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Substitution between Immigrant and Native Farmworkers in the United States: Does Legal Status Matter?

Abstract

The policy debate surrounding the employment of immigrant workers in U.S. agriculture centers around the extent to which immigrant farmworkers adversely affect the economic opportunities of native farmworkers. To help answer this question, we propose a three-layer nested constant elasticity of substitution (CES) framework to investigate the substitutability among heterogeneous farmworker groups based on age, skill, and legal status utilizing National Agricultural Workers Survey (NAWS) data from 1989 through 2012. We use farmwork experience and type of task performed as alternative proxies for skill to disentangle the substitution effect between U.S. citizens, authorized immigrants, and unauthorized immigrant farmworkers. Results show that substitutability between the three legal status groups is small; neither authorized nor unauthorized immigrant farmworkers have a significant impact on the employment of native farmworkers.

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1 Introduction

One of the most controversial aspects of immigration is its potential impact on the labor market opportunities for natives of the host country. In the United States, there are an estimated 11 million unauthorized immigrants,¹ accounting for nearly 50% of the total unauthorized foreigners residing in the developed countries (Martin, 2017). Finding policies to resolve the issue of large stocks of undocumented immigrants in a way that is not disadvantageous to U.S. citizens has been a major topic of debate for decades, gaining a renewed interest during and after the 2016 U.S. presidential election.

Immigration has an important role in the U.S. farm sector, especially within the laborintensive fruits and vegetables industry. Since the 1940s, U.S. farmworker demographics have shifted away from native workers ² to foreign-born workers (Taylor, 2010). With the shift toward foreign-born workers, legal documentation of farmworkers has become a long-standing issue. With the hope of eliminating unauthorized immigrants in the United States, the Immigration Reform and Control Act (IRCA) of 1986 provided amnesty to approximately 1.5 million undocumented farmworkers and established enforcement policies to curb the future influx of unauthorized immigrants. IRCA policies, however, proved ineffective in stopping unauthorized immigration. The use of counterfeit identity and work authorization documents quickly became widespread, and the flow of undocumented migrants resumed shortly after the 1986 reform.

Reforming federal immigration policies with improved guest worker programs and enhanced border security measures have been a controversial point of debate, particularly within the context of the agricultural sector and farmworkers. Legislators find themselves having to balance the two opposing viewpoints. On the one hand, there are concerns from the general public that a rising immigrant population may adversely affect native workers by either driving them out of U.S. farm jobs or lowering their average hourly earnings. On the other hand, there are concerns from agricultural producers that a mass deportation or exodus of foreign-born workers will leave them with an insufficient pool of farmworkers who are willing and able to do agricultural work. The challenge for future legislative efforts to reform the current immigration policies will be to balance both of these concerns. This study aims to help decision makers by answering the following questions: (a) How does the inflow of immigrants affect the employment of native farmworkers and (b) to what extent do authorized and unauthorized immigrants compete with native farmworkers? To answer these questions, we developed and used a nested constant elasticity of substitution (CES) model of agricultural labor demand to investigate the degree of substitutability among heterogeneous groups of farmworkers separated by age, skill, and legal status. Using a three-layered nested CES structure, we estimate the elasticity of substitution among unauthorized immigrant, authorized immigrant (i.e., permanent residents and immigrants with other types of work authorization), and native

¹ *Immigrant* is defined to include both authorized immigrants (i.e., lawful permanent residents [or "green card" holders], refugees, asylees, and persons on certain temporary visas) and unauthorized immigrants (i.e., immigrants lacking proper, unexpired legal documentation to work).

² The term *native* is used in this study to refer to two (interrelated) legal status groups: *Citizen* (used in the main empirical application as the nonimmigrant group) and *U.S.-born* (used in the supplementary analysis in Appendix B as the nonimmigrant group). There is a subtle distinction between the definitions of *U.S.-born* and *Citizen*. *U.S.-born* strictly refers to a U.S. citizen by *birth*. *Citizen* is a broader category that includes both U.S. citizens by *birth* and *naturalized* citizens who used to be lawful permanent residents.

(including both citizens by birth and naturalized citizens) farmworkers within the same skill and age group, the elasticity of substitution across different age groups within the same skill group, and the elasticity of substitution among workers from different skill groups. We use the NAWS data from 1989 through 2012 for the empirical analysis. Although there are other data sources for farm labor employment and wages (namely, Farm Labor Survey [FLS], Current Population Survey [CPS], and Quarterly Census of Employment and wages [QCEW]), NAWS is the only national data source tracking legal immigration status of farmworkers.

This article contributes to the literature on the impact of migration on the U.S. agricultural labor markets in three ways. First, to our knowledge, this is the first study to quantify the substitutability of farmworkers with different legal status backgrounds. Second, by differentiating between authorized and unauthorized status of immigrant workers, the study fills the research gap in the empirical labor economics literature where immigrants are typically treated as one group. Third, because the agricultural sector has a distinct definition of "skill" compared to other less-skilled labor sectors, the study proposes two proxies alternative to formal education to measure the skill in agriculture: the number of years in agricultural work and the type of farmwork tasks performed. This is because the conventional formal education measure that is widely used in the literature to proxy the skill level of workers is meaningless for the agricultural sector where most farmworkers lack any formal education beyond high school.

The main finding of the study is that native farmworkers do not compete with immigrant farmworkers who are at similar age and skill levels for the same jobs. In other words, the substitution possibilities between immigrant farmworkers (both authorized and unauthorized) and native farmworkers are limited; the elasticity of substitution between these three legal status groups is estimated to be between 2.11 and 2.2 depending on the measure of skill used in the analysis.

The rest of the article is organized as follows. Section 2 introduces the background information on immigrant workers in the U.S. farm sector. Section 3 summarizes related literature. Section 4 presents the empirical estimation strategy using the nested CES framework. Data are summarized in Section 5, and the empirical results are presented in Section 6. Section 7 offers conclusions.

