

The Relocation of Crime

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We add a new sector called Crime to a traditional two-sector two-input Heckscher-Ohlin model of trade between countries. Trade is found to increase crime in the resource-rich country and to reduce crime in the resource-poor country by an equal amount. The negative externality from increased crime can be strong enough to cancel out the gains from trade for the resource-rich country. The paper also explores the impact of aid, capital flows, and migration on crime rates, and how crime shapes the degree of specialization in each economy. *Journal of Economic Literature* Classification Numbers: F11, F13, O17

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1. Introduction

Crime rates in wealthy countries are affected by a bewildering number of factors: inequality, unemployment, low wages, the marginalization of certain socioeconomic groups, changes in family structure, idle time for youth, etc.¹ Less research exists on crime in poor countries, but the existing evidence suggests that property crime and armed robbery appear to be more closely correlated with strictly financial pressures: push factors such as urgent consumption needs, low wages, unemployment, and pull factors such as the availability of profitable targets (which is related to inequality). For example, Fafchamps and Minten (2006) demonstrate that a short-term spike in food and fuel prices in Madagascar in 2002 led to sharp increases in poverty, which in turn led directly to crop theft. Demombynes and Ozler (2005) and Bourguignon, Nuñez and Sanchez (2003) find a relationship between inequality and crime in South Africa and Colombia, respectively; Soares (2004) finds a similar role for inequality in a cross-country regression, and Gibson and Kim (2008) find a weak relationship.²

¹ Blau and Blau (1982) and Morgan (2000) explore the effect of income inequality on crime; Raphael and Winter-Ebmer (2001) consider the role of unemployment; Gould Weinberg and Mustard (2002) find a role for both unemployment and inequality. Doyle, Ahmed, and Horn (1999) look at the effect of both income inequality and labor market effects. Kling, Ludwig and Katz (2005), Ludwig, Duncan and Hirschfield (2001) and Oreopoulos (2003) look at the role of neighborhood effects, by studying exogenous relocations. Glaeser and Sacerdote (1999) show that crime is more prevalent in areas with single-parent households. Jacob and Lefgren (2003) show that idle time for youth contributes to crime.

² Historical studies are another interesting source of evidence, as Europe before the Industrial Revolution exhibits some similarities to developing economies. Gatrell and Hadden (1972) note a counter-cyclical pattern in crime before 1860, but Field (1995) finds very little evidence for such a pattern in 20th-century data. Gurr (1981) found that crime rose in the Great Depression. Pre-industrial evidence shows the counter-cyclical pattern much more clearly: in particular, more theft when the price of staples such as grains is high (P and P Brantingham 1984). Interestingly, Brantingham and Brantingham (1984:205) find a link between trade and crime, without having a clear hypothesis to explain it. They review historical research showing a strong rise in crime in the 1560-1610 period, during which time England became the pre-eminent trading power, and in the early Industrial Revolution, when trade was also increasing. There was however a sharp decline in the later Industrial Revolution (Gatrell and Hadden 1972).

Poor countries are also much more vulnerable to shocks in commodity prices, wages, and exchange rates than are wealthy countries. If poverty and inequality are the key drivers of crime, it seems important to explore the effect on crime of large fluctuations in the global economy, such as the increased openness to trade of China and India to trade, with their supply of low-cost labor (Freeman 2005), or the current Global Financial Crisis. But to explore these issues, we need a model of how trade flows affect crime rates. Trade flows can have positive or negative effects on the crime rate, in that they affect the value of output and the returns to labor and capital.

At the same time, a serious model of crime in developing countries needs to take into account the impact of crime on the economy.³ In countries such as Nigeria, Papua New Guinea, and South Africa, crime rates are visibly deterring economic activity outside of the resource sector, and there are a number of other countries with crime rates just as high. If crime is seriously affecting returns to economic activity, then there is a two-way relationship between trade patterns and crime.

This paper is a first look at the interaction between crime rates and trade flows.⁴ It is a classical Heckscher-Ohlin trade model with two sectors and two factors of production, capital and labor. Crime is a third, predatory sector added to the standard framework; crime is a “tax” on productive activity. The crime rate is determined by agents’ work

³ Several authors (Bourguignon 2000, Pradhan and Ravallion 1999, Soares 2006) document the welfare cost of crime in poor countries. Cullen and Levitt (1999) document the role of crime in causing an exodus from US cities. But there is little research on the impact of crime on productive activity in the economy, although there is widespread recognition of the importance of secure property rights for production and investment (Dixit 2009). Bourguignon (2000) and Fajnzylber, Lederman and Loyaza (2002) recognize the empirical difficulty in untangling the effect of poverty rates on crime from the effect of crime on poverty rates. Raphael and Winter-Ebmer (2001) attempt to deal with the econometric identification issue in their study of the effect of unemployment on crime, but do not derive estimates of the effect of crime on unemployment.

⁴ The paper follows the line of literature exploring how trade flows and market imperfections interact with each other (see for example Dixit 1989 and Dixit 2003).

decisions: agents allocate themselves across wage work and crime, so that the payoffs to these two activities are equal.

There is no law enforcement sector in this model, for simplicity. Instead, there is an interior equilibrium in crime rates, determined by the relative payoff to crime and productive work. Without a law enforcement sector, the model will have little explanatory power in wealthy countries. But the model may be a reasonable fit for poor countries, because the effectiveness of law enforcement in many countries is severely limited by resource constraints and corruption: for instance, Fafchamps and Moser (2003) find that the law enforcement sector in Madagascar is completely ineffective against crime. Thus the model may be thought of as a comparison between crime rates in resource-rich developing countries, such as Nigeria or South Africa, and resource-poor countries such as Bangladesh. In line with that interpretation, ‘capital’ in this model may be thought of as fixed resources, such as mining wealth and agricultural land.

This is not a model of organized crime, either: just as we assume no technology for organizing a defense against criminals (either through law enforcement or mutual protection in a group), we assume no technology for organizing criminal activity. We focus on ‘disorganized crime’ to keep the model as simple as possible.

Trade in a Heckscher-Ohlin model breaks the link between factor payments and the value of a country’s output: if both countries are producing both goods, in equilibrium, wage rates and capital rental rates are equal in both countries. Yet the capital-rich country will be producing more valuable output per capita than the capital-poor country. If we think of the return to crime as a function of the value of output, then it becomes clear that trade will raise the crime rate in the capital-rich country, because trade will push down

wages relative to the value of output. The result we obtain is even sharper: in autarky the two countries have the same crime rate, but with the advent of trade, crime goes up in the capital-rich country by exactly the same amount as crime goes down in the capital-poor country. Trade effectively *relocates* crime.

The increase in crime in the capital-rich country is sufficiently serious that it can negate the benefits of trade: a capital-rich country can experience such a large increase in crime with the advent of trade that it is worse off under trade than under autarky. This result echoes existing empirical results on the “resource curse”, that resource-rich countries may paradoxically be worse off (Sachs and Warner 2001). It also implies that the negative externality imposed by crime may be too large to be safely ignored by policymakers. Explosively rising crime rates in Latin America⁵ may be partially attributable to downward pressures on wages and employment from the opening up of China and India; and the governments of Latin America are under increasing pressure to respond to the crime problem.⁶ Likewise, if the Global Financial Crisis leads countries to raise trade barriers, the model would predict a sharp rise in crime in China, as the wage-increasing effects of trade are reversed.

This paper is closest to the trade literature on rent-seeking by Krueger (1974). Similarly to the model of crime in this paper, she models rent-seeking as a third sector of the economy that draws labor out of other sectors until the returns to labor are equal across sectors. However, rent-seeking does not harm the productive sectors directly; it

⁵ Bergman (2006) documents a doubling of homicides in Latin America over the last decade. Giavedoni Pita (2003) finds a similar increase in crime rates in Buenos Aires.

⁶ A recent opinion poll of Latin Americans by The Economist “shows clearly that the two sets of issues uppermost in voters’ minds were *unemployment and poverty* on the one hand, and *crime and public security* on the other (The Economist, Dec 7th, 2006, italics mine). And the Organization of American States is one of the few organizations to stress the issue of the cost of crime for economic activity: “Crime is growing and that discourages investment” said Jose Miguel Insulza, president of the OAS, in a press release on December 8, 2006.

merely competes with those sectors for labor. And her model considers a small open economy that has no impact on world prices. In contrast, allowing crime to affect the productive sectors in a two-country structure allows us to consider the effect of crime on world prices, trade flows, and flows of capital and labor; and the results are quite surprising.

The paper proceeds as follows. Section 2 sets up the model. Section 3 presents the results. In addition to results on the relocation of crime and on the resource curse, we present corollary results on the effect of crime on migration and capital flows; the effect of crime on the degree of specialization in each economy; and the potential impact of crime on a tourism sector. These results suggest that as capital becomes more mobile, and businesses relocate more easily from country to country, the negative effect of crime rates on local economic activity will grow stronger. Section 4 concludes.

2. Hecksher-Ohlin Model

The model is a standard Heckscher-Ohlin model, with two goods, two countries, and two **immobile** factors of production; and we add a third sector, crime. Goods X and Y are produced under Cobb-Douglas production functions from capital and labor, in countries A and B:

$$X_A = k_{xA}^\alpha L_{xA} \quad (1)$$

$$Y_A = k_{yA}^\beta L_{yA} \quad (2)$$

where $0 < \alpha < \beta < 1$ and k_{xA} is the capital-labor ratio in industry X , country A. B is the capital-abundant country, therefore $\frac{K_B}{N_B} > \frac{K_A}{N_A}$, where N is the population (a subset of

whom work, and the remainder of whom engage in crime) and K is the capital or resource endowment of the country.

