

War, Migration and the Origins of the Thai Sex Industry*

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Abstract

This paper analyzes the determinants behind the spatial distribution of the sex industry in Thailand. We relate the development of the sex industry to an early temporary demand shock, i.e., U.S. military presence during the Vietnam War. Comparing the surroundings of Thai military bases *used* by the U.S. army to districts close to *unused* Thai bases, we find that there are currently 5 times more commercial sex workers in districts near former U.S. bases. The development of the sex industry is also explained by a high price elasticity of supply due to female migration from regions affected by an agricultural crisis. Finally, we study a consequence induced by the large numbers of sex workers in few red-light districts: the HIV outbreak in the early 1990s.

JEL: O17, O18, N15, J46, J47, I28.

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1. Introduction

Thailand is known across the world as the largest supplier of commercial sexual services. Since the 1970s, the Thai sex industry has experienced an unparalleled expansion characterized by a high concentration of sex establishments in major red-light districts. While this phenomenon has received a large amount of media attention, there is surprisingly little analysis of the origins and development of this industry. Such spatially concentrated activity is puzzling given the poor locational fundamentals of many red-light districts.

In this paper, we explain the geographic distribution of the sex industry in Thailand by the U.S. military presence during the Vietnam War, and the associated large and temporary shift in the demand schedule for sexual services near U.S. military bases.

Another factor also contributed to the development of the sex industry: a crop price crisis hit Thailand in the 1980s and urban districts experienced a large influx of Thai unemployed women. Our results suggest that the conjunction of these demand and supply shifts explains almost 50% of the variation in the number of sex workers across districts at the peak of the sex industry in 1990.¹

In a first step, we study the impact of a pure, localized, and temporary demand shock: the clustering of sex establishments in districts that formerly housed a U.S. military base.² We use a unique census detailing the size of the sex industry at the district level between 1990 and 2012. In order to identify a causal impact, we create a set of counterfactual locations that could have been used by the U.S. Army: the U.S. government covertly used many Thai military bases during the Vietnam War, but many more were not used. We compare bases strategically chosen by the U.S. Air Force (U.S.A.F.) versus counterfactual bases, airfields and seaplane anchorages that were not used by the Americans during the war. In order to isolate exogenous variation in the decision of U.S. military authorities, we exploit the distance to active enemy bases in Vietnam. Our estimates in both specifications

¹The spatial distribution of sex workers near former U.S. bases has remained mostly unchanged since 1990. Clustering forces such as information asymmetry and reputation may explain the persistence of the sex industry in those districts. Along these lines, there was a transformation toward differentiated and high-quality sexual services in these districts, thereby alleviating potential frictions between consumers and sellers (especially after the HIV outbreak).

²We verify that the presence of U.S. servicemen was a pure temporary demand shock, i.e. that our results are not driven by the U.S. government investment in roads and transport infrastructures during the war.

suggest that districts in the neighborhood of former U.S. bases have 4 to 5 times more commercial sex workers (CSWs) in 1990.

In a second step, we develop a logit model à la Berry (1994) in order to estimate the supply-and-demand equations underlying the spatial equilibrium of sex market in 1990. We rely on precise measures of sex act prices at the district level, and create a supply shifter using an agricultural crisis implied by large fluctuations in crop prices. The construction for the supply shifter builds on anecdotal evidence pointing to poverty incidence in rural districts and female rural-urban migration as one important factor behind the growth of the sex industry during the 1980s (Li 1995, Coxhead and Plangraphan 1998). In order to construct a district-specific measure of the agricultural crisis, we proceed as follows. First, we create a price deviation from its long-term trend value for the commodity associated to each crop. Second, we weight this price deviation with the district-specific crop incidence in order to create the 1980s de-trended value for a district agricultural portfolio. The disparities in agricultural activities across regions and the variations across crops in their exposure to the crisis generate a large heterogeneity in the impact of the crisis across districts. We show that the value of the agricultural portfolio strongly predicts female out-migration from rural districts while we find no evidence of a male out-migration in response to these shocks. Third, we apply a gravity matrix and transform exogenous variations in out-migration incidence into immigration flows.

The variations induced by the former U.S. presence have the features of a local demand shifter. The high willingness to pay of servicemen stationed in Thailand coupled with the large disequilibrium in the local male-female ratio generated a high demand for sex services. In contrast, the synthetic migration influx induced by the agricultural crisis have the features of a supply shifter. The fall in crop prices provoked a shift in female labor supply in cities which, coupled with high demand for sexual services, explain the fast growth of the sex industry in few major red-light districts. These effects are largely consistent with the predictions of Lee and Persson (2013) describing the role of (labor) opportunity costs in the choice to work in the sex industry.

Using (i) the agricultural crisis as a supply shifter and (ii) the proximity to U.S. bases as a demand shifter, we find large price elasticities of demand and supply for the sex industry. A 10% increase in prices, triggered by an increase in labor opportunity costs,

would decrease the number of sex workers by about 17%. In parallel, a 10% increase in the consumer willingness to pay for sexual services would increase the supply of sex workers by about 30%. As regards the external validity of these findings, the shift in demand hinges on a local and temporary gender imbalance, which may occur around many military camps,³ mining towns, construction sites or truck stops (Oster 2012b). However, one feature—quite specific to the Thai context—may explain the high price elasticity of supply (and the large impact of a demand shift). Following the agricultural crisis, many female workers migrated to urban centers with very little opportunities in the manufacturing sector.

In a last section, we analyze one consequence of the implied concentration of sex workers in few red-light districts: the outbreak of the HIV epidemics in these areas. For this exercise, we rely on unique data with HIV testing of male conscripts, female sex workers and pregnant women at the province level. We use a simple epidemiological model (Susceptible-Infected) with proportional mixing (Anderson et al. 1992, Kaplan 1990, Oster 2005), and analyze the impact of the spatial distribution of risky partnerships on HIV prevalence for different sub-populations. Based on simple counterfactual exercises, we attribute about 1 percentage point of the HIV prevalence among male conscripts in 1991 (about 4.5%) to the abnormally high number of sex workers in provinces affected by past U.S. military presence. We then show that, because of non-linearities in HIV propagation, the spatial concentration of the sex industry also plays a role. Intuitively, the likelihood of HIV outbreak is very high in spatial clusters of high-risk partnerships (May and Anderson 1984), and a spatially inhomogeneous population would display a higher overall HIV prevalence. Finally, we document one attenuation factor in HIV propagation. There is a negative correlation between the estimated contact rates for sex workers and the size of the sex industry, which disciplines HIV propagation in red-light districts. This correlation may highlight a positive aspect of concentration: while there are many more risky matches in red-light districts, each individual match is relatively safer.⁴

We make two important contributions in our paper. First, we identify the role of demand-driven and supply-driven exogenous variations behind the development of the sex

³Similar red-light districts can be found around other large military facilities in South-East Asia, notably the Philippines.

⁴This value to concentration may reflect policy interventions. There is anecdotal evidence of vertical differentiation in red-light districts, especially after the peak of the epidemics, with health checks and high turnover among sex workers (Wawer et al. 1996).

industry. The main barrier to studying the sex trade is the issue of data measurement. We address this issue by relying on unique censuses—at a spatially disaggregated level—of the sex industry. In particular, we observe the types of sex establishments and the average price per type of establishment in each district. Second, we shed light on the role of the sex industry in venereal disease propagation at a macro level. In this exercise, we rely on unique data on HIV testing among groups of vulnerable individuals including sex workers and conscripts during the HIV outbreak.

Our research contributes to the literature on the sex industry. We mostly relate to theoretical contributions highlighting the role of opportunity costs either through labor markets (Lee and Persson 2013) or the marriage market (Edlund and Korn 2002). Recent empirical contributions have analyzed the market for sexual services focusing on the role of disease risk and its compensating differential (Arunachalam and Shah 2013, Gertler et al. 2005, Robinson and Yeh 2011, 2012, Rao et al. 2003, Shah 2013), competition (Li et al. Forthcoming) or technological improvements (Cunningham and Kendall 2011). In contrast with most of these analyses, we look at census records of the sex industry rather than surveys (Li et al. Forthcoming, Robinson and Yeh 2012, Wawer et al. 1996) or newspapers and online data sets (Cunningham and Kendall 2011, Seib et al. 2009), and study the macroeconomic determinants of prostitution. Our findings also relate to the work of Levitt and Venkatesh (2007) who study the sex industry in Chicago: we also find a strong geographic concentration in prostitution and large price elasticities of supply.

Our work complements recent studies that analyze the economics of HIV/AIDS (Canning 2006, Oster 2012b) and its relationship with sex work (Talbot 2007, Prüss-Ustün et al. 2013). In particular, our empirical investigation of HIV propagation relates to the work of Oster (2005, 2012a), Geoffard and Philipson (1996), Philipson (2000). The dearth of research on the sex industry and its role in the HIV epidemic is driven, in part, by the lack of reliable data (Prüss-Ustün et al. 2013). For instance, Oster (2010) overcomes the lack of HIV data in early years of the epidemic by using inference from mortality data and Talbot (2007) extrapolates sub-national estimates of the size sex industry based on non-representative surveys to construct measures of the number of sex workers at the country level.

Our findings relate to a recent literature that studies the long-run effects of historical

shocks in the spatial distribution of economic activity and its path dependence (e.g., the division of Germany and Berlin in Redding et al. (2011) and Ahlfeldt et al. (2015), see also Bleakley and Lin (2012), Dell (2010) among many others). In line with most of this literature, we find long-term consequences of historical shocks.⁵ However, our framework differs from these contributions as we focus on the specialization in one specific industry rather than estimating an impact on overall economic growth.

The remainder of this paper is structured as follows. Section 2 provides a brief historical overview of the U.S. military presence in Thailand and its aftermath. Section 3 describes the data collection, data construction and the empirical strategy. We present our main results on the spatial distribution of the sex industry in Section 4 where we also provide estimates for the price elasticities of demand and supply, and discuss external validity. Finally, we analyze the role of sex industry clusters in the propagation of the AIDS epidemic in Section 5. The last section briefly concludes.

2. Historical Background

In this section, we discuss the U.S. military presence during the Vietnam War and briefly describe its aftermath.

2.1. U.S. Presence During the Vietnam War

The presence of United States servicemen in Thailand was a direct consequence of the Vietnam conflict. The American air war against North Vietnam and other communist regimes in Cambodia and Laos resulted in a pressing need for a safe haven from which units could transit to the front and from which aerial raids could be launched. Thailand was the unique country close to Vietnam with pro-American authorities. The increasing presence of Communist rebels and guerrillas linked to the *Pathet Lao* who threatened the borders of Thailand fostered this U.S.-Thai collaboration. Proximity of the front would lower flight distances and fuel costs for air missions, and the U.S. army would provide protection against insurgency in an unstable region (Baral 1973, Randolph 1979). Distance to the front was the main factor determining the locations of U.S.A.F. bases in Northeast

⁵By contrast, Davis and Weinstein (2002) and Miguel and Roland (2011) find very little evidence that bombings in Japan and Vietnam affect the long-run development of some regions relative to others.

Thailand.⁶

The U.S. Army began to fly reconnaissance flights over Laos in 1961. By the end of 1966, there were already over 25,000 U.S.A.F. personnel and 400 U.S. combat aircraft in Thailand. The number of bases and aircraft increased during the conflict. At the peak of the Vietnam War, there were approximately 50,000 men stationed in Thailand, and it is estimated that around 700,000 U.S. servicemen visited Thailand bases between 1962 and 1976 (Clift and Carter 2000). According to historical records, about 80% of U.S.A.F. air strikes over North Vietnam originated from air bases in Thailand.

The U.S. Army did not encourage directly servicemen permanently stationed in Thailand to visit brothels. However, U.S. authorities organized Rest & Recreation (R&R) leave for U.S. servicemen. Around 11 to 16% of total visitors during 1966-7 were R&R military personnel from Vietnam, and they spent between 6.8 and 10.8 million U.S. dollars annually. Ouyyanont (2001) writes that “In 1966, for example, there were at least 652 night clubs, bars, and massage parlors in the whole country of which 336 were in Bangkok, 126 were in the five provinces housing US bases in the northeast, and 190 in the other provinces particularly close to the two bases in provinces in the central region.” Many authors report that it was common for troops to go to shanty towns of brothels surrounding U.S. bases (Enloe 1989). This practice was referred to as going to the “dogpatch.” Kislenco (2004) writes that “A cluster of shanty towns sprang up around the base [U-Tapao], offering servicemen everything from souvenirs to prostitutes.” Thompson (2003) echoes Kislenco and explains that “Club bars provided a ready release from the tension of combat or the boredom of desk duty. Just off base, Thai prostitutes did not want for customers, and the dispensary at each base was handling about a thousand venereal disease cases a year.”

While U.S. or Thai authorities never invested directly in the development of the sex industry,⁷ they adopted several laws that facilitated the development of this new form of entertainment across the country. The Tourist Organization of Thailand and the 1966 Service Establishment Act helped regulate the development of the sex industry. While prostitution remained legally suppressed at the time, the 1966 Act permitted entertain-

⁶The military bases of Nakhon Phanom, Ubon, or Udorn are closer to the front than most U.S. military bases in the South of Vietnam.

⁷U.S. authorities invested mainly in the maintenance of military installations and the construction of adequate infrastructure.

ment establishments throughout the country to employ women who would offer “special services.” For instance, massage parlors, bars and tea-houses where clients could request these services were legalized under a license. The Service Establishment Act was followed by the 1967 Rest & Recreation Treaty, which formalized the agreement of Thai authorities to authorize entertainment services for U.S. servicemen.

2.2. End of the War and Aftermath

With the collapse in Laos and the fall of both Cambodia and South Vietnam in 1975, the political climate between Washington and Bangkok began to sour, and the Thai government demanded that the U.S. Army remove the bulk of its forces from Thailand by the end of the year. Under operation Palace Lightning, U.S.A.F. withdrew its aircraft and personnel from Thailand.

2.2.1. Tourism In the aftermath of the Vietnam War, demand for sexual services remained partly sustained by tourists: the American presence drastically changed the international travel image of Thailand. While there were only 200,000 international and domestic tourists visiting Thailand in 1960, this number increased to 800,000 in 1970 and 5 millions in 1980. Despite the departure of American soldiers in 1975, their legacy in the form of red-light districts around military bases changed the commercial sex industry.⁸ It is also important to point out that demand for sexual services has been sustained by locals or domestic tourists. Cohen (1988) explains that “Thais visit the bars [...] and the massage parlors on the main avenues, which were originally established to serve the needs and preferences of the American G.I.s on R&R from Vietnam.”

The Thai government monitored the growth of the entertainment industry through various policies before and after the U.S. military departure. In 1971, a delegation of the World Bank met with Thai officials and advocated for the development of the Thai entertainment industry, which could foster economic growth.⁹ The Thai government then adopted a National Plan of Tourist Development in 1975 (Li 1995).

⁸In the early 1990s, it was estimated that approximately 70% of travelers visiting Thailand were male (Leheny 1995).

⁹Robert McNamara, President of the World Bank in the 1970s, was a member of this delegation. Interestingly, he was also the U.S. Secretary of Defense during the signing of the 1967 Rest & Recreation Treaty.

