# Imperfect Substitution between Immigrant and Native Farm Workers in the United States

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**Abstract:**

The preponderance of employing unauthorized foreign-born immigrant workers in the farm labor force has made immigration policy a major issue for agriculture sector. The focal points of the policy discussions include two sides of the same coin: to what extent farm growers experience labor shortages and to what extent the immigrant farm workers affect the economic opportunities of native farm workers who are mostly less-educated. In this paper we propose a three-layer nested CES framework to model the labor demand in agricultural sector and empirically investigate the substitutability among heterogeneous farm worker groups defined by different age and education levels as well as immigration status. Using wages and employment information aggregated at different education-age-year cells from the National Agricultural Worker Survey (NAWS) data over the period of 1989 and 2012, we find little evidence that inflows of immigrants are associated with significant impact on native farm workers across different age and education groups. Our findings have important policy implication for the need to streamline the H-2A guest worker program which was intended by legislators to decrease the size of unauthorized immigrant workers meanwhile alleviate the potential labor shortage issues.

*Key words: Elasticity of Substitution, Immigrant, Native, Farm worker, Nested CES structure.*

JEL *Classification*: J20, J61, J43, Q18

## 1. Introduction

The farm sector is characterized by labor-intensive tasks, which typically do not appeal to native workers in the United States. As a result, US agriculture heavily relies on foreign-born workers for most labor-intensive tasks, such as harvesting and picking. This makes agricultural sector particularly sensitive to changes in flow of migrant workers. According to the U.S. Department of Agriculture, Economic Research Service (USDA-ERS, 2014), more than 50 percent of seasonal farm workers in the agricultural sector are foreign born and unauthorized to work in the United States. However, this estimate is believed to be low (Fisher and Knutson, 2012). For instance, Emerson and Iwai (2014) report that 68.9% of immigrants working in Florida specialty crop industries are unauthorized, and 88.2% have less than 12 years of

schooling. Guan *et al*. (2015) report that 80% of labor force in the Florida strawberry industry was unauthorized workers.

Recently, growers have been raising concerns about difficulty in finding farm workers to harvest their crop. Potential labor shortages and how immigration policies would affect labor markets are major concerns for the U.S. agriculture, particularly for specialty crops industry. There has been renewed national interest in an immigration reform. In the last few years, proposals to the U.S. Congress have included recommendations for various combinations of increased border enforcement, legalization programs (such as 287(g) programs) and guest worker programs. On one hand, legislators are concerned that rising immigrant population may adversely affect native farm workers and drive them out of the U.S. agricultural sector. On the other hand, growers are concerned that without reforming the immigration policy, the current declining trend in new-comer migrant workers may cause labor shortages and the subsequent wage increases may lead to significant crop loss in the short-run. According to a recent Pew Research Center analysis, there are more Mexican immigrants leaving than coming to the U.S. causing net loss of 140,000 of Mexican immigrants over the period of 2009 to 2014 (Gonzalez-Barrera, 2015). Labor market issues faced by growers are more complicated than those faced in non-agricultural low-skilled sectors due to the unique nature of agricultural sector, including seasonal nature of the work and willingness (or lack thereof) of domestic workers to perform labor-intensive tasks (Fisher and Knutson, 2012). If, however, foreign-born immigrant and native farm workers were substitutable, diminishing supply of immigrant workers would not be as critical of an issue for the agricultural sector. Therefore, in this paper, we turn our attention to answering the following questions: How does the inflow of immigrants may affect employment and/or unemployment of native workers, particularly less-educated workers? To what extent immigrants are competing with native farm

workers? Due to labor-intensiveness and seasonal nature of agriculture, the work is mostly undertaken by low-skilled and/or less-educated workers. Most of these migrant workers lack proper work authorization. They are mostly from Mexico and Central America and have limited English skills.

There have been efforts in the literature to explain the effect of increased supply of migrant workers on natives' employment and wages through a general equilibrium framework, in which some fraction of the response of labor demand to relative wage changes might be absorbed through inter-sectoral and geographical movements (see for e.g., Lewis, 2005). The results on this point have been mixed, with several empirical studies finding the role of inter-sectoral adjustments to be relatively small (see, Card, 2009 for more details). In this paper, we constrain our attention to the agricultural sector alone when analyzing substitutability of native and immigrant workers, employing a one-sector model as most studies in the labor literature do.

Immigration has long been a crucial topic among economists due to the controversial aspects of immigration policies. A large body of research has been done on this subject to identify the effects of immigration on labor market outcomes. Although there are disagreements on the exact effects of immigrants on wages and employment of native workers, empirical evidence points to limited substitutability between immigrant and native workers in employment. Based on labor market outcomes of unskilled native workers in 120 major cities extracted from 1970 and 1980 Censuses, Altonji and Card (1991) find that the competition between immigrant and unskilled natives is modest and there is little evidence that inflows of immigrants are associated with increased unemployment rates of unskilled native workers. Card (2009) finds an elasticity of substitution between immigrants and natives of 50 (estimated $-\frac{1}{\sigma_I}$ is around -0.02) using pooled time series for 124 U.S cities. Ottaviano and Peri (2012) obtain similar elasticity

estimates for immigrants and natives ($-\frac{1}{\sigma_I}$ ranging between -0.04 to -0.08) using US census data. Using pooled data on British males' wages and employment from the mid-1970s to the mid-2000s, Manacorda *et al.* (2012) also find that immigrants and natives are imperfect substitutes for UK, but with a relatively smaller degree of substitution of around 8 (the estimates of $-\frac{1}{\sigma_I}$ is -0.128). The aforementioned studies are all on nonagricultural sectors. Little is known about the immigrant and native worker substitutability in the agricultural sector.

