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Abstract

Illegal immigration and border enforcement in the United States have increased concomitantly for over thirty years. One interpretation is that U.S. border policies have been ineffective. We offer an alternative view, extending the current immigration-enforcement literature by incorporating both the practice of people smuggling and a role for non-wage income into a two- country, dynamic general equilibrium model. We state conditions under which two steady state equilibria exist: one with a low level of capital and high amount of illegal immigration and the other with a high level of capital, but relatively little migration. We then analyze two shocks: a positive technology shock to smuggling services and an increase in border enforcement. In the low-capital steady state, the capital-labor ratio declines with technological progress in smuggling, while illegal immigration increases. In the high-capital steady state, a technology shock causes the capital-labor ratio to rise while the effect on migration is indeterminate. We show that an increase in border enforcement is qualitatively equivalent to a negative technology shock to smuggling. Finally, we show that a developed country would never chose small levels of border enforcement over an open border. Moreover, a high level of border enforcement is optimal only if it significantly decreases capital accumulation. In addition we provide conditions under which an increase in smuggler technology will lead to a decline in the optimal level of enforcement.

JEL: E61, F22, J61, O15

Keywords: Smuggling, Illegal Immigration, Border Enforcement, Economic Growth

1 Introduction

Illegal immigration has been on the rise in the United States since the early 1970s.[1] Although immigrants come to the United States from many different countries, almost one-half of illegal immigrants are from Mexico. The U.S. government's response to the rise in Mexico-U.S. illegal migration has been to steadily increase border enforcement along the southwest border in the form of more border patrol agents and better detection technology. Figure 1 illustrates the dramatic increase in both illegal alien apprehensions and border patrol linewatch hours over the past thirty years.[2] Given that illegal immigration and border enforcement have increased concomitantly for over thirty years, it is unclear whether border control policies are having the desired deterrent effect.[3]

An important reason why illegal border crossings continue despite tighter enforcement is a growing migrant smuggling industry. There is substantial evidence that migrants have turned increasingly to smugglers as border control has tightened.[4] In Mexican survey data, a majority of undocumented immigrants report using the help of a smuggler, as illustrated in Figure 2. More intense smuggling efforts may partly account for the persistent positive correlation between border enforcement and illegal immigration. Evidence also suggests that as smuggler usage has increased, smuggling methods have also become more sophisticated.[5]

Although there is a significant literature dealing with immigration and border enforcement, none of the literature considers the interaction between enforcement and smuggling: an important omission in view of the evidence. Ethier (1986) offered the first analysis of border enforcement, investigating the impact of two distinct policy instruments — interdiction and inspection — on equilibrium outcomes.[6] Ethier provides conditions under which

[1] Over the last decade, net inflows of undocumented immigrants are estimated at 500,000 per year, while the stock of illegals is currently estimated at between 8.7 and 10.9 million (Costanzo *et al.* (2001).)

[2] Linewatch hours — border patrol man-hours — accounts for the bulk of resources spent on border enforcement. Linewatch apprehensions are a count of the number of migrants caught illegally crossing the border. Changes in apprehensions are a useful indicator for changes in the number of illegal immigrants attempting crossings into the United States. Apprehensions are less useful in estimating the number of immigrants since many migrants are caught more than once. See Warren (1995).

[3] See Warren (1995).

[4] See United States General Accounting Office (2000) report on increased alien smuggling. See also Singer and Massey (1997) for empirical evidence that increased linewatch hours raise the probablity that an undocumented migrant hires a "coyote."

[5] Smugglers increasingly study border patrol practices and use information on less-patrolled areas, shift changes and the placement of motion detectors and cameras to improve their success rates. See Spener (2001) for a detailed description of how smugglers operate in south Texas.

[6] Current U.S. policy prioritizes interdiction of aliens along the border. Inspection policy refers to such enforcement mechanisms as sanctions on employers that hire undocumented workers.

host-country citizens would prefer some positive quantity of each. Bond and Chen (1987), and Yoshida (1998) all discuss the optimal level of inspection in models that allow for labor and/or capital mobility but do not allow for smuggling.

Recently, researchers have put forth empirical evidence related to border enforcement and illegal immigration. For example, Hanson *et al.* (1999) have presented evidence on the effects of tighter enforcement on wages along the United States-Mexico border. They find no impact of enforcement on wages in U.S. border states, suggesting enforcement may not be deterring illegal immigrants and hence not "protecting" U.S. workers from the downward pressure on wages.[7]

The purpose of this paper is to extend the immigration-enforcement literature by incorporating the practice of people smuggling into a two-country, dynamic general equilibrium model.[8] Faced with an influx of migrants, the host-country government devotes resources to limit immigration through tighter border control. Migrants, in turn, have to devote more time to border crossings and consequently spend less time working. A market for smuggler's services exists whereby a migrant can enlist a smuggler to expedite the border crossing and minimize lost work time. We examine the interaction between smugglers, migrants, and the host government in a dynamic setting.

We are particularly interested in the answers to three questions. First, how does technological progress in the smuggling industry affect the level of migration and capital accumulation? Second, do changes in border enforcement affect the level of migration, capital accumulation, and smuggling activity? Third, is the optimal level of enforcement sensitive to technological progress in the smuggling industry? By explicitly modeling the smuggling industry, we study the issue of optimal border enforcement in a richer economic environment. Moreover, by modeling the savings behavior of immigrants in the host country, our setup generalizes the existing literature in which immigrants only contribute to the quantity of labor. These models focus on low-skilled immigrants that lower host-country wages by reducing the capital-labor ratio. In our setup, greater immigration does not necessarily drive

[7]One reason why enforcement has had little deterrent effect is that there is typically no penalty for committing 'entry without inspection,' besides being returned to one's country of origin. For Mexicans, this is a brief trip back across the border. For more studies on the efficacy of border enforcement, see Espenshade (1994), Donato *et al.* (1992), and Orrenius (2001). Another vein of the immigration-enforcement literature explores the role of intergenerational conflict in models where agents vote on the desired number of immigrants (level of enforcement); see, Dolmas and Huffman (2001a,b).

[8]Our work is most closely related to Ethier's interdiction policy; that is, border enforcement embodies the resources devoted to impeding illegal migration. This is the most direct interface between the smuggler's efforts and border policy, though certainly internal enforcement policies would also affect equilibrium outcomes.

down equilibrium wages because these workers contribute positively to both the labor and capital stock.[9]

In this paper, we focus on the properties of steady state equilibria. Our economy may have multiple steady state equilibria (up to three steady states). In our analysis, we focus on the case in which there exists two steady state equilibria; one is associated with a high capital-labor ratio and a small amount of migration and the other has a low capital-labor ratio and greater migration.

Our results can be summarized as follows. First, we show that the host country's steady state capital-labor ratio is positively (negatively) related to smugglers' level of productivity in the high- (low-) capital steady state. When smugglers are more efficient, border-crossing frictions are reduced, and migrants spend less time evading enforcement on the border. In the low-capital steady state, the decrease in crossing time increases the return to migrating and as a result more migrants choose to cross the border. Greater migration will increase savings and the capital stock, but not as much as the increase in migration, thereby lowering the capital-labor ratio. In the high-capital steady state, the impact on migration is ambiguous. Greater capital results in an increase in the wage and hence savings for old age, while a greater capital level also reduces the marginal product of capital, thereby decreasing the returns to saving. Thus, equilibrium migration depends on which of these countervailing forces is greater.

Second, we examine the effect of a change in the level of border enforcement. Border enforcement is funded through a lump-sum tax paid by young native, host-country workers. The effect of an increase in the lump-sum tax is to decrease (increase) the level of the steady state capital stock while rendering the level of migration ambiguous (lower) in the high- (low-)capital steady state. The intuition for these results is completely analogous to the case where smuggler's productivity decreases.

Lastly, we explore the case where the government actively chooses the optimal level of border enforcement, conditional on all other individuals' decisions. The optimal level of border enforcement is chosen so as to maximize the welfare of native host citizens. We show that developed countries would never optimally choose low levels of enforcement relative to no enforcement. In addition, we derive sufficient conditions under which developed countries would choose to never enforce the border. Thus, our results indicate that border enforcement

[9] There is a extensive literature on migration determinants beginning with the seminal work of Sjaastad (1962) and Harris and Todaro (1970). More recent work includes Borjas (1987), Massey and Espinosa (1997), and Markusen and Zahniser (1999). Simon (1999) examines the economic impacts stemming from immigration. See also Borjas (1994) and Friedberg and Hunt (1995) for an overview of the impact literature.

is not a certainty in developed countries. For border enforcement to be welfare maximizing, host-country taxes must induce a large enough decline in the capital stock. Finally, we examine the impact of technological advances in the smuggling industry on the optimal level of enforcement. We state conditions under which advances in smuggling lead to the host country reducing the amount of enforcement.

We investigate these issues in the context of a two-country, overlapping generations model economy. The home country is populated by potential migrants and smugglers while the host country has only non-migrant workers. Workers in both countries are identical with respect to labor endowments, preferences, and job skills. Production in the host economy is characterized by a standard Diamond (1965) neoclassical production function while the home country is characterized by self-employment. Capital is not mobile between the two countries although, obviously, labor is.

