Online Appendix

Spatial Nexus in Crime and Unemployment in Times of Crisis

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Abstract

This document is intended to supplement the main text of 'Spatial Nexus in Crime and the Labor Markets in Times of Crisis'. In particular, we sketch more details about the theoretical environment in Section 1. To be more precise, we elaborate on the Nash bargaining game and the wage determination in Subsection 1.1 of Section 1. We proceed with the reservation wage in Subsection 1.2 of Section 1 whereas we derive the crime-preventing wage in Subsection 1.3 of Section 1. Lemma 3.1 is discussed in Subsection 1.4 whereas the main proposition is further elaborated in Subsection 1.5, both of Section 1. Next, we turn to the empirical part in Section 2 and describe the crime data in more detail. Code to replicate the model can be made available from the authors upon request.

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1 Theoretical Model

1.1 Wage income: Nash bargaining

Let us first evaluate the steady-state, equilibrium valuations of states. Given our assumptions, the continuation valuation by workers of unemployment (U), and employment ($W(\varphi)$), and by firms of an open vacancy (V) versus a job ($J(\varphi)$) must solve the following functional equations that equate normal returns on capitalized valuations of labor market states to their expected periodic payouts

$$rU_{ij} = b_j + \phi_{ij}^{U}\left(K_{ij}^{U} - U_{ij}\right) + \theta_j q(\theta_j)\left(W_{ij}(\varphi) - U_{ij}\right) \ . \tag{1.1}$$

In equation (1.1), the flow yield from the valuation of the state of unemployment U at interest rate r is equated to an expected "capital gain" stemming from finding new employment at φ. Further,

$$rV_{ij} = -c_j + q(\theta_j)\left[\mathcal{J}_{ij}(\varphi) - V_{ij}\right], \tag{1.2}$$

where $\mathcal{J}_{ij}(\varphi)$ is the asset value condition for a filled jobs with a productivity φ. Equation (1.2) governs the valuation of an unfilled vacancy. Moreover,

$$rW_{ij}(\varphi) = w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} \left(W_{ij}(z) - W_{ij}(\varphi)\right) dF(z) - \lambda F(\tilde{\varphi})\left(W_{ij}(\varphi) - U_{ij}\right)$$

$$+ \phi_{ij}^{W}(\varphi) \ \left(K_{ij}^{W}(\varphi) - W_{ij}(\varphi)\right). \tag{1.3}$$

The function $W_{ij}(\varphi)$ in equation (1.3) returns the value of employment in a job-worker match with current productivity φ. The implicit rate of return on the asset of working in a job at productivity φ is equal to the current wage $w_{ij}(\varphi)$ plus the expected capital gain on the employment relationship. The lower bound of the definite integral, $\tilde{\varphi}$ is the cutoff or threshold value of match productivity, determined endogenously in the model. If match productivity φ falls below $\tilde{\varphi}$, the match is no longer profitable and the job/worker pair is destroyed. Finally, a similar arbitrage argument determines the valuation to a firm of a filled job in equation (1.4), given the current realization of φ,

$$r\mathcal{J}_{ij}(\varphi) = \varphi - w(\varphi) + \lambda \textstyle\int_{\tilde{\varphi}}^{1} \left(\mathcal{J}_{ij}(z) - \mathcal{J}_{ij}(\varphi)\right) dF(z) + \lambda F(\tilde{\varphi})\left(V_{ij} - \mathcal{J}_{ij}(\varphi)\right). \tag{1.4}$$

Use now a free entry condition, $V = 0$, and rewrite the two asset value conditions (for jobs),[1]

$$\begin{aligned}
r\mathcal{J}_{ij}(\varphi) &= \varphi - w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} (\mathcal{J}_{ij}(z) - \mathcal{J}_{ij}(\varphi))\, dF(z) - \lambda F(\tilde{\varphi})\, \mathcal{J}_{ij}(\varphi) \\
&= \varphi - w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} \mathcal{J}_{ij}(z)\, dF(z) - \lambda (\mathcal{J}_{ij}(\varphi)(1 - F(\tilde{\varphi})) + F(\tilde{\varphi})\, \mathcal{J}_{ij}(\varphi)) \\
&= \varphi - w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} \mathcal{J}_{ij}(z)\, dF(z) - \lambda \mathcal{J}_{ij}(\varphi),
\end{aligned}$$

leading to

$$\mathcal{J}_{ij}(\varphi) = \frac{\varphi - w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} \mathcal{J}_{ij}(z)\, dF(z)}{r + \lambda}. \tag{1.5}$$

Similarly with the asset value conditions for employment,

$$\begin{aligned}
rW_{ij}(\varphi) &= w_{ij}(\varphi) + \lambda \int_{\tilde{\varphi}}^{1} (W_{ij}(z) - W_{ij}(\varphi))\, dF(z) - \lambda F(\tilde{\varphi})(W_{ij}(\varphi) - U_{ij}) \\
&\quad + \phi_{ij}^{W}(\varphi)\left(K_{ij}^{W}(\varphi) - W_{ij}(\varphi)\right) \\
&= w_{ij}(\varphi) - \lambda \int_{\tilde{\varphi}}^{1} (W_{ij}(z) - W_{ij}(\varphi))\, d(1 - F(z)) - \left(\lambda F(\tilde{\varphi}) + \pi \phi_{ij}^{W}(\varphi)\right) W_{ij}(\varphi) \\
&\quad + \lambda F(\tilde{\varphi})\, U_{ij} + \phi_{ij}^{W}(\varphi)(g_j + \pi J_{ij}) \\
&= w_{ij}(\varphi) - \lambda \int_{\tilde{\varphi}}^{1} W_{ij}(z)\, d(1 - F(z)) - \left(\lambda + \pi \phi_{ij}^{W}(\varphi)\right) W_{ij}(\varphi) + \lambda F(\tilde{\varphi})\, U_{ij} + \phi_{ij}^{W}(\varphi)(g_j + \pi J_{ij}),
\end{aligned}$$

which, after rearranging, can be expressed as

$$W(\varphi) = \frac{w_{ij}(\varphi) - \lambda \int_{\tilde{\varphi}}^{1} W_{ij}(z)\, d(1 - F(z)) + \lambda F(\tilde{\varphi})\, U_{ij} + \phi_{ij}^{W}(\varphi)(g_j + \pi J_{ij})}{r + \lambda + \phi_{ij}^{W}(\varphi)\, \pi}. \tag{1.6}$$