2.2.2. Poverty Incidence in Rural Areas In the 1980s—following the oil price crisis, Thailand experienced a substantial economic slowdown especially in rural areas. As described in Coxhead and Plangpraphan (1998), poverty incidence increased by 25% between 1982 and 1986 essentially driven by lower agricultural returns and low crop prices (e.g., rice). While overall rural-urban migration did not increase during this period, the migration of young female workers did increase quite markedly. As highlighted in Li (1995), the “lack of economic opportunities in the countryside has coincided with the demand for more prostitutes in the cities’ sex industry. Families in rural areas may sell their daughters for money and then rely on the steady income provided by their prostituted daughters.”

3. Data

In this section, we describe our data sources. We then describe the construction of a supply shifter for the sex industry: the synthetic female migration flows as predicted by crop prices and crop incidence. We then discuss our main empirical strategy and provide some descriptive statistics.

3.1. Data sources

The empirical analysis exploits the following data sources: (i) Military records allowing us to locate military bases and their characteristics; (ii) Sex industry census and HIV monitoring from the Ministry of Public Health in Thailand; and (iii) the 1990 Census of Agriculture and World Bank Commodities Prices to extract local agricultural activity and international prices.

3.1.1. Military Records We rely on two sources to construct indicators of U.S. military presence in Thailand. For the locations and characteristics of U.S. military bases, we use the Fact Sheets and Histories of the United States Air Force at Royal Thai Air Force Bases, dated August 12, 1976, and published by the 13th Air Force Office of History. We also collect information on U.S. military bases from reports of the Thailand Laos Cambodia (TLC) Brotherhood’s website.¹⁰ The second source of military data is the National Archives and Records Administration (NARA), which reports on air combat

¹⁰<http://www.tlc-brotherhood.net>

missions flown in Southeast Asia by the U.S. Air Force during the Vietnam War, deliveries of materials, U.S. direct defense spending and U.S. military receipts in foreign countries.

Appendix Table A1 provides a list of all U.S. military bases with descriptive statistics, including the number of air combat missions flown in Southeast Asia, the location of the bases, the average distance to active enemy bases (as of 1969) and the evacuation date. In the empirical analysis, we will mostly ignore the differences in the characteristics of U.S. bases, e.g., their size, essentially because these characteristics fluctuated during the conflict and we hardly observe these changes. Anecdotally, however, the largest concentration of soldiers was in the South of Pattaya (with 3 military bases) and this city is now the biggest red-light district in the world.

Finally, we collect information on pre-Vietnam War military installations and infrastructures. We first use military sources to identify the 33 active Thai military bases that were not used by the U.S.A.F. in 1970 and the bases that were built during the war (from 1971 to 1975). We also collect information on airfields and seaplane anchorages. Second, we digitize detailed 1954 military maps around all bases and airfields (see Figure 1 for the surrounding of Ubon Ratchathani, Mukdahan/Savannakhet, Phetcha Buri and Lampang) in order to capture existing infrastructure before American presence, e.g., roads and railways.

In order to define proximity to military installations, former U.S. bases as well as unused Thai bases, we rely on network routes and railways before the U.S.A.F. presence (1954) and calculate the travel time from each district centroid to the nearest military base.¹¹

3.1.2. Sex Worker Data In order to construct the number of sex workers at the district level, we use an annual nation-wide survey conducted in Thailand by the Venereal Disease Section of the Ministry of Public Health in collaboration with the Department of Public Welfare of the Ministry of Social Development and Human Society (see Boonchalaksi and Guest ((1994) and Guest ((1995) for a description of the survey design). Thai authorities collect information on the commercial sex industry to monitor venereal dis-

¹¹We consider six types of roads and two types of railways: hard surface two or more lanes, loose two or more lanes, hard one lane, loose one lane, fair or dry loose lane, trail, railway normal gauge and railway narrow gauge.

eases and design policies. Data collection began in the early 1970s and the survey is still conducted on a yearly basis. In this study, we rely on the 1990 survey wave, the first year in which data are reported at the district level, and we use later waves in some robustness checks.

The survey objective is to provide an exhaustive registry of establishments offering sex services over the whole country. A database with the locations of establishments in the country is maintained over the years, and updated when receiving information from customers, sex workers or surveyors. The nature of the sex industry facilitates the work of the surveyors as sex workers need local customers and tourists to be able to find them (Levitt and Venkatesh 2007). In addition, when a customer or a sex worker goes to a clinic for a venereal disease test, the location of the establishment is recorded and added to the database.

The database and detailed locality maps provided by the Thailand National Statistical Office are used to plan each yearly field survey. The survey is conducted during the whole month of January in all provinces of Thailand. At least one surveyor is familiar with the local sex industry. Surveyors classify establishments in categories (e.g., brothels, massage parlors), count the number of sex workers thus excluding cleaners, security guards or waitresses, and report the average transaction price.

As the survey design differs from that of a census, there are reporting biases which could be related to the treatment. In theory, the probability for an existing establishment to be recorded as providing sex services depends upon its salience (e.g., visibility, number of transactions or workers), its target customer and the frequency of health checks for sex workers. For instance, given the survey design, surveyors mostly count sex workers in a “permanent” location. Sex workers who operate in streets, public parks or stand around non-suspicious entertainment locations are more likely to be excluded. Such measurement error could bias the estimates of the demand shock upwards since the sex industry in districts near former U.S.A.F. bases is more visible, specifically targets tourists and has stricter health assessment rules. In order to minimize this bias, we will rely on the 1990 wave during the AIDS epidemic, when the survey had the largest coverage and ties between officials and establishments were the strongest.

There exists other sources of measurement error. First, the survey is conducted during

peak season for tourism, and the annual activity of the sex industry markedly fluctuates with tourism. Second, the survey counts the number of sex workers present in the establishment at the time of the survey: some workers may not be counted or counted twice if working in two establishments or more. Third, while prostitution is practiced openly in Thailand, there exist some pressure to close sex establishments employing minor sex workers, and they are likely not to be reported by establishments.

We report statistics of the commercial sex industry at the district level in the first lines of Table 1. There were 1.3 CSWs per 1000 inhabitants, and about 85,000 CSWs in Thailand in 1990. Since most of the CSWs are women aged between 18 and 30 and 12% of the population are women in this age group, around 1% of women aged 18 to 30 were working in the sex industry in the early 1990s. Figure 2 displays the number of commercial sex workers in each district per 10,000 inhabitants in 1990. This map illustrates the relationship between the number of commercial sex workers per capita and U.S. military bases during the Vietnam War.

To empirically capture the development of the sex industry, we use several measures. Our baseline measure is the number of sex workers at the district level in 1990—normalized by population. In robustness checks, we distinguish female from male sex workers and we classify establishments per type in order to capture that some districts specialize in providing sexual services for tourists in luxurious sex establishments and massage parlors whereas other locations are specialized in a more “traditional” sex industry.

Finally, we use HIV testing data at the province level from the Venereal Disease Section of the Ministry of Public Health. As a proxy for HIV prevalence in the general young adult male population, we use the bi-annual HIV testing among 21-year-old Thai men just selected for conscription by lottery.¹² This data set is available from 1989 onward and the province of residence of conscripts is reported. We also collect HIV testing conducted by the Ministry of Public Health among vulnerable individuals such as drug addicts, blood donors, pregnant women and sex workers.

3.1.3. Agricultural Shock In this subsection, we explain how we construct a supply shifter for the sex industry from the interaction of (i) international commodity prices,

¹²Conscription is mandatory but young males from high social classes may be able to obtain exemptions from the lottery, e.g., with educational deferments.

(ii) the composition of crops in each potential origin district, and (iii) a distance matrix between origins and destinations. The exogenous variation in migration inflows result from exogenous variations in outflows from (neighboring) districts coupled with a fixed predictor for origin and destination flows.

We collect geo-coded maps of harvested area from the 1990 World Census of Agriculture, and potential yield as computed in the GAEZ Agricultural Suitability and Potential Yields data set (Food and Agriculture Organization and the International Institute for Applied Systems Analysis). While the first measure is the actual harvested area for each crop in 1990, the second measure is model-based and uses crop requirements, soil characteristics and rainfall conditions to generate a frontier yield, i.e., the yield under ideal input usage. These maps are defined at a very disaggregated level (grids of about $1 \text{ km} \times 1 \text{ km}$), and we collapsed them at the district level such as to generate $h_{d,c}$ and $y_{d,c}$, respectively the harvested area and frontier yield for crop c in district d . In order to construct the potential yearly output, we consider the interaction $h_{d,c}y_{d,c}$. As apparent in Appendix Figure A1 with rice (left panel), cassava and sugarcane (right panel), there is a wide variation in the crop composition across Thai districts even within the same region.¹³

In parallel, we construct a measure capturing the levels of 1982-1989 crop prices using World Bank Commodities Prices Data. We extract prices between 1960 and 2012 for the main cash-crop commodities: banana, cassava, coffee, cotton, groundnut oil, maize, rice, sorghum, sugar, tea, tobacco and wheat. We isolate the commodity-specific price deviation as follows: we apply a Hodrick-Prescott filter on the logarithm of each crop-specific price for the whole period and isolate the average 1982-1989 short-term deviation d_c from this trend. Appendix Figure A2 presents the series for three common exports in Thailand (rice, sugar and cassava). As apparent, the price of rice is almost 40% below its long-term value in 1986 while sugar is less affected. This variation is an example of the variation across cultivated crops that will generate geographic dispersion in the extent to which districts are hit by the agricultural crisis.

In order to generate a district exposure e_d to the crop crisis, we combine the crop-

¹³Using measures of harvested areas in 1990, i.e., after the crop price crisis, may induce an attenuation bias. For example, a decrease in the price of rice should incite farmers to switch away from rice, thus leading the 1990 estimate of harvested area to be smaller than the actual 1980 harvested area. In that respect, the estimates of the first stage will already incorporate this adjustment mechanism, and be biased downward.

specific yearly output with international price deviations $e_d = \sum_c h_{d,c} y_{d,c} d_c / \sum_c h_{d,c} y_{d,c}$. The district exposure is different across districts of Thailand and across districts housing former U.S. bases. Indeed, while the two main former U.S. military bases in the Central regions are surrounded by cassava, corn or sugar cane fields, military bases in the East are in the middle of paddy fields and Southern districts mostly cultivate palm oil and rubber. Over the year 1982-1989, there is a sharp decrease in the price of rice and sugar, but an increase in the price of tea, coffee and oil. As such, regions heavily relying on rice production are the ones that were most affected.

The previous measure captures the *direct* effect of international price variations on a district. However, our main variable of interest is a proxy for the migration influx in a given district generated by these shocks in neighboring districts. We associate a weight $w_{o,d}$ to each pair origin-destination (o, d) , equal to the inverse distance, and calculate the weighted exposure $w e_d = \sum_{o \neq d} w_{o,d} e_o$. Appendix Figure A3 represents the synthetic variation in migration flows (weighted exposure to international price shocks, right panel), and compares it with actual migration inflows (left panel). There is some spatial correlation in this measure but there are strong differences within provinces that are exploited in the empirical analysis.

3.2. Empirical Strategy

In the benchmark specification, we collapse all variables at the district level and analyze the association between the size of the sex industry and proximity to former bases using all districts.¹⁴ In a robustness check, we restrict the sample to districts close to possible military bases, and compare the size of the sex industry around bases used by the U.S.A.F. versus unused Thai bases. This strategy allows us to use the distance to enemy bases in North Vietnam as an instrument explaining which bases were used by the U.S. Army and isolate an exogenous component in the decision to use some military installations versus the others.

3.2.1. Benchmark Specification In our baseline equation, we compare districts close to former U.S. military installations to other Thai districts controlling for covariates sus-

¹⁴Province and district are respectively analogous to state and county. There are about 75 provinces and 800 districts in Thailand.

ceptible to affect the development of the sex industry and the location of military bases, e.g., network and natural amenities.

Our baseline equation is:

$$CSW_{d,r} = \alpha + \beta_r + \gamma USB_{d,r} + \zeta X_d + \varepsilon_{d,r}, \quad (S1)$$

where $CSW_{d,r}$ is the (logarithm of) number of commercial sex workers in district d and region r . $USB_{d,r}$, our variable of interest, is a dummy indicating whether the district is within a given distance of a former U.S. military base. β_r are region fixed effects and X_d is a set of control variables at the district level accounting for district features which could correlate with the decision to settle in a military base and favor the development of the sex industry (e.g., railways, major roads or pre-War population and economic activity). We report standard errors clustered at the nearest military base (U.S. or Thai), which yields a total of 47 clusters of districts in the full sample.

Since our identification strategy relies on the comparison between former U.S. military base and unused bases, we construct proximity to 1970 Thai bases that were not used by the U.S.A.F. ($THB_{d,r}$). We also compare districts near former U.S. bases to 1950s airfields and seaplane anchorages in the Central, Northwest and South regions (i.e., not used by the U.S.A.F.). We include these placebo treatments in specification (S1) to show that military installations are usually not in districts prone to the growth of the entertainment sector.

3.2.2. Instrumental Variable A major concern with the previous specification is that districts near facilities chosen by the U.S. Army could have unobserved characteristics correlated with the development of the sex industry. For instance, U.S. officials may choose locations for which support and supply of fuel or food are easier. Conversely, it is plausible that the U.S.A.F. would prefer isolated locations since they needed to construct temporary facilities for aircraft maintenance or landing.¹⁵

In order to alleviate this issue, we provide a robustness check rationalizing the decision to use certain facilities among the sample of potential Thai military facilities. In this

¹⁵Note that, in spite of U.S. investment, most of these bases converged back to their pre-war usage. In unreported robustness checks, we control for the current status of these bases (e.g., major airport, minor airport, minor Thai base, abandoned sites, etc.) and find similar estimates.

robustness test, we keep districts that were reachable in less than half an hour from a U.S. base or an unused Thai base using 1954 roads and railways, i.e., districts for which either $USB_{d,r}^{0h30}$ or $THB_{d,r}^{0h30}$ equal one. Among this subsample of districts, we create a variable, B_d , which is equal to one if the nearest base was used by the U.S. army (i.e., $USB_{d,r}^{0h30} = 1$) and zero if the nearest base was unused (i.e., $THB_{d,r}^{0h30} = 1$). For the sake of exposure, we may refer to the former as *treated* districts and the latter as *control* districts.

The U.S.A.F. flew many flights from Thailand during the period 1965-1973, and the willingness to diminish fuel costs and air travel time played a major role in determining U.S. base locations. Our strategy relies on the fact that it is easier to reach the front from districts close to Laos and Cambodia borders than from Northwest or South Thailand. We use the base-specific average distance to the active enemy military bases in Vietnam as of 1969 as an instrument for B_d , i.e., the decision of the U.S.A.F. to use only some Thai bases among the existing Thai bases.¹⁶

We estimate:

$$\begin{cases} B_d = \rho + \phi \cdot DE_b + \psi X_d + \nu_d \\ CSW_d = \alpha + \delta \hat{B}_d + \zeta X_d + \varepsilon_d, \end{cases} \quad (S2)$$

where d indexes a district and b denotes an “available” base. DE_b is the over-the-air distance to the closest active enemy bases in Vietnam. For this specification, X_d includes longitude such as to clean for the East-West gradient. Finally, the instrument is the same for all districts close to the same available Thai base and we thus rely on standard errors clustered at the nearest military base level.