2 Immigrant workers and the U.S. farm sector

Currently, more than 1 million of the 11 million unauthorized immigrants in the United States work in the agricultural sector, making up nearly half of the total U.S. farmwork force (Passel and Cohn, 2016). The U.S. Department of Agriculture, Economic Research Service (USDA-ERS) estimates that more than 50% of seasonal U.S. farmworkers in the agricultural sector are foreign-born and unauthorized to work in the country (Hertz, 2015). The U.S. Department of Labor's (DOL) National Agricultural Worker Survey (NAWS) reports similar estimates based on farmworker interviews, and suggests that more than 50% of specialty crop workers do not possess proper documentation to work legally in the United States (ETA, 2014). Fisher and Knutson (2012) argue that the actual percentage of undocumented farmworkers is higher than 50%. Emerson and Iwai (2014) report that 68.9% of immigrants working in Florida specialty crop industries are unauthorized, while Guan et al. (2015) estimate that 80% of the labor force in the Florida strawberry industry lacks proper documentation.

The U.S. farm sector is particularly sensitive to changes in the flow of migrant workers and changes to federal immigration policies because farmers mostly rely on foreign-born workers (often with questionable legal status). Historically, Mexico has been the home country for most foreign-born farmworkers in the United States (Roka and Emerson, 2002; Martin, 2003). Immigration trends have been changing in recent years and between 2009 and 2014, more Mexican-born immigrants exited than entered the United States. Worker demographics and economic growth in Mexico are two major reasons for the changes in immigration flows (Gonzalez-Barrera, 2015). Another reason behind the deceleration in Mexican immigration in the U.S. farm sector is the enhanced border enforcement efforts and the growing national debate over comprehensive immigration reform within the United States. For more than 15 years, the U.S. Congress has been embroiled in heated political debates, with a significant number of its members calling for building walls on the Mexican–U.S. border and mass deportation of unauthorized immigrants. However, recent efforts to pass legislation to reform immigration have all failed.

3 Literature related to the effect of immigration on the domestic labor markets

There is a large literature examining the effect of immigration on the nonfarm labor markets. These studies do not provide any consensus on the outcomes of native workers in host countries in terms of both magnitude and direction of the effects. For example, Borjas (2003) argues that immigration to the United States from 1980 to 2000 has depressed wages of competing workers by 3-4%. Dustmann et al. (2017) show that an inflow of Czech immigration workers leads to a moderate decline in local wages and a sharp decline in local employment for German native workers. Lewis (2005) finds that the wage effects are smaller when the analysis focuses on local rather than nationwide effects. Card (2009) concludes that immigration has had a very small effect on wage inequality among natives in the United States. Simulating the change of supply economy using a 14-sector nested computable general equilibrium (CGE) model, Watson et al. (2012) found that a reduction of the less-educated immigrant labor supply will only modestly increase the demand for less-educated native workers, while causing a reduction in the state gross domestic product (GDP) as well as the total economic output in Idaho. Cattaneo et al. (2013) found similar evidence in European countries that the inflow of immigrants over the period of 1995 through 2001 is not associated with an increase in the probability of natives being unemployed. Ottaviano and Peri (2006) argue that wage effects may even turn positive if imperfect substitutability between immigrant and native workers is taken into account. An analysis by Chassamboulli and Peri (2015) show that restricting unauthorized immigrants through increasing deportation rates or tightening border control actually raises the unemployment rate of U.S. domestic workers and weakens the U.S. domestic labor market.

The aforementioned studies analyze the impact of immigration on nonagricultural labor markets. Further, they look at immigrants as a whole rather than distinguishing between legal status groups within the broad category of immigrants. Labor studies using secondary data seldom consider immigrants' legal status in analyses, partially because legal status is sensitive information and often not revealed in public data. The farm sector is unique in this respect. The large presence of unauthorized immigrants in the farm sector prompted the U.S. DOL to initiate the NAWS after the enactment of IRCA to estimate the size of the immigrant farmworker population as well as their legal status. Understanding the role of legal status on farmworker employment and wages is important for immigration policy debates (Passel, 2006; Caponi and Plesca, 2014). After a few studies published in the early 1990s about the impact of IRCA on agricultural production and labor supply (e.g., Duffield and Coltrane, 1992; Gunter et al., 1992), there has been a renewed interest in analyzing the impact of immigration policies on labor market outcomes for hired farm labor (Pena, 2010; Zahniser et al., 2012; Hertz, 2015). Pena (2010) compares earnings of authorized and unauthorized immigrant farmworkers using NAWS data between 1989 and 2006, and finds that unauthorized immigrants make 5-6% less on average than their authorized immigrant counterparts. Using the CGE model of the U.S. economy, Zahniser et al. (2012) simulate the impact of two hypothetical scenarios on the agricultural sector: increase in the employment of (temporary) authorized immigrant agricultural workers, and decrease in the total number of unauthorized workers in the United States. The first scenario would lead to a 4.4% decrease in the long-run real wages of agricultural workers, whereas a large reduction in the number of unauthorized immigrant workers across the U.S. economy would result in a 3.9-9.9% increase in real agricultural wages in the long run. Clemens et al. (2018) demonstrate that the exclusion of Mexican bracero farmworkers had little impact on the U.S. agricultural labor market.