The representative consumer in each country has the same Cobb-Douglas utility function:

$$U(X, Y) = X^{\frac{1}{\gamma+1}} Y^{\frac{\gamma}{\gamma+1}} \quad (3)$$

where $\gamma > 0$. Good Y is the numéraire, and p is the price of good X (in autarky, there are two different prices, p_A and p_B). Cobb-Douglas preferences imply that consumers spend a share $\gamma/(1+\gamma)$ of their income on Y goods. In autarky, the relative prices of goods X and Y in country A reflect only the output of country A , and relative preferences:

$$\frac{p_A X_A}{1/(\gamma+1)} = \frac{Y_A}{\gamma/(\gamma+1)} \quad \Leftrightarrow \quad p_A = \frac{Y_A}{\gamma X_A} = \frac{k_{yA}^{\beta} L_{yA}}{\gamma k_{xA}^{\alpha} L_{xA}} \quad (4a)^7$$

while under free trade, prices will reflect world output:

$$p = \frac{Y_A + Y_B}{\gamma(X_A + X_B)} = \frac{k_{yA}^{\beta} L_{yA} + k_{yB}^{\beta} L_{yB}}{\gamma(k_{xA}^{\alpha} L_{xA} + k_{xB}^{\alpha} L_{xB})} \quad (5f)^8$$

Crime Technology

The prior theoretical literature on crime is at the intersection of development economics and political economy. Authors such as Grossman and Kim (1995), Hirshleifer (1995) and Skaperdas (1992) have modeled economies with no government in which agents decide how much of their resources to devote to producing, defending themselves or attacking others for their resources. The literature addresses such questions as: when does the current conflict technology imply that property rights are secure? In contrast, Roland and Verdier (2003) include a government enforcement sector, but the

⁷ Equations that apply only in autarky have an “a” in the equation number.

⁸ Equations that apply only in the presence of free trade have an “f” in the equation number.

government's tax and enforcement technology generates multiple equilibria, because when there are many criminals, there may not be enough productive activity to tax for effective law enforcement. Imhoroglu, Merlo and Rupert (2004, 2006) also include a government enforcement sector; similarly to this paper, wages are determined endogenously from a Cobb-Douglas production function. Burdett, Lagos and Wright (2003) embed the choice to engage in crime in more detailed labor search model; they also find a pareto-inferior equilibrium in which everyone engages in crime.

Our model of crime is defined by two technologies: (a) the matching technology, which determines the probability with which robbers and producers meet and (b) the "attacking" technology, which determines the probability that the robber is successful, and how much he carries away.⁹ The attacking technology we choose is that a robber is successful in the attack with a fixed probability s ; and if he is victorious, he carries away all of the firm's output (and none of its inputs). This is equivalent to assuming that he always steals a share s of the output of any firm he attacks. For simplicity, we assume no other disutility from crime; it is a frictionless transfer from the firm to the robber.

We follow Roland and Verdier (2003) in assuming random matching, the simplest matching technology.^{10,11} In a slight variation, we assume that the random matching occurs between **firms** and robbers. The alternative, matching between individual agents

⁹ We ignore any defense technology (as in Grossman and Kim 1995) for the sake of simplicity.

¹⁰ Imhoroglu, Merlo and Rupert (2004, 2006) include an apparently simpler crime technology: they assume that each individual in an economy faces a probability π of being attacked, where π is the share of criminals. If he is attacked, he loses a share $(1-\alpha)$ of his goods. And each criminal gets a share α of average disposable earnings from legitimate activity (defined as an average of wages and unemployment benefits). But those assumptions are not consistent with any type of matching: an increase in the number of criminals should decrease their earnings. Chiu and Madden (1998) allow burglars to target agents with higher-quality housing stock, which implies that inequality has an effect on crime rates.

¹¹ The political economy models do not include a matching technology. If there are two agents, they are already matched; if there are N agents, as in Hirshleifer (1995), they are engaged in one large collective fight for resources. Hirshleifer provides technical conditions for interior equilibria in this class of models.

who are either robbers or one-person-firms, has the unattractive feature that it leads to multiple equilibria: it implies a “no-crime equilibrium” in which no one has an incentive to become a robber, because the choices are to produce one worker’s worth of output, or to become a robber, and steal a subset s of one worker’s worth of output. In order to avoid the multiple-equilibrium problem described above, we assume a minimum efficient scale of n workers (i.e. firm output in industry X is $k_x^\alpha n$ if there are n workers, and output is very low if there are fewer than n workers), at which all firms operate. And we assume that n is “large enough” in the following sense:

Assumption 1. $sn > 1$

Thus, if there are L_x and L_y workers in industries X and Y respectively, there are L_x/n and L_y/n firms of type X and Y respectively, and $(N - L_x - L_y)$ robbers. If we have an atomless distribution of agents, the probability of **not** meeting a robber in random matching is:

$$q = \frac{\frac{L_x}{n} + \frac{L_y}{n}}{(N - L_x - L_y) + \frac{L_x}{n} + \frac{L_y}{n}} = \frac{L_x + L_y}{nN - (n-1)(L_x + L_y)} \quad (6)$$

Therefore a firm producing output of value z would expect revenues of

$$\psi z \equiv qz + (1-q)(1-s)z = (1 - s + sq)z \quad (7)$$

The probability a robber meets a firm of type X is:

$$\psi_x \equiv \frac{L_x}{nN - (n-1)(L_x + L_y)} \quad (8)$$

The probability a robber meets a firm of type Y is:

$$\psi_y \equiv \frac{L_y}{nN - (n-1)(L_x + L_y)} \quad (9)$$

Equalization of returns to labor

Now we can calculate the marginal return to productive factors and to crime. Consider an initial equilibrium with autarky, where the price of good X is “ p_A ” in country A. The first-order condition equalizing the marginal product of labor in industries X and Y, and the first-order condition equalizing the marginal product of capital in industries X and Y, are:

$$\begin{cases} p_A \psi \alpha k_{xA}^{\alpha-1} = \psi \beta k_{yA}^{\beta-1} \\ p_A \psi (1-\alpha) k_{xA}^\alpha = \psi (1-\beta) k_{yA}^\beta \end{cases} \quad (10)$$

$$\Rightarrow k_{yA} = \frac{(1-\alpha)\beta}{\alpha(1-\beta)} k_{xA} \quad (11)$$

$$\Rightarrow p_A = \frac{(1-\beta)k_{yA}^\beta}{(1-\alpha)k_{xA}^\alpha} \quad (12)$$

Notice that the crime rate drops out of the first-order conditions equalizing the returns to capital and labor across industries. Thus crime will not affect factor allocation across industries.

Labor is distributed across crime and legal activity. Agents become criminals until the returns from crime equal the returns from productive labor in both X and Y:

$$\underbrace{p_A \psi (1-\alpha) k_{xA}^\alpha}_{\text{wages in X}} = \underbrace{\psi (1-\beta) k_{yA}^\beta}_{\text{wages in Y}} = \underbrace{\psi_x s p_A n k_{xA}^\alpha + \psi_y s n k_{yA}^\beta}_{\text{expected payoff from crime}} \quad (13)$$

Notice that the payoff to crime is proportional to the total output of the n -person firm, and is therefore proportional to the Average Product of Labor rather than the Marginal Product.

$$\underbrace{\psi MP_{LxA}}_{\text{wages in X}} = \underbrace{\psi MP_{LyA}}_{\text{wages in Y}} = \underbrace{\psi_x sn AP_{LxA} + \psi_y sn AP_{LyA}}_{\text{expected payoff from crime}}$$

$$\Leftrightarrow \psi = \psi_x sn \frac{AP_{LxA}}{MP_{LxA}} + \psi_y sn \frac{AP_{LyA}}{MP_{LyA}}$$

If production functions are Cobb-Douglas:

$$\Leftrightarrow \psi = \psi_x sn \left(\frac{1}{1-\alpha} \right) + \psi_y sn \frac{1}{1-\beta} \quad (14)$$

The ratio of average product to marginal product is larger in industry Y, where capital is more productive. Now we can foresee the result: if trade leads a country to an expansion of industry Y (and corresponding contraction of X), and hence a larger ψ_y , it will have a higher crime rate than before, because a larger Y industry raises the profitability of crime.

Substituting in the values of ψ , ψ_x , and ψ_y we obtain:

$$(1-s)nN_A = L_{xA} \left(n-1 + sn \frac{\alpha}{1-\alpha} \right) + L_{yA} \left(n-1 + sn \frac{\beta}{1-\beta} \right) \quad (15)$$

We will rewrite this equation as

$$cN_A = aL_{xA} + L_{yA} \quad (16)$$

where $c \equiv \frac{(1-s)n}{n-1 + sn \frac{\beta}{1-\beta}}$ and $a \equiv \frac{n-1 + sn \frac{\alpha}{1-\alpha}}{n-1 + sn \frac{\beta}{1-\beta}}$.

Equation (16) expresses the constraints imposed on labor by the presence of crime in the economy, in contrast to the usual full-employment constraint ($L_{xA} + L_{yA} = N_A$). Figure 1

demonstrates how this constraint relates to the total level of crime: if the labor allocation shifts towards industry Y, crime rates will rise and total employment falls.