The instrument is valid if the distance to enemy bases is only correlated with the subsequent increase in supply of CSWs through the presence of U.S.A.F. bases. We assume (i) that, before the Vietnam War, the number of CSWs in districts close to enemy bases in Vietnam was not higher than in districts farther away, and (ii) after the arrival of U.S. servicemen, these districts did not experience a boom of the sex industry due to omitted factors correlated with the distance to enemy bases. We will come back to the plausibility of this assumption and potential biases when presenting the results.

¹⁶Note that we rely on distances to the front for the year 1969 in what follows because U.S. military then reallocated their forces toward North-Eastern bases following the Tet Offensive. We also check the robustness of our results with other years, and the point estimates are virtually the same.

3.3. Descriptive Statistics

We provide a simple mean-comparison exercise along the proximity to former U.S. and Thai facilities in Table 1. The first (resp. second) column shows descriptive statistics for districts less than half an hour (resp. more than half an hour) from a U.S. military base. The fourth column reports statistics for districts less than half an hour from an unused Thai military base. Finally, column 3 reports the difference between “treated” districts (column 1) and “control” districts from specification (S1)—column 2, while column 5 reports the difference between “treated” districts (column 1) and “control” districts from specification (S2)—column 4.

Districts within half an hour of a U.S. base have, on average, 5.9 sex workers per 10,000 inhabitants in 1990, which is more than 8 times the national average of 0.7 (excluding districts near U.S. bases). The difference between the number of CSWs per 10,000 inhabitants for districts near a U.S. base (less than half an hour) and other districts is very large and statistically significant at the 1% level. These numbers suggest that in 1990, approximately 3.8% of young women aged 20-30 living in districts that are within half an hour of a former U.S. base were commercial sex workers against the national average (excluding districts near U.S. military installations) of 0.8% or 1.4% for districts within half an hour of unused Thai bases.

Table 1 also displays differences between districts along other characteristics. We find statistical differences with the other districts for the presence of provincial capitals, a rail line (1954), a road (1954) and a temple or spiritual site, as well as the distance to the closest ports of entry by land. Military installations are in urban districts. However, the characteristics of treated districts and districts within half an hour of unused Thai bases are quite similar. If anything, U.S. officials chose Thai bases that were in slightly less urbanized areas and in districts less likely to have railways (1954). Our empirical findings with specification (S2) will be consistent with this interpretation: Thai bases chosen by the U.S. Army seem to have fewer amenities. Importantly for our empirical strategy (and specification S2), U.S. bases are significantly closer to active enemy bases in Vietnam.

We present our results in the next section, first by relying on the geographic variation in demand implied by the U.S. presence, and second by including the geographic variation

in supply as predicted by movements in crop prices in a supply-and-demand model.

4. Empirical Evidence

In this section, we describe the relationship between the temporary demand shift, i.e., U.S. military presence during the Vietnam War, and the geographic distribution of the sex industry in 1990. We also discuss identification issues and provide robustness checks to shed light on potential mechanisms. Finally, we propose a simple logit model à la Berry (1994) to extract and estimate supply and demand equations. We use the model and the estimates of the price elasticities of demand and supply to discuss external validity.

4.1. Sex Industry Around Former U.S. Bases

4.1.1. Baseline Results Table 2 reports the results of specification (S1). The baseline specification conditions the correlation between the number of CSWs and the proximity to former U.S. bases by regional dummies, the logarithm of district population, a set of controls at the district level accounting for transport networks before the American presence (Oster 2012b) and dummies for whether it is a coastal district or a province capital to control for additional network effects (Felkner and Townsend 2011, Townsend 2011).¹⁷

The estimated relationship between the size of the sex industry in 1990 and being a district that could be reached in less than half an hour from a U.S. base is robust, positive and statistically significant at the 1% level. The point estimates range is stable around 1.5, suggesting that there are 3.5 times more CSWs in 1990 in districts within half an hour of a former U.S. military base (which corresponds to about two thirds of a standard deviation in the dependent variable).

In column 2, we add indicators of proximity to U.S. bases: being a district within half an hour and one hour of a U.S. base, within one hour and one hour and a half and within one hour and a half and two hours. The estimates for the additional variables are not jointly significant and very small, which shows that the impact of U.S. bases is local and the sex industry is concentrated in red-light districts.¹⁸

¹⁷We report in Appendix Table A2 the estimates for covariates.

¹⁸In principle, spillovers on neighboring districts may be negative or positive. On the one hand, these

In column 3, we also include two dummies for placebo treatments, i.e., districts reachable in less than half an hour from an unused Thai base (first control group) and an unused Thai airfield or seaplane anchorage (second control group). The point estimates are very small and statistically insignificant. In parallel, the coefficient of interest remains unchanged.

We provide some insights for possible mechanisms in columns 4 to 6. The association between former U.S. bases and the size of the sex industry may reflect a direct shift in demand for sex services. It may also result from an indirect effect of the U.S. presence on the local economy as a whole, either through consumption (and the development of services) or investment in infrastructure (e.g., transport network). In column 4, we add controls for infrastructures directly related to the U.S. military presence in 1967 (roads and railways built during the Vietnam war) in order to condition for such direct investment. In column 5, we add nightlight intensity in 1992 as a proxy for economy activity around 1990. In column 6, we add controls for tourism (density of hotels and tourist attractions) and specific infrastructure benefiting the service industry (roads, railways, presence of a commercial airport) in 1990. As apparent in column 4, controlling for U.S. military investment in infrastructures during the war does not alter the estimate. By contrast, the correlation between former U.S. bases and the size of the sex industry is halved when controlling for economic activity in 1992, and the association becomes non-significant when adding covariates capturing current tourism and infrastructures for services. One interpretation of these results would be that the military presence raised the demand for sex services, thereby fostering the development of tourism and the economic activity as a whole.¹⁹

One concern with the previous estimates is that they do not account for unobserved components explaining the choice of the U.S.A.F. among this sample of military camps. We present the estimates of specification (S2) in Table 3, where we directly compare districts within half an hour of used and unused Thai bases. In the first three columns, we use districts in the neighborhood of U.S. bases or 1970 Thai military bases. In the last three columns, we use districts in the neighborhood of U.S. bases or Thai airfields. In columns

districts may benefit from some agglomeration economies. On the other hand, there could also be a reallocation of sex workers away from these districts to the red-light districts.

¹⁹In unreported tests, we verify that, conditional on economic activity in 1992, the sectoral composition of the economy does not differ markedly along the distance to former U.S. bases, apart from tourism and the entertainment industry.

1 and 4, we present OLS estimates. In columns 2, 3, 5 and 6, we present the 2-stage estimates of specification (S2) in which we instrument the treatment in a first stage by the over-the-air distance to active enemy bases.

The first stage is reported in Panel A. Consistent with Table 1, the first stage suggests that U.S. bases were closer to enemy bases in Vietnam than unused Thai bases (see column 2) or airfields (see columns 5). The second stage estimates are presented in the bottom panel. We find that districts within half an hour of U.S. bases compared to Thai bases or airfields have substantially more sex workers. The 2SLS estimates are larger than the OLS estimates when comparing U.S. bases to Thai bases and comparable when the control group is airfields and seaplane anchorages.

The 2SLS strategy relies on the identifying assumption that distance to active enemy bases in Vietnam, i.e., distance to the Northern regions just above the 17th parallel, affects the size of the market for sex in 1990, only through the past presence of U.S. military. Such proximity is correlated with the proximity to Laos, a major producer of opium. In addition, the North-Eastern part of Thailand, *Isan*, is a poor, agricultural, matrilineal society. As daughters inherit part of the family's land, they are indebted to their parents and are expected to meet their family's needs. These features are confounding factors which may explain the development of the sex industry in this region. In this regard, we add some controls for alternative mechanisms in columns 3 and 6 with latitude, longitude and distance to the nearest port of entry.²⁰

4.1.2. Robustness Checks We now discuss the sensitivity of our results to the choice of covariates, dependent variables, and the definitions of our treatment and control groups.

First, we provide a sensitivity analysis for the set of covariates in Appendix Table A3. The first two columns report a similar specification as in the first column of Table 2 with different sets of fixed effects. In the first column, we omit the region fixed effects, while we include province fixed effects (the unit just above district – there are 76 provinces in Thailand) in the second column. In the third column, we add additional controls at the district level for network and urbanization effects with the distance to the closest port of

²⁰We can also control for characteristics of local female labor supply, and we will explore this channel in the next section. In addition, we follow a falsification check used by Nunn (2008) in unreported tests and estimate the reduced form relationship between the distance instrument and the sex industry in other Asian countries including Cambodia.

entry by land, presence of a temple or the longitude and latitude of the district centroid. Column 4 of Appendix Table A3 adds amenities at the district level such as the presence of natural parks, tourist beaches, or museums. Column 5 adds agricultural activity in 1960 to control for possible pre-War differences across districts. Finally, column 6 controls for labor supply by adding the minimum wage in 1990 and migration inflows between 1984 and 1989. In all cases, the estimates are similar to the baseline specification.

Second, we replicate our previous analysis using survey waves from 1992, 1995 and 2012. In the early 1990s, two decades after the departure of U.S. servicemen, the sex industry was very concentrated in few red-light districts near former U.S. bases. However, we still do not know whether the effects of the temporary demand shocks are slowly fading away, or instead remain unchanged because of agglomeration forces for instance. Similarly, results may have changed during the HIV outbreak and temporarily modified the distribution of sexual services. As shown in Appendix Tables A4 (specification S1) and A5 (specification S2), there are no signs that the impacts of the shocks are fading away nor changing between 1990 and 2012. The estimates are very similar to those in 1990. Remark that the standard errors increase markedly in 2010 and 2012, which could be due to the lower coverage in recent surveys compared to the HIV outbreak.

Third, we show that our findings are robust to alternative dependent variables. In Appendix Table A6, we use (i) the 1995 survey of the commercial sex industry, in which we can distinguish between informal and formal sex workers, and (ii) the 2000 Population Census from which we extract the share of women between 18 and 30 working in the service industry. The correlations between the proximity to U.S. bases and the number of establishments (column 1), formal female sex workers (column 2), informal female sex workers (column 3), male sex workers (column 4), and women working in the service industry (column 5) generally confirm the results of our baseline specifications in Table 2. It is to be noted, however, that formal sex workers working in brothels, i.e., low quality establishments, are not more likely to be found in the proximity to former U.S. bases.

Fourth, we show that our findings are also robust to alternative definitions for our treated and control groups in Appendix Table A7. In particular, our estimates are robust to the exclusion of the whole region of Bangkok (columns 1 and 2), and to the inclusion of Thai bases built during the war (columns 3 and 4).

4.2. A Structural Approach

In this section, we estimate a simple supply-and-demand model underlying the spatial equilibrium of sex market in 1990. In a first step, we describe a logit framework à la Berry (1994), in which each district produces a different good variety. The identification of the model requires a demand shifter—the location of former U.S. bases—and a supply shifter—female migration to urban centers as proxied by the returns to agriculture in neighboring districts. The use of instrumental variables accounts for the endogeneity of prices due to the presence of unobserved product characteristics (e.g., transmission of diseases during sex transactions in different districts). In a second step, we present the estimates for the price elasticities of demand and supply, and we discuss external validity.

4.2.1. The Model We assume that there is a large number D of differentiated products, each corresponding to one Thai district. In each district, a mass of firms produce one district-specific product variety and use labor as the only production factor.²¹

We model demand as follows. There is a mass of consumers whose preferences depend on the characteristics of the product and the consumer. Letting u_{id} denote the utility of a consumer i for the good provided in market d , we have:

$$u_{id} = \underbrace{\mathbf{x}_d\beta - \alpha p_d + \xi_d}_{U_d} + \nu_{id}$$

where \mathbf{x}_d (resp. ξ_d) is a set of observable (resp. unobservable) product characteristics, p_d is the price and ν_{id} is an identically and independently taste shock distributed across individuals under an extreme value distribution.²² The unobserved characteristics ξ_d are assumed to be independent across districts, and independent of observed characteristics. Consumers purchase the unit of goods that gives the highest utility among the D differentiated varieties, and an outside good providing utility u_0 . Aggregating across consumers

²¹We do not explore possible substitution between different varieties of goods within each district, e.g., informal and formal prostitution: there is only one variety per district and the outside option (the numeraire).

²²Alternatively, the taste shock can be interpreted as a consumer-specific mobility cost across districts.

(and preference draws) gives the following market share for product d :

$$s_d = \frac{e^{U_d}}{\sum_{d'} e^{U_{d'}}}.$$

We model supply as follows. One unit of labor is required to produce one unit of final good, independently of the product variety. There is a mass of workers in each district with preferences over a variety of jobs that are identically and independently distributed under an extreme value distribution. Each worker will choose the job that gives the highest utility, and letting v_{jd} denote the utility of a certain worker j providing sexual services in market d , we have:

$$v_{jd} = \underbrace{aw_d + \mathbf{c}_d\gamma + \gamma_d}_{V_d} + \eta_{jd}$$

where \mathbf{c}_d (resp. γ_d) is a set of observable (resp. unobservable) labor costs including district-specific opportunity costs, and η_{jd} is an identically and independently shock distributed across jobs under an extreme value distribution. Aggregating across workers gives the following labor supply in the sex industry:

$$l_d = \frac{e^{V_d}}{\sum_{d'} e^{V_{d'}}}.$$

We assume that labor markets are competitive such that the price p_d for the product variety in district d equals the district wage w_d . Market equilibrium ensures that labor supply equals demand for sexual services ($s_d = l_d$) and the wage equals the price ($w_d = p_d$). The equilibrium quantities (s_d, p_d) are thus defined by the supply-demand system,

$$\begin{cases} \ln(s_d) = -\alpha p_d + \mathbf{x}_d\beta + \xi_d & (S) \\ \ln(s_d) = \alpha p_d + \mathbf{c}_d\gamma + \gamma_d & (D) \end{cases}$$

where ξ_d and γ_d are unobservable product characteristics (or equivalently here, district characteristics).

One issue in estimating this system of equations is that there may exist some correlation between the unobserved demand characteristic ξ_d and the unobserved marginal cost γ_d , which will introduce a spurious correlation between prices and market shares when

estimating, for instance, the demand equation separately. We need an exogenous supply shifter to estimate the elasticity of demand in (D), and an exogenous demand shifter to estimate the elasticity of supply in (S).

4.2.2. Elasticities of Supply and Demand We already have a candidate demand shifter: the former U.S. presence during the Vietnam war. We describe in the following lines the construction of a supply shifter. During the 1980s, Thailand experienced an agricultural crisis partly triggered by a drop in international crop prices. We use the price shock affecting rural areas as a push factor in female migration to neighboring urban areas.

As explained in Section 3, the supply shifter in district d is constructed from the interaction of two independent exogenous sources of variation: (i) returns to agriculture in neighboring districts as predicted by the value of the agricultural portfolio estimated at international prices, and (ii) the inverse of the distance between these districts and district d . The resulting shifter should capture a variation in female labor cost that is exogenous to district-specific demand characteristics γ_d .