4 Estimation framework

The concept of substitutability is used to draw conclusions on how immigration impacts job opportunities and wages of native farmworkers, and whether natives and authorized or unauthorized immigrants compete for similar agricultural jobs. On the one hand, if immigrant labor is similar to native labor in the sense that there is a perfect substitutability between the two groups, then increased migration into the United States may have a negative effect on native farmworkers' wages due to the competition effect between the two groups. On the other hand, if immigrants and natives within the same skill and age category are imperfect substitutes, then the competitive effects of increased immigrant inflows on natives will likely be minimal and will be concentrated among immigrants themselves (Ottaviano and Peri, 2006; Card, 2009). It is worth noting here that our theoretical framework is a partial equilibrium, one-sector approach and inter-sectoral mobility and adjustment are not considered in this framework.³

Building on the theoretical models by Card (2009), Manacorda et al. (2012), and Ottaviano and Peri (2012), we derive the following wage differential equation between native (denoted by N) and immigrant (denoted by M) farmworkers in each age (a) and skill (s) group at time t, which is a function of relative labor supply in each skill–age–time cell (refer to Appendix A for details of the theoretical framework).

$$ln\frac{W_{sat}^{N}}{W_{sat}^{M}} = -ln\beta_{sat} - \frac{1}{\sigma_{I}} \left(ln\frac{L_{sat}^{N}}{L_{sat}^{M}} \right)$$
(1)

where β_{sat} reflects the efficiency of immigrant workers relative to native workers within each skill-age-time cell. Equation (1) is a major equation of interest, from which the elasticity of

³ Existing empirical evidence has found the role of inter-sectoral adjustments to be small (see Card [2009] for more details).

substitution between native and immigrant farmworkers, σ_i , can be obtained. By the nature of the nested CES structure, when there are multiple legal status groups, σ_i would represent the degree of substitution between any two legal status groups. If native and immigrant farmworkers are perfect substitutes, there should be no statistically significant effect of changes in the relative employment of native workers with respect to immigrant farmworkers on their relative wages. In other words, $1/\sigma_i$ will be zero in cases of perfect substitutability.

Denoting the immigration (or, legal) status by *I*, which takes on values *N* and *M* for native and immigrant, respectively, the relative wages of skilled labor compared to less-skilled labor within the same age but different immigration group at time *t* can be written as

$$ln\frac{W_{1at}^{l}}{W_{2at}^{l}} = ln\theta_{t} + ln\frac{\alpha_{1a}}{\alpha_{2a}} + ln\frac{\beta_{1at}^{l}}{\beta_{2at}^{l}} - \frac{1}{\sigma_{s}}ln\frac{L_{1t}}{L_{2t}} - \frac{1}{\sigma_{s}}\left(ln\frac{L_{1at}}{L_{2at}} - ln\frac{L_{1t}}{L_{2t}}\right) - \frac{1}{\sigma_{t}}\left(ln\frac{L_{1at}}{L_{2at}^{l}} - ln\frac{L_{1at}}{L_{2at}^{l}}\right)$$
(2)

where $s = \{1,2\}$ with 1 representing the skilled labor group and 2 representing the less-skilled labor group. Equation (2) is the base equation for the empirical estimation that yields negative of the inverse of elasticity of substitution between skill groups $\left(-\frac{1}{\sigma_s}\right)$, age groups $\left(-\frac{1}{\sigma_A}\right)$, and legal status groups $\left(-\frac{1}{\sigma_I}\right)$.

Although there is disagreement on the exact effects immigrants have on wages and employment of native workers in the host country, the empirical evidence generally points to imperfect substitutability between immigrant and native workers in less-skilled sectors. Based on the labor market outcomes of less-skilled native workers in 120 major cities extracted from the 1970 and 1980 U.S. Censuses, Altonji and Card (1991) found that the competition between immigrants and less-skilled natives in labor markets is modest and there is little evidence that inflows of immigrants are associated with increased unemployment rates of less-skilled native workers. Card (2009) found an elasticity of substitution between immigrants and natives of 50 (estimated $-1/\sigma_i$ of -0.02) using pooled time series for 124 U.S cities. Ottaviano and Peri (2012) obtained similar elasticity estimates for immigrants and natives ($-1/\sigma_i$ ranging from -0.08 to -0.04) using U.S. census data. Using pooled data on British males' wages and employment from the mid-1970s to the mid-2000s, Manacorda et al. (2012) found that immigrants and natives are imperfect substitutes in the labor markets of the United Kingdom, with a relatively small degree of substitution around 8 (estimated $-1/\sigma_i$ of -0.128).

Strikingly, there is a large research gap in quantifying the elasticity of substitution among farmworkers from different legal status backgrounds. This measure is crucial for assessing the wage effects of immigration and immigration policy changes on the U.S. agricultural sector. Studies using the CGE models typically skip formal estimation of σ_I , and instead assume an ad hoc elasticity of substitution between farmworkers with different legal statuses. For example, Zahniser et al. (2012) set the elasticity of substitution at 5 for unauthorized and authorized (permanent resident) workers, and a higher substitution elasticity of 7.5 between U.S.-born and foreign-born permanent resident workers to simulate the impact of changes in the supply of immigrants on the U.S. agricultural sector. Watson et al. (2012) assume an elasticity of substitution of 3.5 (upper bound) and 1.3 (lower bound) between foreign-born and native workers for their general equilibrium model for Idaho economy.⁴

⁴ Watson et al. (2012) note that they adopt these two estimates from Borjas (2003). However, Borjas's (2003) estimates are not elasticities of substitution between immigrant and native workers. Based on Borjas (2003), 1.3 is the elasticity of substitution across different education groups and 3.5 is the elasticity of substitution across different experience groups.

To obtain substitution elasticities across different skill, age, and immigration status groups using estimates from Equation (2), we first need to have the predicted values of L_{sat} and L_{st} at hand. As shown in Equations (A2) and (A3) in Appendix A, predicting L_{sat} and L_{st} , in return, requires having estimates of σ_I and σ_A . As such, a three-step estimation procedure proposed by Manacorda et al. (2012) is used to iteratively obtain the three elasticity estimates.

Step 1: Estimating σ_{I}

Assuming β_{sat} follows the following additive structure and varies by skill (f_s), age (f_a), and time (f_t) for both native and immigrant farmworkers, f_s , f_a , and f_t capture the fixed effects across different skill and age groups over time.

$$-\ln\beta_{sat} = f_s + f_a + f_t \tag{3}$$

Using Equation (3), Equation (1) can be rewritten as

$$ln\frac{W_{sat}^{N}}{W_{sat}^{M}} = f_{s} + f_{a} + f_{t} - \frac{1}{\sigma_{I}} \left(ln\frac{L_{sat}^{N}}{L_{sat}^{M}} \right)$$

$$\tag{4}$$

Finally, estimates of σ_l and β_{sat} can be obtained from a regression of the log relative wages of native to immigrant workers for each skill–age–time cell on the relative supply of the same group of workers along with skill, age, and time dummies (Equation 4).