In the home country, potential migrants choose the fraction of time to spend working at home relative to the fraction spent crossing the border and working in the host country. Because all home-country workers are identical, one could equivalently interpret the equilibrium outcome as the fraction of workers that migrate. Wages earned in the home country are saved via a simple storage technology, while income earned in the host country is saved via capital in the host country. Although capital (savings) is not mobile between countries, the consumption good return from savings is mobile. The decision to migrate rests crucially on the overall return from saving (inclusive of all migration costs) in either country. One key cost of migrating is the productive time lost while crossing the border and evading border enforcement. Here, labor-smuggling services play a useful role. A fraction of the home-country's agents are endowed with a smuggling technology. Smugglers divide their labor endowment between research and development of new border-crossing methods and actually arranging trips across the border. By devoting some of their labor endowment to research, smugglers will endogenously respond to changes in the level of border enforcement.

Host country natives inelastically supply labor to the production process, pay lump-sum taxes, save in the form of capital, and consume only the product produced in the host country. There exists a government in the host country whose sole objective is to provide border enforcement services. Initially we consider the government's enforcement decisions to be exogenously set. Later in the paper we allow for the government to choose taxes (and hence enforcement) so as to maximize the well being of the host-country natives.

The remainder of the paper is arranged as follows. The basic model is outlined in Section 2 while the conditions that must be satisfied by a competitive equilibrium are stated in section 3. Section 4 solves for steady state equilibrium and explores the impact of changes in enforcement and smugglers' productivity on the steady state equilibria. Section 5 discusses the optimal level of border enforcement while section 6 concludes.

2 The Model

We consider a world consisting of two countries: a home country, from which individuals may choose to emigrate, and a host country, to which individuals immigrate and from which there is no emigration. The economies of both countries are characterized by a standard two-period lived, overlapping generations model with production. Time is discrete and indexed by $t = 0, 1, 2, ...$ In both countries, each generation is composed of a continuum of individuals having unit mass.[10] All individuals, regardless of their country of origin, are identical with respect to their preferences and endowments; they are endowed with one unit of labor when young and nothing when old, and value only old age consumption.[11] In addition, each country has an initial old generation who possess an initial capital endowment.

2.1 Home Country

The home country is characterized by two classes of individuals: migrants and smugglers. Smugglers work only in the smuggling industry while migrants divide their time between home production and host-country production. Migrant production in the home country is characterized by self-employment. It is assumed that migrants produce a single homogenous final good, which is produced and saved in the migrant's first period of life, and then consumed when old. The only input in the production process is labor, and goods are produced according to the decreasing returns to scale production function $F(\mu_t) = A \ln(1 + \mu_t)$, where μ_t represents the quantity of labor supplied by migrants in home production.[12]

[10] There is no loss in generality by assuming that the population of the two countries are identical.

[11] Ethier (1986) suggests that a good theory of migration should consider the migration of skilled vs. unskilled workers. Since our primary emphasis is on understanding the interrelationship between migrants, smugglers and border enforcement, we abstract from the issue of skill level in this paper.

[12] Although each migrant is self employed, we assume that they produce a homogenous product: an example of this would be agricultural products. The production function utilizing labor as the only input was chosen in an attempt to capture the real world fact that often it is the low skilled workers who are migrating to the foreign country and any self-employment opportunities they have would not be capital intensive.

2.1.1 Migrant's Problem

A fraction γ of individuals within any given generation are potential migrants. Each generation of migrants is endowed with one unit of labor when young and nothing when old. There is no initial old generation of migrants. Since only old-age consumption is valued, this labor is supplied inelastically when young. The migrant must decide what fraction of her labor time, μ_t, to spend working in the home country and what fraction, $1 - \mu_t$, to spend crossing the border and working in the foreign country.[13] However, merely deciding to go and work in the host country does not guarantee that the migrant will be successful in her attempt(s) to cross the border. Thus, the fraction of time spent emigrating from the home country, $1 - \mu$, is further divided into two activities; time spent actually working in the foreign country $M(\cdot)$ and time spent crossing the border, $1 - M(\cdot)$.

The amount of time used in crossing the border depends on the level of border enforcement implemented by the host country, e_t, and the amount of services, q_t, a migrant obtains from smugglers. Thus, the amount of time spent working in the host country is a fraction of the time allotment not spent working in the home country; that is, $M(q_t, e_t)(1 - \mu_t)$, where $0 \leq M(q_t, e_t) \leq 1$. Conversely, the time lost crossing the border is given by $[1 - M(q_t, e_t)](1 - \mu_t)$. The level of border enforcement, e_t, is taken as given by the migrant. It is assumed that if $e_t = 0$, that is, there is no border enforcement, then $M(q_t, 0) = 1$ for all $q_t \geq 0$.[14] In addition we assume that $0 > M_e > -\infty$. Thus, an increase in the level of enforcement reduces the amount of time spent working in the host country.

Since crossing the border is time consuming, smugglers exist to reduce the crossing time. At date t, migrants can purchase a quantity q_t of smuggling services, taking the price, p_t, as given; where p_t is measured in units of the home-country production good. It is assumed that the greater the quantity of smuggling services obtained, the less time is used to cross the border, that is, $M_q > 0$, and that there are decreasing returns to additional units of smuggling services, $M_{qq} < 0$. In addition, it is assumed that $M_q < \infty$ and $0 < M(0, e_t,) \leq 1$.[15]

Migrants who work in the home country earn a wage w_t per unit of time spent in home production. This income is saved via a simple storage technology in the home country. For every unit of output saved at time t, the migrant receives x units of consumption good at

[13] Bencivenga and Smith (1997) analyze migration from rural to urban areas using an overlapping generations model. In their setup, the risk to migrating was the chance of unemployment in the urban labor market. In our setup, labor time lost during the migration represents the cost to migrating.

[14] Open borders correspond to perfect labor mobility.

[15] The latter assumption implies that even without the aid of the smuggler, a migrant will eventually cross the border and spend some time working in the foreign country.

date $t+1$. Migrants who are successful in crossing the border earn a real wage w_t in the host country and save in the host country via capital accumulation. Thus, income earned at date t, earns a gross real return r_{t+1} at date $t+1$, where r_{t+1} is the rental rate on capital in the host country.[16] Finally, we assume that migrants spend their retirement in the host country.[17] Thus the proceeds from any savings in the home country must be transported across the border. We assume that this is costly and that the fraction δ of home consumption goods is used up in this process.

We can formally write the migrant's problem as

$$\max_{\mu_t, q_t} U(c_{t+1}) \tag{MP}$$

subject to

$$\begin{aligned} c_{t+1} &= x(1-\delta)\left[F(\mu_t) - p_t q_t\right] + r_{t+1}\left[M(q_t, e_t)(1-\mu_t) w_t\right], \qquad (1) \\ \mu_t w_t &\geq p_t q_t, \text{ and} \\ 0 &\leq \mu_t \leq 1. \end{aligned}$$

Equation (1) is the sum of home- and host-country income inclusive of all costs while the second equation requires that the cost of smuggler services purchased cannot be greater than the income the migrant has on hand when crossing the border.[18] We assume that $U(c_{t+1})$ satisfies all the standard conditions necessary for an interior solution; namely $U(0) = 0$ and $U'(c_{t+1}) > 0$.

The solution to the migrant's maximization problem is characterized by the following two equations:

$$(1-\delta) x F'(\mu_t) = r_{t+1} w_t M(q_t, e_t)$$

and

$$x(1-\delta) p_t = r_{t+1} w_t M_q(q_t, e_t)(1-\mu_t).$$

[16] We assume that savings (capital) is immobile between countries. Thus, the individual must save in the country in which the income is earned. For a model which allows savings across countries via stock ownership, see Lundborg and Segerstrom (2002).

[17] Although the prospect of return migration is an important aspect of real world illegal immigration, since our focus is directed toward the effect of enforcement on smugglers and migration and vice versa we ignore the possibility of return migration.

[18] Thus, we are requiring up-front payment for smuggling services and ruling out the possibility of borrowing against future earnings or indentured servitude as means of payment.

Rearranging terms yields

$$\frac{F'(\mu_t)}{w_t} = \frac{r_{t+1}M(q_t, e_t)}{x(1-\delta)} \tag{2}$$

and

$$p_t = \frac{M_q(q_t, e_t)(1-\mu_t)w_t}{[M(q_t, e_t)]}. \tag{3}$$

Equation (2) indicates the trade-off associated with migrating; the wage ratio in the two countries must equal the ratio of real returns, taking into account time spent crossing the border and the transportation costs associated with moving final goods from home-to-host country. The second condition equates the marginal cost of the smuggling service to the marginal income gain from using smuggling services, where the marginal gain in time working in the host-country labor market is measured by the product $M_q(q_t, e_t)(1-\mu_t)$.

2.1.2 Smuggler's Problem

In each generation, a fraction, $1-\gamma$, of the home-country population are smugglers. Like migrants, smugglers live for two periods. In contrast, smugglers are restricted to only producing smuggling services and may not migrate or work in the home country production sector. When young, smugglers are endowed with one unit of labor that they supply inelastically. As with migrants, smugglers value only old age consumption and are retired when old. Thus they consume the gross return from investing their savings in the same simple storage technology as migrants, which earns a return x in period $t+1$ for every unit of saving invested at time t. Finally, there exists an initial old generation of smugglers who possess smuggling capital a_0.

