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SALE OF VISAS: A SMUGGLER'S FINAL SONG ?

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Abstract

Is there a way of eliminating human smuggling? We set up a model to simultaneously determine the provision of human smuggling services and the demand from would-be migrants. A visa-selling policy may be successful at eliminating smugglers by eroding their profits but it also increases immigration. In contrast, repression decreases migration but fuels cartelized smugglers. To overcome this trade-off we show that legalisation through selling visas in combination with repression can be used to eliminate human smuggling while controlling migration flows. Simulations of the policy highlight the complementarities between repression and selling visas and call into question current policies.

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Keywords : migration, human smuggling, market structure, legalisation.

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1 Introduction

Crossing borders illegally entails very high financial costs. This is particularly true for long distance migration, which is difficult to undertake without the help of smugglers. For example, trans-pacific crossings of Chinese immigrants into the United States cost above $35,000 in the mid 90s and these costs have since increased sharply.[1] This makes human smuggling a lucrative business. As of 2003, it earned smugglers over €4 billion in the EU and $5 billion revenues a year in the US (Padgett, 2003).[2] Over the years, human smuggling has merged with other types of illegal transnational activities such as drug shipping and prostitution.[3] Led by international criminal organizations these activities pose a threat to the rule of law in countries of origin, transit, and destination. Although it is important for policy makers to understand why such illegal activities and their associated criminalities are so prevalent, there are surprisingly very few studies on the supply side of illegal migration (noticeable exceptions are Friebel and Guriev, 2006 and Tamura, 2010, 2013). Our paper contributes to this new literature, first, by studying the industrial organization of human smuggling, notably smugglers' pricing and supply of services. Second, by exploring what type of economic policies can be implemented to fight against human smuggling.

Current migration policies, which combine quotas on visas with repression

[1]On smugglers' fees paid by Chinese migrants in the 1990s see Friebel and Guriev, 2006. On fees paid in 2010 see the website: http://www.havocscope.com/black-market-prices/human-smuggling-fees/ which also gives references to its sources of information. In addition, human smuggling entails important human costs. Each year, an estimated 2,000 people are drowned in the Mediterranean on their journey from Africa to Europe (The Economist, August 06, 2005) and many more on other routes.

[2]The annual associated flows of smuggled immigrants are estimated to be at around 800,000 in the EU and 350,000 in the US (The Economist 6 August 2005). These estimates should be dealt with caution as reliable data on such activity are difficult to obtain.

[3]Trafficking victims coming from 127 countries have been found in 137 countries around the world. It is estimated that there are at least 2.4 million persons who are the victims of trafficking at any time. Approximately 79% of these victims are trafficked for sexual exploitation and 18% for forced labour. They generate an estimated profit of over US$30 billion every year (UNODC 2012).

of illegal migration, are very ineffective against smugglers.[4] In fact, strong restrictions on labour mobility imply that many candidates are obliged to arrange long distance migration with the help of intermediaries who organise air, sea or ground transportation and provide them with forged documents, clothes, food and accommodation during the trip. Since repressive policies are ineffective, this paper proposes legalisation to eradicate the illegal migration business. We analyse how the sale of visas, combined with various repressive measures, can be used to eliminate smugglers while achieving pre-defined migration flow targets. We do not discuss the optimality of such targets, nor the restrictive migration policies adopted by most advanced economies or their lax enforcement (for an analysis of such issues see Facchini and Testa, 2011).

Our analysis shows that the sale of visas at smugglers' price, or higher, will not be sufficient to eliminate smugglers, nor to improve the skill composition of migrants. Indeed prohibition creates a barrier to entry into the market. Mafia organisations rely on this legal barrier, and on violence, to cartelize the industry and to charge high prices. The big markups imply that smugglers will respond to the sale of visas by lowering the price they propose and still make a profit. This will hence increase migration flows. We may also expect the high prices charged by smugglers not to affect all immigrants equally but to act as a positive selection with higher prices disproportionately reducing the flow of lower income immigrants.[5] In this context, the sale of visas,

[4]Illegal migration represents a sizeable proportion of the foreign population living in high wages countries. In Europe for example, the Clandestino Research Project estimates that 1.8 to 3.3 million irregular foreign residents live in the old Member States of the EU15 in 2008 (See at: http://clandestino.eliamep.gr/ or Dustmann and Frattini, 2011). This represents 0.46% to 0.83% of their population and 7% to 12% of their foreign population. Worldwide, the International Labour Organisation estimates that 10 to 15 per cent of migration today involves migration under irregular situations i.e. entering or working in countries without authorization (http://www.ilo.org/public/libdoc/ilo/2006/106B09_492_engl.pdf).

[5]Similar effects were reported by multiple contemporary accounts following the cartelization of the shipping industry at the turn from the 19th to the 20th century (see Deltas et al 2008).

which will push down smugglers's prices, will worsen the skill composition of migrants.

To be more specific, in our model the demand comes from workers who choose to work in the foreign country or in the origin country, weighing the benefits of higher wages in foreign countries against migration costs. Migration price is determined by smugglers who maximise their profits. Policies shape the market structure. They may reinforce the market power of the smugglers by increasing their costs to operate and hence their prices, or force them to propose lower prices to compete with the visas on sale. We will see that neither traditional repressive measures nor more "innovative" pricing tools through the sale of visas are satisfactory policies. The former help to control migration flows but, far from suppressing smugglers, they may even increase their market power and the price paid by the migrants for their service. The latter help to eradicate smugglers' activities at the cost of substantially increasing migration flows. The paper then explores how a combination of these measures may be effective at eradicating human smuggling and controlling migration flows, without necessarily increasing the budget deficit.

To illustrate the importance of combining repression and legalisation to control demand we calibrate the price of visas, which would drive smugglers out of business. Using our model and estimates from previous studies on Chinese migration to the US, this price varies between around $18000 when the risk of deportation for illegal migrants is low (i.e., 20%) and around $50000 in case of high risk (i.e., 70%). With a high risk of deportation for illegal migrants it is easier for the government to apply a high price for the visas, which will eliminate smugglers. Several reasons why such combinations of pricing and repression instruments have not yet been implemented are discussed with the policy implications of the paper.

Link with the literature

The idea of selling visas to regulate migration flows has already fed many debates in the general press and blogs, and policy proposals have discussed different ways of implementing it, notably through auctions (Simon, 1989, Becker, 2002, the Becker-Posner blog of 31rst July 2005, Freeman, 2006, Saint Paul, 2009, Orrenius and Zavodny 2010, The Economist, 24 June 2010).[6] The proponents argue that selling visas allows a government to both collect money and control migration flows instead of fuelling mafias by further restricting migration. The opponents argue that the sale of visas may generate a new type of bonded labour between indebted migrants and their employers and that the market does not necessarily allocate resources efficiently. However these arguments are even more compelling for the illegal migration market, on which candidates are less likely to get formal loans to pay the high smugglers' fees.

Despite the controversy, selling visas to eliminate the smuggling industry and regulate the market has not yet been analysed.[7] Our goal is to study the possibility of using standard economic tools such as market and prices to eliminate the smugglers, and their impacts on the migration market. Moreover we will show that this involves combining carefully the sale of visas with repression measures. Usually these two types of public intervention are perceived as conflicting, and are hence discussed separately by policy makers. Yet the analysis below shows that they are complementary if one aims at eradicating human smuggling while controlling migration flows.

By studying the response by smugglers to policy measures, our paper is close in spirit to Friebel and Guriev (2006), who model how smugglers establish labour/debt contracts with poor migrants, which force them to repay

[6]With the same aim of designing market tools to control migration flows, Moraga and Rapoport (2013) have set up a model where host countries trade immigration quotas.

[7]This legalisation policy will hence be very different from exceptional amnesties, which have been repeatedly granted in the past to illegal migrants living in European countries such as Spain, Greece or in the US and pose an obvious problem of time consistency and credibility of the state. See Chau, 2001, Epstein and Weiss, 2001, Karlson et al., 2003, Solano, 2009 on the rationale and optimal design of amnesties. See Maas, 2009, on their questionable effectiveness at decreasing the number of illegal migrants.

their fee. In this context, they show that deportation and border control policies do not have the same effects on illegal migration: stricter deportation policies may increase the flow of illegal immigrants and worsen the skill composition of immigrants while stricter border controls decrease overall immigration and may result in an increase in debt-financed migration. A key assumption of their model is that migrants are liquidity constrained and cannot pay upfront the fee, which gives rise to these contracts.[8] In a different context where contracts are not legally enforceable between traffickers and smuggled migrants, which leads to migrants' exploitation, Tamura (2010) shows that destination countries with limited resources may prefer to improve the apprehension of smugglers and their clients at the border rather than inland. Similarly, in a setting of asymmetric information, Tamura (2013) shows that improved inland apprehension may increase the incidence of migrants exploitation. Our paper complements this literature by studying the industrial organisation of the smuggling industry. In particular it helps to explain where the high prices, which lead to the establishment of labour/debt contracts first analysed by Friebel and Guriev (2006) come from.

In contrast to these two papers we do not study liquidity constrained nor trafficked migrants.[9] We focus on unconstrained workers who use the services of smugglers to willingly migrate illegally. This allows us to derive tractable results on the effects of a larger set of policy measures - sale of visas versus more traditional repressive policies through border enforcement, deportation or employers' sanctions - on the equilibrium of the market for smuggled migrants. Our results show that only a combination of them may be

[8]Migrants may also respond to these debt labour contracts by choosing optimally the duration of repayment period and consumption behaviour and this affects the complementarities between border controls, deportation measures and employer sanctions as studied by Djajić and Vinogradova, 2011.

[9]Note that financial constraints are likely to be less binding with the introduction of visas as migrants could more easily get loans. And legalisation diminishes the scope for human trafficking as laws can be more easily enforced against exploitative smugglers (see Friebel and Guriev, 2006, on indebted migrants; Tamura, 2010, 2013 or Mahmoud and Trebesch, 2010 on trafficked migrants).

effective at both eliminating smugglers' businesses and controlling migration flows, and that it also limits the increases in budget deficit entailed by stricter controls. Our results are robust to the introduction of risk, which, with the noticeable exceptions of Woodland and Yoshida (2006) and Vinogradova (2010), has rarely been addressed in previous studies on illegal immigration control.

The theoretical literature on illegal immigration control, following the seminal paper by Ethier (1986), focuses on risk neutral agents. Epstein et al.(1999) take into account its dynamic aspects, as migrants who enter legally may subsequently move into the illegal sector in order to avoid deportation and Djajić (1999) investigates its counterproductive effects as migrants may move into new sectors and new areas, where new migration networks may form. In practice countries such as Israel, Cyprus and Lebanon have tried to regulate long distance migration through local agencies located in South East Asian countries such as Philippines and Sri Lanka. These legal intermediaries organise the shipment of cheap labour force to compensate for shortages in labour. As migrants under these schemes are obliged to return to their home country at the end of their contract, this is the source of another type of illegal migration from those overstaying illegally in the destination country (Djajić, 2011, Schiff, 2011). However, none of these papers takes into account the organisation of the supply side of the market by smugglers, which is the main focus of our paper, as well as the associated risk it entails for the migrants.

The empirical literature investigates the determinants of illegal migration and assesses its responsiveness to border enforcement measures (Donato et al., 1992, Massey and Espinosa, 1997, Hanson and Spilimbergo, 1999, Hanson et al., 2002, Angelucci 2012). These papers focus on cross border migration between the US and Mexico and point to a small or insignificant effect of stricter deportation rules and stricter border controls after the Immigration Reform and Control Act (for a review see Hanson, 2006) on migration flows.

For example, using detailed data on cross-border trips of illegal workers from the Mexican Migration Project, Gathman (2008) shows that when the price to cross the border with the help of coyotes increases, migrants may choose to migrate by their own means and forego the services of smugglers by taking additional risks to cross the border in more remote areas.

However, we expect long distance migration to respond differently to smugglers' prices as it is not feasible without their services. Although there is no evidence on the price elasticity of long haul illegal migration, we know from history that long distance *legal* migration responded strongly to changes in the market structure of shipping cartels at the beginning of the 20th century. This has been tested empirically by Deltas et al (2008), who show that the existence of relatively tight, well-organized cartels restricted the flow of transatlantic migrants below what would have occurred in a more competitive environment. Today, long haul illegal migration still entails sizeable costs, which may continue to be prohibitively expensive for poor workers and depend strongly on the industrial organisation of smugglers.

Our work also dovetails with the literature on the economics of crime, which documents the role played by highly organised networks of smugglers (Aronowitz, 2001; Futo and Jandl, 2007; Guerette and Clarke, 2005). Lundgren (2008) illustrates the imperfect competition prevailing among smugglers operating in Belarus and Ukraine in a duopoly model. Consistent with this literature we build a model where oligopolistic smugglers offer their services. Since cartelisation of smugglers may vary across routes and may also change over time, we leave flexible the degree of market concentration. It is indeed straightforward in our model to endogenise the number of smugglers to capture the effects of increased repression in our general set-up of human smuggling markets. Simultaneously with the supply of services we determine the demand from would-be migrants and study the effects of selling visas to legalise migration on the market equilibrium.

The rest of the paper is organised as follows. Section 2 presents the set-up of the model and describes the market structure for illegal migration under *status quo* (absence of legalisation). Section 3 studies the effects of introducing pricing tools and repressive measures to regulate migration flows. Section 4 extends our model by taking into account the strong uncertainty that represents illegal migration for risk averse individuals. Section 5 uses calibrations to illustrate the policy implications of the model and Section 6 concludes.

2 Migration equilibrium

This section studies the migration market equilibrium, when workers pay a migration price to the smugglers, p, to migrate illegally to a high wages destination country. We thereby assume that individuals need to hire a smuggler to migrate.[10] For simplicity of exposition, the analysis is first derived under the assumption that illegal migration entails no risk or equivalently that individuals are risk neutral. Section 4 shows that our results are robust to the introduction of risk aversion.

2.1 Demand for illegal migration

At the beginning of her working life of total duration 1, a worker maximises her lifetime utility. She chooses to locate either abroad or in her home country and consumes all her income.[11]

Potential candidates for illegal migration are heterogeneous according to

[10] Although figures vary a lot across destination countries, we expect this to be the case where it is difficult to migrate through different channels, in particular when migration policies are very restrictive and when geographical borders do not exist between origin and destination countries. In the UK for example smugglers are involved in around 75% of detected cases of illegal border crossing (IND, 2001).

