

Analyzing the Homeland Security of the U.S.-Mexico Border

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We develop a mathematical optimization model at the intersection of homeland security and immigration, that chooses various immigration enforcement decision variables to minimize the probability that a terrorist can successfully enter the United States across the U.S.-Mexico border. Included are a discrete choice model for the probability that a potential alien crosser will attempt to cross the U.S.-Mexico border in terms of the likelihood of success and the U.S. wage for illegal workers, a spatial model that calculates the apprehension probability as a function of the number of crossers, the number of border patrol agents, and the amount of surveillance technology on the border, a queuing model that determines the probability that an apprehended alien will be detained and removed as a function of the number of detention beds, and an equilibrium model for the illegal wage that balances the supply and demand for work and incorporates the impact of worksite enforcement. Our main result is that detention beds are the current system bottleneck (even after the large reduction in detention residence times recently achieved by expedited removal), and increases in border patrol staffing or surveillance technology would not provide any improvements without a large increase in detention capacity. Our model also predicts that surveillance technology is more cost effective than border patrol agents, which in turn are more cost effective than worksite inspectors, but these results are not robust due to the difficulty of predicting human behavior from existing data. Overall, the probability that a terrorist can successfully enter the United States is very high, and it would be extremely costly and difficult to significantly reduce it. We also investigate the alternative objective function of minimizing the flow of illegal aliens across the U.S.-Mexico border, and obtain qualitatively similar results.

KEY WORDS: Discrete choice model; economic equilibrium; immigration; queuing model

1. INTRODUCTION

Immigration is one of the most complex and contentious public policy issues facing the U.S. government,⁽¹⁾ as evidenced by Congress's failure to pass a comprehensive immigration bill in the summers of 2006 and 2007. The September 11, 2001 attacks have

added further complications by extending the concerns about the porous U.S.-Mexico border beyond immigration to homeland security.⁽²⁾ The U.S. Visitor and Immigrant Status Indicator Technology (US-VISIT) Program,⁽³⁾ which uses biometric matching at the U.S. ports of entry to detect people on the terrorist watchlist, may cause some terrorists who seek to enter the United States to do so illegally at the U.S.-Mexico border. The directors of the CIA and FBI testified to the Senate Intelligence Committee that new intelligence strongly suggests that Al Qaeda has considered entering the United States illegally across the U.S.-Mexico border.⁽⁴⁾

This study focuses on the narrow aspect of immigration that intersects with homeland security. We develop a mathematical optimization problem

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for how the U.S. government should allocate its resources across border control (i.e., border patrol agents and technology), detention and removal (i.e., detention beds), and worksite enforcement (i.e., worksite inspectors) to maximize the probability that a terrorist who attempts to cross the U.S.-Mexico border will be apprehended and removed; we also consider the alternative goal of minimizing the amount of illegal crossing at the border. We also investigate the impact on homeland security of legalizing illegal workers that are currently in the United States or introducing a guest worker program, although we do not address the vital issue of whether or not these workers should be offered a path to U.S. citizenship. More generally, competing congressional bills have placed varying emphasis on border security, and our model assesses the enhancement in homeland security from additional investments in immigration enforcement.

The model is described in Section 2 along with a literature review, and the parameter estimation process is reviewed in Section 3. Our results appear in Section 4 and are discussed in Section 5.

2. THE MODEL

The detailed formulation of the mathematical model and the estimation of its parameter values appear in the Appendix, which is maintained by the author at <http://faculty-gsb.stanford.edu/wein>. The model's shortcomings are taken up in Section 5. The model consists of four submodels. An overview of the model is provided in Section 2.1, the relevant literature is reviewed in Section 2.2, and the four submodels are described in Sections 2.3–2.6.

2.1. Model Overview

Congestion effects—in both apprehension by border patrol agents at the border and detention at a Detention and Removal Operations (DRO) Center—play a large role in the likelihood of an alien (who may be a terrorist or nonterrorist) successfully entering the United States. Nearly all (adult male) aliens who cross illegally are seeking (or already have) employment in the United States, although a few may be terrorists. Hence, the congestion effects are caused solely by nonterrorists, and so our model focuses on the behavior and flow of nonterrorist aliens. We then superimpose on the model a single (undeterrable) terrorist who attempts to enter the United States, and determine his or her likeli-

hood of success. A similar approach was used in Reference 5, where to assess the impact of a detection-interdiction system to mitigate the effects of a vehicle containing a nuclear weapon that is driving toward a city center, a queueing model was used that quantified the congestion effects (on interdiction) caused by false alarms generated by nonterrorist vehicles.

Most aliens who cross the U.S.-Mexico border illegally are Mexican⁽⁶⁾ and all other aliens are referred to as OTMs (Other Than Mexicans). Conceptually, for Mexicans and for OTMs, our model (Fig. 1) consists of four key relations (probability is abbreviated by prob.):

$$\text{crossing rate} = f(\text{apprehension prob., detention policy, removal prob., illegal wage}), \quad (1)$$

$$\text{apprehension probability} = f(\text{crossing rate, border patrol agents, border technology}), \quad (2)$$

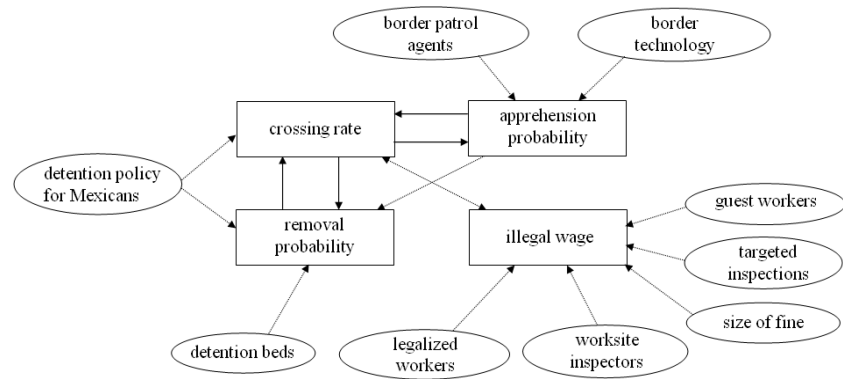
$$\text{removal probability} = f(\text{crossing rate, detention policy, apprehension prob., DRO beds}), \text{ and} \quad (3)$$

$$\text{illegal wage} = f(\text{worksite enforcement policy, legalization policy}), \quad (4)$$

where $f(\cdot)$ is shorthand for “is a function of,” and on the right sides of relations (1)–(4) we have included only the key decision variables and the variables from the left sides of these relations.

