

Our quantitative contribution is an inductive approach to measuring the effect incarceration has had on labor markets. In particular, we use indirect inference to estimate parameters of our model. This allows us to handle censored data, both in independent and dependent variables. This is crucial because microeconomic data identifying both labor market variables and criminal/incarceration variables are limited. The inductive approach also allows us to predict how labor markets will evolve in the future under different incarceration policies. This informs policy discussion because the effects of current high levels of incarceration cannot be directly measured in the data. Instead, we can predict the unfolding of the full effect over future decades as labor markets adjust to cohorts that have spent a larger portion of their adult lives facing the post-2000 levels of incarceration risk.

2 Incarceration in the United States 1970-2012

The recent history of incarceration in the United States is a fascinating and complex phenomenon. We limit our presentation to the facts that motivate the assumptions of our analysis and provide identification in our estimation. These are 1) the rise in the incarceration rate was not strongly related to crime rates or economic conditions; 2) there is large variation across states and over time in sentencing standards and law enforcement resulting in a large variance in incarceration incidence and duration; and 3) there is large variation in incarceration rates across demographic groups.

The rise in incarceration Figure 1 shows the estimated prison population compiled from state and federal prison censuses. The time series has a clear break at 1970. Prior to 1970, these statistics exclude sentenced prisoners in local jails and detained unsentenced prisoners. As such it captures mostly felons with sentences of a year or more. This represents approximately two-thirds of the
the incarceration rate was so constant as to support the stability of punishment hypothesis developed by criminologist Alfred Blumstein, (Blumstein and Cohen (1973)). From 1970 onwards this stability was dramatically broken by a five-fold increase in the incarceration rate before leveling off in the 2000’s.

What caused the massive rise in incarceration in the United States? Sociologist Becky Pettit summarizes the extensive literature as, “there is general agreement that the massive buildup in the size of the penal population has not been due to large-scale changes in crime or criminality,” (Pettit (2012)). This claim seems evident in Figure 2. Neither violent nor property crime trends have mirrored the sharp upturn in incarceration rates. Instead, the rise seems to be a combination of increased expenditure on law enforcement and changing sentencing rules. It is well known the ”war on drugs” originating in the 1980’s both increased the incidence and length of imprisonment for drug-related offenses. The increase in imprisonment for ”public-order” offenses, such as court, traffic, weapons, liquor law, obstruction and other offenses, has also been a key contributor to rising incarceration rates. Figure 3 shows the proportion of those incarcerated for drug or public-order offenses has grown from one-quarter to one-half from 1980 to 2010.

The economics literature finds the causal effect of incarceration on crime to be slightly negative, zero, or even slightly positive, (Johnson and Raphael (2007)). As a result, we will not model this feedback channel directly in the analysis in this paper. Instead we will take changes in crime as exogenous. We also only model the causal effect of incarceration on labor force participation and unemployment, not the reverse. This one-way causality has found support in the literature, (İmrohoroğlu et al. (2004)).

Variation in incarceration across demographic groups Identifying the direct effects of incarceration on the criminal population is complicated by lack of micro-data. Incarceration rate was so constant as to support the stability of punishment hypothesis developed by criminologist Alfred Blumstein, (Blumstein and Cohen (1973)). From 1970 onwards this stability was dramatically broken by a five-fold increase in the incarceration rate before leveling off in the 2000’s.

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tion affects not only those ever imprisoned, but also criminals facing the potential of future incarceration. As a result, we will apply variation in incarceration propensity of different demographic groups to individual-level wage and employment data. This variation allows us to infer the effect of incarceration by comparing statistical moments of demographic groups with low and high incarceration rates in the data to model-simulated “demographic groups” with the same propensities.

The key demographic correlates with incarceration that we can observe in the prison censuses are age, race, and gender. Table 4 shows an example of the variation in incarceration rates for each demographic cell at a fixed point in time (2003). Our analysis requires a more sophisticated set of statistics, namely the variation in incarceration incidence and risk across time and cohorts. This calculation involves prison admission and release, recidivism, and life table data as detailed in the estimation section. Table 5 provides an example of how the static variation in incarceration rates manifest into variation in lifetime incarceration incidence.