To our knowledge, this is the first paper attempting to quantify the substitutability of native and immigrant farm workers. In this paper, we propose a nested Constant Elasticity of Substitution (CES) framework to model labor demand in agricultural sector and empirically investigate the substitutability among heterogeneous farm worker groups defined by different age and education levels as well as different immigration statuses. Through a three-layer nested-CES structure, we identify the elasticity of substitution between immigrant and native farm workers within the same education and age group, the elasticity of substitution across different age groups within the same education group, and the substitution across different education groups using the National Agricultural Worker Survey (NAWS) data from 1993 through 2012.

The rest of the paper is organized as follows. Section 2 presents the nested CES framework and derives the main estimating equations. Section 3 introduces the empirical strategies before the data is presented in Section 4. In Section 5, we present and discuss our empirical results. Section 6 concludes.

## 2. Theoretical Framework

We adopt the theoretical framework from Card (2009), Manacorda et al. (2012) and Ottaviano and Peri (2012). We assume that an agricultural good $y$ is produced in a competitive market

according to the following constant-returns-to-scale (CRS), nested constant-elasticity-of-substitution (CES) production function. Closely following the formulation of Manacorda et al. (2012), a three-nest CES structure is considered to model the heterogeneous labor inputs used in production. [1]

$$y_t = A_t\left(\theta_t L_{1t}^{\rho} + L_{2t}^{\rho}\right)^{\frac{1}{\rho}}. \tag{1}$$

where $L_{et}$ , $e = 1, 2$ denotes the aggregate labor inputs of different skill $e$ at time $t$ , with 1 for skilled labor and 2 for unskilled labor.[2] $A_t$ captures the time-varying Hicks-neutral technological change, and $\theta_t$ is the time-varying skill-biased technological change of skilled worker relative to unskilled worker. The elasticity of substitution between skilled and unskilled labor is $\sigma_E = \frac{1}{1-\rho}$.

In the second nest, both skilled and unskilled labor inputs are modeled as a constant elasticity of substitution (CES) combination of a set of age-specific labor inputs according to the following:

$$L_{et} = \left(\sum_a \alpha_{ea} L_{1at}^{\eta}\right)^{\frac{1}{\eta}}, \ e = 1, 2, \tag{2}$$

where $a$ denotes different age groups within each skill group. The elasticity of substitution between different age and experience groups is $\sigma_A = \frac{1}{1-\eta}$.

In the third nest, we treat native and immigrant workers as different labor inputs and further partition each education-specific labor input $L_{eat}$ into native (i.e. U.S born) and immigrant (i.e., foreign-born) categories:

$$L_{eat} = \left(\beta_{eat}^{N} N_{eat}^{\delta} + \beta_{eat}^{M} M_{eat}^{\delta}\right)^{\frac{1}{\delta}}, \tag{3}$$

[1] We use the same notation as in Mancorda *et al.* (2012) for the purpose of comparison.

[2] Workers with different levels of education within each skill group are implicitly assumed to be perfect substitutes. This assumption is relaxed in empirical analysis by introducing different and more disaggregated educational groups.

where $N$ denotes native worker, $M$ is immigrant and $\beta$ is the efficiency of native workers and immigrant workers in each education-age group . The elasticity of substitution between immigrants and natives is given by $\sigma_I = \frac{1}{1-\delta}$. If $\delta \neq 1$, the immigrants and native farm workers are not perfect substitutes.

Solving the following cost minimization problem

$$\min_{N_{eat},\ M_{eat}} \sum (w_{eat}^N N_{eat} + w_{eat}^M M_{eat})$$

s.t.

$$y_t = A_t\left(\theta_t L_{1t}^{\rho} + L_{2t}^{\rho}\right)^{\frac{1}{\rho}}$$

$$L_{et} = \left(\sum_a \alpha_{ea} L_{1at}^{\eta}\right)^{\frac{1}{\eta}}, \qquad e = 1, 2$$

$$L_{eat} = \left(\beta_{eat}^N N_{eat}^{\delta} + \beta_{eat}^M M_{eat}^{\delta}\right)^{\frac{1}{\delta}}$$

yields the following first order conditions

$$\begin{cases} w_{eat}^N - \lambda \cdot \frac{1}{\rho} \cdot A_t\left[\theta_t L_{1t}^{\rho} + L_{2t}^{\rho}\right]^{\frac{1}{\rho}-1} \cdot \theta_{et} \cdot \rho \cdot L_{et}^{\rho-1} \cdot \frac{1}{\eta} \cdot \left(\sum_a \alpha_{ea} L_{1at}^{\eta}\right)^{\frac{1}{\eta}-1} \\ \qquad \cdot \alpha_{ea} \cdot \eta \cdot L_{eat}^{\eta-1} \cdot \frac{1}{\delta} \cdot \left(N_{eat}^{\delta} + \beta_{eat} M_{eat}^{\delta}\right)^{\frac{1}{\delta}-1} \cdot \beta_{eat}^N \cdot \delta \cdot N_{eat}^{\delta-1} = 0 \\ w_{eat}^M - \lambda \cdot \frac{1}{\rho} \cdot A_t\left[\theta_t L_{1t}^{\rho} + L_{2t}^{\rho}\right]^{\frac{1}{\rho}-1} \cdot \theta_{et} \cdot \rho \cdot L_{et}^{\rho-1} \cdot \frac{1}{\eta} \cdot \left(\sum_a \alpha_{ea} L_{1at}^{\eta}\right)^{\frac{1}{\eta}-1} \\ \qquad \cdot \alpha_{ea} \cdot \eta \cdot L_{eat}^{\eta-1} \cdot \frac{1}{\delta} \cdot \left(N_{eat}^{\delta} + \beta_{eat} M_{eat}^{\delta}\right)^{\frac{1}{\delta}-1} \cdot \beta_{eat}^M \cdot \delta \cdot M_{eat}^{\delta-1} = 0 \end{cases}. \qquad (4)$$