[11] As the model is static, there is no sequential decision. However would-be migrants internalize the risk of deportation and sanctions of their employers. In the risk-neutral case this translates into a lower expected wage to work in the illegal sector than in the legal sector. In the risk averse extension risk is modeled explicitly.

their labour efficiency (or skill), θ, which is distributed identically and independently according to the density function $f(\theta)$ and distribution $F(\theta)$ over $\left[\underline{\theta}, \overline{\theta}\right]$ with $\underline{\theta} \geq 0$. Term $\overline{\theta}$ can be interpreted as the threshold of skill/education level above which workers can apply for legal visas under the current system of selective migration characterising most OECD countries.[12]

If there is no migration visa for sale, we assume that workers can only work in the illegal sector of the economy such that expected earnings abroad are $d\theta w_f$, with θw_f being the wages in the legal sector and $d < 1$. The discount factor d captures the fact that workers would have more opportunities if they worked legally rather than illegally[13] and that there is a risk entailed by working illegally. We assume for the moment that d is exogenous but we will relax this assumption later on, in line with empirical evidence (Cobb-Clark et al., 1995).

Note that the way we model the returns to skills leads to a positive selection of illegal migrants, which characterises long haul migration. Indeed "Greater distances, [...] and (for the poorest regions) the poverty constraint all imply that US and EU migrants coming from farther away should be more positively selected" (Hatton and Williamson, 2008). Accordingly, the empirical evidence on long haul legal migration points to positive selection (see Akee, 2010 on migrants from Federated States of Micronesia to the US during 1995-1997 or Beine et al, 2007 on migration to countries of the Organisation for Economic Co-operation and Development). Similarly, long distance illegal migration, which is difficult to undertake without the help of smugglers and is very costly for workers from low wages countries, leads to a more positive selection of workers than that which has been documented for the Mexican cross border migration (see Rivera-Batiz, 2004 for a com-

[12] Instead of considering skill heterogeneity, we could easily embed into the model other dimensions of heterogeneity, which may affect the returns to migration (such as physical abilities or degrees of risk aversion in the extended model with risk outlined below) without changing its main results.

[13] It is for example the case if they cannot easily change employer in the illegal sector or if they are caught in a debt-labour contract upon arrival (see Friebel and Guriev, 2006).

parative analysis of Mexican and non-Mexican illegal migrants in the US and Camarota, 2012 for descriptive statistics on education and income by country of origin of both legal and illegal migrants in the US).[14] Although we present the model in the case of positive selection, Appendix J discusses the robustness of our main results to the case of negative selection.

The worker knows the discounted income she will earn in the foreign country on the illegal market, $d\theta w_f$, which is assumed higher than the discounted income in home country θw_h:

$$dw_f > w_h$$

Note also that the labour market is considered exogenous, which is justified by the fact that the number of workers on the labour market is very large as compared to the flows of migrants. Earnings in the foreign country are used to repay the smuggler's fee p and to consume $\theta dw_f - p$. If the worker does not migrate, she consumes θw_h in the origin country.[15] Therefore the worker decides to migrate if her life time utility, equal to $u(\theta dw_f - p)$ in case she migrates, is higher than her utility in case she does not migrate, equal to $u(\theta w_h)$. With increasing utility functions, the migration condition can be rewritten as:

$$\theta w_h < \theta dw_f - p$$

This shows that a worker is more likely to migrate the higher the wage differential between foreign and home countries, the higher her skill level (what we called "positive selection") and the lower the migration costs.

[14] Even in the case of cross border migration between Mexico and the US, Chiquiar and Hanson (2005) and Borger (2011) show evidence of intermediary selection in the more recent high-costs migration period due to liquidity constrained and stricter border enforcements, which also increased skill average composition of migrants (Orrenius and Zavodny, 2005).

[15] She perfectly knows the wages per unit of time that she will get at home and abroad and the discount rate. She computes the net present value of her future flow of income. Since wages and discount rate are exogenous we avoid introducing separate notation and directly focus on net present values.

Solving for the skill level such that an individual is indifferent between migrating illegally or not, we obtain the illegal migration threshold θ^I written as:

$$\theta^I := \frac{p}{dw_f - w_h} \tag{1}$$

And aggregating over the distribution of skills, we obtain the demand for illegal migration as a function of migration price p:

$$D^I(p) = \int_{\theta^I}^{\overline{\theta}} f(\theta)d\theta = 1 - F(\theta^I) \tag{2}$$

As θ^I increases with p and decreases with d, the demand for migration is higher the lower the migration price, p, and the higher the wage differential $dw_f - w_h$ between the two countries.

2.2 Supply of services

Because legal restrictions constitute barriers to market entry, the smuggling business is concentrated. A few criminal networks actually provide the service (see Aronowitz, 2001; Futo and Jandl, 2007; Guerette and Clarke, 2005, Lundgren, 2008). We model the oligopolistic market for illegal migration as a generalized Cournot competition. We focus on symmetric equilibrium (i.e., each smuggler has the same market share). The generalized Cournot price with N smugglers, p^N, is such that:

$$\frac{p^N - c}{p^N} = \frac{1}{N}\frac{1}{\varepsilon_{D^I,p}} \tag{3}$$

where c represents their marginal costs, $\varepsilon_{D^I,p}$ is the price elasticity of demand and N is an integer greater than 1. The generalized Cournot competition demand, $D^I(p^N)$, is between the two extreme cases: $D^I(p^m) \leq D^I(p^N) \leq D^I(c)$ for all $N \geq 1$ where $p^m \equiv p^1$ in the monopoly case (when $N = 1$) and $p^\infty = c$ in the competitive case when $N \to \infty$. The detail of the computation and an illustration in the case of uniform distribution is given in Appendix A.

It is worth noting that the smugglers might face different populations of migrants. For instance, illiterate candidates from rural areas are different from educated workers from urban centers. If the oligopolistic smugglers can identify them, they will apply different prices to these different populations. As is standard with third degree price discrimination, groups endowed with the largest price elasticity will get the smallest price. In contrast captive migrants (i.e., groups with low price elasticity) face higher prices.[16]

3 Sale of visas

This section studies the effects of selling visas when the smugglers have already paid for the fixed costs of smuggling. In order to eradicate smugglers the government might try to legalize the market for migration. To do so, it can create a permit to migrate permanently that people can buy. A simple idea would be to create a permit that will cost the same price, p^L, as the price imposed by the smugglers to illegal migrants, denoted $p^I : p^L = p^I$. However, this policy will increase migration flows. Comparing the legal migration threshold, written as $\theta^L = \frac{p}{w_f - w_h}$, with (1), it is easy to see that, for any given migration price p, the legal migration threshold is always lower than the illegal one: $\theta^L(p) < \theta^I(p)\ \forall p > 0$. This is because migration payoffs are higher under legal than illegal migration, which increases the wage differential between foreign and home countries. More importantly such a

[16] Assume that they are J different pools of migrants identified by $j = 1, ..., J$. The skill parameter of workers in group j are distributed identically and independently according to the density function $f_j(\theta)$ and distribution $F_j(\theta)$ over $\left[\underline{\theta}_j, \overline{\theta}_j\right]$. Their wages might also be type dependent: $\{w_{fj}, w_{hj}\}$. The demand for migration in group j is $D_j^I(p) = \int_{\theta_j^I(p)}^{\overline{\theta}_j} f_j(\theta)d\theta = 1 - F_j(\theta_j^I(p))$, where $\theta_j^I(p) = \frac{p}{dw_{fj} - w_{hj}}$. The optimal smuggler prices determined by (3) vary from one group to the other according to the price elasticity of its demand $\varepsilon_{D_j^I,p} = -\frac{pD_j^{I\prime}(p)}{D_j^I(p)}$.

pricing policy of legal migration will not eradicate smuggling.

To determine the pricing scheme for legal migrants the government, a Stackelberg leader, needs to take into account that the smugglers will react to its policy.[17] The model is thus solved by backwards induction.

3.1 Smugglers' reaction to sale of visas

By comparing the payoffs if an individual of type θ migrates legally, $\theta w_f - p^L$, with the payoffs if she migrates illegally, $d\theta w_f - p^I$, we can determine the threshold type, θ^L, defined as :

$$\theta^L := \frac{p^L - p^I}{(1-d)w_f} \tag{4}$$

such that any individual above this threshold prefers to migrate legally than illegally. We can easily check that $\partial\theta^L/\partial d > 0$. This simply says that the larger the income differential between the legal and illegal sectors, the more individuals prefer to migrate legally than illegally.

Using (1), we can write the threshold type $\theta^I = \frac{p^I}{dw_f - w_h}$ above which an individual prefers to migrate illegally through the smugglers than to stay in her origin country. If $\theta^L < \theta^I$ nobody chooses to migrate illegally. A constraint for the smugglers is to fix their price low enough as compared to the price of a legal permit in order to attract the workers of type between θ^I and θ^L.

This constraint can be written as : $\frac{p^I}{dw_f - w_h} < \frac{p^L - p^I}{(1-d)w_f}$ or, equivalently, as:

$$p^I < \frac{dw_f - w_h}{w_f - w_h} p^L \tag{5}$$

This shows that the lower the relative payoffs of illegal migration as compared to legal migration, captured by the ratio $\frac{dw_f - w_h}{w_f - w_h}$, and the lower the legal

[17] Once the government announces its policy, it must stick to it to be credible. The smugglers adjust their prices in reaction to the legal offer.

price of migration, p^L, the more difficult it is for the smugglers to satisfy this constraint.

Under this constraint, the demand faced by the smugglers is:

$$D^I(p^I, p^L) = \int_{\frac{p^I}{dw_f - w_h}}^{\frac{p^L - p^I}{(1-d)w_f}} f(\theta) d\theta. \tag{6}$$

Let $p^N(p^L)$ be the solution of (3) computed with the direct price elasticity of demand (6), $\varepsilon_{D^I, p^I} = -\frac{\partial D^I(p^I, p^L)}{\partial p^I} \frac{p^I}{D^I(p^I, p^L)}$, which depends on p^L . The price reaction function of the smugglers is the solution of the following equation:[18]

$$p^I(p^L) = \begin{cases} p^N(p^L) & \text{if } \ c \leq p^N(p^L) < \frac{dw_f - w_h}{w_f - w_h} p^L \\ \varnothing & \text{otherwise} \end{cases} \tag{7}$$

3.2 Government policies

Illegal activities linked to human smuggling entail large negative externalities for societies. In Mexico for example, human smuggling is often integrated with the drug business and other criminal activities, which lead to high insecurity and became recently one of the main electoral concerns.[19] This is also true for OECD countries, where governments spend considerable resources in an attempt to eradicate this industry. For example, Sweden and Australia have recently adopted strict policies against such criminal networks.[20] This section studies how economic tools can be used to reach this objective and

[18] Appendix C presents the closed form solution obtained in the uniform distribution case (see equation (33)).

[19] The Economist, June 30, 2011. Time Magazine, August 12, 2003 : http://www.time.com/time/magazine/article/0,9171,474582-2,00.html

[20] In its budget 2011-2012 the Australian Government has for instance specifically earmarked "$292 million to support a new Regional Cooperation Framework that will help put people smugglers out of business and prevent asylum seekers making the dangerous journey to Australia by boat." See the Webpage of the Australian Government:
http://www.ag.gov.au/Publications/Budgets/Budget2011/Mediareleases/Pages/Strengtheningourbordersthroughregionalcooperation.aspx

their effects on the migration market.

3.2.1 Eliminating smugglers

We first consider a policy, which aims at breaking all incentives to smuggle. It consists of applying a low enough price for legal migration such that the smugglers will have non positive profits. This requires that the reaction price is pushed below the marginal costs, i.e. $p^I(p^L) \leq c$.

The threshold price, denoted $\underline{p}^L$, below which the smugglers exit the market is such that $\theta^L = \theta^I$ defined respectively in equations (4) and (1) for $p^I = c$. That is, $\underline{p}^L$ is such that: $\frac{\underline{p}^L - c}{(1-d)w_f} = \frac{c}{dw_f - w_h}$. This yields:

$$\underline{p}^L = \frac{w_f - w_h}{dw_f - w_h} c \tag{8}$$

In other words, the government that wants to push smugglers' reaction price down until their mark-up vanishes has to apply the price $\underline{p}^L$. Note that this result applies to any initial structure of the market for smugglers: monopolist, oligopolistic or competitive. Irrespective of the initial market conditions, if the government wants to eradicate smugglers by selling visas it has to apply $\underline{p}^L$ such that the smugglers end up reaching their marginal costs pricing.

Comparing $\underline{p}^L = \frac{w_f - w_h}{dw_f - w_h} c$ and $p^\infty = c$ we can establish, since $d < 1$, that the price imposed by the government to eliminate the smugglers is higher than the price imposed by smugglers under perfect competition. Nevertheless, the migration demand, which is now legal, can be written as:

$$D^L(\underline{p}^L) = \int_{\frac{c\left(\frac{w_f - w_h}{dw_f - w_h}\right)}{w_f - w_h}}^{\overline{\theta}} f(\theta) d\theta$$

$$D^L(\underline{p}^L) = 1 - F\left(\frac{c}{dw_f - w_h}\right) \tag{9}$$

This demand is exactly the same as the demand for illegal migration under perfect competition of smugglers: $D^L(\underline{p}^L) = D^I(c)$. This is because, for a given migration price, more workers are willing to migrate legally than illegally. This result, which is robust to the introduction of risk aversion, is summarized in the next proposition.

Proposition 1 *A policy that reduces the number of illegal migrants to zero through the sale of visas yields the same level of migration as under perfect competition among smugglers.*

It is not possible to empirically test the predictions of Proposition 1 since no country has, so far, used such a pricing scheme to eradicate human smuggling. However, the theoretical framework, which is quite general, applies to other markets with positive demand and legal prohibition. The theory predicts that destroying a mafia organisation by legalizing its activity will inevitably increase the demand of the formerly prohibited product or service. It is thus useful to look at other products and services, such as alcohol, drugs or sexual services, that are, or have been, successively prohibited and legalised to assess the relevance of Proposition 1.

The main problem to test the impact of prohibition on consumption is the lack of data on trade volume during prohibition time. However, using mortality, mental health and crime statistics, Miron and Zwiebel (1991) estimate the consumption of alcohol during Prohibition in the US (1920-1933). They find that alcohol consumption fell sharply at the beginning of Prohibition, to approximately 30% of its pre-Prohibition level. During the next several years alcohol consumption increased, but remained below its pre-Prohibition level, at about 60-70%. Consumption increased to approximately its pre-Prohibition level only during the decade after Prohibition was abolished.

Another piece of evidence concerns prices. The theory predicts a sharp decrease in prices if one aims at eliminating mafia through legalisation. In line with this, Miron (2003) shows that cocaine and heroin are substantially more expensive than they would be in a legalized market: "*the data imply that cocaine is four times as expensive as it would be in a legal market, and heroin perhaps nineteen times.*"

Finally, regarding the sex market, Poulin (2005) claims that the legalisation of prostitution in countries such as the Netherland, Germany or Australia, has generated an expansion of this industry: "*An "abolitionist" country like France, with a population estimated at 61 million, has half as many prostituted people on its territory as does a small country like the Netherlands (16 million) and 20 times fewer than a country like Germany, with a population of around 82.4 million.*"

It is clear that more empirical studies are called to understand the consequences of legalisation through sale of visas. Yet, based on the theory and on the available empirical evidence on other illegal markets, we predict a sharp increase in migration flows if visas are sold at the price that drive the smugglers out of business and that the higher the initial market concentration the larger the increase following the legalisation.