We briefly describe this time-independent system of relations, which is intended to describe the steady-state behavior of the illegal immigration system. An alien can successfully enter the United States by either avoiding apprehension during border crossing, or avoiding detention until removal if he or she is apprehended. Relation (2) is an equilibrium model that incorporates the spatial (the crossing rate, the concentration of agents, and the amount of technology all vary by location along the border), behavioral (aliens try to cross in locations where they are less likely to be apprehended), and congestion (border patrol agents are servers in a queue) aspects at the border, and the apprehension probability increases with the number of border patrol agents and the amount of technology, and decreases with the crossing rate. Relation (3) is a steady-state queueing model in which customers are the apprehended

Fig. 1. A conceptual overview of the model, in which the rectangles contain quantities computed in the submodels described in relations (1)–(4) and the ovals contain decision variables by the U.S. government.



aliens that the government wants to detain, and the servers are the detention beds. The aliens are released into the U.S. interior (i.e., they successfully enter the country) if there is not available bedspace to detain them until they can be removed, and the queuing model determines the probability of detention until removal, which is increasing in the number of detention beds and decreasing in the crossing rate and apprehension probability. The illegal wage in relation (4) is computed by an economic equilibrium model that equates labor supply (which is affected by the legalization policy) and labor demand. The illegal wage decreases with the number of worksite inspectors because employers pass the expected enforcement fines on to the illegal workers in the form of reduced wages. Finally, relation (1) is a discrete choice model in which the crossing rate increases with the illegal wage and with the likelihood that an illegal alien can successfully enter the United States (i.e., without being both apprehended and detained until removal).

This set of relations, which can be viewed as fixed-point equations for the crossing rates of Mexicans and OTMs by substituting the right sides of relations (2)–(4) into the right side of relation (1), is embedded into an optimization framework: choose the decision variables (i.e., detention policy, border patrol agents, border technology, DRO beds, worksite enforcement policy, legalization policy, guest worker program) to maximize the probability that a terrorist (who is assumed to be an OTM because there have not been cases of Mexican terrorists) is successfully apprehended and removed (which can be computed from the values of the left sides of relations (2)–(3)), subject to a budget constraint on border patrol agents, border technology, DRO beds, and worksite inspectors. Hence, the model has the flavor of a Stackelberg (i.e., leader-

follower) game,⁽⁷⁾ in the sense that after the government (i.e., the leader) makes its allocation decisions, the aliens (i.e., the followers) observe the leader’s decisions and then behave in accordance with their utility preferences in the discrete choice model in relation (1) (i.e., rather than having a single follower optimizing his or her utility, as in a typical Stackelberg game, we have a population of followers behaving according to their own preferences).

We are implicitly assuming that a terrorist would be treated no differently than any other OTM, and in particular, would have the same likelihood of being detained until removal as a nonterrorist OTM; i.e., the terrorist would be detained if there is bedspace and would be released into the interior of the United States otherwise. Because these detention decisions are not supposed to be based solely on the alien’s race, ethnicity, nationality, or religion,⁽⁸⁾ we are essentially assuming that the terrorist is nonviolent while crossing and does not arouse suspicion (e.g., during a background check); we relax this assumption in Section 4.8. We are also assuming that a terrorist (unlike a nonterrorist OTM) will not be deterred (e.g., by a high apprehension probability or a low illegal wage) from crossing the border; i.e., we are minimizing the probability that he or she will successfully enter the country conditioned on attempting to do so. In our alternative objective function, which is from the perspective of immigration enforcement rather than homeland security, we minimize the number of OTMs who successfully sneak into the United States.

2.2. Literature Review

We organize our review of the literature around relations (1)–(4). We use the multinomial logit model in relation (1), which is the most widely used random

utility model, particularly in the area of consumer choice.⁽⁹⁾ The probabilistic models we use to estimate the expected utilities in the multinomial logit model can be viewed as extensions of the model in Reference 10, which assumes that border patrol agents return apprehended aliens back to Mexico and that aliens keep crossing until they succeed, or as variants of a utility-based approach.⁽¹¹⁾

The multinomial logit model is closely related to the logistic regression model: the latter model is obtained from the former model by replacing the expected utility by a linear combination of independent variables. The logistic regression model is commonly used in empirical studies on immigration, where the dependent variable is the apprehension rate and the independent variables include the amount of enforcement control and the relative wages in the United States and Mexico;^(12–14) a separate stream of work that is less related to our model looks at the micro-structural variables that provide insight into the personal and community characteristics of the types of aliens who are apt to be apprehended at the border.⁽¹⁵⁾ While these statistical models provide valuable insight, we do not know of any mathematical models that incorporate the spatial, queueing, and game-theoretic aspects of apprehension, as in our model of relation (2). While there are a variety of operations research models aimed at interdiction,⁽¹⁶⁾ they are not specifically concerned with (nor tailored for) apprehending immigrants.

The only mathematical modeling study of DRO that we are aware of is Reference 17, which is used to model relation (3).

Our equilibrium model of relation (4) adopts three key aspects of the model in Reference 18 by using a Cobb-Douglas production function and a neoclassical labor supply function, and assuming that employers pass on expected penalties to illegal workers in the form of lower wages. In relation (4), we also consider how the government allocates enforcement resources across firms, which was done earlier, and in a somewhat different manner, in Reference 19. Although only tangentially related, there is also an important area of research that studies labor market competition between immigrants and natives.^(20–22)

We are aware of only one other attempt to mathematically model the immigration system in a comprehensive manner (as opposed to modeling one aspect of it, such as crossing, apprehension, detention, or employer sanctions), and it captures aspects of relations (1), (2), and (4).⁽²³⁾ The biggest similarity be-

tween that work and our own is probably relation (1), in that both models compute the expected utility of crossing, which depends on the apprehension probability, the expected wages (which are affected by worksite sanctions), and the cost of migrating. However, the model in Reference 23 does not consider DRO, does not optimally allocate resources from the government's viewpoint, and is much simpler than our model in certain ways (e.g., the authors assume the probability of apprehension is a constant times the unemployment rate). Finally, a very thorough investigational study of the U.S.-Mexico border⁽²⁾ was the inspiration for our article.

2.3. The Discrete Choice Submodel

Relations (1)–(4) are mathematical models that will be referred to as submodels. Relation (1) is the Discrete Choice Submodel, which specifies the fraction of potential illegal aliens who decide to illegally cross the U.S.-Mexico border. This submodel captures the fact that potential crossers are more apt to illegally enter the country if they believe they will get a job that pays significantly more than what they can make in their home country. We use two versions (one for Mexicans and one for OTMs) of the multinomial logit model,⁽⁹⁾ which captures the heterogeneity in preferences (e.g., aversion to being apprehended and detained), resources (e.g., money to buy fraudulent documents or hire a coyote, i.e., human smuggler), and perceptions (e.g., about job opportunities or the risk of dying while crossing the border) across people. If we let $j = 1$ represent the choice to illegally enter the United States and $j = 2$ denote the decision to stay home, then the multinomial logit model for OTMs (the notation for OTMs vs. Mexicans is suppressed) takes the form:

$$P_j = \frac{e^{\theta u_j}}{e^{\theta u_1} + e^{\theta u_2}} \quad \text{for } j = 1, 2, \quad (5)$$

where u_j is the expected utility from choosing option j , and θ is a scale variable.⁽⁹⁾ The actual utility for option j is u_j plus a logistic random variable with mean zero, and the model becomes deterministic as $\theta \rightarrow \infty$ and becomes a pure random choice model as $\theta \rightarrow 0$. The expected utilities u_j depend on the wages the aliens would receive in the United States and in their home country over a 2-year horizon, the costs of traveling to the border and being detained (both the loss of income and the psychological toll), the apprehension probability at the border, and the probability of removing an apprehended alien.

