ABSTRACT

Title of dissertation: ESSAYS ON THE IMPACT OF SOCIAL INTERACTIONS ON ECONOMIC OUTCOMES

Nathalia Perez Rojas
Doctor of Philosophy, 2007

Dissertation directed by: Professor Rachel Kranton
Department of Economics

This dissertation consists of two essays, which address the question of how social interactions shape economic outcomes. The first essay examines crime and criminal networks. The second one studies immigration, assimilation, and ethnic enclaves.

The first essay offers a formal model of crime. Criminals often do not act alone. Rather, they form networks of collaboration. How does law enforcement affect criminal activity and structure of those networks? Using a network game, I show that increased enforcement actually can lead to sparse networks and thereby to an increase in criminal activity. When criminal activity requires a certain degree of specialization, criminals will form sparse networks, which generate the highest level of crime and are the hardest to disrupt. I also show that heavy surveillance and large fines do not deter crime for these networks.

The second essay examines the impact that residential location decisions have on economic outcomes of immigrants. About two thirds of the immigrants that

arrived to the United States between 1997 and 2006 settled in six States only. Using a simultaneous-move game on residential choices I show that when all immigrants are unskilled they cluster in an enclave and earn very low wages, although they would be better off assimilating. Hence the enclave is 'trap'. Introducing skill heterogeneity among immigrants reverses the result: the enclave equilibrium becomes socially preferred to assimilation.

ESSAYS ON THE IMPACT OF SOCIAL INTERACTIONS ON ECONOMIC OUTCOMES

by

Nathalia Perez Rojas

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2007

Advisory Committee:
Professor Rachel Kranton, Chair/Advisor
Professor Larry Ausubel
Professor Peter Reuter
Professor John Shea
Professor Dan Vincent

Acknowledgements

I would like to thank my main advisor, Rachel Kranton, for her encouragement and dedication, and also, for the many productive discussions we had since the inception of this project. I am indebted to Dan Vincent for his frank and challenging comments, and for helping me to become more rigorous in my work. To Larry Ausubel, thank you for your crucial feedback and for your generous advice. I am very grateful to John Shea, who took the time to read my dissertation and provide me with very useful (and incredibly detailed) comments. I would also like to thank Peter Reuter for reading my dissertation with fresh eyes and making it better.

To my family, thanks for being so loving and supportive. Mom and Dad, words are not enough, thanks for everything. Andres, I could not have asked for a better companion in this journey. Thank you for your love, understanding and patience. To my brother, Esteban, thank you for cheering me up in difficult moments. Your energy took out the best of me. My deepest gratitude to Carlos Alberto, Juan Carlos and Luca. Helena, I miss you very much. Thanks to you too.

Table of Contents

List of Figures

Chapter 1

Crime Networks

1.1 Introduction

Criminals often do not act alone. Rather, they form networks of collaboration. This chapter examines the impact of law enforcement on those networks and on the resulting level of crime. I define a network as a group of criminals and the pattern of communication links between them. Moreover, I refer to a sparse or diffused network as one that connects a given number of criminals with the fewest links. I find that sparsely connected networks generate the most crime and are the hardest to dismantle. Also, within a diffused network, criminals who establish communication links with the fewest other agents exert the highest level of crime effort. Sparse networks generate the most crime, and even heavy surveillance and large fines do not affect their shape or their level of criminal activity.

Criminal networks participate in a wide range of illegal activities, such as drug trafficking, arms smuggling, and terrorism (Naim [22]). Many hierarchical Mafia-like organizations have shifted their structure towards networks of loosely aligned criminals (Williams [33]). For example, the Colombian cocaine trade, long dominated by the cartels of Medellín and Cali, is now run by independent and specialized trafficking organizations in Colombia, Mexico, and the U.S.[1] Decentralized

[1]For a description of the process of cocaine smuggling into the U.S., see INCSR reports of the

crime networks are typically sparsely connected and very flexible. These features allow them to be less visible and to change their structure constantly, which makes it difficult for law enforcement to dismantle them (Reuter [25], Sageman [28] and Williams [32]).

This chapter shows that, for a given number of criminals, those networks that connect (directly or indirectly) all criminals with the fewest number of links yield the highest level of crime. Within such sparsely connected network, criminals that have few links are less visible to the police through connections, and supply high criminal effort. Well-connected criminals, in contrast, exert low effort, instead providing connections among distant agents. In networks that are densely connected, all criminals face large penalties because of their large number of links, and thus they optimally supply low effort.

To demonstrate these results, I analyze a simultaneous-move game in which criminals in a given network independently select the amount of criminal effort to exert. The basic model has three criminals; I compare the levels of crime generated by all possible configurations of the network.[2] I make the following assumptions: First, no criminal can undertake illicit activity by himself: all agents need at least one link to participate and to exert effort. Second, links allow criminals to coordinate on their efforts and thus to derive spillover benefits. These effort spillovers are stronger

US Department of State [9]. On the cost associated with each phase of the cocaine smuggling process see Reuter [26]. Fuentes [14] has a very detailed description of the Colombian cocaine 'distribution' cells operating in the US during the 1990s.

[2]In section 1.5 I extend the model to more than three criminals.

between pairs of criminals who are more closely connected (in terms of path length). Finally, the penalties from engaging in criminal activity increase with both the links a criminal has and the amount of effort he supplies.

I show that if the effort spillovers are not too strong, then the static game has a unique Nash Equilibrium. Suppose that well-connected criminals face a significantly larger marginal cost of effort than do poorly-connected criminals. Then, within a diffused network, well-connected criminals will supply less effort than criminals with fewer links. When I compare crime levels across networks I find two features that lead to the most crime: connectedness and sparseness of the network. Networks that connect all criminals with the fewest possible links lead to the most crime.

Given that sparse networks generate the most crime, under what conditions do they form? To address this question, I extend the model and allow criminals to form links, and then to select the level of effort to exert. I find that diffused networks are likely to emerge and can afford to pay large fines and face heavy surveillance by the police. Further, when spillovers are sufficiently strong, large penalties do not affect the structure of diffused networks or their level of crime.

This study contributes to the literature on the economic theory of networks, and the economics of crime. Previous works by Calvó-Armengol and Zenou [6] and Ballester, Calvó-Armengol and Zenou [2] studied the effect of social networks on criminal behavior. The first paper shows that the decision among otherwise identical agents to get involved in crime depends on each agent's position in the social network. In the second paper, the authors develop a measure of centrality for each player (Bonacich measure) and ask how this measure affects the individual choice of criminal effort. These papers are in line with the extensive literature on the economics of crime, which focuses both at the theoretical and empirical levels on the incentives for agents to engage in criminal activities.[3] I depart from this approach and assume that all agents are criminals, and study instead the decisions that agents make on who to communicate with and how much crime effort to supply. This study is also related to the theoretical literature on drug markets, which analyzes the effect that law enforcement policies have on agents situated at different levels of the drug production and distribution chain, and ultimately on the number of consumers in the streets (see for example Poret [23] and Chiu et al. [7]).

Adding to the previous literature, my work assumes that agents in the network are criminals, who must collaborate with each other in the illicit activity. In my model criminal efforts of all agents that are linked directly or indirectly are strategic complements. Each criminal derives benefits from the collaboration through effort spillovers. In Calvó-Armengol and Zenou [6] and Ballester, Calvó-Armengol and Zenou [2] there are both local (direct neighbor) complementarities and global substitutabilities in criminal effort. The complementarities reflect peer effects, while the substitutabilities reflect the competition for the booty among criminals who are not connected directly.

By expanding our understanding of crime, this study can inform law enforcement policy. The resiliency of decentralized crime networks requires crime fighting

[3]For a review of the literature on the economics of crime, see Freeman [12] and DiIulio [10].

policies that differ from those targeted towards hierarchical organizations. In the context of decentralized networks, changes in the penalties will affect the level of crime and, more importantly, the structure. As the structure of a crime network changes, law enforcement policies that were effective in the past may be useless. I show that when effort complementarities are sufficiently strong, tougher penalties do not discourage criminal behavior. Policies that target criminal activity and links among criminals, rather than those links alone, are more effective in reducing crime.

The rest of the chapter is organized as follows. In Section 1.2, I describe a static game in which, for a given network, criminals strategically select criminal effort. In Section 1.3, I solve for the Nash Equilibrium of the game, and compare equilibrium outcomes across all networks with three criminals. In Section 1.4, I specify a two-stage game: first criminals form links, and then they choose criminal effort. I look for networks that are pairwise stable; i.e. ones in which no criminal has the incentive to sever a link, and no unlinked pair wants to form a link (Jackson and Wolinsky [17]). In Section 1.5, I extend the analysis to larger networks and consider a dynamic process of network formation. Section 2.4 concludes.

1.2 Setup of the Game

There are three criminals. Denote the set of criminals by $N = \{1, 2, 3\}$ and index each agent by $i = 1, 2, 3$. A network g is the collection of communication links between criminals (or nodes) that belong to N. Links allow criminals to communicate and thereby coordinate on their crime efforts. A communication link

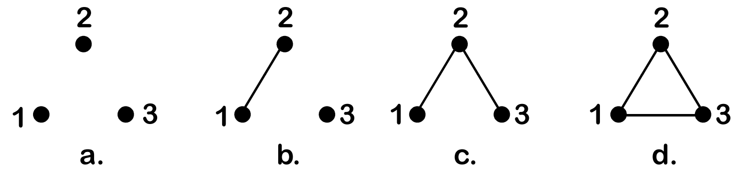

Figure 1.1: Networks with three criminals

between agents i and j where $i, j \in N$ is represented by $g_{ij} = 1$. If i and j are not directly connected then $g_{ij} = 0$. I normalize $g_{ii} = 0$.

Given three criminals, there are four possible network configurations. The first network is the empty network, where all criminals are isolated (Figure 1.1a). The second network is the Single-Link Network, which has only two criminals linked. This network is described by $g^I_{12} = 1$, and $g^I_{13} = g^I_{23} = 0$ (Figure 1.1b). The third network is a Star represented by g^S with $g^S_{12} = 1$, $g^S_{23} = 1$ and $g^S_{13} = 0$. Here only one criminal –the center of the Star– is directly linked to the other two nodes (Figure 1.1c). The last structure is the Complete network that has each agent connected to every other agent ($g^C_{12} = 1$, $g^C_{13} = 1$ and $g^C_{23} = 1$, Figure 1.1d).

I assume that agents are homogeneous and that the value of links only depends on the network structure, not on the identity of agents. For example, a Star network with $g^S_{12} = 1$, $g^S_{23} = 1$ and $g^S_{13} = 0$ generates the same value as one with $g^S_{12} = 1$, $g^S_{13} = 1$ and $g^S_{23} = 0$.

The total number of links that agent i has in network g equals $N^g_i = \sum_{j \in N} g_{ij}$. Let the vector $\mathbf{N}^g = [N^g_1, N^g_2, N^g_3]$ represent the profile of the number of links each criminal has.

To measure the distance between agents, let $s_i^g = (s_{i1}, s_{i2}, s_{i3})$ for $i = 1, 2, 3$. Each element s_{it} of the vector s_i^g corresponds to the inverse of the shortest distance in network g between agents i and t. As a convention $s_{ii} = 0$. If i and t are not connected (directly or indirectly) then $s_{it} = 0$. The magnitude of s_{it} depends on the link pattern of the network and in particular, on the links that agent i has within it. Let $\mathbf{s}^g = [s_1^g; s_2^g; s_3^g]$ be a symmetric matrix in which the it-th element corresponds to s_{it}.

Given a network g, criminals strategically select how much effort to exert. Denote the criminal effort of agent i by e_i^g.[4] Let $\mathbf{e}^g = (e_1^g, e_2^g, e_3^g)$, represent the profile of efforts of all criminals in network g. Define the level of criminal activity of a network as the sum of efforts of all of its members. Crime and crime effort are used interchangeably throughout.

The payoff to a criminal depends on his level of effort (e_i^g), his links (N_i^g), other criminals' efforts (e_j^g), proximity to them (s_{ij}), and two law enforcement parameters. The law enforcement parameters are a fine (f), and an intensity of law enforcement (μ). For example, μ can be the probability that law enforcement will put under surveillance any criminal.

[4] As a convention, subscripts refer to nodes or criminals (i), while superscripts refer to networks (g).

Given a network g, the payoff to criminal i equals:

$$Y_i^g = B(e_i^g, N_i^g) + \sum_{j \neq i, j \in N} K(e_i^g, e_j^g, s_{ij}; \gamma) - \pi(e_i^g, N_i^g; \mu, f) \tag{1.1}$$

Agents can participate in the criminal activity only if they are connected, i.e. if $N_i^g = 0$ then $e_i^g = 0$, and $Y_i^g = 0$. More precisely, I normalize to zero the payoff of a criminal that has no links. Thus the effort that a linked criminal supplies is interpreted as the additional crime effort driven by the gains from coordination and communication with other criminals.

The first term in (1.1) is the private benefit derived from own links and own effort. Even if all other criminals in the network exert minimal or no effort, agent i still benefits from his connections ($B(e_i, N_i^g) > 0$ even if $\forall j \in N$, $e_j^g = 0$). $B(.)$ is increasing in all of its terms and is weakly concave in effort: $\frac{\partial B}{\partial e_i^g} > 0$, $\frac{\partial B}{\partial N_i^g} > 0$ and $\frac{\partial^2 B}{\partial (e_i^g)^2} \leq 0$. And, having more links makes own effort more productive. Thus criminals with more links derive a larger marginal benefit of effort: $\frac{\partial^2 B}{\partial N_i^g \partial e_i^g} > 0$.

The second term in (1.1) is the benefit derived from effort spillovers.

$\sum_{j \neq i, j \in N} K(e_i^g, e_j^g, s_{ij}; \gamma)$ is increasing in own effort (e_i^g), other criminals' efforts (e_j^g), proximity to them (s_{ij}) and the strength of spillovers (γ): $\frac{\partial K}{\partial e_i^g} > 0$, $\frac{\partial K}{\partial e_j^g} > 0$, $\frac{\partial K}{\partial s_{ij}} > 0$, $\frac{\partial K}{\partial \gamma} > 0$. Further spillovers are weakly concave in own effort: $\frac{\partial^2 K}{\partial (e_i^g)^2} \leq 0$. The most important assumption of the model is that e_i and e_j are strategic complements. The strength of these complementarities is measured by the parameter $\gamma > 0$, i.e. $\frac{\partial^2 K(.)}{\partial e_i \partial e_j} = h(\gamma, .) > 0$ and $\frac{\partial h}{\partial \gamma} > 0$. If each node has a very particular skill or knowledge that vastly enhances the value of the criminal effort put in by all others in the network, then γ is large. When γ is small effort complementarities are weak and the gains from collaboration are small. Moreover, stronger spillovers increase the marginal benefit of effort: $\frac{\partial^2 K(.)}{\partial \gamma \partial e_i} > 0$.

The last term in (1.1), $\pi(e_i^g, N_i^g; \mu, f)$, is the cost of engaging in a criminal activity. The law enforcement parameter μ affects the likelihood that a criminal will get caught. A criminal who gets caught by the police must pay an exogenous fine f. Thus I interpret the function $\pi(e_i^g, N_i^g; \mu, f)$ as the fine payment. The cost of engaging in criminal activity is increasing in e_i^g, N_i^g, and in the law enforcement parameters (μ and f): $\frac{\partial \pi}{\partial e_i^g} > 0$, $\frac{\partial \pi}{\partial N_i^g} > 0$, $\frac{\partial \pi}{\partial \mu} > 0$ and $\frac{\partial \pi}{\partial f} > 0$. Further the fine payment is strictly convex in e_i^g , i.e. $\frac{\partial^2 \pi}{\partial \left(e_i^g\right)^2} > 0$. Larger penalties increase the cost of additional effort: $\frac{\partial^2 \pi}{\partial e_i^g \partial f} > 0$ and $\frac{\partial^2 \pi}{\partial e_i^g \partial \mu} > 0$. Even at the margin, increases in the fine (f) and in the intensity of law enforcement (μ) act as criminal deterrents by raising the marginal cost of criminal effort. And, heavier penalties are more costly to criminals with more links: $\frac{\partial^2 \pi}{\partial N_i^g \partial f} > 0$ and $\frac{\partial^2 \pi}{\partial N_i^g \partial \mu} > 0$.

I am interested in examining how law enforcement policies shape criminal effort choices in a given network. The fine (f) and the probability of surveillance (μ) affect Nash Equilibrium efforts through $\pi(e_i^g, N_i^g; \mu, f)$, the cost of being part of a crime network. I assume that criminals with more links find it more costly to marginally increase their effort relative to poorly connected criminals: $\frac{\partial^2 \pi}{\partial e_i^g \partial N_i^g} > 0$. For any given effort level, having more links increases the likelihood of being captured. Within a network, well connected criminals are more visible to the police because of these links. This visibility gives them the incentive to supply less effort than sparsely connected agents. For example, if all criminals in the Star network exert the same level of effort, then increasing it marginally is more costly for the center of the Star than for the corners.

Each criminal in the network faces a tradeoff between the benefit from effort coordination and the cost associated to getting caught. A well-connected criminal coordinates on efforts with several other criminals, and thereby derives larger spillover benefits than a poorly connected agent does. However, holding the effort level fixed, a well-connected criminal is also more likely get caught through links than a criminal with fewer connections.