Factor-price equalization within a country

In autarky, equations (4a) and (12) combined imply that:

$$p_A = \frac{(1-\beta)k_{yA}^\beta}{(1-\alpha)k_{xA}^\alpha} = \left(\frac{1}{\gamma}\right) \frac{k_{yA}^\beta L_{yA}}{k_{xA}^\alpha L_{xA}} \Rightarrow L_{yA} = \gamma \left(\frac{1-\beta}{1-\alpha}\right) L_{xA} \quad (17a)$$

Under free trade, given that $p_A = p_B = p$, equation (12) implies that now the world price p must satisfy:

$$p = \frac{(1-\beta)k_{yA}^\beta}{(1-\alpha)k_{xA}^\alpha} = \frac{(1-\beta)k_{yB}^\beta}{(1-\alpha)k_{xB}^\alpha}$$

Combining this with equation (17a), we obtain

$$\Rightarrow k_{yA} = k_{yB} = \frac{(1-\alpha)\beta}{\alpha(1-\beta)} k_{xA} = \frac{(1-\alpha)\beta}{\alpha(1-\beta)} k_{xB} \quad (18f)$$

Combining equations (5f), (12) and (18f) implies:

$$p = \frac{(1-\beta)k_{yA}^\beta}{(1-\alpha)k_{xA}^\alpha} = \left(\frac{1}{\gamma}\right) \frac{k_{yA}^\beta (L_{yA} + L_{yB})}{k_{xA}^\alpha (L_{xA} + L_{xB})} \quad (19f)$$

$$\Rightarrow \gamma \left(\frac{1-\beta}{1-\alpha}\right) (L_{xA} + L_{xB}) = L_{yA} + L_{yB} \quad (20f)$$

To close the system of equations, we use (18f) and the equation for the capital stock,

$$k_{xA} L_{xA} + k_{yA} L_{yA} = K_A \quad (21)$$

$$\Rightarrow \frac{K_A}{L_{xA} + \frac{(1-\alpha)\beta}{\alpha(1-\beta)} L_{yA}} = k_{xA} = k_{xB} = \frac{K_B}{L_{xB} + \frac{(1-\alpha)\beta}{\alpha(1-\beta)} L_{yB}} \quad (22f)$$

Table 1 summarizes which equations hold in the four cases that we compare: (i) autarky with no crime; (ii) autarky with crime; (iii) trade with no crime; (iv) trade with crime. Note however that in cases (iii) and (iv), these equations hold only in the so-called “*cone of diversification*”, that is, the range of parameters for which both goods are produced in each country. Table 2 at the end of the paper presents the labor allocation in each country, for these four cases.

TABLE 1

**Equilibrium conditions for labor allocation under autarky and under trade
(within the cone of diversification)**

<p style="text-align: center;">Autarky, no crime</p> $L_{yA} = \gamma \frac{1-\beta}{1-\alpha} L_{xA}$ $L_{yB} = \gamma \frac{1-\beta}{1-\alpha} L_{xB}$ $L_{xA} + L_{yA} = N_A$ $L_{xB} + L_{yB} = N_B$	<p style="text-align: center;">Trade, no crime</p> $\gamma \frac{1-\beta}{1-\alpha} (L_{xA} + L_{xB}) = L_{yA} + L_{yB}$ $\left(L_{xA} + \frac{\beta(1-\alpha)}{\alpha(1-\beta)} L_{yA} \right) \frac{K_B}{K_A} = L_{xB} + \frac{\beta(1-\alpha)}{\alpha(1-\beta)} L_{yB}$ $L_{xA} + L_{yA} = N_A$ $L_{xB} + L_{yB} = N_B$
<p style="text-align: center;">Autarky, crime</p> $L_{yA} = \gamma \frac{1-\beta}{1-\alpha} L_{xA}$ $L_{yB} = \gamma \frac{1-\beta}{1-\alpha} L_{xB}$ $aL_{xA} + L_{yA} = cN_A$ $aL_{xB} + L_{yB} = cN_B$	<p style="text-align: center;">Trade, crime</p> $\gamma \frac{1-\beta}{1-\alpha} (L_{xA} + L_{xB}) = L_{yA} + L_{yB}$ $\left(L_{xA} + \frac{\beta(1-\alpha)}{\alpha(1-\beta)} L_{yA} \right) \frac{K_B}{K_A} = L_{xB} + \frac{\beta(1-\alpha)}{\alpha(1-\beta)} L_{yB}$ $aL_{xA} + L_{yA} = cN_A$ $aL_{xB} + L_{yB} = cN_B$

3. Results

We are now in a position to state our first proposition:

Proposition 1.

(a) *Under autarky, both countries have the same crime rate.*

- (b) *When both countries are in the cone of diversification (that is, under trade each country produces both goods): Trade raises crime in the capital-abundant country by exactly the same amount as trade reduces crime in the labor-abundant country. The total amount of crime is unchanged. Thus, **trade relocates crime**. The difference in crime rates is proportional to the difference in factor endowments, hence it is increasing in the relative capital intensity of country B.*
- (c) *Trade has an even stronger effect on crime rates outside of the cone of diversification: trade raises crime even further in the capital-abundant country, and lowers it further in the labor-abundant country.*

PROOF: Result (a) follows directly from Table 2. The table indicates that in autarky, the same share of labor is devoted to industry X and Y in both countries; therefore the share of labor remaining in crime is the same as well. Results (b) and (c) are proven in the Appendix. The stability of the equilibrium under autarky and under trade is also verified in the Appendix.

The intuition for the result is fairly straightforward. If the two countries had identical crime rates under trade, as they did under autarky, then the standard Heckscher-Ohlin result would hold, and factor returns would be equal across countries. Workers would receive the same wages in the capital-rich and the capital-poor country. Now in each country the return to crime must equal wages. Yet crime would be much more profitable in the capital-rich country, because output per firm would be more valuable, which implies a contradiction. Thus the crime rate in the capital-rich country must be higher.

This result depends strongly on our assumption that there is no enforcement sector: if a capital-rich economy could afford more enforcement than a capital-poor country, it might maintain a lower crime rate. But the underlying pressure on crime rates from terms of trade would be the same: for the same level of crime enforcement, there will be more crime in Country A than in Country B, because the payoff to crime is higher in the capital-rich economy, and trade has brought wages closer together.

Proposition 1 has some interesting implications for international flows of capital and labor:

Corollary 1. *Aid in the form of capital transfers from the capital-abundant country to the other country would improve the crime rate in the capital-abundant country (and correspondingly raise it in the labor-abundant country), thus reducing the difference in their crime rates. Aid from a third party to the labor-abundant country, or to both countries equally, would have the same effect (it would worsen crime in the labor-abundant country, and reduce the difference in their crime rates) but of a lesser magnitude.*

The corollary follows directly from the results in Proposition 1: In the presence of trade, the difference in crime rates is a function of the difference in capital-labor ratios in the two countries. Aid in the form of capital transfers reduces the gap in the capital-labor ratios, and hence improves the crime rate in the capital-rich country, and worsens the crime rate in the capital-poor country.

Corollary 2.

- a) *In the absence of crime, factors receive the same return in both countries (within the cone of diversification); but in the presence of crime, factor price equalization no longer holds. Payments to labor and capital are reduced by the expected cost of crime, and therefore payments are lower in country B than in country A.*
- b) *Therefore capital mobility will cause funds to move from the capital-rich country to the labor-rich country. This flow will reduce the crime rate in the capital-rich country.*
- c) *But if migration is allowed, people will migrate from the capital-rich country to the labor-rich country. The effect of migration will be to push the crime rates even further apart. The countries will be pushed out of the cone of diversification (i.e. at least one country will specialize in one of the goods). An equilibrium that is stable in migration rates exists outside of the cone of diversification.*

PROOF: see Appendix.

This Corollary highlights the importance of endogenizing the effect of crime on factor returns. Because a higher crime rate implies lower returns to productive activity, and hence lower returns to the factors of production, it has a real impact on the flow of factors of production. In particular, both capital and labor will flow toward the capital-poor country, strictly because of the lower crime rate. This may explain why resource-rich

countries such as Nigeria or Papua New Guinea see the (captive) resource sector remain in the country, but little investment in other sectors of the economy.

As a result of these factor price effects, migration does not play its usual role of attenuating the differences between the countries. Because higher crime in the rich country implies lower wages, migration occurs from the rich country to the poor country, and aggravates the disparities between the two, in particular disparities in crime rates. (Note however that if migration to the rich country occurred for other reasons, it would not lead to a rise in crime, quite the contrary.) Migration also aggravates the differences in their production structure, as it pushes at least one country to specialize in one good.

Next we consider how the presence of crime shapes other features of the economy besides employment levels. In particular, we ask how crime affects the size of each sector in each country, and the absolute size of trade flows between the countries. We find that crime has the unexpected effect of intensifying the specialization of each economy.

Proposition 2.

- (a) *Crime leads to greater specialization in trade: The capital-abundant country has a larger share of the capital-intensive industry than if there were no crime. This holds true even though crime has reduced the country's employment and hence output.*
- (b) *The cone of diversification (the range of parameter values over which both countries produce both goods) is smaller than if there were no crime.*
- (c) *There is a continuous threshold of parameter values $(\alpha_x(\beta_x), \beta_x)$, above which the volume of trade in good X is greater in the presence of crime, and below which the volume of trade is lower. Similarly, there is a continuous threshold of values $(\alpha_y, \beta_y(\alpha_y))$, above which the volume of trade in good Y is greater in the presence of crime, and below which the volume of trade is lower. All four outcomes are possible (trade goes up in both, down in both, up in X and down in Y, up in Y and down in X).*

PROOF: See Appendix.