Variation in incarceration across US States Variation in crime as well as sentencing laws and norms have provided variation in incarceration incidence and length across states and time. Figures 6 and 7 depict this variation. We will use this variation to test our model. We will feed the different sentencing outcomes and crime rates for a panel of large MSA’s into our model and compare the labor market implications to the data. This is a good test of the model both because of the large variation in crime and incarceration and because labor market externalities are more likely to be concentrated in local labor markets.

### 3 A Four-State Search Model with Incarceration

The model is based on Pissarides (1985, 2000) with random matching between workers and firms, and Nash bargaining to determine the wages. As in den Haan et al. (2005) and Ljungqvist and Sargent (2007), we add skill heterogeneity among the workers. Moreover, to discuss the labor market prospects of the incarcerated people, we explicitly model the state of incarceration and out of the labor force.
Time is continuous. The economy is populated by a continuum of infinitely-lived individuals and firms. Individuals and firms are risk-neutral and they both discount the future at the rate $r$. Firms are all identical. However, individuals are heterogeneous in three dimensions: labor market status, skill and type. Type refers to the criminal activity of the individuals. We assume two types of individuals: criminals ($c$) and non-criminals ($nc$). Each type receives incarceration shock at the rate $\pi_x$, $x \in \{c, nc\}$. We allow for the change of types. At the poisson rate $\eta_{nc}$ a non-criminal turns to criminal type, and at the poisson rate $\eta_c$ a criminal type turns into a non-criminal type.

The second dimension of heterogeneity is the labor market status. At any point in time, individuals can be in any of the four labor market statuses: (i) employment (ii) unemployment (iii) non-participant (iv) incarcerated. Employed individuals are the one who are matched with a firm and currently employed by the firm. Unemployed individuals are the ones who are not employed but actively seeking for a job. Non-participants are the ones who are not employed and are not looking for a job. Lastly, incarcerated individuals are the ones who are currently in prison.

The third dimension of heterogeneity among the individuals is the skill level. Individuals have stochastic skill levels. These skill levels evolve over time at the poisson rate $\gamma$. The evolution of the skill levels differ across the four employment status. $F_i(h'|h)$ denotes the evolution of the skills given the initial skill level $h$ and employment status $i \in \{e, u, n, p\}$, where $e$ denotes employment, $u$ denotes unemployment, $n$ denotes non-participation and $p$ denotes incarceration. We assume that $F_e > F_n > F_u > F_p$ with $>$ denoting first-order stochastic dominance. The support of $F_i$ is $[h, \bar{h}]$ for all $i \in \{e, u, n, p\}$.

3.1 Matching

We assume individuals and firms meet randomly through a matching technology. This technology is denoted by $M(u,v)$ which represent the aggregate number of matches when there are $u$ unemployed individuals and $v$ vacant firms in the economy. We assume single matching technology for all types of individuals and firms. Moreover, the matching technology is
assumed to satisfy constant-returns-to-scale assumption:

\[ M(u, v) = \chi u^\eta v^{1-\eta} \]

with \( M(u, v) \leq \min \{ u, v \} \). Let \( \mu^x_i(h) \) denotes the measure of type \( x \in \{ c, nc \} \) individuals with labor market status \( i \in \{ e, u, n, p \} \) and skill level \( h \). Then the measure of aggregate unemployed individuals in the economy is

\[ u = \sum_x \sum_h \mu^x_u(h) \]

Denoting \( \theta = \frac{u}{v} \) as the market tightness, we can represent the probability of unemployed worker meeting a vacant firm as

\[ \alpha^x_w(h; \theta) = \frac{M(u, v)}{u} = \chi \theta^{1-\eta} \]

Since all firms are identical and there is single matching technology between the individuals and the firms, this probability does not depend on the characteristics of the individual. So we denote \( \alpha^x_w(h; \theta) = \alpha_w \). However, since individuals are heterogenous and the profit of a firm depends on the characteristics of a matched individual, the probability of a vacant firm meeting an unemployed individual with type \( x \) and skill level \( h \) depends on the characteristics of the individual:

\[ \alpha^x_f(h; \theta) = \frac{M(u, v) \mu^x_u(h)}{v} = \chi \theta^{-\eta} \frac{\mu^x_u(h)}{u} = \frac{\alpha_w \mu^x_u(h)}{\theta} \]