Finally, the enjailed is described by the following simple Bellman's equation,

$$rJ_{ij} = z_j + \rho (U_{ij} - J_{ij}), \tag{1.7}$$

where z is the consumption of the enjailed workers and ρ is the rate of release into unemployment.

Wage equation under the Nash bargaining rule should solve the following (where β accounts for

[1] Employing the fundamental theorem of calculus, $\int_{\tilde{\varphi}}^{1} dF(z) = F(z)\,|_{\tilde{\varphi}}^{1} = F(1) - F(\tilde{\varphi}) = 1 - F(\tilde{\varphi})$.

the bargaining power),

$$w(\varphi) = \arg\max \left(W_{ij}(\varphi) - U_{ij}\right)^{\beta} \left(\mathcal{J}_{ij}(\varphi) - V_{ij}\right)^{1-\beta}$$
$$= \arg\max \left(\frac{w_{ij}(\varphi)+\lambda\int_{\tilde{\varphi}}^{1} W_{ij}(z)dF(z)-\left(\lambda(1-F(\tilde{\varphi}))+r+\phi_{ij}^{W}(\varphi)\pi\right)U_{ij}+\phi_{ij}^{W}(\varphi)(g_j+\pi J_{ij})}{r+\lambda+\phi_{ij}^{W}(\varphi)\pi}\right)^{\beta} \tag{1.8}$$
$$\times \left(\frac{\varphi-w_{ij}(\varphi)+\lambda\int_{\tilde{\varphi}}^{1}\mathcal{J}_{ij}(z)dF(z)-(r+\lambda)V_{ij}}{r+\lambda}\right)^{1-\beta},$$

with the first-order necessary condition reads as

$$\beta\frac{dW_{ij}(\varphi)}{dw(\varphi)}\left(W_{ij}(\varphi)-U_{ij}\right)^{\beta-1}\left(\mathcal{J}_{ij}(\varphi)-V_{ij}\right)^{1-\beta}+(1-\beta)\frac{d\mathcal{J}_{ij}(\varphi)}{dw(\varphi)}\left(W_{ij}(\varphi)-U_{ij}\right)^{\beta}\left(\mathcal{J}_{ij}(\varphi)-V_{ij}\right)^{-\beta}=0,$$

and, after factoring out,

$$\left(W_{ij}(\varphi)-U\right)^{\beta}\left(\mathcal{J}_{ij}(\varphi)-V_{ij}\right)^{1-\beta}\left(\beta\frac{dW_{ij}(\varphi)}{dw(\varphi)}\left(W_{ij}(\varphi)-U_{ij}\right)^{-1}+(1-\beta)\frac{d\mathcal{J}_{ij}(\varphi)}{dw(\varphi)}\left(J(\varphi)-V_{ij}\right)^{-1}\right)=0.$$

Since the first component is not at work to produce equality to zero, we require $\beta\frac{dW_{ij}(\varphi)}{dw(\varphi)}\left(\mathcal{J}_{ij}(\varphi)-V_{ij}\right) = -(1-\beta)\frac{d\mathcal{J}_{ij}(\varphi)}{dw(\varphi)}\left(W_{ij}(\varphi)-U_{ij}\right).$ Using equations (1.5) and (1.6), also employing the free entry condition ($V_{ij}=0$), we obtain

$$\frac{\beta}{r+\lambda+\phi_{ij}^{W}(\varphi)\pi}\left(\mathcal{J}_{ij}(\varphi)\right)=\frac{1-\beta}{r+\lambda}\left(W_{ij}(\varphi)-U_{ij}\right).$$

Using (1.5) and (1.6) one more time, and making use of the sharing rule, $\beta\int_{\tilde{\varphi}}^{1}\mathcal{J}_{ij}(z)\,dF(z) = (1-\beta)\int_{\tilde{\varphi}}^{1}\left(W_{ij}(z)-U_{ij}\right)dF(z)$, lead us to

$$\beta\varphi = w_{ij}(\varphi)+(1-\beta)\,\phi_{ij}^{W}(\varphi)\left(g_j+\pi J_{ij}\right)-(1-\beta)\left(r+\phi_{ij}^{W}(\varphi)\pi\right)U_{ij}.$$

Since, by the free entry condition,

$$\mathcal{J}_{ij}(\varphi)=\frac{c_j}{q(\theta_j)},$$

by the equation (1.7), $J_{ij}=\frac{z_j+\rho U_{ij}}{r+\rho}$, also $rU_{ij}=b_j+\phi_{ij}^{U}\left(K_{ij}^{U}-U_{ij}\right)+\theta_j q(\theta_j)\left(W_{ij}(\varphi)-U_{ij}\right)$ and $K_{ij}^{U}-U_{ij}=g_j+\pi J_{ij}-\pi U_{ij}$, we can express wages as

$$w_{ij}(\varphi)=\beta\varphi-(1-\beta)\,\phi_{ij}^{W}(\varphi)\left(g_j+\frac{\pi}{r+\rho}z_j\right)+(1-\beta)\left(r+\phi_{ij}^{W}(\varphi)\pi\left(\frac{r}{r+\rho}\right)\right)U_{ij}. \tag{1.9}$$