To motivate the model, consider the following situation. Suppose that the process of drug smuggling consists of three phases: processing the coca leaf into cocaine, smuggling the cocaine into the foreign country (e.g. the U.S.) and finally, distributing and retailing it. Now assume that each of these activities is undertaken by a different agent within the crime network. The first agent is the producer or Colombian drug-lord, the second agent is the smuggler, and the third is the distributor or dealer. The criminal effort of the drug-lord includes such activities as growing the coca and then refining it to produce the cocaine. Hence e_i^g refers to effort put into the criminal activity itself, and it excludes any action to avoid being captured by the police.

The intuition behind the assumptions of the model are as follows for this example: Criminals must have at least one link to participate in the criminal activity. Therefore, the drug-lord needs connections either with the smuggler or the distributor or both in order to derive a non-zero benefit from his economic activity. Recall that the crime effort of an isolated criminal is normalized to zero. For example, when the drug-lord has no connections he goes to the spot market and has an anonymous transaction with a smuggler. In such a transaction there are no benefits from effort spillovers or from connections. Therefore the value of that transaction is no larger than that of a transaction in which the drug-lord and the smuggler agree on the packaging and the delivery time of the cocaine. Further, the more links a criminal has, the larger his marginal benefit from effort. Suppose that the smuggler marginally increases the amount of cocaine brought illegally into the U.S. Then his marginal benefit is larger when he is connected to two dealers than one.

The key assumption of the model is effort spillovers. In this scenario one example would be: The Colombian drug-lord makes an R&D investment that allows him to process better quality/high-purity cocaine at a low cost. This improvement in quality gives the distributor/dealer the incentive to search for customers who are willing to pay a premium for the high-purity cocaine. The dealer responds to the increased R&D effort of the drug-lord by supplying more effort. These marginal increases in effort become more productive if the traffickers use electronic communications that are encrypted and thus very secure (γ increases). Then it becomes harder for the police to tap into their communications. Such a change gives criminals the incentive to collaborate more closely with each other (i.e. a marginal increase in γ raises the marginal benefit of e_i^g).

1.3 The Game: Strategic Criminal Effort Choices

I specify a simultaneous-move game as follows. For a given network g, each criminal i selects e_i^g to maximize his own payoff. For a given network, criminals play a simultaneous move game in criminal efforts. I compare Nash Equilibrium (NE) efforts across all network configurations shown in Figure 1.1.

Denote a profile of Nash Equilibrium efforts by $\mathbf{e}^{g*} = (e_1^{g*}, e_2^{g*}, e_3^{g*})$.

From (1.1) the payoff to criminal i in network g is:

$$Y_i^g = B(e_i, N_i^g) + \sum_{j \neq i, j \in N} K(e_i, e_j, s_{ij}; \gamma) - \pi(e_i, N_i^g; \mu, f) \tag{1.2}$$

The profile of NE efforts ($\mathbf{e}^*$) is determined by the set of first order conditions given by:

$$\begin{aligned} \frac{\partial Y_i^g}{\partial e_i} &= \frac{\partial B(e_i, N_i^g)}{\partial e_i} + \sum_{j \neq i, j \in N} \frac{\partial K(e_i, e_j^*, s_{ij}; \gamma)}{\partial e_i} - \frac{\partial \pi(e_i, N_i^g; \mu, f)}{\partial e_i} \\ &= 0 \forall i \in N \end{aligned} \tag{1.3}$$

Given that the strategy sets are one-dimensional (effort levels), and that payoffs are continuous and concave in effort, the following condition guarantees that a unique Nash Equilibrium profile of efforts ($\mathbf{e}^*$) exists:

$$\left| \frac{\partial^2 B}{\partial (e_i)^2} + \sum_{j \neq i, j \in N} \frac{\partial^2 K}{\partial (e_i)^2} - \frac{\partial^2 \pi}{\partial (e_i)^2} \right| > \sum_{j \neq i, j \in N} \frac{\partial^2 K}{\partial e_i \partial e_j} \forall i \in N \tag{1.4}$$

When this inequality is satisfied, Best Response functions are contraction mappings, and the system of first-order conditions given by (1.3) has a unique solution (Friedman [13] and Vives [30]). A property of this Nash Equilibrium is symmetry: agents in identical structural positions in the network adopt the same strategy. For example, at the NE, players in the corners of the Star (Figure 1.1c) exert the same amount of criminal effort. The inequalities in (1.4) suggest that the Best Response of criminal i changes proportionately more with a marginal increase in own effort (e_i^g) than with a similar increase in other criminals' effort (e_j^g). Conditions in (1.4) hold if the network effects (γ) are not too strong, and if the cost of engaging in criminal activity is sufficiently convex in own effort. When the effort complementarities are very strong, then an individual might choose either to supply almost no effort at all, given that any small and positive amount of effort is extremely productive or to supply very high effort that feeds back through larger efforts of all others in the network. Thus if γ is too large, then the game can have multiple equilibria.

Let $\bar{\gamma}$ be the largest γ for which a unique Nash Equilibrium exists. The following analysis applies for all $\gamma \leq \bar{\gamma}$.

The first result of the model is that within a network criminals with few links exert more effort than those with more links. Well-connected criminals are more likely to be captured because of their links and they choose to supply low effort. In contrast, criminals with few links are less visible through the links and can exert more effort. Within a network, when the penalties for engaging in criminal activity depend on both e_i^g and N_i^g criminals who have few links supply more effort than well-connected agents. The next proposition formalizes the result.

Proposition 1.1. *Let $\gamma \leq \bar{\gamma}$. Suppose that $\frac{\partial^2 \pi}{\partial e_i^g \partial N_i^g} > 0$ is sufficiently large. Then* *within a network, sparsely connected criminals exert more effort than those with more links.*

Proof. All proofs are in Appendix A. □

More precisely the assumption of large $\frac{\partial^2 \pi}{\partial e_i^g \partial N_i^g}$ in Proposition 1.1 requires that $\frac{\partial^2 \pi}{\partial e_i^g \partial N_i^g} > \frac{\partial^2 B}{\partial e_i^g \partial N_i^g}$. This assumption suggests that a criminal who is well connected faces a higher marginal cost of effort and a lower marginal benefit relative to an agent that is poorly connected. If two criminals who differ in their number of links face the same marginal effort cost (i.e. $\frac{\partial^2 \pi}{\partial e_i^g \partial N_i^g} = 0$), then it would be more profitable for the well-connected criminal to increase his effort relative to the poorly connected agent (the effort spillover benefits of the latter are lower). Furthermore, the well-connected criminal, by exerting marginally more effort, leads to stronger effort spillovers that feed back to everyone else in the network. This feed back translates into more crime than that which would result from a poorly-connected agent increasing his effort. If instead, the marginal cost of effort increases with the number of connections, say because a 'tax' is imposed on each link, then a well-connected criminal has the incentive to supply less effort than a poorly-connected individual (see the Star in Figure 1.1c). The 'tax' on links leads to a decentralization of crime effort in the network: criminals that are sparsely connected supply more effort than criminals with more links. In my model the penalties play the role of the 'tax'.

The system of first order conditions given by (1.3) yield Nash Equilibrium efforts of the form $e_i^{g*} = e_i(N^g, s^g; \gamma, \mu, f)$ for all $i \in N$ in g. These NE efforts are increasing in the strength of spillover effects (γ), and are decreasing in the law enforcement parameters (μ and f).[5] Stronger spillovers increase the marginal benefit of effort and lead to higher e_i^{g*}. In contrast, tougher fines (f) or better surveillance technology (μ) make criminal effort more costly to exert and lead to smaller e_i^{g*}.

For example, in the Star network in Figure 1.1c players 1 and 3 have only one link, while player 2 has two links ($N_2^S > N_1^S = N_3^S$). Further, agents 1 and 3 are symmetric: each is a step away from player 2 and two steps away from the other. Then the NE efforts of the Star network are $e^*_{center} < e^*_{corner}$ for $corner = 1, 3$. Criminals that are sparsely connected select higher effort levels than well connected criminals.

Proposition 1.1 illustrates the role of asymmetries between spillovers and individual effort costs in shaping optimal effort choices. Links let criminals maximize the benefit of effort spillovers. But having more links increases the chance of getting caught. Less-connected criminals have a lower probability of being captured through links, and derive lower spillover benefits due to indirect connections. Given the strong effect of links on the marginal cost of effort and the large penalties, less-connected criminals supply more effort than their counterparts.

For a fixed level of effort, the direct benefits $(B(e_i, N_i^g))$ from participating in the network are larger for criminals with more links. Similarly, spillovers are

[5]These properties are derived using the assumptions on the cross-partial derivatives and the concavity of Y_i^g on e_i^g, and by totally differentiating the system of first-order conditions (1.3).

greater for well-connected criminals: they tend to have higher s_{ij}'s that make $\sum_{j\neq i, j\in N} K(e_i, e_j, s_{ij}; \gamma)$ large. Meanwhile, the cost of engaging in criminal activity is increasing in both e_i and N_i^g. For a given effort level, having more links increases the probability of getting caught and paying a fine. Given the strong complementarities between e_i^g and N_i^g in $\pi(.)$ and the tough penalties for crime, well-connected criminals will supply less criminal effort than their counterparts in equilibrium.

Large penalties linked to e_i^g and N_i^g drive well-connected criminals to supply little effort, and instead channel spillovers among otherwise distant nodes. Those that exert more effort communicate or have links with few criminals. Thus, better connected nodes are not the most dangerous (in terms of crime effort level).

I now derive the central result: that sparse networks generate the most crime. Sparse networks that (directly or indirectly) connect all criminals with the fewest links yield the highest level of crime. In a sparse network, criminals with few links can exert high effort. Their high effort will feed back to the well-connected criminals through spillovers and will lead them to increase their own effort as well. In contrast, in a densely-connected network all criminals face a high probability of getting caught because of the links and optimally supply low effort.

Proposition 1.2. *Let $\gamma \leq \bar{\gamma}$. Suppose that $B(.)$ and $\pi(.)$ are homogenous of degree one in links. Then sparse networks connecting all agents induce the highest (NE) level of crime: $e^{S*} > e^{C*} > e^{I*}$ where $e^{g*} = \sum_{i\in N} e_i^{g*}$. Further $e^*_{corner} > e^*_{center} > e_i^{C*} \geq e_i^{I*}$.*

Sparser networks motivate criminals to supply more effort than they would in more densely connected networks with the same number of nodes.[6] In diffused networks, criminals at the periphery exert the most effort; this feeds back through spillovers to agents who are densely connected, and induces them to supply high effort. Thus $e^*_{center} > e_i^{C*}$, and consequently, $e^{S*} > e^{C*}$.

The second result of proposition 1.2 ($e_i^{C*} \geq e_i^{I*}$) follows from the homogeneity of $B(.)$ and $\pi(.)$ in links and from the spillover benefits. The homogeneity assumption implies that if criminal i has one link and criminal j has two links, then $B(.)$ and $\pi(.)$ are twice as large for criminal j as for criminal i. In both the single-link and the Complete network, connected criminals are only one step away from each other; thus $s_{ij} = s = 1$ for all connected criminals. Given that all players in the Complete network have identical positions, I can use this symmetry to calculate the effort spillovers for criminal i as $2K(e_i, e_j, s, \gamma)$. Similarly, the spillover benefit of a connected player in the Single-link network is $K(e_i, e_j, s, \gamma)$. Then the payoffs to criminals in the Complete network are an increasing monotonic transformation of the payoffs to connected players in the single-link network. Hence $e_i^{I*} = e_i^{C*}$ for $N_i^I > 0$. The gains from spillovers and private benefits in the complete network relative to the single-link network ($B^C + K^C = 2(B^I + K^I)$) fully offset the higher costs of links ($\pi^C = 2\pi^I$).

If, contrary to the assumptions above, the costs of participating in a crime

[6] This result requires the connected components of both networks to have the same number of nodes. A connected component is a set of nodes that are linked, either directly or indirectly.

network increase in own effort only while the benefits increase both in effort and links, then well-connected criminals would choose to exert the most effort. Consequently, more densely connected networks would turn out to be the most dangerous (i.e. with the highest $e^{g*} = \sum_{i \in N} e_i^{g*}$).

1.4 Decentralized Link Formation

If sparse networks are associated with the most crime, when should we expect these networks to emerge? To answer this question, let us now suppose that pairs of criminals must agree to form links. While two criminals agree to a link, either one can sever it unilaterally. I extend the basic model and specify a two-stage game. Fix (γ, f, μ) and let $\gamma \leq \bar{\gamma}$. First criminals form links.[7] A network emerges and is publicly observed. Then, given the network structure, criminals strategically select levels of criminal effort . I solve the game using 'backward induction.' Given the NE efforts of the second stage of the game, criminal i in network g anticipates in the first stage a payoff equal to $Y_i^g(\mathbf{N}^g, \mathbf{s}^g; \gamma, \mu, f) = Y_i^g(e_i^{g*}, N_i^g; \gamma, \mu, f)$. I look for networks that are pairwise stable. This equilibrium concept is developed by Jackson and Wolinsky [17]. A network is pairwise stable if no pair of unlinked agents agree to a new link and if no agent wants to unilaterally sever a link.

[7] I assume that the cost of forming a link is zero (i.e. $c = 0$). The results do not change significantly if I let $c > 0$.

1.4.1 Pairwise Stability

Start with network g. Suppose that previously unlinked criminals i and j add a link to g. Denote the new structure as $g+ij$. Let $g-ij$ be the resulting network when the existing link g_{ij} is removed (i.e. $g_{ij}=0$.)

A network g is pairwise stable (PWS) if:

(1) $\forall g_{ij}=1,\ \ Y_i^g(\mathbf{N}^g,\mathbf{s}^g;.) \geq Y_i^{g-ij}(\mathbf{N}^{g-ij},\mathbf{s}^{g-ij};.)$ and

$Y_j^g(\mathbf{N}^g,\mathbf{s}^g;.) \geq Y_j^{g-ij}(\mathbf{N}^{g-ij},\mathbf{s}^{g-ij};.)$; and

(2) $\forall g_{ij}=0$, if $Y_i^{g+ij}(\mathbf{N}^{g+ij},\mathbf{s}^{g+ij};.) > Y_i^g(\mathbf{N}^g,\mathbf{s}^g;.)$ then $Y_j^{g+ij}(\mathbf{N}^{g+ij},\mathbf{s}^{g+ij};.) < Y_j^g(\mathbf{N}^g,\mathbf{s}^g;.)$.

The first condition says that no agent wants to sever a link in g. The second condition says that no pair of agents gain by forming a new link. Criminals will form or sever links only if they can earn a larger payoff with the deviation. Pairwise stability allows at most two criminals to coordinate on forming a link. Thus, the link formation process is decentralized. For example, the Star network is PWS if: 1) criminals at the corners optimally do not form a link (i.e. $Y_{corner}(\mathbf{N}^S,\mathbf{s}^S;.) > Y_i^C(\mathbf{N}^C,\mathbf{s}^C;.)$); 2) the player at the center optimally does not sever either of his links ($Y_{center}(\mathbf{N}^S,\mathbf{s}^S;\gamma,\mu,f) > Y_{connected}^I(\mathbf{N}^I,\mathbf{s}^I;.)$); and 3) no corner optimally severs his link ($Y_{corner}(\mathbf{N}^S,\mathbf{s}^S;.) > 0$).

I apply PWS to the link formation game.

Let the fine payment be $\pi(e_i^{g*},N_i^g;\mu,f)=\rho(e_i^{g*},N_i^g;f)+\phi(N_i^g,\mu,f)$. Under this specification criminals get caught either because they exert high criminal effort and thereby increase their visibility to the police ($\rho(e_i^{g*}, N_i^g; f)$), or because they are put under surveillance ($\phi(N_i^g, \mu, f)$). When a criminal supplies high effort, and this effort gets him caught, he pays a fine equal to $\rho(e_i^{g*}, N_i^g; f)$. To illustrate the intuition of this penalty consider the following example: Suppose that the amount of effort an agent puts into committing a crime is an increasing function of the fraction of time he spends on criminal activity. The higher the effort, the more time an agent spends on criminal activity, the more likely the police will observe and capture him (i.e. $\rho(e_i^{g*}, N_i^g; f)$ is increasing in e_i^{g*}). Moreover, for any given effort level, the cost of exerting effort is larger for criminals with more links because they are more visible to the police (i.e. $\rho(e_i^{g*}, N_i^g; f)$ is also increasing in N_i^{g*}). A criminal also can get caught if he is put under surveillance, in which case he pays a fine equal to $\phi(N_i^g, \mu, f)$. We can imagine that the probability of a criminal being put under surveillance is increasing in the number of links he has (i.e. $\phi(N_i^g, \mu, f)$ is increasing in N_i^g). In this situation, the police need not observe a criminal engaging in crime in order to fine him. Links are enough to punish a criminal who is under surveillance. For example, the surveillance could consist of the police tapping into the communications of a criminal. Once the police intercept the communications of a criminal, he is captured and pays a fine accordingly. [8]

[8] A more intuitive specification is $\pi(e_i^g, N_i^g; \mu, f) = \rho(e_i^g)\phi(N_i^g, \mu)f$. Here a criminal is captured only if, conditional on being under surveillance, he is observed in criminal activity. Suppose that the network is put under surveillance with some exogenous probability $\mu \in (0, 1)$. Then the probability that criminal i is put under surveillance is $\phi(N_i^g, \mu) \in (0, 1)$, with $\phi(.)$ increasing in all of its arguments. Let $\rho(e_i^g) \in (0, 1)$ be the probability that the police observe a criminal while committing a crime. Hence a criminal gets caught with probability $\rho(e_i^g)\phi(N_i^g, \mu)$.