Although apprehended (nonviolent and non-criminal) Mexicans are typically returned to Mexico within several hours without entering a detention facility (in contrast, OTMs are supposed to be held until they can be removed to their home country, and so are not offered this so-called voluntary departure), we also allow the possibility of detaining Mexican aliens who have been apprehended a fixed number of times, which is referred to as “detention policy” in relation (1). In this case, we assume that potential Mexican crossers are aware of the detention policy. If the policy is to offer voluntary departure to Mexicans for the first $a - 1$ times that an undocumented Mexican is apprehended, then we need to solve a system of $2a$ equations in terms of the $2a$ unknowns, $u_1^{(k)}, P_1^{(k)}$ for $k = 1, \dots, a$. We solve these equations using backward recursion in a fashion reminiscent of optimal stopping problems;⁽²⁴⁾ indeed, the decision problem faced by an individual Mexican is an optimal stopping problem, but we are solving this problem over the aggregate Mexican alien population using the multinomial-logit model.

2.4. The Apprehension Submodel

The Apprehension Submodel represented by relation (2) takes a macro approach to the apprehension probability by incorporating the impact of the alien flow and enforcement effort (both labor and technology). This submodel is a spatial model on a 1,933-mile line segment representing the U.S.-Mexico border, and can be viewed as one step in a sequential Stackelberg game in which the U.S. government is the leader, who chooses the spatial allocation of agents (the number of agents and where on the line they are located) and technology (the number of miles along the border that is monitored by the Integrated Surveillance Intelligence systems, or ISIS, which are remote video surveillance systems⁽²⁾), and the illegal crosser is the follower, who observes the spatial allocation of agents and technology and then decides where to cross. As initial conditions, we assume that the arrival rate of illegal aliens of type i ($i = 1$ for Mexicans, $i = 2$ for OTMs) to each location x ($\lambda_{bi}(x)$) and the density of border patrol agents at each location ($n_b(x)$) are sinusoidal functions with the same frequency and relative amplitude:

$$\lambda_{bi}(x) = \frac{\lambda_{bi}}{L} + \frac{\lambda_{bi}}{L} \alpha_b \sin(2\pi \omega_b x) \text{ for } x \in [0, L], \quad (6)$$

$$n_b(x) = \frac{n_b}{L} + \frac{n_b}{L} \tilde{\alpha}_b \sin(2\pi \omega_b x) \text{ for } x \in [0, L], \quad (7)$$

which captures the observations that some parts of the border are busier than others (the frequency is

chosen so that there are 10 peaks along the border of length $L = 1,933$ miles), and that these sinusoidal functions are similar to the crossing locations in the previous time period (e.g., year); the average arrival rate λ_{bi} in Equation (6) is dictated by the output of the Discrete Choice Submodel in Section 2.3. Moreover, we assume that for a given fraction of the border that is monitored by technology, the technology is employed at those portions of the border that have the highest values of these sinusoidal functions (i.e., at the busier parts of the border). That is, the government will reallocate border patrol agents according to where aliens recently crossed, and aliens will arrive at the border at the locations where aliens recently crossed.

The aliens do not cross at the same location where they arrive. Rather, their crossing location is chosen according to a multinomial logit model with a continuum of choices (each point x on the line segment $[0, L]$ being a choice), where their utility function depends on the likelihood of apprehension (they—or, more likely, the coyotes—can observe the locations of the technology and border patrol agents) and the cost to travel along the border. That is, the probability that an alien of type i arriving at location x will cross at location y is:

$$P_{ci}(x, y) = \frac{e^{\theta u_i(x,y)}}{\int_0^L e^{\theta u_i(x,y)} dy} \text{ for } i = 1, 2, \quad (8)$$

where $u_i(x, y)$ is the utility for a type i alien of arriving at location x and crossing at location y .

The utilities $u_i(x, y)$ in Equation (8) depend on the probability of apprehension at location $y \in [0, L]$, which is denoted by $P_a(y)$. To capture the congestion effects at the border on $P_a(y)$, the detailed apprehension process at each point on the line is modeled as a single-server loss queueing system.⁽²⁵⁾ The server is a border patrol agent who drives back and forth along a small portion of the border (the reciprocal of the density of the border patrol agents at this location on the line segment) and the customers arrive uniformly along this small part of the line segment according to a temporal Poisson process with a rate equal to the crossing rate at that location. If a crosser arrives at the border and finds the agent busy apprehending someone else, then he or she crosses successfully. If the agent is idle, then the probability of apprehension depends on the random distance between the agent and the crosser and on whether technology is present at this location of the border. If the distance between the agent and crosser is larger than an exponential random variable whose mean

depends on whether or not technology is present (the technology makes apprehension more likely), then the crosser is not apprehended, and if this distance is smaller than the exponential random variable, then the crosser is apprehended. This single-server loss queueing model yields the apprehension probability $P_a(y)$.

The crossing rate by type i aliens at location y ($\lambda_{ci}(y)$) is the solution to:

$$\lambda_{ci}(y) = \int_0^L \lambda_{bi}(x) P_{ci}(x, y) dx, \quad (9)$$

which is a fixed-point functional equation because $\lambda_{ci}(y)$ is an input to the single-server loss queueing model that dictates $P_a(y)$, and hence appears in $P_{ci}(x, y)$. Finally, the apprehension probability for a type i alien is:

$$P_{ai} = \frac{\int_0^L \lambda_{ci}(y) P_a(y) dy}{\lambda_{bi}}, \quad (10)$$

which corresponds to relation (2).

2.5. The Removal Submodel

The Removal Submodel in relation (3) is a queueing model that was developed in Reference (17). The customers to this queue are the aliens who the U.S. government wants to detain and remove. Some of the customers come from the apprehensions along the border while others (mostly coming from U.S. jails and in the process of being removed) are exogenous to the model. The servers in our model are DRO beds and the service time corresponds to the residence time in the DRO facility until the alien is removed from the United States and returned to his or her home country. Customers are either mandatory (e.g., criminals) or nonmandatory; in our model, we assume that the apprehended OTMs are nonmandatory. The customers arrive to this queue according to a (temporal) sinusoidal Poisson arrival process that captures the seasonal nature of illegal crossings. If a nonmandatory alien arrives and finds all beds filled, then the alien is released into the United States. If a mandatory alien arrives and finds all beds filled, then a detained nonmandatory alien is released into the United States to make room for the mandatory alien. Released nonmandatory aliens are given a notice to appear in immigration court, but only 13% of nondetained aliens with final removal orders are actually removed.⁽²⁶⁾ If all beds are filled with mandatory aliens, then a new bed is temporarily rented for an arriving mandatory

alien until there is a free DRO bed. Using mathematical formulas from Section 3 in Reference 17, we derive the output of this queueing model, which is the probability that an apprehended alien who is desired to be detained and removed (i.e., an apprehended OTM or a Mexican alien who is apprehended a specified number of times) will actually be removed from the United States and returned to his or her home country. This quantity is expressed in terms of the seven DRO parameters: the number of DRO beds, the mean arrival rates of mandatory and nonmandatory detainees, the mean residence times of mandatory and nonmandatory detainees, and the frequency and relative amplitude of the sinusoidal arrival rates.