The first order conditions require that wages of native and immigrant farm workers equal to their marginal products.

$$\begin{cases} w_{eat}^N = \lambda \cdot A_t^{\rho} \cdot y_t^{1-\rho} \cdot \theta_{et} \cdot L_{et}^{\rho-\eta} \cdot \alpha_{ea} \cdot L_{eat}^{\eta-\delta} \cdot \beta_{eat}^N \cdot N_{eat}^{\delta-1} \\ w_{eat}^M = \lambda \cdot A_t^{\rho} \cdot y_t^{1-\rho} \cdot \theta_{et} \cdot L_{et}^{\rho-\eta} \cdot \alpha_{ea} \cdot L_{eat}^{\eta-\delta} \cdot \beta_{eat}^M \cdot M_{eat}^{\delta-1} \end{cases}. \qquad (5)$$

Plug in $\sigma_E = \frac{1}{1-\rho}$ , $\sigma_A = \frac{1}{1-\eta}$ , $\sigma_I = \frac{1}{1-\delta}$ , and simplify,

$$\begin{cases} w_{eat}^{N} = \lambda \cdot A_t^{1-\frac{1}{\sigma_E}} \cdot y_t^{\frac{1}{\sigma_E}} \cdot \theta_{et} \cdot L_{et}^{\frac{1}{\sigma_A}-\frac{1}{\sigma_E}} \cdot \alpha_{ea} \cdot L_{eat}^{\frac{1}{\sigma_I}-\frac{1}{\sigma_A}} \cdot \beta_{eat}^{N} \cdot N_{eat}^{-\frac{1}{\sigma_I}} \\ w_{eat}^{M} = \lambda \cdot A_t^{1-\frac{1}{\sigma_E}} \cdot y_t^{\frac{1}{\sigma_E}} \cdot \theta_{et} \cdot L_{et}^{\frac{1}{\sigma_A}-\frac{1}{\sigma_E}} \cdot \alpha_{ea} \cdot L_{eat}^{\frac{1}{\sigma_I}-\frac{1}{\sigma_A}} \cdot \beta_{eat}^{M} \cdot M_{eat}^{-\frac{1}{\sigma_I}} \end{cases}. \tag{6}$$

Taking logarithms of equation (6) results in

$$lnw_{eat}^{N} = lnB_t + \frac{1}{\sigma_E} lny_t + ln\theta_{et} + \left(\frac{1}{\sigma_A} - \frac{1}{\sigma_E}\right) lnL_{et} + ln\alpha_{ea} + \left(\frac{1}{\sigma_I} - \frac{1}{\sigma_A}\right) lnL_{eat}$$

$$+ln\beta_{eat}^{N} - \frac{1}{\sigma_I} lnN_{eat}.^{3} \tag{7.1}$$

$$lnw_{eat}^{M} = lnB_t + \frac{1}{\sigma_E} lny_t + ln\theta_{et} + \left(\frac{1}{\sigma_A} - \frac{1}{\sigma_E}\right) lnL_{et} + ln\alpha_{ea} + \left(\frac{1}{\sigma_I} - \frac{1}{\sigma_A}\right) lnL_{eat}$$

$$+ln\beta_{eat}^{M} - \frac{1}{\sigma_I} lnM_{eat}. \tag{7.2}$$

Imposing the normalization assumptions that $\beta_{eat}^{N} = 1$, $\beta_{eat}^{M} = \beta_{eat}$ as in Manacorda *et. al* (2012), we can then derive the expression for the wage differential of native and immigrant farm workers in each education-age-time cell by differencing Equation (7.1) and (7.2).

$$ln\frac{W_{eat}^{N}}{W_{eat}^{M}} = -ln\beta_{eat} - \frac{1}{\sigma_I}\left(ln\frac{N_{eat}}{M_{eat}}\right). \tag{8}$$

Equation (8) is the main equation of interest in this paper from which the elasticity of substitution between native and immigrant farm workers can be obtained. If native and immigrant farm workers are perfect substitutes, $1/\sigma_I$ will be zero and we should find no statistically significant effect of changes in the relative employment of native to immigrant farm workers on their relative wages.

Denote $S$ the immigrant status, which is $N$ for native and $M$ for immigrant farm workers. Then the wage equations (Eq. 7. 1 Eq. 7.2) for native and immigrant farm workers at each education-age-time group can be combined as:

[3] Where $lnB_t$ is a collective term of the two constant terms $ln\lambda + \left(1 - \frac{1}{\sigma_E}\right) lnA_t$.

$$lnw_{eat}^{S} = lnB_t + \frac{1}{\sigma_E} lny_t + ln\theta_{et} + \left(\frac{1}{\sigma_A} - \frac{1}{\sigma_E}\right) lnL_{et} + ln\alpha_{ea} + \left(\frac{1}{\sigma_I} - \frac{1}{\sigma_A}\right) lnL_{eat}$$

$$+ln\beta_{eat}^{S} - \frac{1}{\sigma_I} lnS_{eat}. \quad (8)$$

Then the relative wage of skilled to unskilled workers of immigrant status $S$ $(S = N, M)$for each age group at time $t$ can be derived as:

$$lnw_{1at}^{S} - lnw_{2at}^{S} = (ln\theta_{1t} - ln\theta_{2t}) + \left(\frac{1}{\sigma_A} - \frac{1}{\sigma_E}\right)(lnL_{1t} - lnL_{2t}) + (ln\alpha_{1a} - ln\alpha_{2a}) +$$

$$\left(\frac{1}{\sigma_I} - \frac{1}{\sigma_A}\right)(lnL_{1at} - lnL_{2at}) + (ln\beta_{1at}^{S} - ln\beta_{2at}^{S}) - \frac{1}{\sigma_I}(lnS_{1at} - lnS_{2at}). \quad (9)$$