Two conditions should be verified by the supply shifter. First, the value of the agricultural portfolio in district o needs to predict female migration outflows, and shift female labor supply in potential receiving districts. We verify this condition by constructing migration flows from retrospective data in the 1990 population census. Using information on residence during the previous 5 years and the district of origin, we create district-specific migration outflows between 1984 and 1989 for two different populations, females between 25 and 35 and all males. In panel A of Appendix Table A8, we collapse migration outflows at the origin to create out-migration incidence and relate these outflows to the district-specific crop price deviation e_o . Panel A of Appendix Table A8 shows that an additional price deviation of 10% is associated with 2.9 to 3.6 p.p. lower female migration flows between 1984 and 1989. In order to justify the use of inverse distance as the weight between a potential origin (where the return to agriculture is computed) and destination, we keep all pairs of provinces and relate the share of migrant outflows to the distance between origin and destination. Results are reported in panel B of Appendix Table A8, and a graphical representation of the relationship is shown in Appendix Figure A4. Second, the price shifter should not directly affect urban demand for sexual services. This condition

cannot be tested. However, we present some evidence that the price shifter does not affect migration among the male population (panel A of Appendix Table A8), which would have modified demand for sexual services at destination.

Our synthetic measure of economic adversity is subject to potential biases. As the crop portfolio is computed in 1990—after the general fall in crop prices, the crop incidence of crops subject to falling (resp. rising) prices may be under-estimated (resp. over-estimated). This measurement error is not standard, which has implications on biases in the first- and second-stages. However, the price elasticity of acreage on the medium run for the most common crops in Thailand tend to be small (e.g., 0.05 for rice, see Haile et al., 2016) and we may expect these biases to be of second order.

We report in Table 4 the estimates of the two-stage specifications.²³ In the first column, we report the estimate for the price elasticity of demand using the supply shifter as an instrument for prices and controlling for a large set of district characteristics, i.e., proximity to coasts, borders, latitude, longitude, population in 1990, the shares of the different types of sex establishments, the minimum wage in 1990, the average exposure to rainfall population and province fixed effects. In the second column, we report the estimate for the price elasticity of supply using the presence of US bases as an instrument for prices and controlling for proximity to coasts, borders, latitude, longitude, population in 1990, and the shares of the different types of sex establishments.

The first stage (see Panel A) indicates that a standard deviation in the measure of economic adversity in neighboring districts is associated with a price increase of about 21% (see column 1). The presence of a U.S. base is associated with a 48% increase in prices. The price elasticities of demand and supply are estimated to be -1.7 and 3 (see Panel B). While these elasticities are not very precisely estimated, they provide some novel insights about the slopes of the supply and demand equations underlying the spatial equilibrium of the sex industry. *Caeteris paribus*, a 10% decrease in prices, triggered by a decrease in labor costs, would increase the number of sex workers by 17%. In parallel, a 10% increase in the consumer willingness to pay for sexual services would increase the supply of sex

²³We report in Appendix Table A9 the reduced-form estimates between the size of the sex industry in 1990 and the measure of economic adversity in neighboring districts, and we show the robustness of the correlation to the addition of province-fixed effects, an extended set of controls and the direct agricultural shock or migration flows experienced by the district itself. One standard deviation in the value of crops in neighboring districts decreases the number of sex workers by about 37% or .15 of a standard deviation.

workers by about 30%. In particular, the price elasticity of supply is not negligible and point to small variations in the consumer willingness to pay for sexual services as having a large impact on the spatial distribution of the sex industry.

Our results from specification (S2) indicate that the temporary demand shift induced by the U.S. presence from 1961 to 1975 had a marked effect on the geographic distribution of the sex industry in 1990. A back-of-the-envelope calculation suggests that the U.S. presence accounts for 30%-40% of the spatial variation in sex industry. The estimates for the price elasticities indicate that the direct demand shift was about 56% larger ($(\alpha + a)/a \approx 1.56$) than the one observed at equilibrium. In order to service the additional demand, the returns on sexual services had to increase thereby tempering the initial shift. Along the same lines, one additional standard deviation in the returns to agriculture in rural areas is associated with a lower number of sex workers of about .16 standard deviations. However, the mere supply shift was about 175% larger ($(\alpha + a)/\alpha \approx 2.76$) than the one observed at equilibrium, and general equilibrium responses partially smoothed the implied spatial differences.

4.2.3. Discussion There are two interesting aspects behind these findings, which may explain why the equilibrium distribution of sexual services still reflects the initial shift almost 40 years after the departure of U.S. soldiers. First, the demand shift induced by the U.S. presence was arguably large. Second, the agricultural crisis relaxed the constraint on the supply of female sex workers.

Incorporating these two aspects is essential to discuss the external validity of our findings. The demand shift can be interpreted as a local and temporary gender imbalance, which may occur around military bases, mining towns, large construction sites or large truck stops (Oster 2012b). There are examples of such demand shifts in other countries, even though the shocks were generally more local and circumscribed. For instance, the neighboring town of Clark Air Base, one of the largest U.S. military facility in South-East Asia from 1903 to 1991, is now the center of the Philippines sex industry and the entertainment industry is fueled by tourism from developed economies. In this case, the shock was of similar amplitude and rural poverty may suggest a similar price elasticity of supply as in Thailand. In a similar environment, the Japanese Occupation during the

Second World War contributed to the commercialization of the sex industry in Indonesia (Lim 1998). By contrast, the sex industry in Korea or Japan after the Second World War and the Korean War did not experience any episodes of growth. One interesting extension of our findings would be to explain this observation by the relatively low price elasticity of supply due to rapid urban growth and abundant work opportunities for rural migrants in the manufacturing sector.

The possible differences with other contexts may also be due to cultural features specific to the Thai society or to the empirical framework. First, while rural poverty and low female labor participation in urban centers are common to developing economies, Thailand has some specific cultural features (e.g., matriarchal society, Buddhism) possibly explaining the high price elasticity of supply. In addition, Thai authorities did not hinder the development of sexual services (in contrast with Vietnam for instance, where prostitutes were sent to reeducation centers). Second, we estimate cross-sectional elasticities on the long-term (about 20 years after the initial demand shift), thus accounting for general equilibrium effects.²⁴

In the last section, we use a standard epidemiological model in order to explore one consequence of the sex industry distribution in Thailand: the rapid propagation of HIV in the early stages of the epidemics.

5. A Disamenity Related to the Sex Industry

The previous section has presented evidence on the origins of the sex industry's geographic distribution in Thailand. So far, the study has been silent on its possible implications. In the late 1980s, Thailand suffered a large-scale HIV outbreak, and the sex industry has rapidly been identified as a contributor to this public health crisis (Ungchusak et al. 1989).

In this section, we quantify the contribution of the sex industry's geographic distribution on the HIV outbreak in Thailand, and isolate three separate effects. First, the presence of the U.S. army has a direct effect on the countrywide frequency of risky partnerships with sex workers. Second, there is a high spatial clustering of sex workers, and we study the consequences of such spatially inhomogeneous population. Intuitively, many

²⁴In a different context along both dimensions, Levitt and Venkatesh (2007) estimate a very short-run elasticity within a city (Chicago).

partnerships through the sex industry induce high transmission rates, which generates more infections. As each new infected person transmits the infectious disease, there are increasing returns to the size of the risky group, and average HIV prevalence will be high in a country characterized by high-risk clusters. Third, we show that, in high-risk clusters, each risky partnership is relatively safer. This last effect will mitigate the overall propagation of the disease, and may capture a benefit to concentration, e.g., when designing infection control.²⁵

Our analysis builds on conventional epidemiological models (Susceptible-Infected) with proportional mixing between sub-groups of sellers and buyers (Anderson et al. 1992, Oster 2005). As in the Asian Epidemic Model (AEM, Brown and Peerapatanapokin, 2004), specifically designed for Thailand, or other studies of the Thailand context (Mastro et al. 1994, Surasiengsunk et al. 1998), the model will separately model sex workers.²⁶ The estimation of the model also follows Brown and Peerapatanapokin (2004): the observed size of key populations are inputs of the model while the unobserved contact rates will be estimated in order to match the observed HIV prevalence in different sub-groups.

The model relies on proportional mixing between sub-groups of buyers and sellers, and each location (i.e., a province) will behave as a separate compartment.²⁷ First, the transmission rate is uniform within types of partnership and location. This assumption of random search within a market hinges on the hypothesis that agents cannot observe the infection status of a potential partner. Second, in each location, there are two segmented markets, a tariffed and a “normal” market, and search is random across these two markets. The assumption of random search across markets builds upon the assumption that there are no behavioral responses from agents. For instance, agents do not respond to HIV prevalence among the population of sex workers.²⁸

²⁵The negative and positive returns to concentration directly illustrate theoretical findings on optimal programs of immunization in heterogeneously mixed populations (May and Anderson 1984).

²⁶In contrast with AEM, our model ignores antiretroviral therapy treatment, and restrict the number of sub-population groups with different risky behaviors. For instance, we ignore injection drug users, male sex workers and homosexual partnerships.

²⁷In the baseline model, HIV transmission in a province will be determined by the local HIV prevalence rates and local contact rates in the different markets. In counterfactual experiments, we add spatial mixing by allowing agents to engage in sexual activities in neighboring locations.

²⁸This assumption has been relaxed in a recent contribution (Greenwood et al. 2017), capturing observed behavioral responses in the United States (McKusick et al. 1985). By contrast, Oster (2005) documents very few changes in sexual patterns over time in African countries. Thailand probably stands between these two extremes, and we limit our analysis to the early 1990s—prior to the 100% Condom Programme in 1993 (UNFPA Thailand 2000)—during which information about the disease remains limited. While we

In order to quantify the influence of the sex industry on the propagation of the disease, we proceed in three steps: (i) we model the joint evolution of the disease among buyers and sellers in the stylized accounting framework, (ii) we calibrate a set of parameters and separately estimate the remaining important parameters in each province to match the observed disease prevalence. Finally, (iii) we perform a decomposition exercise by estimating propagation under counterfactual fundamentals (e.g., counterfactual geographic distribution of the sex industry).

5.1. The Susceptible-Infected Framework

We follow a simplified version of the conventional (S-I) model with proportional mixing and multiple locations as separate compartments (May and Anderson 1984). There are K provinces, all populated by a unit mass of buyers.²⁹ All players are born and die exogenously according to a Poisson process with per-period rate δ ,³⁰ independently of their status. Individuals exogenously search for partners, and engage in sex partnerships in continuous time.

There are three types of players within a location: buyers (*type-M*) which are single, young adult males, *type-C* sellers, charging a fee, and *type-F* sellers which are single, young adult females. While the two types of sellers and buyers are assumed immobile in the baseline model, we will allow buyers to search for a partnership outside their initial location in counterfactual experiments. All matches are random, independent of the infectious status of both partners and characterized by a matching function exhibiting constant returns to scale. The arrival of matches within each market follows a Bernoulli process (Kaplan 1990), and we denote ρ_F^k (resp. ρ_C^k) the arrival rate of partnerships with *type-F* sellers (resp. *type-C* sellers) for buyers. We denote π_C^k (resp. π_F^k) the contact rate of *type-C* sellers (resp. *type-F* sellers) with buyers.

cannot provide a formal empirical test for the proportional mixing hypothesis, we present in Appendix Table A10 descriptive statistics from a survey of military conscripts in 1991, 1993 and 1995 (Nelson et al. 1996). As apparent in Appendix Table A10, sexual behaviors among conscripts, e.g., their visit to sex workers, mostly respond to the epidemics after 1993.

²⁹The National Sentinel Seroprevalence Surveys conducted by the Ministry of Public Health are geolocated at the province level (there are 76 provinces in Thailand) and we need to collapse our analysis to this geographic unit.

³⁰This assumption is equivalent to assuming a constant replacement rate across provinces. In practice, birth rates, migration or death rates may vary across provinces and such variation could be related to HIV prevalence. We ignore these differences in the present model (see Surasiengsunk et al., 1998, for a detailed analysis of the demographic impact of the HIV epidemic).

We assume that the probability that a susceptible individual is infected from matching with an infectious individual, v , is constant across provinces and the two types of unprotected partnerships, and we assume that condom use within types of partnership (c_C, c_F) is constant across provinces. The effective HIV transmission parameters are thus $v_C = (1 - c_C)v$ and $v_F = (1 - c_F)v$.

Letting (h_C^k, h_F^k, h_M^k) denote the type-specific HIV prevalence rates, the evolution of HIV prevalence among *type-M* in location k is characterized by:

$$\dot{h}_M^k = -\delta h_M^k + (1 - h_M^k) \left[1 - (1 - v_F h_F^k)(1 - v_C h_C^k)^{\rho^k} \right] \quad (\text{Dm})$$

The evolution of HIV prevalence among *type-C* in location k is characterized by:

$$\dot{h}_C^k = -\delta h_C^k + (1 - h_C^k) \left[1 - (1 - v_C h_M^k)^{\pi_C^k} \right] \quad (\text{Dc})$$

The evolution of HIV prevalence among *type-F* in location k is characterized by:

$$\dot{h}_F^k = -\delta h_F^k + (1 - h_F^k) \left[1 - (1 - v_F h_M^k)^{\pi_F^k} \right] \quad (\text{Df})$$

In the empirical exercise, as common in this literature, we calibrate the model using its steady-state characterized by $\dot{h}_T^k = 0$ for $T \in \{M, C, F\}, k \in \{1, \dots, K\}$. We interpret this steady-state as the value at the peak of the HIV propagation (see the plateau in Appendix Figure A6 representing HIV incidence among sex workers), before the implementation of the 100% Condom Programme, and we mostly analyze differences between steady-states in the counterfactual experiments thereby ignoring the dynamic convergence to these steady-states.³¹

5.2. Model Estimation and Calibration

We calibrate the model in a similar fashion to Brown and Peerapatnanapokin (2004).

In a first step, we set observable parameters (see Table 5). We rely on Mastro et al. (1994) which use a survey on the behaviors of conscripts in 1991 to set a female-to-male HIV

³¹With our calibrated contact rates, the half-life of the epidemics adjustment is around 4-5 years.

transmission rate v , as well as countrywide condom usage within each market (c_C, c_F).³² We set the birth rate δ to be constant across provinces. We set the province-specific population sizes such as to match the number of commercial sex workers per 1,000 females, as well as the province-specific male-to-female ratios. We finally set ρ_F^k , the arrival rate of partnership with *type-F* sellers for buyers, to be constant across provinces and match the average contact rate reported in surveys of military conscripts (Nelson et al. 1996, Surasiengsunk et al. 1998).