2.6. The Illegal Wage Submodel

The Illegal Wage Submodel in relation (4) is an equilibrium model that equates the unskilled labor demanded and the unskilled labor supplied, which includes legal and illegal workers. We take the view that immigrants tend to fill jobs that native workers do not want, and that in the absence of these workers, many of these jobs would be replaced by capital or move offshore.⁽²⁷⁾ Hence, we compute the unskilled labor demand using a Cobb-Douglas production function with two factors, unskilled workers and capital.⁽¹⁸⁾

Worksite inspectors monitor workplaces and penalize employers who hire illegal aliens. We have m_w worksite enforcement agents, each of whom inspects μ_w firms per year. There are N_i illegal workers in the United States and N_w firms that hire illegal aliens, and we assume that the number of illegal workers in a firm is an exponential random variable with mean $\frac{N_i}{N_w}$, which succinctly captures the phenomenon that many illegal workers are concentrated in a handful of industries.⁽²⁸⁾ We assume a fraction r_w of inspections are targeted, i.e., occur at the firms in the highest $\frac{r_w m_w \mu_w}{N_w}$ fractile of illegal workers, which corresponds to the firms with more than $\frac{N_i}{N_w} \ln\left(\frac{N_w}{r_w m_w \mu_w}\right)$ illegal workers. The remaining fraction $1 - r_w$ of inspections are randomly sampled from the untargeted industries, so that the annual probability of inspecting a firm that hires x illegal aliens is:

$$p_w(x) = \begin{cases} \frac{(1 - r_w)m_w\mu_w}{N_w - r_w m_w \mu_w} & \text{if } x < \frac{N_i}{N_w} \ln\left(\frac{N_w}{r_w m_w \mu_w}\right); \\ 1 & \text{if } x \geq \frac{N_i}{N_w} \ln\left(\frac{N_w}{r_w m_w \mu_w}\right). \end{cases} \quad (11)$$

Employers in our model pass on the expected worksite enforcement sanctions to the illegal workers in the form of lower wages.^(18,19) Illegal laborers at a firm with x illegal laborers are paid:

$$w_i(x) = \max\{w - p_w(x) f_w, 0\}, \quad (12)$$

where w is the legal wage (determined from an economic equilibrium condition) and f_w is the fine per illegal worker per hour of work.

There are four sources of labor supply. The labor supply from the legal U.S. workers is modeled using the neo-classical labor supply function.⁽²⁹⁾ The model allows for the legalization of illegal workers who are currently in the United States and for a guest worker program that brings in new legal workers, which are the second and third sources of supply. The newly legal laborers (those who have been legalized) use a multinomial logit model to decide whether to return home or to stay and receive the equilibrium legal wage (nearly all choose the latter option), and the new guest workers all stay. The last source of labor supply comprises the illegal aliens who have been working in the United States but may have their pay reduced by increased worksite enforcement. We consider a two-step process for these workers. First, we use a multinomial logit model to decide what fraction of these workers stay in their reduced-wage job. Those who quit their job from an untargeted firm return home, and those who quit their job from a targeted firm enter a matching process (of the Cobb-Douglas form with constant returns to scale,⁽³⁰⁾ where the multinomial logit model generates a probability distribution for the wage that these workers are willing to accept rather than returning to their home country) between the workers who quit their job and the jobs that were vacated. Illegal workers who are not matched with a vacated job return home.

The legal wage is computed from the equilibrium condition that equates the labor demanded to the total (over the four sources) labor supplied. The illegal wage is then determined as the weighted average among the various types of illegal workers, which corresponds to relation (4). The U.S. government has five decision variables in this submodel: the number of illegal workers who are legalized, the number of new legal workers from a guest worker program, the number of worksite inspectors, the fraction of inspections that are targeted, and the size of the fine for employing an illegal alien.

3. PARAMETER ESTIMATION

All parameters are estimated using existing data, as described in Section 5 in the Appendix. The parameters for the Removal Submodel were estimated in Reference 17 using government data. After the study in Reference 17 was performed, nonmandatory OTM residence times in detention were reduced through the use of Expedited Removal, and so we first consider the base case without Expedited Removal and then assess this program's impact. The Wage Submodel parameters use a variety of data, including the number of illegal workers currently working in the United States, the unemployment rate of U.S. high school dropouts, the manufacturing wage in Mexico, the aggregate labor supply elasticity, the elasticity with respect to employment, and the wage elasticity of demand. The most difficult parameters to estimate are the detention cost (which includes a psychological component), the multinomial logit parameter (which dictates population heterogeneity in preferences), and the two exponential parameters that specify the effectiveness of apprehension in the absence and presence of surveillance technology. They are jointly estimated using data on the sensitivity of the number of apprehensions to the U.S.-Mexico wage ratio, the fraction of apprehensions that are aided by surveillance technology, and the base-case apprehension probability (for both Mexicans and OTMs). The values of these four parameters are tightly coupled. More specifically, for a given value of the multinomial logit parameter, there is a somewhat narrow range of detention costs that give stable values for the two apprehension parameters. For example, if we increase the detention cost above this range, too many crossers travel to regions on the border where there is no surveillance technology, making it impossible for the surveillance technology to aid in a sufficient fraction of apprehensions. In addition, we found two solutions for the values of these four parameters, the main difference being that the multinomial logit parameter was six-fold higher in one solution than in the other (i.e., the values of the other three parameters changed only slightly). The solution with the high value of the multinomial logit parameter generated an illegal unemployment rate of 41%, and we consequently discarded this solution and used the solution with the low value of the multinomial logit parameter.