Step 2: Estimating σ_{A} and α_{sa}

Using σ_l and β_{sat} estimated from Equation (4), we can compute L_{sat} and obtain σ_A by estimating the following equation:

$$ln\frac{W_{1at}^{I}}{W_{2at}^{I}} = d_{a} + d_{t} + d_{I} - \frac{1}{\sigma_{A}} \left(ln\frac{L_{1at}}{L_{2at}} \right) - \frac{1}{\sigma_{I}} \left(ln\frac{L_{1at}^{I}}{L_{2at}^{I}} - ln\frac{L_{1at}}{L_{2at}} \right)$$
(5)

where d_a , d_t , and d_t are dummy variables indicating age, year, and immigration/legal status, respectively. Age dummies, d_a , capture the relative age effects; d_t captures the time-varying components; and d_t captures the relative productivity of immigrant farmworkers within a given skill-age-time cell to that of native farmworkers, $\left(ln\frac{\beta_{sat}^M}{\beta_{sat}^N}\right)$. The coefficient on the relative supply of skilled and less-skilled farmworkers $\left(-\frac{1}{\sigma_A}\right)$ is the estimate of the negative of the inverse elasticity of substitution across different age groups.

We then run the following regression (based on equation (A11) in Appendix A) to recover α_{ω} , which indicates the relative productivity of different age groups within each skill category:

$$lnW_{sat}^{I} = d_{st} + d_{sa} - \frac{1}{\sigma_{A}}L_{sat} - \frac{1}{\sigma_{I}}\left(\ln L_{sat}^{I} - lnL_{sat} - \sigma_{I}\ln\beta_{sat}\right)^{5}$$

$$\tag{6}$$

The coefficients on d_{sa} dummies are In α_{sa} , by definition; therefore, they can be used to recover α_{sa} . Once α_{sa} is known, L_{st} can be computed.

Step 3: Estimating σ_{s}

Labor supply estimates obtained from the first and second steps can be used to reestimate Equation (2) using the following specification:

⁵ Coefficients are normalized such that $\beta_{sat}^{N} = 1$, $\beta_{sat}^{M} = \beta_{sat}$.

$$ln\frac{W_{1at}^{I}}{W_{2at}^{I}} = \kappa_{0} + \kappa_{1}t + d_{a} + d_{I} - \frac{1}{\sigma_{s}}ln\frac{L_{1t}}{L_{2t}} - \frac{1}{\sigma_{A}}\left(ln\frac{L_{1at}}{L_{2at}} - ln\frac{L_{1t}}{L_{2t}}\right) - \frac{1}{\sigma_{I}}\left(ln\frac{L_{1at}^{I}}{L_{2at}^{I}} - ln\frac{L_{1at}}{L_{2at}}\right)$$
(7)

Equation (7) allows us to obtain an estimate of the negative of inverse elasticity of substitution between different skill groups $(-1/\sigma_s)$. κ_l captures the skill-biased technological change. Equation (7) also yields a new set of estimates for σ_l and σ_A , which may serve as specification tests for estimating equations in the previous steps.

To pin down the three substitution elasticity parameters (σ_{I} , σ_{A} , σ_{S}) in the production function and examine the consistency of the model, we consider different nesting structures by partitioning heterogeneous workers into different combinations of skill, age, and legal status groups as illustrated in Figs. 1 and 2. In the theoretical framework, the production function considers two distinct skill groups: skilled and less-skilled workers. Although it is a wellestablished tradition in the literature to use formal education years in measuring skill levels of workers, the validity of this measure is questionable for crop farmworkers, who typically lack high school diploma. Therefore, we use formal education only as a supporting measure and report results based on education proxy in Appendix B. Instead, we propose two alternatives, more realistic proxies, to categorize agricultural labor into skilled and less-skilled groups: (a) the *type of operational tasks* that farmworkers perform and (b) the number of years working in the farm sector (i.e., the *farmwork experience*).

The division of age groups is relatively straightforward. Four age cohorts are considered in the empirical analysis: Teenager (14–19), young (20–39), middle-aged (40–59), and old (≥ 60).⁶

Legal status is an additional characteristic to differentiate heterogeneous farmworker groups. Foreign-born workers differ from native workers in several aspects, such as legal status,



Figure 1 Nested CES Model A: Skill is approximated by task type

⁶ We also considered an alternative case where age was truncated to only include farmworkers between the ages of 20 and 69 years old—young (20–29), middle-aged (40–59), and old (60–69). Empirical results using this alternative age classification did not differ significantly from those using the classification described above.



Figure 2 Nested CES Model B: Skill is approximated by farmwork experience

education, and English proficiency (Caponi and Plesca, 2014; Kaushal et al., 2016). Even considering workers within the same skill and age cohort, immigrant and native workers tend to differ in several other aspects that are relevant to the labor market. Immigrants may have different work ethics, motivations, and preferences that differentiate them from native workers. Immigrants may have comparative advantages in some tasks and occupations because of their culture-specific skill sets that native workers do not possess (Ottaviano and Peri, 2006). Furthermore, authorized immigrants may have more bargaining power in the labor market than unauthorized immigrants, although this disparity likely decreases with educational attainment (Caponi and Plesca, 2014). Based on their immigration status, we categorize farmworkers into three legal status groups: U.S. citizens (including both citizens by birth and naturalized citizens), authorized immigrants (permanent legal residents and immigrants holding other types of work authorization), and unauthorized immigrants (immigrants without proper legal documentation authorizing them to work in the United States).⁷

5 Data

Before proceeding to the estimation of the conceptual model introduced in the previous section, we first describe the key variables constructed for the empirical analysis. Data from the NAWS, an employment-based random sampled survey of seasonal hired crop workers, are used in this study. NAWS is the only national survey that collects data on U.S. hired farmworkers' immigration status as well as their demographic characteristics and detailed employment information through face-to-face interviews. We use the portion of the NAWS data that is open to the public and available online from the DOL website.⁸ After removing some observations

⁷ An alternative classification using birthplace (i.e., U.S.-born vs. foreign-born) is presented in Appendix B.

