# Endogenous Immigration Behavior and Effects of Immigration Policies

Shiyun Zhang*

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**Abstract**

Immigration becomes an important topic that policy makers are concerned in the recent decades. This paper studies the motivation of immigrants move from their home countries to the host countries by using a two-country labor search and matching model. It shows that the labor mobility between developed and developing countries are double direction. It finds that skilled immigrants moves from developing countries to developed countries for better social security, while the ones move from developed countries to developing countries is for higher human capital return. There is no unskilled workers move from developed countries to developing countries. Subsidizing firms that hiring native workers in developed countries makes labor market outcomes better off but attracts more immigrants. Taxing firms that hire foreign workers in developed countries increases unemployment rate and makes the labor market in developed countries less attractive. Taxing immigrants from developing countries helps to reduce the population of immigrants. Subsidising skilled workers from developed countries can help to attracting skilled immigrants from developed countries to developing countries.

Key words: immigration, labor mobility, unemployment, search and matching

JEL code: E2, J61, J64, J68, J82

*Department of Economics and Business Economics, Aarhus University

# 1 Introduction

Thank to the technology in this modern society, the cost of relocation becomes cheaper. The reduction of moving cost makes workers relocate more frequently nowadays than in the past. This increasing global labor mobility becomes an important subject, and the public is concerned about how to control this labor movement, especially the coming immigrants, and how they affects the local labor market. A lot of literature has analyzed how immigrants affect the labor market in the host country but the results are not conclusive. For example, Borjas (2003; 2005) finds that immigration reduces natives' wages, but Ottaviano and Peri (2012) and Peri et al. (2015) provide evidence of the opposite effect.

Most literature assumes that the stock of immigrants is exogenous. They focus on the effects of immigration on the labor market outcomes when the stock of immigrants increases. In fact, the stock of immigrants depends on the migration behavior of workers endogenously and is highly related to the labor market conditions, especially incomes and unemployment rates. Greenwood (1969) provides evidence that income and unemployment significantly affect people's migration. In addition, the United Nations population data displays flows into and out of a country. For example, there are about 363,000 US-born workers in Canada and about 1 million Canadians live in the US. There are about 1 million Mexicans in the United States and about 669,000 Americans in Mexico in 2015. The local labor market is affected by both population inflows and outflows. To study the effects of immigration on the labor market outcomes, the migration behavior of workers cannot be ignored.

This paper studies effects of immigration policy on labor market outcomes by modeling the migration behavior in frictional labor markets. The migration behavior of workers is endogenous, which depends on the labor market conditions of the home and foreign countries. In this model, there are two countries and two skill-bias labor markets. All workers are able to search and immigrate to the other country legally. Country 1 has many high-skilled workers and good social security system (e.g. the U.S.). Country 2 has few low-skilled workers and bad social security system (e.g. Mexico). When skilled workers stay in the country of

origin, they are able to search in the skilled and unskilled labor markets. Unskilled workers cannot search in the skilled labor market, since they cannot achieve the skill requirements of the skilled labor market, for example, the requirement of college degrees. Skilled and unskilled workers can also choose to emigrate to the other country when a migration opportunity arrives. The migration opportunity comes with a heterogenous migration cost. This migration cost includes relocation and search costs, and the benefits that workers give up in their home country. Workers observe the surplus of immigration, by comparing the value of searching in the foreign country with the migration cost and the value of staying in their home country. If the surplus is positive, workers search and migrate to the foreign country. Skilled workers from either country 1 or country 2 may emigrate to the other country while unskilled workers only emigrate from country 2 to country 1 at the steady state equilibrium.

The model is calibrated to the labor market data in the U.S. and Mexico in 2010. It predicts that about 0.5% of skilled workers in Mexico come from the US, 2% of skilled workers in the US come from Mexico, and 3% of unskilled Mexican work in the US. There is no unskilled US-born worker in Mexico. I introduce four immigration policy examples in the United States and in Mexico that are able to apply in this model. Subsidizing firms in the United States that hire US-born workers encourages more firms to enter into labor markets in the United States. Therefore the market tightnesses in skilled and unskilled labor markets in the United States increase. This policy decreases the unemployment rate in the United States. The wage of skilled workers in the US decreases while the wage of unskilled workers in the US increases. The labor markets in the US attract more workers from Mexico. Taxing firms in the United States that hire Mexicans decreases the labor market tightness in the skilled labor market in the US. More skilled workers works in the unskilled labor market since the skilled labor market is weak. The unskilled labor market tightness is ambiguous because the skilled workers increase the expected surplus of a match while the taxation decreases this surplus in the unskilled labor market. The labor markets in the U.S. become less attractive to Mexicans so that fewer Mexicans move to the US. Taxing

Mexican immigrants that move to the US increases the migration cost of Mexicans and discourages Mexican immigrants to move to the US. When there are fewer Mexicans in the labor markets in the US, the expected surplus of a match in the United States decreases. As a result, the wages decreases and the unemployment rate increases in the US labor markets. The Mexican government subsidizes US-born skilled workers to immigrate to Mexico because these workers have high productivity. This subsidy increases the share of US-born skilled workers in Mexico, so the expected surplus of a match in Mexico increases. When the match surplus in Mexico increases, the value of migration of Mexicans decreases. The wages of Mexicans and unemployment rates in Mexico are analytically ambiguous. Quantitatively, the wages of Mexicans decrease and the unemployment rates in Mexican labor markets increase.

This paper is the first one that captures double-direction immigration flows between two countries. Chassamboulli and Peri (2015) and Ortega (2000) endogenize migration behavior with two-country search and matching framework. Chassamboulli and Peri (2015) study the effects of illegal immigrants from Mexico on labor market outcomes in the United States. They assume that no US-born workers move to Mexico and only unskilled Mexicans emigrate to the United States. US-born workers cannot search across markets or countries. My paper releases these assumptions that US-born workers are allowed to search across markets or countries with a heterogenous migration cost. Ortega (2000) assumes that all workers search in the other country when the job duration is longer in that country than their country of origin. My paper introduce heterogenous migration opportunities that workers can choose to emigrate or to stay in their own country. With the model in this paper, the effects of immigration polices on labor market outcomes and the population of immigrants are trackable.

Other papers that studies effects of immigration with frictional labor market assume that immigration is an exogenous variable. Chassamboulli and Palivos (2014) introduce imperfect substitution with skilled-bias labor markets to show that immigration benefit native workers

from wages and employments. Liu (2010) shows that an increase in illegal immigrants generate a significant social welfare gain. Liu et al. (2017) introduces mismatch and imperfect transferability of foreign human capital in the search and matching labor market model with immigrants. They shows that with the increase of immigrants in 2000 to 2009 in the United States, all workers in the US gain in terms of income and employment.

The paper describes two skill-bias frictional labor markets within two countries in section 2 and 3. The steady state equilibrium of the model is recursively solved in section 4. In steady state equilibrium, skilled workers move into and out of the US and Mexico simultaneously while there is only unskilled Mexican immigrants move to the US and unskilled US-born workers stay in the United States. Section 5 calibrates the model by using the US and Mexico labor market data in 2010. Some immigration policy effects on labor market outcomes are discussed in section 6. Section 7 concludes.

# 2 Model

Time is continuous. Firms and workers are risk neutral and discount the future value at a rate $r$. There are two countries in this economy. I consider country 1 as a developed country and country 2 as a developing country. In each country, there are skilled and unskilled workers. Country 1 has higher technology than country 2. Country 1 has more high skilled workers while country 2 has fewer high skilled workers and more unskilled workers. Unemployed workers in country 1 have higher unemployment benefit than in country 2. Skilled (unskilled) workers search in skilled (unskilled) labor market only in both countries. There is no on the job search. All workers legally search across countries.

## 2.1 Production

In both countries, there are two production sectors, final good sector and intermediate good sector. Firms in final good sector produce final goods by using intermediate goods. Both

final goods and intermediate goods are sold in a complete market. Final good firms in country $i$ maximize their profit,

$$\begin{aligned} &\max\ Y_i - p_i^H Y_i^H - p_i^L Y_i^L \\ &s.t.\ Y_i = A_i[\alpha(Y_i^H)^\rho + (1-\alpha)(Y_i^L)^\rho]^{1/\rho}, \end{aligned} \tag{1}$$

where $Y_i$ is the production of final good, $p_i^H$ is the price of skilled intermediate goods $Y_i^H$, and $p_i^L$ is the price of unskilled intermediate goods $Y_i^L$. The production function of final goods follows a CES production function with imperfect substitution between skilled and unskilled intermediate goods, where $A_i$ represents the technology in country $i$, $\alpha$ represents the importance of skilled intermediate goods and $\rho$ is a parameter of substitution. According to the first order condition of the maximization problem with respect to intermediate goods, the price of intermediate goods are follows,

$$\begin{aligned} p_i^H &= \alpha A_i \left[\alpha + (1-\alpha)\left(\frac{Y_i^L}{Y_i^H}\right)^\rho\right]^{\frac{1-\rho}{\rho}} \\ p_i^L &= (1-\alpha) A_i \left[\alpha\left(\frac{Y_i^H}{Y_i^L}\right)^\rho + (1-\alpha)\right]^{\frac{1-\rho}{\rho}}. \end{aligned}$$

Intermediate good firms hire workers from a frictional labor market to produce intermediate goods. To simplify the model, I assume that each individual employee produces one unit of intermediate good according to her skill level, such that,

$$Y_i^\kappa = E_i^\kappa$$

where $E_i^\kappa$ represents the measure of employment in country $i$ with skill $\kappa \in \{H, L\}$.