Let $\theta_{1t} = \theta_t$ and $\theta_{2t} = 1$, we can rewrite Equation (9) after simplifying and re-organizing some terms,

$$ln\frac{W_{1at}^{S}}{W_{1at}^{S}} = ln\theta_t + ln\frac{\alpha_{1a}}{\alpha_{2a}} + ln\frac{\beta_{1at}^{S}}{\beta_{2at}^{S}} - \frac{1}{\sigma_E} ln\frac{L_{1t}}{L_{2t}} - \frac{1}{\sigma_A}\left(ln\frac{L_{1at}}{L_{2at}} - ln\frac{L_{1t}}{L_{2t}}\right) - \frac{1}{\sigma_I}\left(ln\frac{S_{1at}}{S_{2at}} - ln\frac{L_{1at}}{L_{2at}}\right). \quad (10)$$

Equation (10) is the base equation to obtain the elasticities of substitution between different education groups $\left(\frac{1}{\sigma_E}\right)$ and age groups $\left(\frac{1}{\sigma_A}\right)$, and an updated estimate of the elasticity of substitution between native and immigrant $\left(\frac{1}{\sigma_I}\right)$ workers.

## 3. Empirical Estimation Strategy

It would be ideal if we could directly estimate Equation (10) and obtain the three key elasticities across different education, age and legal status groups. However, we will need estimates of $L_{eat}$ and $L_{at}$ before we can estimate equation (10) to obtain $\frac{1}{\sigma_A}$ and $\frac{1}{\sigma_E}$. Meanwhile, Equation (2) and (3) show that estimating $L_{eat}$ and $L_{at}$ in turn requires estimates of $\sigma_A$ and $\sigma_E$.

Hence, we adopt the three-step estimation procedure developed by Manacorda *et al*. (2012) to iteratively obtain the three elasticity estimates.

**Step 1: Estimating $\boldsymbol{\sigma_I}$**

Assuming $\beta_{eat}$ follows the following additive structure and varies by skill, age, and time for both native and immigrant farm workers,

$$-\ln \beta_{eat} = f_e + f_a + f_t \tag{11}$$

Hence, Equation (8) can be rewritten as

$$ln\frac{W_{eat}^N}{W_{eat}^M} = f_e + f_a + f_t \; - \frac{1}{\sigma_I}\left(ln\frac{N_{eat}}{M_{eat}}\right). \tag{12}$$

By regressing the log relative wage of native to immigrant workers on their relative supply for each education-age-time cell, we can obtain estimates of $\sigma_I$ and $\beta_{eat}$.

**Step 2: Estimating $\boldsymbol{\sigma_A}$ and $\boldsymbol{\alpha_{ea}}$**

Using $\beta_{eat}$ estimated from Equation (12), we can compute $L_{eat}$ from equation (3) and obtain $\sigma_a$ by estimating the following equation derived from Equation (10).

$$ln\frac{W_{1at}^S}{W_{1at}^S} = d_a + d_t + d_S - \frac{1}{\sigma_A}\left(ln\frac{L_{1at}}{L_{2at}}\right) \; - \frac{1}{\sigma_I}\left(ln\frac{S_{1at}}{S_{2at}} - ln\frac{L_{1at}}{L_{2at}}\right) \tag{13}$$

where, $d_a$ is the age dummies to capture the age effect, $d_t$ is the time dummies to capture the year effects, and $d_S$ is the immigration status dummy to capture the relative productivity effect of immigrant versus native farm workers of similar education and age. The coefficient on the relative supply of skilled and unskilled farm workers ($ln\frac{L_{1at}}{L_{2at}}$) is the estimate of the inverse elasticity of substitution across different age groups.

We then run the following regression based on Equation (8) to recover $\alpha_{ea}$, which is the measure of relative efficiency of different age groups within each education category.

$$lnW_{eat}^{S} = d_{et} + d_{ea} - \frac{1}{\sigma_A} L_{eat} - \frac{1}{\sigma_I}(lnS_{eat} - lnL_{eat} + \sigma_I \ln \beta_{eat}) \quad (14)$$

The coefficients of $d_{ea}$ dummies can be used to calculate $\alpha_{ea}$and then compute $L_{et}$ from Equation (2). By definition, $\alpha_{ea}$ is $\exp(d_{ea})$ for each skill-age group)

**Step 3: Estimating $\boldsymbol{\sigma_E}$**

Using computed labor supplies based on previous estimation, we can now re-estimate Equation (10) using the following specification.

$$ln\frac{W_{1at}^{S}}{W_{1at}^{S}} = \kappa_0 + \kappa_1 t + d_a + d_S - \frac{1}{\sigma_E} ln\frac{L_{1t}}{L_{2t}} - \frac{1}{\sigma_A}\left(ln\frac{L_{1at}}{L_{2at}} - ln\frac{L_{1t}}{L_{2t}}\right) - \frac{1}{\sigma_I}\left(ln\frac{S_{1at}}{S_{2at}} - ln\frac{L_{1at}}{L_{2at}}\right). \quad (15)$$

From Equation (15), we obtain an estimate of the inverse elasticity of substitution between different education groups ($\sigma_E$). $\kappa_1$ captures the skill-biased technological change. Equation (15) also provides a new set of estimates for $\sigma_I$ and $\sigma_A$.