3.2.2 The policy trade-off: controlling migration flows

Such increases may not be acceptable in most OECD countries, where there is a strong popular demand for controlling migration flows. As we mentioned earlier we do not discuss here the optimality of such an objective but simply analyse whether standard economic instruments can help to reach it. We thus study what happens if the government sells visas to control migration flows. A constraint for the government is that the price of these visas, p^L, has to be lower than $\overline{p}_L$, the threshold price above which no worker will migrate legally. This threshold is the minimum value of two constraints:

- The Incentive Rationality (IR) constraint: $p^L \leq \overline{\theta}(w_f - w_h)$, which implies that someone at least prefers to migrate legally than stay at home, and

- The Incentive Compatibility (IC) constraint: $p^L \leq \overline{\theta}(1-d)w_f + p^I$, which implies that someone at least prefers to migrate legally than illegally.

The legal migration is positive if and only if $p^L \leq \min\left\{\overline{\theta}(w_f - w_h), \overline{\theta}(1-d)w_f + p^I\right\}$. Since by assumption, $dw_f > w_h$ it is easy to check that the (IC) constraint is binding whenever the smugglers are active. Indeed $\overline{\theta}(w_f - w_h) > \overline{\theta}(1-d)w_f + p^I$ is equivalent to $p^I < \overline{\theta}(dw_f - w_h)$, which, by virtue of (1), necessarily holds when the smugglers are active. We deduce that $\overline{p}^L = \overline{\theta}(1-d)w_f + p^I$. Since the smugglers price, $p^I(p^L)$, is endogenously determined in equation (7), the threshold $\overline{p}^L$ is a fixed point such that:

$$\overline{p}^L = \overline{\theta}(1-d)w_f + p^I(\overline{p}^L) \tag{10}$$

Under the assumption that $\frac{\partial^2 D^I(p^I,p^L)}{\partial p^I \partial p^L} \geq 0$, which is true as long as $f'(\theta) \leq 0$ (e.g., with a uniform distribution of skills $\frac{\partial^2 D^I(p^I,p^L)}{\partial p^I \partial p^L} = 0$), one can check that $\frac{dp^I(p^L)}{dp^L} > 0$ (see Appendix B). This implies that $\overline{p}^L$ exists and is unique. Indeed if $p^L = 0$ then $\overline{\theta}(1-d)w_f + p^I(0) > 0$, while $\overline{\theta}(1-d)w_f + p^I(+\infty) = \overline{\theta}(1-d)w_f + p^N < +\infty$ where p^N is defined in equation (3). We deduce that p^L and $\overline{\theta}(1-d)w_f + p^I(p_L)$ cross once and only once at $\overline{p}^L > 0$. It is worth noting that, contrary to $\underline{p}^L$ which is invariant, $\overline{p}^L$ depends on N the number of smugglers active in the market.[21]

We want to study the objective function of a government that would aim at minimizing the increase in migration flows following the introduction of sale of visas. Since the status quo level of immigration is independent of the new policy to sell visas, this objective is equivalent to minimizing migration

[21] This result illustrated in Appendix in the uniform distribution example is intuitive: the upper limit for visa prices decreases with the number of smugglers on the market since their response price decreases with the degree of competition and the government has to compete with them to encourage legal migration.

flows following this scheme. By using (1) the objective function is :

$$\min_{p^L \leq \overline{p}^L} \int_{\frac{p^I(p^L)}{dw_f - w_h}}^{\overline{\theta}} f(\theta)d\theta = \min_{p^L \leq \overline{p}^L} \left[1 - F\left(\frac{p^I(p^L)}{dw_f - w_h}\right)\right] \tag{11}$$

where the government internalizes the reaction function of the smuggler $p^I(p^L)$ in (7). Since $\frac{dp^I(p^L)}{dp^L} > 0$ differentiating equation (11) with respect to p^L yields $-\frac{1}{dw_f - w_h} f\left(\frac{p^I(p^L)}{dw_f - w_h}\right)\frac{dp^I(p^L)}{dp^L} \leq 0$. A government, which aims at minimizing migration flows, will fix the highest possible price for its visas $\overline{p}^L$.

The migration demand under such policy is higher than in the case of an unconstrained smuggler oligopoly. Indeed when $\overline{p}^L \leq p^L \leq \overline{\theta}(w_f - w_h)$, the smugglers are the only ones to be active on the market as nobody wants to migrate legally if the smugglers apply their optimal reaction price $p^I(p^L)$. However they cannot apply the unconstrained oligopoly price p^N of equation (3) as some migrants would then choose legal migration, lowering the smugglers' profit. This entails larger migration flows even though no visa is sold in such case.[22]

Figure 1 illustrates this result in the uniform example. It shows the reaction function $p^I(p^L)$ as defined by (7) where the slope of the active part of the reaction function, $p^N(p^L) = \frac{p^L}{N+1}\frac{dw_f - w_h}{w_f - w_h} + \frac{N}{N+1}c$, decreases with $N \geq 1$ (see equation (33) in the appendix). It becomes flat when N goes to infinity (i.e. it converges to the constant value of c).[23]

Moreover, since there is positive selection through long haul migration, more migration following a sale of visas worsens the average skill composition

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[22] Smugglers are unconstrained to apply their oligopolistic price only when $p^L > \overline{\theta}(w_f - w_h)$.

[23] With the uniform distribution example, replacing $p^I(p^L) = \frac{p^L}{N+1}\frac{dw_f - w_h}{w_f - w_h} + \frac{N}{N+1}c$ into (10) the upper limit for the visa price satisfies: $\overline{p}^L = [Nc + (1+N)(1-d)w_f]\,\frac{w_f - w_h}{(1-d)w_f + N(w_f - w_h)}$. Comparing the reaction smugglers price $p^I(\overline{p}^L)$ with the unconstrained smugglers' oligopoly price p^N defined in (3) it is straightforward to check that $p^I(\overline{p}^L) \leq p^N$ if and only if $dw_f - w_h \geq c$, which is the necessary condition for the smugglers being active in the first place (see Appendix C).

of migrants.

The next proposition, which is robust to the introduction of risk-aversion, summarizes the policy result this section implies:

Proposition 2 *A sale of visas necessarily increases the total number of migrants and worsens their skill composition.*

Proposition 2 implies that a government that aims at minimizing the demand for migration, cannot do better than an unconstrained monopoly smuggler. So, if the objective is to decrease the total number of migrants, there are more effective policies than selling migration visas.

3.2.3 Controlling migration flows through increased repression

Using our results in Section (2) it is straightforward to check that any instrument that either increases the market concentration through increasing smugglers' entry sunk cost, or increases their costs to operate, c, or decreases the benefits gained by illegal migrants, d, decreases migration demand.

The analysis of smugglers pricing behavior outlines that repressive policy measures may have very different effects depending on whether they directly affect the smuggling business or the demand for their services: any measure which increases the marginal costs for smugglers to operate, c, such as increased border enforcement will necessarily increase the fees paid by would be migrants. This has been documented by Roberts et al (2010) who show that the increase in enforcement on the Southwest border of the US accounted for all of the increase in smuggling costs during 2006-2008 and half of it during 2004-2008. In contrast, measures, which decrease the benefits of illegal migration through a decrease in d, such as sanctions to employers of illegal workers that are transmitted into lower wages paid to illegal migrants, decrease the fees charged by smugglers (see equation (25) in Appendix).

In a more dynamic perspective, one could easily endogenise N, the number of smugglers on the market. Denoting K the level of sunk costs to enter this market, the number of smugglers N is the integer part of μ such that $\pi(\mu) = K$ where $\pi(\mu) = (p^{\mu} - c)D^{I}(p^{\mu})/\mu$ is the firm rent. Therefore any repressive measure increasing c or K reduces the number of smugglers on the market, N, thereby increasing the price they charge for their services. For example, Roberts et al (2010) note that rising smuggling prices during 2004-2008 also "indicate increased demand for smuggling services whose supply is limited, or changing characteristics of the marketplace such as the formation of cartels by smugglers". So, if migrants have no other alternative to migrate than using smugglers' services, as assumed in our model, this pushes down the demand for migration.

3.2.4 Affordable migration control through sale of visas

So far we have considered two types of policies: one policy relies on pricing schemes and economic tools to eliminate smuggling, while the other policy is essentially repressive and aims at controlling illegal migration flows. Both solutions are politically unsatisfactory. The former leads to an increase in migration flows, while the latter does not eradicate smugglers and increases their market power (i.e., market concentration). In what follows we explore how a combination of both types of approaches might help to simultaneously fight the smugglers and control migration flows, without increasing the burden of public deficit. To do so, we consider a policy where the funds raised from the sale of the legal permits are used to fight illegal migration by increasing c and decreasing d in such a way that increases in migration flows following the legalisation are limited as much as is affordable.

We start from the status quo situation where the marginal cost to smuggle is c and the discount rate to work as an illegal workers is d. The government can use a share of the new funds raised through the sale of migration permits to increase the smugglers' marginal costs by reinforcing "external" (or border) controls. We denote $c(R_1)$ the marginal costs that the smugglers face when the government invests $R_1 \geq 0$ in additional repression. We assume that, in the absence of additional investment, the marginal costs of the smuggler are the status quo level: $c(0) = c$. Moreover we assume that $c'(R_1) > 0$ and $c''(R_1) < 0$. The concave shape indicates decreasing returns to scale in the fight against smugglers.

Similarly, the government can use another share of the funds raised through the sale of visas to increase "internal" controls at worksites and enforce the sanctions paid by the employers of illegal migrants. We denote $d(R_2)$ the illegal migrant wage discount factor resulting from increased enforcement measures. Here again we assume that, in the absence of additional investment $d(0) = d$, and that $d'(R_2) < 0$[24] and $d''(R_2) > 0$. The convex shape indicates decreasing returns to scale in the fight against illegal employment.

Replacing c by $c(R_1)$ and d by $d(R_2)$ in (8), we can determine the new legal migration price such that smugglers do not have any interest to operate given their inflated marginal costs and reduced migrant wages:

$$\underline{p}^L(R_1, R_2) = \frac{w_f - w_h}{d(R_2)w_f - w_h} c(R_1) \tag{12}$$

We deduce that the increase in demand following the introduction of the sale of visas for legal migration would be defined in (9) with the price $\underline{p}^L$ being replaced by $\underline{p}^L(R_1, R_2)$:

$$D^L(R_1, R_2) = 1 - F\left(\frac{c(R_1)}{d(R_2)w_f - w_h}\right) \tag{13}$$

Finally, the government chooses the investments R_1 and R_2 so as to minimize the increase in migration flows following the introduction of visas, under the constraint that the cost of repression is covered by the visa sales:

$$\min_{R_1, R_2} D^L(R_1, R_2) \quad \text{s.t.} \quad R_1 + R_2 \leq D^L(R_1, R_2)\underline{p}^L(R_1, R_2). \tag{14}$$

[24] See Woodland and Yoshida, 2006, for a theoretical foundation of this assumption and Cobb-Clark et al.(1995) for empirical evidence.

Focusing on interior solutions the optimal affordable policy, which is derived in Appendix D, is summarized in the next proposition.[25]

Proposition 3 *A government that aims at dismantling smugglers while limiting migration flows without increasing its budget deficit invests the amounts* (R_1^*, R_2^*) *solution of the following equations:*

$$R_1 + R_2 = \underline{p}^L(R_1, R_2) D^L(R_1, R_2) \tag{15}$$

$$\frac{c'(R_1)}{c(R_1)} = \frac{-d'(R_2) w_f}{d(R_2) w_f - w_h} \tag{16}$$

Equation (15) shows that the government invests the maximum possible amount in reinforcing border controls and employers' sanctions, which is affordable through the sale of visas. The optimal allocation of the budget for repression is such that the marginal impact of R_1 on D^L is equal to the marginal impact of R_2 on D^L, as shown by (16). Note that enforcing the fines paid by employers of undocumented workers may contribute to raising additional funds for the government, which could easily be embedded into our model by adding a term (increasing with R_2) on the right hand side of the budget constraint in (14). The optimal investments R_1 and R_2 would be changed accordingly.

Since the demand for visas is a normal good and since $c'(R_1) > 0$ (alternatively $d'(R_2) < 0$) it is straightforward to check that $\frac{dD^L(R_1,R_2)}{dR_1} < 0$ (and that $\frac{dD^L(R_1,R_2)}{dR_2} < 0$). When repression against smugglers increases, the marginal cost of their activity, c, increases, which is transmitted to the smugglers' price. Similarly, when sanctions are enforced against employers of illegal migrants, this is transmitted to the payoffs of migrants through a decrease in d. As a result the government can raise the price of legal visas without fuelling smugglers' demand. This policy enables the government to

[25] Depending on the functions $c(.)$ and $d(.)$ it may be the case that the optimal solution involves increasing c only (i.e., $R_2 = 0$) or decreasing d only (i.e., $R_1 = 0$). However, in other cases there will be an interior solution defined in (15) and (16).

control migration flows without relying on the help of smugglers. Indeed, by construction, such policy pushes smugglers out of the market by eroding their profits.

4 Risk aversion

So far we considered either situations entailing no risk or risk neutral individuals. It is probably more realistic to consider that individuals are risk averse. As migrating illegally entails important risks, this may be of significance to determine the number and type of migrants. This section shows the robustness of our results to the introduction of risk aversion. It reports only the main results. For the detailed computations we refer to Appendix E.

We extend the model by introducing standard CARA utility function $u(x) = 1 - exp(-ax)$, where a is the absolute risk aversion parameter.[26] We also assume that illegal migration entails a risk: once migrants pay the sunk costs to the smugglers and reach the destination country, they may stay abroad with probability $1 - q$, but have a probability q of being deported and sent back to their home country. In order to compare the results in the cases with and without risk aversion, we assume that if they manage to avoid deportation while in migration, they earn a wage δw_f with $\delta \leq 1$ so that the expected revenue from illegal migration is the same in the two cases. Since in the case without risk aversion the expected revenue from illegal migration is dw_f with $d < 1$, in the case with risk aversion the expected revenue can be written as:

$$(1 - q)\delta w_f + qw_h = dw_f \tag{17}$$

Any distortion can hence be ascribed to the introduction of the risk aversion.

[26] Results in this section are robust to using other specifications of concave utility functions, such as for example the log function, which is CRRA. However the computations are messier. For the ease of the exposition we thus present here the simplest version with CARA.