In a second step, we estimate the parameters commanding province-specific sexual behaviors such as to match a set of province-specific moments. More specifically, we use the 1991-1993 waves of the National Sentinel Seroprevalence Surveys conducted by the Ministry of Public Health among vulnerable individuals.³³ From these surveys, we construct three sets of province-specific moments that need to be matched, (i) HIV prevalence $(h_M^k)_{k \in \{1, \dots, K\}}$ among conscripts (as a proxy for *type-M*), (ii) HIV prevalence $(h_C^k)_{k \in \{1, \dots, K\}}$ among sex workers (as a proxy for *type-C* sellers) and (iii) HIV prevalence $(h_F^k)_{k \in \{1, \dots, K\}}$ among pregnant females (as a proxy for *type-F* sellers). We use these $3 \times K$ moments to identify $3 \times K$ parameters, i.e., the annual contact rates $(\pi_C^k)_{k \in \{1, \dots, K\}}$ of *type-C* sellers, the annual contact rates $(\pi_F^k)_{k \in \{1, \dots, K\}}$ of *type-F* sellers and the contact rates (with *type-C* sellers) for buyers $(\rho_C^k)_{k \in \{1, \dots, K\}}$.

Table 6 provides summary statistics of the calibrated parameters and moments. As apparent in Panel A, HIV prevalence for conscripts is relatively higher in provinces with a large sex industry (top quartile, column 3).³⁴ In order to match the patterns of (i) high prevalence among buyers and (ii) relatively low prevalence among sex workers in red-light provinces, red-light provinces also need to be characterized by a relatively low contact rate for *type-C* sellers. Panel B shows that the contact rate for *type-C* sellers is indeed

³²In this model, we can only identify the period transmission rate in the two markets, which is the product of the contact rate and the effective male-to-female transmission rate per contact (accounting for condom usage). We cannot identify the two components separately. We thus set a countrywide measure of male-to-female transmission per contact equal to the female-to-male parameter, and countrywide measures of condom use across markets. In practice, the probability of male-to-female transmission per contact usually differs from the probability of female-to-male transmission rate, and condom usage may vary across provinces. The model will flexibly account for these measurement errors or provincial differences in transmission rates or condom use through the province-specific contact rates $(\pi_C^k, \pi_F^k)_{k \in \{1, \dots, K\}}$.

³³Appendix Figure A7 shows the geographical distribution of HIV prevalence among conscripts, pregnant females and sex workers.

³⁴We report in Appendix Figure A8 the cross-sectional relationship between HIV prevalence rates and the size of sex industry. The elasticities of HIV prevalence for *type-M*, *type-C* and *type-F* to the size of the sex industry are respectively 0.39, 0.15 and almost 0.

calibrated to be markedly lower in red-light provinces. Note that, as the contact rate for *type-F* sellers is also lower, this pattern could reflect higher condom usage across the two markets in red-light provinces.

5.3. Counterfactual Experiments

In order to understand the role of the sex industry’s geographic distribution in the propagation of HIV, we run a series of simple counterfactual experiments.

In a first set of experiments (see Panel I of Table 7), we generate three counterfactual distributions of the sex industry and estimate HIV propagation in these three scenarios. In order to translate the number of *type-C* sellers into arrival rates of matches for buyers in this market, we transform, in each province, the log-difference between the number of *type-C* sellers in the baseline and the number of *type-C* sellers in each counterfactual scenario into a log-difference in contact rates. More precisely, we define the relative number of contacts per seller θ^k in the *type-C* market as the contact rate between buyers and *type-F* sellers ρ_C^k normalized by the relative prevalence of the two sellers’ types in the baseline, n_C^k/n_F^k . The counterfactual contact rate with n_C^k *type-C* sellers is $\rho_C^k = \theta^k n_C^k/n_F^k$.

The three scenarios may be interpreted as counterfactual sex industry equilibria in 1990 under three counterfactual price elasticities of supply. In experiment I.1, we remove the effect on the sex industry implied by the presence of former U.S. bases. We run specification (1) in Table 2, collapsed at the province level, and we subtract the predicted effect of proximity to U.S. military bases from the province-specific sex industry size. This experiment would correspond to the same demand as in the baseline, but with a price elasticity of supply of 0. We then estimate counterfactual distributions of the sex industry with a price elasticity of supply of 1 (experiment I.2) and an infinitely elastic supply (experiment I.3). We find that countrywide HIV prevalence would have been about 20%-25% lower without U.S. bases for the three sub-groups of agents (from a baseline of 4.5% for males, 31.5% for commercial sex workers and 0.03% for females). HIV prevalence would have been about 15% lower with a low price elasticity of supply and 10% higher with an infinitely elastic supply. As only 15% of the total population is in the proximity of U.S. bases, these country-wide differences between scenarios mask very large local variations.

In a second set of counterfactual experiments (see Panel II of Table 7), we highlight the

role of concentration by shutting down spatial differences in the relative number of *type-C* sellers. In experiment II.1, we keep the baseline set of estimated parameters $(\pi_C^k, \pi_F^k, \theta^k)$ and replace the relative prevalence of the two sellers' types, n_C^k/n_F^k , by its weighted average over the country such as to keep the total number of *type-C* sellers constant across the country. This experiment neutralizes differences in the prevalence of high-risk partnerships across provinces. HIV prevalence across all three groups is about 15% lower in this counterfactual scenario, mostly driven by a compression of the right tail of the distribution.

We then estimate the role of the negative correlation between contact rates for commercial sex workers and the size of the sex industry as an attenuation factor in the HIV propagation.³⁵ In order to do this, we keep constant the arrival rates for buyers and contact rates of *type-F* sellers, and neutralize spatial differences in effective contact rates π_C^k for *type-C* sellers. In experiment II.2, we attribute to all provinces the average contact rate $\bar{\pi}_C$. In experiment II.3, we reallocate randomly the actual contact rates π_C^k across provinces thereby keeping the same distribution, but neutralizing the negative correlation between sex industry presence and contact rates. HIV prevalence is higher under both scenarios because contact rates are now much higher than before in red-light provinces.³⁶

In a third set of counterfactual experiments (see Panel III of Table 7), we analyze the role of mobility between provinces. The role of this exercise is twofold. First, it provides a sensitivity analysis and relaxes the assumption of separate spatial compartments. Second, it highlights one possible attenuation factor: the dilution of the spatial distribution of risky partnerships when provinces in the neighborhoods of red-light districts are safe.

In this exercise, we allow buyers to be matched, with a given probability $\varepsilon = 0.05, 0.15, 0.30$, in three neighboring provinces instead of their own, and assume that the behavior of a buyer matched in another province is determined by the underlying parameters of the re-

³⁵The contact rates π_C^k may capture provincial differences in sexual behaviors and condom use, in which case the observed correlation may result from targeted health policies and higher condom usage in red-light provinces. The following experiments could be interpreted as an indirect evaluation of such targeted policies.

³⁶We illustrate the distributional changes implied by the concentration experiments in Appendix Figure A9. In the baseline scenario, HIV incidence is concentrated in the North and the coastal regions of Central Thailand. The three experiments have non-negligible distributional effects. In experiment II.1, many red-light provinces in the North and around Bangkok experience a large decrease in HIV incidence while HIV incidence slightly increases in neighboring provinces. On the whole, the experiment flattens the female-to-male annual transmission rate across Thailand. By contrast, experiments II.2 and II.3 produce a more acute clustering in the few red-light provinces (Central, North and Northeast regions), thus exacerbating the differences across regions in annual transmission rates.

ceiving province.³⁷ Allowing for some permeability between spatial compartments reduces HIV prevalence, but the overall decrease remains very small.

In order to shed light on forces behind this decrease, we replace actual neighboring provinces by counterfactual neighbors. For instance, there may be a negative correlation between fundamentals of neighboring provinces. As in experiment II.1, mobility between dissimilar provinces would then smooth differences in the prevalence of high-risk partnerships across provinces. In experiment III.4, we hinge on experiment III.2, i.e., $\varepsilon = 0.15$, and replace the three actual neighboring provinces by a dissimilar province. For provinces with male HIV prevalence above the median, we set neighboring provinces as the 25%-quantile province in terms of male HIV prevalence. For provinces with male HIV prevalence below the median, we set neighboring provinces as the 75%-quantile province in terms of male HIV prevalence. In experiment III.5, we replace the three actual neighboring provinces by the median province in terms of male HIV prevalence. Finally, in experiment III.6, we attribute the 75%-quantile neighbor to the above-median province such as to generate a positive correlation between neighbors.

There are two take-away messages from these experiments. First, there is a positive gradient in overall HIV prevalence as neighbors become more similar. Second, the closest experiment to experiment III.2 (with actual neighbors) is the one with dissimilar neighbors. This observation illustrates the negative correlation observed in the data between neighboring provinces. As shown in Figure 2 or column 2 of Table 2, the spatial clusters for the sex industry are small geographic units.

6. Conclusion

This paper studies the geographic distribution of the sex industry in Thailand and provides evidence that its massive development since the 1960s is due to the combination of two factors: (i) a temporary demand shock—the U.S. presence during the Vietnam War— and (ii) a subsequent agricultural crisis with young female workers migrating to cities.

By combining historical records of U.S. military presence in Thailand and census estimates of the commercial sex industry, we analyze the relationship between the presence of

³⁷The evolutions of HIV prevalence in the spatial model are reported in the online Appendix Section C.

U.S. military bases and the size of the local sex industry in the early 1990s. We document that districts easily reachable by U.S. servicemen during the war have become red-light districts. We then develop a simple supply-demand model à la Berry (1994) and use a measure of economic adversity in rural districts to construct a supply shifter, proxying for female migration inflows to urban centers. We find a relatively large price elasticity of supply: The U.S. presence can be interpreted as a large demand shift, which was not mitigated by supply. Last, we analyze one disamenity associated with widespread prostitution. We develop a standard (S-I) model of HIV propagation and estimate HIV propagation under counterfactual geographic distributions in order to highlight the role of four factors associated with the sex industry growth: (i) its size, (ii) its concentration, (iii) its qualitative transformation and (iv) mobility across provinces.

Our empirical findings have interesting policy implications. First, we relate the development of the sex industry to the combination of two factors each displaying a large geographic heterogeneity. Understanding these factors may help to control the growth of the sex industry. A government may be willing to avoid disequilibria in male to female ratio which leads to the development of prostitution, or may want to subsidize female formal work in such instances. Second, we assess the importance of the sex industry and its characteristics in the HIV propagation. These findings may inform the debate on the negative externalities of prostitution on health or female labor supply.

Finally, while a geographic correlation between prostitution and the presence of military bases is not surprising just after the war, we do not find any return to the mean over the past decades. An interesting extension to the present project would consist in documenting the transformation of the sex industry and the forces behind its persistent clustering.

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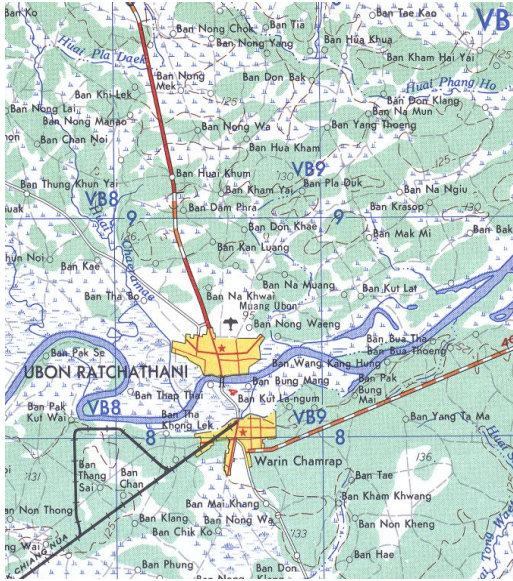
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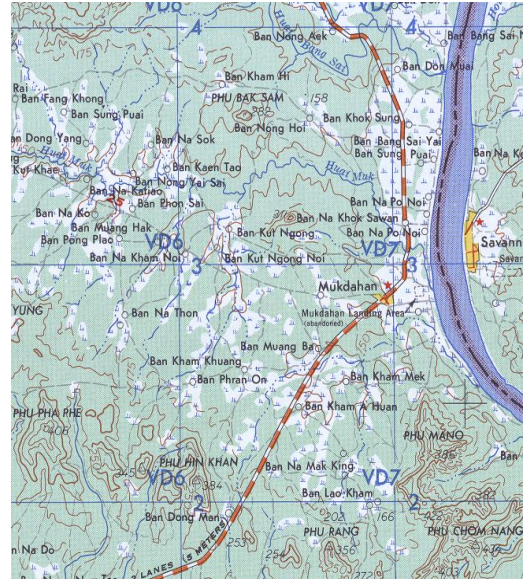
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A. Figures

Figure 1: U.S. Military Bases in 1954.



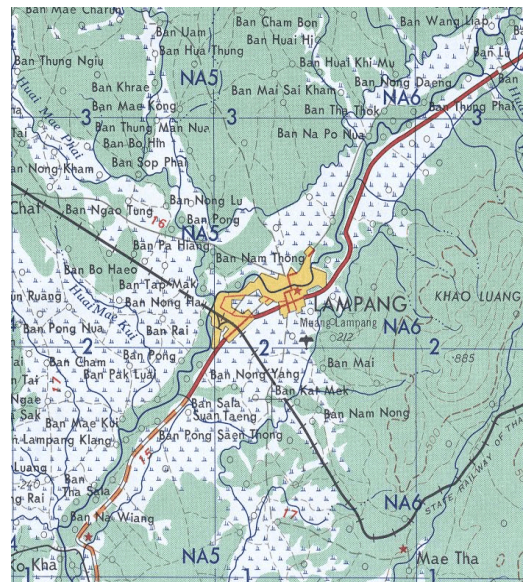
(a) Ubun Ratchathani



(b) Mukdahan/Savannakhet



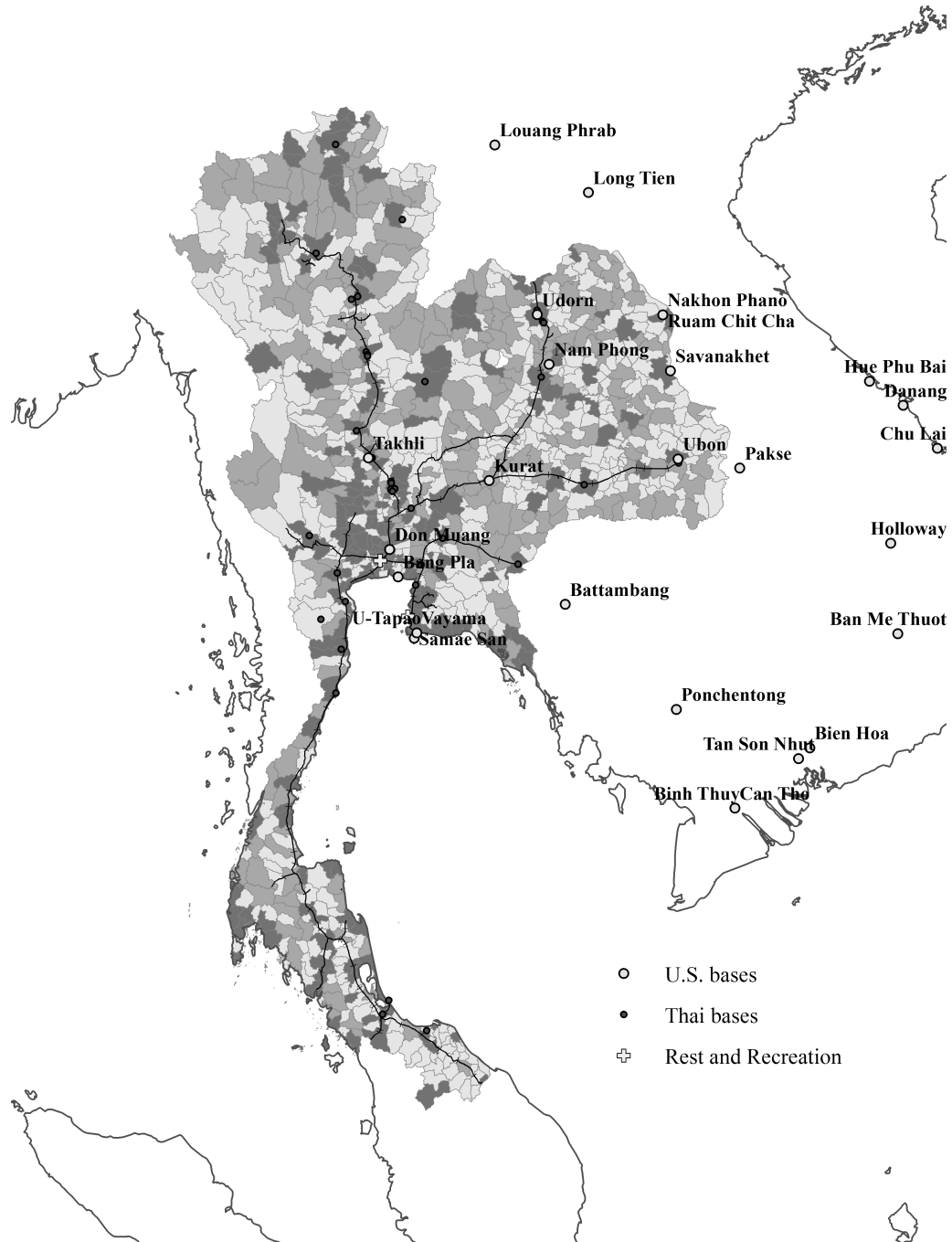
(c) Phetcha Buri



(d) Lampang

Note: Surroundings of four future U.S. military bases in 1954. We digitize six types of roads and two types of railways to compute travel time through different means of transportation. Sources: Indochina and Thailand, Series L506, 1:250,000, U.S. Army Map Service, 1954.