The closed-form solution for the U_{ij} is

$$\begin{aligned} rU_{ij} &= b_j + \phi_{ij}^U \left(g_j + \pi J_{ij} - \pi U_{ij}\right) + \theta_j q\left(\theta_j\right)\left(W_{ij}\left(\varphi\right) - U_{ij}\right) \\ &= b_j + \phi_{ij}^U \left(g_j + \pi J_{ij} - \pi U_{ij}\right) + \left(\tfrac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^W(\varphi)\pi\right)}\tfrac{\theta_j q(\theta_j) c_j}{q(\theta_j)}\right), \end{aligned}$$

or, after working out U_{ij},

$$U_{ij} = \frac{1}{r + \phi_{ij}^U \pi \left(\frac{r}{r+\rho}\right)}\left[b_j + \phi_{ij}^U\left(g_j + \frac{\pi}{r+\rho}z_j\right) + \left(\frac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^W\left(\varphi\right)\pi\right)}\frac{\theta_j q\left(\theta_j\right) c_j}{q\left(\theta_j\right)}\right)\right]. \tag{1.10}$$

Plugging it back into the wage equation, we get

$$\begin{aligned} w_{ij}\left(\varphi\right) &= \beta\varphi - (1-\beta)\,\phi_{ij}^W\left(\varphi\right)\left(g_j + \tfrac{\pi}{r+\rho}z_j\right) \\ &+ (1-\beta)\,\tfrac{r+\phi_{ij}^W(\varphi)\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^U\pi\left(\frac{r}{r+\rho}\right)}\left[b_j + \phi_{ij}^U\left(g_j + \tfrac{\pi}{r+\rho}z_j\right) + \left(\tfrac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^W(\varphi)\pi\right)}\theta_j c_j\right)\right]. \end{aligned} \tag{1.11}$$

This is the main result that links wages to the match productivities, labor market tightness, and primitive parameters that describe not only labor market but also criminal activities. A few special (extreme) cases are worthwhile to mention: provided criminals are to be found among both unemployed and employed, $\phi_{ij}^W\left(\varphi\right) = 1$ and $\phi_{ij}^U = 1$,

$$w_{ij}\left(\varphi\right) = \beta\left[\varphi + \tfrac{(r+\lambda)}{(r+\lambda+\pi)}\theta_j c_j\right] + (1-\beta)\,b_j.$$

Provided crime happens among unemployed only, $\phi_{ij}^W\left(\varphi\right) = 0$ and $\phi_{ij}^U = 1$, this leads to

$$\begin{aligned} w_{ij}\left(\varphi\right) &= \beta\left[\varphi + \tfrac{r}{r+\pi\left(\frac{r}{r+\rho}\right)}\theta_j c_j\right] \\ &+ (1-\beta)\,\tfrac{r}{r+\pi\left(\frac{r}{r+\rho}\right)}\left[b_j + g_j + \tfrac{\pi}{r+\rho}z_j\right]. \end{aligned}$$

Wages, are thus a weighted average of a productivity match, labour market tightness and vacancy posting costs, and outside options, which include not only traditional benefits but also the opportunities for crime (monetary gain of a crime and consumption once in jail). In an honest equilibrium, $\phi_{ij}^W\left(\varphi\right) = 0$ and $\phi_{ij}^U = 0$, and there is no crime. Wages collapse to

$$w_{ij}\left(\varphi\right) = \beta\left[\varphi + \theta_j c_j\right] + (1-\beta)\,b_j.$$

Interestingly, wages are higher under no crime than under a full crime, since

$$r + \lambda + \pi > r + \lambda.$$

A portion π of agents would be caught when committing a crime, a factor that is absent in an honest equilibrium.

1.2 Reservation wage

The wage in (1.11) can be adapted to derive the reservation wage. However, to make a cross-validation, we first start off with the observation that the value from the observation that, absent costs associated with the layoffs, the value of a job at a reservation (threshold) productivity $\tilde{\varphi}_j$ is equal to zero (also we make use of (1.11)):

$$\begin{gathered} r\mathcal{J}_{ij}\left(\tilde{\varphi}\right) = \tilde{\varphi} - \beta\tilde{\varphi} + \left(1-\beta\right)\phi_{ij}^{W}\left(\tilde{\varphi}\right)\left(g_j + \tfrac{\pi}{r+\rho}z_j\right) \\ -\left(1-\beta\right)\tfrac{r+\phi_{ij}^{W}\left(\tilde{\varphi}\right)\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\left[b_j + \phi_{ij}^{U}\left(g_j + \tfrac{\pi}{r+\rho}z_j\right) + \left(\tfrac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^{W}\left(\tilde{\varphi}\right)\pi\right)}\theta_j c_j\right)\right] \\ +\lambda\int_{\tilde{\varphi}}^{1}\left(\mathcal{J}_{ij}\left(z\right) - \mathcal{J}_{ij}\left(\tilde{\varphi}\right)\right)dF\left(z\right) + \lambda F\left(\tilde{\varphi}\right)\left(V_{ij} - \mathcal{J}_{ij}\left(\tilde{\varphi}\right)\right) = 0, \end{gathered}$$

and rearranging gives

$$\begin{gathered} \lambda\int_{\tilde{\varphi}}^{1}\mathcal{J}_{ij}\left(z\right)d\left(1-F\left(z\right)\right) = \left(1-\beta\right)\left[\tilde{\varphi} + \phi_{ij}^{W}\left(\tilde{\varphi}\right)\left(g_j + \tfrac{\pi}{r+\rho}z_j\right)\right] \\ -\left(1-\beta\right)\tfrac{r+\phi_{ij}^{W}\left(\tilde{\varphi}\right)\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\left[b_j + \phi_{ij}^{U}\left(g_j + \tfrac{\pi}{r+\rho}z_j\right) + \left(\tfrac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^{W}\left(\tilde{\varphi}\right)\pi\right)}\theta_j c_j\right)\right]. \end{gathered}$$