One can check in Appendix E that the illegal migration threshold θ_{ra}^{I} is now a solution of the following equation:

$$\frac{1-e^{-ap^{I}}}{1-e^{-a\theta(\delta w_f - w_h)}} = 1-q \tag{18}$$

The risk neutrality (and/or absence of risk) benchmark case of equation (1), $\theta^{I} = \frac{p^{I}}{dw_f - w_h}$, is simply obtained in equation (18) by setting $q = 0$, which also implies, according to (17), that $\delta = d$. Since θ_{ra}^{I} is increasing with q and since $\theta_{ra}^{I} = \theta^{I}$ when $q = 0$ we deduce that $\theta_{ra}^{I} > \theta^{I}$ for all $q > 0$. This shows that, as we may expect, the risk of being deported discourages risk averse individuals to migrate illegally.

The logic of the pricing scheme of smugglers described in section 2 remains the same as before but it takes into account the new (lower) demand from risk averse individuals. Risk aversion implies that the price imposed by smugglers is then lower than the price they would impose to risk neutral individuals with the same expected revenue from migration, an intuitive result formally shown in Appendix E.

Lemma 1 *Risk aversion limits the number of illegal migrants,* $\theta_{ra}^{I} > \theta^{I}$*, and reduces the price imposed by smugglers* $p_{ra}^{I} < p^{I}$ *.*

We now turn to the government policy of visa sale and the reaction of smugglers. If individuals can buy a legal permit to migrate at price p^{L}, smugglers need to price their services low enough so that at least one individual wishes to migrate illegally. The skill level θ_{ra}^{L} of the migrant who is just indifferent between migrating illegally and legally satisfies the following equation:

$$\frac{1-e^{-a(\theta(w_f - w_h)+p^{I}-p^{L})}}{1-e^{-a\theta(\delta w_f - w_h)}} = 1-q \tag{19}$$

Solving for the threshold θ_{ra}^{L} and comparing it to (4) we show in Appendix E that risk aversion increases the demand for legal visas as established by Lemma 2.

Lemma 2 *Risk aversion increases the demand for legal visas:* $\theta^L_{ra} < \theta^L$.

When legal visas are put on sale, risk averse individuals are willing to pay a higher price to get valid documentation. Since we also showed that $\theta^I_{ra} > \theta^I$, risk aversion reduces the illegal migration demand, $D^I_{ra}(p^I, p^L) = \int_{\theta^I_{ra}}^{\theta^L_{ra}} f(\theta)d\theta = F(\theta^L_{ra}) - F(\theta^I_{ra})$, by the two ends. On the one hand, in the absence of legal pricing schemes, illegal migration flows are lower if individuals are risk averse than if they are risk neutral. On the other hand, selling visas decreases illegal migration flows even further since individuals are less willing to bear the risk of deportation.

For the sake of realism we focus on situations where smugglers are initially active in equilibrium. Their reaction function, $p^I_{ra}(p^L)$, is the solution of the same equation as in (7) using the demand $D^I_{ra}(p^I, p^L)$. If the government wants to eliminate them by its pricing policy, it still needs to push their reaction price to the limit value c so that $\theta^L_{ra}(c, \underline{p}^L_{ra}) = \theta^I_{ra}(c)$. It follows that Proposition 1 holds true under risk aversion.[27] If the government wants to eradicate smugglers through legalisation it will face the same demand as under perfect competition among smugglers: $D^L(\underline{p}^L_{ra}) = D^I_{ra}(c)$. The main difference is that the demand is lower than in the risk neutral case, $D^I_{ra}(c) < D^I(c)$.

We show in Appendix E that $\underline{p}^L_{ra}$ is increasing with q. Moreover, as for $q = 0$ $\underline{p}^L_{ra} = \underline{p}^L$, this implies that the visa price, which drives smugglers out of business, is higher with risk (when $q > 0$) than without as established by Lemma 3.

Lemma 3 *Risk aversion increases the visa price, which drives the smugglers out of business:* $\underline{p}^L_{ra} > \underline{p}^L$.

Finally the results of section 3.2.2 are robust to the introduction of risk aversion. If the smuggler is active the binding constraint is the IC and $\overline{p}^L_{ra}$ is

[27] We can also see that Proposition 1 does not depend on the specification of the Demand function. Hence it is robust to other specifications of utility functions.

the solution of the following equation derived in Appendix E:

$$e^{-a(\overline{\theta}w_f-p^L)}=(1-q)e^{-a(\overline{\theta}\delta w_f-p^I_{ra}(p^L))}+qe^{-a(\overline{\theta}w_h-p^I_{ra}(p^L))} \tag{20}$$

Therefore the rest of the reasoning and Proposition 2 hold true.

Proposition 3 can also be generalized taking into account the risk entailed by migration. With risk averse migrants the government has more instruments to raise the visa price that drives the smugglers out of business and, hence, limit migration flows. By investing in repression it can, as before, increase marginal costs for smugglers to operate through the increasing concave function $c(R_1)$, or decrease the benefits of working as an illegal worker through the decreasing convex function $\delta(R_2)$. In addition, it can also increase the probability of deportation q through the increasing concave function $q(R_3)$. This new instrument is relevant only under risk aversion. Let $\underline{p}^L(R_1,R_2,R_3)=\frac{w_f-w_h}{a(\delta(R_2)w_f-w_h)}\log\left(\frac{1-q(R_3)}{e^{-c(R_1)a}-q(R_3)}\right)$ be the price that eliminates human smuggling and let

$D^L(R_1,R_2,R_3)=1-F\left(\frac{\underline{p}^L(R_1,R_2,R_3)}{w_f-w_h}\right)$ be the legal demand for visas associated with this price. Focusing on interior solutions Proposition 4 summarises how these three instruments can be optimally combined.[28]

Proposition 4 *A government that aims at dismantling smugglers while limiting migration flows without increasing its budget deficit invests the amounts*

[28]Depending on the functions $c(.)$, $\delta(.)$ and $q(.)$ it may be the case that the optimal solution involves repression to increase c only (i.e., $R_2=R_3=0$), to decrease δ only (i.e., $R_1=R_3=0$), to increase q only (i.e., $R_1=R_2=0$), or any combination of two instruments only (i.e., $R_1=0$ or $R_2=0$ or $R_3=0$). However, in other cases there will be an interior solution defined in (21) to (23).

(R_1^*, R_2^*, R_3^*) *solution of the following equations:*

$$\begin{aligned}
R_1 + R_2 + R_3 &= D^L(R_1, R_2, R_3)\underline{p}^L(R_1, R_2, R_3) && (21)\\
\frac{c'(R_1)ae^{-c(R_1)a}}{e^{-c(R_1)a} - q(R_3)} &= \frac{-\delta'(R_2)w_f}{\delta(R_2)w_f - w_h}\log\left(\frac{1-q(R_3)}{e^{-c(R_1)a} - q(R_3)}\right) && (22)\\
&= \frac{q'(R_3)}{1-q(R_3)}\frac{1-e^{-c(R_1)a}}{e^{-c(R_1)a} - q(R_3)} && (23)
\end{aligned}$$

As shown by equation (21) the government invests the total amount of resources in reinforcing border controls, employers' sanctions and deportations, which is raised through the sale of visas. And the optimal allocation of repression between the various instruments equalises their marginal effect on demand (i.e., $\frac{\partial D^L}{\partial R_1} = \frac{\partial D^L}{\partial R_2} = \frac{\partial D^L}{\partial R_3}$) as shown by equations (22) and (23).

Moreover, we find that the amount of investment in deportation, R_3, which minimizes migration flows, is higher than the investment minimising expected earnings from illegal migration (see Appendix E). This result, in line with Becker (1968), simply states that since individuals are risk averse, they respond more strongly to a change in the probability of deportation than to a "compensated" change in their earnings, which would leave equal their expected earnings from migrating illegally.

The main issue raised by the policy of legalisation combined with tight migration control is its effectiveness at limiting migration flow without weighing too much on public finances. This ultimately depends on the elasticities of the functions $c(R_1)$, $\delta(R_2)$ and $q(R_3)$. Policy makers have to take into account that these elasticites vary from one country to the other. For example, when there is a physical border between two countries it is difficult to raise smugglers' costs by increasing repression, as the evidence on illegal migration between Mexico and the US mentioned in the introduction shows. Hence, the elasticity of the function $c(R)$ is likely to be low. By contrast, in the case of long-haul migration, it might be easier to increase smugglers' costs by reinforcing external controls. Similarly, in countries with a large informal sector, it will be harder to reduce δ, than in countries with a small informal economy. With inelastic functions $c(R_1)$, $\delta(R_2)$ and $q(R_3)$, the equilibrium price of migration visas will be quite low. Such a policy of legalisation will be ineffective at limiting migration flows, unless investments into additional repression are extremely large. This poses a policy trade-off: high burden on public finances or large increase in migration flows, which will be hard to sustain politically. Moreover, in practice, the way the repressive policy is set up is very important. The goal is to raise the smugglers' costs to increase their concentration, and not necessarily to dismantle existing cartels. Breaking established smugglers networks might give rise, through the emergence of several smaller smuggler networks, to more competition in the illegal migration business and, hence, to lower prices and higher demand.[29]

5 Policy Implications

As it is impossible to run regressions to test our model, this section uses calibrations to interpret its results and quantify the policy effects outlined above before discussing their implications. Since the model focuses on the migration market and abstracts from other changes that may occur in the rest of the economy as a consequence of increases in migration flows, the results are not full-fledged policy simulations.[30] Yet they complete our theoretical analysis by illuminating the strong complementarities existing between legalisation policies through selling visas and repression.

[29] The failure of the "war on drugs" launched in the United States in the 1980s has been partly explained by such effects. The US authorities decided to infiltrate the drug mafia to dismantle it. The infiltration operation, which was very costly, was successful. The dismantling of the well organized cartels which followed gave rise to the emergence of many smaller drug networks fighting fiercely in price to gain market share. As a result, the consumption of cocaine increased in the US (see Poret 2002).

[30] In particular, adjustments on the labour market may dampen the initial incentives to migrate, leading to smaller increases in migration flows following sale of visas than the ones we calibrate.

5.1 Simulations

We borrow most of the estimates used in our calibrations from Friebel and Guriev, 2006, and from the information we have on the smuggling industry from case-studies on Chinese smugglers such as Yun and Poisson, 2005.[31] For all our simulations we also need some estimates of the degree of risk aversion of would-be migrants, a, and of the deportation probabilities q, which are typically difficult to observe. Instead, we have some direct evidence from Chinese smugglers reporting their marginal costs to operate at around €8000 to cross the borders to France and higher to the US (Yun and Poisson, 2005), which we estimate to be around \$10000 for our simulations.[32] Using this information, the lower bound of the price paid by Chinese to migrate illegally to the US, $p^I = \$35000$, and our model we can infer a range of risk parameters a compatible with a range of deportation probabilities, q (see Appendix G). To perform some static comparative on the effects of varying the risk we vary q in the neighborhood of the chosen values. Finally, as there is very little quantitative information on the degree of market concentration, Tables J1 and J2 also analyse the sensitivity of our results when the number of smugglers varies. For example Chin and Zhang, 2002, stress the existence of several smugglers' networks operating in China.[33] All simulations are explained in further details in Appendix H.

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[31] Appendix F checks that the individual rationality constraint is satisfied for the wages differential observed between the US and China in 2005 as well as for a large range of wage differentials that have been reported between advanced and developing countries (Clemens et al.,2009).

[32] This is an average. Marginal costs vary depending on the type of trip undertaken and on the type of migrant. Some Chinese migrants obtain fake visas and invitations for business trips, which allow them to travel directly by air. Others have to cross several borders using several intermediary smugglers, which increases the overall marginal costs of the operation.

[33] Comparing results of Table 1 with those in Tables J1 ($N = 3$) or J2 ($N = 5$) shows that the efforts required to eliminate the smugglers and maintain migration demand constant are smaller the higher the number of smugglers on the market, an intuitive result. It is indeed less difficult to fight against smugglers when their initial profit is low, which decreases with the level of competition.

Table 1: Policy implications for N=2 when risk q varies for different degrees of risk aversion a.

a	0.00000086			0.00001			0.00002			0.00004		
q	0.68	0.7	0.72	0.48	0.5	0.52	0.38	0.4	0.42	0.18	0.2	0.22
$\underline{p}_{ra}^{L}$	43624	46575	49954	28232	29516	30924	23785	24726	25744	17755	18336	18957
ΔD	0.43	0.49	0.55	0.32	0.36	0.41	0.28	0.32	0.36	0.20	0.24	0.30
Δc	2.73	2.50	2.26	2.67	2.50	2.33	2.67	2.50	2.34	2.70	2.50	2.32
$\Delta\delta$	-0.48	-0.47	-0.46	-0.51	-0.51	-0.50	-0.52	-0.52	-0.51	-0.53	-0.53	-0.52

Note: prices $\underline{p}_{ra}^{L}$ are in USD.

Rows 3 and 4 of Table 1 simulate the visa price, $\underline{p}_{ra}^{L}$ in USD, that would eradicate smugglers following a pure "visa sale" scheme (i.e. not using the other available instruments to control migration) and the subsequent relative increase in migration demand, ΔD, predicted by our model. These increase with the risk of deportation captured by the probabilities of deportation q calibrated for each degree of risk aversion a considered successively in columns (2) to (5).

We next allow the government to combine sale of visas with repressive instruments in order to control migration flows while elimiminating smugglers. Since we do not know the functions $c(.)$, $q(.)$ and $\delta(.)$ it is not possible to simulate the optimal combination of instruments described in Proposition 4. Instead, we show how different repressive instruments may be combined with a sale of visas to reach a "0 migration increase" objective while eradicating human smuggling.

Policy makers may first consider reinforcing border controls, which increases marginal costs for smugglers to operate. Row 5 of Table 1 shows that the relative increase in marginal costs necessary to reach these objectives, Δc, is substantial, around 250%, and decreases with the probability of deportation.[34] Policy makers could alternatively reinforce the sanctions to

[34] For each degree of risk aversion displayed in each column, Δc decreases as q increases. Note that, by construction of the pairs (a, q), each column is such that $\Delta c = 2.50$ for the

employers of undocumented employees, which translates into lower expected earnings abroad for illegal migrants. Row 6 of Table 1 shows that the relative decrease in the discounting factor, $\Delta\delta$, necessary to reach these objectives is around 50% and decreases in magnitude with the probability of deportation.

These simulations show that the additional efforts required to combine a sale of visas with migration control decrease with the probability of deportation. Indeed, when risk is low the differential between smugglers' price and marginal costs is large. As already shown in Lemma 1, when risk increases smugglers have to lower their margin to be able to attract risk-averse migrants. It is therefore easier to drive them out of business and keep migration demand constant when the risk of deportation increases. In other words, our results highlight strong complementarities between different types of repressive instruments and sale of visas.