For a given network g and its corresponding NE crime efforts, criminal i anticipates a payoff in the first period equal to :

$$
\begin{aligned}
Y_i^g(\mathbf{N}^g, \mathbf{s}^g; \gamma, \mu, f) &= B(e_i^{g*}, N_i^g) + \sum_{j \neq i, j \in N} K(e_i^{g*}, e_j^{g*}, s_{ij}; \gamma) - \pi(e_i^{g*}, N_i^g; \mu, f) \quad (1.5)\\
&= B(e_i^{g*}, N_i^g) + \sum_{j \neq i, j \in N} K(e_i^{g*}, e_j^{g*}, s_{ij}; \gamma) - \quad (1.6)\\
&\quad [\rho(e_i^{g*}, N_i^g; f) + \phi(N_i^g, \mu, f)]
\end{aligned}
$$

When $\pi(e_i^{g*}, N_i^g; \mu, f) = \rho(e_i^{g*}, N_i^g; f) + \phi(N_i^g, \mu, f)$ NE crime efforts in (1.5) are independent of the intensity of law enforcement (μ): $e_i^{g*} = e_i^g(\mathbf{N}^g, \mathbf{s}^g; \gamma, f)$.[9] High μ discourages link formation without affecting effort choices. μ can be interpreted as the ability of law enforcement to tap into the communications of the criminals.

For more precise results, I use a specific functional form. Consider the following payoff function:

$$
Y_i^g = N_i^g e_i^g + \gamma s_{ij} e_i^g e_j^g + \gamma s_{ik} e_i^g e_k^g - \frac{N_i^g}{\bar{N}} \frac{(e_i^g)^2}{2} f \quad - \frac{N_i^g}{\bar{N}} \mu f \quad (1.7)
$$

for $i \neq j \neq k$ and $i, j, k = 1, 2, 3$. $\bar{N} = 6$ is the largest possible number of links in a network with three players. Let $e_i^g \in (0, 1)$. This function is a particular representation of (1.5). The first term ($N_i^g e_i^g$) is the private benefit of own links (N_i^g) and effort (e_i^g). The second and third terms are the benefits from spillovers. The last two terms, $\frac{N_i^g}{\bar{N}} \frac{(e_i^g)^2}{2} f + \frac{N_i^g}{\bar{N}} \mu f$ are the cost of engaging in criminal behavior. Here, the probability of surveillance is independent of the amount of effort a criminal

[9] It turns out that in the specification of the fine payment in the previous footnote NE efforts are functions of both μ and f, which make the analysis of PWS networks less tractable than with the specification in (1.5).

exerts. The higher the effort of a criminal, the more likely he is to get caught. Moreover for a given effort level, criminals with more links are more likely to be captured ($\frac{N_i^g}{N}\frac{(e_i^g)^2}{2}f$ increases with N_i^g and e_i^g). Additionally, criminals with more links are more likely to be put under surveillance and to get caught ($\frac{N_i^g}{N}\mu f$ increases with N_i^g).

With the functional form in (1.7) I can characterize all PWS networks using an algorithm that I construct in Matlab.[10] I find that if the penalties for engaging in criminal activity (μ and f) are large enough to drive the payoffs of all networks with at least one link negative, then the only PWS network is the empty network.

Let the range of fines (f) be such that there are some values of (γ, μ) for which the payoffs in networks with links are non-negative. I now derive the third main result. Sparse networks with a high degree of specialization lead to the highest level of crime and are the hardest to dismantle. They can sustain even very large fines and heavy surveillance. If γ is sufficiently large, then the Star network forms regardless of the level of f and μ.

Proposition 1.3. *Fix the fine f and let $\gamma \leq \bar{\gamma}$.*[11] *If spillovers are sufficiently strong (γ close to $\bar{\gamma}$), then diffused networks can sustain heavy surveillance by the police and large fines. These features make sparse networks hard to disrupt. Diffused networks have the fewest possible number of links and connect (directly or indirectly) all criminals. These networks decrease the probability and the cost of getting caught,*

[10]The Matlab code is available upon request.

[11]I fix $f = 150$.

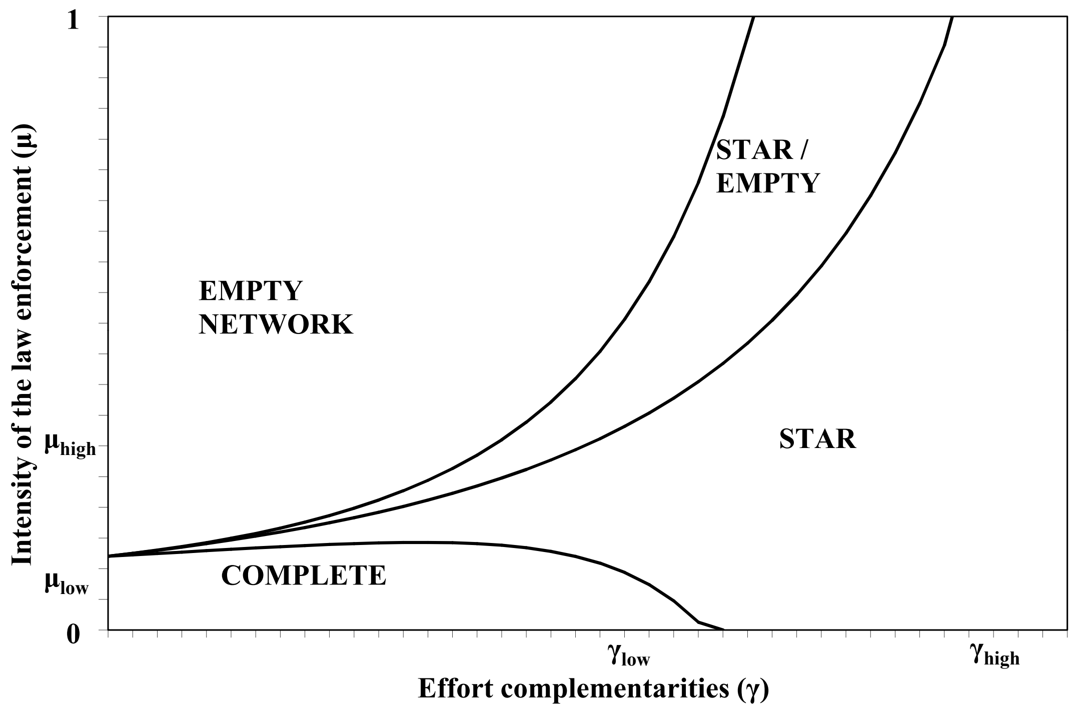

Figure 1.2: PWS networks for a fixed fine $f = 150$

and achieve the highest level of criminal activity.

Under the assumptions of Proposition 1.2 the single-link network is never PWS (Figure 1.2). At least one of the conditions required for PWS is never met.[12] Criminals either prefer to belong to a network with a larger connected component or not to be connected at all. For some combinations of (γ, μ), the Star and the Empty networks are mutually PWS.

Regardless of the level of surveillance (μ) and for some fixed fine f, if effort

[12]The single-link network is PWS if: 1) no connected criminal wants to sever his link ($Y^I_{connected}(\mathbf{N}^I, \mathbf{s}^I; \gamma, \mu) > 0$) and 2) the isolated criminal and a connected one don't agree to a link ($Y^I_{connected}(\mathbf{N}^I, \mathbf{s}^I; \gamma, \mu) > Y_{center}(\mathbf{N}^S, \mathbf{s}^S; \gamma, \mu)$ and $Y_{corner}(\mathbf{N}^S, \mathbf{s}^S; \gamma, \mu) < 0$).

complementarities are strong (i.e. γ close to $\bar{\gamma}$), then criminals form the Star network. When γ is large and close to $\bar{\gamma}$, all criminals have an incentive to connect with the fewest links possible: a high γ leads to large NE crime efforts, and high levels of effort increase the cost of engaging in criminal activity. Anticipating high effort in the second stage, criminals will choose to form a diffused network in the first stage. This choice translates into the highest possible level of crime.

1.4.2 Policy Interventions

How do changes in law enforcement policies affect the network structure and its level of crime?

Using the functional form in (1.7), I fix the strength of the spillovers (γ) and analyze how changes in the intensity of law enforcement (μ) alters the network structure.[13] Let μ^g belong to the set of surveillance probabilities in which network g is PWS. If spillovers are weak, then law enforcement policies targeted towards very densely connected networks lead to more crime.

Set $\gamma = \gamma_{low}$ as in Figure 1.2. For such γ_{low}, the Complete, the Star and the Empty network are all PWS for some range of μ. Law enforcement intensities for which each of these networks is PWS can be ranked as follows: $\mu^C < \mu^S \leq \mu^{empty}$. From Proposition 1.2 $e^{C*} < e^{S*}$ and $e^{S*} > 0$. Thus, for low values of γ,

[13] In the future I would like to look at how varying the fine (f) affects crime. This case is slightly more complicated than that in which f is fixed and μ varies. When f changes it affects not only the network structure but also NE crime efforts.

increases in the surveillance activity can be counterproductive. If the change in the surveillance probability is not large enough to make some criminals drop out, then the resulting network yields more crime. Increases in the penalties for engaging in criminal activity can increase crime. As the complete network becomes sparser, the probability of getting caught through links decreases for some criminals, and overall criminal activity goes up.

1.5 Larger Populations of Criminals

Using the specific functional form of the payoffs in (1.7), I analyze in this section the behavior of large populations of criminals. Now there are $|N|$ criminals for $N = \{1, 2, 3, ...\}$. The largest possible number of links in a network with $|N|$ criminals is $\bar{N} = |N| * (|N| - 1)$. Following (1.7) the payoff to criminal i in network g is:

$$Y_i^g = N_i^g e_i^g + \gamma \sum_{j \neq i, j \in N} s_{ij} e_i^g e_j^g - \frac{N_i^g}{\bar{N}} \frac{(e_i^g)^2}{2} f \quad - \frac{N_i^g}{\bar{N}} \mu f \tag{1.8}$$

To obtain the following results I construct an algorithm for large populations of criminals using Matlab. I solve the game as follows. I start at the second-stage: given a network structure g, I solve for the NE criminal efforts, which maximize (1.8) for all $i \in N$. Then I turn to the first-stage of the game and find the networks that are PWS.

1.5.1 Equilibrium Crime in Large Populations

Within a large network, criminals with fewer links exert more effort than those with more links. Note that $B = N_i^g e_i^g$ and $\pi = \frac{N_i^g}{N} \frac{\left(e_i^g\right)^2}{2} f + \frac{N_i^g}{N} \mu f$ are homogeneous of degree one in links. Then from Proposition 1.2 it follows that the NE crime efforts of a Complete network with $|N|$ criminals are described by e_i^{C*}. And the aggregate crime level of a Complete network is $e^{C*} = |N| \, e_i^{C*}$, which is increasing in $|N|$.

When networks with more than three criminals are considered, there can be several connected components. Intuitively, a *connected component* is a group of nodes that are linked to each other either directly or indirectly. Whether i and j belong to the same connected component can be seen by looking at s_{ij}: if $s_{ij} > 0$ then i and j are in the same connected component. If $s_{ij} = 0$, then i and j are not connected (directly or indirectly).

Networks sparser than the Complete, and such that $\forall i \in N$, $N_i^g > 0$, yield at least the same level of aggregate crime as the Complete network. Suppose there exists some large network g that has at least two connected components. If each of the components is maximally connected, – i.e. if within a component each criminal can reach every other criminal in just one step– then the level of criminal activity of this network is identical to that of a Complete network with the same number of agents. For example, suppose that g' is a Complete network with four criminals. Let g'' be such that it only has two links, $g''_{12} = 1$ and $g''_{34} = 1$. Then the NE crime efforts of g' and g'' coincide.

Fix $|N| > 3$. Suppose that there are two networks g' and g'' and that both networks have a single connected component linking all criminals. Using the algorithm in Matlab for larger populations of criminals, I find that if g' can be obtained by cutting links from g'' and if g' and g'' differ significantly on their link density, then the sparser structure g' leads to more crime.

1.5.2 Pairwise Stable Networks in Large Populations

After calculating the NE efforts for a given network structure, I turn to the first stage and ask which network is likely to emerge. I fix f and let (γ, μ) vary.[14] Using the existence results of Jackson and Watts [16] I know that for any (γ , μ) there exists at least a PWS network or a closed cycle of networks. In the case of three criminals, for any pair (γ , μ) there always exists a PWS network and there are no closed cycles. With larger populations of criminals, I can find combinations of (γ , μ) for which no PWS network exists. The absence of a PWS network for such pairs of (γ , μ) raises the possibility of having cycling networks in these areas of the parameter space.

Consider the following dynamic process of link formation proposed by Jackson and Watts [16]: A set of N criminals form network g. In each period t a pair (i, j) is selected with some positive probability p_{ij} where $\sum_{ij} p_{ij} = 1$. Criminals i and j either can form a link, resulting in network $g' = g + ij$, or each can sever the link $g_{ij} = 1$ so that $g' = g - ij$. In every period, a pair of criminals is randomly

[14] Again, set $f = 150$ and $z = 1$.

selected and decides whether to form a link or to sever an existing link.[15] If a dynamic process that starts from network g leads with strictly positive probability to network g', then an *improving path* exists from g to g'. A *closed cycle* C is a set of networks such that for any $g, g' \in C$ there exists an improving path from g to g' and all networks in the path also belong to C. Networks that are PWS in the static game are always reached in this dynamic process.

Applying the existence results of Jackson and Watts [16] , for any combination (γ, μ) there is at least a PWS network or a closed cycle. We can find ranges of (γ, μ) in which there are closed cycles and/or PWS networks. And in regions for which no network is PWS, criminal activity is going on through cycling networks. For example, let $N = \{1, 2, 3, 4\}$. Start at network g with $g_{12} = g_{13} = 1$ and $g_{i4} = 0$ for $i = 1, 2, 3$. A cycle can exist over some range of (γ, μ) as follows: player 1 severs link g_{13} so that the new network g' has just one link $g'_{12} = 1$. Then criminals 3 and 4 connect and g'' forms with $g''_{12} = 1$ and $g''_{34} = 1$. Next, players 2 and 3 form a link and a line results: $g'''_{12} = g'''_{23} = g'''_{34} = 1$. Finally, players 3 and 4 are selected and player 3 severs the link $g'''_{34} = 1$. This leads back to the original network $g_{12} = g_{13} = 1$. Similar examples can be constructed for larger networks.

[15] This process is myopic because when pairs of agents are deciding on forming or a severing link, they do not take into account future decisions of other agents to alter the resulting network g'.

1.6 Conclusion

In this chapter of the dissertation I construct a network model that captures the strategic interactions among criminals who jointly engage in an illicit activity. This theoretical framework is appropriate for understanding how decentralized crime networks operate and how they react to changes in law enforcement policies.

I specify a static game in which for a given network, criminals select the level of effort to exert. I solve the game for all possible network configurations and compare the levels of crime generated. My first result is that, within a diffused network, sparsely connected criminals are the most dangerous. When I compare crime across networks that differ in their link density, I get my second result: networks that are sparsely connected yield the highest level of crime. From a policy perspective, densely connected networks thus should be preferred to diffused networks.

I then extend the model and allow criminals to form links endogenously. Using a specific functional form, I find that the degree of specialization of a network determines its resiliency to law enforcement policies. My third result suggests that sparse networks with a high degree of specialization, or strong spillovers, are very hard to dismantle. Even large fines and heavy surveillance can be ineffective in altering their structure or their level of crime.

Finally, I derive results for larger populations of criminals. I observe that effort choices within a larger network resemble those of networks with three criminals. Extending the result that sparse networks yield more crime to larger populations of criminals requires comparing networks that differ significantly in their link density.

The model provides intuition on how crime networks operate. In the drug trafficking example, once the kingpins of the Colombian cartels were killed or put behind bars in the early 1990s, new drug-lords started to emerge. In contrast to the kingpins, these new drug-lords chose to maintain a low profile in order to reduce their visibility to law enforcement. They opted to stay small and to collaborate instead with criminal organizations in Mexico and the U.S. During the second half of the 1990s and the beginning of the twenty-first century this partnership was coupled with a steady increase in the total amount of cocaine smuggled into the U.S. Looser and more decentralized structures raised the volume of the cocaine smuggled. The collaboration between criminals is not exclusive to the drug-smuggling business, many illicit activities have led criminals to form decentralized networks (e.g. human smuggling, arms smuggling, and terrorism).

The analysis offered is just a beginning in terms of our understanding of crime networks. Two avenues are worth exploring in the future. The first is letting law enforcement be a strategic player in the game. We could imagine a (repeated) three-stage game proceeding as follows. In the first stage, the police announce the penalties for engaging in criminal behavior and the intensity of law enforcement. Then, criminals form links and the network structure is publicly observed. Finally, in the third-stage, criminals choose effort given a network structure. If the degree of specialization of the network is publicly known, then the police set penalties in the first stage that will lead to the lowest level of crime, and the game will end. If the degree of specialization of the network is not known to the police, then the police and the criminals will interact repeatedly. Through repeated interaction, the police will learn the degree of specialization of the network by observing its structure and its level of crime, and respond by changing the penalties accordingly.