⁸ Data are available at www.doleta.gov/naws/.

with missing wage rate information, the sample size reduces to 52,527 individual farmworkers or 565 age–skill–immigration cells, covering the period from 1989 through 2012.

The NAWS uses a stratified multistage sampling design to account for seasonal and regional fluctuations in the level of employment in crop agriculture. The sampling design involves first obtaining a random selection of employers from a universe list compiled mainly from public agency records. Once the random sample of employers is identified, then a random sample of workers is chosen for each employer. The interviewers, who are bilingual and generally work in pairs, approach workers directly to set up interview appointments in their homes or other agreed-upon locations outside the farm. In 2008–2009, 92% of the approached workers agreed to be interviewed for NAWS. NAWS methodology has been adapted to maximize response from this hard-to-survey population. Interviewers speak with workers in English or Spanish, as necessary. All interviewers are bilingual and bicultural. The NAWS questionnaires are available in both Spanish and English. In addition to anonymity, interviewers ensure that potential respondents know that they are not associated with any enforcement agency, such as the Immigration and Customs Enforcement agency. These measures increase the likelihood of obtaining truthful answers to some key questions regarding legal status and employment (DOL, 2019).

5.1 Skill measures

As expressed in the previous section, we utilize different survey questions to approximate skill levels of farmworkers in alternative ways. Accordingly, we estimate the nested CES model using each alternative skill measure. The first measure we use to approximate skill is the type of operational tasks that farmworkers perform, following the literature on farm wage differentials between different task groups (e.g., Autor et al., 2003; Goos and Manning, 2007; Autor et al., 2008). For the first skill proxy using task codes in the NAWS data, we categorize workers conducting tasks coded as "Pre-harvest," "Harvest," "Post-harvest," and "Other" into the less-skilled manual labor group; workers conducting tasks coded as "Semi-skilled" and "Supervisor" into the semi-skilled and skilled labor group.⁹ The second measure we use to approximate farmworker skill is the farmwork experience based on the survey question asking individual farmworkers to report how many years they have been doing farmwork in the United States.¹⁰ Using this second skill proxy, we categorize workers with less than 10 years of farmwork experience as less-skilled farmworkers and skilled farmworkers, respectively. The longer a worker works in the farm sector, the better he or she can master a specific skill set and become more skilled.

We follow the convention in the literature and add formal education years as a third proxy for farmworkers' skill levels. However, we use this measure as a sensitivity check and

⁹ We have also considered two alternative task groupings as robustness checks for our elasticity estimates. Under the first alternative, "Pre-harvest," "Harvest," and "Post-harvest" tasks were grouped into the less-skilled labor group, and "Semi-skilled," "Supervisor," and "Other" tasks were classified into the semiskilled and skilled labor group. Under the second alternative, we classified "Harvest" and "Post-harvest" tasks into the less-skilled group, and "Pre-harvest," "Semi-skilled," "Supervisor," and "Other" tasks into the semiskilled and skilled group, and "Pre-harvest," and "Post-harvest" tasks into the less-skilled group, and "Pre-harvest," and "Dother" tasks into the semiskilled and skilled group. There were virtually no changes in the major elasticity estimates compared to Table 3. The results of these robustness checks of the task groupings are available from the authors upon request.

¹⁰ Farmworkers were instructed to count any year in which they did farmwork for 15 days or more when answering this question.

a comparison of our elasticities to those reported in the literature for nonagricultural lowskilled labor markets. The empirical results using education as a skill proxy are reported in Appendix B. As discussed in Section 4, the conventional categorization of college (or college equivalent) graduates as skilled workers does not work for the case of agricultural workers; because, nearly 80% of the hired farmworkers in the NAWS data lack a high school diploma. The median and mean education levels in the NAWS are six and seven years, respectively. Therefore, we construct our education proxy by defining less-skilled farmworkers as those who did not complete elementary school (i.e., less than or equal to six years of formal education) and skilled farmworkers as those who have at least some secondary education (i.e., greater than six years of formal education).

5.2 Immigration status

The NAWS asks farmworkers to identify their current legal status in the United States. Based on the question about legal status, the primary definition of immigration groups used in the two main models is as follows. Workers who reported their status as "U.S. citizen by birth" or "naturalized U.S. citizen" were classified into the *U.S. Citizens* group; workers who reported their legal status as "permanent resident/green card holder" and "other work authorization" were classified into the *Authorized Immigrants* group; and workers who reported "undocumented, or pending status" were classified into the *Unauthorized Immigrants* group.¹¹ The unauthorized immigrants account for 40% of the total NAWS sample between 1989 and 2012.

To have a close investigation of data based on legal status, age, and skill levels, we crosstabulate farmworkers' legal status at different skill levels and age groups in Table 1. At the same experience level, compared to U.S. citizen and authorized immigrant farmworkers, undocumented farmworkers tend to be more concentrated in the less-experienced labor category. In terms of performed task types, although majority of farmworkers tend to be concentrated in the less-skilled manual tasks group across all three immigrant-status groups, unauthorized immigrants are slightly more concentrated in the less-skilled manual tasks compared to other legal status groups. Furthermore, U.S. citizens engaged in agricultural work generally have relatively higher formal education levels than immigrants; the number of less-educated U.S. citizens (less than or equal to six years in school) is significantly smaller compared to that of authorized immigrants and unauthorized immigrants (results available upon request).