Since this expression is valid for the generic job value, we can work out the value function as

$$\begin{gathered} \mathcal{J}_{ij}\left(\varphi\right) = \tfrac{(1-\beta)(\varphi-\tilde{\varphi})+(1-\beta)\left(\phi_{ij}^{W}(\varphi)-\phi_{ij}^{U}\right)\left(g_j+\frac{\pi}{r+\rho}z_j\right)}{r+\lambda} \\ -\left(\tfrac{(1-\beta)\left(b_j+\phi_{ij}^{U}\left(g_j+\frac{\pi}{r+\rho}z_j\right)\right)}{r+\lambda}\right)\left(\tfrac{\left(\phi_{ij}^{W}(\varphi)-\phi_{ij}^{U}\right)\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\right) \\ -\left(r+\lambda\right)\beta\tfrac{\theta_j c_j}{r+\lambda}\left(\tfrac{r+\phi_{ij}^{W}(\varphi)\pi\left(\frac{r}{r+\rho}\right)}{\left(r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)\right)\left(r+\lambda+\phi_{ij}^{W}(\varphi)\pi\right)} - \tfrac{1}{\left(r+\lambda+\phi_{ij}^{U}\pi\right)}\right). \end{gathered}$$

Using the free entry condition, $\mathcal{J}_{ij}\left(\varphi\right) = c_j/q\left(\theta_j\right)$; hence,

$$\begin{gathered} \tfrac{(1-\beta)(\varphi-\tilde{\varphi})}{r+\lambda} = \tfrac{c_j}{q(\theta_j)}\left[1 + \beta\tfrac{\theta_j}{q(\theta_j)}\left(\tfrac{r+\phi_{ij}^{W}(\varphi)\pi\left(\frac{r}{r+\rho}\right)}{\left(r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)\right)\left(r+\lambda+\phi_{ij}^{W}(\varphi)\pi\right)} - \tfrac{1}{\left(r+\lambda+\phi_{ij}^{U}\pi\right)}\right)\right] \\ -\tfrac{(1-\beta)\left(\phi_{ij}^{W}(\varphi)-\phi_{ij}^{U}\right)\left(g_j+\frac{\pi}{r+\rho}z_j\right)}{r+\lambda} + \left(\tfrac{(1-\beta)\left(b_j+\phi_{ij}^{U}\left(g_j+\frac{\pi}{r+\rho}z_j\right)\right)}{r+\lambda}\right)\left(\tfrac{\left(\phi_{ij}^{W}(\varphi)-\phi_{ij}^{U}\right)\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\right). \end{gathered} \tag{1.12}$$

This condition links the reservation productivity (and wage) with the primitive parameters, given labor market tightness. Evaluating the above expression at the reservation productivity yields the fact that $\mathcal{J}_{ij}\left(\tilde{\varphi}\right)=0$.

The reservation wage can be obtained from the equation (1.11) and making use of $\phi_{ij}^{W}\left(\tilde{\varphi}\right)=\phi_{ij}^{U}$,

$$w_{ij}\left(\tilde{\varphi}\right)=\beta\tilde{\varphi}+\left(1-\beta\right)\left(b_j+\frac{(r+\lambda)\beta}{(1-\beta)\left(r+\lambda+\phi_{ij}^{U}\pi\right)}\theta_j c_j\right).$$

The wage is a weighted average of the productivity of a match, unemployment benefits, and the costs of employment, adjusted for the odds to get caught if one commits the crime. Note that the reservation wage in a crime-less equilibrium would have been a standard result in the Mortensen and Pissarides environment:

$$w_{ij}\left(\tilde{\varphi}\right)=\beta\left(\tilde{\varphi}+\theta_j c_j\right)+\left(1-\beta\right)b_j. \tag{1.13}$$

1.3 Crime-preventing wage

To pin down the crime-preventing wage, we first concentrate on a new cutoff level φ^c, defined as the crime-preventing productivity when the potential losses dominate potential gains from a crime. In such a case, $\phi_{ij}^{W}\left(\varphi^c\right)=0$ and we can evaluate the wage equation (1.11) at $\varphi=\varphi^C$:

$$\begin{gathered}w_{ij}\left(\varphi^C\right)=\beta\left(\varphi^C+\theta_j c_j\right)\\+\left(1-\beta\right)\frac{r}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\left(b_j+\phi_{ij}^{U}\left(g_j+\frac{\pi}{r+\rho}z_j\right)\right).\end{gathered} \tag{1.14}$$

Notice that we are effectively dealing with the fixed point problem -- the wage at crime productivity depends on the term which is also dependent on φ^C. We can employ (1.12) to derive

$$\begin{gathered}\frac{(1-\beta)\left(\varphi^C-\tilde{\varphi}\right)}{r+\lambda}=\frac{c_j}{q(\theta_j)}\left[1+\beta\frac{\theta_j}{q(\theta_j)}\left(\frac{r}{\left(r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)\right)(r+\lambda)}-\frac{1}{\left(r+\lambda+\phi_{ij}^{U}\pi\right)}\right)\right]\\+\frac{(1-\beta)\phi_{ij}^{U}\left(g_j+\frac{\pi}{r+\rho}z_j\right)}{r+\lambda}-\left(\frac{(1-\beta)\left(b_j+\phi_{ij}^{U}\left(g_j+\frac{\pi}{r+\rho}z_j\right)\right)}{r+\lambda}\right)\left(\frac{\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}{r+\phi_{ij}^{U}\pi\left(\frac{r}{r+\rho}\right)}\right).\end{gathered}$$