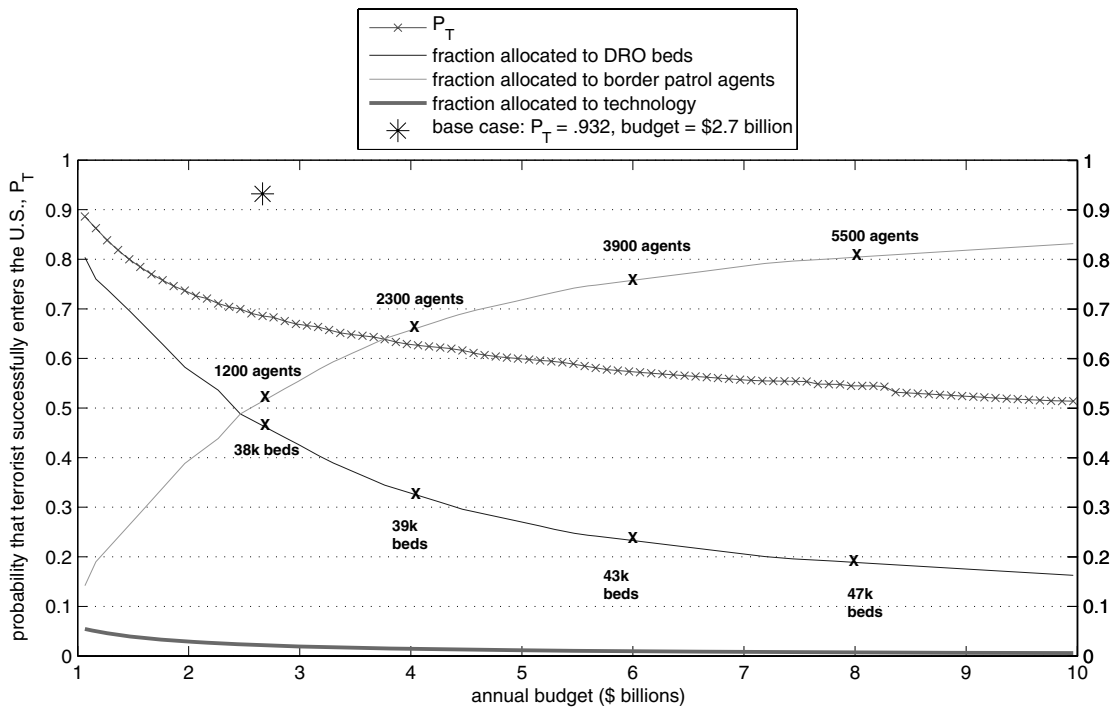


Fig. 2. The optimal budget allocation across border patrol agents, border technology, and DRO beds. The numbers appearing along the curves are the optimal number of agents (on the border at any given time), miles of technology, and DRO beds at various budgets. The *denotes the base-case allocation with Expedited Removal, which represents current practice.

4. RESULTS

4.1. Base-Case Results Without Expedited Removal

Our main performance measure is the probability that an OTM terrorist successfully enters the United States, which is denoted by P_T . If we let P_a be the probability that an OTM is apprehended at the border and P_r be the probability that an apprehended OTM is removed from the country, then $P_T = 1 - P_a + P_a(1 - P_r)$. In our base case (apprehended Mexicans are not detained, no illegal workers are legalized, no new guest workers are introduced, 65 worksite inspectors perform 60% of their inspections at targeted firms with a fine of \$5 per illegal worker-hour, 15% of the U.S.-Mexico border is monitored by surveillance technology, 1,636 border patrol agents are on the border at all times, Expedited Removal is not being used, and there are 22,580 DRO beds; see Section 5 in the Appendix for details), we have $P_a = 0.2$, $P_r = 0.137$, and hence $P_T = 0.973$. The annual cost of this strategy is \$2.7B. Other notable features of the base-case results include: the multinomial logit parameter implies considerable population heterogeneity, many border crossers are willing to travel to avoid apprehension

(Fig. 1 in the Appendix), the impact of worksite enforcement is minimal (the difference between the annual legal and illegal wage is \$180), the illegal U.S. wage is 4.5-fold larger than the wage in the home country, the detention cost incurred by an OTM is 1.8 times the annual illegal wage, $\approx 90\%$ of potential crossers decide to cross the border, the exponential apprehension parameter is 31.3-fold larger without technology than with technology, and the illegal labor supply in the United States is 7.76M (implying a 7.2% unemployment rate among illegal aliens).

4.2. The Impact of Detaining Apprehended Mexican Crossers

If all apprehended nonmandatory Mexicans are detained, then P_T increases to 0.989 (Fig. 2 in the Appendix) because the apprehended Mexicans overwhelm the DRO facilities. Even a dramatic increase in DRO capacity (e.g., 10^5 beds) would not be able to accommodate the detained Mexicans. Not detaining nonmandatory Mexicans until their fourth apprehension is nearly equivalent to not detaining them at all (Fig. 2 in the Appendix) because the probability of being apprehended four consecutive times is less

than $0.2^4 = 1.6 \times 10^{-3}$. Hereafter, we assume that nonmandatory Mexicans are never detained.

4.3. The Impact of Expedited Removal

In 2006, Immigration and Customs Enforcement expanded the use of Expedited Removal authority, in which nonmandatory OTMs could be removed without an immigration hearing, to the entire U.S.-Mexico border, which reduced the mean residence time for nonmandatory OTMs to 19 days.⁽³¹⁾ In our model, this dramatic reduction in residence times increases the removal probability P_r from 0.137 to 0.430 and reduces P_T from 0.973 to 0.932. Hereafter, we assume that Expedited Removal is used in the base case.

4.4. Optimizing Nonworksite Decision Variables

Increasing the number of border patrol agents 6-fold or deploying surveillance technology on the entire U.S.-Mexico border each has a negligible impact (P_T decreases by 0.01 to 0.922) if done in isolation (or in combination) because there is no DRO capacity to handle the increase in apprehensions (Figs. 3a and 3b in the Appendix). Increasing DRO capacity by 33% to 30k beds (leaving other decision variables at their base-case values) reduces P_T from 0.932 to 0.880; further increases have no effect because the bottleneck resource is no longer DRO beds (Fig. 3c in the Appendix).

To better understand the interaction of the decision variables, we leave the worksite enforcement decision variables at their base-case values, and choose the number of border patrol agents, number of miles of border monitored by surveillance technology, and the number of DRO beds to maximize P_T subject to an annual budget constraint; solving this optimization problem for a variety of budgets generates an optimal P_T vs. cost curve (Fig. 2). For the base-case budget of \$2.7B, the optimal P_T is 0.686, compared to the base-case value of 0.932. This improvement is achieved by deploying more technology, more beds, and less agents than in the base case. More generally, the optimal budget allocates much of its initial money to deploy surveillance technology on the entire U.S.-Mexico border, and then balances border patrol agents and DRO beds so as to maintain enough beds to remove >95% of potential detainees. Increasing the budget 4-fold to \$10B reduces P_T to

0.514, but the P_T vs. cost curve is convex (i.e., generates diminishing returns).

4.5. The Impact of Positioning Border Patrol Agents

Recall that in our model, the crossers' arrival location and the border patrol agents' location both follow sinusoidal functions that have the same frequency and relative amplitude. The value of P_T can be reduced significantly (particularly for annual budgets >\$2B) by using a relative amplitude for the border patrol agents' location that is smaller than the relative amplitude of the crossers' arrival location; indeed, the optimal relative amplitude for the border patrol agents appears to be zero (Fig. 4 in the Appendix). That is, a uniform spacing of border patrol agents along the border prevents crossers from moving to remote locations where there are fewer agents, thereby improving the apprehension probability.

4.6. The Impact of Worksite Decision Variables

Leaving the nonworksite decision variables at their base-case values, we first investigate how the equilibrium illegal wage is influenced by the worksite decision variables. When the employer fine is \$5/worker-hr, the annual illegal wage drops from the base-case value of \$22.3k to \$12.3k as the number of worksite inspectors is increased from its negligible base-case value of 65 to 10,850 (which causes every firm to be inspected every year), and the illegal wage is smaller when the fraction of randomized inspections is higher (Fig. 5a in the Appendix). We also consider a 5-fold higher fine of \$25/worker-hr, which is closer to the value used in Germany.⁽³²⁾ This larger fine lowers the annual illegal wage to \$5k, which is the home-country wage, with 4k to 9k inspectors, depending upon the fraction of inspections that are targeted (Fig. 5b in the Appendix). In contrast to the scenarios with a \$5/worker-hr fine, when the fine is \$25/worker-hr the illegal wage increases as the fraction of randomized inspections increases. The annual illegal wage drops by \approx \$200 (and by \approx \$150 when the fine is \$25/worker-hr) for every 1M illegal workers that are legalized or every 1M new legal workers that are introduced via a guest worker program (Figs. 6a and 6b in the Appendix). Both of these policies increase the supply of legal labor, which reduces the equilibrium legal wage, which in turn reduces the illegal wage for any given level of worksite enforcement.