A smuggler's unit of labor is divided between two activities when young: accumulating smuggling capital (research and development), a_t, and selling border crossings. For a smuggler, these operations are ordered sequentially; that is, the young smuggler first accumulates smuggling capital by crossing people, then begins selling services. We think of smuggling capital as the knowledge of methods and means for circumventing the border enforcement of the host country. The smuggler uses the remaining time endowment to arrange border crossings. We let d_t represent the fraction of time which smugglers devote to accumulating smuggling capital and $(1-d_t)$ be the fraction of time devoted to arranging crossings.[19]

[19] One can think of the smuggler's first period as divulged into two subperiods. The initial subperiod of his young life is spent as an apprentice to an old smuggler, who has institutional knowledge about crossing and enforcement. In this subperiod, the smuggler undertakes the actual process of crossing migrants over the border. While the apprenticeship provides no income, it does provide the required knowledge to make income-generating arrangements for migrant crossings during the second subperiod.

When determining the amount of time to devote to accumulating smuggling capital in period t, we assume that the quantity of smuggling capital (knowledge) previously acquired by all past generations, a_{t-1}, is available to the current generations of smugglers; that is, there is no depreciation of smuggling capital. We let the function $g(d_t, a_{t-1}; z_t)$ represent the process by which time devoted to capital accumulation is transformed into smuggler's capital. The variable z_t represents an exogenous technology parameter. Thus we have

$$a_t = g(d_t, a_{t-1}; z_t) \tag{4}$$

where $0 \leq d_t \leq 1$. We assume that $g(d_t, a_{t-1}; z_t)$ has the following properties: $g_d, g_a, g_z > 0$ and $g_{dd} < 0$. Finally, let $g(0, a_{t-1}; z_t) = 0$, that is, a smuggler must devote some time to actually smuggling people over the border in order to develop knowledge about effective crossing methods and techniques.[20]

The smuggler arranges migration services in a perfectly competitive environment.[21] As such, the representative smuggler takes the price of smuggling services, p_t, as given. In addition, the smuggler also takes as given the level of enforcement, e_t, in period t. Finally, it is only the process of arranging for migrant crossings that generates income. To produce migration services, the smuggler must devote sufficient time to capital accumulation, so that he may overcome the anticipated level of enforcement. Formally, let the quantity of migration services supplied be given by

$$\begin{aligned} Q_t &= B\left[a_t - e_t\right](1 - d_t) \ \text{ for } a_t \geq e_t \\ &= 0 \text{ otherwise and} \end{aligned} \tag{5}$$

where $B > 0$ is a constant scale factor, $a_t - e_t$ is the effectiveness of the smuggling methods relative to enforcement methods, and $1 - d_t$ is the fraction of time devoted to selling migration

This is not unlike arrangements smugglers currently make on the U.S.-Mexican border. In practice, apprentice smugglers "run" the migrants across until they have been caught so many times (usually ten) that they risk prosecution if caught again. They then become coordinators and recruiters charged with getting clients for the new generation of runners.

[20] Alternatively, one could think of capital accumulation as simultaneously learning and improving upon existing crossing methods. Thus, it is as costly to copy methods as it is to develop them. In this case, there is no free riding as previous knowledge is not a common good once developed. In contrast, Segerstrom (1991) specifies a model in which research and development costs and copying costs are differentiated.

[21] Perfect competition may not be a completely accurate appraisal of the smuggling industry. For example, in parts of Mexico the smuggling industry is marked by local monopolies. Along the border, however, smuggling operations at popular crossing points are highly competitive..

services.

We can therefore write the smuggler's maximization problem as

$$\max_{d_t} U\left(c_{t+1}^s\right) \tag{CP}$$

subject to the constraints

$$\begin{aligned} s_t^s &= p_t Q_t = p_t B\left[a_t - e_t\right]\left(1 - d_t\right), \\ c_{t+1}^s &= x s_t^s, \text{ and} \\ a_t &= g\left(d_t, a_{t-1}; z_t\right) \\ a_t &\geq e_t, \end{aligned}$$

where c^s (s^s)denotes consumption (saving) by the smuggler. Given the interior solution guaranteed by the properties of the utility function, the efficiency condition for the smuggler is

$$x p_t B\left\{g_d\left(d_t, a_{t-1}; z_t\right)\left(1 - d_t\right) - \left[g\left(d_t, a_{t-1}; z_t\right) - e_t\right]\right\} = 0 \tag{6}$$

Equation (6) describes the smuggler's trade-off. The first term inside the brackets represents the marginal gain from capital accumulation while the second term inside the brackets represents the marginal cost of time allocated to capital accumulation — time not spent arranging migration services.

2.2 Host Country

All individuals in the host country are identical with respect to endowments and preferences. For simplicity and ease of exposition, individuals born in the host country do not emigrate to the home country. In each period, there is a single consumption good which individuals either consume or invest. The consumption good is produced using capital and labor inputs according to the constant returns to scale production function $F\left(K_t, L_t\right)$. Total labor, L_t, represents both host and migrant labor and K_t represents savings from both host and migrant workers from the previous period. Let $f\left(k_t\right)$ denote the intensive production function, where $k_t = K_t / L_t$ is the capital-labor ratio inclusive of those who immigrate to the host country. It is assumed that $f\left(k_t\right)$ is increasing, strictly concave, satisfies $f(0) = 0$, and that the standard Inada conditions hold. It is also assumed that capital used in the production process each period depreciates completely. Finally, the initial host-country old generation has an aggregate capital endowment of $K_0 > 0$, while subsequent generations have no endowments of either capital or final goods.

2.2.1 Host-Country Native's Problem

Individuals live for two periods and inelastically supply their one unit of labor when young. They take the real wage w_t as given. They also face a lump-sum tax, τ_t, to pay for the level of border enforcement erected by the host country. Since only old-age consumption is valued, they save their entire wage income net of taxes in the form of capital and earn the real rate of return, r_{t+1}, on their savings when old. Thus we can write the individual's problem as

$$\max_{s_t^n} U\left(c_{t+1}^n\right) \tag{FP}$$

subject to

$$\begin{aligned} s_t^n &= w_t - \tau_t, \text{ and} \\ c_{t+1}^n &= r_{t+1} s_t^n, \end{aligned}$$

where c^n (s^n) denotes the consumption (savings) of a native host-country citizen. Obviously, given that the wage rate and gross real return to saving is taken as given, the host individual's maximization problem is trivial.

2.2.2 Host-Country Government

The host-country government is assumed to engage in a single activity — border enforcement. To this end, all revenues generated through the lump-sum tax on host-country native workers is directed towards enforcement efforts.[22] We also assume that the government runs a balanced budget on a period by period basis. Therefore, total government expenditures will exactly equal tax revenue: $g_t = \tau_t$. For simplicity, we assume that the government sets the lump-sum tax in period zero and makes no subsequent changes to it.[23]

[22] Only host country natives pay the income tax in an effort to capture the fact that often times illegal immigrants fall below the radar when it comes to paying federal and state income taxes. Our results would not qualitatively change if both natives and migrants were taxed.

[23] In essence we assume that the government takes a passive role in determining the level of border enforcement. We allow for a more active (utility maximizing) government role in determining the level of border enforcement in section 5.

Let the function $h(\tau_t)$ denote the technology that transforms government taxes into border enforcement. More specifically, $h(\tau_t)$ transforms the units of the (host country) consumption good collected as taxes into a measure of the enforcement level,

$$h(\tau_t) = e_t.$$

The function $h(\tau_t)$ is assumed to have the following two properties: $h' > 0$ and $h(0) = 0$. In other words, greater tax revenue allows for greater border enforcement and that without any tax revenue, there is no enforcement at the border.

3 Equilibrium

Equilibrium requires that individuals and governments make optimal choices and that the following markets clear: the factor markets in both the home and host country, the goods markets (final goods and capital) in both countries, and the market for smuggler's services in the home country.

3.1 Factor Markets

We begin by characterizing equilibrium in the factor markets. At each date t, we assume that both labor and capital are traded in competitive markets in the host country. Thus, at time t the real wage, w_t, and the rental rate of capital, r_t, are both equal to their marginal products:

$$r_t = f'(k_t)$$

and

$$w_t = f(k_t) - k_t f'(k_t) \equiv w(k_t).$$

3.2 Goods Markets

We now characterize equilibrium in the product markets — consumption goods, capital goods, and migrant and smuggler services. As with the factor markets, all markets are assumed to be perfectly competitive.

In order for the market for migrant services to clear, the efficiency conditions (equations (2) and (3)) most hold. The market for smuggler's capital requires that equation (6) holds.

In order for the smuggler's services market to be in equilibrium, it must be the case that

$$\begin{aligned} q_t &= Q_t \\ &= B\left[a_t - e_t\right](1 - d_t). \end{aligned} \tag{7}$$

Finally, the goods market in the host country must also clear. However, the goods market clearing is equivalent to the market for investment and savings clearing. Thus it must be the case that

$$\begin{aligned} K_{t+1} &= w_t + \gamma M\left(q_t, e_t\right)(1 - \mu_t) w_t - \tau_t \\ &= w_t\left[1 + \gamma M\left(q_t, e_t\right)(1 - \mu_t)\right] - \tau_t \end{aligned} \tag{8}$$

where the first term inside the brackets on the right-hand side represents the savings from host-country natives and the second term represents the savings from migrants.