The second avenue to explore relates to the consequences of the strength of effort spillovers within a crime network. I showed that when the effort spillovers are sufficiently strong, sparse networks form and further, they are very hard to dismantle. This result is relevant to the extent that crime networks are highly specialized, so that effort spillovers are strong. To better understand the role of specialization, for example, we could allow for heterogeneity in the value of the links according to the identity (and skills) of each of the criminals. This exercise could guide crime fighting policy.

Chapter 2

Immigration, Assimilation and Ethnic Enclaves

2.1 Introduction

Residential clustering by immigrants, i.e. the formation of ethnic enclaves, is fairly common in the United States: about two thirds of the immigrants that arrived between 1997 and 2006 settled in six States only (California, New York, Florida, Texas, New Jersey and Illinois).[1] This chapter examines the impact that residential location decisions have on economic outcomes of immigrants. I introduce a simultaneous-move game in which immigrants decide whether to settle among natives and assimilate or to cluster and form an ethnic enclave. The results of the model show that the skill mix within the enclave (or the 'quality' of the enclave) shapes the economic outcomes of immigrants. If all immigrants are unskilled and if an equilibrium exists in which the enclave forms, then it is trap or a bad equilibrium. In contrast, if both skilled and unskilled immigrants move to the enclave, I find that the enclave equilibrium is socially preferred to that in which all immigrants assimilate. And regardless of where unskilled immigrants locate, their wages are higher if a positive fraction of skilled co-ethnics settle in the enclave.

Previous literature in immigration suggests that the benefits and costs of liv-

[1] According to the Immigration Statistics of the U.S. Department of Homeland Security. This calculation takes into account legal residents only.

ing in an enclave depend on the quality of the enclave (see for example Borjas [5] and Edin et al. [11]). In this chapter I propose a model with skill heterogeneity among immigrants. In the model skilled immigrants who settle the enclave become entrepreneurs and hire unskilled co-ethnics. This assumption allows me to assess the quality of an enclave in terms both of the availability of jobs and the value of the output produced in it. I make the following additional assumptions: first, there are language complementarities in production (both in the enclave and out of it); second, immigrants that settle among natives are more likely to assimilate than those who live in the enclave; third, immigrants that assimilate earn higher wages in the general labor market (because of stronger language complementarities with natives). Finally, unskilled immigrants who work in the enclave eventually become self-employed, and thus gain upward mobility without assimilation.[2]

I specify a simultaneous-move game in residential location decisions. First, immigrants choose where to live. If some skilled people go to the enclave then a labor market emerges in it; and in that case, immigrants decide whether to work in the enclave or in the general labor market. I solve for the Nash Equilibria of the game. I start by studying residential location decisions of a pool of identical unskilled immigrants. I find, first, if the benefits from assimilation (other than higher wages) are rather small, then unskilled immigrants do not assimilate and earn very low wages. Second, if native employers cannot tell apart unskilled immigrants who assimilate, and if the wages for assimilated unskilled immigrants are not

[2] In the enclave workers receive on-the-job training and informal advice from the entrepreneurs, and eventually start their own businesses.

sufficiently large, then all unskilled immigrants cluster in the enclave, which emerges as a poverty trap.

I then ask whether entrepreneurship in the enclave improves the economic outcomes of unskilled immigrants who settle in it. The model yields the following set of results. First, no enclave exists in which there is excess labor demand. Skilled immigrants move to the enclave only if the supply of labor in it is abundant. One plausible explanation for this outcome is that the value of assimilation is correlated with skill. Second, if the enclave ever forms, then it is socially preferred to the assimilation equilibrium. Once skilled immigrants settle in the enclave, it is no longer a poverty trap. Hence the quality of the enclave matters when studying the economic outcomes of immigrants who cluster. Third, ethnic enclaves and ethnic enterprises improve the economic outcomes not only of immigrants that live in the enclave, but also of those who live out of it. The demand for labor in the enclave soaks up part or all of the unskilled (unassimilated) labor supply, and allows unskilled immigrants that assimilate to earn wages comparable to those of natives in the general labor market. Finally, better quality enclaves allow unskilled immigrants to achieve upward mobility faster.

This study contributes to the literature on immigration. By accounting for the 'quality' of an enclave I am able to explain the wide set of experiences of diverse immigrant groups in the U.S.[3] Empirical studies in the economics of immigration

[3] Sociologists have studied extensively the immigrant enclaves in the U.S. See for example Light and Gold [20] and Portes and Rumbaut [27].

have shown that the quality of an enclave matters. For example Edin et al. [11] examine the economic outcomes of refugee immigrants in Sweden and find that those who live in enclaves with high rates of self-employment have positive returns from living there, while people who settle in enclaves with mostly unskilled individuals experience lower earnings possibly due to clustering itself.[4] Finally Borjas [5] reports that people who settle in the enclaves and do not acquire the social norms and skills of the U.S. (i.e. assimilate), have wages growing at a slower pace than that of the rest of the population.

The rest of the chapter is organized as follows. Section 2.2, describes a simultaneous-move game in which unskilled immigrants choose where to live. I solve for the Nash Equilibria in residential location decisions. In Section 2.3, I incorporate skilled immigrants and introduce a labor market in the enclave. Then I solve for the Nash equilibria and Pareto-rank them. Section 2.4 concludes.

2.2 A Game of Residential Clustering

2.2.1 Setup

Suppose there exists a continuum of unskilled immigrants with unit measure that arrive to a large metropolitan area in the U.S. Each person decides independently and noncooperatively whether to settle in a neighborhood with his co-ethnics or in an area where the majority of the population is native. The location decision

[4] In their study of the Cuban and Haitian enclaves in Miami Portes and Stepick [24] reach a similar conclusion.

determines the likelihood that a person assimilates: I assume that an immigrant is more likely to assimilate if he chooses to live among natives than if he settles with his co-ethnics. The intuition for this assumption is as follows. As in Lazear [19] we could imagine a situation in which individuals can trade only if they speak the same language. Immigrants can assimilate in order to expand their pool of potential trading partners. The incentive to assimilate is stronger for people who live and work among natives than for those who settle with co-ethnics. I also assume that immigrants who acquire the skills and speak the language of the host country earn higher wages in the general labor market. Thus in my model assimilation, or equivalently living among natives, leads to upward economic mobility. In contrast, residential clustering of (unskilled) immigrants hampers this process and can lead to worse economic outcomes; in particular to lower wages (for empirical evidence see Edin, et al. [11] and Borjas [5]).

Define the enclave as the residential neighborhood where unskilled immigrants cluster, and let $0 \leq n_u \leq 1$ represent the fraction of people who settle in the it. Suppose that $\widetilde{w}_{uc}(n_u)$ is the wage earned by an immigrant who lives in the enclave. Let $J(n_u) \in [0, K]$ be the cost of finding a job for an immigrant of the enclave. Assume that individuals within the enclave share information about potential jobs, and that an informal network of job contacts emerges. Further, suppose that the larger the enclave, the 'thicker' the network and the lower the cost to an individual of finding a job: $J'(n_u) < 0$ and $J''(n_u) > 0$ (thus $J(0) = K$ and $J(1) = 0$).[5] I

[5]For empirical evidence on the efficiency of these ethnic networks in channeling job information see Munshi [21] and Waldinger and Lichter ([31], p. 83, 104-105).

assume that immigrants derive utility from sharing common culture. This benefit is captured by the function $h(n_u)$ with $h'(n_u) > 0$ and $h''(n_u) < 0$. The sign of the second derivative suggests some crowding effect as more people move to the enclave. For example, if too many people settle in the enclave, it may be harder to get a spot for the kids in the bilingual school of the neighborhood. Thus the utility of an unskilled immigrant who settles in the enclave equals:

$$U_{uc}(n_u) = \widetilde{w}_{uc}(n_u) - J(n_u) + h(n_u) \tag{2.1}$$

Suppose that an immigrant who goes to a neighborhood where natives are majority assimilates. Let the costs/benefits of assimilation be given by b. $b < 0$ corresponds to the costs of acquiring the host country skills, or learning the language and the social norms of natives. In contrast $b > 0$ represents the benefits of learning the social norms of natives, which for example, might prevent the immigrant from being discriminated against; $b > 0$ could also account for the gains derived from having access to high quality public services (e.g. schools). Suppose that an immigrant who assimilates faces a job finding cost equal to K and receives wage $\widetilde{w}_{us}(n_u)$. Therefore the utility received by an unskilled immigrant who assimilates is:

$$U_{us}(n_u) = \widetilde{w}_{us}(n_u) - K + b \tag{2.2}$$

I assume that the general labor market works as follows. All immigrants, assimilated or not, compete for jobs. There are a large number of firms hiring both immigrants and natives. Suppose that there are language complementarities in production: If a worker speaks English his marginal product is MPh, and if he does not then his marginal product is $MPl < MPh$.[6] If language ability is fully observable, then a worker that speaks English earns $w_{us} = MPh$ and one that does not receives $w_{uc} = MPl$. Suppose that the only characteristic of a worker that is observable to the employers is her ethnicity. Then all employers pay natives $w_{us} = MPh$. However, the employers cannot tell apart those immigrants who assimilate from those who do not. The information available to firms is that a fraction n_u of immigrants lives in the enclave and therefore, do not speak English. They also know that an immigrant who assimilates reveals to his boss that he speaks English with some positive probability $0 < \beta < 1$.[7]

The average productivity and therefore the expected wage of immigrants who do not reveal is:

$$\begin{aligned} \overline{w} &= \Pr\left[low|reveal = 0\right] * MPl + \Pr\left[high|reveal = 0\right] * MPh \\ &= \frac{n_u}{n_u + (1 - n_u)(1 - \beta)} w_{uc} + \frac{(1 - n_u)(1 - \beta)}{n_u + (1 - n_u)(1 - \beta)} w_{us} \\ &= \widetilde{w}_{uc}(n_u) \end{aligned} \tag{2.3}$$

and $\frac{\partial \widetilde{w}_{uc}}{\partial n_u} < 0$, the larger the enclave, the lower the fraction of the workers that are

[6] In their study of the immigrant labor market in the area of Los Angeles, Waldinger and Lichter ([31], p. 69-72) conclude that the job assignment of an immigrant (and consequently the wage) depends on her fluency in the English language.

[7] This setup could be thought of as a reduced form model of statistical discrimination (e.g. Aigner and Cain [1]). All immigrants must take a test that measures imperfectly the likelihood that a person speaks English. While immigrants who do not assimilate fail the exam with probability 1, those who assimilate pass the exam only with probability β.

assimilated among the pool of individuals who do not reveal, the lower the wage for the individual who does not assimilate. An immigrant who assimilates expects to receive wage $\widetilde{w}_{us}$ equal to:

$$\widetilde{w}_{us}(n_u) = \beta w_{us} + (1-\beta)\widetilde{w}_{uc}(n_u) \tag{2.4}$$

for $\widetilde{w}_{uc}(n_u)$ given by equation (2.3). Notice $\frac{\partial \widetilde{w}_{us}}{\partial n_u} = (1-\beta)\frac{\partial \widetilde{w}_{uc}}{\partial n_u} < 0$. For a given β, the larger the enclave, the lower the pooling wage $\widetilde{w}_{uc}(n_u)$, the lower $\widetilde{w}_{us}(n_u)$. Using (2.2) and (2.4) it is straightforward to show that $\frac{\partial U_{us}}{\partial n_u} < 0$. Not always being able to differentiate from the enclave immigrant in the labor market, the individual that assimilates faces a negative externality from the enclave in the labor market, which is larger for higher n_u (enclave size). Because $\widetilde{w}_{us}(n_u) \leq w_{us}$, $\widetilde{w}_{us}(n_u) \geq \widetilde{w}_{uc}(n_u)$ and thus assimilated immigrants receive wages no lower than the wage of a person living in the enclave.

The utility of immigrants who settle in the enclave is larger the higher is n_u:

$$\begin{aligned} \frac{\partial U_{uc}}{\partial n_u} &= \frac{\partial \widetilde{w}_{uc}}{\partial n_u} - J'(n_u) + h'(n_u) > 0 \\ &\therefore \; h'(n_u) - J'(n_u) > \left| \frac{\partial \widetilde{w}_{uc}}{\partial n_u} \right| \end{aligned}$$

In contrast, the utility of someone who assimilates is lower for higher values of n_u: $\frac{\partial U_{us}}{\partial n_u} = \frac{\partial \widetilde{w}_{us}}{\partial n_u} = (1-\beta)\frac{\partial \widetilde{w}_{uc}}{\partial n_u} < 0$. Additionally I assume that $\left|\frac{\partial J}{\partial n_u}\right| < \left|\frac{\partial \widetilde{w}_{uc}}{\partial n_u}\right| < \left|\frac{\partial J}{\partial n_u}\right| + h'(n_u)$.

2.2.2 The Game: Residential Location Choice

I specify a simultaneous-move game. Immigrants decide independently and noncooperatively whether to settle in the enclave or among natives. An enclave n_u^* is a NE if for such n_u^* an immigrant's best response is to settle in the enclave (i.e. $U_{uc}(n_u^*) \geq U_{us}(n_u^*)$). Given that a fraction n_u of immigrants go to the enclave, an individual settles in the enclave if the utility he receives there is larger than the utility he derives from assimilation ($U_{uc}(n_u) \geq U_{us}(n_u)$), otherwise if $U_{us}(n_u) > U_{uc}(n_u)$ his best response is to assimilate.

Suppose that no one goes to the enclave ($n_u = 0$) then the wages of all immigrants are $\widetilde{w}_{us}(0) = \widetilde{w}_{uc}(0) = w_{us}$. If there are no benefits from assimilation other than high wages, i.e. if $b < 0$, then all immigrants strictly prefer to settle in the enclave ($U_{us}(0) < U_{uc}(0)$); and in that case living out of the enclave is never a Nash Equilibrium. When $n_u = 0$ and $b < 0$ an immigrant has the incentive to unilaterally deviate and settle in the enclave. In doing so he free rides on the high wages received by his co-ethnics and forgoes the assimilation cost b. In contrast if assimilation translates not only into higher wages but also into being (socially) less discriminated against ($b > 0$), then no enclave forming can be a NE: for $n_u = 0$ if $b > 0$ it is a Best Response to assimilate (and thus $n_u^* = 0$). The following propositions formalize the results.

Proposition 2.1. *If $b < 0$ then the unique NE is the enclave forming ($n_u^* = 1$).*

Proof. All proofs are in the appendix. □

Immigrant groups that are likely to be discriminated against, or for whom $b < 0$, do not to assimilate, and instead cluster in an ethnic neighborhood at the expense of earning low wages. As an example consider the Haitian refugees that arrived to Miami in 1980. They were black and unskilled and chose to cluster in an ethnic neighborhood. They faced racial discrimination, and ultimately remained unemployed or held jobs at very low wages (Portes and Stepick [24]).

Proposition 2.2. *Let $h(1) > b - K$. If $b > 0$ and $w_{us} - w_{uc} \geq \frac{h(1)-b+K}{\beta}$ then the unique Nash equilibrium is everyone assimilating ($n_u^* = 0$).*

Suppose everyone is going to the enclave and $n_u = 1$. When all immigrants go to the enclave if the wage differential net of search costs $(\widetilde{w}_{us}(1) - \widetilde{w}_{uc}(1) - K)$ is sufficiently large to offset the relative benefits of sharing common culture (i.e. $h(1) - b$), then it is individually optimal to assimilate. This incentive is stronger when assimilated workers are more likely to reveal as such (i.e. when β high). Larger β leads to higher wages for assimilated people ($\widetilde{w}_{us}$) and lower for those who live in the enclave ($\widetilde{w}_{uc}$). If at $n_u = 1$ the opposite happens, i.e. if the wage differential is no larger than the relative benefits of sharing common culture, then both the enclave forming and everyone assimilating are NE of the game.

Proposition 2.3. *Let $h(1) > b - K$. If $b > 0$ and $w_{us} - w_{uc} < \frac{h(1)-b+K}{\beta}$ then multiple equilibria exist:*

i. no enclave forming is a NE, $n_u^* = 0$;

ii. the enclave forming is a NE, $n_u^* = 1$, and

iii. the enclave forming with $n_u^* \in (0,1)$ is a NE.

When the wage differential is no larger than the (highest) net benefits of culture $(h(1) - b)$ then multiple equilibria emerge: If no one goes to the enclave, then an individual prefers not to go to the enclave. In contrast, when she expects all others to go to the enclave, then her best response is to settle in the enclave. And there is an $n_u \in (0, 1)$ where the person is indifferent between settling in the enclave or out of it. For such n_u the wage differential is identical to the cultural gains in the enclave. For given $(w_{us}, w_{uc}, h(1), b, K)$ higher β make it more likely for a group to assimilate.

According to the model then the existence of ethnic enclaves of unskilled people (e.g. Mexicans) in the U.S. is partly driven by the inability of the employers to tell apart the assimilated immigrants. Lower β decreases the wages of assimilated immigrants and makes assimilation less attractive.[8] Under what conditions is assimilation socially preferred to clustering? The next proposition addresses this question.