5.2 Discussion

The optimal combination of the different repression instruments depends on the elasticities of the functions $c(R_1)$, $\delta(R_2)$ and $q(R_3)$. Although we do not have precise estimates of them, it seems unlikely that the current policy adopted by the US and most EU countries is optimal. There are huge discrepancies between the amounts invested in border control versus employer's sanctions. For example, in 2008 in France, only 1706 labour inspectors were employed for more than 3.8 million firms.[35] Among those firms, only 1.6 million, the largest ones, were eligible for a control although many illegal migrants work in small construction firms and in restaurants.[36]

central value of q of the neighbourhood considered. Similar remarks hold for $\Delta\delta$, displayed in Row 6 of the Table, which gets closer to zero as q increases.

[35] See the report "L'inspection du travail en France en 2008", Ministère du travail, des relations sociales, de la famille, de la solidarité et de la ville, Direction générale du travail Service de l'animation territoriale de la politique du travail et de l'action de l'inspection du travail.

[36] With only 22590 controls to check for illegal workers, an eligible firm is inspected on average once every 70 years, or alternatively faces a 1.42% probability of being inspected

At the same time France has spent hundreds of millions of euros on repression measures such as dismantling illegal immigrants' camps, police enforcement at the borders and deportation measures. Similarly in the US, there is very little enforcement against illegal immigration at worksites (Hanson, 2007). Between 1999 and 2003, the number of man hours US immigration agents devoted to worksite inspections declined from 480,000 to 180,000 hours and few US employers who hire illegal immigrants are detected or prosecuted.[37] But considerable amounts are invested in the controls of the US borders.[38] For instance the Border Patrol, which was increased from 9,000 agents in 2001 to 20,000 in 2009, costs an estimated $4 billion annually.

It is puzzling that the US government is investing so little in stricter internal repression measures, which decrease δ and increase q in our model, and so much in external controls, which increase c. Indeed the evidence on illegal migration between Mexico and the US shows that such a policy is ineffective at limiting migration flows. By contrast the effects of stricter internal repression measures, which would increase penalties paid by employers of undocumented immigrants and deportation probabilities, are unknown and understudied. Yet such policies have been effective in other industries. Focusing on the sex business, Poulin (2005) shows that repressive policy can successfully decrease demand, when, as in Sweden, legislation is passed to prosecute the customers, who are the final users of the service. As technologies develop to detect forged documents, for example using biometric identity cards, prosecuting firms that employ illegal workers could be a much more

each year and smaller firms face a 0 probability of inspection.

[37] The number of US employers paying fines of at least $5.000 for hiring unauthorized workers was only fifteen in 1990, which fell to twelve in 1994 and to zero in 2004 (see "Immigration Enforcement : Preliminary Observations on Employment Verification and Worksite Enforcement" GAO-05-822T June 21, 2005, cited by Hanson 2007, p19.)

[38] The Washington Post, July 18, 2010 reported that more than 670 miles of border fences, walls, bollards and spikes that Congress decreed in 2006 at an estimated cost of $4 billion (plus future maintenance) had been almost completed. Similarly the number of man hours spent policing the US-Mexico border increased by 2.9 times between 1990 and 2005.

cost effective way to control illegal migration flows than border enforcement measures. Moreover fines paid by employers would contribute to raising additional funds.

Given the discrepancies between the investments in external and internal controls, the lack of effectiveness of border enforcement measures and the availability of new technologies, systematic controls of undocumented workers at the workplace is a much more promising means of controlling illegal migration than border enforcement. It is striking that despite several attempts to mandate participation by all U.S. employers in the E-Verify program, an Internet-based system designed to check the employment authorization status of employees, participation is still voluntary, with limited exceptions. Small businesses and agricultural employers are strongly opposed to mandatory E-Verify and actively lobby against it.[39] Similarly, within the European Union, representatives of Business Europe are opposed to the Commission's idea that employers should check the validity of residence permits to avoid the risk of being excluded from public contracts and, under certain circumstances, penalised by temporary or permanent closure of their companies in case of failure (Bertozzi, 2009).

6 Conclusion

This paper has addressed a simple question: is it possible to eliminate human smuggling by selling visas and regulate migration flows ?

The answer is nuanced. When smugglers have already paid fixed costs to settle their businesses, it is difficult for the government to compete. The model shows that eliminating smugglers by proposing a low enough price would be at the cost of increasing substantially migration flows and decreasing the average skill level of migrants. For probabilities of deportation be-

[39] The American Farm Bureau Foundation stated in July that it "could have a significant, negative impact on US farm production, threatening the livelihoods of many farmers and ranchers in labor intensive agriculture."

tween 20% and 70% we estimate the price of visas that would erode the profits of the smugglers on the China to the US route to be between $\$18,000$ and $\$50,000$ and this would lead to an increase in migration demand between 25% and 50%. Hence there is a trade-off between suppressing smugglers or having fewer migrants in the economy. So if the goal is to control migration, demand is the lowest with a monopolistic smuggler. Increasing cartelisation of the market through repression contributes to controlling migration flows. However, such policy is not satisfactory either, as it favors the emergence of a dominant criminal network.

The paper proposes instead to combine different types of repression measures with pricing tools to dismantle the smugglers while limiting the increase in migration flows following the legalisation. Some calibrations highlight the sensitivity of the magnitude of the policy implications to the level of risk entailed by illegal migration, as well as the complementarity between the different types of repression measures, which, in practice, target different groups: the smugglers, the illegal migrants or the firms which employ them.

Since a policy mix using traditional instruments combined with innovating pricing tools would be a more cost-effective means of eliminating smugglers while regulating migration, a question that remains largely open is why this has not yet been implemented. Although answering this question is beyond the scope of the paper, we may consider a few hypotheses that are worth investigating in future work and other fields of social sciences. In countries like France one immediate answer is that introducing such pricing schemes in the field of migration may be considered as unethical or violating human rights.[40] Their implementation would surely generate many complicated issues such as the feasibility of pricing visas differently depending on the country of origin of the applicants or the duration of the permit. From this viewpoint, it is, however, not clear that transparent pricing tools are

[40] Moreover, people may not be willing to trade a sacred value such as the right to immigrate for money -what psychologist Philip Tetlock (2007) refers to as a "taboo tradeoff".

less ethical than the existing policy of visa rationing, which creates "rents" to the lucky applicants, generates important monetary hidden costs, such as briberies, paid by all applicants, and feeds all kinds of illegal activities. A second answer suggested by our results is that natives may prefer to have lowly paid illegal immigrants rather than a larger number of legal workers, who would enjoy a more complete set of rights. Moreover, although reinforcing sanctions paid by employers of illegal migrants would be a more cost-effective way to combine legalisation with migration control than reinforcing border controls, such policy would typically encounter strong resistance from powerful lobbies. The status quo reflects complex political-economy issues with some people benefitting more than others from lax enforcement. These considerations may explain why, under current policies, a large number of illegal migrants still bear the costs of being exploited in destination areas and face the constant risk of being deported.

Our model focuses on one particular channel of illegal entry through the services of smugglers, which applies very well to long haul migration. While this makes the originality of the paper, which proposes a general set-up of human smuggling markets, it also limits the interpretation of the policy implications. If would-be migrants choose between different channels of entry, as it is the case for the US-Mexico cross-border migrants or for migrants overstaying student/visitor visas to work illegally in high wages countries, we may expect spill-over effects of the policies under studies, which we hope to highlight in future research.

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Appendix

Appendix A: Market Equilibrium and an illustration in the case of uniform distribution

We model the oligopolistic market for illegal migration as a generalized Cournot competition. We focus on symmetric equilibrium (i.e., each smuggler has the same market share). Let $P^I(Q) = (dw_f - w_h)F^{-1}(1-Q)$ denote the inverse demand function for illegal migration. Smuggler $j = 1,..,N$ maximises with respect to quantity Q^j the profit function:

$$\pi^j(Q^j, Q^{-j}) = \left[P^I(Q^j + Q^{-j}) - c\right] Q^j$$

where $Q^{-j} = \sum_{k \neq j} Q^k$ is the offer made by the competitors of $j = 1, ..., N$. The first order condition is sufficient under the assumption that the demand function is not too convex. In a symmetric equilibrium $Q^j = \frac{Q}{N}$ and the generalized Cournot price with N smugglers, p^N, is such that (3) holds.

We next illustrate the market equilibrium with the example of a uniform distribution of skills over $[0, 1]$, which gives easily tractable closed form solutions. From (1) and (2) we can write explicitly the demand for illegal migration as:

$$D^I(p) = 1 - \frac{p}{dw_f - w_h} \tag{24}$$

In the case of a generalized Cournot competition, we can use (3) to establish that the price is as follows:

$$p^N = \frac{dw_f - w_h + Nc}{N+1} \tag{25}$$

such that $p^m (= p^1) = \frac{dw_f - w_h}{2} + \frac{c}{2}$ and $p^\infty (= \lim_{N \to +\infty} p^N) = c$.

We deduce that the generalized Cournot demand is

$$D^I(p^N) = \frac{N}{N+1}\left(1 - \frac{c}{dw_f - w_h}\right)$$

Depending on the degree of competitiveness of the market, measured by N, the demand is between the demand on monopolistic market $D^I(p^m) = \frac{1}{2} - \frac{c}{2(dw_f - w_h)}$, and the demand in perfect competition $D^I(c) = 2D^I(p^m)$.

Appendix B : Proof of $\frac{dp^I(p^L)}{dp^L} > 0$

To show that $\frac{dp^I(p^L)}{dp^L} > 0$ we totally differentiate (3) where the direct price elasticity of demand, which is derived from (6), is parameterized by p^L.

We obtain that

$$\frac{dp^I(p^L)}{dp^L} = -\frac{(p^I - c)\frac{\partial^2 D^I(p^I,p^L)}{\partial p^I \partial p^L} + \frac{1}{N}\frac{\partial D^I(p^I,p^L)}{\partial p^L}}{\frac{N+1}{N}\frac{\partial D^I(p^I,p^L)}{\partial p^I} + (p^I - c)\frac{\partial^2 D^I(p^I,p^L)}{\partial p^{I2}}} \tag{26}$$

Second order condition of the oligopoly optimization problem implies that the denominator is negative. Since the two commodities are substitutes (i.e., $\frac{\partial D^I}{\partial p^L} \geq 0$), a sufficient condition for the numerator to be positive is that $\frac{\partial^2 D^I(p^I,p^L)}{\partial p^I \partial p^L} \geqslant 0$. Using equation (6) we can easily show that this is always true as long as $f'(\theta) \leq 0$, which characterises for example the case with a uniform distribution ($f'(\theta) = 0$ over the support). By virtue of equation (27) below with a uniform distribution we get $\frac{\partial^2 D^I(p^I,p^L)}{\partial p^I \partial p^L} = 0$. It is also true when the density function is strictly decreasing as in developing countries where the vast majority of people do not have any education and are thus low skilled. QED

Appendix C: Uniform Distribution Example for Proposition 2

This section develops Proposition 2 in the case of a uniform distribution of skills distributed over 0 and 1. The demand faced by the smugglers when the government proposes a (legal) migration price, p^L, is:

$$D^I(p^I, p^L) = \int_{\frac{p^I}{dw_f - w_h}}^{\frac{p^L - p^I}{(1-d)w_f}} f(\theta)d\theta = \int_{\frac{p^I}{dw_f - w_h}}^{\frac{p^L - p^I}{(1-d)w_f}} d\theta = \frac{p^L - p^I}{(1-d)w_f} - \frac{p^I}{dw_f - w_h} \tag{27}$$

We deduce that the inverse demand function faced by the smugglers is:

$$P^I(Q, p^L) = \frac{dw_f - w_h}{w_f - w_h}(p^L - (1-d)w_f Q) \tag{28}$$

Smuggler $j = 1, .., N$ maximises with respect to q^j the profit function:

$$\pi^j(q^j, Q^{-j}) = \left[P^I(q^j + Q^{-j}, p^L) - c\right] q^j$$

where c represents the marginal costs for the smuggler and $Q^{-j} = \sum_{k \neq j} q^k$ is the offer made by the competitors of $j = 1, ..., N$. In a symmetric equilibrium $q^j = \frac{Q}{N}$ so that the Cournot quantity Q^N is such that:

$$P^I(Q^N, p^L) - c + \frac{\partial P^I(Q^N, p^L)}{\partial Q^N} \frac{Q^N}{N} = 0 \tag{29}$$

Symmetrically the generalized Cournot price with N smugglers, p^N, is such that:

$$\frac{p^N - c}{p^N} = \frac{1}{N} \frac{1}{\varepsilon_{D^I, p^I}} \tag{30}$$

Second order condition requires that

$$\frac{\partial^2 P^I(Q, p^L)}{\partial Q^2} \frac{Q}{N} + 2\frac{\partial P^I(Q, p^L)}{\partial Q} \leq 0 \tag{31}$$

which is always true with the uniform distribution example (see (28)).