### 3.2 Individuals

Given the three-dimensional heterogeneity of the individuals, the value function for the individuals depend on three state variables: type, labor market status and skill. We denote \( V^x_i(h) \) as the value of an individual with labor market status \( i \in \{ e, u, n, p \} \), type \( x \in \{ c, nc \} \) and skill level \( h \). Employed individuals receive instantaneous wage, \( w^x(h) \), which potentially depends on the skill level and type. At the poisson rate \( \delta \) they receive exogenous separation shock. Then, they need to choose between unemployment and non-participation. At the poisson rate \( \pi^x \) they receive incarceration shock, quit the job and serve in the prison. At the
rate $\gamma$ they receive skill shock, and decide whether to stay in the job, become unemployed
or non-participant. Since we assume Nash bargaining, the decision of terminating the match
or not is a joint-decision by the individual and the firm. We will be more explicit about
this decision below when we introduce the wage determination process between the worker
and the firm. We denote $I^x_m(h)$ as the indicator function for the continuation of the match
between the individual of type $x$ and the firm. $I^x_m(h) = 1$ if the match continues and
$I^x_m(h) = 0$ if the match dissolves. Lastly, the type changes at the rate $\eta^x$. So, the flow value
of an employed worker with skill level $h$ and type $x$ becomes the following equation:

$$rV_e^x(h) = w^x(h) + \delta \max \{V_u^x(h), V_n^x(h)\} - V_e^x(h) + \pi^x \left( V_p^x(h) - V_e^x(h) \right)$$

$$+ \gamma \sum_{h'} F_e(h'|h) [I^x_m(h') V_e^x(h'), (1 - I^x_m(h')) \max \{V_u^x(h'), V_n^x(h')\} - V_e^x(h)]$$

$$+ \eta^x \left( I_{m}^{-x}(h) V_e^{x^{-}}(h) + (1 - I_{m}^{-x}(h)) \max \{V_u^{x^{-}}(h), V_n^{x^{-}}(h)\} - V_e^x(h) \right),$$

where $-x$ denotes the other type, i.e. $-x = \{c, nc\} \setminus x$.

Unemployed individuals receive instantaneous unemployment benefit, $b$. At the rate $\pi^x$
they receive incarceration shock. At the rate $\alpha_w$, they match with a firm, and they choose
whether to get employed or stay unemployed. At the rate $\gamma$ unemployed workers receive skill
shocks, and choose whether stay unemployed or become non-participant. Lastly, at the rate $\eta^x$ the type changes. Similarly, the flow value of an unemployed individual with skill level $h$
and type $x$ can be written as follows:

$$rV_u^x(h) = b + \pi^x \left( V_p^x(h) - V_u^x(h) \right) + \alpha_w \left( \max \{V_e^x(h), V_u^x(h)\} - V_u^x(h) \right)$$

$$+ \gamma \sum_{h'} F_u(h'|h) \left[ \max \{V_u^{x'}(h'), V_n^{x'}(h')\} - V_u^x(h) \right] + \eta^x \left( V_u^{x^{-}}(h) - V_u^x(h) \right)$$

Non-participants receive instantaneous benefit $z$, which can be interpreted as the combination
of leisure and home production. They also receive incarceration shock at the rate $\pi^x$, and
skill shock at the rate $\gamma$. Upon receiving the skill shock, they may choose to return to the
labor market as an unemployed worker. Lastly, at the rate $\eta^x$ the type changes. So, the flow value of a non-participant individual with skill level $h$ and type $x$ becomes the following:

$$rV_n^x(h) = z + \gamma \sum_{h'} F_n(h'|h) \left[ \max \{V_u^{x'}(h'), V_n^{x'}(h')\} - V_n^x(h) \right] + \pi^x \left( V_p^x(h) - V_n^x(h) \right)$$