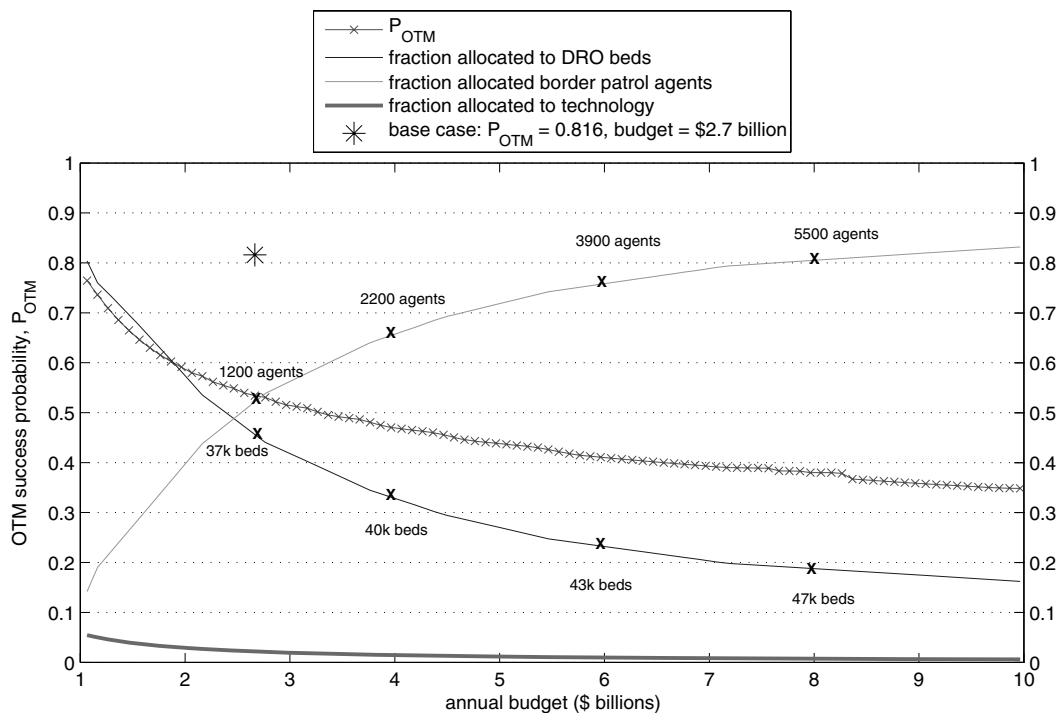


Fig. 3. For the alternative objective of minimizing the OTM success probability (P_{OTM}), the optimal budget allocation across border patrol agents, border technology, and DRO beds. The numbers appearing along the curves are the optimal number of agents (on the border at any given time), miles of technology, and DRO beds at various budgets. The * denotes the base-case allocation with Expedited Removal, which represents current practice.

To understand the effect of wage reduction, we note that when the annual illegal wage drops from \$22.3k to \$5k, the probability that an illegal alien attempts to cross the border decreases from 90% to 43% (Fig. 7 in the Appendix); the large population heterogeneity embodied in the multinomial logit parameter prevents a larger drop. This 90-to-43% reduction in attempted border crossings in turn has two main effects: it increases the apprehension probability P_a from 0.158 (note that Expedited Removal reduces P_a from 0.2 to 0.158 in the base case) to 0.212 because of reduced congestion at the border and it causes the removal probability P_r to increase from 0.430 to 0.605 because of reduced congestion at DRO. In the calculation of $P_T = 1 - P_a + P_a(1 - P_r)$, it is the former effect that dominates because P_T changes from $1 - 0.158 + 0.158(1 - 0.43) = 0.932$ to $1 - 0.212 + 0.212(1 - 0.605) = 0.872$.

In our model, the cost of one border patrol agent (on the border at all times) is equal to the cost of 4.8 worksite inspectors, and border patrol agents are more cost effective than worksite inspectors at lowering P_T for all budget values. More specifically, with 100% deployed surveillance technology,

evenly-spaced agents, and ample DRO beds (i.e., $P_r = 1$, so that $P_T = 1 - P_a$), putting additional money into border patrol agents decreases P_T 5-fold more than putting money into worksite inspectors (Fig. 8a in the Appendix). Hence, even if worksite inspectors are included as a decision variable in the optimization problem, the optimal budget allocation remains identical to that in Fig. 2.

4.7. Sensitivity Analyses

To assess the robustness of the desirability of surveillance technology, we fix the exponential apprehension parameter without technology and increase the apprehension parameter with technology (thereby degrading the effectiveness of technology) to the point where, with the base-case annual budget of \$2.7B, we are indifferent between using surveillance technology along the entire border and not using the technology at all. The break-even ratio of the two parameters is 1.03, compared to the base-case ratio of 31.3. This small break-even ratio (a ratio of 1.0 corresponds to useless technology) suggests that surveillance technology need only be marginally

effective to merit inclusion in a P_T -minimizing strategy.

A central question in this study is whether border patrol or worksite enforcement is the more cost-effective approach to minimizing P_T . We investigate this question with respect to a decision variable (the workforce penalty) and three parameters that are difficult to estimate: the detention cost, the initial legal labor supply, and the multinomial logit parameter. First, cutting the detention cost for both OTMs and Mexicans by a factor of 10 (so that the OTM detention cost is 0.18 times the annual illegal wage) leads to very little change in the results relative to the base case. Next, we fix the worksite fine at \$25/worker-hr and change the initial (i.e., before legalization or a guest worker program) legal labor supply from its base-case value of 30M to either 20M or 40M. The initial legal labor supply dictates the reduction in the illegal wage as a result of an increase in the supply of legal labor via a legalization policy or a guest worker program. The annual illegal wage dropped by \$150 for every 1M new legal workers with the base-case initial legal labor value of 30M, but the magnitude of the sensitivity is asymmetric: this value increases to \$250 when the initial legal labor supply is 20M and decreases to \$125 when the initial legal labor supply is 40M. This reduction to 20M is not nearly sufficient to tip the tradeoff from border patrol agents to worksite inspectors.

For the last two parameters, the worksite penalty and the multinomial logit parameter, we seek break-even values that would lead to indifference between investments in border patrol agents and worksite inspectors. In each case, we assume there are ample DRO beds (which allows us to focus on apprehension rather than detention and removal) and consider two scenarios: the base-case scenario that has surveillance technology along 15% of the border and a spatially-heterogeneous allocation of border patrol agents, and an alternative scenario that has technology along the entire border and evenly-spaced agents. Using Fig. 8a in the Appendix, which assumes the latter of these two scenarios, we find a break-even value for the enforcement fine of \$41.20/worker-hr, which is 65% larger than the fine currently used in Germany.⁽³²⁾ In the base-case scenario, the break-even value is only \$17.00/worker-hr because it is easier in this scenario for crossers to find portions of the border that are not under surveillance and have few border patrol agents.