## 2.2 Labor markets

Firms in intermediate good sectors enter the labor market and search in the labor market in either skilled or unskilled labor market. The search frictions in labor markets cause unemployment. The number of matches in the high (low) skilled labor market in country $i$ follows a match function, $M_i^\kappa = m(V_i^\kappa, U_i^\kappa)$ where $V_i^\kappa$ is the number of vacancies and $U_i^\kappa$ is the number of unemployed workers in $\kappa$-skilled labor market in country $i$. All firms in this model are small firms and each of them only has one job, vacant or filled. They can post a vacant job freely in either skilled or unskilled labor market in the country $i$ that they locate. Firms are not able to move. When firms post a vacant job, they pay a constant recruitment cost $k^\kappa$. They match with a worker at a rate $q(\theta_i^\kappa) = M_i^\kappa / V_i^\kappa$. When firms and workers match with each other, they start producing. Firms receive $p_i^\kappa$ by selling the intermediate goods to the final good producer. An unemployed worker matches with a firm at a Poisson rate $f(\theta_i^\kappa) = M_i^\kappa / U_i^\kappa$, where tightness $\theta_i^\kappa$ is defined as the vacancy-unemployment ratio in the $\kappa$-skilled labor market in country $i$, i.e. $\theta_i^\kappa \equiv V_i^\kappa / U_i^\kappa$. Skilled (unskilled) unemployed workers match with a firm in skilled (unskilled) labor market at rate $f(\theta_i^H)$.

# 3 Bellman equations

This section decribes the bellman equations of each agent in this model with details.

## 3.1 Workers

The value of employed workers with skilled $\kappa$ who were born in country $i$ and work in country $j$ is denoted as $\mathcal{W}_{ji}^\kappa$, and the value of unemployed workers is $\mathcal{U}_{ji}^\kappa$.[1] If $i = j$, the worker was born in country $i$ and stay in country $i$. The employed stayer receives wages $w_{ii}^\kappa$ and separates with the firm at rate $s^\kappa$. The unemployed stayer receives a flow of unemployment benefit

[1] The first digit of the subscript represents the job location of the worker. The second digit of the subscript represents the country of birth of the worker.

$b_i^\kappa$. She is able to search in the domestic labor market and the foreign labor market via the internet. The unemployed stayer matches a domestic firm in country $i$ at rate $f(\theta_i^\kappa)$, or a foreign firm in country $j$ at rate $f(\theta_j^\kappa)$. When she matches a foreign firm, she calculates if the capital gain of being employed in a foreign country $\mathcal{W}_{ji}^\kappa - \mathcal{U}_{ii}^\kappa - c$ is greater than zero, where $c$ is the moving cost to a foreign country. If the capital gain of moving is greater than zero, the worker moves to country $j$ instead of staying in country $i$. The bellman equations of skilled workers who were born in country $i$ and work in country $i$ are

$$r\mathcal{W}_{ii}^\kappa = w_{ii}^\kappa - s^\kappa(\mathcal{W}_{ii}^\kappa - \mathcal{U}_{ii}^\kappa) \tag{2}$$

$$\begin{aligned} r\mathcal{U}_{ii}^\kappa &= b_i^\kappa + f(\theta_i^\kappa)(\mathcal{W}_{ii}^\kappa - \mathcal{U}_{ii}^\kappa) \\ &+ f(\theta_j^\kappa)\int_0^\infty \max\{\mathcal{W}_{ji}^\kappa - \mathcal{U}_{ii}^\kappa - c, 0\}dF(c) \end{aligned} \tag{3}$$

If she decides to move to country $j$, she receives the wage $w_{ji}^\kappa$ in country $j$. Similarly, the employed immigrant separates with her employer at rate $s^\kappa$. Additionally, she has to return to country $i$ at an exogenous rate $d$ as an unemployed workers. If the immigrant separates with her employer, she becomes unemployed and receives a flow of unemployment benefits $b_j^\kappa$. Meanwhile, the immigrant searches more intensively than native workers in country $j$. The more intensive job search costs some leisure from the immigrants. She matches a firm at rate $f(\theta_j^\kappa)$ but has to return at rate $d$. When the worker decides to move in country $j$, the bellman equations are as follows,

$$r\mathcal{W}_{ji}^\kappa = w_{ji}^\kappa - s^\kappa(\mathcal{W}_{ji}^\kappa - \mathcal{U}_{ji}^\kappa) - d(\mathcal{W}_{ji}^\kappa - \mathcal{U}_{ii}^\kappa) \tag{4}$$

$$r\mathcal{U}_{ji}^\kappa = b_j^\kappa - l_i^\kappa + f(\theta_j^\kappa)(\mathcal{W}_{ji}^\kappa - \mathcal{U}_{ji}^\kappa) - d(\mathcal{U}_{ji}^\kappa - \mathcal{U}_{ii}^\kappa). \tag{5}$$

## 3.2 Firms

Firms in country $i$ can post a vacancy and match with a worker in either the skilled labor market or the unskilled labor market. The value of a vacant job is denoted as $\mathcal{V}_i^\kappa$ and the value of a filled job as $\mathcal{J}_{ij}^\kappa$, where the first digit of the subscription represents the location of the firm and the second digit represents the country that the employee was born. The firm posts a vacancy in market $\kappa$ with a recruitment cost $k^\kappa$. It matches a worker in the labor market and fills the vacancy at rate $q(\theta_i^\kappa)$. Before matching, the firm does not know the immigration status of the worker, but knows the distribution of foreign workers and native workers. Therefore, the firm has an expectation of a filled job. If the firm matches a native worker, the value of the filled job is $\mathcal{J}_{ii}^\kappa$. The firm receives the price of intermediate good that the worker produces and sells to the final good producer. It pays wage $w_{ii}^\kappa$ to the native worker. At rate $s^H$ the firm and its employee separate and the job becomes vacant again. If the firm matches a foreign worker, it pays wage $w_{ij}^\kappa$ and the effective separation rate includes the return rate $d$ of the foreign worker. Other factors are the same as matching a native worker. The bellman equations of the firm are following,

$$r\mathcal{V}_i^\kappa = -k^\kappa + q(\theta_i^\kappa)(\mathbb{E}\mathcal{J}_i^\kappa - \mathcal{V}_i^\kappa) \tag{6}$$

$$r\mathcal{J}_{ii}^\kappa = p_i^\kappa - w_{ii}^\kappa - s^\kappa(\mathcal{J}_{ii}^\kappa - \mathcal{V}_i^\kappa) \tag{7}$$

$$r\mathcal{J}_{ij}^\kappa = p_i^\kappa - w_{ji}^\kappa - (s^\kappa + d)(\mathcal{J}_{ji}^\kappa - \mathcal{V}_i^\kappa). \tag{8}$$

Firms can observe the unemployed workers' distribution in the market. The expected value of a filled job is $\mathbb{E}\mathcal{J}_i^\kappa = (U_{ii}^\kappa/U_i^\kappa)\mathcal{J}_{ii}^\kappa + (U_{ij}^\kappa/U_i^\kappa)\mathcal{J}_{ij}^\kappa$. The total unemployment in the market $\kappa$ in country $i$ is $U_i^\kappa = U_{ii}^\kappa + U_{ij}^\kappa$, which represents the sum of skilled unemployed workers from country $i$ and $j$.