NAWS also collects detailed information about farmworker demographics, including the country and region of birth. Using birthplace information, we create an alternative classification of immigration status—one that follows the nonagricultural labor literature more closely: *U.S.-born* versus *foreign-born* farmworkers. U.S.-born farmworkers are defined as those born in the United States or Puerto Rico, while foreign-born farmworkers are defined as those born in any country except for the United States and Puerto Rico.¹² We use this alternative definition

¹¹ The NAWS questionnaire allows for selection among more disaggregated legal status categories and visa programs. However, the publicly accessible version of the NAWS dataset only releases legal status information after aggregating it into four broader categories: Citizen, permanent legal resident (i.e., Green Card holder), other work authorization, and unauthorized. We combine Green Card holder and Other Work Authorization into one group denoted as "authorized immigrants."

¹² This definition of "native" versus "immigrant" based on birthplace was also used by Borjas (2015), who considered persons who are noncitizens or naturalized citizens as "immigrants" and all other persons as "natives."

Table 1 Distribution of individuation	al and ag	gregated	observat	ions by leg	al status, ¿	age, and s	skill group	is (1989–20	12)				
		U.S. c	itizen		AL	uthorized	immigran	It	Un	authorized	d immigra	Int	
Skill and age groups	14–19	20–39	40-59	≥60	14–19	20–39	40-59	≥60	14–19	20–39	40-59	≥60	Total ^a
		Nu	mber of in	idividual fa	armworker	rs within €	each immi	igration sta	atus, age,	and skill c	ell		
Skill proxy: Task type													
Less-skilled manual	1.114	4.219	3.348	670	298	6.135	4.405	598	2.174	13.607	2.593	194	39.355
Semi-skilled and skilled	337	1.352	1.276	246	82	2.475	2.170	291	473	3.658	763	49	13.172
Total	1.451	5.571	4.624	916	380	8.610	6.575	889	2.647	17.265	3356	243	52.527
Skill proxy: Experience													
Less than 10-year experience	1.388	2.980	826	106	368	3.758	845	75	2.635	13.747	1.679	88	30.174
More than 10-year experience	63	2.570	3.773	803	10	4.809	5.679	805	11	3.441	1.652	153	25.273
Total	1.451	5.550	4.599	606	378	8.567	6.524	880	2.646	17.188	3.331	241	52.264
		N	umber of	aggregate	d observat	ions/cells	s generate	ed from inc	lividual ob	oservation	IS		
Skill proxy: Task type													
Less-skilled manual	24	24	24	24	22	24	24	24	24	24	24	24	286
Semi-skilled and skilled	24	24	24	24	21	24	24	24	24	24	24	18	279
Total	48	48	48	48	43	48	48	48	48	48	48	42	565
Skill proxy: Experience													
Less than 10-year experience	24	24	24	24	24	24	24	22	24	24	24	22	284
More than 10-year experience	18	24	24	24	8	24	24	24	8	24	24	24	250
Total	42	48	48	48	32	48	48	46	32	48	48	46	534
<i>Note</i> : Not all survey participants a match under the alternative skill <i>ç</i> size of 576 cells with 24 observatic	answered proxy (i.e ons in ea	all skill-r ., experie ch skill-a	elated NA nce), lead ge-immig	WS questic ing to diffe ration stat	ons. Theref rent samp tus cell wou	ore, total le sizes ac uld have l	number c cross alter been achi	of observat rnative mo eved.	ions wher dels. With	i task type out any m	e is used a	s skill pro servation	xy does not s, a sample

Immi- gra- tion		izon			Author	izod im	migrant		Upput	borizod	immigra	nt
Status	0.5. 01	lizen			Author	izeu iiii	illigrafit		Unauti	Ionzeu	IIIIIIgra	<u> </u>
Age	14–19	20-39	40-59	≥60	14–19	20-39	40-59	≥60	14–19	20-39	40-59	≥60
group												
1989	\$4.00	\$4.81	\$4.99	\$4.82	\$4.50	\$4.82	\$4.87	\$4.46	\$4.57	\$4.86	\$4.69	\$2.70
1990	\$4.33	\$5.22	\$5.17	\$4.86	\$4.83	\$5.32	\$5.19	\$4.46	\$4.82	\$4.87	\$4.71	\$3.60
1995	\$5.04	\$6.04	\$6.35	\$5.79	\$5.70	\$5.87	\$5.65	\$5.25	\$5.29	\$5.42	\$5.47	\$5.62
2000	\$6.32	\$7.48	\$7.26	\$7.50	\$6.72	\$7.13	\$6.85	\$6.57	\$6.13	\$6.46	\$6.62	\$6.57
2005	\$7.06	\$8.48	\$8.45	\$8.38	\$7.38	\$8.07	\$8.13	\$7.29	\$7.06	\$7.33	\$7.32	\$7.73
2010	\$8.39	\$9.85	\$10.39	\$9.81	\$8.43	\$9.34	\$9.46	\$8.86	\$8.04	\$8.65	\$8.78	\$8.41
2012	\$8.77	\$10.50	\$11.17	\$10.47	\$9.58	\$9.94	\$10.00	\$9.77	\$8.26	\$8.96	\$8.96	\$8.81

Table 2Average hourly wage rates by age groups and legal status

Source: Authors' calculation based on NAWS data, 1989–2012.

of legal/immigration status with three alternative skill measures as the robustness check of the results for the main legal status groups defined earlier (i.e., U.S. citizens, authorized immigrants, and unauthorized immigrants). About 21% of farmworkers in the NAWS sample used were U.S.-born and 78% were foreign-born. For the sake of brevity, we report the empirical results with this alternative legal status classification in Table B2 in Appendix B.