3.3 Equilibrium Law of Motion

We can now describe the evolution of the capital/labor ratio and migration patterns over time. However, it will be useful to first describe the relationship between the level of enforcement and the smuggler's decision on how to allocate his time.

It follows from equation (6), that a smuggler will chose d_t such that

$$g_d\left(d_t, a_{t-1}; z_t\right)(1 - d_t) - g\left(d_t, a_{t-1}; z_t\right) = -e_t. \tag{9}$$

Using the implicit function theorem we can write $d_t = d\left(e_t, a_{t-1}, z_t, \right)$. The following lemma describes the properties of $d\left(e_t, a_{t-1}, z_t, \right)$.

Lemma 1 *a) $d_e > 0$, b) for $g_a > g_{da}$, then $d_{a_{t-2}} < 0$ and c) for $g_z > g_{dz}$, then $d_z < 0$*

The results of Lemma 1 follow directly from differentiating equation (9). Parts (b) and (c) hold if $g\left(d_t, a_{t-1}; z_t\right)$ is separable in research time, previous smuggler's capital, and the technology shock or if these cross-partials are sufficiently small: an assumption we henceforth make. The intuition for this lemma is straightforward. Part (a) implies that an increase in border enforcement results in the smuggler allocating greater time to research and development in order to overcome the greater level of enforcement. For parts (b) and (c), an increase in the amount of prior smuggler capital or technology will lead to less research and development since for part (b) the effort necessary to overcome the level of border enforcement has been undertaken by previous generations of smugglers and for part (c) each unit of time spent in research and development yields a greater level of capital. Thus less time, d_t, is required to overcome the level of enforcement and greater time $(1 - d_t)$ can be spent arranging crossings (the source of second period consumption).

Using the results of Lemma 1, we can also characterize the effect that changes in enforcement and technology on the equilibrium quantity of smuggling services, q_t. Rewriting equation (7) we obtain

$$q_t = B \left\{ \left[g \left(d \left(e_t, a_{t-1}, z_t, \right) \right) - e_t \right] \left[1 - d \left(e_t, a_{t-1}, z_t, \right) \right] \right\}. \tag{10}$$

Again applying the implicit function theorem yields $q_t = q \left(e_t, a_{t-1}, z_t, \right)$. The properties of $q \left(e_t, a_{t-1}, z_t, \right)$ are described in the following lemma.

Lemma 2 *a)* $q_e < 0$, *b)* $q_a > 0$, *and c)* $q_z > 0$.

The results of Lemma 2 follow directly from differentiating equation (10) and using equation (9). The intuition is as follows. For part (a), greater enforcement leads to less smuggling activity, as smugglers devote greater time to learning about these new enforcement levels and thus less time actually arranging for crossings (part (a) of Lemma 1). For a given level of enforcement, smugglers with a higher level of accumulated knowledge (smuggler's capital)–part (b)–or better technology–part (c)– will choose to arrange for a greater number of illegal border crossings.

As the reader will see below, we use Lemmas (1) and (2) to characterize the equilibrium laws of motion in this economy. In addition, the results shed light on the smuggler's problem and the equilibrium quantity of smuggling. In particular, it is worth noting that smugglers sell less services, for instance, given an increase in border enforcement. Note that things do not stop there. Smugglers invest more time in the research and development phase, ultimately leading to accumulating more smuggling capital. We view this result as consistent with the anecdotal evidence that smugglers endogenously respond to more intense border patrols by putting efforts into finding new ways to avoid detection.

We can now condense the dynamics of the economy down to two equations. Substituting for the value of q_t, we can rewrite equation (8) as

$$K_{t+1} = w \left(k_t \right) \left\{ 1 + \gamma M \left[q \left(e_t, z_t \right), e_t \right] \left(1 - \mu_t \right) \right\} - \tau_t. \tag{11}$$

Writing $M[q(e_t, z_t), e_t]$ as $M(e_t, z_t)$, recall that the capital-labor ratio is defined as

$$\begin{aligned} K_{t+1} &= N_{t+1} k_{t+1} \\ &= \left[1 + \gamma M(e_{t+1}, z_{t+1}) \left(1 - \mu_{t+1}\right)\right] k_{t+1} \end{aligned}$$

Thus, substituting this last equation into equation (11) yields the first equilibrium law of motion:

$$k_{t+1} = \frac{w(k_t)\{1 + \gamma M(e_t, z_t)(1 - \mu_t)\} - \tau_t}{\left\{1 + \gamma M(e_{t+1}, z_{t+1}) \left(1 - \mu_{t+1}\right)\right\}}. \tag{12}$$

The second equation necessary to describe the economy is equation (2), which can be rewritten as

$$\frac{Ax(1-\delta)}{1+\mu_t} = f'(k_{t+1}) w(k_t) M(e_t, z_t) \tag{13}$$

Equations (12) and (13) completely describe the economy in terms of the migration decision in the home country and capital accumulation in the host country.

4 Steady State Equilibrium

We begin by analyzing steady state equilibria. Letting $k_t = k_{t+1} = k$, $\mu_t = \mu_{t+1} = \mu$, and $\tau_t = \tau$, we can rewrite the equilibrium laws of motion from the previous section as

$$k = w(k) - \frac{\tau}{1 + \gamma M(e, z)(1 - \mu)} \tag{14}$$

and

$$\frac{Ax(1-\delta)}{1+\mu} = f'(k) w(k) M(e, z). \tag{15}$$

To ascertain the number of steady states, it will be useful to know the properties of the above two equations. Differentiating equation (14) with respect to the level of the capital stock yields

$$1 - w'(k) = \frac{-\tau\gamma M(e, z)}{[1 + \gamma M(e, z)(1 - \mu)]^2} \frac{d\mu}{dk}$$

Since $-\tau\gamma M(e, z) / [1 + \gamma M(e, z)(1 - \mu)]^2 < 0$ and $w'(k) > 0$, the sign of $d\mu/dk$ depends on whether $1 - w'(k) \lesseqqgtr 0$. Let $\hat{k}$ be such that $w'\left(\hat{k}\right) = 1$, then we have

$$\frac{d\mu}{dk} > 0 \ \ for \ \ k < \hat{k}$$
$$\frac{d\mu}{dk} < 0 \ \ for \ \ k > \hat{k}$$
$$\frac{d\mu}{dk} = 0 \ \ for \ \ k = \hat{k}$$

Thus equation (14) has an inverted u-shape. Differentiating equation (15) yields

$$[f''(k)\, w(k) + f'(k)\, w'(k)]\, M(e,z) = \frac{-x(1-\delta)\, A}{[1+\mu]^2}\frac{d\mu}{dk}$$

Since $-x(1-\delta)\, A \big/ [1+\gamma\mu]^2 < 0$, the sign of $d\mu/dk$ depends on the sign of $f''(k)\, w(k) + f'(k)\, w'(k)$.

Assumption 1 (A1) *: For all $k > 0$, let $f''(k)\, w(k) + f'(k)\, w'(k) < 0$.*

This assumption holds, for example, for a Cobb-Douglas production technology in which capital's share of income is less than one half. Thus we have $d\mu/dk > 0$. It is also easy to show that $d^2\mu/dk^2 < 0$, and thus equation (15) is concave.

For a Cobb-Douglas production function, there are four generic possibilities regarding the number of steady states: 0, 1, 2, or 3 steady states. For the remainder of the paper, we restrict ourselves to a Cobb-Douglas production function and to examining the generic case of two steady state equilibria, where (k_H, μ_H) denotes the high-capital steady state and (k_L, μ_L) the low-capital steady state as represented in Figure 3.[24]

4.1 Comparative Statics

Given steady state equations (14) and (15), as depicted in Figure 3, it will be relatively straight forward to analyze the impact of a change in exogenous variables on the equilibrium steady state values of the capital stock and migration. The two variables of interest are a technology shock, z, to the smuggling capital accumulation process and a change in the host-country's level of border enforcement (which is equivalent to the government's tax policy, τ.)

[24] For the comparative statics which follow, the analysis is also relevant to the case where there exists a unique steady-state equilibria. In section 5 we allow for the government to actively choose the level of border enforcement and discuss conditions under which there exist multiple steady states.

4.1.1 Technology Shock

To ascertain the effect of a positive technology shock, it will first be useful to establish how such a shock will impact the crossing times for migrants, $M[q(e,z),e]$. From Lemma 2, we have $q_z > 0$, and thus it follows that $M_z = M_q q_z > 0$. For a fixed value of k, M is increasing in z. Thus, from equation (14), μ must increase to maintain equality. Figure 4 depicts this as an upward shift in equation (14). Using the same logic in equation (15), μ must decline in order to maintain equality, implying a downward shift of that equation in the graph.

Proposition 1 *An increase in the smuggler's technology, z, results in (i) an increase in the steady state value of capital-labor ratio and an indeterminate effect on migration in the high-capital equilibrium; (ii) a decline in the steady state value of the capital-labor ratio and an increase in migration in the low-capital equilibrium.*

The intuition behind this result is as follows. A positive technology shock makes smugglers more productive and hence raises the equilibrium level of smuggler services. For migrants this has the effect of decreasing the time spent crossing the border while increasing the time spent actually working in the foreign country. In the low-capital steady state, the decrease in crossing time increases the return to migrating and as a result more migrants choose to cross the border. Greater migration implies greater capital accumulation in the host country. However, the additional capital from migrants' savings is less than the increase in the number of workers migrating, and thus the level of the capital-labor ratio falls.