Let's analyze both cases: when all the unemployed agents submit to crime and when they do not. In the former case, $\phi_{ij}^{U}=1$, and

$$
\begin{aligned}
(1-\beta)\left(\varphi^C-\tilde{\varphi}\right) = \tfrac{c_j}{q(\theta_j)}\left[r+\lambda+\beta\tfrac{\theta_j}{q(\theta_j)}\left(\tfrac{r}{r+\pi\left(\frac{r}{r+\rho}\right)}-\tfrac{r+\lambda}{r+\lambda+\pi}\right)\right] \\
+(1-\beta)\left(\tfrac{r}{r+\pi\left(\frac{r}{r+\rho}\right)}\right)\left[g_j+\tfrac{\pi}{r+\rho}\left(z_j-b_j\right)\right].
\end{aligned}
\tag{1.15}
$$

The difference between the reservation and the crime-preventing productivities is driven by the relative magnitudes of the rate of release from jail, ρ, and the probability to get caught when committing a crime, π, also relative outside options, consumption once in jail, z_j, and benefits once unemployed, b_j. In case of no crime, $\phi_{ij}^U = 0$,

$$
\begin{aligned}
(1-\beta)\left(\varphi^C-\tilde{\varphi}\right) &= (r+\lambda)\tfrac{c_j}{q(\theta_j)} \\
&= (r+\lambda)\,\mathcal{J}_{ij}(\varphi),
\end{aligned}
$$

and, clearly, $\varphi^C = \tilde{\varphi}$ is consistent with $\mathcal{J}_{ij}(\tilde{\varphi}) = 0$.

The difference between the threshold productivities in the equation 1.15 can be entertained to learn the reaction to changes in the labor market. In particular, any exogenous shock that increases labor market tightness $\partial\theta/\partial\varepsilon^\theta > 0$, would generate

$$
\frac{\beta}{q(\theta_j)}\left(\frac{r}{\left(r+\pi\left(\frac{r}{r+\rho}\right)\right)(r+\lambda)}-\frac{1}{(r+\lambda+\pi)}\right)\left[1-2\epsilon_{q,\theta}\right]-\frac{1}{\theta_j}\epsilon_{q,\theta},
$$

where elasticity $\epsilon_{q,\theta} \equiv \theta q'(\theta)/q(\theta) < 0$ because $q'(\theta) < 0$. The expression above is positive whenever

$$
\epsilon_{q,\theta} < \frac{\beta\theta_j\pi r(\rho-\lambda)}{q(\theta_j)(r(r+\rho)+\pi r)(r+\lambda)(r+\lambda+\pi)+2\beta\theta_j\pi r(\rho-\lambda)}. \tag{1.16}
$$

This condition is satisfied for all values given $\rho > \lambda$ but failing this requirement, the condition can be still met and depends on the convexity of function $q(\theta)$ and the relative size of ρ and λ. We proceed with the result that $\partial\varphi^C/\partial\varepsilon^\theta > \partial\tilde{\varphi}/\partial\varepsilon^\theta$, meaning that crime-preventing productivity is more responsive to the movements in the labor market. This also makes good sense since the opportunity costs for the "marginal employed criminal" are larger compared to the costs for the "marginal unemployed criminal".

1.4 Lemma 3.1

Lemma 1.1. *Agents are less likely to commit crimes when their wage incomes are higher; unemployed agents engage in criminal activities if and only if agents employed at the reservation wage* $w(\tilde{\varphi})$ *do.*

Proof. The result trivially follows from the above environment, Sections 1.1-1.3, also see Burdett et al.

(2003) for such a result. Note that

$$
\begin{aligned}
K_{ij}^{U} &= g_j + \pi J_{ij} + (1-\pi) U_{ij} \\
K_{ij}^{W}(\varphi) &= g_j + \pi J_{ij} + (1-\pi) W_{ij}(\varphi),
\end{aligned}
\tag{1.17}
$$

implies that the difference in the payoff from crime and employment is $K_{ij}^{W}(\varphi) - W_{ij}(\varphi) = g_j + \pi (J_{ij} - W_{ij}(\varphi))$, which is decreasing in wage $w_{ij}(\varphi)$ as can be traced from (1.3)-(1.7): hence, the first statement. Further, the value difference for an unemployed agent is given by $K_{ij}^{U} - U_{ij} = K_{ij}^{W}(\tilde{\varphi}) - W_{ij}(\tilde{\varphi}) = g_j + \pi (J_{ij} - W_{ij}(\tilde{\varphi})) = g_j + \pi (J_{ij} - U_{ij})$ since by definition $W_{ij}(\tilde{\varphi}) = U_{ij}$. □

1.5 Proposition 3.2

Since productivity is isomorphic to wages, we can analyze an increase in crime-wages. From equation (3.11), an increase is warranted if, ceteris paribus, a financial gain from a crime in region j increases, a probability of getting caught decreases, economic volatility increases, the rate of time preference increases, reservation wage (productivity) decreases, and the consumption of the en-jailed workers increases in j.

Moreover, an influx of more productive employees from i to j who raise the productivity of a match in j leads to an increase in crime in j if criminals are more sensitive to changes in match-specific productivity than wage-earners whose earnings are above a crime wage. Note that more productive job seekers, ceteris paribus, induce an increase in the reservation wage (productivity). This leads to an increase in a crime rate. To see this, we need to calculate crime rate with four segments of population. We split employed agents into E_{ji}^{L} who earn less than a crime wage $w_{ij}(\varphi) < C_{ij}$, and those that earn more, E_{ji}^{H}, $w_{ij}(\varphi) \geq C_{ij}$.