The wages are determined by Nash bargaining. The bargaining power of workers is denoted as $\beta$. Workers and firms decide the match surplus by their bargaining power. If workers stay in their country of origin and work in the market that match with their skill, the

surplus of workers is $\mathcal{W}_{ii}^{\kappa} - \mathcal{U}_{ii}^{\kappa}$. If workers move to the other country, their surplus becomes $\mathcal{W}_{ij}^{\kappa} - \mathcal{U}_{ij}^{\kappa}$. Similarly, firms' surplus in $\kappa$-skilled labor market in country $i$ is $\mathcal{J}_{ii}^{\kappa} - \mathcal{V}_{i}^{\kappa}$ if firms match with a worker who was born in the same country. If they match with a worker comes from the other country, the surplus of a filled job is $\mathcal{J}_{ji}^{\kappa} - \mathcal{V}_{i}^{\kappa}$. If firms are in the unskilled labor market, they may match with a skilled worker who was born in the same country as the location of the firm. Hence the surplus of firms that mismatch with a skilled worker is $\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{H}$. The surplus maximization problems of $\kappa$-skilled workers who were born in country $i$ or $j$ and work in country $i$ are written as follows,

$$w_{ii}^{\kappa} = \arg\max(\mathcal{W}_{ii}^{\kappa} - \mathcal{U}_{ii}^{\kappa})^{\beta}(\mathcal{J}_{ii}^{\kappa} - \mathcal{V}_{i}^{\kappa})^{1-\beta} \tag{9}$$

$$w_{ji}^{\kappa} = \arg\max(\mathcal{W}_{ji}^{\kappa} - \mathcal{U}_{ji}^{\kappa})^{\beta}(\mathcal{J}_{ji}^{\kappa} - \mathcal{V}_{i}^{\kappa})^{1-\beta} \tag{10}$$

$$w_{ii}^{HL} = \arg\max(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H})^{\beta}(\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{L})^{1-\beta}. \tag{11}$$

When skilled workers search in the unskilled labor market, their productivity is higher than unskilled workers but lower than when they work with a skilled job. If skilled workers work with an unskilled job, the value of this job should be at least the same as the unemployment value of skilled workers, i.e. $\mathcal{W}_{ii}^{HL} \geq \mathcal{U}_{ii}^{H}$. Otherwise, no skilled workers search in the unskilled labor market. Proposition 1 concludes the condition of the existence of mismatch.

**Proposition 1.** *Mismatch of skilled workers in unskilled labor market exists if*

$$\frac{r + s^{H} + \beta f(\theta_{i}^{H})}{r + s^{H}} y_{ii}^{HL} \geq \frac{\beta f(\theta_{i}^{H})}{r + s^{H}} y_{ii}^{H} + b_{ii}^{H} + \mu_{i} \int_{0}^{\bar{c}_{i}^{H}} F(c)dc..$$

The proof of Proposition 1 is in the appendix.

## 3.3 Reservation migration cost

When the migration opportunity arrives, workers can accept the opportunity and pay the one-time cost of migration, or reject this opportunity and stay in the country that they were

born. This one-time cost of migration includes the cost of relocation, the opportunity cost of moving out of the original country, and the discounted present value of the flow of search cost in the foreign country. When the worker moves to the other country, she loses her benefit in her country of origin and suffers some hardships in the new country. Therefore when she moves, the new country needs to compensate her equal or more than her cost. If the cost of migration is equal to the compensation from the new country, this cost is the reservation cost of migration. If the cost of migration is higher than the reservation, workers reject the opportunity and stay in the country of origin. If this is not the case, they migrate to the new country. The determination of this reservation cost is the comparison between the value of unemployment in the other country and in the country of origin. Intuitively, if migration costs more than the worker can gain, then she rejects the migration opportunity. Therefore, the reservation migration cost is

$$\bar{c}_i^{\kappa} = \max\{\mathcal{U}_{ij}^{\kappa} - \mathcal{U}_{ii}^{\kappa}, 0\}. \tag{12}$$

The reservation cost is non-negative. When $\bar{c}_i^{\kappa} = 0$, there is no worker with skill $\kappa$ emigrates from country $i$.

# 4 Equilibrium

The equilibrium is determined by the equality between the average cost of a match and the expected revenue from a match. This equality is given by the job creation condition, according to the free entry condition of vacancy, $\mathcal{V}_i^{\kappa} = 0$. In the unskilled labor market in country $i$, the job creation condition is written as

$$\frac{k^L}{q(\theta_i^L)} = \frac{U_{ii}^H}{U_i^L + U_{ii}^H}\mathcal{J}_{ii}^{HL} + \frac{U_{ii}^L}{U_i^L + U_{ii}^H}\mathcal{J}_{ii}^{L} + \frac{U_{ji}^L}{U_i^L + U_{ii}^H}\mathcal{J}_{ji}^{L}. \tag{13}$$

According to the environment of the model, there are three types of workers search in the unskilled labor market: skilled and unskilled workers who were born in country $i$ and unskilled workers who were born in country $j$. Similarly, the job creation condition of the skilled labor market in country $i$ is

$$\frac{k^H}{q(\theta_i^H)} = \frac{U_{ii}^H}{U_i^H}\mathcal{J}_{ii}^H + \frac{U_{ji}^H}{U_i^H}\mathcal{J}_{ji}^H \tag{14}$$

At the steady state, the flows into and out of employment and unemployment are equal to each other.

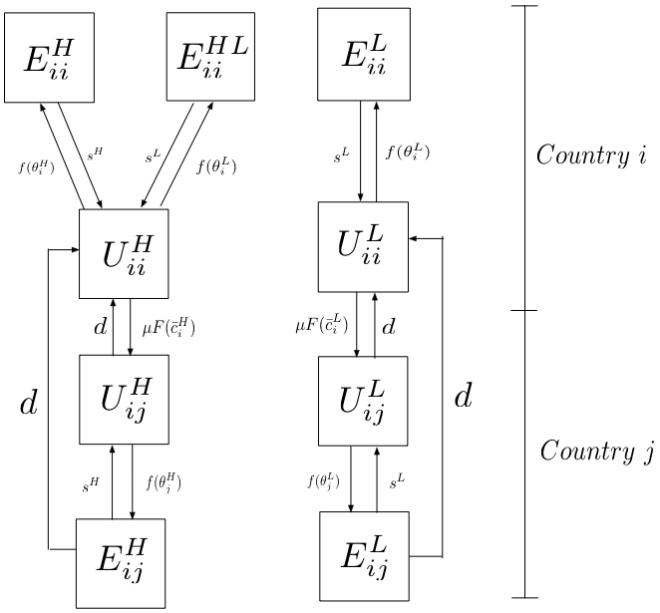


Figure 1: Workers flows

According to figure 1, the flows into and out of each country equal each other, i.e. $\mu F(\bar{c}_i^\kappa)U_{ii}^\kappa = d(E_{ii}^\kappa + U_{ii}^\kappa)$. In country $i$, the flows into skilled unemployment are employed workers lose their jobs in skilled and unskilled market, and the returned workers from country $j$. The flows out of skilled unemployed workers are workers who get a job in the skilled or unskilled labor market, and workers who decide to search in country $j$. For unskilled unemployment, the inflows are the unskilled employees who lose their jobs and the workers return from country $j$. The outflows of unskilled unemployment in country $i$ are workers who get a job and the ones who decide to search in the unskilled labor market in country $j$.

In country $j$, the flows into the skilled (unskilled) unemployment are workers coming from country $i$ and the ones who lose their jobs. The flows out of the skilled (unskilled) unemployment are workers who get a job and the ones who return to country $i$. The following equations show the equality of flows into and out of employment and unemployment,

$$H_i = E_{ii}^H + E_{ii}^{HL} + U_{ii}^H + E_{ij}^H + U_{ij}^H \tag{15}$$

$$1 - H_i = E_{ii}^L + U_{ii}^L + E_{ij}^L + U_{ij}^L \tag{16}$$

$$d(E_{ij}^\kappa + U_{ij}^\kappa) = \mu F(\bar{c}_i^\kappa) U_{ii}^\kappa \tag{17}$$

$$s^\kappa E_{ij}^\kappa = f(\theta_j^\kappa) U_{ij}^\kappa \tag{18}$$

$$[f(\theta_i^H) + f(\theta_i^L) + \mu F(\bar{c}_i^H))] U_{ii}^H = s^H E_{ii}^H + s^L E_{ii}^{HL} + d(E_{ij}^H + U_{ij}^H) \tag{19}$$

$$[f(\theta_i^L) + \mu F(\bar{c}_i^L)] U_{ii}^L = s^L E_{ii}^L + d(E_{ij}^L + U_{ij}^L). \tag{20}$$

With this system of equations, the steady state equilibrium is defined as a set of variables: the market tightness in skilled and unskilled labor market, the distribution of workers, and the reservation migration cost.