Figure 2: Military Bases and the Sex Industry in 1990.



Note: Commercial sex workers in each district per 10,000 inhabitants (per quartile: light gray indicates the lower quartile and dark gray the top quartile). Large circles indicate U.S. military bases. Small circles indicate 1970 Thai military bases not used by the U.S.A.F. Current major railways are plotted.

B. Tables

Table 1: Summary Statistics for Districts near U.S. Military Bases

	Less than 0h30 from U.S. Base (1)	More than 0h30 from U.S. Base (2)	Diff. (1-2) (3)	Less than 0h30 from Thai Base (4)	Diff. (1-4) (5)
CSW per 1,000 (1990)	5.93 (13.4)	0.71 (2.42)	5.17 (1.38)	1.29 (1.84)	4.64 (1.83)
CSW per 1,000 (2012)	7.92 (25.2)	0.65 (3.04)	7.27 (1.06)	0.59 (1.04)	7.33 (3.43)
Estab. per 1,000 (1990)	0.25 (0.54)	0.07 (0.17)	0.18 (0.04)	0.11 (0.12)	0.14 (0.07)
Estab. per 1,000 (2012)	1.50 (4.39)	0.25 (0.73)	1.24 (0.20)	0.22 (0.29)	1.28 (0.59)
Distance to Enemy Base	747 (68.9)	805 (169)	-57 (25.9)	840 (138)	-91.7 (23.0)
Rails (1954)	0.51 (0.51)	0.18 (0.39)	0.32 (0.06)	0.69 (0.46)	-0.18 (0.10)
Roads (1954)	0.69 (0.48)	0.37 (0.46)	0.32 (0.08)	0.81 (0.39)	-0.12 (0.09)
Population (1990, log)	11.7 (0.60)	10.8 (0.72)	0.94 (0.12)	11.2 (0.80)	0.53 (0.15)
Population (1960, log)	10.61 (0.72)	9.89 (0.76)	0.72 (0.12)	10.49 (0.73)	0.12 (0.15)
Coasts	0.12 (0.32)	0.11 (0.31)	0.01 (0.05)	0.20 (0.40)	-0.08 (0.08)
City District (Capital)	0.19 (0.39)	0.08 (0.26)	0.11 (0.04)	0.33 (0.47)	-0.14 (0.09)
Distance to Port Entry	131 (40.6)	89.9 (59.3)	40.8 (9.14)	97.7 (55.1)	32.9 (10.0)
Temples or Spiritual Sites	0.61 (1.23)	0.22 (0.89)	0.38 (0.14)	0.60 (1.18)	0.01 (0.24)
Observations	36	742	778	55	91

Standard deviations are reported in parentheses (replaced by standard errors in the third and fifth columns). Column 1 reports averages for districts near U.S. military bases (less than half an hour). Column 2 reports averages for other districts in Thailand, and column 3 reports the difference with column 1. Column 4 reports averages for districts near unused Thai military bases (less than half an hour), and column 5 reports the difference with column 1. *CSW per 1,000* and *Estab. per 1,000* are respectively the number of commercial sex workers and establishments per 1,000 inhabitants.

Table 2: Relationship Between U.S. Military Bases and the Sex Industry (1990) – Specification (S1).

Sex workers (1990)	(1)	(2)	(3)	(4)	(5)	(6)
U.S. Base (less 0h30)	1.477 (.305) [.669]	1.451 (.365) [.658]	1.491 (.294) [.676]	1.450 (.333) [.657]	.693 (.331) [.315]	.250 (.350) [.114]
U.S. Base (0h30–1h)		-.081 (.396)				
U.S. Base (1h–1h30)		-.284 (.222)				
U.S. Base (1h30–2h)		.091 (.397)				
Unused Base (less 0h30)			-.211 (.351)			
Unused Airfield (less 0h30)			.325 (.445)			
Observations	778	778	778	778	778	778
Adjusted R-squared	.444	.442	.443	.444	.455	.481
Fixed effects (region)	Yes	Yes	Yes	Yes	Yes	Yes
Controlling for...						
Direct aid	No	No	No	Yes	Yes	Yes
GDP	No	No	No	No	Yes	Yes
Tourism/infrastructure	No	No	No	No	No	Yes

The dependent variable is the (log of) the number of commercial sex workers. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population. In column 4, we add controls for roads and railways built during the Vietnam war. In column 5, we add nightlight intensity in 1992. In column 6, we add controls for tourism (density of hotels and tourist attractions) and specific infrastructure benefiting the service industry (roads, railways, presence of a commercial airport) in 1990.

Table 3: Relationship Between U.S. Military Bases and the Sex Industry (1990) – Specification (S2).

Panel A: First stage						
U.S. Base	(1)	(2)	(3)	(4)	(5)	(6)
Distance to the Front		-.0018 (.0007)	-.0016 (.0007)		-.0022 (.0003)	-.0023 (.0005)
Observations		90	90		94	94
F-statistic		13.33	9.38		41.86	49.40
Sample		Base	Base		Airfield	Airfield
Extended controls		No	Yes		No	Yes
Panel B: Second stage						
Sex workers (1990)	(1)	(2)	(3)	(4)	(5)	(6)
U.S. Base	1.183 (.595) [.536]	2.206 (.760) [1.000]	2.678 (1.042) [1.215]	1.400 (.644) [.635]	1.435 (.663) [.635]	1.261 (.569) [.572]
Observations	90	90	94	94		
Sample	Base	Base	Base	Airfield	Airfield	Airfield
Extended controls	No	No	Yes	No	No	Yes

The dependent variable is the (log of) the number of commercial sex workers (panel B). The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base (or airfield) are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population. The set of extended controls include latitude, longitude and distance to the nearest port of entry. Each district is assigned a distance equals to the average over-the-air distance to active enemy bases in 1969.

Table 4: Elasticities of Demand and Supply (1990).

<i>Panel A: First Stage</i>		
Price (1990)	(1)	(2)
Indirect Price Shock	.218 (.061)	
U.S bases		.484 (.093)
Observations	778	778
<i>Panel B: Second Stage</i>		
Sex workers (1990)	(D)	(S)
Price (1990)	-1.74 (.811)	3.03 (.836)
Observations	756	756
Kleibergen-Paap F-statistics (First Stage)	12.74	26.77

The unit of observation is a district. *Indirect Price Shock* is the measure of crop price deviation interacted with the distance matrix (see measure we_d in Section 3). Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital and the (log of) 1990 district population, latitude, longitude, distance to ports of entry, the shares of the different types of establishments, and region fixed effects. In column (1), we add the minimum wage in 1990, the usual exposure to rainfall and province fixed effects.

Table 5: Calibrated Parameters.

	Value	Description	Source
<i>HIV transmission</i>			
v	0.031	HIV transmission rate	Mastro et al. (1994)
c_C	0.30	Condom use (type-C)	Mastro et al. (1994)
c_F	0.018	Condom use (type-F)	Mastro et al. (1994)
<i>Population inputs</i>			
δ	0.025	Population replacement rate	Ministry of Interior
$\left(\frac{n_C^k}{n_F^k}\right)_k$	2.5*	CSW per 1,000 females	Mastro et al. (1994)
$\left(\frac{n_M^k}{n_F^k}\right)_k$	0.5*	Male to female ratio	Population Census (1990)
<i>Sexual behaviors</i>			
ρ_F	1.40	Contact rate with <i>type-F</i> sellers	Surasiengsunk et al. (1998)

* These values are the country-wide average of the 76 province-specific calibrated parameters.

Table 6: Moments and Estimated Parameters.

Panel A: Moments		Sex industry		
	Mean	Std. dev.	High	Low
HIV prevalence of conscripts $(h_M^k)_k$	.045	.037	.056	.041
HIV prevalence of sex workers $(h_C^k)_k$	.315	.146	.348	.305
HIV prevalence of pregnant women $(h_F^k)_k$	.026	.018	.028	.025
Panel B: Estimated parameters		Sex industry		
	Mean	Std. dev.	High	Low
Contact rate with <i>type-C</i> $(\rho_F^k)_k$	.010	.068	.021	.006
Contact rate for <i>type-C</i> $(\pi_C^k)_k$	15.1	57.1	9.78	17.1
Contact rate for <i>type-F</i> $(\pi_F^k)_k$	.871	5.07	.475	1.01

This table presents descriptive statistics for three province-specific moments matched at the province-level, and three province-specific set of estimated parameters. The province-specific HIV prevalence for conscripts, commercial sex workers and pregnant women are computed from the 1991-1993 waves of the National Sentinel Seroprevalence Surveys conducted by the Ministry of Public Health among vulnerable individuals. The first column is the weighted countrywide average. The third and fourth columns are averages in two subgroups of provinces divided along the prevalence of the sex industry (top quartile in column 3, remaining provinces in column 4).

Table 7: Counterfactual Experiments.

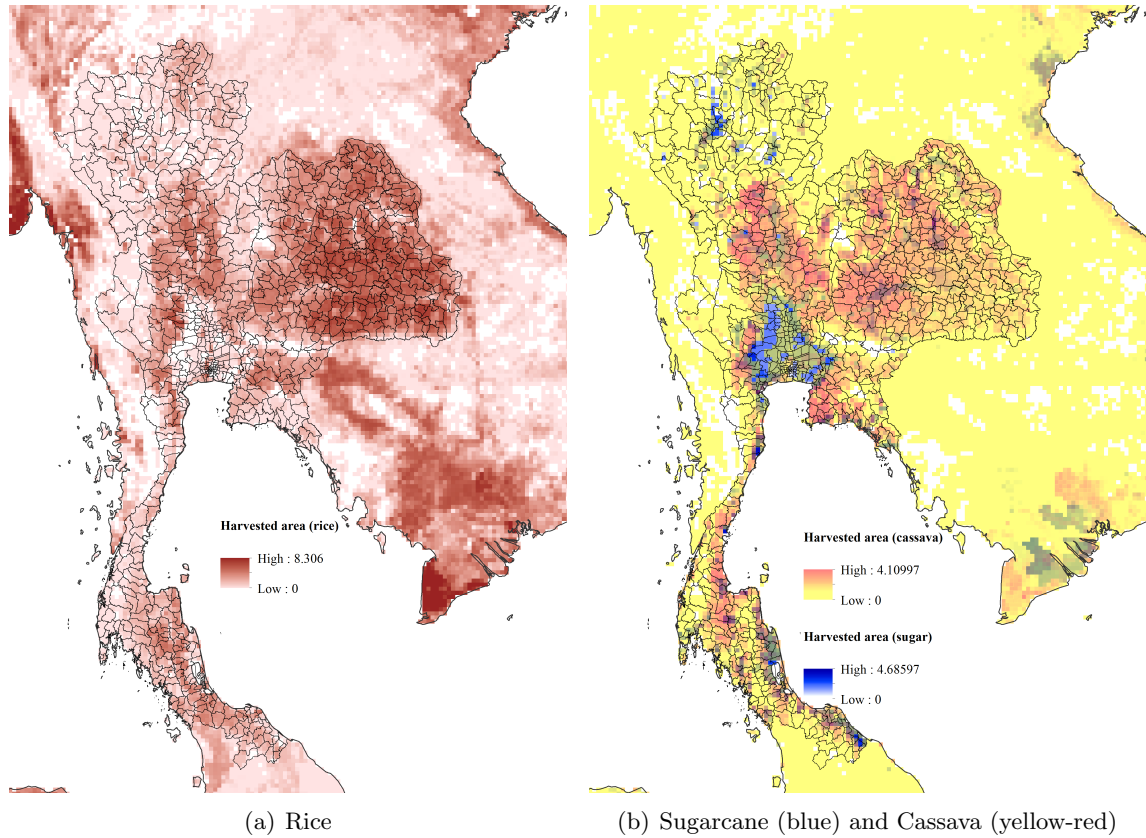
HIV prevalence	males	CSW	females
Baseline	.044	.309	.026
<i>I. Size</i>			
I.1: Inelastic supply	.034	.254	.021
I.2: Low elasticity	.039	.278	.023
I.3: High elasticity	.049	.324	.028
<i>II. Concentration</i>			
II.1: Same incidence of sex industry n_C/n_F	.038	.199	.023
II.2: Same contact rate π_C for CSW	.056	.473	.030
II.3: No correlation	.051	.358	.028
<i>III. Mobility</i>			
III.1: $\varepsilon = 5\%$, actual neighbors	.044	.306	.024
III.2: $\varepsilon = 15\%$, actual neighbors	.042	.290	.024
III.3: $\varepsilon = 30\%$, actual neighbors	.041	.238	.024
III.4: $\varepsilon = 15\%$, dissimilar neighbors	.043	.293	.024
III.5: $\varepsilon = 15\%$, neutral neighbors	.046	.321	.029
III.6: $\varepsilon = 15\%$, similar neighbors	.048	.317	.030

This table reports the outcomes of three sets of counterfactual experiments. In Panel I, we adjust the contact rates for buyers to match counterfactual distributions of commercial sex workers, and we consider three counterfactual distribution (see Section 5 for details). In Panel II, we cast away heterogeneity across-province in the relative prevalence of the sex industry (II.1) and the contact rates for *type-C* sellers (II.2 and II.3). In Panel III (1,2,3), we allow for spatial mixing with the three neighboring provinces. In Panel III (4,5,6), we allow for spatial mixing with counterfactual neighboring provinces.