First, unemployed is composed of those employed whose matches are dissolved at rate $\lambda F(\tilde{\varphi})$ and those released to unemployment from a jail less those who find a job and are enjailed as criminals:

$$\triangle u_j = \lambda F(\tilde{\varphi}_j)(1 - u_j - n_j) + \rho n_j - \left(\theta_j q(\theta_j) + \pi \phi_j^{U}\right) u_j,$$

leading to

$$u_j = \frac{\lambda F(\tilde{\varphi}_j) + (\rho - \lambda F(\tilde{\varphi}_j)) n_j}{\lambda F(\tilde{\varphi}_j) + \theta_j q(\theta_j) + \pi \phi_j^{U}}.$$

Then, steady-state workers with a wage lower than $w\left(\varphi_j^{C}\right)$ are composed of a share of unemployed agents who transit into employment with a probability $\theta_j q(\theta_j) F\left(\varphi_j^{C}\right)$ because there had to be two events happening, a successful match, $\theta_j q(\theta_j)$, and a match productivity falling below φ_j^C in order to join the labor force E_j^L, and are diminished by those who lose job (with a probability $\lambda F(\tilde{\varphi}_j)$), transit into higher than crime wage category (with the same probability as finding a new job $\theta_j q(\theta_j)$ times the odds to draw a match with $\varphi \geq \varphi_j^C$, $1 - F\left(\varphi_j^C\right)$), and are caught as criminals (with a probability π). Hence,

$$\begin{gathered}\triangle E_j^L = \theta_j q(\theta_j) F\left(\varphi_j^C\right) u_j - \left(\theta_j q(\theta_j)\left(1 - F\left(\varphi_j^C\right)\right) + \lambda F(\tilde{\varphi}_j) + \pi\right) E_j^L = 0,\\ E_j^L = \tfrac{\theta_j q(\theta_j) F\left(\varphi_j^C\right)}{\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)+\pi} u_j.\end{gathered}$$

The steady-state workers with higher wage than $w\left(\varphi_j^C\right)$ is composed of those who transit from being unemployed and E_j^L (with a probability of getting matched and drawing $\varphi \geq \varphi_j^C$, $\left(1 - F\left(\varphi_j^C\right)\right)\theta_j q(\theta_j)$), and lose jobs (with a probability $\lambda F(\tilde{\varphi}_j)$):

$$\begin{gathered}\triangle E_j^H = \left(1 - F\left(\varphi_j^C\right)\right)\theta_j q(\theta_j)\left(E_j^L + u_j\right) - \lambda F(\tilde{\varphi}_j) E_j^H = 0,\\ E_j^H = \tfrac{\left(1-F\left(\varphi_j^C\right)\right)\theta_j q(\theta_j)}{\lambda F(\tilde{\varphi}_j)}\left(E_j^L + u_j\right) = \tfrac{\left(1-F\left(\varphi_j^C\right)\right)\theta_j q(\theta_j)}{\lambda F(\tilde{\varphi}_j)}\left(\tfrac{\theta_j q(\theta_j)+\lambda F(\tilde{\varphi}_j)+\pi}{\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)+\pi}\right) u_j.\end{gathered}$$

At last, the enjailed criminals are composed of unemployed agents and those earning less than a crime wage caught with a probability π, and those released into unemployment with a probability ρ:

$$\triangle n_j = \pi\left(E_j^L + u_j\right) - \rho n_j = 0,$$

yielding

$$n_j = \frac{\pi}{\rho}\left(E_j^L + u_j\right) = \frac{\pi}{\rho}\left(\frac{\theta_j q(\theta_j) + \lambda F(\tilde{\varphi}_j) + \pi}{\theta_j q(\theta_j)\left(1 - F\left(\varphi_j^C\right)\right) + \lambda F(\tilde{\varphi}_j) + \pi}\right) u_j.$$

Then, steady states of the partitioned population are given by

$$\begin{aligned} u_j &= \tfrac{\rho\lambda F(\tilde{\varphi}_j)\left(\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)+\pi\right)}{\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)},\\ E_j^L = E_{jj}^L + E_{ij}^L &= \tfrac{\rho\lambda F(\tilde{\varphi}_j)\theta_j q(\theta_j) F\left(\varphi_j^C\right)}{\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)},\\ E_j^H = E_{jj}^H + E_{ij}^H &= \tfrac{\rho\left(1-F\left(\varphi_j^C\right)\right)\theta_j q(\theta_j)(\theta_j q(\theta_j)+\lambda F(\tilde{\varphi}_j)+\pi)}{\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)},\\ n_j &= \tfrac{\lambda F(\tilde{\varphi}_j)\pi(\theta_j q(\theta_j)+\lambda F(\tilde{\varphi}_j)+\pi)}{\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)}, \end{aligned} \tag{1.18}$$

where

$$\begin{aligned}\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)\equiv{}&\rho\left(\lambda F\left(\tilde{\varphi}_j\right)+\theta_j q\left(\theta_j\right)+\pi\phi_j^U\right)\left(\theta_j q\left(\theta_j\right)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F\left(\tilde{\varphi}_j\right)+\pi\right)\\&-\left(\rho-\lambda F\left(\tilde{\varphi}_j\right)\right)\pi\left(\theta_j q\left(\theta_j\right)+\lambda F\left(\tilde{\varphi}_j\right)+\pi\right)\end{aligned}$$

and, under $\phi_j^U=1$, can be simplified into

$$\begin{aligned}\Omega_j\left(\varphi_j^C,\tilde{\varphi}_j\right)\equiv{}&\left(\theta_j q\left(\theta_j\right)+\lambda F\left(\tilde{\varphi}_j\right)+\pi\right)\\\times&\left(\rho\theta_j q\left(\theta_j\right)\left(1-F\left(\varphi_j^C\right)\right)+\left(\rho+\pi\right)\lambda F\left(\tilde{\varphi}_j\right)\right),\end{aligned}$$

just as reported in the main text. The crime rate is given by

$$\mathsf{c}_j=\tfrac{E_j^L+u_j}{1-n_j}=\tfrac{\rho\lambda F\left(\tilde{\varphi}_j\right)}{\theta_j q\left(\theta_j\right)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F\left(\tilde{\varphi}_j\right)}.$$