Proposition 2.4. *Suppose that the conditions in proposition 2.3 are satisfied. If* $h(1) - b + K < w_{us} - w_{uc} < \frac{h(1)-b+K}{\beta}$ *then the enclave equilibrium is a 'trap'. The equilibrium in which all immigrants spread-out Pareto-dominates the enclave*

[8] One possible solution to β being low is for the employers to hire a bilingual supervisor at a low cost. Although not modeled directly, we could imagine that the interaction with the bilingual supervisor raises the marginal productivity of all enclave workers. Indeed there is empirical evidence of sweatshops in the area of Los Angeles, where bilingual supervisors are hired to interact with Latino workers in order to improve their productivity through more effective communication (Waldinger and Lichter [31] p. 69).

equilibrium. If $w_{us} - w_{uc} < h(1) - b + K$, then the enclave equilibrium Pareto-dominates the assimilation equilibrium.

If assimilation translates into sufficiently high wages, then the enclave equilibrium is a trap. In contrast if the wage premium from assimilation is not too large relative to the cultural benefits of the enclave, then the assimilation equilibrium is the 'bad' equilibrium. Thus if the wage gap is in an intermediate range, immigrants are socially better off assimilating. However, this equilibrium may fail to be achieved if there is a lack of coordination among immigrants.[9] For given assimilation benefit (b) and job finding cost (K), when all immigrants assimilate, the gains from assimilation are the largest possible because everyone earns the same wage as natives (w_{us}); in contrast, when all individuals go to the enclave wages are very low (w_{uc}), but the benefits from common culture are the largest possible ($U_{uc}(1) = w_{uc} + h(1)$).

From the conditions in propositions (2.2) to (2.4), if employers can readily assess assimilation (i.e. β is close to 1) and can reward it properly (i.e. if $w_{us} - w_{uc}$ is sufficiently large) then immigrants will assimilate: the region of $w_{us} - w_{uc}$ for which multiple equilibria exist shrinks as β goes to 1, and the assimilation equilibrium is more likely to emerge as the unique equilibrium. If the government could observe better the ability of immigrants to 'speak' English relative to the employers, for example because it gives a more comprehensive set of exams, then

[9] In the next section I introduce skill heterogeneity among immigrants and show that having a labor market in the enclave improves the outcomes of unskilled immigrants, and furthermore, that the enclave equilibrium is always the socially preferred equilibrium.

residential clustering would be less likely to occur.

2.3 A Game with Residential and Entrepreneurial Clustering

In this section I allow for skill heterogeneity in the immigrant pool. Specifically I consider two types of immigrants: skilled (h) and unskilled (u). Let n_h denote the fraction of immigrants who move to the enclave in equilibrium. The presence of skilled immigrants in the enclave increases the benefits of clustering for the unskilled co-ethnics in two basic ways: first, skilled immigrants who settle in the enclave become entrepreneurs and create a demand for unskilled labor. Workers filling in these jobs receive training and financial advice from their employers and eventually move on to start their own businesses.[10] Thus jobs in the enclave give unskilled immigrants the opportunity to gain upward mobility without assimilation. Second, skilled agents start up immigrant-oriented businesses including legal advice, credit unions or healthcare services that further raise the benefit of living in the enclave $\left(h\left(n_u, n_h\right) > 0, \frac{\partial h}{\partial n_h} > 0, \frac{\partial^2 h}{\partial n_h \partial n_u} > 0\right)$. These assumptions are based on studies by sociologists on ethnic enclaves (e.g. Light and Gold [20]).

2.3.1 Setup

For $d < 1$ let $n_h \in [0, d]$ be the fraction of skilled individuals who locate in the enclave. The assumptions on the unskilled population are the same as those of the previous section. I describe an enclave with a vector (n_u, n_h). Immigrants

[10]There is extensive evidence on self-employment in immigrant communities (e.g. Koreans and Cubans), see Light and Gold [20].

can either live in the enclave (c) or out of it (s). Once they make their residential choice (c or s), they decide where to work: each immigrant can work in the enclave or in the general labor market (c or s). The place where an immigrant chooses to live affects his labor market outcomes.

I specify a game as follows: first immigrants decide independently and non-cooperatively where to settle; and then they decide where to work. Once location choices have been made an enclave labor market emerges.

The production technology in the enclave is as follows. If an entrepreneur hires an unskilled worker they produce two units of output ($q\,(unskilled, skilled) = 2$), which yield some revenue $2y > 0$. If the entrepreneur decides to be self-employed, then he produces one unit of output ($q\,(skilled) = 1$) for which he receives y. And the unskilled person by herself produces no output $q\,(unskilled) = 0$. Hence the production technology in the enclave is described by:

$$q\,(unskilled, skilled) = 2$$

$$q\,(skilled) = 1$$

$$q\,(unskilled) = 0$$

Let w_x denote the clearing wage in the enclave labor market. I assume that the cost of finding a job in the enclave is zero, because the ethnic network channels information on these jobs more effectively than it does on jobs out of the enclave. Language complementarities between an entrepreneur and a co-ethnic worker allow for upward mobility without assimilation: workers initially earn w_x, and after a fraction d of time, they become self-employed and earn income $y \geq w_x$. Given that an unskilled person spends a fraction of time $d < 1$ with the entrepreneur, the entrepreneur requires of $1/d$ unskilled individuals to produce 2 units of output (and thus $n_h \in [0, d]$).

The enclave wage w_x follows a reduced-form bargaining model. Define $\theta = \frac{dn_u}{n_h}$ as the ratio of labor supply and demand within the enclave. If there is excess labor supply in the enclave ($\theta > 1$) entrepreneurs have more bargaining power and pay workers a wage equal their outside option, which is the wage they would receive in the general labor market net of the job finding cost. Hence for $dn_u > n_h$, $\theta > 1$ the enclave wage is $w_x = \widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h)$. When there is no excess labor demand or supply ($dn_u = n_h,\ \theta = 1$) parties have equal bargaining power and the wage equals the wage an immigrant would receive in the general labor market ($w_x = w_{us} - K$). If there is excess labor demand workers have more bargaining power and get half of the production surplus $w_x = y$. Summarizing,

$$\begin{aligned} & = y & \text{if } dn_u < n_h \quad & (2.5a) \\ w_x & = w_{us} - K & \text{if } dn_u = n_h \quad & (2.5b) \\ & = \widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h) & \text{if } dn_u > n_h \quad & (2.5c) \end{aligned}$$

Let $b > 0$. When there is no excess labor supply or demand ($\theta = 1$) unskilled immigrants who locate in the enclave always find jobs in it. They receive wage $w_x = w_{us} - K$. Let $U_{uc}(n_u, n_h)$ represent the utility received by an unskilled individual who lives and works in the enclave. This utility is equal to:

$$U_{uc}(n_u, n_h) = d(w_{us} - K) + (1 - d)y + h(n_u, n_h)$$

For any $0 \leq n_u, n_h \leq 1$ the utility received by an unskilled individual who lives and works in the enclave must be no larger than that of a self-employed immigrant $U_{self}(n_u, n_h)$ where

$$U_{self}(n_u, n_h) = y + h(n_u, n_h)$$

and thus $y \geq w_{us} - K$. An immigrant who settles in the enclave and works in the general labor market earns utility:

$$U_{uc,out}(n_u, n_h) = w_{us} - K + h(n_u, n_h)$$

and all immigrants who settle in the enclave prefer to work in it so that $U_{uc}(.) \geq U_{uc,out}(.)$. If only one immigrant chooses to work out of the enclave then he receives wage $\widetilde{w}_{uc}(0) = w_{us}$. If the immigrant assimilates and works in the general labor market, he derives utility:

$$U_{us}(n_u, n_h) = w_{us} + b - K$$

where $w_{us} = \widetilde{w}_{us}(0)$. Finally if the assimilated immigrant works in the enclave he receives utility equal to:

$$U_{us,in} = d(w_{us} - K) + (1 - d)y + b - K$$

When there is excess labor demand ($\theta < 1$) all unskilled immigrants find jobs in the enclave and $w_x = y$. Then the utilities derived from each option become:

$$\begin{aligned} U_{uc}(n_u, n_h) &= y + h(n_u, n_h) \\ U_{uc,out}(n_u, n_h) &= w_{us} - K + h(n_u, n_h) \\ U_{us}(n_u, n_h) &= w_{us} + b - K \\ U_{us,in}(n_u, n_h) &= y + b - K \end{aligned}$$

When there is excess labor supply ($\theta > 1$) unskilled immigrants who settle in the enclave find jobs in it only with probability $0 < \frac{1}{\theta} < 1$. A fraction $n_u - \frac{n_h}{d}$ of unskilled persons search for jobs in the general labor market. Thus:

$$\begin{aligned}
U_{uc}(n_u, n_h) &= \frac{1}{\theta}[dw_x + (1-d)y] + \frac{\theta - 1}{\theta}[\widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h)] + h(n_u, n_h) \\
U_{uc,out}(n_u, n_h) &= \widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h) + h(n_u, n_h) \\
U_{us}(n_u, n_h) &= \widetilde{w}_{us}(n_u, n_h) + b - K \\
U_{us,in}(n_u, n_h) &= \frac{1}{\theta}[dw_x + (1-d)y] + \frac{\theta - 1}{\theta}\widetilde{w}_{us}(n_u, n_h) + b - K
\end{aligned}$$

A skilled immigrant can live in the enclave and become an entrepreneur, live in the enclave or work out of it, live out of the enclave and work in the general labor market or live out and work in the enclave. When labor demand equals labor supply ($\theta = 1$), all entrepreneurs hire workers and pay wage $w_x = w_{us} - K$. Given such (n_u, n_h) an entrepreneur earns utility U_{hc} equal to:

$$U_{hc}(n_u, n_h) = 2y - (w_{us} - K) + h(n_u, n_h)$$

If the skilled individual decides to assimilate, then he earns utility:

$$U_{hs}(n_u, n_h) = U_{hs} = w_h + b_h - Z$$

here $b_h > 0$ is the benefit of assimilation and $Z > 0$ is the cost of finding a job in the general labor market. Let $U_{hs}(n_u, n_h) > U_{us}(n_u, n_h)$ so that skilled immigrants gain more from assimilating relative to unskilled individuals. This assumption suggests that the monetary and non-monetary benefits from assimilation are larger for a doctor (skilled) than for a janitor (unskilled person). If the skilled individual lives in the enclave and decides to work out of it he receives utility:

$$\begin{aligned} U_{hc,out} &= w_{us} - K + h\left(n_u, n_h\right) \\ &= U_{uc,out} \end{aligned}$$

Without assimilation, the skilled immigrant competes with unskilled co-ethnics in the general labor market. Finally if the immigrant assimilates and decides to become an entrepreneur in the enclave, he receives utility:

$$U_{hs,in}\left(n_u, n_h\right) = 2y - \left(w_{us} - K\right) + b_h - Z$$

When there is excess labor demand ($\theta < 1$) an entrepreneur is matched to an unskilled worker with probability θ and pays him wage $w_x = y$. For $\theta < 1$ the utilities become:

$$\begin{aligned} U_{hc}\left(n_u, n_h\right) &= y + h\left(n_u, n_h\right) \\ U_{hs}\left(n_u, n_h\right) &= U_{hs} = w_h + b_h - Z \\ U_{hc,out} &= w_{us} - K + h\left(n_u, n_h\right) \\ U_{hs,in}\left(n_u, n_h\right) &= y + b_h - Z \end{aligned}$$

If there is excess labor supply in the enclave ($\theta > 1$) all entrepreneurs are guaranteed to get workers. In that case the enclave wage is $w_x = \widetilde{w}_{uc}\left(n_u, n_h\right) - J\left(n_u, n_h\right)$ for $\widetilde{w}_{uc}\left(n_u, n_h\right) - J\left(n_u, n_h\right) \leq y$. When there is excess labor supply the alternatives available to a skilled immigrant yield utilities equal to:

$$
\begin{aligned}
U_{hc}(n_u, n_h) &= 2y - [\widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h)] + h(n_u, n_h) \\
U_{hs}(n_u, n_h) &= U_{hs} = w_h + b_h - Z \\
U_{hc,out} &= \widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h) + h(n_u, n_h) \\
U_{hs,in}(n_u, n_h) &= 2y - [\widetilde{w}_{uc}(n_u, n_h) - J(n_u, n_h)] + b_h - Z
\end{aligned}
$$

2.3.2 The Game: Residential and Workplace Decisions

I now solve for the Nash Equilibria of the game. For $i = u, h$ and given (n_u, n_h) an immigrant decides to live and work in the enclave only if:

$$
\begin{aligned}
U_{ic}(n_u, n_h) &\geq U_{is}(n_u, n_h) \text{ for } i = u, h \\
&\geq U_{ic,out}(n_u, n_h) \\
&\geq U_{is,in}(n_u, n_h)
\end{aligned}
$$

The full enclave $(1, d)$ is a NE if for such $(1, d)$ an immigrant's best response is to settle and work in the enclave. Similarly, full assimilation $(0, 0)$ is a NE if given $(0, 0)$ an immigrant's best response is to assimilate and work in the general economy. Denote a NE enclave by (n_u^*, n_h^*). An enclave $(0, 0) < (n_u^*, n_h^*) < (1, d)$ is an interior NE if first, for such (n_u^*, n_h^*) all immigrants are indifferent between settling and working in the enclave or living and working out of it; and second, all immigrants (weakly) prefer either option to living and working in different areas. Define $0 \leq n_{ucrit}, n_{hcrit} \leq 1$ such that an immigrant is indifferent between locating in the enclave or out of it, i.e. for $i = u, h$ $U_{ic}(n_{ucrit}, n_{hcrit}) = U_{is}(n_{ucrit}, n_{hcrit})$.

The first result of the model is that there exist NE with no excess labor supply or demand in the enclave, i.e. $0 \leq n_u^* = \frac{n_h^*}{d} \leq 1$. These equilibria emerge when the wage skilled immigrants receive out of the enclave (w_h) is large, and when the cultural benefits of the enclave are smaller than the non-monetary gains from assimilation for unskilled immigrants (i.e. when $b \geq h(n_u, n_h)$).

NE with no excess labor supply or demand emerge if the workers in the enclave get upward mobility at a speed equal to $\widehat{d} = \frac{U_{hs} - U_{us} - (y - w_{us} + K)}{y - w_{us} + K}$, where $U_{us} = w_{us} + b - K$. If it takes longer for an individual to gain upward mobility in the enclave, i.e. if $d > \widehat{d}$, then the person prefers to assimilate and the enclave is no longer an equilibrium. An unskilled immigrant gets upward mobility faster (i.e. $\widehat{d}$ is smaller) when the entrepreneur is able to extract more rents from the him (i.e. when $y - w_{us} + K$ is large) and when the utility he receives if he assimilates is large (U_{us}). Therefore, holding all other variables fixed, an increase in the value of output (y), for example due to improvements in the production technology, increases the rents received by the entrepreneurs and allows unskilled immigrants to become self-employed faster ($\widehat{d}$ decreases). Finally, if a skilled immigrant assimilates, he receives utility U_{hs}. And the higher this utility is, the larger the share of the worker's surplus that he as an entrepreneur must receive in order for him to locate in the enclave (i.e. $\widehat{d}$ is increasing in U_{hs}). The following proposition formalizes these results.

Proposition 2.5. *For $b > 0$ let $w_{us} - K \leq y$, $w_h \geq 2y - w_{us} + K$ and $b_h \geq Z$. If $U_{hs} > y + b$ and*

$$d = \frac{U_{hs} - y - b}{y - w_{us} + K}$$

then i. no enclave forming is an equilibrium ($n_u^* = n_h^* = 0$)*;*

ii. The enclave forming is an equilibrium ($n_u^* = 1, n_h^* = d$)*;*

iii. An interior equilibrium exists with $0 < n_h^* = dn_u^* < d$*; and*

iv. The enclave is Pareto-superior to the assimilation equilibrium.

Allowing for skill heterogeneity in the pool of immigrants leads to an improvement in the economic outcomes of unskilled immigrants who live in the enclave in comparison to a situation in which the all immigrants are unskilled. In the enclave with skilled immigrants, unskilled individuals can get upward mobility without assimilation. Consequently in this setup the enclave is no longer a trap or a 'bad' equilibrium, regardless of skill all immigrants are better off moving to the enclave. Although the wage in the enclave ($w_x = w_{us} - K$) is lower than that of the general labor market ($\widetilde{w}_{uc}(0) = w_{us}$), unskilled immigrants are better off settling in the enclave because they still get upward mobility and additionally, they derive benefit from sharing common culture. At the same time, having entrepreneurs in the enclave reduces its negative externality on the wages of assimilated unskilled individuals; in fact for $n_h^* = dn_u^*$ the negative externality completely disappears and $\widetilde{w}_{us}(n_u) = w_{us}$.