**Definition 1.** The steady state equilibrium in country $i$ is a set of variables, $\{\theta_i^H, \theta_i^L, U_{ii}^\kappa, E_{ii}^\kappa, U_{ji}^\kappa, E_{ji}^\kappa, E_{ii}^{HL}, \bar{c}_i^\kappa\}$ for all $i \neq j \in \{1, 2\}$, $\kappa \in \{H, L\}$, such that: $\theta_i^H$ satisfies (14); $\theta_i^L$ satisfies (13); $\{U_{ii}^\kappa, E_{ii}^\kappa, U_{ji}^\kappa, E_{ji}^\kappa, E_{ii}^{HL}\}$ satisfy (15) – (20); $\bar{c}_i^\kappa$ satisfies (12).

The equilibrium in country $i$ is recursively solvable. Given any certain $\theta_i^\kappa$, the workers distribution at steady state is solved by equations (15) to (20). The wage is determined by equation (9) to (11). The reservation migration cost is given by (12). At the end, (13) and (14) solve the equilibrium labor market tightness in $\kappa$-skilled labor market in country $i$. The solution of wages, unemployment and the reservation costs are presented in the appendix.

At the steady state, some of skilled workers in both country 1 and country 2 may migrate simultaneously but the flows of unskilled immigrants are only from country 2 to country 1. According to the assumption in this economy, skilled workers from country 1 have high productivity than skilled worker from country 2, even though they are in country 2. When

these skilled workers move to country 2, their unemployment benefit is relatively lower than when they are in country 1. Therefore, the surplus of a skilled job in country 2 with a skilled worker from country 1 can be high enough to compensate the migration cost of skilled workers from country 1. For unskilled workers from country 1, they have high productivity and unemployment benefit in country 1 so that the compensation is not high enough to motivate them to relocate to country 2. Unskilled workers in country 2 benefit from the high productivity and unemployment benefit so that they are willing to move to country 1 and gain more from the match in country 1. Therefore, the

**Proposition 2.** *At steady state,*

*i)* $\bar{c}_1^H > 0$ *if*

$$\frac{\beta f(\theta_2^H) y_{12}^H + (r + s^H + d) b_{12}^H}{r + s^H + d + \beta f(\theta_2^H)} > \frac{b_{11}^H + \beta f(\theta_1^H) y_{11}^H/(r + s^H) + \beta f(\theta_1^L) y_{11}^L/(r + s^L) + \mu_1 \int_0^{\bar{c}_1^H} F(c)dc}{1 + \beta f(\theta_1^H)/(r + s^H) + \beta f(\theta_1^H)/(r + s^L)}; \quad (21)$$

*ii)* $\bar{c}_2^H > 0$*;*

*iii)* $\bar{c}_1^L = 0$*;*

*iv)* $\bar{c}_2^L > 0$.

# 5 Calibration

The parameter value in the model is calibrated to the labor market data in the United States and Mexico. Assume that country 1 represents the U.S. and country 2 represents Mexico. All parameters are presented monthly. The population in the U.S. is normalized to 1 so that the population in Mexico is 1/3. According to Krusell et al. (2000), skilled workers are defined as workers with at least a college degree, and unskilled workers are defined as worker without any college education. According to IPUMS International 2010 in the U.S. and in Mexico, the measure of skilled worker is 0.3144 in the US and 0.0265

in Mexico. The productivity gap between skilled and unskilled workers targets the wage premium of education. In the US, the productivity of skilled workers who were born in the U.S. is normalized to 1 and the productivity of US-born unskilled workers is 0.4699. The productivity of mismatched US-born skilled worker is 0.7143. The mismatch productivity targets the wage gap between skilled US-born workers with and without professional jobs in the US. There is also a productivity gap between workers who are from the US and from Mexico. The productivity gap between two countries targets to the gap of the total factor productivity between two countries. Therefore, the productivity of Mexico-born skilled workers is 0.6944 and the productivity of unskilled Mexicans is 0.1968. The productivity of mismatched skilled Mexican workers is 0.1240, which targets the wage gap between skilled Mexican workers with and without professional jobs. The productivity of mismatch workers in Mexico is too low so that the model rules out the mismatch in Mexico. Because US-born skilled workers have better education than Mexican skilled worker, the productivity of US-born skilled workers in Mexico is 0.9561, which targets the wage gap between US-born and Mexican skilled workers. Mexican skilled and unskilled workers have the same productivity as US-born skilled and unskilled workers when they work in the US. The US-born unskilled workers in Mexico also have the same productivity as Mexican unskilled workers. From IPUMS International U.S. data in 2010, the wage gap between skilled U.S. and Mexican workers is -0.4305. The unemployment benefit in the U.S. is 71% to the employment income from Hall (2005). Therefore, the unemployment benefit is 0.7345 for US skilled workers and 0.5134 for Mexican skilled workers in the US. The unemployment benefit in Mexico is 40% of the employment income, assuming that it is equal to the lower bound of the US unemployment benefit from Shimer (2005). Therefore, the unemployment benefit of skilled and unskilled Mexicans are 0.2397 and 0.0774 respectively. The unemployment benefit of US-born skilled and unskilled workers in Mexico targets the wage gap between U.S. and Mexican unskilled workers in Mexican. As a result, the unemployment benefit of U.S.-born skilled and unskilled workers in Mexico is 0.2397 and 0.0774 respectively.

The matching function follows Petrongolo and Pissarides (2001), which is $m(V_i^H, U_i^H) = A(V_i^H)^{1-\alpha}(U_i^H)^{\alpha}$ for skilled labor market and $m(V_i^L, U_i^L + U_{ii}^H) = A(V_i^L)^{1-\alpha}(U_i^L + U_{ii}^H)^{\alpha}$. The unemployment elasticity of the matching function $\alpha$ is 0.5 from Petrongolo and Pissarides (2001). The bargaining power of workers $\beta$ is 0.5, which satisfies Hosios (1990) condition. The value of the exogenous departure rate, separation rates in the skilled and unskilled labor markets, and the labor market tightnesses in both countries are from Chassamboulli and Peri (2015), which are 0.0023, 0.024, 0.032, and 0.62 respectively. The matching technology $A$ targets the employment rate in the US, which is 0.9520 in the skilled labor market and 0.8743 in the unskilled labor market. As a result, the matching technology $A$ is equal to 0.3501. The constant recruitment cost in the skilled and unskilled labor market are 0.6906 and 0.0630, which are calibrated to the job creation conditions in the U.S., (14) and (13) when $i = 1$. At the end, the arrival rate of migration opportunity $\mu_1$ is $8.04 \times 10^{-5}$ for the US-born workers, and $\mu_2$ is $1.86 \times 10^{-4}$ for the Mexicans, which matches the flows of workers between Mexico and the US.

# 6 Discussion: immigration policy examples

Policy maker may consider to attract or decrease the population of immigrant in the United States or Mexico. This section discusses three immigration policy examples to control the population of immigrants within both countries.

## 6.1 Subsidy of firms in the US

The US government can subsidize firms in the United States when they hire US-born workers because policy makers in the US consider to encourage firms to hire more US-born workers. When firms in the United States match with a worker from the US, they can receive a one-

time subsidy $\gamma$ from the government. Therefore the value of vacancies in the US becomes

$$r\mathcal{V}_1^H = -k^H + q(\theta_1^H)[\frac{U_{11}^H}{U_1^H}(\mathcal{J}_{11}^H + \gamma) + \frac{U_{21}^H}{U_1^H}\mathcal{J}_{21}^H] \tag{22}$$

$$r\mathcal{V}_1^L = -k^L + q(\theta_1^L)[\frac{U_{11}^L}{U_1^L + U_{11}^H}(\mathcal{J}_{11}^L + \gamma) + \frac{U_{11}^H}{U_1^L + U_{11}^H}(\mathcal{J}_{11}^{HL} + \gamma) + \frac{U_{21}^L}{U_1^L + U_{11}^H}\mathcal{J}_{21}^L]. \tag{23}$$

When firms receive the subsidy, the expected value of a match increases. The market tightness increases when more firms enter into the labor market in the United States. The wage of unskilled workers in the US increases and the unemployment rate of the unskilled labor market in the US decreases with the unskilled labor market tightness. The wage of skilled worker in the US is ambiguous because it depends on both the skilled and unskilled labor market tightness. When the market tightness in the skilled labor market increases, the wage of skilled workers increases but decreases when the market tightness of the unskilled labor market increase. As a result, the wage of skilled workers in US slightly decreases quantitatively.

This policy also affects the labor markets in Mexico because the effects on labor market outcomes in the US affect the migration behavior of Mexicans. When the labor market tightnesses in the US go up, the reservation migration cost of Mexicans increases. This increase in the reservation migration cost drives the wages of both skilled and unskilled Mexicans to increase. According to (13), this increase in wages reduces the expected surplus of a filled job in Mexico. Therefore, the labor market tightnesses in Mexico decrease. The unemployment rates of Mexicans in skilled and unskilled labor markets are ambiguous. The decreasing market tightnesses cause an increase in the unemployment rates but the increase of reservation migration cost decreases the unemployment rates. Quantitatively, the unemployment rate in the unskilled labor market decreases while the unemployment rate of the skilled labor market in Mexico increases because the effect of decreasing market tightnesses dominates the effect of the increasing reservation migration cost.