We use the hourly wage rates reported in the NAWS to measure farmworkers' wages. Table 2 suggests that, on average, unauthorized immigrants earned lower hourly wages than U.S. citizens and authorized immigrants over the past three decades. Due to the seasonality of most agricultural work, farmworkers may be paid by the hour, piece rate, or a combination of both. For farmworkers not paid hourly wages (i.e., paid by piece rate or combination of piece rate and hour), we convert payments under these alternative schemes to their equivalent hourly wage rates using the total payments received divided by hours reported for that payment period. Labor supply (i.e., employment) of immigrant and native farmworkers is measured by work hours in each skill–age–year cell, which is aggregated using the final individual weight variable created by the NAWS.¹³ Although 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), this does not create a limitation for the nested CES models, since the estimating equations depend only on relative labor supply of workers holding different legal status.

6 Estimation results

In this section, we discuss the estimates of key parameters and elasticities from different skill measures and nesting structures. We primarily focus our discussions on nested CES Models A and B (Figs. 1 and 2), where farmworkers are grouped into citizen, authorized immigrant, and unauthorized immigrant categories at the lowest nesting level, and skill levels are

¹³ For details about the calculation of the final weight variable, refer to the NAWS Survey Documentation: Statistical Methods (The National Agricultural Workers Survey, Part B) at https://www.doleta.gov/agworker/naws.cfm.

approximated by task type (nested CES Model A) and farm experience (nested CES Model B), respectively (Tables 3 and 4). The model where skill level is approximated by formal education is reported in Table B1 in Appendix B. Additional supplementary results using the alternative immigration grouping by birthplace (i.e., U.S.-born vs. foreign-born) and three skill proxies are presented in Table B2 in Appendix B.

6.1 Estimates of elasticity of substitution between different immigration status groups (σ_i)

The estimated coefficients—negative of the inverse elasticity of substitution between farmworkers with different legal status $(-1/\sigma_l)$ —from the two skill models, Models A and B, are reported in Tables 3 and 4. The point estimate of $-1/\sigma_l$ is -0.475 in Model A (where skill is approximated by task type), and -0.454 in Model B (where skill is approximated by number of years in farmwork), and -0.484 when skill is approximated by formal education level (Table B1 in Appendix). The corresponding elasticities of substitution between the three legal status groups (σ_l) for the models using task type, farmwork experience, and education as skill proxies are 2.11, 2.20, and 2.07, respectively. A point estimate near 2 for the elasticity of substitution, σ_l , between the three legal status/immigration groups suggests that unauthorized immigrant, authorized immigrant, and U.S. citizen farmworkers within a given skill and age cohort are not close substitutes regardless of how skill is approximated in the estimation.

As mentioned in Section 2, if farmworkers with different immigration statuses were perfect substitutes, the changes in the relative employment of these workers would have no statistically significant impacts on their relative wages (i.e., H_0 :-1/ $\sigma_I = 0$ could not be rejected). This is clearly not the case, and the estimated coefficients from all three models are statistically different than zero, indicating limited substitution possibilities among these legal status groups of farmworkers. The estimated elasticities of substitution in nested CES Model A (task type) and nested CES Model B (farmwork experience) are slightly larger than using education as skill proxy. This suggests that native and immigrant farmworkers within a specific task–age or experience–age group tend to be slightly more substitutable compared to native and immigrant farmworkers within a specific (formal) education–age group, which supports the notion that in the agricultural sector, experience and familiarity with tasks performed matter more than formal education levels.

As expected, the coefficient on the less-experienced dummy in Model B is negative compared to the base group of more-experienced farmworkers. Age group dummies are not significant in Step 1 estimation, potentially due to the correlation between age and farmwork experience. On the other hand, dummy variables reflecting different age groups were found to have a positive impact over time in Steps 2 and 3 in Model B. Task differences did not seem to matter for the differences in relative wages of immigrant groups in Model A.

Under the birthplace-based alternative classification of immigration status presented in Table B2 in Appendix B, with U.S.-born and foreign-born farmworker groups, the estimated elasticity of substitution for farmworkers with different immigration statuses, σ_i , is similar in magnitude and around 2 as is the case where legal status groups are created based on citizen, authorized immigrant, and unauthorized immigrant categories. The estimated elasticity of substitution between different legal status groups of farmworkers is lower than estimates in

Nested CES Mo	del A: Skill is approxir	nated by task type	
	Step 1 Estimation:	Step 2 Estimation:	Step 3 Estimation:
	Three immigration	Four age groups	Two-task groups
	groups (Citizens,	(14–19, 20–39, 40–59,	(Less-skilled
	authorized immig.,	and ≥60 yrs.)	manual vs. semi-
V · 11	unauthorized immig.)		skilled and skilled)
Variable:	Ma_	jor coefficients of intere	st
Citizen vs. Authorized immigrants vs. Und	authorized immig. (by	age ana task)	0.010+++ (0.000)
Coefficient $(-1/\sigma_i)$	-0.475^^^ (0.038)	-0.606^^^ (0.038)	-0.619^^^ (0.029)
Elasticity (σ_{l})	2.11		
Less-skilled Manual vs. semi-skilled and s	skilled (by age)		
Coefficient $(-1/\sigma_i)$		-0.383*** (0.100)	-0.351*** (0.063)
Elasticity (σ_{A})		2.61	
Less-skilled manual vs.			
semi-skilled and Skilled (aggregate)			0 000+++ (0 0 4 4)
Coefficient $(-1/\sigma_i)$			-0.208^^^ (0.044)
Elasticity (σ_{l})			4.81
		Other coefficients	
Task type dummies:	-		
Semi-skilled and skilled	Base		
Less-skilled manual	-0.005 (0.048)		
Age group dummies:	_	_	_
14–19	Base	Base	Base
20–39	-0.019 (0.071)	0.059*** (0.058)	0.037 (0.030)
40–59	0.282*** (0.082)	0.069 (0.080)	0.032 (0.038)
≥60	0.425*** (0.101)	0.115 (0.087)	0.066 (0.044)
Immigration status dummies: Citizens		Base	Base
Authorized immigrants		0.156 (0.050)	-0.101 (0.047)
Unauthorized immigrants		-0.149*** (0.048)	0.766*** (0.069)
Recovered $\alpha_{_{sa}}$ in step 2:			
$\alpha_{_{II}}$		1.000	
$\alpha_{_{12}}$		2.321	
$\alpha_{_{13}}$		2.406	
$\alpha_{_{14}}$		1.502	
$\alpha_{_{21}}$		1.725	
$\alpha_{_{22}}$		3.866	
$\alpha_{_{23}}$		3.783	
$\alpha_{_{24}}$		2.175	
Estimated κ_1 in Step 3:			
K ₁			0.017*** (0.002)
No. of observations	373	255	414
<i>R</i> ²	0.714	0.735	0.676