Partitioning heterogeneous workers with certain flexibility, four nesting structures allowing different combinations of education and age groups are estimated to examine consistency of the model (Figure 1). In the theoretical framework, the production function considers only two distinct skill groups: skilled and unskilled workers. However, empirical evidence in immigration studies indicate that two groups may not be able to detect the potential effect of immigration on native workers because most immigrant workers are relatively low-skilled workers. This is particularly the case for farm workers in the agricultural sector. In addition, established tradition in labor and immigration research tends to categorize high school equivalents (i.e., high school graduate or less) as unskilled workers and college equivalents (i.e., some college and above) as skilled workers. This categorization is not adequate for agricultural

workers as most workers barely complete elementary school. The majority of hired workers (more than 80%) in the NAWS data have not completed high school. The median and mean education levels in the NAWS sample is six years and seven years, respectively. Therefore, we define skill groups in a few alternative ways. The baseline case defines unskilled workers as those who did not complete elementary schools (i.e., $\leq$ 6 years) and skilled workers as those who have at least some secondary education (i.e., $>$ 6 years). To be consistent with the standard convention in migration economics, an alternative definition for skill groups is to classify those with less than 12 years of education (high school or less) as unskilled workers and those with at least 12 years of education (high school graduates or above) as skilled workers. We also examine a finer disaggregation to allow the data to identify the skill differences. Three educational groups are considered: Elementary or less (i.e., $\leq$ 6 years), Some Secondary (7-11 years) and High School graduates and above ($\geq$ 12 years).

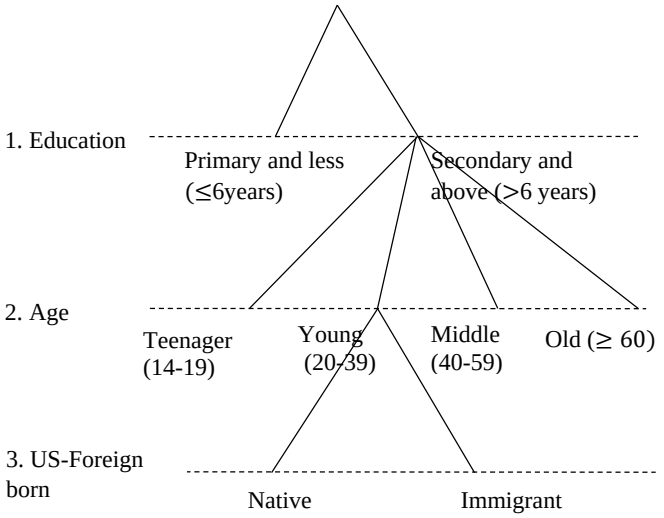
Given the labor intensive nature of agricultural work, two alternative categorizations are considered for age cohorts. In the baseline case, we consider four age cohorts: Teenager (14-19), Young (20-39), Middle (40-59) and Old ($\geq$ 60). We also consider an alternative of three age cohorts by focusing on farm workers with ages between 20 and 69 only and divide them into three groups –Young (20-29), Middle (40-59) and Old (60-69) – to reflect the fact that the majority of farm workers hired for field work are young and middle-aged males.

Farm workers are further divided into two groups based on their immigration statuses and their birth places. Native workers are defined as those who were born in the United States or

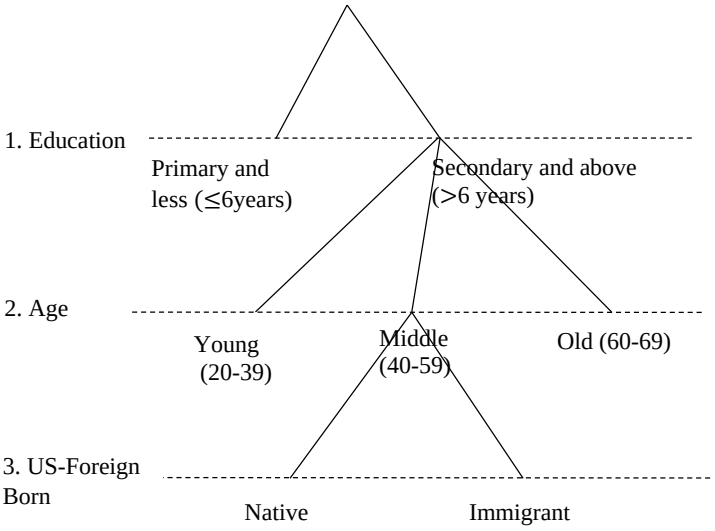
Puerto Rico while immigrant workers are defined as those who were born in countries other than the United States and Puerto Rico. [4]

[4] Birth place is the only criterion to define the status of immigrant and native farm workers. Under this definition, naturalized workers are treated as immigrants. Similarly, the second-generation farmers with undocumented parents are treated as natives as long as they were born in the US or Puerto Rico.

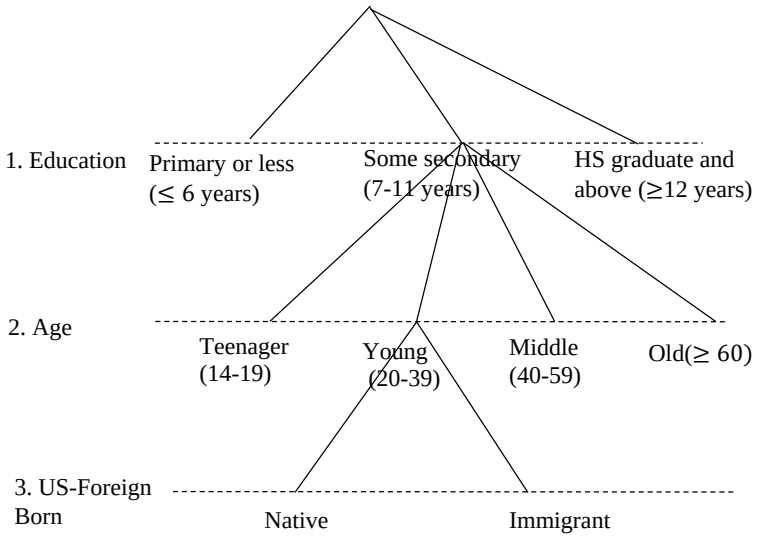
Figure 1: Baseline Nesting Structure and Alternatives