Combining all effects of the subsidy on labor market outcomes in two countries, the

share of skilled workers in the US and Mexico increases. The share of unskilled Mexicans in the US does not change significantly and there is no US-born unskilled workers in Mexico. Proposition 3 concludes the effects of this subsidy on the labor market outcomes in the US and the labor mobility between the United States and Mexico.

**Proposition 3.** *With an increase in $\gamma$, for all $\kappa \in \{H, L\}$,*

*i) $\theta_1^\kappa$ increases;*

*ii) $\theta_2^H$ decreases, $\theta_2^L$ is ambiguous;*

*iii) $w_{11}^H$ is ambiguous, $w_{11}^L$ increases;*

*iv) $u_{11}^\kappa$ decreases;*

*v) skilled immigrants from the US to Mexico increases;*

*vi) immigrants from Mexico to the US is ambiguous.*

## 6.2 Taxation of firms in the US

The US government taxes firms that hire foreign workers to reduce firms incentives to hire foreigners. When firms match with Mexicans, they need to pay a one-time tax $\tau$. Therefore the value of vacancies of firms in the US becomes

$$r\mathcal{V}_1^H = -k^H + q(\theta_1^H)[\frac{U_{11}^H}{U_1^H}\mathcal{J}_{11}^H + \frac{U_{21}^H}{U_1^H}(\mathcal{J}_{21}^H - \tau)] \tag{24}$$

$$r\mathcal{V}_1^L = -k^L + q(\theta_1^L)[\frac{U_{11}^L}{U_1^L + U_{11}^H}\mathcal{J}_{11}^L + \frac{U_{11}^H}{U_1^L + U_{11}^H}\mathcal{J}_{11}^{HL} + \frac{U_{21}^L}{U_1^L + U_{11}^H}(\mathcal{J}_{21}^L - \tau)]. \tag{25}$$

This tax makes the expected match value lower. Fewer firms enter the skilled labor market in the US; therefore, the labor market tightness of the skilled labor market decreases. This reduction in the labor market tightness makes more skilled workers in the US match with unskilled jobs. Since skilled workers have higher productivity than unskilled workers when they are with non-professional jobs, the expected match surplus in the unskilled labor market in the US increase. As a result, the labor market tightness of the unskilled labor market is ambiguous. Similar to the effects of taxation in section 6.1, the wage of skilled workers goes

down slightly as the effects of decreasing labor market tightness in the skilled labor market dominates the effects of the unskilled labor market. The wage of unskilled workers in the US is ambiguous because the unskilled labor market tightness is ambiguous. The unemployment rate of skilled workers in the US increases with the decreasing labor market tightness. The unemployment rate of unskilled labor market is ambiguous because of the ambiguous labor market tightness of the unskilled labor market in the US.

Per the change in the labor markets in the United States, the reservation migration costs of Mexicans decrease. The decreased value of migration leads to a decrease in the wage of skilled and unskilled Mexicans. Therefore, the expected surplus of a match in Mexico increases and the labor market tightnesses in both skilled and unskilled labor markets in Mexico go up. However, the impacts on labor markets in Mexico is quantitatively small. As a result, the labor markets in Mexico do not attract US-born workers move to Mexico. The share of Mexican in the United States changes insignificantly. Proposition 4 concludes the effects of this taxation on the labor market outcomes in the US and the labor mobility between the United States and Mexico.

**Proposition 4.** *With an increase in $\tau$, for all $\kappa \in \{H, L\}$,*

*i) $\theta_1^H$ decreases, $\theta_1^L$ is ambiguous;*

*ii) $\theta_2^\kappa$ increases;*

*iii) $u_{11}^\kappa$ increases;*

*iv) $w_{11}^H$ increases, $w_{11}^L$ is ambiguous;*

*v) immigrants with skill $\kappa$ from Mexico to the U.S. are ambiguous;*

*vi) no workers move from the US to Mexico.*

## 6.3 Taxation of Mexicans in the US

Another way to control the population of Mexican immigrants is to increase their migration cost. If Mexicans decides to search in the labor market in the US, they need to pay additional fees $\phi$, such as an application fee for the working permit. Therefore the value functions of

unemployed Mexicans become

$$r\mathcal{U}_{22}^{H} = b_{22}^{H} + f(\theta_2^H)(\mathcal{W}_{22}^{H} - \mathcal{U}_{22}^{H}) + f(\theta_2^L)(\mathcal{W}_{22}^{HL} - \mathcal{U}_{22}^{H}) + \mu \int_0^\infty \max\{\mathcal{U}_{21}^{H} - \mathcal{U}_{22}^{H} - \phi - c, 0\} dF(c) \quad (26)$$

$$r\mathcal{U}_{22}^{L} = b_{22}^{L} + f(\theta_2^L)(\mathcal{W}_{22}^{L} - \mathcal{U}_{22}^{L}) + \mu \int_0^\infty \max\{\mathcal{U}_{21}^{L} - \mathcal{U}_{22}^{L} - \phi - c, 0\} dF(c). \quad (27)$$

The tax on Mexicans reduces the value of migration to the United States. This taxation discourages these Mexican workers to immigrate to the United States. Therefore, the share of Mexicans in the labor force in the United States decreases. When the share of Mexicans decreases, the expected surplus of a match in the US decreases since Mexicans provide higher surplus in the US. The labor market tightnesses of both skilled and unskilled labor markets in the US decrease. The wage of skilled workers is ambiguous and goes up slightly because the market tightness of the unskilled labor market decreases. With the decrease in the unskilled labor market tightness, the wage of unskilled workers in the US decreases and the unemployment rates of skilled and unskilled labor markets increase.

Since the labor markets in the US become less attractive, skilled workers move from the US to Mexico. The expected surplus of a skilled job in Mexico increases because these skilled workers provide higher productivity. The labor market tightness of the skilled labor market in Mexico increases. However, because the reservation costs of migration of Mexicans decrease, the wages of Mexicans in Mexico decreases and the unemployment rates of Mexicans increase quantitatively. Proposition 5 concludes the effects of this taxation on the labor market outcomes in the US and the labor mobility between the United States and Mexico.

**Proposition 5.** *With an increase in $\phi$, for all $\kappa \in \{H, L\}$,*

*i) $\theta_1^\kappa$ decreases;*

*ii) $\theta_2^\kappa$ increases;*

*iii) $u_{11}^\kappa$ increases;*

*iv)* $w_{11}^H$ *increases,* $w_{11}^L$ *decreases;*

*v) immigrants with skill* $\kappa$ *from Mexico to the U.S. decrease;*

*vi) skilled immigrants from the U.S. to Mexico increase.*

## 6.4 Subsidy of US workers in Mexico

Since US-born skilled workers have higher productivity, the Mexican government may want to attract US-born skilled workers to move to Mexico. Therefore, the Mexican government subsidizes US-born workers when they search for jobs in Mexico. The value functions of unemployed US-born workers become

$$r\mathcal{U}_{11}^H = b_{11}^H + f(\theta_1^H)(\mathcal{W}_{11}^H - \mathcal{U}_{11}^H) + f(\theta_1^L)(\mathcal{W}_{11}^{HL} - \mathcal{U}_{11}^H) + \mu_1 \int_0^\infty \max\{\mathcal{U}_{12}^H - \mathcal{U}_{11}^H - c + \lambda, 0\} dF(c) \quad (28)$$

$$r\mathcal{U}_{11}^L = b_{11}^L + f(\theta_1^L)(\mathcal{W}_{11}^L - \mathcal{U}_{11}^L) + \mu_1 \int_0^\infty \max\{\mathcal{U}_{12}^L - \mathcal{U}_{11}^L - c + \lambda, 0\} dF(c). \quad (29)$$

US-born workers are attracted to move to Mexico. The share of US-born workers in Mexico increases. Since the productivity of skilled US-born workers is higher than skilled Mexicans, the expected match surplus in the skilled labor market in Mexico increases. More firms enter the skilled labor market in Mexico and post vacancies. As a result, the labor market tightness of the skilled labor market in Mexico increases. However, the wage of skilled workers in Mexico decreases quantitatively. The wage of skilled workers in Mexico is affected by the labor market tightnesses in the skilled and unskilled labor markets in Mexico and the expected value of migration. Theoretically, the wage of skilled workers increases with the skilled labor market tightness and decreases with the unskilled labor market tightness or the expected value of migration. Since the effects of the unskilled labor market tightness and the expected value of migration dominate the effect of the skilled labor market tightness, the wage of skilled workers in Mexico decreases. Similarly, the wage of unskilled workers

decreases because it is affected by the labor market tightness and the value of migration and the decrease in the value of migration dominates.