In the high-capital steady state, the decrease in crossing time also leads to an increase in wage income for migrants and this translates into greater savings and additional capital stock. With an increase in the capital-labor ratio, wages increase and the real return to savings decreases. Thus, the home-country agent's incentive to migrate is unclear; if the increase in wages outweighs the decrease in the rate of return on savings, the net affect would be to increase the overall return to migrating and we would expect to see greater migration until the overall returns from saving in both countries are equalized. Conversely, if the overall return to migrating fell, we would expect less migration.

4.1.2 Tax Policy

Next we consider the effect of the government's natural counter-measure to the smugglers' productivity shock — greater enforcement. In our model, an increase in enforcement requires an increase in tax revenues. Thus to analyze the effect of greater enforcement on steady states, we examine the impact of a change in taxes, τ, on the steady state values of the capital-labor ratio and the fraction of migrants' time spent working in the home market.

As with a technology shock, it will first be useful to note the impact that an increase in the tax payment has on migrant's crossing time. Formally, $M_\tau = M_q q_e e_\tau + M_e e_\tau$. With $e_\tau > 0$ and from Lemma 2, $q_e < 0$, the assumptions on the crossing function imply that $M_\tau < 0$. Thus, from equation (14), for a fixed value of k, μ must decrease to maintain equality. Figure 5 depicts this as a downward shift in equation (14). Using the same logic on equation (15), μ must increase in order to maintain equality, implying an upward shift in this equation. Thus, we have the following proposition.

Proposition 2 *An increase in border enforcement via an increase in taxes, τ, results in (i) a decrease in the capital-labor ratio and an indeterminate effect on migration in the high-capital steady state; and (ii) an increase in the capital-labor ratio and a decrease in migration in the low-capital steady state.*

The intuition is again easily summarized. An increase in the host-country's lump-sum tax leads to a tightening of border enforcement. This results in the crossing time experienced by migrants workers increasing. In the low-capital steady state, the increase in crossing time decreases the return to migrating and as a result fewer migrants chose to cross the border. Although the decrease in migrants lowers the overall quantity of savings, the decrease in the quantity of labor is even greater, resulting in an increase in the steady-state capital-labor ratio.

In the high-capital steady state, we observe a decline in the steady-state capital-labor ratio. This is the result of both decreased savings by host-country natives due to greater taxes and of a reduction in the number of migrants due to increased crossing times. Thus, the decline of the capital-labor ratio leads to lower wages and a higher real return to savings. The incentive to migrate is unclear; if the decrease in wages outweighs the increase in the rate of return on savings, the net effect would be to decrease the overall return to migrating and we would expect to see less migration until the overall returns from saving in both countries are equalized. Conversely, if the overall return to migrating rose, we would expect more migration.

5 Optimal Border Enforcement Levels

In this section, we analyze the host-country government's problem of choosing the level of border enforcement that maximizes its citizens welfare. Here, the government takes the actions of migrants and smugglers as given. As such, the solution is essentially a Nash equilibrium. Because there is a monotonic relationship between taxes and the intensity of border enforcement, the solution to the government's Nash problem is equivalent to solving for the welfare-maximizing level of lump-sum taxes. Proposition 2 is important in this exercise because the government must take the effect of changes in taxes into account when it solves the maximization problem. In addition, we examine how exogenous changes in the smuggling technology affect the government's choice of taxes. At some point, smuggling technology may build up to the point where open borders are the welfare-maximizing policy.

Ascertaining the optimal level of border enforcement is closely related to Ethier's (1986) analysis of the change in interdiction policy on host-country welfare. We delve a bit deeper into the mechanisms operating in Ethier's model. Ethier develops an elegant economic environment in which interdiction policy chiefly redistributes national (wage) income from skilled to unskilled workers. He then claims that interdiction policy, used alone, can probably not redistribute enough income to offset the cost of border enforcement.[25]

In contrast, our setup makes explicit decisions across countries and across factor inputs, thus generalizing Ethier's structure in two distinct ways. In our model economy, the chief tension arises because of both elements; illegal migrant workers make decisions based on two sources of income and they evaluate their options over both countries. Because migrant workers save in the form of capital in the host country, there is a trade-off between wages, which are positively related to capital, and the real return to savings, which is inversely related to capital. The tax burden faced by native workers will also affect the capital stock and hence the migration decision. Consequently, the question naturally arises as to whether there exists a positive level of taxes and border enforcement such that the resulting level of the capital stock and quantity of migration will provide for greater welfare than open borders. Finally, while developing a fairly general economic structure, our assessment is limited to the economic realm. Conditions that render border enforcement suboptimal in this model economy obviously ignore all the political considerations that go into such real world decisions.

Consider the host-country's citizens's problem. Let $k(\tau)$ represent the steady state equilibrium level of capital as a function of the tax level, which corresponds to simultaneously solving equation (14) and (15). If the government is interested in maximizing its citizens'

[25] Whereas Ethier finds non-zero border enforcement to be sub-optimal, both Ethier (1986) and Bond and Chen (1987) show that positive levels of internal enforcement (for example, fines on employers who hire illegal labor) can be welfare-maximizing for the host country.

well-being, then it solves the following problem:

$$\max_{\tau} U\left(c\right) \tag{GP}$$

subject to

$$c\left(\tau, z\right) = r\left(s - \tau\right) = f'\left(k\left(\tau, z\right)\right)\left[w\left(k\left(\tau, z\right)\right) - \tau\right]. \tag{16}$$

For a given z, differentiating equation (16) yields

$$c_{\tau} = k_{\tau}\left(\tau\right)\left\{f''\left(k\left(\tau\right)\right)\left[w\left(k\left(\tau\right)\right) - \tau\right] + f'\left(k\left(\tau\right)\right)w'\left(k\left(\tau\right)\right)\right\} - f'\left(k\left(\tau\right)\right). \tag{17}$$

Equation (17) identifies the basic trade-off facing the benevolent government. Taxes paid when young reduce consumption at the gross real return (the last term of equation (17). However, any potential benefit from greater enforcement (the first term of equation (17), should it be positive) depends on both the prevailing steady state (high or low capital) and also whether the changes in wage income or rental income are relatively larger for the given change in steady state capital. In the low-capital steady state, an increase in border enforcement results in a higher capital-labor ratio, meaning that the marginal benefit increases if and only if pre-tax wages increase at a fast enough rate to more than offset the decline the host country's gross real return. Conversely, in the high-capital steady state, higher taxes result in a lower capital-labor ratio. Thus, the marginal benefit of the tax increase requires that the gross real return increases at a fast enough rate to more than offset the decline in pre-tax wages.

It is not analytically possible to show that there exists a $\tau > 0$ which satisfies both equation (17) and $c_{\tau\tau}\left(\tau\right) < 0$. Alternatively, to prove that it is optimal to have some border enforcement, it would be sufficient to show that $c\left(\tau\right) \geq c\left(0\right)$ for some $\tau \in \left(0, w\left(k\left(\tau\right)\right)\right]$. We take equation (16), assume a Cobb-Douglas production technology, and simplify to obtain the following expression:

$$w\left(k\left(\tau\right)\right) - \tau \geq \left(1 - \alpha\right)^{\frac{a}{1-\alpha}}\left[k\left(\tau\right)\right]^{1-\alpha} \tag{18}$$

Equation (18), which simply states that lump-sum taxes need to be "sufficiently" small relative to the prevailing wage, represents the condition necessary for host-country citizens to have greater consumption with some positive level of border enforcement than with an open border. In general, it is difficult to say much about the optimal level of border enforcement because we have not specified functional forms for smugglers' capital, $g\left(\cdot\right)$, and migrant crossing technology, $M(\cdot)$. Consequently, in the remainder of this section we focus on deriving conditions under which the host country will decide not to enforce the border and also the impact of a change in smuggler technology on the optimal level of enforcement.

5.1 No Border Enforcement

It will be useful to first define some limiting conditions regarding taxes and equilibrium levels of the capital stock. Based on Figure 5), we see that as taxes *decrease*, equation (15) shifts down while equation (14) shifts up. Consequently, for sufficiently small lump-sum taxes, the low-capital steady state disappears.

Lemma 3 *There exists a unique (high-capital) steady state for $\tau \in [0, \bar{\tau})$, where $\bar{\tau}$ satisfies the following equation:*

$$\left[\frac{\alpha(1-\alpha)M(e(\bar{\tau}), z)}{Ax(1-\delta)}\right]^{\frac{1}{1-2\alpha}} = (1-\alpha)\left[\frac{\alpha(1-\alpha)M(e(\bar{\tau}), z)}{Ax(1-\delta)}\right]^{\frac{\alpha}{1-2\alpha}} - \frac{\bar{\tau}}{1+\gamma M(e(\bar{\tau}), z)}$$

The proof of this lemma is left to the appendix. The implication of this lemma is that there exists a bifurcation in the number of steady state equilibria which exist: a result of the migrant's budget constraints and the Cobb-Douglas technology. The total return of working in the host-country is the product of the return on savings and the quantity of savings, $f'(k(\tau))\,w(k(\tau))$. For a Cobb-Douglas production function, this is a decreasing function of the capital stock. Thus, at lower levels of capital, the return to migrating is extremely high. As a result, migrants would optimally want to spend more than their time endowment working in the host-country; clearly violating their budget constraints. Consequently, for $\tau < \bar{\tau}$, low capital steady states vanish.