Intuitively, if the crime rate is higher in the capital-rich country, a smaller share of the population is gainfully employed. That country becomes effectively even more capital-rich per worker, as a result, and therefore it attracts even more of the capital-intensive industry. It is interesting, however, that this effect dominates the fall in employment and output in that country: its share of the capital-intensive industry is larger than if there were no crime.

The intuition for the result on the volume of trade is more difficult. When capital has a high productivity in industry Y (high β), there is a more pronounced shift the capital-intensive industry to country B, and therefore more Y is traded overall.

Having characterized the results in the presence of crime, we now turn to the central welfare question: Do negative externalities from increased crime outweigh the benefits of engaging in trade? Specifically, can trade make country B worse off than in autarky, because of the increase in crime?

Proposition 3. *In the presence of crime, trade can make a capital-abundant country worse off. A sufficient condition for trade to make a capital-abundant country worse off is $s > \frac{n-1}{n}$.*

PROOF: See Appendix.

Evidently, if the attacking technology is sufficiently powerful (i.e. if robbers who attack producers capture a large share of their goods), then if trade leads to an increase in crime, the effects on a country's welfare will be negative on balance.

Our final results concern the stability of equilibrium. Thus far we have found stable interior equilibria, and only labor mobility appeared to have a destabilizing effect. The following results suggest that the more mobile are factors and the locus of

production, and the more sensitive they are to crime rates, the more potential there is for crime to have a destabilizing effect. For example, let us consider an industry that can only operate in a low-crime environment; let's call that industry 'tourism'. The purpose of the assumption is to model the strong negative effect that increases in crime can have on the tourism industry in a location, and the implications for the stability of the local economy.

Proposition 4. *Suppose that there are two industries, and one industry, called tourism, can only operate in the country with the lowest crime rate (i.e. all tourism moves to the lowest crime location). The output of "tourism" is consumed by the residents of both countries.*

- (a) *If tourism is relatively more labor-intensive than the other industry, then tourism will locate in the labor-abundant country. Crime will be higher in the capital-abundant country than it would be if both industries could operate in both countries, and crime in the labor-abundant country will be lower.*
- (b) *If tourism is relatively more capital-intensive, then no stable equilibrium exists: the tourism industry is perpetually relocating from one country to the other.*

PROOF: See Appendix.

4. Conclusion

This is the first model to incorporate the effect of crime into a standard trade model. We begin by modeling a world with no law enforcement sector, in order to identify the underlying forces. In the absence of law enforcement, crime has some surprising effects: crime relocates from the capital-poor country to the capital-rich country. This effect can be so strong that the welfare effects of opening up to trade are completely negated. Crime has other interesting effects, such as leading to increased specialization and, under some parameter values, increased trade volume.

The obvious extension of this work is to consider law enforcement regimes. Roland and Verdier (2003) have a model that incorporates law enforcement, paid for

through taxes. In their model, law enforcement induces multiple equilibria, in that a high-crime low-output equilibrium is also one in which there are few productive resources to tax for law enforcement costs. Thus a high-crime equilibrium may persist and even be aggravated by changes in the tax base for law enforcement. On the other hand, a capital-rich country has more resources with which to fight crime, so the presence of law enforcement may attenuate the effects described in the present paper.

Further research is also needed on the geography of crime. Papers such as Glaeser, Sacerdote and Scheinkman (1996) seek to explain huge geographic variation in crime; for example, their paper considers using peer effects in one's social network. But the interaction between locations is rarely considered, with the notable exception of Freeman, Grogger and Sonstelie (1996), who model criminality across neighborhoods, and allow criminals to choose which neighborhood to target; their model finds multiple equilibria even though wages are not endogenized. In the present model, migration and tourism both play a potentially destabilizing role. The presence of alternative investment locations, opportunities to migrate, and highly mobile industries such as tourism all have the potential to intensify the negative externalities from crime and possibly destabilize equilibrium. Policymakers will need to understand the factors that can tip a location into a high-crime equilibrium.

5. APPENDIX

We adopt several changes of variables, for visual clarity:

$$\theta \equiv \frac{\alpha(1-\beta)}{(1-\alpha)\beta} \quad \text{and} \quad \sigma \equiv \frac{1-\beta}{1-\alpha} \quad \text{therefore} \quad 0 < \theta < \sigma < 1$$

$$c \equiv \frac{(1-s)n}{n-1+sn\frac{\beta}{1-\beta}} \quad \text{and} \quad a \equiv \frac{n-1+sn\frac{\alpha}{1-\alpha}}{n-1+sn\frac{\beta}{1-\beta}} \quad \text{therefore} \quad 0 < c < a < 1.$$

Proof of Proposition 1(b). Using Table 2 to compare the labor allocation under autarky and under free trade, we note that:

$$L_{xA}^a + L_{yA}^a + L_{xB}^a + L_{yB}^a = \frac{c(N_A + N_B)[1 + \gamma\sigma]}{a + \gamma\sigma} = L_{xA}^f + L_{yA}^f + L_{xB}^f + L_{yB}^f$$

So there has been no change in the total amount of labor devoted to productive work, and hence in the total amount of labor devoted to crime.

Remains to show that employment is higher in country A after trade, and that the increase in employment is proportional to the difference in A and B's factor endowments: Using the results from Table 2,

$$(L_{xA}^f + L_{yA}^f) - (L_{xA}^a + L_{yA}^a) = \left(\frac{c(N_B K_A - N_A K_B)}{K_A + K_B} \right) \left(\frac{1 + \gamma\sigma}{a + \gamma\sigma} - \frac{1 - \theta}{a - \theta} \right)$$

Recall that $(N_B K_A - N_A K_B) < 0$, because B is the capital-rich country. Remains to show that the second bracket is negative. First we demonstrate that $\theta < a < 1$. By its definition, a is clearly less than 1, since $\alpha < \beta$.

$$\text{Suppose } \theta > a, \text{ then } \frac{\alpha}{\beta} \left(\frac{1-\beta}{1-\alpha} \right) > a \equiv \frac{n-1+sn\frac{\alpha}{1-\alpha}}{n-1+sn\frac{\beta}{1-\beta}}$$

$$\Leftrightarrow \frac{\alpha}{\beta} \left(\frac{1-\beta}{1-\alpha} \right) (n-1) + sn \frac{\alpha}{1-\alpha} > n-1 + sn \frac{\alpha}{1-\alpha}$$

$$\Leftrightarrow \alpha > \beta \quad \text{and we have a contradiction. } \square$$

Using the fact that $\theta < a < 1$, we show that $\frac{1 + \gamma\sigma}{a + \gamma\sigma} > \frac{1 - \theta}{a - \theta}$ is a contradiction:

$$\frac{1 + \gamma\sigma}{a + \gamma\sigma} > \frac{1 - \theta}{a - \theta} \quad \Leftrightarrow \quad (a-1)(\theta + \gamma\sigma) > 0 \quad \text{which contradicts } a < 1. \quad \square$$

Proof of Proposition 1(c). We begin by considering the parameter values for which only industry Y operates in Country B. (Recall that Y is the capital-intensive industry, so if Country B specializes, it will specialize in industry Y.)

The equalization of the return to crime with the return to wage work in each country implies that:

In country A: $cN_A = aL_{xA} + L_{yA}$ as before.

In country B: Payoff to crime = Wages in industry Y

$$s\tilde{q}nk_{yB}^\beta = (1-s+s\tilde{q})(1-\beta)k_{yB}^\beta \quad (\text{A1})$$

$$\Rightarrow \tilde{q} = \frac{(1-s)(1-\beta)}{s(n-1)+s\beta} \quad (\text{A2})$$

where \tilde{q} = probability that a criminal meets a producer = $\frac{\frac{L_{yB}}{n}}{N_B - L_{yB} + \frac{L_{yB}}{n}}$

$$\Rightarrow \frac{(1-s)(1-\beta)}{s(n-1)+s\beta} = \frac{\frac{L_{yB}}{n}}{N_B - L_{yB} + \frac{L_{yB}}{n}} \Leftrightarrow L_{yB} = \frac{n(1-s)(1-\beta)}{(n-1)(1-\beta)+s\beta n} N_B = cN_B$$

In terms of Figure 1, we are at the corner solution along the y-intercept. It is clear from Figure 1 that the employment rate is lower (and therefore crime is higher) in country B than it would be if the country was anywhere in the cone of diversification and L_{xB} and L_{yB} were positive (in which case $cN_B = aL_{xB} + L_{yB}$ would be satisfied; we label this case “0” for convenience). This also implies that employment in B is lower than in Country A (where a positive amount of labor is in industry X) and lower than employment in autarky (in which case $cN_B = aL_{xB} + L_{yB}$ would be satisfied).

$$\text{Employment rate} = \frac{L_{yB}}{N_B} = c < \begin{cases} \frac{L_{xB}^0 + L_{yB}^0}{N_B} = c + (1-a)\frac{L_{xB}^0}{N_B} \\ \frac{L_{xA}^0 + L_{yA}^0}{N_A} = c + (1-a)\frac{L_{xA}^0}{N_A} \end{cases} \quad (\text{since } 0 < a < 1).$$

There are also parameter values for which country A is out of the cone of diversification, and has only industry X. By a similar calculation to the above we show that the equations governing its labor supply is now: $L_{xA} = \frac{c}{a} N_A$. The labor supply is at the corner solution

in Figure 1, along the x-intercept. The employment rate in A is higher outside the cone than it would be if both industries were operating in country A, higher than in country B, and higher than in autarky:

$$\text{Employment rate} = \frac{L_{xA}}{N_A} = \frac{c}{a} > \frac{L_{xA}^0 + L_{yA}^0}{N_A} = \frac{c}{a} + \underbrace{\left(\frac{a-1}{a}\right)}_{<0} \frac{L_{yA}^0}{N_A}$$

Proof of Stability of equilibrium in autarky and in trade. We explore the stability of equilibrium in the following sense: we verify that if the number of agents engaged in crime is below (above) its equilibrium level, the relative payoff to crime and to wage work will lead agents to move into (out of) crime. Note that the crime rate does not affect

the relative payoff to working in industry X and industry Y, so we abstract away from the adjustment forces that stabilize employment in industries X and Y, and we assume that capital and labor are in equilibrium across the two industries, in the sense that the payoff to employment in industry X is the same as the payoff to employment in industry Y, and capital earns the same return in X and Y. (Recall that crime does not affect the relative payoff to factors in these industries, so the normal adjustment dynamics should prevail.) This greatly simplifies the adjustment dynamics we need to consider.