With this subsidy, the value of migration of US-born workers increases and the value of unemployment increases. Therefore, the surplus of a job in the US decreases and it leads to the labor market tightness in the US decreasing. The wage of skilled workers in the US increases and the wage of unskilled workers decreases. The unemployment rates of both skilled and unskilled labor markets decrease. Proposition 6 concludes the effects of this subsidy on the labor market outcomes in Mexico and the labor mobility between the United States and Mexico.

**Proposition 6.** *With an increase in $\lambda$, for all $\kappa \in \{H, L\}$,*

*i) $\theta_2^\kappa$ increases;*

*ii) $\theta_1^H$ decreases, $\theta_1^L$ is ambiguous;*

*iii) $u_2^H$ is ambiguous, $u_2^L$ increases;*

*iv) $w_{22}^\kappa$ decreases;*

*v) more immigrants from the US move to Mexico;*

*vi) the number of skilled Mexicans move to the US is ambiguous, fewer unskilled Mexicans move to the US.*

# 7 Conclusion

This paper studies policy examples that can control the number of immigrants in the United States and Mexico. I apply a search and matching framework to model the migration behavior with two skill-bias labor markets and two countries. In this model, all unemployed workers encounter with a migration opportunity with a heterogenous migration cost. If the migration cost is low enough, workers search and work in the foreign country. The model is calibrated to the labor market data in the US and Mexico and captures the labor mobility between the US and Mexico.

The model predicts the effects of immigration policy examples on labor market outcomes and the labor mobility within two countries. Subsidizing firms that hire native workers in the US attracts more Mexicans to move to the US, since the US labor markets become stronger. Taxing firms that hire Mexican decreases the labor mobility between the US and Mexico, because the labor markets in the US are less attractive. The tax to Mexicans who move to the US discourage Mexicans to move to US as the migration cost goes up. The reduction in the population of Mexicans is harmful for labor market outcomes in the US. The subsidy to the US-born workers search in Mexico attracts US-born workers move to Mexico but it hurts labor market outcomes in Mexico.

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# Solution of the steady state equilibrium

According to (2) to (**??**), the workers surplus are following,

$$\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H} = \frac{w_{ii}^{H} - b_{ii}^{H} - f(\theta_i^L)(\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H}) - \int_0^{\bar{c}_i^H} F(c)dc}{r + s^H + f(\theta_i^H)} \tag{30}$$

$$\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H} = \frac{w_{ii}^{HL} - b_{ii}^{H} - f(\theta_i^H)(\mathcal{W}_{ii}^{H} - \mathcal{U}_{ii}^{H}) - \int_0^{\bar{c}_i^H} F(c)dc}{r + s^L + f(\theta_i^L)} \tag{31}$$

$$\mathcal{W}_{ii}^{L} - \mathcal{U}_{ii}^{L} = \frac{w_{ii}^{L} - b_{ii}^{L} - \int_0^{\bar{c}_i^L} F(c)dc}{r + s^L + f(\theta_i^L)} \tag{32}$$

$$\mathcal{W}_{ji}^{H} - \mathcal{U}_{ji}^{H} = \frac{w_{ji}^{H} - b_{ji}^{H}}{r + s^H + d + f(\theta_i^H)} \tag{33}$$

$$\mathcal{W}_{ji}^{L} - \mathcal{U}_{ji}^{L} = \frac{w_{ji}^{L} - b_{ji}^{L}}{r + s^L + d + f(\theta_i^L)}. \tag{34}$$

According to (6) to (**??**) and the free entry condition, the firms surplus are following,

$$\mathcal{J}_{ii}^{H} - \mathcal{V}_{i}^{H} = \frac{y_{ii}^{H} - w_{ii}^{H}}{r + s^H} \tag{35}$$

$$\mathcal{J}_{ii}^{HL} - \mathcal{V}_{i}^{L} = \frac{y_{ii}^{HL} - w_{ii}^{HL}}{r + s^L} \tag{36}$$

$$\mathcal{J}_{ii}^{L} - \mathcal{V}_{i}^{L} = \frac{y_{ii}^{L} - w_{ii}^{L}}{r + s^L} \tag{37}$$

$$\mathcal{J}_{ji}^{H} - \mathcal{V}_{i}^{H} = \frac{y_{ji}^{H} - w_{ji}^{H}}{r + s^H} \tag{38}$$

$$\mathcal{J}_{ji}^{L} - \mathcal{V}_{i}^{L} = \frac{y_{ji}^{L} - w_{ji}^{L}}{r + s^L}. \tag{39}$$

Following the share rule of Nash Bargaining, the wages are solved, which are

$$w_{ii}^{H} = \beta y_{ii}^{H} + (1-\beta)\frac{b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^H} F(c)dc + \beta f(\theta_i^H) y_{ii}^{H}/(r+s^H) + \beta f(\theta_i^L) y_{ii}^{HL}/(r+s^L)}{1+\beta f(\theta_i^H)/(r+s^H) + \beta f(\theta_i^L)/(r+s^L)} \tag{40}$$

$$w_{ii}^{HL} = \beta y_{ii}^{HL} + (1-\beta)\frac{b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^H} F(c)dc + \beta f(\theta_i^H) y_{ii}^{H}/(r+s^H) + \beta f(\theta_i^L) y_{ii}^{HL}/(r+s^L)}{1+\beta f(\theta_i^H)/(r+s^H) + \beta f(\theta_i^L)/(r+s^L)} \tag{41}$$

$$w_{ii}^{L} = \frac{\beta(r+s^L+f(\theta_i^L))y_{ii}^{L} + (1-\beta)(r+s^L)(b_{ii}^{L} + \mu_i \int_0^{\bar{c}_i^L} F(c)dc)}{M_i^L} \tag{42}$$

$$w_{ji}^{H} = \frac{\beta(r+s^H+f(\theta_i^H))y_{ji}^{H} + (1-\beta)(r+s^H+d)b_{ji}^{H}}{M_i^H + d} \tag{43}$$

$$w_{ji}^{L} = \frac{\beta(r+s^L+f(\theta_i^L))y_{ji}^{L} + (1-\beta)(r+s^L+d)b_{ji}^{L}}{M_i^L + d}, \tag{44}$$

where $M_i^{\kappa} = r + s^{\kappa} + \beta f(\theta_i^{\kappa})$ for all $\kappa \in \{H, L\}$ and $i \in \{1, 2\}$. The first digit of the subscript represents the country that the worker was born and the second digit represents the location of her job. Per the value of unemployment in the foreign country and in the country of origin, the reservation migration cost of a worker who was born in country $i$ with skill $\kappa$ is solved as

$$\begin{aligned}(r+d)\bar{c}_i^H = \max\{&\frac{\beta f(\theta_j^H) y_{ij}^{H} + (r+s^H+d)b_{ij}^{H}}{r+s^H+d+\beta f(\theta_j^H)} \\ &- \frac{b_{ii}^{H} + \beta f(\theta_i^H) y_{ii}^{H}/(r+s^H) + \beta f(\theta_i^L) y_{ii}^{HL}/(r+s^L) + \mu_i \int_0^{\bar{c}_i^H} F(c)dc}{1+\beta f(\theta_i^H)/(r+s^H) + \beta f(\theta_i^L)/(r+s^L)}, 0\}\end{aligned} \tag{45}$$

$$\begin{aligned}(r+d)\bar{c}_i^L = \max\{&\frac{\beta f(\theta_j^L) y_{ij}^{L} + (r+s^L+d)b_{ij}^{L}}{r+s^L+d+\beta f(\theta_j^L)} \\ &- \frac{\beta f(\theta_i^L) y_{ii}^{L} + (r+s^L)(b_{ii}^{L} + \mu_i \int_0^{\bar{c}_i^L} F(c)dc)}{r+s^L+\beta f(\theta_i^L)}, 0\}.\end{aligned} \tag{46}$$