$$+ \eta^x \left( V_n^{x^{-}}(h) - V_n^x(h) \right)$$
Lastly, incarcerated individual receives flow benefit of $\kappa$. They receive skill shock at the rate $\gamma$, and they get out of the prison at the rate $\tau$ upon which they choose to become unemployed or non-participant. At the rate $\eta^x$ the type changes. So, the flow value of an incarcerated individual becomes the following:

$$rV_p^x (h) = \kappa + \gamma \sum_{h'} P_r (h'|h) (V_p^x (h') - V_p^x (h)) + \tau (\max \{V_u^x (h), V_n^x (h)\} - V_p^x (h)) \quad (3.6)$$

$$+ \eta^x (V_p^{-x} (h) - V_p^x (h))$$

For notational convenience, we denote $I^x_u (h)$ as the indicator function for the decision of choosing unemployment or non-participation for an individual with skill level $h$ and type $x$. We define $I^x_u (h)$ as follows:

$$I^x_u (h) = \begin{cases} 
1 & V_u^x (h) \geq V_u^x (h) \\
0 & \text{o.w.}
\end{cases} \quad (3.7)$$

### 3.3 Firms

A firm posts a vacancy by incurring a cost of vacancy posting, $k$. At the poisson rate $\alpha_f$, a vacant firm meets an unemployed individual. Unemployed individuals are heterogenous in skill level and type. At the matching stage the firm and the worker bargain over the wage. Once the match is formed, the pair produces $y (h)$ and the firm pays the worker the bargained wage $w (h)$. At the rate $\delta + \pi^x$ the match dissolves, and at the rate $\gamma$, the worker receives a new skill shock, and the pair re-bargains over the wage conditional on the match continues. Then, the flow value of vacancy becomes the following:

$$rJ_v = -k + \sum_{x,h} \alpha_f^x (h) [J_f^x (h) - J_v (h)] \quad (3.8)$$

Similarly, the flow value of a filled job with an individual of skill level $h$ and type $x$ becomes the following:

$$rJ_f^x (h) = y (h) - w (h) + (\delta + \pi^x) [J_v - J_f^x (h)]$$

$$+ \gamma \sum_{h'} F_e (h'|h) [(J_f^x (h') - J_f^x (h)) I^x_m (h') + \eta^x (1 - I^x_m (h')) (J_v - J_f^x (h))] \quad (3.9)$$
where $I_m^x(h)$ is the indicator function showing whether the match continues or not for a type $x$ agent. We assume perfect competition among the firms so that in equilibrium we have $J_v = 0$.

### 3.4 Wage determination

Wages are determined through Nash bargaining. The threat point for the individual is the maximum of staying unemployed and staying out of the labor force. The threat point for the firm is value of vacancy. Assuming $\beta$ represents the exogenous bargaining power of the individual we can write down the bargaining problem as follows:

$$w^x(h) = \arg \max (V_e^x(h) - \max \{V_u^x(h), V_n^x(h)\})^\beta (J_f^x(h) - J_v)^{1-\beta}$$

Implicit in the bargaining problem is the dependency of the wages on the skill level, $h$. Moreover, notice that we assume wages are determined conditional on the type of the individual, $x \in \{c, nc\}$. However, the formulation of the value of vacancy for the firms make it explicit that the job cannot be created conditional on the type of the individual. These assumptions are motivated by the fact that it is, in general, against the law to discriminate among the workers for their criminal histories. However, workers and firms can bargain over the wages upon creating the match. The above formulation also determines the decision of continuing the match or not. We assume that if the outside option is better for any party the match dissolves:

$$I_m^x(h) = \begin{cases} 1 & V_e^x(h) \geq \max \{V_u^x(h), V_n^x(h)\} \text{ and } J_f^x(h) \geq J_v \\ 0 & \text{o.w.} \end{cases}$$