Substituting (28) in the equation (29) we deduce that

$$Q^N(p^L) = \frac{N}{N+1}(p^L - c\frac{w_f - w_h}{dw_f - w_h})\frac{1}{(1-d)w_f} \tag{32}$$

or, alternatively, that

$$P^N(p^L) = P^I(Q^N(p^L), p^L) = \frac{p^L}{N+1}\frac{dw_f - w_h}{w_f - w_h} + \frac{N}{1+N}c \tag{33}$$

We now turn to showing that such reaction smugglers price is smaller than the price imposed by the smugglers under unconstrained oligopoly. With the uniform distribution example, replacing (33) into (10) the upper limit for the visa price satisfies:

$$\overline{p}^L = [Nc + (1+N)(1-d)w_f] \frac{w_f - w_h}{(1-d)w_f + N(w_f - w_h)} \tag{34}$$

Comparing the reaction smugglers price $p^I(\overline{p}^L)$ with the unconstrained smugglers' oligopoly price $p^N = \frac{dw_f - w_h + Nc}{N+1}$ defined in (25) it is straightforward to check that $p^I(\overline{p}^L) \leq p^N$ if and only if $dw_f - w_h \geq c$, which is a necessary condition for the smugglers to be active in the first place. Indeed from (1), we obtain that: $dw_f - w_h > p^I$ otherwise there is no illegal migrant. Moreover, necessarily $c < p^I$ otherwise smugglers do not operate. Therefore, when smugglers operate, the condition $c < dw_f - w_h$ is necessarily satisfied, which implies that $p^I(\overline{p}_L) < p^N$. QED

Appendix D: Proof of Proposition 3

Let $\underline{p}^L(R_1, R_2) = \frac{w_f - w_h}{d(R_2)w_f - w_h} c(R_1)$ be the price which pushes smugglers out of business and let $D^L(R_1, R_2) = 1 - F\left(\frac{\underline{p}^L(R_1,R_2)}{w_f - w_h}\right)$ the legal demand for visas associated with this price. The problem (14) the government aims to solve is equivalent to:

$$\max_{R_1, R_2} \underline{p}^L(R_1, R_2) \qquad \text{s.t.} \qquad R_1 + R_2 \leq D^L(R_1, R_2)\underline{p}^L(R_1, R_2) \tag{35}$$

The Lagrangian of this optimization problem is :

$$L = \underline{p}^L(R_1, R_2) + \lambda \Big\{ D^L(R_1, R_2) p^L(R_1, R_2) - (R_1 + R_2) \Big\} \tag{36}$$

The Lagrangian derivatives are for $k = 1, 2$:

$$\frac{\partial L}{\partial R_k} = \frac{\partial \underline{p}^L}{\partial R_k} \Big(1 + \lambda D^L(R_1, R_2) \Big) + \lambda \underline{p}^L(R_1, R_2) \frac{\partial D^L}{\partial R_k} - \lambda \tag{37}$$

Focusing on interior solutions, the optimal combination of (R_1, R_2) satisfies necessarily $\frac{\partial L}{\partial R_1} = \frac{\partial L}{\partial R_2}$, which yields:

$$\frac{\partial \underline{p}^L}{\partial R_2}\Big(1 + \lambda D^L(R_1, R_2)\Big) + \lambda \underline{p}^L(R_1, R_2)\frac{\partial D^L}{\partial R_2}$$
$$= \frac{\partial \underline{p}^L}{\partial R_1}\Big(1 + \lambda D^L(R_1, R_2)\Big) + \lambda \underline{p}^L(R_1, R_2)\frac{\partial D^L}{\partial R_1}$$

Simplifying this expression by noting that $\frac{\partial D^L}{\partial R_k} = -\frac{\frac{\partial \underline{p}^L}{\partial R_k}}{w_f - w_h} f\left(\frac{\underline{p}^L(R_1,R_2)}{w_f - w_h}\right)$, the optimal combinaison of (R_1, R_2) is such that $\frac{\partial \underline{p}^L}{\partial R_1} = \frac{\partial \underline{p}^L}{\partial R_2}$, which yields equation (16). The Lagrangian derivative with respect to λ yields equation (15). We now check with a simple example that the set of functions supporting an interior solution is not empty.

An example:

Let's assume that $w_h \simeq 0$ and that $c(R) = c\frac{1+2R}{1+R}$ and $d(R) = \frac{d}{1+R}$. Consistently with the model assumptions $c(R)$ is increasing and concave and $d(R)$ is decreasing and convex. Let's note $k(R) = \frac{c'(R)}{c(R)} = \frac{1}{(1+R)(1+2R)}$ and let $g(R) = \frac{-d'(\overline{R}-R)}{d(\overline{R}-R)} = \frac{1}{1+\overline{R}-R}$ for all $R \in [0, \overline{R}]$ with $\overline{R}$ being a fixed point such that $\overline{R} = D^L(R, \overline{R} - R)\underline{p}^L(R, \overline{R} - R)$. The interior solution of our problem is determined by that: $k(R) = g(R)$.[41]

$$R_2^*(\overline{R}) = \overline{R} - R_1^*(\overline{R}) = \overline{R} + 1 - \sqrt{1 + \frac{\overline{R}}{2}} \tag{38}$$

It is easy to check that both $R_1^*(\overline{R})$ and $R_2^*(\overline{R})$ take their value between $[0, \overline{R}]$. They constitute an interior solution of the optimisation problem.

Let $p^L(\overline{R}) = \underline{p}^L(R_1^*(\overline{R}), R_2^*(\overline{R}))$ and $D^L(\overline{R}) = D^L(R_1^*(\overline{R}), R_2^*(\overline{R}))$. To complete the proof we need to show that there exists a fixed point, $\overline{R} > 0$, such that $\overline{R} = D^L(\overline{R})p^L(\overline{R})$.

[41] It is easy to check that $k'(R) < 0$ and that $g'(R) > 0$ $\forall R \in [0, \overline{R}]$. Since $k(R)$ is strictly decreasing and $g(R)$ is strictly increasing for all $R \in [0, \overline{R}]$, and since $g(0) < k(0)$, and $g(\overline{R}) > k(\overline{R})$ $\forall \overline{R} > 0$, there exists an unique interior solution to $k(R) = g(R)$.

The assumption $w_h \simeq 0$ implies that $p^L(\overline{R}) = \frac{c(R_1^*)}{d(R_2^*)} = \frac{c}{d}\frac{1+2R_1^*}{1+R_1^*}(1+R_2^*)$. Substituting R_1^* and R_2^* by their value from (38) and rearranging the expression we get

$$p^L(\overline{R}) = \frac{c}{d}\Big(\sqrt{2(2+\overline{R})}-1\Big)^2 \tag{39}$$

We deduce that $\overline{R}$ is the solution to:

$$R = \frac{c}{d}\big(\sqrt{2(2+R)}-1\big)^2\Big(1-\frac{c}{dw_f\overline{\theta}}\big(\sqrt{2(2+R)}-1\big)^2\Big) \tag{40}$$

The demand is defined if $1 \geq \frac{c}{dw_f\overline{\theta}}\big(\sqrt{2(2+R)}-1\big)^2$, which is equivalent to $R \leq R^{max} = 0.5\Big(1+\sqrt{\frac{dw_f\overline{\theta}}{c}}\Big)^2 - 2$. We deduce that $R^{max} > 0$ if and only if

$$\frac{dw_f\overline{\theta}}{c} > 1 \tag{41}$$

Note that this assumption is always verified whenever there is some human smuggling: $c < dw_f\overline{\theta}$. Therefore $R^{max} > 0$ and it is straightforward to check that $\overline{R}$ exists. Indeed when $R = 0$ the left hand side of equation (40) is equal to $LHS(0) = 0$, while the right hand side is equal to $RHS(0) = \frac{c}{d}\left(1-\frac{c}{dw_f\overline{\theta}}\right) > 0$ under (41). Symmetrically the left hand side of equation (40) when $R = R^{max}$ is equal to $LHS(R^{max}) = R^{max} > 0$ under (41), while $RHS(R^{max}) = 0$. Since both functions are continuous they cross necessarily at least once at $\overline{R} \in (0, R^{max})$.

Moreover, after noting that:

$$RHS'(R) = 2\frac{c}{d}\left[\frac{\sqrt{2(2+R)}-1}{\sqrt{2(2+R)}}\right]\left\{1-\frac{c}{dw_f\overline{\theta}}2(\sqrt{2(2+R)}-1)^2\right\}$$

we can check that $RHS'(R) < 0 \Leftrightarrow dw_f\overline{\theta} < 2c(\sqrt{2(2+R)}-1)^2$, which is for instance true if $2 > \frac{dw_f\overline{\theta}}{c} > 1$. In this case the function $LHS(.)$ is increasing and $RHS(.)$ is decreasing: they cross only once. QED

Appendix E: Risk aversion

Proof of Lemma 1

Applying the expected utility theorem and comparing the individual's expected utility in case he/she migrates, equal to $(1-q)\,u(\theta\delta w_f - p^I) + qu\left(\theta w_h - p^I\right)$ with the expected utility in case she does not migrate, equal to $u\left(\theta w_h\right)$, we can write the migration condition as: $u\left(\theta w_h\right) < (1-q)u(\theta\delta w_f - p^I) + qu\left(\theta w_h - p^I\right)$. Studying the threshold such that an individual is just indifferent between migrating illegally or not migrating, the marginal type θ^I_{ra} is the solution of the following equation: $u\left(\theta w_h\right) = (1-q)u(\theta\delta w_f - p^I) + qu\left(\theta w_h - p^I\right)$. Substituting $u(x) = 1 - exp(-ax)$ and rearranging this expression, we obtain the illegal migration threshold θ^I_{ra} as a solution of the equation (18): $\frac{1-e^{-ap^I}}{1-e^{-a\theta(\delta w_f - w_h)}} = 1-q$.

Let $\nu(\theta) = \frac{1-e^{-ap^I}}{1-e^{-a\theta(\delta w_f - w_h)}}$. Deriving twice the function $\nu(\theta)$ one can easily check that it is decreasing and convex in θ. Moreover $\lim_{\theta\to 0}\nu(\theta) = +\infty$ and $\lim_{\theta\to\infty}\nu(\theta) = 1 - e^{-ap^I}$. We deduce, first, that if q is strictly lower than e^{-ap^I} then θ^I_{ra} exists and is unique and, second, that θ^I_{ra} is increasing with q.

We can write the demand for illegal migration as a function of the migration price p^I similarly as before, except that θ^I is now replaced by θ^I_{ra}:

$$D^I_{ra}(p^I) = \int_{\theta^I_{ra}}^{\overline{\theta}} f(\theta)d\theta = 1 - F(\theta^I_{ra}) \tag{42}$$

As θ^I_{ra} increases with p^I and decreases with δ, the demand for migration remains higher the lower the migration price, p^I, and the higher the wage differential $\delta w_f - w_h$ between the two countries. The logic of the pricing scheme of smugglers described in section 2 remains thus the same as before but it takes into account the new (lower) demand from risk averse individuals (42).

We now formally show in the uniform example that risk aversion implies that the price imposed by smugglers is then lower than the price they would impose to risk neutral individuals with the same expected revenue from migration With risk neutrality we have $\theta^I(p) = \frac{p}{dw_f - w_h}$ and

$$D^I(p) = \int_{\theta^I}^{1} f(\theta)d\theta = 1 - F(\theta^I) = 1 - \theta^I(p) \tag{43}$$

We deduce that the (absolute value) of the price elasticity of demand is:

$$\varepsilon_{D,p} = \frac{-D^{I\prime}(p)p}{D^I(p)} = \frac{\theta^I(p)}{1-\theta^I(p)} = \frac{p}{(dw_f - w_h) - p}$$

With risk aversion, we have θ^I_{ra} which is such that:

$$\frac{1 - e^{-ap}}{1 - e^{-a\theta(\delta w_f - w_h)}} = 1 - q \tag{44}$$

We deduce that :

$$\theta^I_{ra}(p) = \frac{log(1-q) - log\left(e^{-ap} - q\right))}{a(\delta w_f - w_h)} \tag{45}$$

the demand is:

$$D^I_{ra}(p) = \int_{\theta^I_{ra}}^{1} f(\theta)d\theta = 1 - F(\theta^I_{ra}) = 1 - \theta^I_{ra}(p) \tag{46}$$

It is straightforward to check that if $q = 0$ (i.e., there is no risk of deportation in migrating illegally) then $\delta = d$ so that $\theta^I_{ra}(p) = \theta^I(p)$.

We deduce that the (absolute value) of the price elasticity of demand is:

$$\varepsilon_{D_{ra},p} = \frac{-D^{I\prime}_{ra}(p)p}{D^I_{ra}(p)} = \frac{p\frac{e^{-ap}}{e^{-ap}-q}}{(\delta w_f - w_h) - \frac{log(1-q)-log(e^{-ap}-q))}{a}} \tag{47}$$

Here again it is easy to check that $\varepsilon_{D_{ra},p} = \varepsilon_{D,p}$ when $q = 0$. After differentiating $\varepsilon_{D_{ra},p}$ with respect to $q \leq 1$ and noting that $a(\delta w_f - w_h) - log(1 - q) + log(e^{-ap} - q) > 0$ as $0 < \theta^I_{ra}(p) < 1$ one can check that $\varepsilon_{D_{ra},p}$ increases with q:

$$\frac{d\varepsilon_{D_{ra},p}}{dq} \equiv \Big(a(\delta w_f - w_h) - log(1-q) + log\left(e^{-ap} - q\right)\Big) + \frac{1-e^{-ap}}{1-q} > 0 \quad (48)$$

So when the risk q augments the demand price elasticity increases, and thus, everything else being equal, the monopoly price is lower.QED

Proof of Lemma 2

We now turn to the government policy of visa sale and the reaction of smugglers. If individuals can buy a legal permit to migrate at price p^L, smugglers need to price their services low enough so that at least one individual wishes to migrate illegally. The skill level θ^L_{ra} of the marginal illegal migrant who is just indifferent between migrating illegally and legally satisfies $u\left(\theta w_f - p^L\right) = (1-q)u(\theta\delta w_f - p^I) + qu\left(\theta w_h - p^I\right)$. Substituting $u(x) = 1 - exp(-ax)$ and rearranging this expression, we obtain the legal migration threshold θ^L_{ra} as a solution of the following equation:

$$\frac{1-e^{-a(\theta(w_f-w_h)+p^I-p^L)}}{1-e^{-a\theta(\delta w_f - w_h)}} = 1-q \quad (49)$$

Solving for the threshold θ^L_{ra} and comparing it to (4) we show in the following that $\theta^L_{ra} < \theta^L$.

Proof. Let $\rho(\theta) = \frac{1-e^{-a(\theta(w_f-w_h)+p^I-p^L)}}{1-e^{-a\theta(\delta w_f - w_h)}}$. Equation (49)defines θ^L_{ra} as a solution of $\rho(\theta) = 1-q$. The benchmark case of risk neutrality is obtained by setting $q = 0$ in this equation. Indeed when $q = 0$ and $\delta = d$ the unique solution of $\rho(\theta) = 1$ is θ^L defined equation (4). This also implies that the function $\rho(\theta)$ crosses once and only once the horizontal line 1.

Next, deriving $\rho(\theta)$ with respect to θ yields:

$$\rho'(\theta) = \frac{a(1-e^{-a(\theta(w_f-w_h)+p^I-p^L)})}{1-e^{-a\theta(\delta w_f-w_h)}} \times \left\{ \frac{(w_f-w_h)e^{-a(\theta(w_f-w_h)+p^I-p^L)}}{1-e^{-a(\theta(w_f-w_h)+p^I-p^L)}} - \frac{(\delta w_f-w_h)e^{-a\theta(\delta w_f-w_h)}}{1-e^{-a\theta(\delta w_f-w_h)}} \right\}$$

To study the sign of $\rho'(\theta)$ we consider 2 cases:

- If $\theta \leq \frac{p^L-p^I}{w_f-w_h}$ then $\theta(w_f-w_h)+p^I-p^L \leq 0$ so that $1-e^{-a(\theta(w_f-w_h)+p^I-p^L)} \leq 0$. Since by assumption $w_f-w_h \geq \delta w_f - w_h \geq 0$ all the other elements in the fractions composing $\rho'(\theta)$ are positive. We deduce that both the first term and the term in the brackets are negative such that $\rho'(\theta) > 0$.
- If $\frac{p^L-p^I}{w_f-w_h} < \theta \leq \frac{p^L-p^I}{(1-\delta)w_f} = \theta^L$ then $0 < \theta(w_f-w_h)+p^I-p^L \leq \theta(\delta w_f-w_h)$ and $1-e^{-a(\theta(w_f-w_h)+p^I-p^L)} > 0$. Since $1-e^{-ax}$ is log concave in x, we have that $\frac{e^{-a(\theta(w_f-w_h)+p^I-p^L)}}{1-e^{-a(\theta(w_f-w_h)+p^I-p^L)}} \geq \frac{e^{-a\theta(\delta w_f-w_h)}}{1-e^{-a\theta(\delta w_f-w_h)}}$. Moreover we have $w_f-w_h \geq \delta w_f - w_h \geq 0$ such that the term in the brackets is now positive. Similarly the first term is also now positive such that $\rho'(\theta) > 0$.