The sign of the derivative of the above equation with respect to cutoff productivity level is given by equation

$$\begin{aligned}&\left(\tfrac{\partial E_j^L}{\partial\tilde{\varphi}_j}+\tfrac{\partial u_j}{\partial\tilde{\varphi}_j}\right)\left(1-n_j\right)+\tfrac{\partial n_j}{\partial\tilde{\varphi}_j}\left(E_j^L+u_j\right)\\&=\tfrac{E_j^H}{\tilde{\varphi}_j}\left(E_j^L+u_j\right)\left(\varepsilon_{E_j^L+u_j,\tilde{\varphi}_j}-\varepsilon_{E_j^H,\tilde{\varphi}_j}\right),\end{aligned}$$

where ε_f denotes the elasticity of a particular function f. We used the property of the elasticity of a sum of two functions. Hence, the sign is given by $\varepsilon_{E_j^L+u_j,\varphi}-\varepsilon_{E_j^H,\varphi}$ which depends on the impact of a threshold productivity on crime productivity, $\partial\varphi_j^C/\partial\tilde{\varphi}_j$. The dependence between reservation and crime wages is obvious from equation (1.15).

Turning to the proposition claims, we note that an increase in a frequency of match-specific shocks increases crime rate follows from the fact that $\rho F\left(\tilde{\varphi}_j\right)\left(1-F\left(\varphi_j^C\right)\right)\theta_j q\left(\theta_j\right)>0$. This result can be interpreted as the one stating that an increase in volatility of economic environment tends to increase crime rate. To be more precise,

$$\frac{\partial\mathsf{c}_j}{\partial\lambda}=\frac{\rho\left(\theta_j q\left(\theta_j\right)\left(1-F\left(\varphi_j^C\right)\right)\right)F\left(\tilde{\varphi}_j\right)}{\left(\theta_j q\left(\theta_j\right)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F\left(\tilde{\varphi}_j\right)\right)^2}>0.$$

Second, an exogenous increase in the crime wage (or productivity φ_j^C) also increases crime rate since $\lambda F\left(\tilde{\varphi}_j\right)\theta_j q\left(\theta_j\right)f\left(\varphi_j^C\right)>0$ where $f\left(\varphi_j^C\right)\equiv dF\left(\varphi_j^C\right)/d\varphi_j^C$ and $\partial\varphi_j^C/\partial\tilde{\varphi}_j=0$. This is a partial effect when a change in the crime productivity has no effect on the reservation productivity. Accounting for the adjustments in the endogenous productivities and labour market tightness leads to

$$\frac{\partial \mathsf{c}_j}{\partial \varphi_i^C} = f\left(\varphi_j^C\right) \varphi_j^C \rho \lambda F\left(\tilde{\varphi}_j\right) \frac{\theta_j q(\theta_j)}{\varphi_j^C}$$
$$+ \left(f\left(\tilde{\varphi}_j\right) \frac{\partial \tilde{\varphi}_j}{\partial \varphi_j^C} - \left(1 + \epsilon_{q(\theta_j),\theta_j}\right) \frac{\epsilon_{\theta_j,\varphi_j^C}}{\varphi_j^C} F\left(\tilde{\varphi}_j\right) \right) \rho \lambda \left(1 - F\left(\varphi_j^C\right)\right) \theta_j q\left(\theta_j\right),$$

the sign of which is determined by the term in the brackets on the second line (note that we think of an exogenous change in φ_j^C whose effect we are analyzing; to simplify expressions, we abuse the notation by failing to report ε^{φ^C} and we deal directly with φ_j^C) . To pin down the sign, recall $\partial \varphi_j^C / \partial \tilde{\varphi}_j > 0$ from (1.15) and (1.16). We also assumed (refer to the main text) that $\epsilon_{q(\theta_j),\theta_j} < 0$; also, drawing from Petrongolo and Pissarides (2001), it is assumed that matching occurs at constant returns to scale. which implies linear homogeneity and $1 + \epsilon_{q(\theta_j),\theta_j} > 0$. Finally, $\epsilon_{\theta_j,\varphi_j^C}$ requires modeling general equilibrium in order to learn the interactions between the goods and labor markets. However, either using the separability property when productivity is independent from the labor market tightness (Felbermayr et al., 2011) or the outside sector with a fixed wage (Helpman and Itskhoki, 2010), the implication is such that threshold productivity either has not relationship with the labor market tightness or it is negative (to see the latter, refer to the equations (1.13) and (1.14), and fix the wage). We therefore conclude:

$$\frac{\partial \mathsf{c}_j}{\partial \varphi_j^C} \frac{\partial \varphi_j^C}{\partial \varepsilon^{\varphi^C}} > 0. \tag{1.19}$$

Intuitively, an increase in a crime-wage increases a number of firms which pay a wage smaller or equal to $w\left(\varphi^C\right)$ and this how it increases a number of criminals.