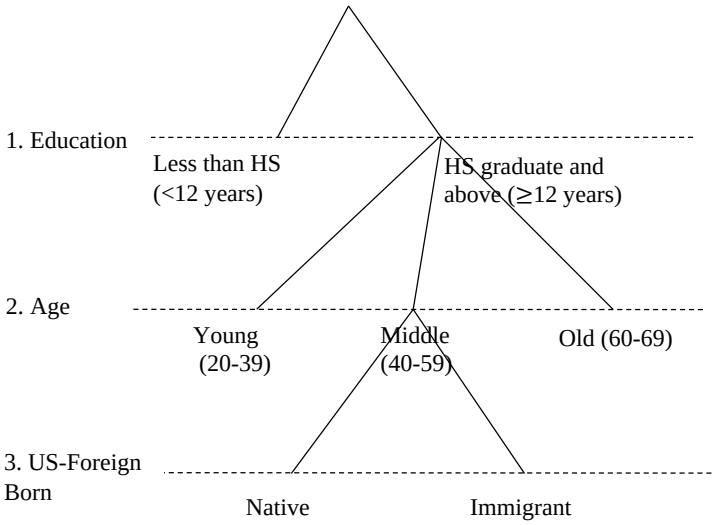

Baseline




Alternative 1




Alternative 2




Alternative 3

## 4. The National Agricultural Workers Survey (NAWS)

Before proceeding to the estimation of the nested CES model, we provide a brief introduction to the National Agricultural Worker Survey (NAWS) data and the key variables constructed for this study. The NAWS data is an employment-based, random sampled survey of seasonal hired crop workers. It is the most detailed national survey which collects hired crop farmworkers' demographic and employment information through face-to-face interviews.

The data set is available for download from the Department of Labor's (DOL) website. In this paper, we use a national sample of 53,359 workers covering the period from 1989 through 2012. All observations with missing information are excluded from the analysis to obtain a balanced sample of immigrant and native farm workers aggregated at education-age-year cell.

We use hourly wage rate to measure farm worker's wage. Due to the seasonality of agricultural work, farm workers are usually paid by different wage rates including hourly wage, piece rate, both, or other payment method. For workers not paid by hour (i.e., piece rate or other payment method), we are able to compute their equivalent hourly wage rates using the total payment amount divided by working hours reported for that payment period.

Labor supply (i.e., employment) of immigrant and native farm workers is measured by working hours in each education-age-year cell, which is aggregated from the final individual weight variable.[5] We do not have a direct measure of labor supply from the NAWS data due to the normalization of the individual weight variable (i.e., individual weights sum to the number of observations in each year). However, we are able to circumvent this because only the relative labor supply of native and immigrant farm workers is needed in our estimating equations.

[5] For details about the calculation of the final weight variable, please refer to the NAWS Survey Documentation: Statistical Methods (The National Agricultural Workers Survey, Part B) at https://www.doleta.gov/agworker/naws.cfm.

## 5. **Estimation Results and Discussion**

### *5.1. Estimates of Elasticity of Substitution between Immigrants and Native farm workers ($\sigma_I$)*

The estimated inverse elasticity of substitution between immigrants and native farm workers ($\frac{1}{\sigma_I}$) from the baseline nesting structure is reported in Table 1. In addition to the baseline specification using all observations in the sample, we estimate the elasticity of substitution between immigrants and native farm workers for different sub-sample groups. Although the estimated inverse elasticity varies across different sub-sample groups, a narrow range of -0.50 to -0.70 for $-\frac{1}{\sigma_I}$ indicates relatively small substitutability between immigrant and native workers. The point estimate of $-\frac{1}{\sigma_I}$ using all observations is -0.497 (Row 1, Table 1) with an equivalent degree of substitution of about 2, implying immigrant and native farm workers do not compete for similar jobs. The interpretation of the coefficient is that a 1 percent increase in the relative supply of immigrant and native farm workers will result in a 0.50 percent decrease of their relative wages, which illustrates a very small possibility of substitution between immigrant and native farm workers. As mentioned earlier, if the native and immigrant farm workers are perfect substitutes, we should have found no significant effect of changes in the relative employment on the relative wages (i.e., $H_0: \frac{1}{\sigma_I} = 0$).

Table 1. Estimated elasticity of substitution between immigrants and natives.

| Sample and Specification* | Estimated Inverse Elasticity ($-\frac{1}{\sigma_I}$) |
|---|---|
| Sample all | -0.497 *** |
| | (0.055) |
| Male only | -0.501 *** |
| | (0.051) |
| Female only | -0.691 *** |
| | (0.075) |
| Earlier immigrants only (enter U.S. before 1987) | -0.622 *** |
| | (0.074) |
| Recent immigrants only (enter U.S. after 2001) | -0.686 *** |
| | (0.147) |

Notes: All the estimates are based on the baseline nesting structure. Standard errors are reported in parenthesis. * significant at 10%. ** significant at 5%, and ***significant at 1%.

We also estimate elasticities of substitution for female and male farm workers separately for the following two reasons. First, most hired farm workers are men due to the intensive labor requirements for farm work. Second, women's labor force participation decisions are more complicated because of the significant roles they play in child care. We find that the substitutability between female immigrant and female native workers (Row 3 of Table 1, point estimate of $\frac{1}{\sigma_I}$ is 0.70 transferring to an elasticity of substitution of 1.45) are significantly less than that of males (Row 2, point estimate of $\frac{1}{\sigma_I}$ is 0.50 corresponding to an elasticity of substitution of 2).