We have just shown that the continuous function $\rho(\theta)$ is increasing for $\theta \in [0, \theta^L]$. Moreover it crosses once and only once the horizontal line at $q = 0$ for $\theta = \theta^L$. We deduce that for $\theta > \theta^L$ $\rho(\theta) > 1$ so that equation (49) never holds. The relevant domain for θ^L_{ra} in equation (49) when q varies between 0 and 1 is $\theta \in [0, \theta^L]$. This implies that if θ^L_{ra} exists it is necessarily such that $\theta^L_{ra} \leq \theta^L$ with a strict inequality for any $q > 0$.

To finish the proof of Lemma 2 we need to show that θ^L_{ra} exists and is unique. It is done by noting that $\lim_{\theta \to 0} \rho(\theta) = -\infty$. So the function $\rho(\theta)$ strictly increases between $-\infty$ and 1 when θ varies between 0 and θ^L. It necessarily crosses the line $q \in [0,1]$ once and only once.QED ■

Proof of Lemma 3

In order to eradicate the smugglers we know that

$$\theta^I_{ra}(c) = \theta^L_{ra}(c, \underline{p}^L_{ra}) \tag{50}$$

with $\theta^I_{ra}(c) = \frac{log(1-q)-log\left(e^{-ca}-q\right)}{a(\delta w_f - w_h)}$

Moreover, from (18) $\theta^L_{ra}(c, \underline{p}^L_{ra})$ is the implicit solution of

$$1 - q = \frac{1 - e^{-a(\theta(w_f - w_h) + c - \underline{p}^L_{ra})}}{1 - e^{-a\theta(\delta w_f - w_h)}}$$

This implies that $\underline{p}^L_{ra}$ satisfies the following equation

$$\begin{aligned} (1-q)\left(1 - e^{-a\theta(\delta w_f - w_h)}\right) &= 1 - e^{-a(\theta(w_f - w_h) + c - \underline{p}^L_{ra})} \\ \text{with } \theta &= \theta^I_{ra}(c) = \frac{\log(1-q) - \log\left(e^{-ca} - q\right))}{a(\delta w_f - w_h)} \end{aligned}$$

This yields successively that:

$$\begin{aligned} c &= \theta^I_{ra}(c)(w_f - w_h) + c - \underline{p}^L_{ra} \\ \underline{p}^L_{ra} &= \frac{\log(1-q) - \log\left(e^{-ca} - q\right))}{a(\delta w_f - w_h)}(w_f - w_h) \end{aligned} \tag{51}$$

and we can check easily that $d\underline{p}^L_{ra}/dq > 0$.QED

The reasoning of section 3.2.2 remains valid under risk aversion. The IR constraint, which can be written $1 - e^{-a(\overline{\theta}w_f - p^L)} \geq 1 - e^{-a\overline{\theta}w_h}$, is unchanged. The IC constraint becomes $1 - e^{-a(\overline{\theta}w_f - p^L)} \geq (1-q)\left(1 - e^{-a(\overline{\theta}\delta w_f - p^I)}\right) + q(1 - e^{-a(\overline{\theta}w_h - p^I)})$. The IC constraint is binding if $(1-q)\left(1 - e^{-a(\overline{\theta}\delta w_f - p^I)}\right) + q(1 - e^{-a(\overline{\theta}w_h - p^I)}) \geq 1 - e^{-a\overline{\theta}w_h}$, which is a necessary condition for the smuggler to be active. So if the smuggler is active the binding constraint is the IC and $\overline{p}^L_{ra}$ is the solution of the following equation:

$$e^{-a(\overline{\theta}w_f - p^L)} = (1-q)\, e^{-a(\overline{\theta}\delta w_f - p^I_{ra}(p^L))} + qe^{-a(\overline{\theta}w_h - p^I_{ra}(p^L))}$$

Proof of Proposition 4

Using three instruments to eradicate human smuggling while controlling migration flows, the government solves :

$$\max_{R_1,R_2,R_3} \underline{p}^L(R_1,R_2,R_3) \qquad \text{s.t.} \qquad R_1+R_2+R_3 \leq D^L(R_1,R_2,R_3)\underline{p}^L(R_1,R_2,R_3) \tag{52}$$

The Lagrangian of this optimization problem is :

$$L = \underline{p}^L(R_1,R_2,R_3)+\lambda\Big\{D^L(R_1,R_2,R_3)\underline{p}^L(R_1,R_2,R_3)-(R_1+R_2+R_3)\Big\} \tag{53}$$

The Lagrangian derivatives are for $k=1,2,3$:

$$\frac{\partial L}{\partial R_k} = \frac{\partial \underline{p}^L}{\partial R_k}\Big(1+\lambda D^L(R_1,R_2)\Big) + \lambda \underline{p}^L(R_1,R_2)\frac{\partial D^L}{\partial R_k} - \lambda \tag{54}$$

Focusing on interior solutions, the optimal combination of (R_1,R_2,R_3) satisfies necessarily: $\frac{\partial L}{\partial R_1} = \frac{\partial L}{\partial R_2} = \frac{\partial L}{\partial R_3}$. Simplifying this expression by noting that $\frac{\partial D^L}{\partial R_k} = -\frac{\frac{\partial \underline{p}^L}{\partial R_k}}{w_f - w_h} f\left(\frac{\underline{p}^L(R_1,R_2,R_3)}{w_f-w_h}\right)$ yields that the optimal combination is such that $\frac{\partial \underline{p}^L}{\partial R_1} = \frac{\partial \underline{p}^L}{\partial R_2} = \frac{\partial \underline{p}^L}{\partial R_3}$, which yields equation (23). Moreover the Lagrangian derivative with respect to λ yields equation (21).QED

Link with Becker (1968)

Assuming to simplify that $w_h = 0$ we can determine the investments such that expected earnings from illegal migration, $(1-q(R_3))\delta(R_2)w_f + q(R_3)w_h = (1-q(R_3))\delta(R_2)w_f$, are minimized under the budget constraint $R_2 + R_3 = \overline{R}$. As $R_2 = \overline{R} - R_3$, R_3 is the solution to:

$$\frac{-\delta'(\overline{R}-R_3)}{\delta(\overline{R}-R_3)} = \frac{q'(R_3)}{1-q(R_3)} \tag{55}$$

Under the assumption that the functions $1-q(R)$ and $\delta(R)$ are log convex, which is for instance the case when $q(R) = 1 - q/(1+R)$ and $\delta(R) =$

$\delta/(1+R)$, the function $f(R) = \frac{q'(R)}{1-q(R)}$ decreases with R and the function $g(R) = \frac{-\delta'(\overline{R}-R)}{\delta(\overline{R}-R)}$ increases with R. Under the assumption that $f(0) > g(0)$ and $f(\overline{R}) < g(\overline{R})$ then R_3^{rn} solution of (55) exists and is unique. When for instance $q(R) = 1 - q/(1+R)$ and $\delta(R) = \delta/(1+R)$ then $g(R) = \frac{1}{1+\overline{R}-R}$ and $f(R) = \frac{1}{1+R}$. This implies $f(0) = 1 > g(0) = \frac{1}{1+\overline{R}}$ and $f(\overline{R}) = \frac{1}{1+\overline{R}} < g(\overline{R}) = 1$ so that $R_3^{rn} = \overline{R}/2$. This determines the optimal allocation of investment between the two instruments to reduce migration flows under the assumption of risk neutrality.

However, if individuals are risk-averse, minimizing the flow of migrants is not equivalent to minimising expected earnings of would be migrants. Using our model, minimizing the flow of migrants is equivalent to maximizing the price of visas, which can be written as $\underline{p}_{ra}^{L}(R_3) = \frac{\log(1-q(R_3)) - \log\left(e^{-ca} - q(R_3)\right)}{a\delta(\overline{R}-R_3)w_f}(w_f - w_h)$.

Assuming again to simplify that $w_h = 0$, we can rewrite the price $\underline{p}_{ra}^{L}(R_3) = \frac{\log(1-q(R_3)) - \log\left(e^{-ca} - q(R_3)\right)}{a\delta(\overline{R}-R_3)}$ and maximise it with respect to R_3 with the constraint that $R_3 + R_2 = \overline{R}$.

We find that

$$\begin{aligned} \partial \underline{p}_{ra}^{L}/\partial R_3 &= \frac{1}{a\delta(\overline{R}-R_3)} \left\{ \frac{q'(R_3)}{1-q(R_3)} \left[\frac{1-q(R_3)}{e^{-ca}-q(R_3)} - 1 \right] + \right. \\ & \left. \frac{\delta'(\overline{R}-R_3)}{\delta(\overline{R}-R_3)} \left[\log\left(1-q(R_3)\right) - \log(e^{-ca} - q(R_3)) \right] \right\} \end{aligned}$$

Under risk aversion an interior solution of our problem is such that $\partial \underline{p}_{ra}^{L}/\partial R_3 = 0$, which determines implicitly the optimal investment R_3^{ra} as solution of the following equation:

$$\frac{-\delta'(\overline{R}-R_3)}{\delta(\overline{R}-R_3)} = \frac{q'(R_3)}{1-q(R_3)} \frac{\frac{1-q(R_3)}{e^{-ca}-q(R_3)} - 1}{\log(1-q(R_3) - \log\left(e^{-ca} - q(R_3)\right)} \tag{56}$$

By comparing (55) and (56) it is easy to see that the investment to increase the probability of deportation is higher under risk aversion than under risk neutrality: $R_3^{ra} > R_3^{rn}$. Indeed, since $f(R) = \frac{q'(R)}{1-q(R)}$ decreases and $g(R) = \frac{-\delta'(\overline{R}-R)}{\delta(\overline{R}-R)}$ increases with R, $R_3^{ra} > R_3^{rn}$ if the function $f(R)$ is shifted to the right (i.e., if it increases). This depends on the distortion in (56) being greater than 1, which is equivalent to:

$$\frac{1-q(R_3)}{e^{-ca}-q(R_3)} - 1 > \log\left(\frac{1-q(R_3)}{e^{-ca}-q(R_3)}\right) \tag{57}$$

Since $\frac{1-q(R_3)}{e^{-ca}-q(R_3)} > 1$ this is always true (i.e., $x - logx - 1 > 0 \ \forall x > 1$). We have thus established that $q(R_3^{rn})$ is lower than the probability of deportation $q(R_3^{ra})$, which minimises migration flows.QED

Appendix F : Rationality of migration decisions

This Appendix departs from the estimated prices paid by Chinese illegal migrants to go to the US, which have been documented in Friebel and Guriev, 2006 and previous work to be above \$35000 in mid 1990s and then continued to rise and checks that the rationality constraint of our model is satisfied for the wage differential between the US and China observed in 2005 and for a large range of wage differentials observed between advanced and developing countries..

To calibrate d, we use Cobb-Clark and Kossoudji's (2002) estimates of 14 to 24% legalisation premia which, we round at 20%. Assuming $d = 0.8$ is also in line with the findings of Rivera-Batiz (1999) on the gap in wage differential between legal and undocumented immigrants on the US market, which remains unexplained by differences in measured characteristics of these two groups.[42]

To calculate the net present value of working illegally in the US we follow Friebel and Guriev, 2006, and take the average minimum wages in the US,

[42] Although these estimates are based on Mexican immigrants and may be different for long-distance illegal migrants, who may come from very different areas such as South East Asia, Russia or Africa and may have different skill distributions, these are, to our knowledge, the best available proxies.

\$6.15 per hour, and assume that a migrant works 45 hours for 52 weeks per year over a period of 40 years. Accordingly, assuming the discount and growth rates of future wages are equal and without loss of generality setting it to zero, NPV of earnings in the US is around \$575640 ($= 52*45*\$6.15*40$) Moreover, estimates of the GDP per capita in China in terms of purchasing power parity are in the range of \$4000 such that, over 40 years, the NPV of earnings in China are estimated around \$160000 ($= \$4000 * 40$).[43] We can check that the IR constraint, $p^I \leq (dw_f - w_h)$, is largely satisfied (as $p^I < 575640 * 0.8 - 160000$) for the case of the Chinese migration to the US.

More generally, we check that the constraint $p^I \leq w_h(d\frac{w_f}{w_h} - 1)$ is easily satisfied for a large range of ratios $\frac{w_f}{w_h}$ (=2, 3, 4, 5, 7, 10, 15, and 25) based on wage differentials between advanced and developing countries reported by Freeman et al. (2000) or on purchasing power adjusted wages ratios computed by Clemens et al. (2009) for workers who are otherwise observably identical. However, since we do not have good estimates for the prices to cross illegally from one origin to another destination country, we prefer to focus on the illegal Chinese migration to the US for the remainder of our simulations.

Appendix G : Risk aversion and probability of deportation

From the Cournot Price (3) and replacing the price elasticity of the demand for migration $\varepsilon_{D_{ra},p}$ using our calculations above (47) we can write the marginal costs for smugglers to operate, c_{ra}, as follows:

$$c_{ra} = p^I - \frac{1}{N} \frac{(\delta w_f - w_h) - \frac{log(1-q) - log\left(e^{-ap^I} - q\right)}{a}}{\frac{e^{-ap^I}}{e^{-ap^I} - q}} \tag{58}$$

Replacing in (58) with $p^I = 35000$, $\delta = 0.8$, $w_f = 575640$, $w_h = 160000$,

[43] This estimate of GDP per capita reported by the CIA World Factbook 2005 corresponds to a wage equal to 1.7 dollar per hour in China, which, given the adjustment by the differential in purchasing power between China and the US, does not seem unreasonable. See https://www.cia.gov/library/publications/the-world-factbook/

$N = 2$, and $c_{ra} = 10000$ we can determine a set of absolute risk aversion parameters a, which correspond to a set of deportation probabilities q.

To illustrate the magnitude of the policy implications of the model, we present our results for four sets of compatible values $(0.7, 0.00000086)$, $(0.5, 0.00001)$, $(0.4, 0.00002)$, $(0.2, 0.000039)$.

Appendix H : Policy Simulations

Price of visas and migration demand following a "pure sale of visas" scheme

This Appendix estimates the increase in migration demand following a "pure" sale of visas implemented to eliminate smugglers (i.e. not using the other available instruments, such that marginal costs for smugglers to operate, sanctions against employers and probability of deportation remain unchanged).