### 3.5 Steady-State Flows

We focus on the steady-state of this economy. In the steady-state, the flow of individuals across different labor market statuses should be equal. We start with the inflow and outflow equations for the incarcerated individuals. Individuals are incarcerated from each employment status at a constant rate, $\pi^x$. Plus they receive skill shock at the rate $\gamma$ when incarcerated. Lastly, at the rate $\eta^{-x}$ there is an inflow from the other type. So, the inflow
measure of the incarcerated with skill level $h$ and type $x$, defined as $\Gamma_{p^+}^x(h)$ is

$$\Gamma_{p^+}^x(h) = \sum_i \mu_i^x(h) \pi_x + \gamma \sum_{h' \neq h} \mu_{p}^x(h') F_p(h|h') + \eta^{-x} \mu_{p}^x(h).$$

(3.12)

The outflow happens for three reasons. First, at the rate $\tau$, incarcerated individuals get out of the prison. Second, at the rate $\gamma$, they receive skill shock. Third, at the rate $\phi_x$ the type changes. So, the total outflow of the incarcerated with skill level $h$ and type $x$, defined as $\Gamma_{p^-}^x(h)$ is

$$\Gamma_{p^-}^x(h) = \mu_p^x(h) \left[ \tau + \gamma \sum_{h' \neq h} \sum F_p(h|h') + \eta^x \right].$$

(3.13)

Next, we analyze the flows in and out of the non-participation state. The inflow to non-participation happens for five reasons. First, if an incarcerated individual gets out of the prison, he might choose to stay non-participant. Second, unemployed individual might choose non-participation upon receiving a skill shock. Third, an employed individual can choose non-participation either after receiving a separation shock or a skill shock. Fourth, a non-participant with a different skill level can receive skill shock. Fifth, the type changes at the rate $\eta^x$. So, the total inflow to non-participation with skill level $h$ and type $x$, defined as $\Gamma_{n^+}^x(h)$ is

$$\Gamma_{n^+}^x(h) = \tau \mu_p^x(h) (1 - I_u^x(h)) + \gamma \sum_{h' \neq h} \mu_u^x(h') F_u(h|h') (1 - I_u^x(h))$$

$$+ \delta \mu_e^x(h) (1 - I_u^x(h)) + \eta^{-x} \mu_n^x(h).$$

(3.14)

The outflow from the non-participation happens due to three reasons: First, the non-participant might receive skill shock. Second, he might receive incarceration shock. Third, he might receive type change shock. So, the outflow measure for the non-participants with skill level $h$ and type $x$, defined as $\Gamma_{n^-}^x(h)$ is

$$\Gamma_{n^-}^x(h) = \mu_n^x(h) \left[ \gamma \sum_{h' \neq h} F_n(h|h') + \pi^x + \eta^x \right].$$

(3.15)
Next, we analyze the unemployment pool. The inflows to the unemployment pool is very similar to the inflows to the non-participant pool. Defining $\Gamma^{x+}_{u+}(h)$ as the inflow measure to the unemployment pool of skill level $h$ and type $x$, we have:

$$\Gamma^{x+}_{u+}(h) = \tau m^{x+}(h) I^{x+}_{u}(h) + \gamma \sum_{h' \neq h} m^{x+}_{u}(h') F^{x+}_{u}(h|h') I^{x+}_{u}(h)$$

$$+ \gamma \sum_{h' \neq h} m^{x+}_{e}(h') F^{x+}_{e}(h|h') I^{x+}_{e}(h) (1 - I^{x+}_{m}(h))$$

$$+ \delta m^{x+}_{e}(h) I^{x+}_{u}(h) + \eta^{-x} m^{x+}_{u}(h).$$   \hspace{1cm} (3.16)

Similarly, the outflow equation is very similar to the outflow equation for the non-participant. Defining $\Gamma^{x-}_{u-}(h)$ as the outflow measure from the unemployment pool of skill level $h$ and type $x$, we have:

$$\Gamma^{x-}_{u-}(h) = m^{x-}_{u}(h) \left[ \gamma \sum_{h' \neq h} F^{x-}_{u}(h'|h) + \pi^{x} + \eta^{x} \right].$$   \hspace{1cm} (3.17)