For simplicity, the theoretical model pools all immigrants into a single group which largely ignores the heterogeneity of immigrants. However, the first year of entry to the United States by foreign-born workers can influence their ability to attain legal status, education acquirement and thus job opportunities. One might expect workers who came to the United States as children and grow up in the United States to be closer substitutes for natives than those who came to the United States in later years of their lives. Hence, we partition immigrant farm

workers into earlier immigrants and recent immigrants in light of two significant changes of immigration regulations in the United States: the passage of the Immigration Reform and Control Act of 1986 (IRCA) and the tightening of regulations after the tragedy of September 11 in 2001. We then estimate the elasticity of substitution among earlier immigrants and recent immigrants separately. Using information on first entry to the United States in the NAWS data set, we define farm workers who entered prior to the passage of IRCA as earlier immigrants, because they were likely eligible for the Special Agricultural Workers (SAWs) component of the legislation. Similarly, we define those who entered after 2001 as recent immigrants. As expected, the degree of substitution between immigrant and native farm workers for recent immigrants is around 1.46, which is slightly lower than earlier immigrants (1.61).

We compare our estimates of $\frac{1}{\sigma_I}$ (i.e. inverse of the elasticity of substitution) with those obtained in previous major migration and labor studies using similar framework. It is clear that the elasticity of substitution between immigrant and native farm works are significantly smaller than those obtained across all industries (Table 2), which means small substitution between native and immigrant farm workers.

Table 2. Comparison of Estimates of the Substitution Elasticity with Major Labor Economics

| Authors and Data | Inverse Elasticity of Substitution Estimate $\left(\frac{1}{\sigma_I}\right)$ | Calculated Elasticity of Substitution of Preferred Estimate $(\sigma_I)$ |
|---|---|---|
| This paper<br>U.S National Agricultural Worker survey (1989-2012) | 0.487~0.531(sample all) | $\approx$ 2 (sample all) |
| Ottaviano and Peri (2012)<br>U.S. Decennial Census 1960-2000 and ACS 2006 | 0.033~0.063 (men all)<br>0.07~0.10 ( less educated men) | $\approx$ 20 (men all)<br>$\approx$ 11.1 (less educated men ) |
| Manacorda et al. (2012)<br>UK cross-sectional data | 0.128 (baseline, sample all)<br>0.069* (secondary) | 7.8<br>14.49 |
| Card (2012) | 0.019~0.023 (HS equivalent) | $\approx$ 40 (HS equivalent) |

| | | |
|---|---|---|
| U.S. cross-city panel (1980, 1990, 2000, 2005/06) | 0.06 (College equivalent) | ≈ 17 (College equivalent) |

Notes: * not statistically significant.

*5.2. Estimates of Elasticity of Substitution across different age ($\sigma_A$) and education groups ($\sigma_E$)*

After obtaining $\sigma_I$, we estimate the elasticity of substitution across different age and education groups following Step 2 (estimating Nest Level 2) and Step 3 (estimating Nest Level 1). Table 3 summarizes the complete set of estimates for the three key elasticities under four different nesting structures. The inverse of elasticity of substitution between immigrant and native farm workers ($\frac{1}{\sigma_I}$) is consistently estimated through all nesting specifications to be around -0.50, rejecting the hypothesis that immigrant and native farm workers are perfect substitutes. The implied point estimate of $\sigma_I$ is approximately 2.

It is worth noting here that when estimating $\sigma_A$ and $\sigma_E$ in Step 2 and Step 3, Equation (13) and Equation (15) provide updated sets of estimates of $\sigma_I$. This procedure provides an implicit robustness check of our model specifications as we are using calculated relative labor supply of immigrant and native workers based on estimates from Step 1. We find that the estimated inverse elasticity of substitution between native and immigrant farm worker ($\frac{1}{\sigma_I}$) remain virtually unchanged in all three nests. In particular, $\frac{1}{\sigma_I}$ tends to be more stable (in Alternative 1 and Alternative 3) as we reduce the heterogeneity of farm workers by keeping only those aged between 20 and 69 years old.

The estimated inverse elasticity of substitution across different age groups ($-\frac{1}{\sigma_A}$) is ranging from -0.212 to -0.55 and the corresponding elasticity ($\sigma_A$) is moving from 1.80 to about 4.72 depending on different age grouping. Our estimated $\frac{1}{\sigma_A}$ from Alternative 2 with a resulting point estimate of $\sigma_A$ around 4.72 is closer to the mainstream estimates in most recent literature.

For example, Manacorda *et al.* (2012) obtain a point estimate of 5 for the elasticity of substitution across seven different age groups. Card and Lemieux (2001)'s estimate is 4.5 with similar grouping of age cohort. The middle point of the estimated range by Ottaviano and Peri (2012) across eight experience groups under different nesting structures is 5. However, it is not surprising that we have relatively small elasticity estimates across different age groups in other nesting specifications. Our age groups are more roughly divided. Substitutability within each education groups is expected to increase with more disaggregated age group divisions as differences across age groups become smaller. In addition, as pointed by Borjas *et al.* (2012) under the three-nesting structure, the estimates of $\sigma_A$ is more dependent on the aggregated or disaggregated levels of education groups standing on the top of the first nest, because education attainment and age are more closely interrelated.

The estimated elasticities of substitution between different education groups ($\sigma_E$) vary between 1.93 and 3.69 depending on definition of skill groups. Using conventional definition of skilled (≥12yrs) and unskilled labor (<12yrs), Alternative 3 yields a point estimate of 2.5 for elasticity of substitution between skilled and unskilled farm workers, which is comparable to estimates obtained in previous studies. Our estimated $\sigma_E$ is only slightly higher than the established standard in labor economics which ranges between 1 and 2. [6]

[6] For more details, see Ciccone and Peri (2003). They provide an excellent summary of the estimates of elasticities of substitution between more and less educated workers.