The second result of the model is that there exists an interior NE with excess labor supply in the enclave, i.e. $0 < \frac{n_h^*}{d} < n_u^* < 1$. For such an equilibrium $\theta(n_u^*, n_h^*) = \frac{(1-d)[y-\widetilde{w}_{uc}(.)+J(.)]-J(.)}{2[y-\widetilde{w}_{uc}(.)+J(.)]-U_{hs}+\widetilde{w}_{us}(.)+b-K-J(.)}$. This θ emerges if the wage of a skilled and assimilated immigrant (w_h) is sufficiently large, if the value of the enclave output y is high and if unskilled immigrants spend a relatively large fraction of time in the job (i.e. if d is high). Thus enclaves with excess labor supply may fail to form if the value of the output produced in them is too low. When that occurs, workers need stay even longer with an entrepreneur (d has to be very large) so that the skilled person's utility from living and working in the enclave is large enough to discourage him from assimilating. Furthermore when d is too large unskilled individuals could choose not to settle in the enclave. If the rents extracted by the entrepreneur are large, then more skilled immigrants will have the incentive to settle in the enclave and the equilibrium excess labor supply will be smaller (i.e. θ is decreasing in $(y - \widetilde{w}_{uc}(.) + J(.))$). Finally, as the utility received by an assimilated skilled immigrant gets larger, the excess labor supply in the enclave increases. The next proposition summarizes these results.

Proposition 2.6. *For $b > 0$ let $w_{us} - K < y$, $w_h >> y$ and*

$$h(1, d) \geq \max\{b - (1-d)(y - w_{us} + K); U_{hs} - 2y + w_{us} - K\}$$

then i. no enclave forming is an equilibrium ($n_u^* = n_h^* = 0$);

ii. The enclave forming is an equilibrium ($n_u^* = 1, n_h^* = d$);

iii. An interior equilibrium exists with $0 < n_h^* < dn_u^* < d$ only if $\widetilde{w}_{us}(n_u^*, n_h^*) \leq y$, $w_h \geq 2y - \widetilde{w}_{uc}(.) + J(.)$; $d \geq \frac{y - \widetilde{w}_{us}(.)}{y - \widetilde{w}_{uc}(.) + J(.)}$ and

$$\theta(n_u^*, n_h^*) = \frac{(1-d)[y - \widetilde{w}_{uc}(.)] - dJ(.)}{2[y - \widetilde{w}_{uc}(.)] - U_{hs} + \widetilde{w}_{us}(.) + b - K - J(.)}$$

iv. The enclave is Pareto-superior to the assimilation equilibrium.

The presence of immigrant entrepreneurs in the enclave improves the economic outcomes of all unskilled co-ethnics. The quality of the enclave affects the economic outcomes of all immigrants. Even unskilled persons that assimilate benefit from the presence of the entrepreneurs because fewer co-ethnics who live in the enclave end up working in the general labor market. For a given probability of a worker revealing as assimilated (β), the fewer enclave people working in the general labor market, the higher the average marginal productivity of workers who do not reveal, the higher the wages for all immigrants in the general market.

The benefits of the enclaves with entrepreneurs are apparent: Portes and Stepick [24] compare black Cubans and Haitians who arrived to Miami in 1980 and find that the Cubans were able to find jobs in the Cuban enclave, and even comparable jobs in the general economy. In contrast the Haitians, who did not have an ethnic economy, experienced high rates of unemployment and operated mostly in the informal economy. An extreme case of proposition 2.6 is an equilibrium given by $n_u^* = 1$ and $n_h^* = 0$, in which sorting by skill occurs. All unskilled immigrants cluster, while the skilled ones assimilate. This type of equilibrium is consistent with the recent wave of Chinese migration into the U.S.: highly skilled and educated individuals assimilate, while very low skilled people tend to cluster (Karas [18]).

Finally no equilibrium exists in which there is excess labor demand in the enclave. If there were excess labor demand, then the wage would be $w_x = y$ and skilled and unskilled immigrants in the enclave would all earn the same (self-employment) utility: $U_{uc}(.) = U_{hc}(.) = U_{self}(.) = y + h(n_u, n_h)$. For an enclave with excess labor demand ($dn_u < n_h$) to be an equilibrium we require $U_{us}(.) =$

$U_{uc}(.) = U_{hc}(.) = U_{hs}$. But this equality can never hold because by assumption $U_{us}(.) < U_{hs}$. Skilled immigrants do not cluster by themselves. They find enclaves attractive because they can hire co-ethnics fairly easily. The ethnic network that emerges in the enclave seems to be a stronger magnet for unskilled people than for skilled persons (Portes and Rumbaut [27]). For example, Filipino immigrants who are highly skilled (typically doctors) have never formed ethnic enclaves (Karas [18]). One possible explanation for why enclaves with excess labor demand never form is that language complementarities in the general labor market are stronger for skilled people than for unskilled persons. Hence skilled people are more likely to assimilate relative to unskilled individuals. In fact, Lang et al. [3] find that among Russian immigrants in Israel, the value of learning Hebrew is large for skilled individuals and close to zero for unskilled people.

2.4 Conclusion

In this chapter I construct a model to study the effect that residential location choices have on the economic outcomes of immigrants. It is a game in which immigrants decide simultaneously and independently where to settle. I start by analyzing the strategic decisions of an homogeneous group of unskilled immigrants. When the benefits of assimilation come only through higher wages, immigrants decide to settle in an enclave. In order for immigrants to be willing to assimilate, they must perceive some positive non-monetary benefit from assimilation (such as less discrimination in their social endeavor). When there are monetary and non-monetary benefits from assimilation, and when employers in the general labor market are unlikely to screen out the assimilated immigrants, then multiple equilibria emerge. And in such case, it is very likely that the enclave equilibrium is a poverty trap. Immigrants may end up forming the enclave because of a lack of coordination in their decisions, although they could all be better off if they assimilated.

I then modify the game so that both skilled and unskilled immigrants decide where to settle. I assume that skilled immigrants who settle in the enclave become entrepreneurs and have a positive demand for unskilled labor. Thus adding skilled immigrants to the model, opens the possibility for a labor market within the enclave. I show that enclaves that emerge in equilibrium never have excess labor demand. Skilled people have a stronger incentive to assimilate than unskilled individuals. If the enclave emerges in equilibrium, the speed of upward mobility of unskilled immigrants is increasing in the value of the output produced in the enclave. Furthermore, if the value of the output produced in the enclave is too small, then the enclave may fail to form. For prevailing wages in the general economy, enclave entrepreneurs have the incentive to produce output that has more technology embedded because they can then extract larger rents from the workers. Finally the results of the model suggest that when immigrants with a mix of skills settle in the enclave, the enclave equilibrium is the socially-preferred outcome. When skilled immigrants locate in the enclave, the quality of the enclave improves and it is no longer a trap (all individuals are better-off clustering).

Throughout the analysis I assume that immigrants make decisions independently. Although in the model an individual takes into account the social gains of clustering when making his decision, this approach may conflict with the empirical evidence, which shows that the decision of one individual to migrate is conditioned on the decisions of others in his social network (e.g. Portes and Rumbaut [27] and Munshi [21]). One way to reconcile my approach with the evidence is to partition the fraction of immigrants who settle in the enclave in smaller communities. Coordination among members of a community could lead them to get out of the enclave trap whenever it is likely to emerge. As the community gets larger, coordination becomes harder, and in that case the results of my model would remain unchanged.

Two policy recommendations emerge from this analysis. The first is that if the pool of immigrants is uniformly unskilled, then the government can help native employers in screening out unskilled immigrants who assimilate. For example the government could provide immigrants with English lessons and then give a comprehensive examinations which would be required for employment. The second recommendation is that the government could extend credits to immigrant entrepreneurs, who could improve the technology of their production, allow unskilled co-ethnics to achieve upward mobility sooner, and also lessen the negative externality that the enclave imposes on the wages of assimilated unskilled immigrants. And better technologies available to the enclave entrepreneurs guarantee that the enclave forms, which prevents the unskilled people from clustering by themselves and earning very low wages in the general labor market.

Chapter A

Proofs of Propositions of Chapter 1

Proof of proposition 1.1. The Nash equilibrium in efforts of the second stage is unique only if:

$$\left| \frac{\partial^2 B}{\partial (e_i)^2} + \sum_{j \neq i, j \in N} \frac{\partial^2 K}{\partial (e_i)^2} - \frac{\partial^2 \pi}{\partial (e_i)^2} \right| > \sum_{j \neq i,\ j \in CC_i} \frac{\partial^2 K}{\partial e_i \partial e_j} \text{ for all } i \in N \tag{A.1}$$

In this game I consider Star networks ($g^S = \{12, 23\}$) with symmetric Nash equilibria in which $e_1^* = e_3^*$. The profile of NE efforts in these networks is represented by $\mathbf{e}^* = (e_1^*, e_2^*, e_1^*)$. All the analysis that follows looks at two players only, assuming that players 1 and 3 behave identically.

Rewriting condition A.1 for two players and rearranging terms yields:

$$\frac{\frac{\partial^2 K}{\partial e_i \partial e_j}}{\left| \frac{\partial^2 B}{\partial (e_i)^2} + \frac{\partial^2 K}{\partial (e_i)^2} - \frac{\partial^2 \pi}{\partial (e_i)^2} \right|} = \frac{\partial e_i}{\partial e_j} < 1 \text{ for } i \neq j,\ i, j \tag{A.2}$$

The condition A.2 has two implications: first, because efforts are strategic complements then any BR_i is increasing in e_j if $s_{ij} > 0$. Second, the absolute value of the slope of the reaction function of any player is less than one.

Under the assumptions made on the payoff functions the uniqueness condition A.1 is always satisfied. Let $g^S = \{12, 23\}$. I will show that the profile of efforts $\left(e_1^S, e_2^S, e_3^S\right) = (\hat{e}_1, \hat{e}_1, \hat{e}_1)$ is not a NE and furthermore that at the NE $e^*_{corner} > e^*_{center}$. Suppose that $(\hat{e}_1, \hat{e}_1, \hat{e}_1)$ is the NE. The payoff to player 1 (corner) in the Star network is:

$$Y_1^S = B(e_1; N_1^S) + K(e_1, e_2, s_{12}; \gamma) + K(e_1, e_3, s_{13}; \gamma) - \pi(e_1, N_1^S; \mu, f)$$

where $s_{13} = \frac{1}{2}s_{12}$. Taking the first order condition and using the symmetry between players 1 and 3 yields:

$$\frac{\partial Y_1^S}{\partial e_1} \mid_{\substack{e_1=\hat{e}_1 \\ e_2=e_3=\hat{e}_1}} = \frac{\partial B(\hat{e}_1; N_1^S)}{\partial \hat{e}_1} + \frac{\partial K(\hat{e}_1, \hat{e}_1, s_{12}; \gamma)}{\partial \hat{e}_1} + \frac{\partial K(\hat{e}_1, \hat{e}_1, \frac{1}{2}s_{12}; \gamma)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1, N_1^S; \mu, f)}{\partial \hat{e}_1} = 0$$

or equivalently,

$$\frac{\partial K(\hat{e}_1, \hat{e}_1, \gamma, s_{12})}{\partial \hat{e}_1} = \frac{\partial \pi(\hat{e}_1, N_1^S; \mu, f)}{\partial \hat{e}_1} - \frac{\partial B(\hat{e}_1; N_1^S)}{\partial \hat{e}_1} - \frac{\partial K(\hat{e}_1, \hat{e}_1, \frac{1}{2}s_{12}; \gamma)}{\partial \hat{e}_1} \tag{A.3}$$

The payoff to player 2 is:

$$Y_2^S = B(e_2; N_2^S) + K(e_2, e_1, s_{12}; \gamma) + K(e_2, e_3, s_{12}; \gamma) - \partial\pi(e_2, N_2^S; \mu, f)$$

and the best reply function is given by:

$$\frac{\partial Y_2^S}{\partial e_2} \mid_{\substack{e_2=\hat{e}_1 \\ e_1=e_3=\hat{e}_1}} = \frac{\partial B(\hat{e}_1; N_2^S)}{\partial \hat{e}_1} + \frac{\partial K(\hat{e}_1, \hat{e}_1, s_{12}; \gamma)}{\partial \hat{e}_1} + \frac{\partial K(\hat{e}_1, \hat{e}_1, s_{12}; \gamma)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1, N_2^S; \mu, f)}{\partial \hat{e}_1} \tag{A.4}$$

$$= \left[\frac{\partial B(\hat{e}_1; N_2^S)}{\partial \hat{e}_1} - \frac{\partial B(\hat{e}_1; N_1^S)}{\partial \hat{e}_1}\right] + \left[\frac{\partial K(\hat{e}_1, \hat{e}_1, s_{12}; \gamma)}{\partial \hat{e}_1} - \frac{\partial K(\hat{e}_1, \hat{e}_1, \frac{1}{2}s_{12}; \gamma)}{\partial \hat{e}_1}\right] - \left[\frac{\partial \pi(\hat{e}_1, N_2^S; \mu, f)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1, N_1^S; \mu, f)}{\partial \hat{e}_1}\right] \tag{A.5}$$

where the last equality follows from substituting A.3 in A.4.

Given that own effort and links are strategic complements in both $B(.)$ and $C(.)$, and $N_2^S > N_1^S$, it follows that $\frac{\partial B(\hat{e}_1;N_2^S)}{\partial \hat{e}_1} - \frac{\partial B(\hat{e}_1;N_1^S)}{\partial \hat{e}_1} > 0$ and $\frac{\partial \pi(\hat{e}_1,N_2^S;\mu,f)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1,N_1^S;\mu,f)}{\partial \hat{e}_1} > 0$. Benefits from spillovers decrease with distance, i.e. $K(\hat{e}_1, \hat{e}_1, \gamma; s_{12}) > K(\hat{e}_1, \hat{e}_1, \gamma; \frac{1}{2}s_{12})$. And spillovers are linearly increasing in own effort. Then

$\frac{\partial K(\hat{e}_1,\hat{e}_1,s_{12},\gamma)}{\partial \hat{e}_1} - \frac{\partial K(\hat{e}_1,\hat{e}_1,\frac{1}{2}s_{12};\gamma)}{\partial \hat{e}_1} > 0$. All terms in brackets in A.5 are strictly positive. The difference $\frac{\partial \pi(\hat{e}_1,N_2^S;\mu,f)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1,N_1^S;\mu,f)}{\partial \hat{e}_1}$ is an approximation to $\frac{\partial^2 \pi(e_1,N_1^S;\mu,f)}{\partial e_1 \partial N_1}$. By assumption these complementarities are large so that $\frac{\partial \pi(\hat{e}_1,N_2^S;\mu,f)}{\partial \hat{e}_1} - \frac{\partial \pi(\hat{e}_1,N_1^S;\mu,f)}{\partial \hat{e}_1}$ is strictly positive and large. But then $\frac{\partial Y_2^S}{\partial e_2} |_{e_2=\hat{e}_1} < 0$, and $\left(e_1^S, e_2^S, e_3^S\right) = (\hat{e}_1, \hat{e}_1, \hat{e}_1)$ would not be a NE.

At $e_2 = \hat{e}_1$, the marginal cost of effort for the center of the Star is larger than the marginal benefits, thus it is optimal for the agent to select some effort level $\hat{e}_2 < \hat{e}_1$. Since $\frac{\partial^2 K(e_1,e_1,s_{12};\gamma)}{\partial e_1 \partial e_2} > 0$, player 1 would respond to $\hat{e}_2$ by decreasing his effort too. Given that A.2 holds, player 1 decreases his effort by less than the initial decrease in effort of player 2. Then the NE of a Star network is characterized by $\left(e_1^S, e_2^S, e_3^S\right) = (e_1^*, e_2^*, e_1^*)$ with $e_1^* > e_2^*$.

Given the existence of a NE in which $e_1^* > e_2^*$, any equilibrium of the form $e_2^* > e_1^*$ is ruled out. The latter equilibrium would require that around its neighborhood the (absolute value of the) slope of at least one of the reaction functions be greater than 1, which would violate A.2.

□

Proof of proposition 1.2. I now compare crime efforts across networks. Any criminal in the complete network has two links and is a step away from any other criminal. Similarly, in the Star network, the center has two links and is only a step away from the other two criminals ($N_{center} = N_i^C = 2, s(center, j) = s\,(i, j) = s_{12},\ j = 1, 3$). Let the profile of NE efforts of the Star be $\left(e_1^S, e_2^S, e_3^S\right) = (e_{corner}^*, e_{center}^*, e_{corner}^*)$.

Evaluating the first-order condition of the center of the Star at the NE:

$$\begin{aligned}
\frac{\partial Y^S_{center}}{\partial e_{center}} \quad | \quad & {}_{e_{center}=e^*_{center}} = \\
&= \frac{\partial B(e^*_{center}; N_{center})}{\partial e^*_{center}} + 2\frac{\partial K(e^*_{center}, e^*_{corner}, s_{12}; \gamma)}{\partial e^*_{center}} - \frac{\partial \pi(e^*_{center}, N_{center}; \mu, f)}{\partial e^*_{center}} \\
&= 0
\end{aligned}$$

or equivalently,

$$\frac{\partial \pi(e^*_{center}, N_{center}; \mu, f)}{\partial e^*_{center}} - \frac{\partial B(e^*_{center}; N_{center})}{\partial e^*_{center}} = 2\frac{\partial K(e^*_{center}, e^*_{corner}, s_{12}; \gamma)}{\partial e^*_{center}} \quad \text{(A.6)}$$

Suppose that all nodes in the complete network select an effort level $e^C_i = e^*_{center}$:

$$\frac{\partial Y^C_i}{\partial e^C_i} |_{e^C_i=e^*_{center}} = \frac{\partial B(e^*_{center}; N_{center})}{\partial e^*_{center}} + 2\frac{\partial K(e^*_{center}, e^*_{center}, s_{12}; \gamma)}{\partial e^*_{center}} - \frac{\partial \pi(e^*_{center}, N_{center}; \mu, f)}{\partial e^*_{center}} \quad \text{(A.7)}$$

Substituting A.6 in A.7 and for $e^*_{center} < e^*_{corner}$ (from proposition 1.1),

$$\frac{\partial Y^C_i}{\partial e^C_i} |_{e^C_i=e^*_{center}} = 2\left[\frac{\partial K(e^*_{center}, e^*_{center}, s_{12}; \gamma)}{\partial e^*_{center}} - \frac{\partial K(e^*_{center}, e^*_{corner}, s_{12}; \gamma)}{\partial e^*_{center}}\right] < 0$$

e^*_{center} is not the NE effort level of criminals in the complete network. At e^*_{center} the marginal cost of effort is larger than the marginal benefit. Thus the NE effort levels are $e^{C*}_i < e^*_{center} < e^*_{corner}$.