It will be useful when deriving conditions under which border enforcement is not optimal, to consider two cases: (1) there exists only a high steady state capital equilibrium and (2) there exist two steady state equilibria. We begin with the first case. When lump sum taxes are close to zero (that is, very little enforcement) and thus there exists a unique high capital steady state equilibrium, we have the following proposition.

Proposition 3 *For sufficiently small lump sum taxes, $\tau \in [0, \varepsilon)$, $c_\tau(\tau) < 0$. Thus, if the alternative is between small levels of border enforcement and an open border, the welfare maximum is an open border.*

This result follows directly from evaluating equation (17) at $\tau = 0$, and hence the proof is omitted. Thus, for a sufficiently small increase in taxes relative to no taxes, the resulting decline in the steady state level of capital results in the overall decrease in savings, $w(k(\tau)) - \tau$, being greater than the increase in the rate of return on savings, $f'(k(\tau))$. More generally, the following proposition states conditions under which no enforcement is preferred to a high-capital steady state equilibrium with enforcement.

Proposition 4 *For any high capital steady state equilibrium $k_H(\tau)$ and $\tau \geq 0$, if $-k_H'(\tau) < \frac{\alpha}{1-2\alpha}$, then a benevolent host-country government would choose an open border.*

The proof can be found in the appendix. The condition in Proposition 4 is a sufficient condition to guarantee that $c'(\tau) < 0$ for the high capital steady state equilibrium and thus no taxes (enforcement) would be optimal. As taxes increase, the level of capital is decreasing and thus the return to savings in increasing, since $f'(k_H) < 0$. At the same time the quantity of savings, $w(k_H) - \tau$, is decreasing. Proposition 4 is merely a sufficient condition which effectively restricts the size of a change in the capital level; consequently, an increase in taxes results in a larger decline in after-tax wages than in rental payments to capital owners.

Together, Propositions 3 and 4 provide support for Ethier's claims that it is unlikely that border enforcement alone is desirable. We show that a developed country would never choose small levels of border enforcement over an open border.[26] In addition, even if a country implements a level of enforcement above the minimum level needed for an optimal use of resources, this enforcement will be beneficial to society only if the taxes needed to fund the enforcement sufficiently distort (decrease) savings and capital investment. Note that Ethier finds that governments are more likely to choose some positive levels of *both* interdiction policy and inspection policy. However. because both policies are distortionary, Ethier's optimality results fall within the realm of Theorem of the Second Best. We have restricted ourselves to only examine the optimality of interdiction policies in our more general setting.

5.2 Technological Progress and Enforcement

In sections 3.3 and 4.1 we analyzed how changes in enforcement affected smugglers decisions and changes in smuggling affected the economy. In this section we consider the effect that technological progress in the smuggling industry would have on the host-country's welfare-maximizing level of border enforcement: as stated in the following proposition

[26] Here, we adopt the conventional terminology in which there exist multiple steady states. The economy at the high-capital steady state is identified as the developed one and the economy at the low-capital steady state is the less developed one.

Proposition 5 *Let $\hat{\tau} > 0$ be the optimal tax level derived from solving problem (GP)*
1) if there exists a high capital steady state, $k_H(\hat{\tau})$, and $k_{\tau z} \in (-\varepsilon, \infty)$, then $\tau_z < 0$
2) if there exists a low capital steady state, $k_L(\hat{\tau})$, and $k_\tau > 1/(1-2\alpha)$ and $k_{\tau z} \in (-\infty, \varepsilon)$, then $\tau_z < 0$

The proof to Proposition 5 is found in the appendix. This proposition states sufficient conditions under which a benevolent government will reduce border enforcement in response to technological progress in the smuggling industry. In these cases, the resources (taxes) necessary to maintain the level of immigration and capital stock are greater than the benefits from doing so.

It is worth noting that when there exists a high-capital steady state and positive border enforcement, the result of Proposition 5 hinges only on the cross partial of k being "sufficiently" large. Whereas when we have a low-capital steady state equilibrium consistent with border enforcement not only does the cross partial need to be "sufficiently" small, but we also have a second sufficient condition requiring that the capital stock be sufficiently responsive to changes in border policies. This asymmetry in sufficient conditions stems from the fact that changes in the equilibrium level of the capital stock as a result of changes in both smuggler technology and enforcement levels behave exactly opposite in the low and high capital steady states, as discussed in Propositions 1 and 2.

6 Conclusion

Recent empirical evidence suggests smugglers have been important facilitators of illegal immigration in the face of rising border enforcement. The theoretical literature, meanwhile, has largely ignored the smuggler's role when modeling the interrelationship between undocumented migrants and enforcement. Previous literature has also focused overwhelmingly on wage levels as the driving force in international migration. As a result, migrants are typically viewed as contributing only to the host country's stock of labor. This approach ignores the importance of other sources of income, such as the return on savings (investment), which are part of a worker's migration decision. As a result, such an approach also ignores the contribution of immigrants to a host country's stock of capital, another important consideration.

This paper develops a more comprehensive, general equilibrium model which better accounts for the role that smugglers and non-wage income play in the migration decision. Our chief contribution is that we introduce a market for labor-smuggling services. By explicitly modelling smugglers, we provide a natural link between the level of enforcement, the smuggler's decision regarding the quantity of time to spend on research and development of methods to overcome enforcement, and the quantity of time migrants spend getting across the border. Thus, the introduction of smugglers reduces the effectiveness of border patrols and a growing smuggling industry may partly account for the seemingly inefficacy of increased border enforcement. We also make the migration decision richer by allowing for both wage differentials *and* returns to savings to have an effect. Since both the rental and wage rate in the host country depend on the capital-labor ratio and move in opposite directions, we encounter situations where despite a high wage, migration does not occur because the return to savings is sufficiently low.

We focus on the case where, and state conditions under which, there exist two steady state equilibria. One is associated with a low level of capital and a high amount of illegal migration while the other has a high level of capital stock but relatively little migration. The effect of a positive technology shock to the smuggler's production function result in an increase (decrease) in the capital-labor ratio in the high- (low-) capital steady state. Correspondingly, the level of migration is ambiguous (rises) in the high- (low-) capital steady state. The ambiguity regarding the effect on migration is the result of migrants having both wage and savings income, as whichever increases (decreases) more for the given increase in capital will determine if migration increases or decreases. The technology shock also induces smugglers to devote fewer resources to research and development, but still provide a greater quantity of services.

Governments can attempt to reduce the flows of immigrants by intensifying the level of border enforcement. In our model this is accomplished by raising the host-country native workers' taxes. Such a policy shock will reduce (increase) the steady state level of capital in the high- (low-) capital steady state. As with the technology shock, steady state migration will be ambiguous (fall) in the high- (low-) capital steady state. If the wage effect dominates the increased return to savings as a result of a decline in the capital level, the tax increase results in a lower equilibrium quantity of migration to the host country. Smugglers respond to the increase in enforcement by devoting more time to research, although fewer smuggling services are provided.

We also state conditions under which more developed countries, those with a high-capital steady state, would choose to have an open border. It is always the case that a developed country is better off with no enforcement as compared to a relatively little amount of enforcement. Whether a developed country would institute a sufficiently high level of enforcement so as to be beneficial to its citizenry depends on how the taxes necessary for the enforcement affect capital accumulation. If levying taxes has a relatively small impact on capital accumulation, then the cost of the taxes will outweigh any benefits from enforcement and the country is better off without border enforcement.

Finally, we briefly touch on the issue of technological progress in the smuggling industry. For cases in which some positive amount of border enforcement is welfare maximizing, we derive conditions under which host countries (both developed and developing) may wish to respond to productivity increases in the smugglers' industry by lowering taxes and reducing border enforcement. For developed countries, if the change in the level of the capital stock, as both technology and enforcement change, is sufficiently large, then the cost of maintaining the current tax policy outweighs the benefits for a given increase in smuggler productivity. For less developed countries the converse holds true and in addition it must also be the case that a change in tax policy must have a sufficiently large impact on the capital stock in order to induce the government to lower the level of enforcement.

We mention two additional topics that we have not considered but would be of interest in future research. First, it would interesting to explore the equilibrium dynamics. In particular, what are the dynamic properties of the steady state equilibria and what are the properties of any transition paths?

Second, we have imposed homogeneity across countries. Yet, many researchers have documented the different attributes of both natives and migrants. It would be interesting to ascertain how heterogeneous individuals in the home and host countries would affect the market for smugglers, level of enforcement, wages and economic growth.