Online Appendix (not for publication)

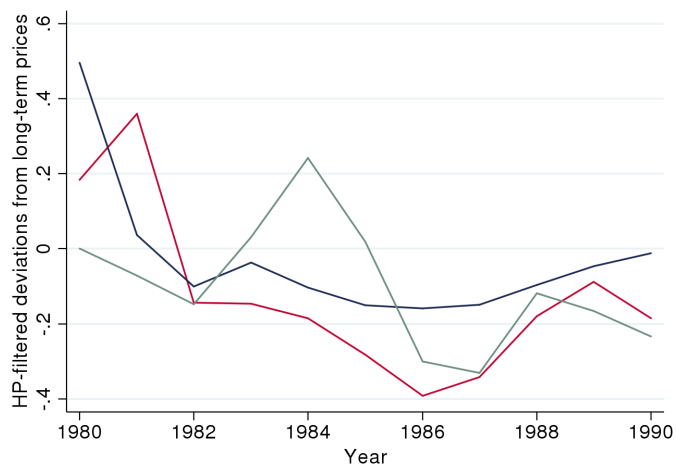
A. Appendix Figures

Figure A1: Harvested Areas in Thailand (1990).



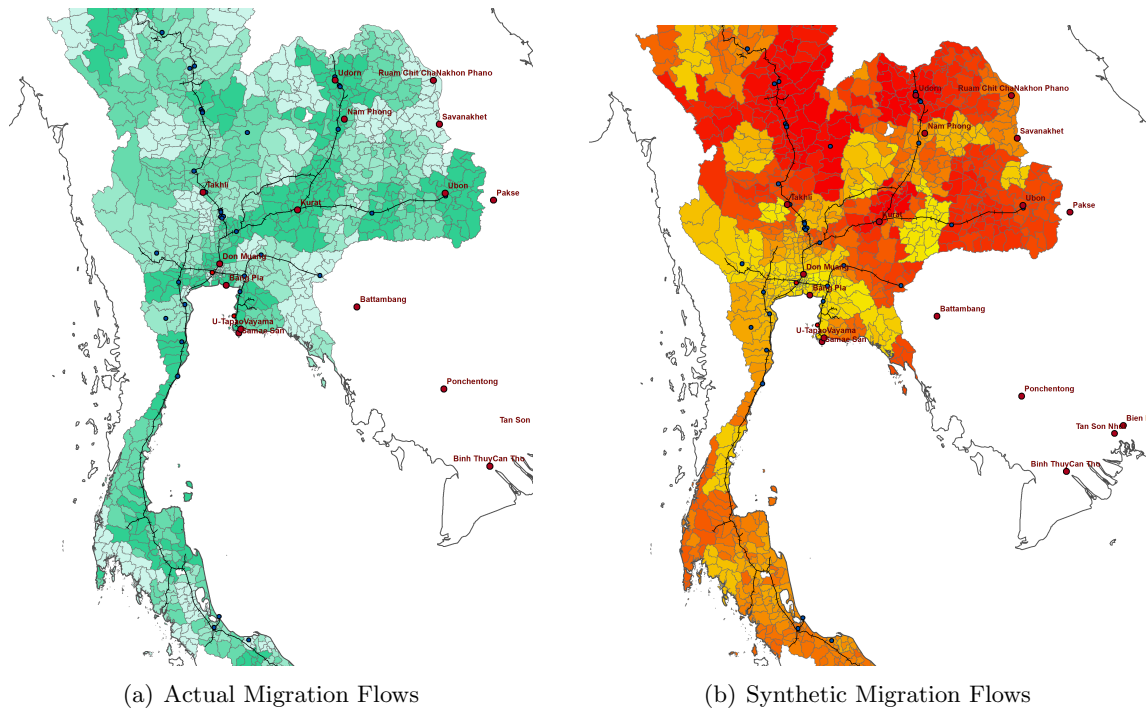
Note: These two maps represent the relative harvested areas in 1990 for 3 common crops in Thailand, i.e., wetland rice (left panel), cassava and sugar cane (right panel). The data are from the 1990 World Agricultural Census (Food and Agriculture Organization of the United Nations).

Figure A2: Deviations from Trends for International Commodity Prices (red: rice, blue: sugar, teal: cassava).



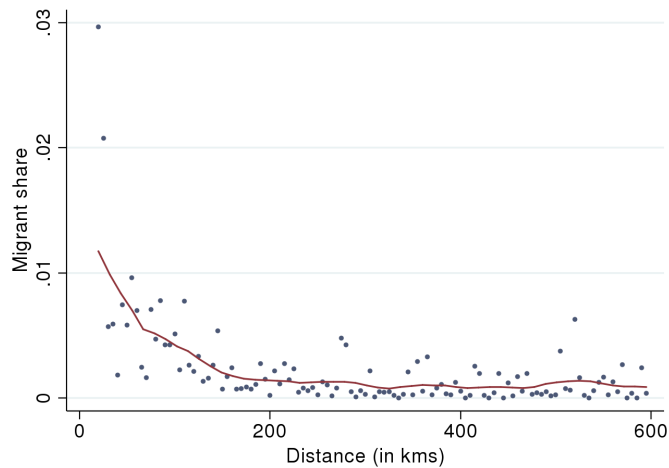
Note: These series represent the Hodrick Prescott residual applied to the logarithm of international commodity prices for three commodities: rice, sugar and cassava. The price of rice can be interpreted as being 40% below its long-term value in 1986, which corresponds to the peak of the agricultural crisis.

Figure A3: Actual and Synthetic Migration Flows as Predicted by Agricultural Prices.



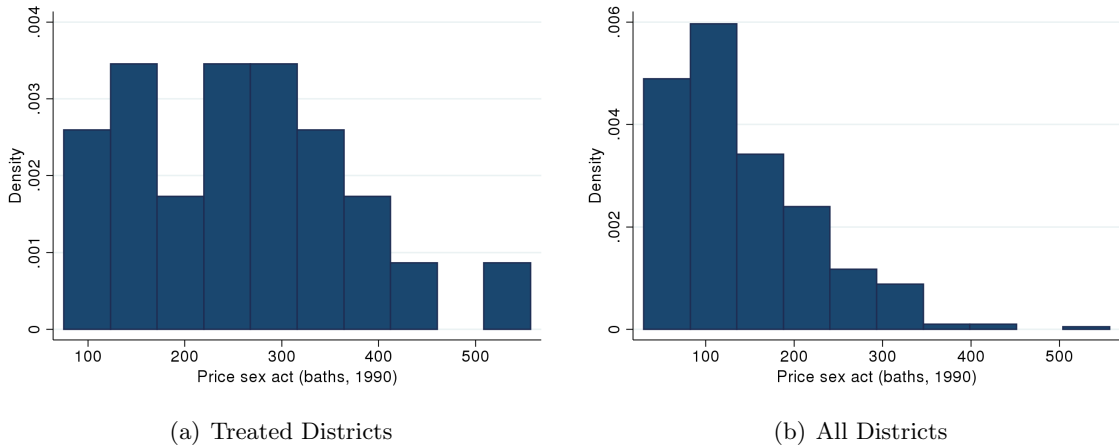
Note: Panel A represents migrant inflows between 1984 and 1989 normalized by the receiving district population. Light green is the lowest quintile and dark green the top quintile. Panel B represents the weighted price shock as a proxy for migration inflows between 1984 and 1989. Yellow is the highest quintile in the shock (and lowest predicted migration inflow) and red the lowest quintile (and highest predicted migration inflow).

Figure A4: Migration Flows and Distance.



Note: This figure represents the relationship between the share of province-specific female migration outflows to a province of destination and the distance between origin and destination.

Figure A5: Distribution of Sex Act Prices (1990).



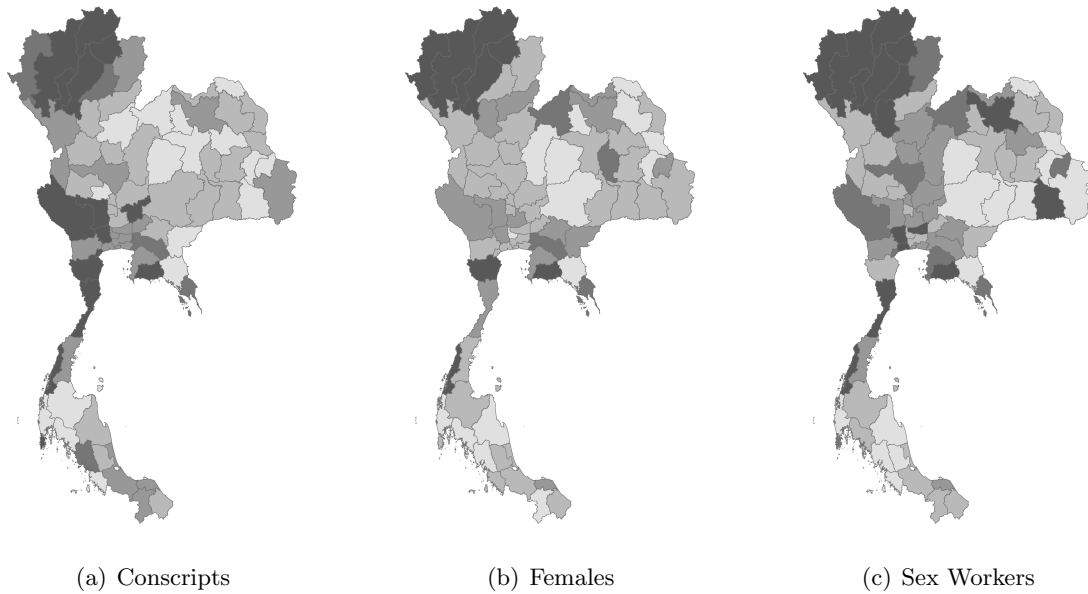
Note: Distribution of sex act prices in bahts ($\$1 = 25.7$ bahts). The price is the benchmark price reported by commercial sex establishments for the annual national census. Panel A presents the distribution of sex act prices across treated districts ($USB_{d,r}=1$). Panel B presents the distribution of sex act prices across all districts.

Figure A6: Average HIV Prevalence Among Direct (blue) and Indirect (red) Female Sex Workers in Thailand (1989-2012).



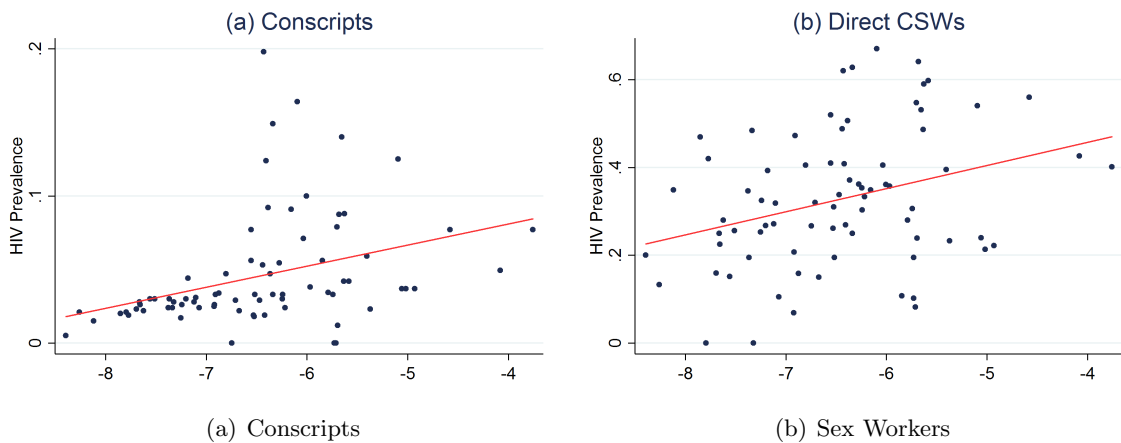
Source: Sentinel surveillance data from the Venereal Disease Section of the Ministry of Public Health (1989-2012). Direct establishments are defined as locations having an actual “room” for sexual services whereas indirect establishments are locations where sellers and buyers meet, but without a room on site.

Figure A7: Maps of HIV Prevalence (1991-1993).



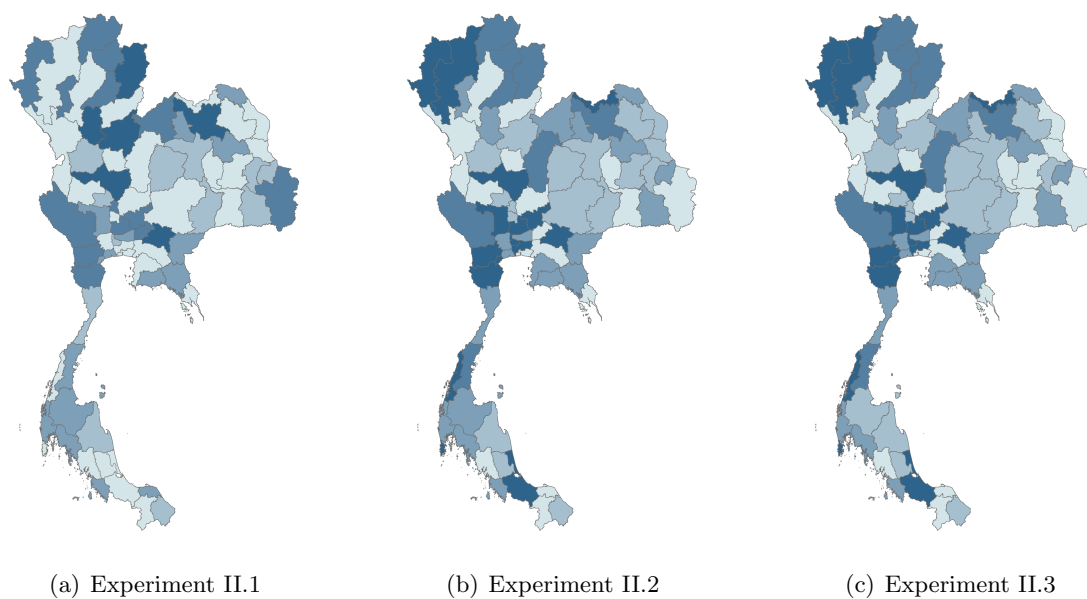
Source: Sentinel surveillance data from the Venereal Disease Section of the Ministry of Public Health. These maps represent the average HIV prevalence for male conscripts, pregnant females and sex workers over the waves 1991, 1992 and 1993 for the 76 provinces in Thailand.

Figure A8: Province Level HIV Prevalence (1991-1993) and the Size of the Sex industry (1990).



Source: Sentinel surveillance data from the Venereal Disease Section of the Ministry of Public Health (collapsed at the province level). The y-axis is the average HIV prevalence for conscripts and sex workers over the waves 1991, 1992 and 1993 while the x-axis is the (log of) the number of sex workers in 1990 normalized by the total female population.