Lastly, we analyze the flows for the employment pool. The inflow happens due to three reasons. First, the unemployed individual meet with a firm at the rate $\alpha_{w}$ and can become employed. Second, the employed can receive skill shock. Third, the type changes at the rate $\eta^{-x}$. So, defining the inflow to the employment pool of individuals with skill level $h$ and type $x$ as $\Gamma^{x+}_{e+}(h)$, we have:

$$\Gamma^{x+}_{e+}(h) = \alpha_{w} I^{x+}_{m}(h) m^{x+}_{u}(h) + \gamma \sum_{h' \neq h} m^{x+}_{e}(h') F^{x+}_{e}(h|h') I^{x+}_{e}(h) + \eta^{-x} m^{x+}_{e}(h).$$ \hspace{1cm} (3.18)

The outflow from the employment happens due to four reasons: First, the employed receives separation shock at the rate $\delta$. Second, at the rate $\gamma$ the employed receives skill shock. Third, at the rate $\pi^{x}$, the employed receives incarceration shock. And lastly the employed receives type change shock at the rate $\eta^{x}$. Defining the inflow to the employment pool of individuals with skill level $h$ and type $x$ as $\Gamma^{x-}_{e-}(h)$, we have:

$$\Gamma^{x-}_{e-}(h) = m^{x-}_{e}(h) \left[ \delta + \gamma \sum_{h' \neq h} F^{x-}_{e}(h'|h) + \pi^{x} + \eta^{x} \right].$$   \hspace{1cm} (3.19)

In steady-state, the inflow and the outflow from each pool grouped by the type, labor market status and skill level should be equal. This gives us the following equilibrium steady-state
relationship for the flows:

\[ \Gamma_{i+}^{x}(h) = \Gamma_{i-}^{x}(h), \quad \forall h \in [h, \bar{h}], x \in \{c, nc\}, i \in \{e, u, n, p\}, \]  

(3.20)

where \( \Gamma_{i+}^{x}(h) \) and \( \Gamma_{i-}^{x}(h) \) are defined by equations (3.12) – (3.19).

### 3.6 Equilibrium

Now, we are ready to define the stationary equilibrium of the model.

**Definition 3.1.** A stationary equilibrium consists decision rules \( I_{m} : [h, \bar{h}] \times \{c, nc\} \rightarrow \{0, 1\} \), \( I_{u} : [h, \bar{h}] \times \{c, nc\} \rightarrow \{0, 1\} \), wage policy function \( w : [h, \bar{h}] \times \{c, nc\} \rightarrow \mathbb{R}_{+} \), stationary measure of individuals \( \mu : [h, \bar{h}] \times \{c, nc\} \rightarrow \mathbb{R}_{+} \), value functions for individuals \( V : [h, \bar{h}] \times \{c, nc\} \times \{e, u, n, p\} \rightarrow [0, 1] \), value of a filled job for the firm \( J_{f} : [h, \bar{h}] \times \{c, nc\} \rightarrow \mathbb{R}_{+} \) and a matching parameter for the individual, \( \alpha_{w} \) and a matching function for the firm, \( \alpha_{f} : [h, \bar{h}] \times \{c, nc\} \rightarrow \mathbb{R}_{+} \) such that

1. Given \( \alpha_{w} \) and \( \alpha_{f} \), wage policy function \( w \) solve (3.10), value function for the individuals \( V \) solve (3.3) – (3.6), value function for the firm \( J_{f} \) solves (3.9), decision rules \( I_{m}, I_{u} \) solve (3.11) and (3.7).

2. Given decision rules, stationary measure \( \mu \) solves (3.20).

3. Given stationary measure \( \mu \), \( \alpha_{w} \) and \( \alpha_{f} \) satisfy (3.1) and (3.2).

4. Perfect competition implies zero profit for the value of vacancy: \( J_{v} = 0 \) in (3.8).

### 4 Quantitative Analysis

We are interested in two quantitative questions. What has been the effect of rising incarceration rates on labor markets and cross-sectional inequality from 1970-2000? What will be the effect on labor markets and cross-sectional inequality if incarceration rates remain at year 2000 levels and the economy reaches a new steady state? We will be able to decompose our results into the direct effect of incarceration on inmates’ skills and the indirect general equilibrium effects in the labor search market.
4.1 Calibration and Estimation