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A Appendix

A.1 Lemma 3

To show that there exists a range of taxes, $\tau \in [0, \bar{\tau})$, over which there is a unique, high-capital steady state, it will suffice to examine where equations (14) and (15) intersect the $k - axis$. Note that on the $k - axis$ we have $\mu = 0$ and equation (14) reduces to

$$k(\tau) = w(k(\tau)) - \frac{\tau}{1 + \gamma M(e(\tau), z)} \tag{A1}$$

Let $k_1(\tau)$ and $k_2(\tau)$, where $k_1(\tau) < k_2(\tau)$, be the values of the capital stock such that $k_1(\tau)$ and $k_2(\tau)$ are solutions to equation (A1). When there does not exist any enforcement, that is, $\tau = 0$, equation (A1) reduces to

$$\begin{aligned} k(0) &= w(k(0)) \\ &= (1 - \alpha) k(0)^{\alpha} \end{aligned} \tag{A2}$$

in steady state equilibrium for a Cobb-Douglas production function. There are two solutions to equation (A2), the vertical lines $k_1(0)^* = 0$ and $k_2(0)^* = (1 - \alpha)^{\frac{1}{1-Ga}}$. In addition, note that

$$\begin{aligned} \lim_{\tau \to 0} \left(k(\tau) - w(k(\tau)) + \frac{\tau}{1 + \gamma M(e(\tau), z)} \right) &= k(0) - w(k(0)) + \frac{0}{1 + \gamma} \\ &= k(0) - w(k(0)), \end{aligned}$$

and thus $k_i(\tau)$, for $i = 1, 2$ is continuous at $\tau = 0$. Finally, as state in Proposition 2 (and depicted in Figure 5), $k_1^{'}(\tau) > 0$ and $k_2^{'}(\tau) < 0$.

When $\mu = 0$, the second law of motion, equation (15) reduces to

$$Ax(1 - \delta) = f'(k(\tau)) w(k(\tau)) M(e(\tau), z). \tag{A3}$$

Let $k_3(\tau)$ be the solution to this equation. When there is no enforcement, that is, $\tau = 0$, this further reduces to

$$\begin{aligned} Ax(1 - \delta) &= f'(k(0)) w(k(0)) \\ &= \alpha (1 - \alpha) k(0)^{2\alpha - 1}. \end{aligned} \tag{A4}$$

The solution to equation(A4) is given by

$$k_3(0) = \left[\frac{\alpha(1-\alpha)}{Ax(1-\delta)}\right]^{\frac{1}{1-2\alpha}} > 0.$$

Finally, note that $k_3'(\tau) < 0$ by Proposition 2.

Thus for

$$\alpha(1-\alpha)^{\frac{\alpha}{1-\alpha}} < Ax(1-\delta),$$

an assumption we henceforth make, we have that

$$0 = k_1(0) < k_3(0) < k_2(0) = (1-\alpha)^{\frac{1}{1-G\alpha}}$$

and at $\tau = 0$ there exists a unique, high capital steady state equilibrium.[27] Define $\bar{\tau}$ as the level of taxes such that $k_1(\bar{\tau}) = k_3(\vec{\tau})$ and $\bar{\tau} \leq w(k(\bar{\tau}))$. Solving equation (A3) for $k(\bar{\tau})$ and plugging this into equation (A1) yields

$$\left[\frac{\alpha(1-\alpha)M(e(\bar{\tau}),z)}{Ax(1-\delta)}\right]^{\frac{1}{1-2\alpha}} = (1-\alpha)\left[\frac{\alpha(1-\alpha)M(e(\bar{\tau}),z)}{Ax(1-\delta)}\right]^{\frac{\alpha}{1-2\alpha}} - \frac{\bar{\tau}}{1+\gamma M(e(\bar{\tau}),z)}$$

which implicitly defines $\bar{\tau}$ as a function of the exogenous parameters. Finally, by the continuity of $k_1(\tau)$ and Proposition 2, we have that for $\tau \in [0, \bar{\tau})$, there exists a unique, high capital steady state equilibrium.

A.2 Proposition 4

To prove this proposition, we need to show conditions under which $U(k_H(\tau)) < U(k_H(0))$ for all $\tau > 0$, i.e., host country individuals would be worse off with any level of enforcement in the high capital steady state. Given the properties of $U(\cdot)$ it is sufficient to state conditions under which $c'(\tau) < 0$ for all $k_H(\tau)$ where $\tau > 0$. Recall that from equation (17) we have

$$c'(\tau) = k_\tau(\tau)\{f''(k(\tau))[w(k(\tau)) - \tau] + f'(k(\tau))w'(k(\tau))\} - f'(k(\tau)).$$

For a Cobb-Douglas production function this can be rewritten as

$$c'(\tau) = \alpha(1-\alpha)k_H(\tau)^{\alpha-2}k_H'(\tau)[(2\alpha-1)k_H(\tau)^\alpha + \tau] - \alpha k_H(\tau)^{\alpha-1}.$$

[27] It is assumed that equations (14) and (15) have the general shapes as depicted in Figure 5. We refer to equilibria that occur on the downward sloping portion of equation (14) as high capital steady states.

Thus $c'(\tau) < 0$ if and only if

$$(1-\alpha)\, k_H^{'}(\tau)\left[(2\alpha-1)\, k_H(\tau)^{\alpha} + \tau\right] < k_H(\tau)$$

or

$$\tau > \frac{k_H(\tau)}{(1-\alpha)\, k_H^{'}(\tau)} + (1-2\alpha)\, k_H(\tau)^{\alpha}, \tag{A5}$$

where the first term is negative (since $k_H^{'}(\tau) < 0$) and the second term is positive on the right-hand side of the equation. A sufficient condition for equation (A5) to hold is

$$0 > \frac{k_H(\tau)}{(1-\alpha)\, k_H^{'}(\tau)} + (1-2\alpha)\, k_H(\tau)^{\alpha} \tag{A6}$$

since by definition $\tau > 0$. Rearranging terms in equation (A6) yields

$$-k_H^{'}(\tau) < \frac{k_H(\tau)^{1-\alpha}}{(1-\alpha)(1-2\alpha)} \tag{A7}$$

Finally, noting that

$$\left[\alpha(1-\alpha)\right]^{\frac{1}{1-\alpha}} \leq k_H(\tau) \leq (1-\alpha)^{\frac{1}{1-\alpha}}$$

and equation (A7) is increasing in $k_H(\tau)$, these conditions together imply that

$$-k_H^{'}(\tau) < \frac{\alpha}{(1-2\alpha)}$$

is sufficient to guarantee that $c'(\tau) < 0$ for all high capital steady state equilibrium.

A.3 Proposition 5

From equation (17) we have

$$c_{\tau} = k_{\tau}(\tau)\left\{f''(k(\tau))\left[w(k(\tau)) - \tau\right] + f'(k(\tau))\, w'(k(\tau))\right\} - f'(k(\tau)), \tag{A8}$$

which using the Implicit Function Theorem allows us to define

$$\tau = \tau(z).$$

Thus we know that

$$\tau_z = -\frac{c_{\tau z}}{c_{\tau\tau}}.$$

At an interior optimum it must be the case that $c_{\tau\tau} < 0$ and thus the sign of τ_z is equivalent to the sign of $c_{\tau z}$. Differentiating equation (A8) with respect to z yields

$$\begin{aligned} c_{\tau z} &= k_{\tau z}\left\{f''\left(k\left(\tau\right)\right)\left[w\left(k\left(\tau\right)\right)-\tau\right]+f'\left(k\left(\tau\right)\right)w'\left(k\left(\tau\right)\right)\right\}+ \\ &\quad k_z\left\{k_\tau\left[f'''\left(k\left(\tau\right)\right)\left(w\left(k\left(\tau\right)\right)-\tau\right)+2f''\left(k\left(\tau\right)\right)w'\left(k\left(\tau\right)\right)+f'\left(k\left(\tau\right)\right)w''\left(k\left(\tau\right)\right)\right]-f''\left(k\left(\tau\right)\right)\right\} \end{aligned}$$

Using the fact that $c_\tau = 0$ and a Cobb-Douglas production function gives us

$$c_{\tau z} = k_{\tau z}\frac{\alpha k^{\alpha-1}}{k_\tau} + k_z\left\{\alpha\left(\alpha-1\right)k^{\alpha-3}\left[k_\tau\left\{\left(1-\alpha\right)k^\alpha\left(4\alpha-2\right)-\left(\alpha-2\right)\tau\right\}-k\right]\right\} \tag{A9}$$

The sign of the second term on the right-hand side depends on the sign of the term in the square brackets:

$$k_\tau\left\{\left(1-\alpha\right)k^\alpha\left(4\alpha-2\right)-\left(\alpha-2\right)\tau\right\}-k. \tag{A10}$$

Using the fact that at an interior optimum

$$\tau = \left(1-2\alpha\right)k^\alpha + \frac{k}{\left(1-\alpha\right)k_\tau}$$

it is straightforward to show that the expression in (A10) is positive for a high-capital steady state and is negative for a low-capital steady state if

$$k_\tau > \frac{1}{1-2\alpha}.$$

Then in a high capital steady state, we have $k_z > 0$, $k_\tau < 0$ and the second term on the right hand side of equation (A9) is negative. Given that $k_\tau < 0$, then if $k_{\tau z} \geq 0$ or if $k_{\tau z} < 0$ but sufficiently close to zero, then $c_{\tau z} < 0$ and $\tau_z < 0$.