Figure A9: Counterfactual HIV Prevalence – Differences with Baseline (1991-1993).



Source: Authors' own calculations (see Table 7). These maps represent the differences in HIV prevalence between the counterfactual experiments and the baseline for male conscripts, pregnant females and sex workers over the waves 1991, 1992 and 1993 for the 76 provinces in Thailand. Dark (resp. Light) blue indicates an increase (resp. a decrease) in HIV prevalence relative to the baseline.

B. Appendix Tables

Table A1: List of U.S. Military Bases

Base Name	Lat.	Lon.	Evacuation Date	Dist. Front 1969	Num. of Missions
Bang Pla (Camp)	13.302	100.434	1975	746	0
Don Muang	13.544	100.362	1966	610	343
Kurat	14.560	102.044	1976	677	101,160
Mukdahan/Savanakhet	16.332	104.453		604	6,495
Nakhon Phanom	17.230	104.383	1975	772	66,736
Nam Phong	16.390	102.575	1975	719	18,325
Ruam Chit Chai (Camp)	17.230	104.383	1975	684	0
Samae San (Camp)	12.360	100.580	1975	704	0
Takhli	15.160	100.173	1975	852	51,774
Ubon Air Force	15.150	104.521	1975	493	215,527
Udorn Air Force	17.231	102.471	1975	788	97,723
U-Tapao	12.404	101.001	1975	887	37,261
Vayama (Camp)	12.404	101.001	1975	701	0
Pakse (Laos)	15.070	105.470	1976	437	13,017
<i>U.S. Bases in neighboring countries</i>					
Luang Prabang (Laos)	15.070	105.470		1042	
Long Tieng (Laos)	16.332	104.453	1975	905	
Battambang (Cambodia)	13.060	103.120		500	

This table describes the military bases housing U.S. military air forces during the Vietnam War, which are used to define in-sample treated districts. We also use three U.S. bases at the border between Thailand and Laos or Cambodia. *Camps* are military bases hosting supply or refueling units. Distance to the front (1969) is the average distance to active enemy bases in 1969. The last column presents the number of distinct air missions flown from each base during its period of activity as reported by the National Archives and Records Administration.

Table A2: Relationship Between Covariates and the Sex Industry (1990) – Specification (S1).

Sex workers (1990)	(1)	(2)
U.S. Base (less 0h30)	1.477 (.304)	1.457 (.317)
Population (1960, log)	-0.079 (.100)	-0.045 (.094)
Population (1990, log)	1.159 (.119)	1.150 (.118)
Rails (1954)	0.125 (.210)	0.145 (.210)
Roads (1954)	0.258 (.154)	0.264 (.162)
Coasts	0.941 (.204)	0.969 (.194)
Central District (Capital)	2.059 (.214)	1.909 (.258)
Distance Ports Entry (log)		-0.107 (.052)
Temples or Spiritual Sites		0.190 (.209)
Observations	778	778
Adjusted R-squared	.444	.447
Fixed effects (region)	Yes	Yes

The dependent variable is (the log of) the number of commercial sex workers. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses.

Table A3: Relationship Between U.S. Military Bases and Sex Industry (1990) – Sensitivity to Covariates, Specification (S1).

Sex workers (1990)	(1)	(2)	(3)	(4)	(5)	(6)
U.S. Base (less 0h30)	1.635 (.366) [.742]	1.231 (.368) [.558]	1.386 (.298) [.628]	1.460 (.264) [.662]	1.476 (.254) [.669]	1.366 (.263) [.619]
Observations	778	778	778	778	764	764
Adjusted R-squared	.420	.487	.462	.472	.472	.473
Fixed effects	No	Province	Region	Region	Region	Region
Controlling for...						
Network	No	No	Yes	Yes	Yes	Yes
Amenities	No	No	No	Yes	Yes	Yes
Agriculture (1960)	No	No	No	No	Yes	Yes
Labor supply	No	No	No	No	No	Yes

The dependent variable is (the log of) the number of commercial sex workers. The unit of observation is a district. Standard errors, clustered at the closest U.S. or unused Thai base, are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include dummies for presence of railways (1954), presence of a major road (1954), coastal districts, a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population. The set of network controls add distance to port of entry (minor or major), presence of a spiritual site and latitude/longitude. The set of controls for amenities include dummies for the presence of natural parks, tourist beaches, zoos and safaris, and museums. *Agriculture (1960)* is the share of working-age population working in agriculture in 1960, and *Labor supply* includes migration inflows between 1984 and 1989, and the provincial minimum wage in 1990.

Table A4: Sensitivity with Other Census Waves: 1992, 1995, 2010, 2012 – Specification (S1).

Sex workers	1992	1995	2010	2012
U.S. Base (less 0h30)	1.459 (.279)	1.763 (.320)	1.294 (.542)	1.154 (.433)
Observations	778	724	754	755
Adjusted R-squared	.470	.531	.312	.369
Fixed effects (province)	Yes	Yes	Yes	Yes
District controls	Yes	Yes	Yes	Yes

The dependent variable is (the log of) the number of commercial sex workers. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population.

Table A5: Sensitivity with Other Census Waves: 1992, 1995, 2010, 2012 – Specification (S2).

Second stage Sex workers (1990)	1992	1995	2010	2012
U.S. Base	2.116 (.794)	3.217 (.943)	2.809 (1.744)	2.010 (1.339)
Observations	90	87	89	89
District controls	Yes	Yes	Yes	Yes
F statistic (first stage)	13.33	13.57	13.74	13.74

The dependent variable is (the log of) the number of commercial sex workers. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include longitude, dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population. Each district is assigned a distance equals to the average over-the-air distance to active enemy bases in 1969.

Table A6: Sensitivity to Other Sex Industry Indicators – Specification (S1).

	Establishments	Formal	Informal	Males	Services
U.S. Base (less 0h30)	1.082 (.196)	.087 (.326)	2.41 (.331)	.647 (.189)	1.131 (.203)
Observations	724	724	724	724	695
Adjusted R-squared	.529	.522	.492	.099	.349
Fixed effects (province)	Yes	Yes	Yes	Yes	Yes
District controls	Yes	Yes	Yes	Yes	Yes

The dependent variable is (the log of): the number of establishments in column 1, the number of formal (resp. informal) female sex workers in column 2 (resp. column 3), the number of male sex workers in column 4, and the share of women between 18 and 30 working in the service industry in column 5 (Population Census, 2000). The first three variables are constructed from the 1995 sex industry survey. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population.

Table A7: Robustness Checks (other Control Groups) – Specification (2).

Panel A: First stage				
U.S. Base	(1)	(2)	(3)	(4)
Distance to the front		-.00209 (.00088)		-.00146 (.00039)
Observations		80		97
F statistic		15.64		14.21
Sample	Thai Bases	Thai Bases	Thai Bases	Thai Bases
Sample	Drop Bangkok	Drop Bangkok	Since 1975	Since 1975
Controls (geography)		Yes		Yes
Panel B: Second stage				
Sex workers (1990)	(1)	(2)	(3)	(4)
U.S. Base	1.042 (.585)	2.157 (.765)	1.179 (.680)	3.188 (.875)
Observations	80	80	97	97
Sample	Thai Bases	Thai Bases	Thai Bases	Thai Bases
Sample	Drop Bangkok	Drop Bangkok	Since 1975	Since 1975
Controls (geography)	Yes	Yes	Yes	Yes

The dependent variable is (the log of) the number of sex workers. The unit of observation is a district. Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. Columns 1 and 2 omit the Bangkok region from the analysis. Columns 3 and 4 add the unused Thai bases built over the period 1970-1975 in the control group. The set of geographic controls include dummies for coastal districts, presence of railways or a major road, a dummy for the provincial capital and the (log of) 1990 district population. Each district is assigned a distance equals to the average over-the-air distance to enemy bases.

Table A8: Migration Flows, Price Shocks and Distance.

Panel A: Migration outflows and price shocks				
	Men		Women 25-35	
Migration Outflows	(1)	(2)	(3)	(4)
Price Shock	.076 (.143)	-.052 (.157)	-.298 (.113)	-.362 (.123)
Observations	882	880	882	880
Region fixed effects		Yes		Yes
District controls		Yes		Yes
Panel B: Migration flows and distance				
Migration Flows (share)	(1)	(2)	(3)	(4)
Distance (kms)	-.00232 (.00024)		-.00263 (.00031)	
Distance (inverse)		.3322 (.02191)		.3526 (.0279)
Observations	2,850	2,850	2,850	2,850
R-squared	.030	.074	.024	.053

In panel A, the unit of observation is a district. The dependent variables are the share of migrants in 1984-1989 among the population of men (columns 1 and 2) and the share of migrants in 1984-1989 among the population of women 25-35 years old (columns 3 and 4). In panel B, the unit of observation is a province of origin \times a province of destination. The dependent variables are the share of migrants from a province of origin in 1984-1989 going to a certain province of destination. Robust standard errors are reported between parentheses. The set of controls include longitude, latitude and regional fixed effects.

Table A9: Relationship Between Price Shocks and the Sex Industry (1990).

Sex workers (1990)	(1)	(2)	(3)	(4)	(5)
Indirect Price Shock	-.187 (.091) [-.084]	-.372 (.159) [-.169]	-.388 (.187) [-.176]	-.369 (.161) [-.167]	-.372 (.185) [-.169]
Direct Price Shock				-.126 (.047)	
Migration (1984-1989)					.001 (.263)
Observations	778	778	778	778	778
Adjusted R-squared	.433	.479	.491	.487	.479
Fixed effects	Region	Province	Province	Province	Province
District controls	Yes	Yes	Yes	Yes	Yes
Extended controls	No	No	Yes	No	No

The dependent variable is (the log of) the number of commercial sex workers. The unit of observation is a district. The *indirect price shock* is the measure of crop price deviation interacted with the distance matrix (see measure we_d in Section 3). The *direct price shock* is the direct measure of crop price deviation for the district (see measure e_d in Section 3). Standard errors clustered at the closest U.S. or unused Thai base are reported between parentheses. Standardized effects are reported between brackets. The set of baseline controls include dummies for coastal districts, presence of railways (1954), presence of a major road (1954), a dummy for the provincial capital, the (log of) 1960 district population and the (log of) 1990 district population. Extended controls include latitude, longitude, distance to ports of entry, the shares of the different types of establishments, the minimum wage in 1990, and the usual exposure to rainfall. *Migration (1984-1989)* captures the migration inflows between 1984 and 1989.

Table A10: Risky Behavior of 21-Year-Old Military Conscripts in 1991, 1993 and 1995.

Sexual Behavior	1991	1993	1995
<i>Sexual Activity</i>			
Any	.923	.932	.872
Before Age 17	.363	.465	.420
<i>Visits to Sex Workers</i>			
Ever	.815	.807	.638
In Past Year	.571	.443	.238
<i>Sexual Activity with Others</i>			
With Girlfriend	.231	.271	.281
With Male Partner	.028	.038	.048
Observations	1819	1667	821

This table presents descriptive statistics from a survey of military conscripts in 1991, 1993 and 1995 (Nelson et al. 1996).

C. Appendix – S-I model

This appendix complements Section 5, and provides some details about the derivations of underlying parameters from the equations characterizing the steady-state, and the equations commanding HIV propagation when there are some spatial spillovers.

Steady-state characterization At the steady-state, we have $\dot{h}_C^k = 0$, $\dot{h}_F^k = 0$ and $\dot{h}_M^k = 0$. Using equations (Dm), (Dc) and (Df), we obtain:

$$\pi_C^k = \frac{\ln\left(1 - \frac{\delta h_C^k}{(1-h_C^k)}\right)}{\ln(1 - v_C h_M^k)}$$

$$\pi_F^k = \frac{\ln\left(1 - \frac{\delta h_F^k}{(1-h_F^k)}\right)}{\ln(1 - v_F h_M^k)}$$

$$\rho_C^k = \frac{\ln\left(1 - \frac{\delta h_M^k}{(1-h_M^k)}\right) - \rho_F \ln(1 - v_F h_F^k)}{\ln(1 - v_C h_C^k)}$$

These equations allow to separately set the annual contact rates $(\pi_C^k)_{k \in \{1, \dots, K\}}$ of *type-C* sellers, the annual contact rates $(\pi_F^k)_{k \in \{1, \dots, K\}}$ of *type-F* sellers and the contact rates (with *type-C* sellers) for buyers $(\rho_C^k)_{k \in \{1, \dots, K\}}$ in order to match exactly HIV prevalences $(h_M^k, h_C^k, h_F^k)_{k \in \{1, \dots, K\}}$.

Spatial spillovers In order to account for spatial spillovers, we allow a fraction $\varepsilon_{k,j}$ of buyers in district k to seek sexual partnership in district j (May and Anderson 1984, Kremer and Morcom 1998).³⁸ We assume, as in gravity models, that $\varepsilon_{k,j}$ depends on geographical distance between k and j , and we set $\varepsilon_{k,j} = \bar{\varepsilon}$ for the three nearest neighboring provinces denoted (j_1^k, j_2^k, j_3^k) and 0 for the others.

Letting (h_C^k, h_F^k, h_M^k) denote the type-specific HIV prevalence rates, the evolution of

³⁸As in May and Anderson (1984), Kremer and Morcom (1998), we allow the HIV transmission rate to differ between intra-location and inter-location partnerships.

HIV prevalence among *type-M* in location k is characterized by:

$$\begin{aligned} \dot{h}_M^k &= -\delta h_M^k + (1 - \varepsilon)(1 - h_M^k) \left[1 - (1 - v h_F^k)(1 - v h_C^k)^{\rho^k} \right] \\ &\quad + \frac{\varepsilon}{3} \sum_{j=j_1^k, j_2^k, j_3^k} (1 - h_M^k) \left[1 - (1 - v h_F^j)(1 - v h_C^j)^{\rho^j} \right] \end{aligned}$$

The evolution of HIV prevalence among *type-C* in location k is characterized by:

$$\begin{aligned} \dot{h}_C^k &= -\delta h_C^k + (1 - \varepsilon)(1 - h_C^k) \left[1 - (1 - v h_M^k)^{\pi_C^k} \right] \\ &\quad + \frac{\varepsilon}{3} \sum_{j=j_1^k, j_2^k, j_3^k} \left[(1 - h_C^k)(1 - (1 - v h_M^j)^{\pi_C^j}) \right] \end{aligned}$$

The evolution of HIV prevalence among *type-F* in location k is characterized by:

$$\begin{aligned} \dot{h}_F^k &= -\delta h_F^k + (1 - \varepsilon)(1 - h_F^k) \left[1 - (1 - v h_M^k)^{\pi_F^k} \right] \\ &\quad + \frac{\varepsilon}{3} \sum_{j=j_1^k, j_2^k, j_3^k} \left[(1 - h_F^k)(1 - (1 - v h_M^j)^{\pi_F^j}) \right] \end{aligned}$$

At the steady-state, we have $\dot{h}_C^k = 0$, $\dot{h}_F^k = 0$, $\dot{h}_M^k = 0$ for all provinces, which generates $3 \times K$ equations for $3 \times K$ unknowns $(h_M^k, h_C^k, h_F^k)_{k \in \{1, \dots, K\}}$.