Table 3: Estimated Elasticities of Substitution by Immigrant Status, Age and Education

| Parameter | | Step1/Nest 3 | Step2/Nest 2 | Step3/Nest 1 |
|---|---|---|---|---|
| | | | Baseline Nesting Structure | |
| | | Native/Immigrant | Four Age Groups | $\leq$ 6 yrs vs. >6 yrs |
| Native-immigrant (by age and education) | $-1/\sigma_I$ | -0.497*** (0.055) | -0.584*** (0.048) | -0.588*** (0.049) |
| Primary and less vs. Secondary and above (by age group) | $-1/\sigma_A$ | | -0.555*** (0.077) | -0.526*** (0.063) |
| Primary and less vs. Secondary and above (Aggregate) | $-1/\sigma_E$ | | | -0.417*** (0.106) |
| | | | Alternative 1 | |
| | | Native/Immigrant | Young/Middle/Old | $\leq$ 6 yrs vs. >6 yrs |
| Native-immigrant (by age and education) | $-1/\sigma_I$ | -0.515*** (0.058) | -0.524*** (0.044) | 0.528*** (0.0) |
| Primary and less vs. Secondary and above (by age group) | $-1/\sigma_A$ | | -0.514*** (0.099) | 0.538*** (0.068) |
| Elementary and less vs. Secondary and above (Aggregate) | $-1/\sigma_E$ | | | -0.518*** (0.101) |
| | | | Alternative 2 | |
| | | Native/Immigrant | Four Age Groups | 6 yrs vs. 7-11yrs vs. $\geqslant$ 12yrs |
| Native-immigrant (by age and education) | $-1/\sigma_I$ | -0.487*** (0.040) | -0.372*** (0.032) | -0.376 *** (0.031) |
| Primary and less vs. Some secondary vs. HS graduate and above(by age group) | $-1/\sigma_A$ | | -0.212*** (0.031) | -0.229*** (0.031) |
| Primary and less vs. Some secondary vs. HS graduate and above(Aggregate) | $-1/\sigma_E$ | | | -0.271*** (0.074) |
| | | | Alternative 3 | |
| | | Native/Immigrant | Young/Middle/Old | <12 yrs vs. ≥12 yrs |
| Native-immigrant (by age and education) | $-1/\sigma_I$ | -0.531*** (0.064) | -0.551*** (0.051) | -0.571 *** (0.045) |
| Less than HS vs. (by age group) | $-1/\sigma_A$ | | -0.470*** (0.072) | -0.474*** (0.073) |
| Less than HS vs. Secondary and above (by age group) | $-1/\sigma_E$ | | | -0.393*** (0.112) |
| Education dummies | | Yes | | |
| Age group dummies | | Yes | Yes | |
| Year dummies | | Yes | Yes | Yes |
| Immigrant dummies | | | Yes | Yes |

Notes: The table reports OLS estimates of equations (12), (13) and (15). The set of different combinations of education, age, year and immigrant status fixed effects are applied to all four nesting structures. Standard errors in parenthesis. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

## 6. Conclusions

The large share of unauthorized foreign-born immigrant workers in the farm labor force has made immigration policy a major issue for the agriculture sector. The focal points of the policy discussions include two sides of the same coin: to what extent growers have difficulty finding and keeping the labor they need, and to what extent immigrant farm workers affect the economic opportunities that native farm workers with similar education levels face. If immigrant and native farm workers are imperfect substitutes in employment, then the inflows of foreign-born farm workers may even benefit the sector by complementing native farm workers.

Using individual wage and employment information obtained from the National Agricultural Worker Survey (NAWS) over the period of 1989 and 2012 and aggregated at different education-age-year cells, we find a large and significant degree of imperfect substitutability between immigrant and native farm workers. Within a specific age-education cell, the point estimate of the elasticity of substitution between immigrant and native workers is around 2 (the estimated coefficient on the relative supply term ($-\frac{1}{\sigma_I}$) is around -0.5). This estimate is robust to all four nesting structures under different combinations of age and education groups, suggesting small substitution possibilities between native and immigrant farm workers, as opposed to previous literature on other industries showing higher degree of substitution between native and immigrant low-skilled workers. This result is consistent with Hotchkiss and Quispe-Agnoli (2012)'s findings for Georgia and authors' own observations for Florida strawberry industry. Wage differentials are mostly likely to be caused by productivity differences suggesting

that the removal of undocumented workers from the labor market will not likely increase employment levels of native workers, nor will it raise wages of native workers.

There is some variation in the estimates of the substitution elasticities across different age and education groups depending on different groupings and nesting structures. The coefficient on age-specific relative supply of native and immigrant workers ($-\frac{1}{\sigma_A}$) ranges from -0.212 to -0.55, and the resulting elasticity ($\sigma_A$) ranges from 1.80 to 4.72. The estimated elasticity of substitution between different education groups ($\sigma_E$) vary between 1.93 and 3.69 depending on how skill groups are defined.

Overall, we find little evidence that inflows of immigrant farm workers significantly impact labor market outcomes of native farm workers across different age and education groups. Our findings have important implications for immigration policy. Results suggest that legislators should keep potential impact that a new immigration reform will have on agriculture in mind. Providing easier access to the pool of legal migrant farm workers by streamlining the H-2A guest workers program will help US agricultural sector stay competitive without threatening employment opportunities of domestic farm workers.

Substitution elasticities we compute in this paper for native and immigrant workers from different age and education groups should be interpreted as long-run aggregate elasticities of substitution, and should be taken with caution when evaluating local agricultural markets. Hired farm labor is mobile across states in the United States, and local agricultural markets may have unique supply and demand conditions (Fisher and Knutson 2012). For example, a farm worker may have picked apples in Michigan before coming down to Florida to harvest strawberries and then may move to North Carolina to pick blueberries. All in all, given the robustness checks of our results with different samples, nesting structures, and different variable definitions, and the

fact that our results relatively trace previous results from the labor literature, we are confident in our estimates.

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