When we have a low-capital steady state, then the second term on the right hand side of equation (A9) is negative since $k_z < 0$. Given that $k_\tau > 0$, then if $k_{\tau z} \leq 0$ or if $k_{\tau z} > 0$ but sufficiently close to zero, then $c_{\tau z} < 0$ and $\tau_z < 0$.

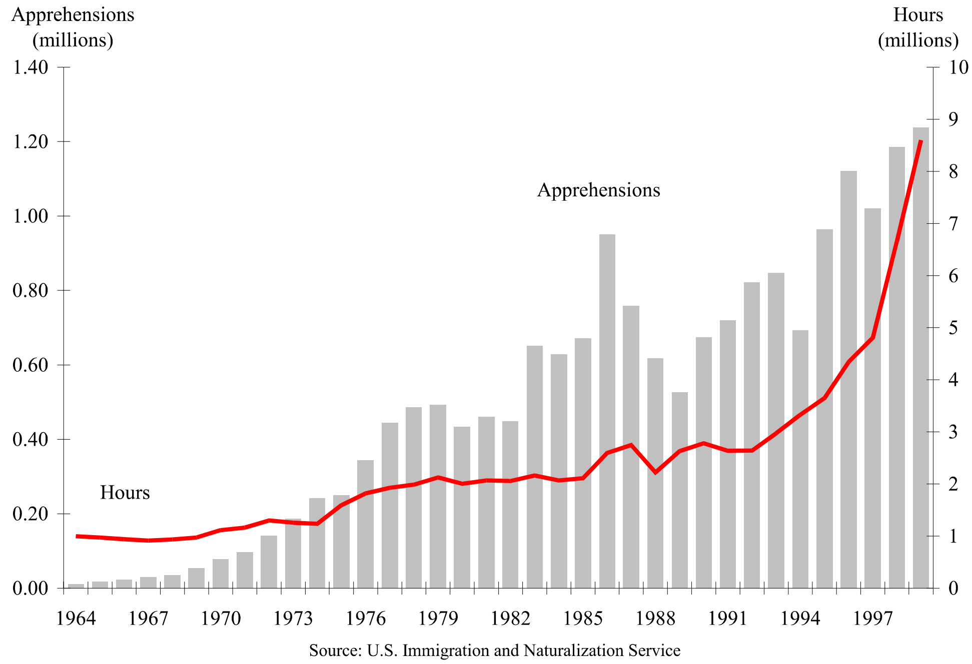

Figure 1: Border Linewatch Apprehensions and Hours

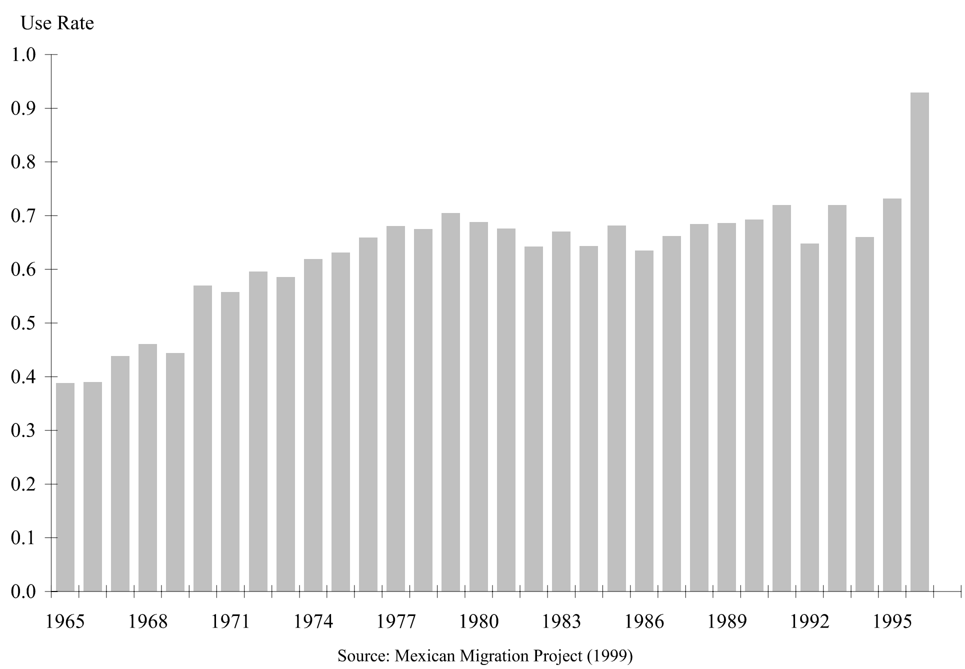

Figure 2: Smuggler Use Rates

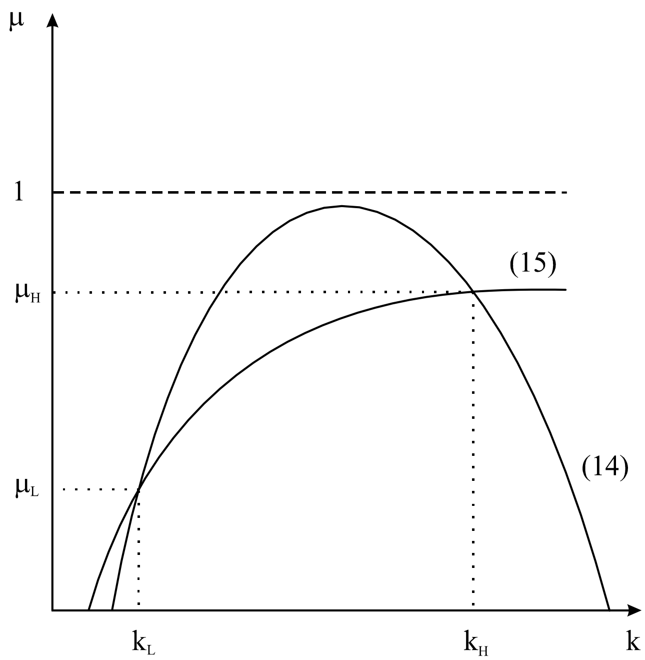

Figure 3: Multiple Steady State Equilibria

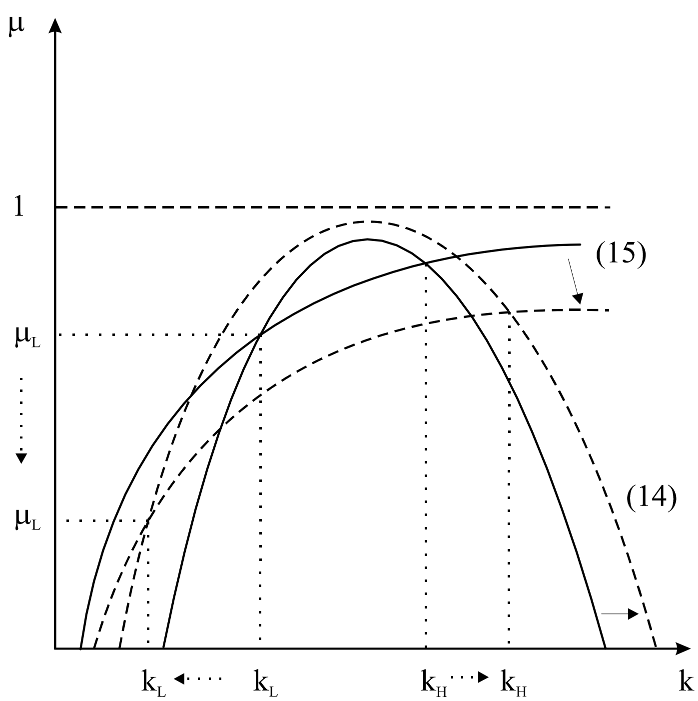

Figure 4: Effect of an Increase in Smuggling Technology

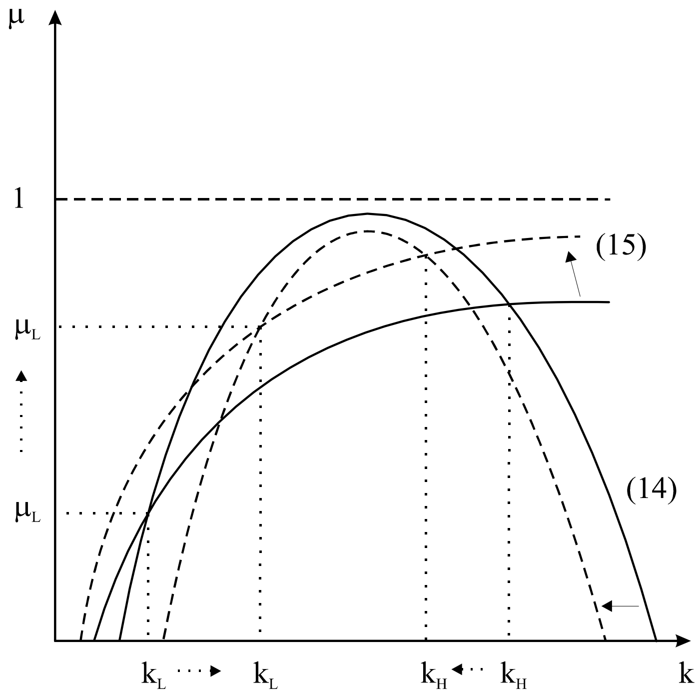

Figure 5: Effect of an Increase in Border Enforcment (Taxes)