In the complete network all nodes have two links, and are one step away from each other. Therefore payoffs are symmetric. Without loss of generality consider player 1's payoff for given e_2:

$$\begin{aligned}
Y^C_1 &= B(e^C_1, N^C_1) + K(e^C_1, e^C_2, s_{12}; \gamma) + K(e^C_1, e^C_3, s_{12}; \gamma) - \pi(e^C_1, N^C_1; \mu, f) \\
&= 2\left[B(e^C_1, 1) + K(e^C_1, e^C_2, \gamma, s_{12}) - \pi(e^C_1, 1; \mu, f)\right] \text{ with } e_2 = e_3, s_{12} = s_{13} \quad \text{(A.8)}
\end{aligned}$$

using H.O.D.1 of $B(.)$ and $\pi(.)$ in N_i^g and symmetry.

In the single-link network, $g^I = \{12\}$, only two agents are connected. The payoff to player 1 in this network is:

$$\begin{aligned} Y_1^I &= B(e_1^I, N_1^I) + K(e_1^I, e_2^I, s_{12}; \gamma) - \pi(e_1^C, N_1^C; \mu, f) \\ &= B(e_1^I, 1) + K(e_1^I, e_2^I, \gamma, s_{12}) - \pi(e_1^I, 1; \mu, f) \end{aligned} \tag{A.9}$$

From A.8 and A.9, $Y_1^C = 2Y_1^I$. The payoff of the complete network is an increasing monotonic transformation of that of a connected node in the single-link network. Thus for given (e_2, e_3), if e_1^* maximizes A.8 then it also maximizes A.9. Hence $e_i^C = e_{connected}^I > e_{isolated}^I = 0$. □

Chapter B

Proofs of Propositions of Chapter 2

Proof of proposition 2.1. For $n_u = 0$: $U_{us}(0) = w_{us} + b - K$ and $U_{uc}(0) = w_{us} - K$. If $b < 0$ then $U_{uc}(0) > U_{us}(0)$ and an immigrant unilaterally deviated and settles in the enclave. Consequently everyone assimilating ($n_u^* = 0$) is never a Nash Equilibrium (NE). Given that $\frac{\partial U_{us}}{\partial n_u} < 0$ and $\frac{\partial U_{uc}}{\partial n_u} > 0$ then for $n_u > 0$ $U_{uc}(n_u) > U_{us}(n_u)$. Therefore, if $b < 0$, for $0 \leq n_u \leq 1$, it is always a best response to go to the enclave. Thus $n_u^* = 1$ is the unique Nash Equilibrium. □

Proof of proposition 2.2. For $b > 0$ and $n_u = 0$: $U_{us}(0) = w_{us} + b - K > w_{us} - K = U_{uc}(0)$, all immigrants assimilating is a Nash Equilibrium. Now I show that if $h(1) > b - K$ and $w_{us} - w_{uc} \geq \frac{h(1)-b+K}{\beta}$, then full assimilation is the unique equilibrium. Given that $\frac{\partial U_{us}}{\partial n_u} < 0$ and $\frac{\partial U_{uc}}{\partial n_u} > 0$, the lowest possible utility received by an immigrant who assimilates is $U_{us}(1)$, and the highest possible if he settles in the enclave is $U_{uc}(1)$. If at $n_u = 1$ $U_{us}(1) \geq U_{uc}(1)$, then all immigrants weakly prefer to assimilate for any $0 \leq n_u \leq 1$. Notice $U_{us}(1) = w_{us} + b - K - (1-\beta)(w_{us} - w_{uc}) \geq w_{uc} + h(1) = U_{uc}(1) \therefore \beta(w_{us} - w_{uc}) \geq h(1) - b + K > 0$, which holds given the assumptions above. □

Proof of proposition 2.3. For $b > 0$ all immigrants assimilating is a Nash Equilibrium. By assumption $h(1) > b - K$ and $w_{us} - w_{uc} < \frac{h(1)-b+K}{\beta}$. Is the enclave forming also a NE? $U_{uc}(1) = w_{uc} + h(1) \geq w_{us} + b - K - (1-\beta)(w_{us} - w_{uc})$ $\therefore \beta(w_{us} - w_{uc}) \leq h(1) - b + K$, hence the enclave is a NE if $w_{us} - w_{uc} < \frac{h(1)-b+K}{\beta}$, which is always satisfied. If $U_{us}(0) > U_{uc}(0)$ and $U_{uc}(1) > U_{us}(1)$, then there exists $0 < n_u < 1$ such that $U_{uc}(n_u) = U_{us}(n_u)$. For given $0 < n_u < 1$ an immigrant is indifferent between going to the enclave or assimilating, and thus $0 < n_u^* < 1$ is an interior Nash Equilibrium. □

Proof of proposition 2.4. By assumption both the enclave and full assimilation are NE of the game. All immigrants are better off assimilating when $U_{us}(0) > U_{uc}(1)$. Equivalently, $U_{us}(0) = w_{us}+b-K > w_{uc}+h(1) = U_{uc}(1)$, which holds for $w_{us}-w_{uc} > h(1) - b + K$. The enclave equilibrium is Pareto superior to the assimilation equilibrium when $U_{us}(0) < U_{uc}(1)$, which requires $w_{us} - w_{uc} < h(1) - b + K$. As β gets closer to 1, if $w_{us} - w_{uc}$ is not sufficiently large, the assimilation equilibrium may emerge as the 'bad' equilibrium. □

Proof of proposition 2.5. Using the conditions $b > 0$, $w_{us} - K \leq y$, $2y - w_{us} + K \leq w_h \leq 2y$, $b - K \leq b_h - Z \leq b$, $U_{hs} > y + b$ and

$$\frac{y - w_{us} + K - (b - b_h + Z)}{w_h - y} \leq d \leq \min\left\{\frac{y - w_{us} + K - (b - b_h + Z)}{w_h - y}, \frac{U_{hs} - y - w_{us} + K - b}{y}\right\}$$

I show that three equilibria exist: i. $n_u^* = n_h^* = 0$; ii. $dn_u^* = n_h^* = d$; and iii. $0 < dn_u^* = n_h^* < d$. The first step is to show that $(n_u^*, n_h^*) = 0$ is a NE. Given $(n_u^*, n_h^*) = 0$ is it a best response to assimilate? Start with the unskilled immigrants.

For $(n_u^*, n_h^*) = 0$: $U_{uc}(0,0) = U_{uc,out}(0,0) = w_{us} - K$ and $U_{us}(0,0) = U_{us,in}(0,0) = w_{us} - K + b$. These equations imply that $U_{us}(0,0) > U_{uc}(0,0) = U_{uc,out}(0,0)$ and $U_{us}(0,0) \geq U_{us,in}(0,0)$. For $(n_u^*, n_h^*) = 0$ the best response of an unskilled immigrant is to assimilate and work out of the enclave. Now I show that it is also a best response for a skilled immigrant to assimilated and work in the general labor market when $(n_u^*, n_h^*) = 0$. When $(n_u^*, n_h^*) = 0$ $U_{hc}(0,0) = y$, $U_{hs} = w_h + b_h - Z$, $U_{hc,out} = U_{uc,out}$ and $U_{hs,in} = y + b_h - Z$. By assumption $U_{hs} > y$, and thus a skilled immigrant prefers to assimilated and work out of the enclave. And he prefers this alternative to either of the other two options: $U_{hc,out}(0,0) = w_{us} - K < y < U_{hs}$, and $U_{hs,in}(0,0) = y + b_h - Z < U_{hs}$ since $w_h > y$. Thus $(n_u^*, n_h^*) = 0$ is a NE.

The second step is to show that $0 < dn_u^* = n_h^* < d$ is a NE. An unskilled immigrant chooses among the four alternatives, which yield utilities: $U_{uc}(n_u^*, n_h^*) = dw_x(n_u^*, n_h^*) + (1-d)y + h(n_u^*, n_h^*)$, $U_{us}(n_u^*, n_h^*) = w_{us} + b - K$, $U_{uc,out} = w_{us} - K + h(n_u^*, n_h^*)$ and $U_{us}(n_u^*, n_h^*) = dw_x(n_u^*, n_h^*) + (1-d)y + b - K$. Given $(n_u^*, n_h^*) < (1, d)$ an unskilled immigrant is indifferent between living and working in the enclave or living and working out of the enclave if $U_{us}(n_u^*, n_h^*) = U_{uc}(n_u^*, n_h^*)$, which is equivalent to $w_x(n_u^*, n_h^*) = y - \frac{U_{hs} - w_{us} - b + K}{1+d}$. This equilibrium wage is always non-negative because by assumption $\frac{U_{hs} - w_{us} - b + K - y}{y} \geq d$. The person strictly prefers to live and work in the enclave to live in and work out of the enclave: $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*) \therefore b \geq h(n_u^*, n_h^*)$. From $U_{hs}(n_u^*, n_h^*) = U_{hc}(n_u^*, n_h^*)$ we find $h(n_u^*, n_h^*) = \frac{dU_{hs} - w_{us} - b + K}{1+d} - y$. Now $b \geq \frac{dU_{hs} - w_{us} - b + K}{1+d} - y$ only if $d \leq \frac{y - w_{us} + K}{U_{hs} - y - b} \therefore w_h \geq 2y - w_{us} + K$, and this inequality holds by assumption. Hence $U_{uc}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*)$. Finally, an unskilled immigrant that assimilates prefers to work out of the enclave to working in the enclave if: $U_{us}(n_u^*, n_h^*) \geq U_{us,in}(n_u^*, n_h^*) \therefore U_{uc}(n_u^*, n_h^*) \geq U_{us,in}(n_u^*, n_h^*) \therefore h(n_u^*, n_h^*) \geq b - K$. This last condition holds whenever $h(n_u^*, n_h^*) \geq b_h - Z \geq b - K$. Below I prove that this is the case. Now I show that for $0 < dn_u^* = n_h^* < d$ a skilled immigrant is indifferent between settling and working in the enclave or out of it, and prefers either option to all others. Given $(n_u^*, n_h^*) < (1, d)$ the alternatives available to a skilled individual yield utilities: $U_{hc}(n_u^*, n_h^*) = 2y - w_x(n_u^*, n_h^*) + h(n_u^*, n_h^*)$, $U_{hs} = w_h + b_h - Z$, $U_{hc,out}(n_u^*, n_h^*) = U_{uc,out}(n_u^*, n_h^*)$, and $U_{hs,in}(n_u^*, n_h^*) = 2y - w_x(n_u^*, n_h^*) + K + b_h - Z$. Given the enclave $(n_u^*, n_h^*) < (1, d)$ a skilled immigrant is indifferent between living and working in the enclave or out of it if $U_{hs} = U_{hc}(n_u^*, n_h^*)$, which is equivalent to $h(n_u^*, n_h^*) = \frac{dU_{hs} - w_{us} - b + K}{1+d} - y > 0$. A skilled immigrant prefers to settle and work in the enclave than assimilate and become an entrepreneur in the enclave, i.e. $U_{hc}(n_u^*, n_h^*) \geq U_{hs,in}(n_u^*, n_h^*) \therefore h(n_u^*, n_h^*) \geq b_h - Z \therefore d \geq \frac{y - w_{us} + K - (b - b_h + Z)}{w_h - y}$. And he never chooses to live in the enclave and work out of it: $U_{hc}(n_u^*, n_h^*) \geq U_{uc}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*) = U_{hc,out}(n_u^*, n_h^*)$. Thus $0 < dn_u^* = n_h^* < d$ is a NE.

The third step is to show that everyone locating and working in the enclave is also a NE $(n_u^* = 1, n_h^* = d)$. Start with the unskilled immigrants: $U_{uc}(1, d) = dw_x(1, d) + (1 - d)y + h(1, d)$; $U_{us}(1, d) = w_{us} - K + b$; $U_{uc,out}(1, d) = w_{us} - K + h(1, d)$ and $U_{us}(1, d) = dw_x(1, d) + (1 - d)y + b - K$. Notice that $U_{uc}(1, d) \geq U_{us}(1, d)$ only if $w_x^*(1, d) \geq y - \frac{1}{d}[y - w_{us} + K - b + h(1, d)]$, which holds by assumption. Since $h(n_u^*, n_h^*) = \frac{dU_{hs} - w_{us} - b + K}{1+d} - y$ and $h(.)$ is increasing in both of its arguments, then $h(1, d) \geq h(n_u^*, n_h^*) \geq b \geq b - K$. Hence $U_{uc}(1, d) \geq U_{uc,out}(1, d)$ or equivalently, $h(1, d) \geq b - K$ is always met. Similarly

$U_{uc}\left(n_u^*, n_h^*\right) \geq U_{us,in}\left(n_u^*, n_h^*\right)$ because $h\left(n_u^*, n_h^*\right) \geq b - K$. Then $h\left(1, d\right) > h\left(n_u^*, n_h^*\right) \geq b - K$. Now look at the skilled immigrants. The utilities from all alternatives are: $U_{hc}(1,d) = 2y - w_x\left(1,d\right) + h\left(1,d\right)$; $U_{hs}(1,d) = U_{hs}$; $U_{hc,out}\left(1,d\right) = w_{us} - K + h\left(1,d\right)$ and $U_{hs}(1,d) = U_{hs}$. Notice that for $0 < dn_u^* = n_h^* < d$, $U_{hs} = U_{hc}\left(n_u^*, n_h^*\right)$. Because $U_{hc}\left(n_u, n_h\right)$ is increasing in both of its arguments, then $U_{hc}(1,d) > U_{hs}$. Thus given $(n_u^* = 1, n_h^* = d)$, the best response of a skilled immigrant is to live and work in the enclave. Furthermore, $U_{hc}\left(1,d\right) \geq U_{uc}\left(1,d\right) > U_{uc,out}\left(1,d\right) = U_{hc,out}\left(1,d\right)$, and $U_{hc}\left(n_u, n_h\right) > U_{hs,in}\left(1,d\right) \therefore h\left(1,d\right) \geq h\left(n_u^*, n_h^*\right) > b_h - Z$.

Finally, the enclave equilibrium is Pareto-superior to the assimilation equilibrium: i. $U_{us}\left(0,0\right) = w_{us} - K + b < dw_x\left(1,d\right) + \left(1-d\right)y + h\left(1,d\right) = U_{uc}(1,d) \therefore w_x^*\left(1,d\right) \geq y - \frac{1}{d}\left[y - w_{us} + K - b + h\left(1,d\right)\right]$; ii. $U_{hs} = U_{hc}\left(n_u^*, n_h^*\right) < U_{hc}\left(1,d\right)$. □

Proof of proposition 2.6. Using the conditions $b > 0$, $y > \min\left[w_{us} - K,\ \widetilde{w}_{us}\left(n_u, n_h\right)\right]$, $y << w_h \leq 2y$ and $b - K \leq b_h - Z$, I show that three equilibria exist: i. $n_u^* = n_h^* = 0$; ii. $dn_u^* = n_h^* = 1$; and iii. $0 < n_h^* < dn_u^* < d$. From the proof of proposition 2.5, the conditions for the existence of NE $n_u^* = n_h^* = 0$ and $dn_u^* = n_h^* = 1$ are:

$$w_h \leq 2y \quad \text{(B.1)}$$

$$h\left(1,d\right) \geq \frac{w_{us} + b - K - dU_{hs}}{1+d} - y \quad \text{(B.2)}$$

$$h\left(1,d\right) \geq b - K \quad \text{(B.3)}$$

$$h\left(1,d\right) \geq b_h - Z \quad \text{(B.4)}$$

$$y - \frac{1}{d}\left[y - w_{us} + K - b + h\left(1,d\right)\right] \leq w_x^*\left(1,d\right) \leq 2y - U_{hs} + h\left(1,d\right) \quad \text{(B.5)}$$

By assumption equations (B.1), (B.2) and (B.5) are satisfied. Two additional conditions are $d \leq \min\left\{\frac{y-\widetilde{w}_{us}(.)}{w_h-y},\ \frac{y-\widetilde{w}_{uc}(.)+J(.)}{U_{hs}-\widetilde{w}_{us}(.)-b+K-(y-\widetilde{w}_{uc}(.)+J(.))}\right\}$, and

$$\frac{y-\widetilde{w}_{uc}(.)+J(.)-d(w_h-y)}{\widetilde{w}_{us}(.)-\widetilde{w}_{uc}(.)+J(.)+b_h-Z} \leq \theta^*(n_u,n_h) \leq \frac{d\left[U_{hs}+\widetilde{w}_{us}(.)-\widetilde{w}_{uc}(.)+J(.)\right]}{d\left[y-\widetilde{w}_{uc}(.)+J(.)\right]+y-\widetilde{w}_{us}(.)+d\left[\widetilde{w}_{us}(.)+b-K\right]}.$$

$d \leq \frac{y-\widetilde{w}_{us}(.)}{w_h-y}$ guarantees that the lower bound of θ is smaller than its upper bound. Further the upper bound of θ is greater than one if $h(n_u^*, n_h^*) > b-K$. One equilibrium condition is that $h(n_u^*, n_h^*) \geq b_h - Z$, since $b_h - Z \geq b-K$, then the conditions for $\theta > 1$ and (B.3)-(B.4) will be met.