Finally, an increase in the multinomial logit parameter leads to a more responsive alien population,

which has two major effects: wage reductions would cause a larger drop in the crossing probability than we see in the base case (Fig. 7 in the Appendix), and crossers would more aggressively seek out poorly patrolled areas of the border, leading to a reduction in the apprehension probability. In the base-case scenario, the break-even value for the multinomial logit parameter is 2.6-fold higher than the base-case value. There is no break-even value for the multinomial logit parameter in the alternative scenario, where savvy crossers are less able to exploit weaknesses in border security (in this case, crossers cross at high-traffic locations).

4.8. Identifiable Terrorists

We have thus far assumed that an apprehended terrorist would be treated the same way at DRO as any other OTM because the government would not realize that he or she is a terrorist. In actuality, a certain fraction of apprehended terrorists could be identified as terrorists; in particular, starting in 2004, border patrol agents began taking fingerprint images of apprehended aliens and matching them against the prints in the government's watchlists.⁽³³⁾ However, there are no publicly available data to estimate the fraction of apprehended terrorists that are identifiable at the border. As an illustrative example, we assume that half of the apprehended terrorists can be identified as terrorists, so that $P_T = 1 - P_a + 0.5P_a(1 - P_r)$, and recompute the optimal P_T vs. budget curve (Fig. 9 in the Appendix). Relative to the base case, it is now optimal for the government to put more resources into border patrol agents and less into DRO beds. Although P_T is lower for a given budget than it is in the base-case curve in Fig. 2, the improvement is rather small due to the difficulty in increasing the apprehension probability when border patrol agents are distributed sinusoidally across the border.

4.9. Maximizing Immigration Enforcement

We now consider the objective function of minimizing the number of OTMs that successfully sneak across the border, which is equivalent to minimizing P_T times the OTM crossing probability, which is the left side of relation (1). We refer to the product of these two probabilities as the OTM success probability, P_{OTM} . In the base case, $P_{OTM} = 0.863$ without Expedited Removal and $P_{OTM} = 0.816$ with Expedited Removal. The optimal P_{OTM} vs. budget

curve and the optimal allocation of nonworksite decision variables (Fig. 3) are very similar to those under the homeland security objective of minimizing P_T (Fig. 2), except that the percentage reductions achieved for a given budget are somewhat larger for P_{OTM} than for P_T . While worksite enforcement plays only an indirect role (i.e., by reducing congestion at the border and at DRO) in minimizing P_T , it plays a direct role in minimizing P_{OTM} . If we assume 100% surveillance technology deployment, evenly-spaced agents, and ample DRO beds, then border patrol is 35% more cost effective than worksite enforcement (Fig. 8c in the Appendix) for this objective, rather than 5-fold more cost effective, as when minimizing P_T .

5. DISCUSSION

Immigration is a difficult issue to mathematically model: even restricting our attention to the small part of immigration that affects homeland security leads to an unwieldy system of equations and a formidable parameter estimation task. The level of detail in our submodels is dictated by the level of detail in the available data. The Removal Submodel is the only one of the four submodels that we are confident provides a reasonably accurate model of reality, due to our previous calibration of the model with the ample data on detention and removal operations.⁽¹⁷⁾ While the Discrete Choice Submodel is a workhorse in a wide variety of fields and seems like a natural choice here, the multinomial logit parameter and the cost of detention are very difficult to estimate, even to within an order of magnitude. Although the Apprehension Submodel is spatially nonhomogeneous and captures the game-theoretic and congestion aspects of apprehension, it is still a mere caricature of the evolving struggle between border crossers (and coyotes) and border patrol agents, and the data on the efficacy of surveillance technology are very sparse. The Illegal Wage Submodel is also a very crude idealization of reality that—while capturing many important features of the problem—uses simple toy models such as the Cobb-Douglas production function and the neo-classical labor supply function, and does not attempt to employ detailed data from different industrial sectors.⁽¹⁹⁾ Furthermore, as broad as our model is, it omits entire aspects that have a direct bearing on the issues, including (i) other ways to sneak into the United States, such as along the U.S.-Canada border (although Canada has a better infrastructure than Mexico for catching illegal aliens upon arrival), by

private boat or airplane, or at legal points of entry; (ii) the interaction between illegal border crossing and drug trafficking; (iii) the policies (including the number of staff, which dictates visa waiting times) of the U.S. Consulate and the availability of visas; (iv) whether legalized workers are offered a path to U.S. citizenship; and (v) the efficacy of U.S. government investments to strengthen the Mexican economy.

Consequently, the model's numerical output is not intended—and indeed is unable—to capture the quantitative impact of various decisions with any degree of accuracy, and so the model is incapable of directly guiding policy, except in a very crude manner. Rather, this study—by framing the immigration/homeland security problem in a way that captures most of its salient features—is meant primarily as a vehicle for rational dialog about a complex problem that often elicits strong emotional responses.

Our main policy question is how to allocate funds across border patrol agents, DRO beds, surveillance technology, and worksite enforcement (and the related question of the appropriate size of the budget), although we also look at the impact on homeland security of the detention policy (whether apprehended Mexicans should be detained), the legalization policy (whether illegal workers should be legalized), and a guest worker program. Our objective of minimizing $P_T = 1 - P_a + P_a(1 - P_r)$ makes clear that there are two sequential operations, apprehension followed by detention and removal, that need to be successfully completed to prevent a terrorist from entering the U.S. Investments in border patrol agents, surveillance technology, and worksite enforcement increase the probability of apprehension, while DRO beds and worksite enforcement increase the probability of detention and removal. Our analysis reveals that detention and removal was a severe bottleneck under the existing resource allocation through 2005, and hence further investments in technology and border patrol agents without a significant concomitant increase in DRO beds did not reduce P_T during this period. The implementation of Expedited Removal in 2006, which significantly reduced residence times for nonmandatory detainees but raised human rights concerns,⁽³⁴⁾ caused a modest reduction in P_T . Nonetheless, congressional plans still lead to significant underfunding of DRO: the security triggers (i.e., before initiating guest worker and legalization programs) in the proposed May 2007 Senate immigration bill called for 18k border patrol agents (which corresponds to 2,587 agents in our model) and 27.5k DRO beds,⁽³⁵⁾ whereas our model's optimal bed

allocation when there are 2,587 agents is 40k beds. It seems doubtful that increased border patrol and surveillance would provide a deterrent effect in the absence of ample DRO capacity, given the fact that many aliens (and coyotes) had been well aware of the pre 2006 catch-and-release strategy.⁽³⁶⁾ We also show that detaining apprehended, Mexicans would overwhelm DRO, leading to an increase in P_T . These two results—DRO is the bottleneck and detaining apprehended Mexicans would overwhelm DRO—are the only ones that we can state with confidence.