We will estimate the model using individual level wage and employment data from the 2000 Census. Since the criminal and incarceration histories of the population are not observable, we will estimate these histories by simulating the model. This requires a sequence of the following parameters for each birth cohort \(j\) and year \(t\) to be fed into the model: (1) \(\mu_{t-1,t}\) probability individual of age 17 is a criminal (cohort \(t\) is aged 18 in year \(t\) and of size \(N_{t-1,t}\)); (2) \(\pi_t\) probability a criminal becomes incarcerated; (3) \(\eta_{j,t}\) probability a non-incarcerated criminal of cohort \(j\) becomes a non-criminal; (4) \(\tau_{jt}\) probability an incarcerated becomes a non-incarcerated criminal; (5) \(d_{jt}\) probability an individual of cohort \(j\) dies in year \(t\). These four sequences imply the following law of motions according to the timing (1) admissions to jail, (2) discharges from jail, (3) exit from life of crime, (4) death:

\[
\begin{align*}
\text{New Cohort} & \quad N^C_{t-1t} = \mu_{t-1,t}N_{t-1t} \quad ; \quad N^n_{t-1t} = (1 - \mu_{t-1,t})N_{t-1t} \\
\text{Incarcerated} & \quad N^I_{jt+1} = [\pi_tN^C_{jt} + (1 - \tau_{jt})N^I_{jt}](1 - d_{jt}) \quad j \geq t \\
\text{Criminals} & \quad N^C_{jt+1} = [(1 - \pi_t)N^C_{jt} + \tau_{jt}N^I_{jt}](1 - \eta_{jt})(1 - d_{jt}) \quad j \geq t \\
\text{Non-Criminals} & \quad N^n_{jt+1} = [(1 - \pi_t)N^C_{jt} + \tau_{jt}N^I_{jt}]\eta_{jt}(1 - d_{jt}) \quad j \geq t
\end{align*}
\]

Our estimation exploits the variation across four demographic groups: white males, black males, white women, and black women. Population of each cohort entering at age 18 by sex and race taken from CDC National Center for Health Statistics annual residential population estimates. Death probabilities from National Vital Statistics Reports.

Conceptually, the number of criminals \(N^C_{jt}\) are the number of people at risk of incarceration. We make two assumptions: (1) the number of reported crimes \(\beta_{\text{crime freq}}\) per criminal is constant for all demographic groups and over time; (2) the number of criminals in a specific demographic group is proportional to the share of the group in annual prison admissions. Therefore our estimate is: \(N^C_{jt} = \frac{\text{prison.admission}_{jt}}{\text{total.prison.admission}} \times \frac{\text{reported.crimes}}{\beta_{\text{crime freq}}}\) and, coincidentally, the incarceration probability is \(\pi_t = \frac{\text{prison.admission}_{jt}}{\text{total.prison.admission}} \beta_{\text{crime freq}} \text{reported.crimes}\). The proportion of criminals in the new aged-17 cohort is calculated as: \(\mu_{t-1,t} = \frac{\text{prison.admission}_{jt}}{\pi_tN_{t-1,t}}\). Thus, exit rate from prison
\( \tau_{jt} \) can be calculated from the law of motion for the incarcerated population and exit rate from life of crime \( \eta_{jt} \) can be calculated from the law of motion for the criminal population. Prison admissions by demographic groups taken from National Corrections Reporting Program from 1983-2000, (U.S. Dept. of Justice (1983-2000)). Previous years estimated from Langan and of Justice Statistics (1991) and BJS and of Prisons (1974, 1979, 1986, 1991, 1997). Total incarcerated population, \( N_{jt}^I \), by demographic group from Hindelang et al. (2003). Reported Crimes are taken from FBI Uniform Crime Report statistics.

We start the simulation by computing a steady state for 1970. This is motivated by the stability in incarceration incidence and length prior to the 1970s. We then simulate the transition to 2000 by feeding in 30 year time series of each parameter calibrated for four demographic groups: white men, black men, white women, and black women. This cohort-cross-gender-cross-race variation is the source of identification to estimate the remaining parameters related to skill transitions. Our targets for indirect inference are the mean and variance of individual level residuals of a Mincerian regression on hourly wage, labor force participation rate and employment rate; grouped by race/gender/cohort cell.