We first simulate the visa price that would eradicate the smugglers using equation (51). Consistent with Lemma 3, row 3 of Table I shows that, for each degree of risk aversion a considered successively in columns (1) to (4), the price increases with the risk of deportation. In column (1) this price ranges between \$43624 and \$49954 for probabilities of deportation, q, between 0.68 and 0.72. In column (4), the visa price ranges between \$17755 and \$18957 for probabilities of deportation between 0.18 and 0.22. A relatively high a coupled with a low q leads to much smaller equilibrium visa prices than a relatively low a coupled with a high q. In other words the visa price is very sensitive to the risk entailed by illegal migration.

We then estimate the magnitude of the increase in demand resulting from this "pure sale of visas" scheme, $\Delta D = \frac{D^L_{ra}(\underline{p}^L_{ra}) - D^I_{ra}(p^I)}{D^I_{ra}(p^I)}$, which depends on the distribution of migrants' skills.

Assuming a uniform distribution over $[0, 1]$ the demand for illegal migration before the policy is implemented is: $D^I_{ra}(p^I) = 1 - \theta^I_{ra}$, with θ^I_{ra} solution of the equation (18), such that:

$$D^I_{ra}(p^I) = 1 - \frac{log(1-q) - log\left(e^{-ap^I} - q\right)}{a(\delta w_f - w_h)} \tag{59}$$

whereas, following the policy, the demand becomes

$$D^L_{ra}(\underline{p}^L_{ra}) = 1 - \frac{log(1-q) - log\left(e^{-ac} - q\right))}{a(\delta w_f - w_h)} \tag{60}$$

For the values (a, q) discussed above we can simulate the relative increase in migration demand following the policy as follows:

$$\Delta D = \frac{D^L_{ra}(\underline{p}^L_{ra}) - D^I_{ra}(p^I)}{D^I_{ra}(p^I)} = \frac{log\left(e^{-ca} - q\right) - log\left(e^{-ap^I} - q\right)}{a(\delta w_f - w_h) - log(1-q) + log\left(e^{-ap^I} - q\right)}$$

Our results presented in Table 1 show that the jump in demand following the "pure sale of visas" policy increases with the initial risk of deportation q. It varies between around 20% for low values ($q = 0.18$) and 55% for high values ($q = 0.72$), as displayed in Row 4 of the table. Finally, Tables J1 and J2 in the Appendix I report the simulations for $N = 3$ and $N = 5$ and show, in line with the model, that the less competitive the smugglers' market the larger the relative increase in demand, ΔD, following the policy: indeed, strongly cartelised smugglers keep the demand for illegal migration at a low level with high prices charged to migrants. Accordingly, our simulations assuming $N = 2$ give higher bounds for all implied changes.[44]

Sale of visas with migration control policy using reinforced border controls : $c(R^*)$

To keep the migration demand unaffected by the sale of visas, policy

[44]We can also use simulations to show that the values of risk compatible with $N = 10$ would imply that q is lower than 0.05. This makes this case not very plausible for the China to US route under study.

makers may first consider reinforcing border controls, which would increase marginal costs for smugglers to operate.

After replacing (59) and (60) in $D^I_{ra}(p^I) = D^L\left(\underline{p}^L_{ra}(R^*)\right)$ we find that $c(R^*)$ must satisfy the following equation:

$$\frac{log(1-q) - log\left(e^{-ap^I} - q\right)}{a(\delta w_f - w_h)} = \frac{log(1-q) - log\left(e^{-ac(R^*)} - q\right))}{a(\delta w_f - w_h)}$$

which is equivalent to $p^I = c(R^*)$.

As $c(.)$ increases with R, this determines a unique level of repression above which the policy of sale of visas with repression brings a lower level of migration than under the status quo. To give an idea of the magnitude of the required efforts we can compare the level of marginal costs for smugglers to operate, which must be equal to \$35000 following the policy, to the actual marginal costs for Chinese smugglers reported to be around \$10000. Therefore the policy would require increasing the marginal costs for smugglers by 250% (i.e.$\Delta c = \frac{c(R^*)-c}{c} = 2.5$ such that $c(R^*) = 3.5c$). As it seems reasonable to assume decreasing returns to scale for border enforcement measures this would require increasing by more than 3,5 times the budget allocated to such measures.

Sale of visas with migration control policy using reinforced sanctions to employers : $\delta(R^*)$

To keep the migration demand unaffected by the sale of visas, policy makers could alternatively reinforce the sanctions to employers of undocumented employees, which would translate into lower expected earnings abroad for illegal migrants. We determine the discounting factor, $\delta(R^*)$, which yields the same level of migration following the policy as under the status quo.

Solving $D^I_{ra}(p^I) = D^L\left(\underline{p}^L_{ra}(R^*)\right)$ yields $\delta(R^*)$ as an implicit solution of the following equation:

$$\frac{\delta(R^*)w_f - w_h}{\delta w_f - w_h} = \frac{log(\frac{1-q}{e^{-ac}-q})}{log(\frac{1-q}{e^{-ap^I}-q})} \tag{61}$$

Row 6 of Table I shows that this policy would require decreasing the discount factor δ by around 50% (i.e.$\Delta\delta = \frac{\delta(R^*)-\delta}{\delta} = -0.5$), such that the earnings of workers employed in the illegal sector of the economy falls below 40% of those of same skill workers in the legal sector.

Appendix I : Sensitivity analysis when the number of smugglers on the market varies

First we can check that the observations of a large differential between the migration price charged by smugglers (i.e., $p = 35000$) and the marginal cost (i.e., $c = 10000$) is not compatible with a relatively competitive market. The large markup suggests a cartelized smuggling market. For instance assuming $N = 10$ or above would imply, using equation (58), that deportation risk is below 0.05 which is not very realistic.

For our simulations above we assumed that $N = 2$. We now turn to testing the sensitivity of our results when the market for smugglers is more competitive, assuming successively $N = 3$ and $N = 5$ smugglers' networks. Simulations presented in the tables J1 and J2 show the magnitude of all implied changes. Note that, similarly as above, the degrees of risk aversion and deportation probabilities displayed in the first two rows of each table have been chosen to be compatible with the information $c = 10000$ and $p = 35000$, characterising the market for Chinese smuggled migrants.

Appendix J : The case of negative selection

Since our main focus is to design a policy to eliminate smugglers, which are primarily used in long haul migration, we assumed in the presentation of the model that workers self-select positively through migration according to their skill level. This generates interesting findings as a government will compete with smugglers to attract the highest skilled of the candidates for illegal migration by selling migration visas. However, depending on the relative returns to skill in the origin and destination countries the case of negative self-selection of workers through illegal migration cannot be ruled out, in particular for low-costs cross-border migration.

To give the intuition of how the results would change in the case of negative selection, we adopt the extreme assumption that workers working in the illegal sector of the destination country are paid at a flat rate, $d\underline{\theta}w_f$ which does not depend on their skill. After writing the migration condition as $\theta w_h < d\underline{\theta}w_f - p^I$, we can solve for the skill threshold, denoted θ^I, *below* which an individual prefers to migrate illegally than not to migrate:

$$\theta^I = \frac{d\underline{\theta}w_f - p^I}{w_h} \tag{62}$$

After aggregating over the distribution of skills, we obtain the demand for illegal migration as a function of migration price p^I:

$$D^I(p^I) = \int_{\underline{\theta}}^{\theta^I} f(\theta)d\theta = F(\theta^I) \tag{63}$$

As θ^I decreases with p^I and w_h and increases with d and w_f, it is easy to show that, once again, the demand for illegal migration is higher the lower the migration price, p^I, and the higher the difference between the income earned as an illegal migrant, $d\underline{\theta}w_f$, and the income in the home country, w_h.

We next study what happens if the government enters the migration market by selling visas. We consider the case where wages of legal migrants are independent of their skills. This is for example the case of migrants hosted by destination countries to work on specific work contracts in sector where there is a shortage of low skilled labour, such as immigrants working in agriculture in California. If the government sells visas at price p^L, migration candidates prefer to migrate legally rather than illegally as long as $\underline{\theta} w_f - p^L \geq \underline{\theta} d w_f - p^I$. If the government wants to eradicate smugglers through a pricing policy it has to sell visas at the price

$$\underline{p}^L = c + (1-d)\underline{\theta} w_f. \tag{64}$$

As in the case of positive selection, the only way to eliminate the smugglers through a "pure" sale of visas is to push their reaction price below their marginal costs. With such a pricing strategy the marginal migrant, indifferent between migrating legally and staying at home, is such that:

$$\theta^L = \frac{\underline{\theta} w_f - \underline{p}^L}{w_h}. \tag{65}$$

Replacing $\underline{p}^L$ by its value from (64) yields $\theta^L = \frac{d\underline{\theta} w_f - c}{w_h}$, which is the threshold in (62) evaluated at $p^I = c$. In other words, a policy that reduces the number of illegal migrants to zero through the sale of visas yields the same level of migration as under perfect competition among smugglers. Therefore Proposition 1 holds true under negative selection. It is also easy to show that the main message of proposition 2 still holds, such that whenever the government enters the market by selling visas, migration demand increases. One difference, however, is that selling visas leads, in this case, to an improvement of the skill composition of migrants since $\theta^L > \theta^I$.

Since the average skill of migrants increases (respectively, decreases) following the policy when the self-selection of workers through illegal migration is negative (positive), we have also shown that the policy increases the skills diversity of migrants in all cases.

Studying $\theta^L = \frac{d\underline{\theta} w_f - c}{w_h}$, it is easy to show that, as in the case of positive selection, the only way a government can control migration following a legalisation policy through the sale of visas is to increase repression. This reinforces our main message showing that policy makers must combine strict repression with sale of visas if the aim is to both legalise migration and control migration demand.

Tables in Appendix

Table J1: Policy implications for N=3 when risk q varies for different degrees of risk aversion a.

a	0.000002			0.000008			0.000015			0.000035		
q	0.58	0.6	0.62	0.48	0.5	0.52	0.38	0.4	0.42	0.18	0.2	0.22
$\underline{p}_{ra}^{L}$	33361	35069	36961	27621	28819	30127	23429	24319	25280	17650	18211	18810
ΔD	0.30	0.32	0.35	0.26	0.29	0.31	0.23	0.26	0.28	0.18	0.20	0.23
Δc	2.68	2.50	2.32	2.66	2.50	2.34	2.65	2.50	2.35	2.68	2.50	2.33
$\Delta\delta$	-0.48	-0.47	-0.46	-0.50	-0.49	-0.48	-0.51	-0.50	-0.49	-0.52	-0.51	-0.51

Note: prices $\underline{p}_{ra}^{L}$ are in USD

Table J2: Policy implications for N=5 when risk q varies for different degrees of risk aversion a.

a	0.0000005			0.000005			0.000026		
q	0.44	0.46	0.48	0.38	0.4	0.42	0.18	0.2	0.22
$\underline{p}_{ra}^{L}$	24749	25670	26663	22658	23446	24291	17414	17932	18481
ΔD	0.19	0.20	0.21	0.18	0.19	0.20	0.15	0.16	0.17
Δc	2.63	2.50	2.37	2.63	2.50	2.37	2.64	2.50	2.36
$\Delta\delta$	-0.46	-0.45	-0.44	-0.48	-0.47	-0.47	-0.50	-0.49	-0.49

Note: prices $\underline{p}_{ra}^{L}$ are in USD

Figure

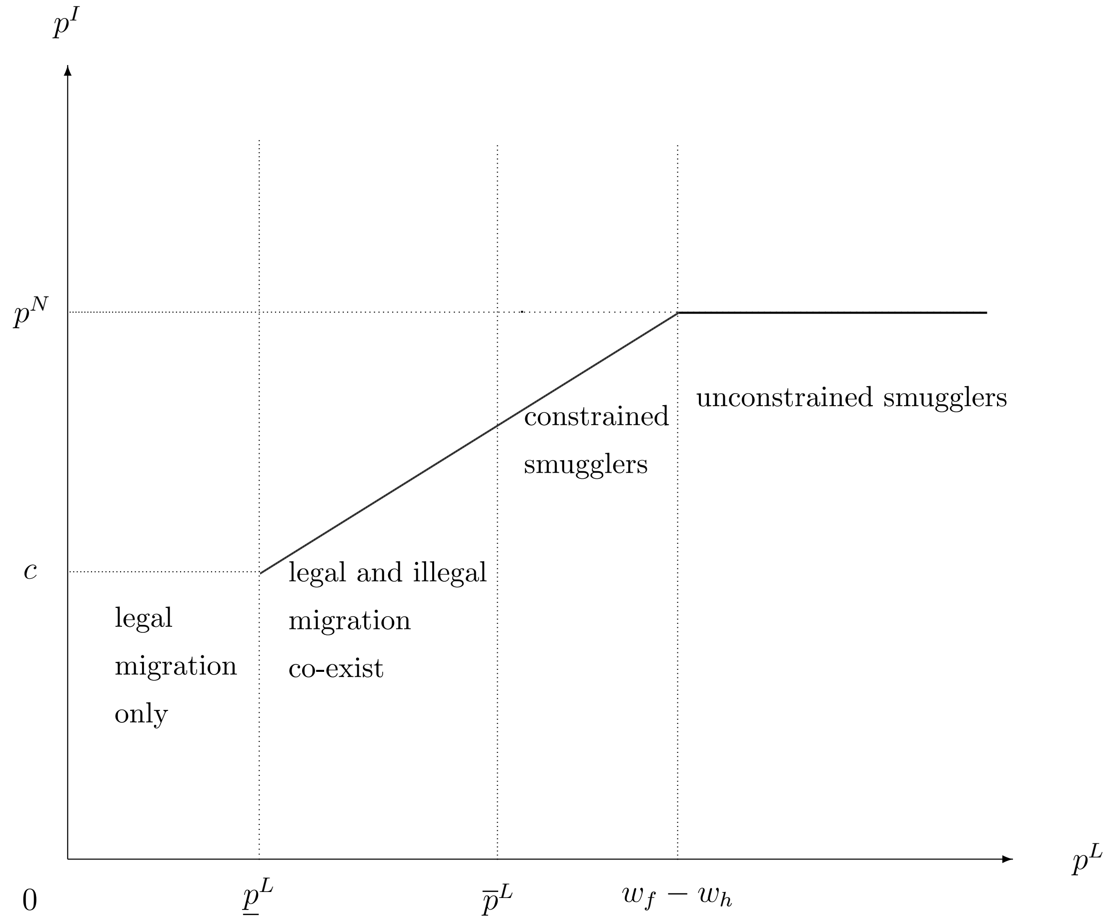

Figure 1: Pricing scheme of the smugglers $p^I(p^L)$ in the uniform example