The unemployment of each type of workers are solved with (15) to (20), which are

$$U_{ii}^{H} = \frac{s^{L} H_i}{f(\theta_i^{L}) + s^{L} + s^{L} f(\theta_i^{H})/s^{H} + s^{L}\mu_i F(\bar{c}_i^{H})/d} \tag{47}$$

$$U_{ji}^{H} = \frac{s^{H}\mu_j F(\bar{c}_j^{H}) U_{jj}^{H}}{d[f(\theta_i^{H}) + s^{H} + d]} \tag{48}$$

$$U_{ii}^{L} = \frac{s^{L}(N_i - H_i)}{s^{L} + f(\theta_i^{L}) + \mu_i F(\bar{c}_i^{L})/d} \tag{49}$$

$$U_{ji}^{L} = \frac{(d + s^{L})\mu_j F(\bar{c}_j^{L}) U_{jj}^{L}}{d[s^{L} + d + f(\theta_i^{L})]}. \tag{50}$$

# Proofs

## Proof of Proposition 1

*Proof.* According to (31) and (41), the surplus of mismatched skilled workers in country $i$ is rewritten as

$$\mathcal{W}_{ii}^{HL} - \mathcal{U}_{ii}^{H} = \frac{\beta[y_{ii}^{HL} + (\beta f(\theta_i^{H})/(r + s^{H}))(y_{ii}^{HL} - y_{ii}^{H}) - b_{ii}^{H} - \mu_i \int_0^{\bar{c}_i^{H}} F(c)dc]}{1 + \beta f(\theta_i^{H})/(r + s^{H}) + \beta f(\theta_i^{L})/(r + s^{L})}. \tag{51}$$

If this surplus is negative, no skilled worker searches in the unskilled labor market. They prefer to stay unemployed and search in the skilled labor market only. Therefore, the productivity of skilled workers who work in the unskilled labor market should be high enough to ensure that the surplus of skilled workers in unskilled labor market is non-negative. Per equation (51), the productivity of skilled workers in the unskilled labor market satisfied

$$\frac{r + s^{H} + \beta f(\theta_i^{H})}{r + s^{H}} y_{ii}^{HL} \geq \frac{\beta f(\theta_i^{H})}{r + s^{H}} y_{ii}^{H} + b_{ii}^{H} + \mu_i \int_0^{\bar{c}_i^{H}} F(c)dc. \tag{52}$$

□

## Proof of Proposition 2

*Proof.* According to (45) and (46), it is obvious that $\bar{c}_2^H$ and $\bar{c}_2^L$ are positive, and $\bar{c}_1^L = 0$. The reservation cost of skilled workers in country 1 is positive if and only if

$$\frac{\beta f(\theta_j^H) y_{ij}^H + (r + s^H + d) b_{ij}^H}{r + s^H + d + \beta f(\theta_j^H)} > \frac{b_{ii}^H + \beta f(\theta_i^H) y_{ii}^H/(r + s^H) + \beta f(\theta_i^L) y_{ii}^{HL}/(r + s^L) + \mu_i \int_0^{\bar{c}_i^H} F(c)dc}{1 + \beta f(\theta_i^H)/(r + s^H) + \beta f(\theta_i^L)/(r + s^L)} \tag{53}$$

□

# Proof of Proposition 3

*Proof.* When $\gamma$ increases, the expected match surplus increases. According to (14) and (13) when $i = 1$ and $j = 2$, the labor market tightness $\theta_1^\kappa$ increases. Per (47) and (49), the unemployment rates of both skilled and unskilled labor markets in the US decrease with $\gamma$. From (40), take the first order derivative with respect to $\theta_1^H$,

$$\frac{\partial w_{11}^H}{\partial \theta_1^H} > 0.$$

The wage of skilled workers in the US is also affected by the unskilled labor market because skilled workers search in the unskilled labor market simultaneously. Take the first order derivative of $w_{11}^H$ with respect to $\theta_1^L$,

$$\frac{\partial w_{11}^H}{\partial \theta_1^L} < 0.$$

Thus, the effect of this subsidy on the wage of skilled workers in the United States is ambiguous. The wage of unskilled workers in the US is affected by the unskilled labor market tightness, so the first order derivative of $w_{11}^L$ with respect to $\theta_1^L$ is

$$\frac{\partial w_{11}^L}{\partial \theta_1^L} > 0.$$

Therefore the wage of unskilled workers in the US increases with $\gamma$.

The population of Mexicans in the US depends on the unemployment and the reservation migration cost. The reservation migration cost of Mexicans increases because the labor market tightnesses in the US increase. The unemployment of Mexicans is ambiguous. Thus, the population of Mexicans in the US increases. □

# Proof of Proposition 4

*Proof.* Per (14), taxing firms in the United States that hire Mexicans decrease the expected surplus of a match in the skilled labor market. According to (47), the unemployment $U_{11}^H$ decreases with the decreasing skilled labor market tightness. Equation (13) shows that when $U_{11}^H$ increases, the expected match surplus in the unskilled labor market increases because of the high productivity of skilled workers. As a result, the effect of this taxation on the unskilled labor market tightness is ambiguous. So do the effects on the wage and unemployment of unskilled workers in the US. □

# Proof of Proposition 5

*Proof.* The fee that is paid by Mexican immigrants directly increases the migration cost of Mexicans. Thus, the expected value of migration of Mexicans decreases and the population of Mexican immigrants in the United States decreases. Since the surplus of matching with a Mexican immigrants is higher than a US-born worker, the decrease of population of Mexican immigrants reduces the expected surplus of a match in the United States. Therefore, the labor market tightnesses in the United States decrease. According to (40) and (42) when $i = 2$, the wages of Mexicans decrease and it leads to an increase in the match surplus. Therefore, the labor market tightnesses in both the skilled and the unskilled labor market in Mexico increase.

Similar to the proof of preposition 3, the wage of skilled workers is ambiguous and the

unemployment rate of the skilled labor market in the US decreases. The wage of unskilled workers decreases and the unemployment rate of the unskilled labor market in the United States increases. □

## Proof of Proposition 6

*Proof.* Subsidizing US-born workers who search for jobs in Mexico directly decreases the migration cost of US-born workers. Hence the expected value of migration of US-born workers increases and the wage of skilled workers increases. It reduces the surplus of a match and the skilled labor market tightness decreases. The unskilled labor market tightness is ambiguous. Similar to the skilled workers, the expected value of migration of unskilled workers increases as well and it reduces the expected surplus of an unskilled match. Meanwhile, the unemployment of skilled workers increases, so there are more skilled workers works in the unskilled labor market. These mismatched skilled workers increase the expected surplus of an unskilled match.

The population of US-born workers in Mexico increases and it raises the expected surplus of a match in Mexico. Thus, the labor market tightnesses in Mexico increases. The reservation migration cost of Mexicans decreases since the labor market tightnesses in the US decreases. Therefore, the wages of Mexicans and unemployment rates of labor markets in Mexico are ambiguous. □

# Tables and graphs

Table 1: Calibration results

| | | description | sources/target |
|---|---|---|---|
| $y_{11}^H$ | 1 | Normalized skilled productivity in the US | |
| $y_{11}^L$ | 0.4699 | Relative unskilled productivity in the US | The college-plus wage premium: 1.1281 |
| $y_{11}^{HL}$ | 0.7143 | Mismatch productivity in the US | Wage gap between college workers work in professional and in unprofessional jobs:1.4 |
| $y_{22}^H$ | 0.6944 | skilled productivity in Mexico | TFP gap between US and Mexico: 1.44 |
| $y_{22}^L$ | 0.1968 | relative unskilled productivity in Mexico | college-plus wage premium in Mexico: 2.53 |
| $y_{12}^H$ | 0.9561 | skilled productivity of US-born in Mexico | Wage gap between skilled US-born and Mexicans: 0.3767 |
| $\beta$ | 0.5 | Bargaining power | Hosios (1990) |
| $\alpha$ | 0.5 | Elasticity of matching function | Pretongolo and Pissarides (2001) |
| | | | Estimated from data: |
| $r$ | 0.0040 | real interest rate | Fed. of Saint Louis |
| $s^H$ | 0.0240 | job separation rate in skilled labor market | Chassamboulli and Peri (2015) |
| $s^L$ | 0.0320 | job separation rate in unskilled labor market | |
| $d$ | 0.0023 | return rate of immigrants | |
| $N_2$ | 1/3 | measure of population in Mexico | |
| $H_1$ | 0.3144 | measure of skilled workers in US | |
| $H_2$ | 0.0265 | measure of skilled workers in Mexico | |

Note: Subscripts represent countries. The first digit of the subscript represents the country that the worker was born. The second digit of subscripts represents the location of the job. The superscript represents the skill of the market/workers.