Thirdly, an increase in job seekers in the other region increases crime rate given the elasticity of the labor market tightness is smaller than minus one (larger than one in absolute value). Recall that $\theta_j \equiv v_j / S_j = v_j / \left(u_{jj} + u_{ij}\right)$. Hence, the more the job seekers from the other region, the smaller is the labor market tightness, ceteris paribus. Then, differentiating equation (3.13) with respect to θ_j we obtain $-\lambda F\left(\tilde{\varphi}_j\right)\left(q\left(\theta_j\right) + \theta_j q'\left(\theta_j\right)\right)$ as a partial effect. This term is positive if and only if $q\left(\theta_j\right) + \theta_j q'\left(\theta_j\right) = q\left(\theta_j\right)\left(1 + \theta_j q'\left(\theta_j\right) / q\left(\theta_j\right)\right) < 0$ which implies that the elasticity of instantaneous meeting probability for vacancies is $\theta_j q'\left(\theta_j\right) / q\left(\theta_j\right) < -1$ or $\left|\theta_j q'\left(\theta_j\right) / q\left(\theta_j\right)\right| > 1$. However, we ruled this possibility out by drawing from the evidence about matching probability put forward by Petrongolo and Pissarides (2001). Hence, a full effect is such that

$$\frac{\partial \mathsf{c}_j}{\partial \varepsilon^\theta} = \frac{\rho\lambda f(\tilde{\varphi}_j)}{\left(\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)\right)} \frac{\partial \tilde{\varphi}_j}{\partial \theta_j}$$
$$-\frac{\rho\lambda F(\tilde{\varphi}_j)\left(\left(1+\epsilon_{q(\theta_j),\theta_j}\right)q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)-\theta_j q(\theta_j) f\left(\varphi_j^C\right)\frac{\partial \varphi_j^C}{\partial \theta_j}+\lambda f(\tilde{\varphi}_j)\frac{\partial \tilde{\varphi}_j}{\partial \theta_j}\right)}{\left(\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)\right)^2}.$$

Under the separability assumption, it is clear that

$$\frac{\partial \mathsf{c}_j}{\partial \varepsilon^\theta} = -\frac{\rho\lambda F(\tilde{\varphi}_j)\left(\left(1+\epsilon_{q(\theta_j),\theta_j}\right)q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)\right)}{\left(\theta_j q(\theta_j)\left(1-F\left(\varphi_j^C\right)\right)+\lambda F(\tilde{\varphi}_j)\right)^2} < 0,$$

where $1+\epsilon_{q(\theta_j),\theta_j} > 0$ is assumed to hold.

Fourth, an influx of more productive employees from i to j who raise the productivity of a match in j leads to an increase in crime in j. Note that more productive job seekers, ceteris paribus, induce an increase in the reservation wage (productivity). This leads to an increase in crime rate. Recall that we are working under the case of $\phi_{ij}^U = 1$, therefore, an increase in reservation productivity for a successful match increases an army of unemployed who will find it optimal to engage in criminal activities (to counteract this effect one needs a very large decrease in criminal wage, so that a distance between two cutoffs becomes small). Yet this is not possible given relationship between productivities in equilibrium, as captured by (1.15), and discussed in the Part 2 of this proposition (refer to the effect (1.19) and the required assumptions for it to hold).

2 Empirical Part

Crime Categories - 2009 Report of the German Federal Criminal Police Office

435*00 Theft by Burglary of a Dwelling

including:

436*00 Daytime burglaries of residences (committed between 6:00 a.m. and 9:00 p.m.)

***50*00 Theft of/ from Motor Vehicles**

674000 Damage to Property

including:

674100 damage to motor vehicles

674300 other damage to property committed in streets, lanes or public places

674500 destruction of important equipment

730000 Drug Offenses - Narcotics Act

including:

731000 general violations

thereof:

731100 involving heroin

731200 involving cocaine

731300 involving LSD

731400 involving amphetamine/ methamphetamine and their derivatives in powder or liquid form

731500 involving amphetamine/ methamphetamine and their derivatives in tablet or capsule form

731800 involving cannabis and preparations thereof

731900 involving other drugs

732000 trafficking in, and smuggling of drugs

thereof:

732100 in/of heroin

732200 in/of cocaine

732300 in/of LSD

732400 in/of amphetamine/ methamphetamine and their derivatives in powder or liquid form

732500 in/of amphetamine/ methamphetamine and their derivatives in tablet or capsule form

732800 in/of cannabis and preparations thereof

732900 in/of other drugs

733000 illegal importation of drugs (significant amounts)

thereof:

733100 of heroin

733200 of cocaine

733300 of LSD

733400 of amphetamine/methamphetamine and their derivatives in powder or liquid form

733500 of amphetamine/ methamphetamine and their derivatives in tablet or capsule form

733800 of cannabis and preparations thereof

733900 of other drugs

734000 other violations of the NCA

899000 Street Crime includes the following offenses:

111100 offenses against sexual self-determination by sudden attack (individual offender)

111200 offenses against sexual self-determination by sudden attack (group of offenders)

132000 indecent exposure and indecent acts in public

213000 transports of cash and valuables

214000 assault on motorists with intent to rob

215000 robbery following restaurant/bar visit

216000 handbag robbery

217000 other robberies in streets, lanes or public places

222100 dangerous and serious bodily injury in streets, lanes or public places

233300 extortionate kidnapping in connection with robberies of transports of cash and valuables

234300 hostage taking in connection with robberies of transports of cash and valuables

*20*00 theft in/from kiosks

*30*00 in/from store windows, showcases and display cases

*50*00 theft in/from motor vehicles

*55000 theft of motor vehicles

*90*00 pickpocketing

*001001 theft of motor vehicles

*002001 theft of mopeds and motorcycles

*003001 theft of bicycles

*007001 theft of/from coin-operated machines

623000 breach of the public peace

674100 damage to motor vehicles

674300 other damage to property committed in streets, lanes or public places

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