4.2 Effect of Rising Incarceration 1970-2000

tba

4.3 Labor Markets if Incarceration Rates Remain at 2000-levels

tba

5 Local Labor Market Analysis

To further test our model, we will apply our simulation to a sample of large Metropolitan Statistical Areas. The main question is: how much of the variation in labor force participation and employment rates across demographic groups can our theory account for? We
use MSA’s for two reasons. First, MSA’s are a reasonable representation of a labor market. Second, this allows us to exploit state-level variation in incarceration incidence and length.

### 6 Conclusion

tba

### References


A Figures
Figure 1: Source: Hindelang et al. (2003). Sentenced prisoners in state and federal prison only.

Figure 2: Crime Statistics from FBI Uniform Crime Reports.
Figure 3: Source: Hindelang et al. (2003). Includes sentenced prisoners in state and federal prison only.
## Sentenced Prisoners per 100,000 Residents of Each Group in 2003

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male Total</th>
<th>Male White</th>
<th>Male Black</th>
<th>Female Total</th>
<th>Female White</th>
<th>Female Black</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>915</td>
<td>465</td>
<td>3405</td>
<td>62</td>
<td>38</td>
<td>185</td>
</tr>
<tr>
<td>18-19 years</td>
<td>597</td>
<td>266</td>
<td>2068</td>
<td>28</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>20-24 years</td>
<td>1996</td>
<td>932</td>
<td>7017</td>
<td>112</td>
<td>71</td>
<td>286</td>
</tr>
<tr>
<td>25-29 years</td>
<td>2380</td>
<td>1090</td>
<td>9262</td>
<td>147</td>
<td>99</td>
<td>406</td>
</tr>
<tr>
<td>30-34 years</td>
<td>2074</td>
<td>1042</td>
<td>7847</td>
<td>164</td>
<td>109</td>
<td>456</td>
</tr>
<tr>
<td>35-39 years</td>
<td>1895</td>
<td>1017</td>
<td>6952</td>
<td>170</td>
<td>106</td>
<td>491</td>
</tr>
<tr>
<td>40-44 years</td>
<td>1584</td>
<td>873</td>
<td>5854</td>
<td>133</td>
<td>82</td>
<td>386</td>
</tr>
<tr>
<td>45-54 years</td>
<td>899</td>
<td>501</td>
<td>3500</td>
<td>60</td>
<td>36</td>
<td>190</td>
</tr>
<tr>
<td>55 years and over</td>
<td>208</td>
<td>141</td>
<td>747</td>
<td>8</td>
<td>5</td>
<td>22</td>
</tr>
</tbody>
</table>


## Population Ever Incarcerated in Federal or State Prison in 2001

<table>
<thead>
<tr>
<th>Age</th>
<th>18-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>55-64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong></td>
<td>2.7%</td>
<td>6.0%</td>
<td>6.5%</td>
<td>5.3%</td>
<td>4.0%</td>
<td>3.1%</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>0.2%</td>
<td>0.7%</td>
<td>0.9%</td>
<td>0.6%</td>
<td>0.3%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>White</strong></td>
<td>0.6%</td>
<td>1.6%</td>
<td>2.0%</td>
<td>1.7%</td>
<td>1.4%</td>
<td>1.1%</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>1.1</td>
<td>2.8</td>
<td>3.5</td>
<td>3.1</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Black</strong></td>
<td>4.4%</td>
<td>10.9%</td>
<td>12.1%</td>
<td>9.5%</td>
<td>6.7%</td>
<td>5.9%</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>8.5</td>
<td>20.4</td>
<td>22.0</td>
<td>17.7</td>
<td>13.0</td>
<td>11.6</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>0.4</td>
<td>2.1</td>
<td>2.8</td>
<td>1.9</td>
<td>1.1</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Figure 5: Source: Bonczar (2003)
Figure 6: Source: Stemen et al. (2005). Sentenced state prisoners only.

Figure 7: Source: Stemen et al. (2005). Sentenced state prisoners only.