Table 1: Calibration results (continued)

| | | | Jointly calibrated to match: |
|---|---|---|---|
| $A$ | 0.3501 | Match technology | Employment rate of skilled labor market in US: 0.9520 |
| $k^H$ | 0.4349 | Fixed recruitment cost in skilled labor market | Employment rate of unskilled labor market in US: 0.8743 |
| $k^L$ | 0.0371 | Fixed recruitment cost in unskilled labor market | Employment rate of skilled labor market in Mexico: 0.9671 |
| $b_{11}^H$ | 0.6760 | Unemployed. flow value, skilled US worker in US | Employment rate of unskilled labor market in Mexico: 0.9553 |
| $b_{11}^L$ | 0.3207 | Unemployed. flow value, unskilled US worker in US | Measure of skilled US-born workers in Mexico: 0.0030 |
| $b_{21}^H$ | 0.6979 | Unemploy. flow value, skilled Mexican in US | Measure of skilled Mexicans in US: 0.0096 |
| $b_{21}^L$ | 0.3200 | Unemploy. flow value, unskilled Mexican in US | Measure of unskilled Mexicans in US: 0.0638 |
| $b_{22}^H$ | 0.2319 | Unemploy. flow value, skilled Mexican in Mexico | ratio of employed income to unemployed income in US: 0.71 |
| $b_{22}^L$ | 0.0789 | Unemploy. flow value, unskilled Mexican in Mexico | ratio of employed income to unemployed income in Mexico: 0.4 |
| $b_{12}^H$ | 0.3732 | Unemploy. flow value, skilled US workers in Mexico | Labor market tightness: 0.62 |
| $b_{12}^L$ | 0.0763 | Unemploy. flow value, unskilled US workers in Mexico | |
| $\mu_1/c^{max}$ | $8.03 \times e^{-5}$ | Arrival rate of migration opportunity in US | |
| $\mu_2/c^{max}$ | $1.86 \times e^{-4}$ | Arrival rate of migration opportunity in Mexico | |

Note: See the footnote in table 1 for the definitions of variables.

Table 2: Subsidy of firms in the US

| subsidy of firms | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | 2.5234 | 3.0895 | 3.7843 | 4.5754 |
| $\theta_1^L$ | 0.8833 | 1.4219 | 2.3384 | 3.7652 |
| $\theta_2^H$ | 2.4140 | 2.2548 | 2.2358 | 2.1779 |
| $\theta_2^L$ | 0.2408 | 0.2005 | 0.2279 | 0.2226 |
| $w_{11}^H$ | 0.9474 | 0.9443 | 0.9406 | 0.9366 |
| $w_{11}^L$ | 0.4565 | 0.4589 | 0.4611 | 0.4628 |
| $w_{22}^H$ | 0.6384 | 0.6401 | 0.6377 | 0.6376 |
| $w_{22}^L$ | 0.2004 | 0.2002 | 0.2003 | 0.2003 |
| $u_{11}^H$ | 0.0290 | 0.0252 | 0.0217 | 0.0187 |
| $u_{11}^L$ | 0.0886 | 0.0712 | 0.0564 | 0.0450 |
| $u_{22}^H$ | 0.0043 | 0.0044 | 0.0044 | 0.0044 |
| $u_{22}^L$ | 0.0095 | 0.0096 | 0.0095 | 0.0096 |
| $h_{12}$ | 0.0073 | 0.0085 | 0.0197 | 0.0236 |
| $h_{21}$ | 0.0018 | 0.0018 | 0.0018 | 0.0018 |
| $l_{12}$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $l_{21}$ | 0.0135 | 0.0135 | 0.0135 | 0.0135 |

Note: The variable $\theta_i^\kappa$ represents the labor market tightness in the skilled-$\kappa$ labor market in country $i$. The variable $w_{ii}^\kappa$ represents the wages of native skilled-$\kappa$ workers in country $i$. The variable $u_{ii}^\kappa$ represents the unemployment rate of native skilled-$\kappa$ in country $i$. The variable $h_{ij}$ and $l_ij$ represents the share of workers from country $i$ work in country $j$.

Table 3: Tax of firms in the US

| tax of firm | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | 2.0633 | 2.0635 | 2.0572 | 2.0535 |
| $\theta_1^L$ | 0.5598 | 0.5522 | 0.5548 | 0.5519 |
| $\theta_2^H$ | 1.7393 | 1.7566 | 1.9981 | 2.0263 |
| $\theta_2^L$ | 0.0910 | 0.0926 | 0.1320 | 0.1366 |
| $w_{11}^H$ | 0.9499 | 0.9501 | 0.9500 | 0.9500 |
| $w_{11}^L$ | 0.4538 | 0.4537 | 0.4538 | 0.4537 |
| $w_{22}^H$ | 0.6485 | 0.6483 | 0.6452 | 0.6450 |
| $w_{22}^L$ | 0.1996 | 0.1995 | 0.1998 | 0.1998 |
| $u_{11}^H$ | 0.0332 | 0.0332 | 0.0333 | 0.0333 |
| $u_{11}^L$ | 0.1089 | 0.1095 | 0.1093 | 0.1096 |
| $u_{22}^H$ | 0.0046 | 0.0046 | 0.0045 | 0.0045 |
| $u_{22}^L$ | 0.0101 | 0.0101 | 0.0099 | 0.0099 |
| $h_{12}$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $h_{21}$ | 0.1996 | 0.1995 | 0.1998 | 0.1998 |
| $l_{12}$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $l_{21}$ | 0.0137 | 0.0137 | 0.0136 | 0.0136 |

Note: See the footnote in table 2 for the definitions of variables.

Table 4: Tax of Mexicans

| tax of Mexicans | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | 2.0672 | 2.0643 | 2.0582 | 2.0594 |
| $\theta_1^L$ | 0.5631 | 0.5605 | 0.5546 | 0.5548 |
| $\theta_2^H$ | 4.7921 | 6.0929 | 6.6408 | 7.0766 |
| $\theta_2^L$ | 1.5275 | 2.6739 | 2.8329 | 2.8329 |
| $w_{11}^H$ | 0.9499 | 0.9499 | 0.9500 | 0.9500 |
| $w_{11}^L$ | 0.4539 | 0.4538 | 0.4538 | 0.4538 |
| $w_{22}^H$ | 0.6073 | 0.5955 | 0.5944 | 0.5953 |
| $w_{22}^L$ | 0.1921 | 0.1905 | 0.1904 | 0.1904 |
| $u_{11}^H$ | 0.0331 | 0.0331 | 0.0331 | 0.0331 |
| $u_{11}^L$ | 0.1086 | 0.1088 | 0.1093 | 0.1093 |
| $u_{22}^H$ | 0.0046 | 0.0055 | 0.0076 | 0.0128 |
| $u_{22}^L$ | 0.0135 | 0.0252 | 0.0515 | 0.0515 |
| $h_{12}$ | 0.0295 | 0.0392 | 0.0422 | 0.0445 |
| $h_{21}$ | 0.0017 | 0.0016 | 0.0014 | 0.0010 |
| $l_{12}$ | 0 | 0 | 0.0000 | 0 |
| $l_{21}$ | 0.0115 | 0.0075 | 0.0000 | 0.0000 |

Note: See the footnote in table 2 for the definitions of variables.

Table 5: subsidy to US-born workers in Mexico

| subsidy of us workers | 0.1 | 0.2 | 0.3 | 0.4 |
|---|---|---|---|---|
| $\theta_1^H$ | 2.0644 | 2.0278 | 1.2544 | 1.0275 |
| $\theta_1^L$ | 0.5696 | 0.5722 | 0.1224 | 0.0398 |
| $\theta_2^H$ | 1.2301 | 1.1345 | 1.3907 | 1.7263 |
| $\theta_2^L$ | 0.0406 | 0.0160 | 0.7942 | 0.9117 |
| $w_{11}^H$ | 0.9499 | 0.9504 | 0.9610 | 0.9655 |
| $w_{11}^L$ | 0.4543 | 0.4403 | 0.4412 | 0.4391 |
| $w_{22}^H$ | 0.6522 | 0.6602 | 0.5954 | 0.5884 |
| $w_{22}^L$ | 0.1992 | 0.1989 | 0.1950 | 0.1908 |
| $u_{11}^H$ | 0.0327 | 0.0323 | 0.0446 | 0.0529 |
| $u_{11}^L$ | 0.1080 | 0.1078 | 0.0814 | 0.0765 |
| $u_{22}^H$ | 0.0050 | 0.0053 | 0.0041 | 0.0061 |
| $u_{22}^L$ | 0.0103 | 0.0105 | 0.0107 | 0.0142 |
| $h_{12}$ | 0.1560 | 0.3479 | 0.6726 | 0.5786 |
| $h_{21}$ | 0.0018 | 0.0018 | 0.0019 | 0.0018 |
| $l_{12}$ | 0.0000 | 0.0000 | 0.0434 | 0.0541 |
| $l_{21}$ | 0.0138 | 0.0140 | 0.0127 | 0.0120 |

Note: See the footnote in table 2 for the definitions of variables.