Stability of equilibrium under autarky. Suppose that wage employment was higher

(lower) than its equilibrium level in Table 2: $L_{xA} + L_{yA} = \frac{cN_A(1 + \gamma\sigma)}{a + \gamma\sigma} + \varepsilon$, where ε is

greater (less) than zero. And suppose that workers were allocated so that the payoff to wage work in industry X and Y was identical, then $L_{yA} = \gamma\sigma L_{xA}$ and therefore

$$L_{xA} = \frac{cN_A}{a + \gamma\sigma} + \frac{\varepsilon}{1 + \gamma\sigma} \text{ and } L_{yA} = \frac{\gamma\sigma cN_A}{a + \gamma\sigma} + \frac{\gamma\sigma\varepsilon}{1 + \gamma\sigma}, \text{ thus } aL_{xA} + L_{yA} = cN_A + \varepsilon \left(\frac{a + \gamma\sigma}{1 + \gamma\sigma} \right).$$

We aim to show that if wage employment was higher (lower) than its equilibrium level, then the payoff to crime would be higher (lower) than the payoff to wage work, that is, from the derivation of equation (16), that $cN_A < (>) aL_{xA} + L_{yA}$, which follows directly.

Therefore, if agents move into the activity with the highest relative payoff, the number of agents in crime would adjust upwards (downwards) to equilibrium, and we have stability.

Stability of equilibrium under trade. Again we assume that capital and labor are allocated efficiently across the two industries; then equations (20f) and (22f) hold. Suppose that the labor allocation between crime and labor has deviated from its equilibrium values. Then we define ε and ε_1 as follows:

$$\varepsilon \equiv L_{xA} + L_{yA} - \frac{cK_A}{K_A + K_B} \left[\frac{(N_A + N_B)(1 + \gamma\sigma)}{a + \gamma\sigma} + \frac{\left(N_A \frac{K_B}{K_A} - N_B \right)(1 - \theta)}{a - \theta} \right]$$

$$\varepsilon_1 \equiv L_{xB} + L_{yB} - \frac{cK_B}{K_A + K_B} \left[\frac{(N_A + N_B)(1 + \gamma\sigma)}{a + \gamma\sigma} + \frac{\left(N_B \frac{K_A}{K_B} - N_A \right)(1 - \theta)}{a - \theta} \right]$$

where the last term is the equilibrium value from Table 2.

Compare the relative payoff to crime and to wage work:

- Crime is more profitable than wage work in Country A if $aL_{xA} + L_{yA} > cN_A$
- Crime is more profitable than wage work in Country B if $aL_{xB} + L_{yB} > cN_B$

Substituting in equations (20f), (22f) and the above definitions, $(aL_{xA} + L_{yA})$ becomes:

$$aL_{xA} + L_{yA} = cN_A + \varepsilon \left(\frac{a - \theta}{1 - \theta} \right) + (\varepsilon + \varepsilon_1) \left(\frac{K_A}{K_A + K_B} \right) \frac{(1 - a)(\theta + \gamma\sigma)}{(1 - \theta)(1 + \gamma\sigma)}$$

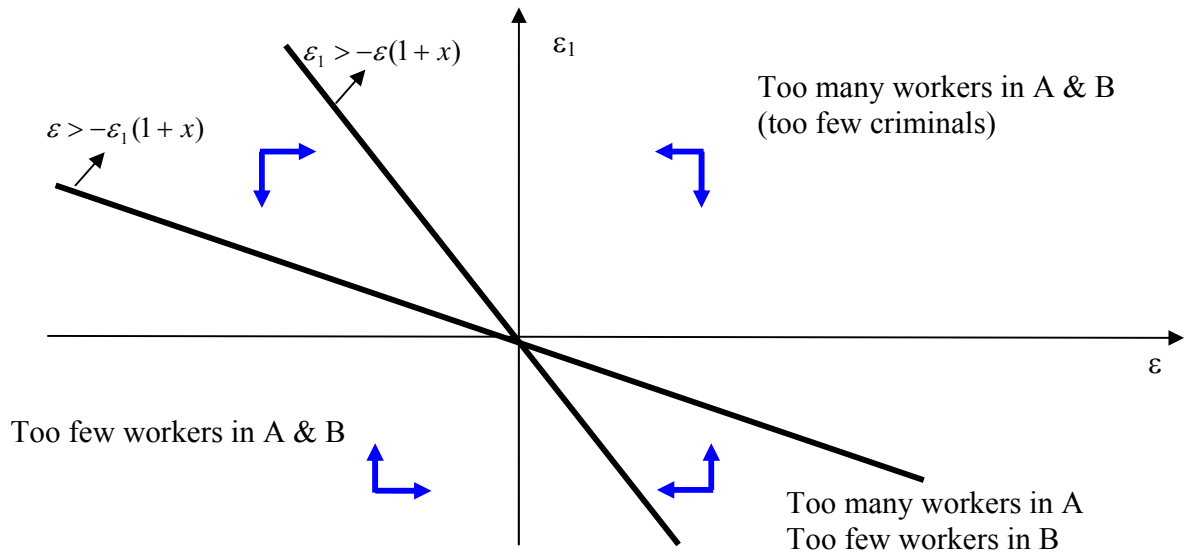
Therefore we have the following equivalence:

$$aL_{xA} + L_{yA} > cN_A \Leftrightarrow \varepsilon_1 > -\varepsilon \left(1 + \frac{a-\theta}{1-a} \left(\frac{K_A + K_B}{K_A} \right) \left(\frac{1+\gamma\sigma}{\theta+\gamma\sigma} \right) \right) \quad (\text{A3})$$

Likewise we obtain

$$aL_{xB} + L_{yB} > cN_B \Leftrightarrow \varepsilon > -\varepsilon_1 \left(1 + \frac{a-\theta}{1-a} \left(\frac{K_A + K_B}{K_B} \right) \left(\frac{1+\gamma\sigma}{\theta+\gamma\sigma} \right) \right) \quad (\text{A4})$$

And then the proof of stability is graphical: the stable equilibrium is $\varepsilon = \varepsilon_1 = 0$. The slope of the lines relative to a slope of (-1) comes from (A3), (A4) and the fact that $\theta < a < 1$:



Proof of Corollary 2(a) and 2(b). Within the cone of diversification:

$$\text{Wages in A} = \psi_A (1-\beta) k_{yA}^\beta = (1-s + sq_A)(1-\beta) k_{yA}^\beta$$

$$\text{Wages in B} = \psi_B (1-\beta) k_{yB}^\beta = (1-s + sq_B)(1-\beta) k_{yB}^\beta$$

(We focus on the wages in industry Y, bearing in mind that these are equal to the wages in industry X.) Recall from equation (18f) that $k_{yA} = k_{yB}$, and therefore wages are higher in A because $q_A > q_B$, where “ q_A ” is the probability of meeting an honest person in country A, because crime is lower in A.

Likewise the returns to capital are

$$\text{Rent to capital in A} = (1-s + sq_A) \beta k_{yA}^{\beta-1}$$

$$\text{Rent to capital in B} = (1-s + sq_B) \beta k_{yB}^{\beta-1}$$

The rent to capital in A will be higher than in B, by the same proportion as wages, because of the lower crime rate in A. Corollary 2(b) follows directly.

Proof of Corollary 2(c). Corollary 2(a) implies that there is no stable equilibrium within the cone of diversification: allowing migration raises the population in country A, and lowers it in country B, and therefore pushes the crime rates even lower in A.

We borrow a result from the proof of Proposition 2(b) below: as N_B/N_A continues to fall with migration, one of the two countries is out of the cone of diversification, because one of inequalities (A5) and (A6) will be violated. And if N_B/N_A continued to fall, eventually both countries would be out of the cone.¹²

It is sufficient to show wages are continuous as countries exit the cone of diversification, and that eventually the inequality in wages (wages in A > wages in B) is reversed. By the intermediate value principle, there is a level of migration for which wages in the two countries are equal, and no more migration occurs.