I first show that the interior equilibrium exists, and will then show that the remaining constraints above are met. I now prove that an interior Nash Equilibrium exists ($0 < n_h^* < dn_u^* < d$ and $\theta^*(.) = \theta = \frac{dn_u^*}{n_h^*} > 1$). For given (n_u^*, n_h^*), the utilities from each possible action taken by an unskilled immigrant are: $U_{uc}(n_u^*, n_h^*) = U_{uc}(.) = \frac{1}{\theta}\left[dw_x(n_u^*, n_h^*) + (1-d)y\right] + \frac{\theta-1}{\theta}(\widetilde{w}_{uc}(.) - J(.)) + h(.)$; $U_{us}(n_u^*, n_h^*) = \widetilde{w}_{us}(.) + b - K$; $U_{uc,out}(n_u^*, n_h^*) = \widetilde{w}_{uc}(.) - J(.) + h(.)$; and

$U_{us,in}(n_u^*, n_h^*) = \frac{1}{\theta}\left[dw_x(n_u^*, n_h^*) + (1-d)y\right] + \frac{\theta-1}{\theta}\widetilde{w}_{us}(.) + b - K$. The utilities for a skilled immigrant are:$U_{hc}(n_u^*, n_h^*) = 2y - w_x(n_u^*, n_h^*) + J(.) + h(n_u^*, n_h^*)$, $U_{hs} = w_h + b_h - Z$, $U_{hc,out}(n_u^*, n_h^*) = U_{uc,out}(n_u^*, n_h^*)$, and $U_{hs,in}(n_u^*, n_h^*) = 2y - w_x(n_u^*, n_h^*) + J(.) + b_h - Z$. (n_u^*, n_h^*) is a NE only if an immigrant is indifferent between living and working in the enclave, or assimilating and working in the general economy. Thus $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \therefore w_x(n_u^*, n_h^*) = y + \frac{\theta}{d}\left[\widetilde{w}_{us}(.) + b - K - \widetilde{w}_{uc}(.) + J(.) - h(.)\right] - \frac{1}{d}\left[y - \widetilde{w}_{uc}(.) + J(.)\right]$. And $U_{hc}(n_u^*, n_h^*) = U_{hs}(n_u^*, n_h^*) \therefore h(n_u^*, n_h^*) = \frac{d(U_{hs}-y)+\theta^*(.)[\widetilde{w}_{us}(.)-\widetilde{w}_{uc}(.)+b-K+J(.)]-[y-\widetilde{w}_{uc}(.)+J(.)]}{\theta^*(.)+d}$.

Substituting $h(.)$ in $w_x(.)$ yields

$$w_x(n_u^*, n_h^*) = y + \frac{1}{\theta^*(.)+d}\left\{\theta^*(.)\left[\widetilde{w}_{us}(.) + b - K\right] + (\theta - 1)\left[y - \widetilde{w}_{uc}(.) + J(.)\right] - U_{hs}\right\}.$$

An unskilled agent prefers settling and working in the enclave to assimilating and working in the enclave only if $U_{uc}(n_u^*, n_h^*) \geq U_{us,in}(n_u^*, n_h^*) \therefore w_x(n_u^*, n_h^*) \leq y - \frac{1}{d}\left[y - \widetilde{w}_{us}(.)\right] \therefore \theta \leq \frac{d[U_{hs}+\widetilde{w}_{us}(.)-\widetilde{w}_{uc}(.)+J(.)]}{d[y-\widetilde{w}_{uc}(.)+J(.)]+y-\widetilde{w}_{us}(.)+d[\widetilde{w}_{us}(.)+b-K]}$. Similarly, he prefers to live and work in the enclave to living in and working out of the enclave if $U_{uc}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*) \therefore w_x(n_u^*, n_h^*) \geq y - \frac{1}{d}\left[y - \widetilde{w}_{uc}(.) + J(.)\right] \therefore d \leq \frac{y-\widetilde{w}_{uc}(.)+J(.)}{U_{hs}-\widetilde{w}_{us}(.)-b+K-(y-\widetilde{w}_{uc}(.)+J(.))}$. Thus given interior (n_u^*, n_h^*) an unskilled person is indifferent between living and working in the enclave or living and working out of it, and both alternatives are preferred to all others.

Next, I show that for given (n_u^*, n_h^*) skilled immigrants prefer both to locate and live in one place, than live and work in different places. In equilibrium $U_{hs} = U_{hc}(n_u^*, n_h^*) \geq U_{hs,in}(n_u^*, n_h^*)$ only if $h(n_u^*, n_h^*) \geq b_h - Z$, or equivalently if $\theta \geq \frac{y-\widetilde{w}_{uc}(.)+J(.)-d(w_h-y)}{\widetilde{w}_{us}(.)-\widetilde{w}_{uc}(.)+J(.)+b_h-Z}$, which is satisfied by assumption. But then $h(1,d) \geq h(n_u^*, n_h^*) \geq b_h - Z$, and so equation (B.4) above is also met and $\theta > 1$. Notice that $U_{hc,out}(n_u^*, n_h^*) = U_{uc,out}(n_u^*, n_h^*) \leq U_{hc}(n_u^*, n_h^*)$ because $y \geq w_x \geq w_{us} - K \geq \widetilde{w}_{uc}(.) - J(.)$. Therefore, given (n_u^*, n_h^*) a skilled immigrant is indifferent between living and working in the enclave or out, and both alternatives are preferred to all others. Thus an interior NE with excess labor supply exists. Finally because both $n_u^* = n_h^* = 0$ and $dn_u^* = n_h^* = 1$ are NE, and utilities at these equilibria do not change from those of the proof of proposition (2.5), the enclave Pareto-dominates assimilation. □

Proof of Proposition **??**. Using the conditions $b > 0$, $w_{us} \leq y << w_h \leq 2y$, $U_{hs} > y + b$, $b - K \leq b_h - Z$, and

$$d \geq \frac{(y - w_{us})[U_{hs} - w_{us} - b + K]}{(w_h - y)[U_{hs} - U_{us} - 2(y - w_{us})]}$$

$$y - \frac{1}{d}[y - w_{us} + K - b + h(1, d)] \leq w_x^*(1, d) \leq 2y - U_{hs} + h(1, d)$$

$$\frac{d[U_{hs} - y - b]}{y - w_{us} + K} \leq \theta^*(n_u, n_h) \leq \frac{d[U_{hs} - y - b + K]}{y - w_{us}}$$

I show that three equilibria exist: i. $n_u^* = n_h^* = 0$; ii. $dn_u^* = n_h^* = 1$; and iii. $0 < dn_u^* < n_h^* < d$. By assumption equations (B.1), (B.2) and (B.5) are satisfied. I will show that equations (B.3) and (B.4) are met. First I prove that an interior Nash Equilibrium exists ($0 < dn_u^* < n_h^* < d$ and $\theta^*(.) = \theta = \frac{dn_u^*}{n_h^*} < 1$). For given (n_u^*, n_h^*), the utilities from each possible action taken by an unskilled immigrant are $U_{uc}(n_u^*, n_h^*) = dw_x(n_u^*, n_h^*) + (1 - d)y + h(n_u^*, n_h^*)$, $U_{us}(n_u^*, n_h^*) = w_{us} + b - K$, $U_{uc,out} = w_{us} - K + h(n_u^*, n_h^*)$ and $U_{us}(n_u^*, n_h^*) = dw_x(n_u^*, n_h^*) + (1 - d)y + b - K$. For a skilled immigrant they are: $U_{hc}(n_u^*, n_h^*) = \theta(2y - w_x(n_u^*, n_h^*)) + (1 - \theta)y + h(n_u^*, n_h^*)$, $U_{hs} = w_h + b_h - Z$, $U_{hs,in} = \theta(2y - w_x(n_u^*, n_h^*)) + (1 - \theta)y + b_h - Z$ and $U_{hc,out} = U_{uc,out} = w_{us} - K + h(n_u^*, n_h^*)$. An unskilled immigrant is indifferent between living and working in the enclave and living and working out of it if $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \therefore w_x(n_u^*, n_h^*) = y - \frac{1}{d}[y - w_{us} + b + h(n_u^*, n_h^*) - K]$; and a skilled immigrant is indifferent between these two options if $U_{hc}(n_u^*, n_h^*) = U_{hs}(n_u^*, n_h^*), \therefore h(n_u^*, n_h^*) = U_{hs} - y - \theta(y - w_x(n_u^*, n_h^*))$. Using these two equations I find $w_x(n_u^*, n_h^*) = y - \frac{U_{hs} - (w_{us} + b - K)}{\theta + d}$ and $h(n_u^*, n_h^*) = \frac{d}{d + \theta}U_{hs} + \frac{\theta}{\theta + d}(w_{us} + b - K) - y$. An unskilled immigrant prefers to live and work in the same place rather than live in the enclave and work out of it only if $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*) \therefore$

$b \geq h(n_u^*, n_h^*) \therefore \theta \geq \frac{d[U_{hs}-y-b]}{y-w_{us}+K}$. He also prefers the former option to assimilating and working in the enclave if $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \geq U_{us,in}(n_u^*, n_h^*) \;\therefore h(n_u^*, n_h^*) \geq b - K \therefore \theta \leq \frac{d[U_{hs}-y-b+K]}{y-w_{us}}$.

A skilled immigrant prefers to live and work in the same place rather than live in the enclave and work out of it if $U_{hc}(n_u^*, n_h^*) = U_{hs}(n_u^*, n_h^*) \geq U_{hc,out}(n_u^*, n_h^*) = U_{uc,out}(n_u^*, n_h^*)$. Notice $U_{hc}(n_u^*, n_h^*) \geq U_{uc}(n_u^*, n_h^*)$ because $(\theta + d)\, y \geq (\theta + d)\, w_x(n_u^*, n_h^*)$. Since $U_{uc}(n_u^*, n_h^*) \geq U_{uc,out}(n_u^*, n_h^*) = U_{hc,out}(n_u^*, n_h^*)$, then $U_{hc}(n_u^*, n_h^*) = U_{hs}(n_u^*, n_h^*) \geq U_{hc,out}(n_u^*, n_h^*)$. A skilled immigrant also prefers to live and work in the same place instead of assimilating and working in the enclave if $U_{hc}(n_u^*, n_h^*) = U_{hs}(n_u^*, n_h^*) \geq U_{hs,in}(n_u^*, n_h^*) \therefore w_x(n_u^*, n_h^*) \geq 2y - w_h \therefore \theta \geq \frac{U_{hs-(w_{us}+b-K)}}{w_h-y} - d$. For

$d \geq \frac{(y-w_{us})[U_{hs}-w_{us}-b+K]}{(w_h-y)[U_{hs}-U_{us}-2(y-w_{us})]}$, $\frac{U_{hs-(w_{us}+b-K)}}{w_h-y} - d \leq \frac{d[U_{hs}-y-b+K]}{y-w_{us}} \leq \theta$, hence

$U_{hs}(n_u^*, n_h^*) \geq U_{hs,in}(n_u^*, n_h^*)$. It remails to show that inequalities (B.3) and (B.4) are met. From $U_{uc}(n_u^*, n_h^*) = U_{us}(n_u^*, n_h^*) \geq U_{us,in}(n_u^*, n_h^*)$ I find that $h(n_u^*, n_h^*) \geq b - K$; but then $h(1, d) \geq h(n_u^*, n_h^*) \geq b - K$. From $U_{hc}(n_u^*, n_h^*) \geq U_{hs,in}(n_u^*, n_h^*)$ $h(n_u^*, n_h^*) \geq b_h - Z + (1-\theta)(w_h - y)$. Since $b - K \leq b_h - Z$ and $(1-\theta)(w_h - y) > 0$, then $h(1, d) \geq h(n_u^*, n_h^*) > b_h - Z$. $\square$

Bibliography

[1] Aigner, D. and G. Cain (1977) "Statistical theories of discrimination in labor markets," *Industrial and Labor Relations Review*, 30 (2): 175-187.

[2] Ballester, C., A. Calvó-Armengol and Y. Zenou (2006) "Who's who in networks. Wanted: the key player," *Economietrica*, 75 (4): 1403-1418.

[3] Berman, E., K. Lang and E. Siniver (2003) "Language-skill complementarity: returns to immigrant language acquisition," *Labour Economics*, 10: 265-290.

[4] Borjas, G. (1994) "The economics of immigration," Journal of Economic Literature, 23: 1667-1717.

[5] Borjas, G. (2000) "Ethnic enclaves and assimilation," *Swedish Economic Policy Review,* 7: 89-122.

[6] Calvó-Armengol, A. and Y. Zenou (2004) "Social networks and crime decisions: the Role of social structure in facilitating delinquent behavior," *International Economic Review*, 45(3): 939-958.

[7] Chiu S., E.C. Mansley and J. Morgan (1998) "Choosing the right battlefield for the war on drugs: an irrelevance result," *Economic Letters*, 59: 107-111.

[8] Cutler, D. and E. Glaeser (1997) "Are ghettos good or bad?," *Quarterly Journal of Economics*, 112 (3): 827-872.

[9] U.S. Department of State (2001-2004) "International Narcotics Control Strategy Report, INCSR," Washington, DC: Department of State.

[10] DiIulio, J.J. (1996) "Help wanted: economists, crime and public policy," *Journal of Economic Perspectives,* 10 (1): 3-24.

[11] Edin, P., P. Fredriksson and O. Aslund (2003) "Ethnic enclaves and the economic success of immigrants - evidence from a natural experiment," *Quarterly Journal of Economics*, 118 (1): 329-357.

[12] Freeman, R. (1999) "The Economics of Crime" in Ashenfelter and Card (eds.) *Handbook of Labor Economics*, Vol. 3, 3529-3571. Amsterdam: Elsevier Science B.V.

[13] Friedman, J.W. (1983). *Oligopoly Theory.* Cambridge: Cambridge University Press.

[14] Fuentes, J.R. (1998). "Life of a cell: managerial practice and strategy in Colombian cocaine distribution in the United States," PhD. dissertation, City University of New York.

[15] Goyal, S. and J.L. Móraga-González, (2001): "R&D Networks," *Rand Journal of Economics*, 32 (4): 686-707.

[16] Jackson, M. and A. Watts (2002): "The evolution of social and economic networks," *Journal of Economic Theory*, 106: 265-295.

[17] Jackson, M. and A. Wolinsky (1996): "A strategic model of social and economic networks," *Journal of Economic Theory*, 71: 44-74.

[18] Karas, J. (2002) Bridges and Barriers: Earnings and Occupational Attainment among Immigrants (The New Americans). New York: LFB Scholarly Publishing LLC.

[19] Lazear, E. (1999) "Culture and language," *Journal of Political Economy* ,107 (6):95-126.

[20] Light, I. and S. Gold (2000) Ethnic Economies. San Diego, CA: Academic Press.

[21] Munshi, K. (2003). "Networks in the modern economy: Mexican migrants in the U.S. labor market." *Quarterly Journal of Economics*, 118 (2): 549-597.

[22] Naím, M. (2005). *Illicit: How Smugglers, Traffickers and Copycats are Hijacking the Global Economy.* New York: Doubleday.

[23] Poret, S. (2003). "The illicit drug market: paradoxical effects of law enforcement policies," *International Review of Law and Economics,*22 (4):465-93.

[24] Portes, A. and A. Stepick (1985) "Unwelcome immigrants: the labor market experiences of 1980 (Mariel) Cuban and Haitian refugees in South Florida," *American Sociological Review*, 50 (4): 493-514

[25] Reuter, P. (1983). *Disorganized Crime, Illegal Markets and Mafia.* Cambridge: MIT Press.

[26] Reuter, P. (2005). "The Political Economy of Drug Smuggling" in Vellinga (ed.) *The Political Economy of the Drug Industry*, Florida: University Press of Florida.

[27] Portes, A. and R. G. Rumbaut (2006). Immigrant America: A Portrait. Third edition, Berkeley, CA: University of California Press.

[28] Sageman, M. (2004). *Understanding Terror Networks.* Philadelphia: University of Pennsylvania Press.

[29] Tirole, J. (1988) *The Theory of Industrial Organization.* Ch. 5. Cambridge: MIT Press.

[30] Vives, X. (1999) *Oligopoly Pricing. Old Ideas and New Tools.* Cambridge: MIT Press.

[31] Waldinger, R. and M. Lichter (2003). How the Other Half Works: Immigration and the Social Organization of Labor. Berkeley, CA: University of California Press.

[32] Williams, P. (1998) "The nature of drug-trafficking networks," *Current History*, April, 154-159.

[33] Williams, P. (2002) Transnational Criminal Networks, in: J. Arquilla, D. Ronfeldt (eds.), Networks and Netwars: The Future of Terror, Crime, and Militancy, Santa Monica, CA: RAND Corporation.