Surveillance technology appears to be cost effective in our model, but there are two important caveats beyond the fact that the data on its efficacy are sparse. First, regardless of whether the technology is passive (e.g., video that requires a human to detect a suspicious event) or active (i.e., sets off its own alarm), its efficacy relies on having sufficient human resources to process and screen the output data of these systems and to quickly communicate information to the appropriate border patrol agents; such resources have been woefully inadequate in recent years.⁽²⁾ Second, it is important to keep in mind that our model does not include the U.S.-Canada border or approaches by air or sea. If effective surveillance technology was actually deployed along the entire U.S.-Mexico border, it seems likely that potential crossers would choose an alternative route into the U.S. Hence, the U.S. government would need to provide surveillance technology along the entire U.S.-Canada border and along the nation's shores and airspace, which seems daunting, both financially and logistically.

Our analysis also suggests that, at least over the longer run, spacing agents evenly along the border is more effective than concentrating them in the busiest areas. This result is driven by viewing the Apprehension Submodel as a Stackelberg game⁽⁷⁾ in which the U.S. government moves first (decides where to locate border patrol agents) and the aliens (perhaps with the help of coyotes) move second (i.e., decide where to cross). This Stackelberg assumption is not only conservative (relative to, e.g., seeking a Nash equilibrium in which both players move simultaneously) but realistic, in that many aliens cross at remote locations on the border in response to increased security,⁽³⁷⁾ and the apprehension probability along the U.S.-Mexico border has actually dropped over the last several decades despite large increases in technology deployment and the number of border patrol agents.⁽³⁸⁾ On a related note, a nonobvious aspect of our results is that crossers become more savvy (i.e.,

are more willing to cross at remote locations on the border) when there are more severe consequences of being apprehended. In particular, a large increase in the number of DRO beds (or, equivalently, a large reduction in DRO residence times, as was achieved with Expedited Removal) leads to a reduction in the apprehension probability because more crossers are willing to pay the cost of traveling to remote areas to avoid being removed (as opposed to being released) upon apprehension.

An important goal of our analysis is to understand the extent to which border patrol agents and worksite inspectors are substitutes for one another, and which resource is more cost effective. Although our model predicts that border patrol agents are ≈ 5 -fold more cost effective than worksite inspectors at reducing P_T , ultimately our Apprehension Submodel and Illegal Wage Submodel are too idealized—and the values of some of the key parameters (particularly the behavioral parameters) too difficult to estimate accurately—for us to make any policy recommendations based on these results. Nonetheless, our analysis does shed light on the detailed mechanics that are at play. Worksite enforcement (and, to a much lesser extent, a legalization policy or a guest worker program) acts to reduce the wage of illegal workers because employers pass the risk on to the illegal workers in the form of lower wages, which reduces the crossing probability of aliens because the illegal U.S. wage looks less attractive relative to the wage in their home country, which in turn increases the apprehension probability (and hence our objective, P_T) by reducing congestion along the border (i.e., reducing the likelihood that an agent cannot apprehend a crosser because he or she is busy apprehending someone else) and increase the removal probability by reducing congestion at DRO. In contrast, an increase in the number of border patrol agents has a two-pronged effect: as with increased worksite enforcement, it has a deterrent effect (the deterrent effect achieved by worksite enforcement is approximately two-fold more cost-effective than the deterrent effect achieved by border patrol agents, Fig. 8b in the Appendix) by reducing the crossing probability and hence congestion at the border, but it also directly increases the probability of apprehension at the border.

Our cost estimates do not include two important components that each represent $\approx \$1,000$ per removed alien:⁽³⁹⁾ the transportation costs associated with removal and the legal costs associated with prosecution. The transportation costs are not relevant to

our optimization problem because they do not vary with how the alien was detected (i.e., at the border vs. at the workplace): in either case, the alien needs to be flown to his or her home country. However, legal costs may differ by how the alien was detected. In particular, the legal costs associated with border apprehension have been significantly reduced by the implementation of Expedited Removal. The majority of legal costs associated with worksite enforcement may be due to prosecuting employers as opposed to removing illegal workers. To the extent that legal costs are higher for worksite enforcement than for border apprehension, our omission of legal costs biases our results on the border patrol agents vs. worksite inspectors tradeoff in favor of the latter. That is, the omission of legal costs strengthens our argument that border patrol agents are more cost effective than worksite inspectors.

Our results are qualitatively similar, regardless of whether we are maximizing homeland security (Fig. 2) or maximizing immigration enforcement (Fig. 3). The main difference is that while border patrol agents are clearly more cost effective than worksite inspectors for maximizing homeland security, the tradeoff is much less one-sided when maximizing immigration enforcement because of the strong deterrent effect of worksite enforcement on the OTM crossing probability.

Several other issues pertaining to worksite enforcement deserve mention. In particular, a tamper-proof identification system is a prerequisite to implementing an effective worksite enforcement program. Judging by the cost of—and problems plaguing—the US-VISIT program,⁽⁴⁰⁾ and the document fraud and third-party worker-verification firms that were encountered during IRCA⁽⁴¹⁾ and still persist today,⁽⁴²⁾ the cost of such a system would be huge and the risk (i.e., whether the system actually worked as intended) would be high. On the other hand, a worksite enforcement program—and, more generally, bringing all the employment of aliens above ground—would have other impacts that may be at least as important as homeland security, such as improving worker conditions,⁽¹⁾ and perhaps affecting the unemployment rate and wages of native unskilled workers.^(20–22)

To summarize the preceding discussion, we contribute to risk science by formulating and analyzing an interacting suite of four models that captures many of the behavioral, technological, and systems issues at the heart of one of the most challenging problems currently facing the U.S. government: illegal immigration and its impact on homeland security.

We can state several results with confidence: the likelihood of successfully sneaking into the country is very high, apprehending Mexican noncriminals would overwhelm DRO capacity and be counterproductive, and DRO capacity is currently the bottleneck in the process of apprehending and removing aliens, implying that increases in other resources (e.g., border patrol agents) without concomitant increases in DRO capacity are wasteful. Border patrol agents are more cost effective than worksite inspectors from the viewpoint of homeland security, but there are too many uncertainties in the model's parameters and in the effectiveness of worksite enforcement implementation (e.g., fraud-resistant documents) to assess which is more cost effective for immigration enforcement. The cost effectiveness of technology at the U.S.-Mexico border hinges on three assumptions that have questionable validity: the technology is reliable,⁽⁴³⁾ there are sufficient human resources to quickly act on the surveillance information generated by the technology, and potential crossers—when faced with effective technology at the U.S.-Mexico border—will not opt to cross along the U.S.-Canada border or enter by air or sea. Finally, while it is clear that crossers exploit the spatial clustering of border patrol agents and technology, and the spatial location of agents can be improved, a more detailed spatial model (e.g., including actual roads and footpaths near the border) would be required to develop a spatial deployment that would reliably improve performance.

In conclusion, because our model has focused on only the narrow set of issues at the intersection of homeland security and immigration, we are not in a position to make concrete recommendations about the size and composition of the U.S. Immigration and Customs Enforcement (ICE) budget, aside from the observation that DRO capacity is currently lacking relative to border patrol capacity. However, it seems clear that the current security system at the U.S.-Mexico border is very porous ($P_T > 0.93$ in the base case) and efforts to meaningfully reduce P_T (e.g., to 0.1 or 0.2) would be immensely costly and might not succeed.

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