Let us consider the extreme range in which neither country is diversified: industry X is only operating in country A, and industry Y is only operating in country B. Then:

$$\text{Wages in A} = (1 - s + sq_A)(1 - \alpha)pk_{xA}^\alpha$$

$$\text{Wages in B} = (1 - s + sq_B)(1 - \beta)k_{yB}^\beta$$

$$\text{Now } p \equiv \frac{Y}{X} = \frac{k_{yB}^\beta L_{yB}}{k_{xA}^\alpha L_{xA}}, \text{ and therefore wages in A are } = (1 - s + sq_A)(1 - \alpha)k_{yB}^\beta \frac{L_{yB}}{L_{xA}}$$

When do we have Wages in B > Wages in A?

$$\Leftrightarrow (1 - s + sq_B)(1 - \beta) > (1 - s + sq_A)(1 - \alpha) \frac{L_{yB}}{L_{xA}}$$

$$\Leftrightarrow (1 - s + sq_B)(1 - \beta) > (1 - s + sq_A)(1 - \alpha) \frac{cN_B}{\frac{c}{a}N_A}$$

Using equations (A1) and (A2): $(1 - s + sq_B) = sq_B n = \frac{(1 - s)(1 - \beta)n}{(n - 1) + \beta}$. Likewise we can

show that in country A: $(1 - s + sq_B)(1 - \alpha) = sq_B n = \frac{(1 - s)(1 - \alpha)n}{(n - 1) + \alpha}$. Therefore the

inequality is equivalent to: $\frac{(n - 1)(1 - \beta) + sn\beta}{n - 1 + \beta} \frac{N_B}{N_A} > \frac{(n - 1)(1 - \alpha) + sn\alpha}{n - 1 + \alpha}$.

This inequality would eventually hold, if migration from B to A continued. Therefore if wages are continuous, there is an intermediate value of N_B/N_A for which wages are equal and migration ceases. □

Continuity in wages is straightforward: For example, suppose that B exits the cone of diversification first. Wages in country B as parameters approach the point of exit are

¹² For example, if country B left the cone of diversification first, and only produced good Y, country A would exit the cone when $\gamma\sigma N_A = aN_B$.

$$w_B = \psi_B (1 - \beta) k_{yB}^\beta = \left(1 - s + s \frac{L_{xB} + L_{yB}}{nN_B - (n-1)(L_{xB} + L_{yB})} \right) (1 - \beta) \left(\frac{K_B}{L_{xB} + \frac{1}{\theta} L_{yB}} \right)^\beta$$

As the labor allocation prior to that point satisfies $cN_B = aL_{xB} + L_{yB}$, and satisfies $cN_B = L_{yB}$ once $L_{xB}=0$, this is clearly continuous at $L_{xB}=0$. As N_B falls further, $cN_B = L_{yB}$ still holds and therefore w_B is continuous over the entire parameter range.

Likewise wages in A can be written as a function of labor allocations:

$$w_A = \psi_A (1 - \alpha) p k_{xA}^\alpha = \left(1 - s + s \frac{L_{xA} + L_{yA}}{nN_A - (n-1)(L_{xA} + L_{yA})} \right) (1 - \alpha) \frac{k_{yA}^\beta L_{yA} + k_{yB}^\beta L_{yB}}{\gamma(k_{xA}^\alpha L_{xA} + k_{xB}^\alpha L_{xB})} k_{xA}^\alpha$$

where $k_{xA} = \frac{K_A}{L_{xA} + \frac{1}{\theta} L_{yA}}$ and so on. Within the cone, labor satisfies the equations in Table

1, bottom right quadrant; when B exits the cone, L_{xA} , L_{yA} and L_{yB} satisfy the first third and fourth equations, with $L_{xB}=0$; and when A exits the cone of diversification, L_{xA} and L_{yB} satisfy the third and fourth equations, with $L_{yA}=0$ and $L_{xB}=0$. Thus labour allocations and wages are continuous. \square

Proof of Proposition 2a. We compare trade in a world with no crime (nc) to trade in a world with crime (c). From table 2:

$$\frac{L_{yB}^{nc}}{L_{yA}^{nc} + L_{yB}^{nc}} = \frac{K_B}{K_A + K_B} + \frac{(N_A K_B - N_B K_A) \theta (1 + \gamma \sigma)}{(1 - \theta)(K_A + K_B)(N_A + N_B) \gamma \sigma}$$

$$\frac{L_{yB}^c}{L_{yA}^c + L_{yB}^c} = \frac{K_B}{K_A + K_B} + \frac{(N_A K_B - N_B K_A) \theta (a + \gamma \sigma)}{(a - \theta)(K_A + K_B)(N_A + N_B) \gamma \sigma}$$

We aim to show that $\frac{L_{yB}^c}{L_{yA}^c + L_{yB}^c} > \frac{L_{yB}^{nc}}{L_{yA}^{nc} + L_{yB}^{nc}}$. Suppose not, then

$$\frac{K_B}{K_A + K_B} + \frac{(N_A K_B - N_B K_A) \theta (a + \gamma \sigma)}{(a - \theta)(K_A + K_B)(N_A + N_B) \gamma \sigma} < \frac{K_B}{K_A + K_B} + \frac{(N_A K_B - N_B K_A) \theta (1 + \gamma \sigma)}{(1 - \theta)(K_A + K_B)(N_A + N_B) \gamma \sigma}$$

Using the fact that B is more capital-rich, and therefore $(N_A K_B - N_B K_A) > 0$, this expression simplifies to:

$$\Leftrightarrow \frac{a + \gamma \sigma}{a - \theta} < \frac{1 + \gamma \sigma}{1 - \theta} \text{ which we showed to be a contradiction in the proof of 1(b). } \square$$

Proof of Proposition 2b: The parameter values outside of the cone of diversification are easy to identify using Table 2, which gives the equilibrium labour allocation inside the cone of diversification. Any parameter values for which L_{xA} , L_{yA} , L_{xB} or L_{yB} is zero or negative in Table 2 is outside of the cone of diversification.

B is the capital-rich country, therefore outside of the cone of diversification B will produce only the capital-intensive good, Y. So we look for the parameter values in Table 2 for which L_{xB} is greater than zero, to infer when it is zero.

$$\begin{aligned}
\text{Trade but no crime: } \quad & \text{if } L_{xB} = \frac{K_B}{K_A + K_B} \left[\frac{N_A + N_B}{1 + \gamma\sigma} + \frac{N_B \frac{K_A}{K_B} - N_A}{1 - \theta} \right] > 0 \quad \text{then} \\
& \Leftrightarrow (N_A + N_B)(1 - \theta) > \left(N_A - N_B \frac{K_A}{K_B} \right) (1 + \gamma\sigma) \\
& \Leftrightarrow \frac{N_A}{N_B} < \left(\frac{1 - \theta}{\theta + \gamma\sigma} \right) + \frac{K_A}{K_B} \left(\frac{1 + \gamma\sigma}{\theta + \gamma\sigma} \right) \\
\text{Trade and crime: } \quad & \text{if } L_{xB} = \frac{cK_B}{K_A + K_B} \left[\frac{N_A + N_B}{a + \gamma\sigma} + \frac{N_B \frac{K_A}{K_B} - N_A}{a - \theta} \right] > 0 \quad \text{then} \\
& \Leftrightarrow (N_A + N_B)(a - \theta) > \left(N_A - N_B \frac{K_A}{K_B} \right) (a + \gamma\sigma) \\
& \Leftrightarrow \frac{N_A}{N_B} < \left(\frac{a - \theta}{\theta + \gamma\sigma} \right) + \frac{K_A}{K_B} \left(\frac{a + \gamma\sigma}{\theta + \gamma\sigma} \right) \tag{A5}
\end{aligned}$$

Since $0 < a < 1$, the range of parameter values outside of the cone of diversification has increased with crime.

The calculation of the parameter values for which $L_{yA} = 0$ proceeds along identical lines, using Table 2: Without crime, the parameter range is in the cone of diversification if

$$\begin{aligned}
\left(\frac{N_B}{N_A} \right) &> \left(\frac{K_B}{K_A} \right) \frac{\theta(1 + \gamma\sigma)}{(\theta + \gamma\sigma)} - \frac{\gamma\sigma(1 - \theta)}{(\theta + \gamma\sigma)}. \quad \text{With crime, we are in the cone of diversification if} \\
\frac{N_B}{N_A} &> \frac{\theta(a + \gamma\sigma)}{a(\theta + \gamma\sigma)} \left(\frac{K_B}{K_A} \right) - \frac{\gamma\sigma(a - \theta)}{a(\theta + \gamma\sigma)}; \quad \text{the cone is smaller because } 0 < a < 1. \tag{A6}
\end{aligned}$$

Proof of Proposition 2c, part (i). Country A's share of total revenue is $\delta = \frac{pX_A + Y_A}{pX_{Tot} + Y_{Tot}}$,

thus Country A will consume δX_{Tot} and δY_{Tot} . Therefore the total trade in commodity X is $|X_A - \delta X_{Tot}|$, and the total trade in commodity Y is $|Y_A - \delta Y_{Tot}|$.

$$\begin{aligned}
\text{Thus total trade in commodity X} &= \left| \frac{pX_A + Y_A}{pX_{Tot} + Y_{Tot}} X_{Tot} - X_A \right| = \left| \frac{Y_A X_{Tot} - X_A Y_{Tot}}{pX_{Tot} + Y_{Tot}} \right| \\
&= \frac{1}{1 + \gamma} \left| \frac{1}{p} Y_A - \gamma X_A \right| \quad \left(\text{using equation (5f) } pX_{Tot} = \frac{1}{\gamma} Y_{Tot} \right).
\end{aligned}$$

Substituting the value of p from equation (12), $p = \frac{(1-\beta)k_{yA}^\beta}{(1-\alpha)k_{xA}^\alpha}$, we obtain:

$$\text{Total trade in commodity X} = \frac{k_{xA}^\alpha}{1+\gamma} \left(\frac{1-\alpha}{1-\beta} L_{yA} - \gamma L_{xA} \right)$$

$$\text{and using equation (22f):} = \frac{\gamma}{1+\gamma} K_A^\alpha \left(L_{xA} + \frac{1}{\theta} L_{yA} \right)^{-\alpha} \left(\frac{1}{\gamma\sigma} L_{yA} - L_{xA} \right)$$

For what parameter values has the trade in commodity X increased with the introduction of crime? That is, for what values is $|X_A^c - \delta X_{Tot}^c| > |X_A^{nc} - \delta X_{Tot}^{nc}|$? Substituting in the values from Table 2, and simplifying, this is equivalent to:

$$\Leftrightarrow \frac{c(1-\theta)}{a-\theta} > \left(\frac{c(1+\gamma\sigma)}{a+\gamma\sigma} \right)^\alpha$$

Substituting in the values of c , a , σ , and θ , the inequality becomes:

$$\frac{n-ns}{n-1} > \left(\frac{n-ns}{n-1+sn \left(\frac{\alpha+\gamma\beta}{1-\alpha+\gamma(1-\beta)} \right)} \right)^\alpha$$

Clearly this inequality holds as α approaches 1, and does not hold as α approaches zero. It is trivial to show that the right-hand side is monotonically decreasing¹³ in α , which is sufficient to prove that there is a threshold level α^* , for any given value of β . To complete the proof it is sufficient to notice that the right-hand-side is monotonically decreasing in β as well. \square

Proof of Proposition 2c, part (ii). The value of trade in Y is equal to the value of trade in X:

$$|\delta Y_{Tot} - Y_A| = p |\delta X_{Tot} - X_A|$$

$$\begin{aligned} \text{Total trade in commodity Y} &= \left| \frac{\gamma p X_A - Y_A}{1+\gamma} \right| \\ &= \left| \frac{1}{1+\gamma} \left(\left(\frac{1-\beta}{1-\alpha} \right) \frac{k_{yA}^\beta}{k_{xA}^\alpha} \gamma k_{xA}^\alpha L_{xA} \right) - k_{yA}^\beta L_{yA} \right| \\ &= \left| \frac{\sigma\gamma}{1+\gamma} \left(L_{xA} - \frac{1}{\sigma\gamma} L_{yA} \right) \left(\frac{K_A}{\theta L_{xA} + L_{yA}} \right)^\beta \right| \end{aligned}$$

Notice that these are essentially the same terms as in part (i), except that the power is now β instead of α . The rest of the proof follows the same lines as in part (i).

¹³ The logarithm of the inverse is increasing: $\frac{d}{d\alpha} \left(\alpha \log \left(sn \left(\frac{1+\gamma}{1-\alpha+\gamma(1-\beta)} \right) + 1 - \frac{1}{n-ns} \right) \right) > 0$

Proof of Proposition 2c, part (iii). Clearly if $\alpha=\beta\cong 1$, then crime increases the trade in X and Y. And if $\alpha=\beta\cong 0$, then crime decreases the trade in X and Y. Fix $\beta\cong 1$, then trade in good Y increases, and the inequality from the Proof of Proposition 2c(i) becomes

$$\frac{n - ns}{n - 1} > \left(\frac{n - ns}{n - 1 + sn \left(\frac{\alpha + \gamma}{1 - \alpha} \right)} \right)^\alpha. \text{ Again, there is a threshold value of } \alpha \text{ below which the}$$

inequality does not hold. Therefore there exist values of α and β for which trade in Y increases and trade in X decreases; by an identical argument, there exist values of α and β for which trade in X increases and trade in Y decreases. \square

Proof of Proposition 3. In autarky, country B just consumes its own output.

$$\begin{aligned} \text{Per-capita utility in autarky} &= \frac{X_B^{\frac{1}{\gamma+1}} Y_B^{\frac{\gamma}{\gamma+1}}}{N_B} \\ &= \frac{1}{N_B} \left(k_{xB}^\alpha L_{xB} k_{yB}^{\beta\gamma} L_{yB}^\gamma \right)^{\frac{1}{\gamma+1}} \quad (\text{superscripts for “autarky” omitted for now}) \\ &= \frac{1}{N_B} \left(k_{xB}^{\alpha+\beta\gamma} \theta^{-\beta\gamma} L_{xB} L_{yB}^\gamma \right)^{\frac{1}{\gamma+1}} \quad (\text{using equation 11}) \\ &= \frac{1}{N_B} \left(\left(\frac{K_B}{L_{xB} + \frac{1}{\theta} L_{yB}} \right)^{\alpha+\beta\gamma} \theta^{-\beta\gamma} L_{xB} L_{yB}^\gamma \right)^{\frac{1}{\gamma+1}} \quad (\text{using equation 22f}) \\ &= \frac{1}{N_B} \left(K_B^{\alpha+\beta\gamma} \left(\frac{\theta}{\theta + \gamma\sigma} \right)^{\alpha+\beta\gamma} \theta^{-\beta\gamma} \left(\frac{cN_B}{a + \gamma\sigma} \right)^{1-\alpha+\gamma(1-\beta)} (\gamma\sigma)^\gamma \right)^{\frac{1}{\gamma+1}} \end{aligned}$$

In the presence of trade, country B consumes its share of world output, where the share is

$$\text{determined by the value of B’s output at world prices: } \delta = \frac{pX_B + Y_B}{pX_{Tot} + Y_{Tot}}.$$

$$\begin{aligned} \text{Per-capita utility in the presence of trade} &= \frac{(\delta X_{tot})^{\frac{1}{\gamma+1}} (\delta Y_{tot})^{\frac{\gamma}{\gamma+1}}}{N_B} \\ &= \frac{\delta}{N_B} X_{tot}^{\frac{1}{\gamma+1}} Y_{tot}^{\frac{\gamma}{\gamma+1}} \\ &= \frac{1}{N_B} \left(\frac{pX_B + Y_B}{(\frac{1}{\gamma} + 1)Y_{Tot}} \right) (p\gamma)^{\frac{-1}{\gamma+1}} Y_{tot} \quad (\text{using equation 5f, } pX_{Tot} = \frac{1}{\gamma} Y_{Tot}) \end{aligned}$$

$$\begin{aligned}
&= \frac{1}{N_B} \left(\frac{\gamma}{\gamma+1} \right) (pk_{xB}^\alpha L_{xB} + k_{yB}^\beta L_{yB}) (p\gamma)^{\frac{-1}{\gamma+1}} \\
&= \frac{1}{N_B} \left(\frac{\gamma}{\gamma+1} \right) k_{xB}^\alpha \left(L_{xB} + \frac{1}{\sigma} L_{yB} \right) (\sigma \theta^{-\beta} k_{xB}^{\beta-\alpha})^{\frac{\gamma}{\gamma+1}} \gamma^{\frac{-1}{\gamma+1}} \quad (\text{using equation 11 and 12}) \\
&= \frac{1}{N_B} \frac{\gamma^{\frac{\gamma}{\gamma+1}}}{\gamma+1} \left(L_{xB} + \frac{1}{\sigma} L_{yB} \right) \left(\sigma^\gamma \theta^{-\beta\gamma} \left(\frac{K_B}{L_{xB} + \frac{1}{\theta} L_{yB}} \right)^{\alpha+\beta\gamma} \right)^{\frac{1}{\gamma+1}} \quad (\text{using 22f})
\end{aligned}$$

Utility in autarky > Utility under trade if and only if

$$\begin{aligned}
\left(\frac{\theta}{\theta + \gamma\sigma} \right)^{\alpha+\beta\gamma} \left(\frac{cN_B}{a + \gamma\sigma} \right)^{1-\alpha+\gamma(1-\beta)} &> (\gamma+1)^{-\gamma-1} \left(L_{xB}^t + \frac{1}{\sigma} L_{yB}^t \right)^{\gamma+1} \left(L_{xB}^t + \frac{1}{\theta} L_{yB}^t \right)^{-\alpha-\beta\gamma} \\
\left(\frac{cN_B}{a + \gamma\sigma} \right)^{1+\gamma} &> (\gamma+1)^{-\gamma-1} \left(L_{xB}^t + \frac{1}{\sigma} L_{yB}^t \right)^{\gamma+1} \left(\frac{K_A + K_B}{K_B} \left(\frac{N_B}{N_A + N_B} \right) \right)^{\alpha+\beta\gamma} \\
1 &> \left[\frac{K_B}{K_A + K_B} \left[\frac{N_A + N_B}{N_B} + \frac{\left(\frac{N_A}{N_B} - \frac{K_A}{K_B} \right) \left(\frac{\theta}{\sigma} - 1 \right) (a + \gamma\sigma)}{(a - \theta)(1 + \gamma)} \right] \right]^{\gamma+1} \underbrace{\left(\frac{K_A + K_B}{K_B} \left(\frac{N_B}{N_A + N_B} \right) \right)^{\alpha+\beta\gamma}}_{<1}
\end{aligned}$$

A sufficient condition for this inequality to be satisfied is if the first bracket is less than 1:

$$\begin{aligned}
\text{If } 1 &> \frac{K_B}{K_A + K_B} \left[\frac{N_A + N_B}{N_B} + \frac{\left(\frac{N_A}{N_B} - \frac{K_A}{K_B} \right) \left(\frac{\theta}{\sigma} - 1 \right) (a + \gamma\sigma)}{(a - \theta)(1 + \gamma)} \right] \\
\Leftrightarrow \frac{(K_B N_A - K_A N_B) \left(1 - \frac{\theta}{\sigma} \right) (a + \gamma\sigma)}{(a - \theta)(1 + \gamma)} &> K_B N_A - K_A N_B \\
\Leftrightarrow \left(1 - \frac{\theta}{\sigma} \right) (a + \gamma\sigma) &> (a - \theta)(1 + \gamma)
\end{aligned}$$

Substituting in the values of a, σ , and θ :

$$\begin{aligned}
\Leftrightarrow \left(\frac{\beta - \alpha}{\beta} \right) \left((n-1) \left[1 + \frac{\gamma(1-\beta)}{1-\alpha} \right] + sn \left[\frac{\alpha + \gamma\beta}{1-\alpha} \right] \right) &> (n-1) \left(\frac{\beta - \alpha}{\beta(1-\alpha)} \right) (1 + \gamma) \\
\Leftrightarrow s &> \frac{n-1}{n} \quad \square
\end{aligned}$$

Proof of Proposition 4(a). Industry X is relabeled “tourism.” Industry X can only operate in the low-crime environment. Then Proposition 4(a) follows directly from the proof of Proposition 1(c).

As trade opens up between countries A and B, and their crime rates begin to diverge, all of the tourism moves out of country B. As we showed in Proposition 1(c), employment in country B satisfies: $cN_B = L_{yB}$.

We show that crime is (weakly) higher in country B than it would be if the industry could operate in both locations:

- If the parameter values are such that country B would be outside of the cone of diversification anyway, the outcome is unchanged (i.e. only industry Y exists in country B).
- If the parameter values are such that country B would be within the cone of diversification if tourism could operate in both countries (i.e. it would be the case that $cN_B = aL_{xB} + L_{yB}$; we label this case “0” for convenience), we compare actual employment to what it would be if tourism could operate in B:

$$\frac{L_{yB}}{N_B} = c < \frac{L_{xB}^0 + L_{yB}^0}{N_B} = c + (1-a) \frac{L_{xB}^0}{N_B}$$

This also leads to less of industry Y in Country A, which further lowers crime, according to Figure 1.

Proof of Proposition 4(b). Now suppose that industry Y is “tourism”, the capital-intensive industry. Now as the crime rates start to diverge, industry Y moves to country A. In country A: $cN_A = L_{yA}$.

Now we need to compare the crime rate in A to the crime rate in B, to check whether A is still the low-crime location. There are two possible cases:

- If both industries are operating in B: employment satisfies $cN_B = aL_{xB} + L_{yB}$.
Then crime is higher in country A: $\frac{L_{yA}}{N_A} = c < \frac{L_{xB} + L_{yB}}{N_B} = c + (1-a) \frac{L_{xB}}{N_B}$
- If only industry X is operating in B (it will never be the case that neither location produces X): $L_{xB} = \frac{c}{a} N_B$ and therefore $\frac{L_{yA}}{N_A} = c < \frac{L_{xB}}{N_B} = \frac{c}{a}$.

So A becomes the high-crime environment. But then tourism shifts to country B, and B becomes the high-crime environment, and so on. There is no stable equilibrium. □

6. References

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FIGURE 1
Employment and the constraint imposed by crime

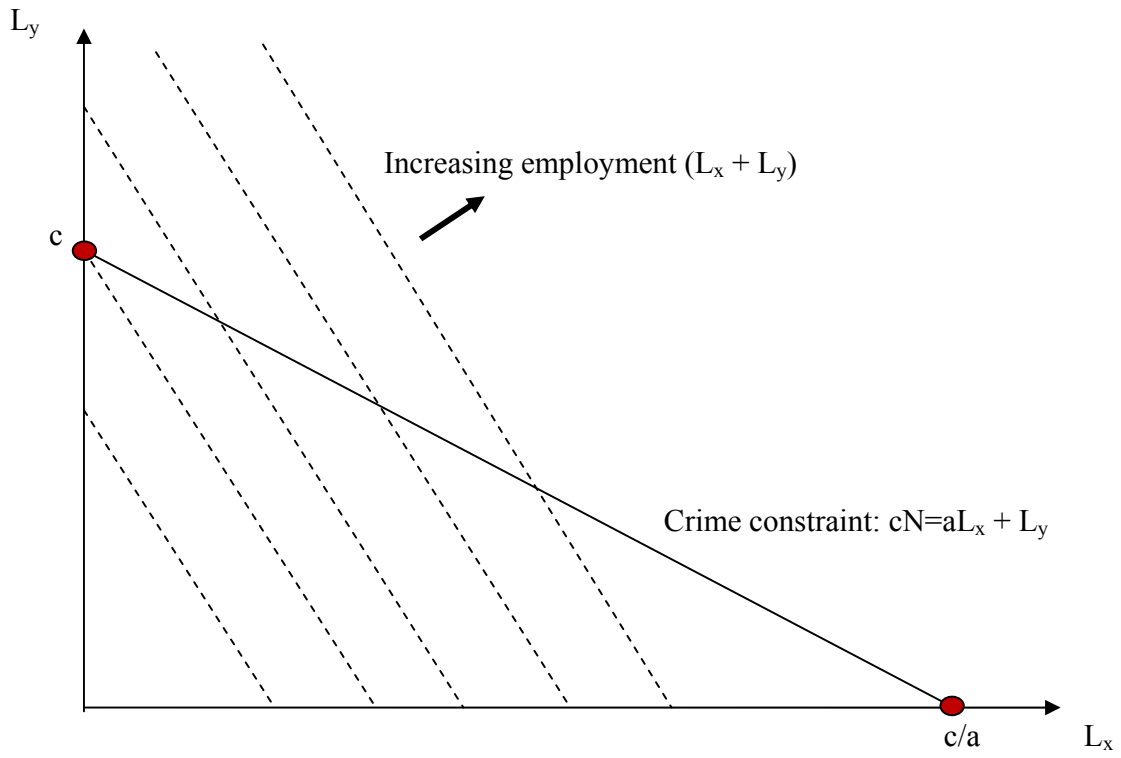


TABLE 2
Labor allocation under autarky and under trade (in the cone of diversification)

We adopt a change of variables, for visual clarity:

$$\theta = \frac{\alpha(1-\beta)}{(1-\alpha)\beta} \quad \text{and} \quad \sigma = \frac{1-\beta}{1-\alpha} \quad \text{therefore} \quad 0 < \theta < \sigma < 1$$

Autarky, no Crime	Trade, no Crime
$L_{xA} = \frac{N_A}{1+\gamma\sigma}$	$L_{xA} = \frac{K_A}{K_A + K_B} \left[\frac{N_A + N_B}{1+\gamma\sigma} + \frac{N_A \frac{K_B}{K_A} - N_B}{1-\theta} \right]$
$L_{yA} = \frac{N_A \gamma\sigma}{1+\gamma\sigma}$	$L_{yA} = \frac{K_A}{K_A + K_B} \left[\frac{(N_A + N_B)\gamma\sigma}{1+\gamma\sigma} - \frac{\left(N_A \frac{K_B}{K_A} - N_B \right) \theta}{1-\theta} \right]$
$L_{xB} = \frac{N_B}{1+\gamma\sigma}$	$L_{xB} = \frac{K_B}{K_A + K_B} \left[\frac{N_A + N_B}{1+\gamma\sigma} + \frac{N_B \frac{K_A}{K_B} - N_A}{1-\theta} \right]$
$L_{yB} = \frac{N_B \gamma\sigma}{1+\gamma\sigma}$	$L_{yB} = \frac{K_B}{K_A + K_B} \left[\frac{(N_A + N_B)\gamma\sigma}{1+\gamma\sigma} - \frac{\left(N_B \frac{K_A}{K_B} - N_A \right) \theta}{1-\theta} \right]$
Autarky, Crime	Trade, Crime
$L_{xA} = \frac{cN_A}{a+\gamma\sigma}$	$L_{xA} = \frac{cK_A}{K_A + K_B} \left[\frac{N_A + N_B}{a+\gamma\sigma} + \frac{N_A \frac{K_B}{K_A} - N_B}{a-\theta} \right]$
$L_{yA} = \frac{cN_A \gamma\sigma}{a+\gamma\sigma}$	$L_{yA} = \frac{cK_A}{K_A + K_B} \left[\frac{(N_A + N_B)\gamma\sigma}{a+\gamma\sigma} - \frac{\left(N_A \frac{K_B}{K_A} - N_B \right) \theta}{a-\theta} \right]$
$L_{xB} = \frac{cN_B}{a+\gamma\sigma}$	$L_{xB} = \frac{cK_B}{K_A + K_B} \left[\frac{N_A + N_B}{a+\gamma\sigma} + \frac{N_B \frac{K_A}{K_B} - N_A}{a-\theta} \right]$
$L_{yB} = \frac{cN_B \gamma\sigma}{a+\gamma\sigma}$	$L_{yB} = \frac{cK_B}{K_A + K_B} \left[\frac{(N_A + N_B)\gamma\sigma}{a+\gamma\sigma} - \frac{\left(N_B \frac{K_A}{K_B} - N_A \right) \theta}{a-\theta} \right]$