Table 3Nested constant elasticity of substitution (CES) Model A: Estimated elasticities of substitution by
immigration status, age, and task groups

Note: The table reports least squares estimates of Equations (4), (5), (6), and (7). Different combinations of experience, age, year, and immigration status fixed effects are applied in the model. Year dummies are included in all three steps but excluded from the table for the sake of brevity. The following notation is used for α_{sa} that are recovered in Step 2: $s = \{1,2\}$ represent "semi-skilled and skilled tasks" and "less-skilled manual tasks," respectively; $\alpha = \{1,2,3,4\}$ represent age groups 14–19, 20–39, 40–59, and greater than 60. Standard errors are in parentheses.

***Denote significance at the 1% level.

Table 4Nested constant elasticity of substitution (CES) Model B: Estimated elasticities of substitution by
immigration status, age, and experience groups

Nested CES Model I	3: Skill is approximated by	/ farmwork experience	
	Step 1 Estimation:	Step 2 Estimation:	Step 3 Estimation:
	Three immigration	Four age groups	Two experience
	groups (Citizens,	(14–19, 20–39,	groups less than
	authorized immig.,	40–59, and ≥60 yrs.)	10 yrs. ≥10 yrs.
	unauthorized immig.)		
Variable:	Major	coefficients of interest	
Citizen vs. authorized immigrants vs. und	authorized immig. (by age	and experience)	
Coefficient (–1/ $\sigma_{_{l}}$)	-0.454*** (0.031)	-0.443*** (0.053)	-0.450*** (0.037)
Elasticity (σ_{l})	2.2		
Less-experienced vs. more-experienced ((by age)		
Coefficient (–1/ $\sigma_{_{\!\!A}}$)		-0.569*** (0.124)	-0.575*** (0.086)
Elasticity ($\sigma_{_{\!A}}$)		1.76	
Less-experienced vs.			
more-experienced (aggregate)			
Coefficient (–1/ $\sigma_{ m s}$)			-0.706*** (0.079)
Elasticity (σ_s)			1.42
		Other coefficients	
Experience dummies:			
More experienced (≥10 years)	Base		
Less experienced (≥10 years)	-0.191*** (0.055)		
Age group dummies:			
5 5 1			
14–19	Base	Base	Base
14–19 20–39	Base -0.082 (0.082)	Base 1.768*** (0.372)	Base 1.739*** (0.258)
14–19 20–39 40–59	Base -0.082 (0.082) 0.12 (0.082)	Base 1.768*** (0.372) 2.725*** (0.622)	Base 1.739*** (0.258) 2.705*** (0.434)
14–19 20–39 40–59 ≥60	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529)
14–19 20–39 40–59 ≥60 Immigration status dummies:	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529)
14–19 20–39 40–59 ≥60 <i>Immigration status dummies:</i> Citizens	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base
14–19 20–39 40–59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047)
14–19 20–39 40–59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14–19 20–39 40–59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{c} in Step 2:	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14–19 20–39 40–59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} in Step 2: α_{11}	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098)	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α _{sa} in Step 2: α ₁₁ α ₁₂	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α _{sa} in Step 2: α ₁₁ α ₁₂ α ₁₂	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
$14-19$ $20-39$ $40-59$ ≥ 60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} <i>in Step 2:</i> α_{11} α_{12} α_{13} $\alpha_{c.}$	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
$14-19$ $20-39$ $40-59$ ≥ 60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} <i>in Step 2:</i> α_{11} α_{12} α_{13} α_{14} α_{re}	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α _{sa} in Step 2: α ₁₁ α ₁₂ α ₁₃ α ₁₄ α ₂₁ α	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957 6.233	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
$14-19$ $20-39$ $40-59$ ≥ 60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} <i>in Step 2:</i> α_{11} α_{12} α_{13} α_{14} α_{21} α_{22} α	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957 6.233 2.99	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
$14-19$ $20-39$ $40-59$ ≥ 60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} <i>in Step 2:</i> α_{11} α_{12} α_{13} α_{14} α_{21} α_{22} α_{23} α	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957 6.233 2.99 1.862	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α_{sa} in Step 2: α_{11} α_{12} α_{13} α_{14} α_{21} α_{22} α_{23} α_{24} Estimated κ in Step 3:	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957 6.233 2.99 1.862	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α _{sa} in Step 2: α ₁₁ α ₁₂ α ₁₃ α ₁₄ α ₂₁ α ₂₂ α ₂₃ α ₂₄ Estimated κ ₁ in Step 3: κ ₁	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 3.499 7.168 5.791 3.957 6.233 2.99 1.862	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069) -0.766*** (0.003)
14-19 20-39 40-59 ≥60 <i>Immigration status dummies:</i> Citizens Authorized immigrants Unauthorized immigrants <i>Recovered</i> α _{sa} in Step 2: α ₁₁ α ₁₂ α ₁₃ α ₁₄ α ₂₁ α ₂₂ α ₂₃ α ₂₄ Estimated κ ₁ in Step 3: κ ₁ No. of observations	Base -0.082 (0.082) 0.12 (0.082) 0.138 (0.101)	Base 1.768*** (0.372) 2.725*** (0.622) 2.900*** (0.750) Base 0.095 (0.069) -0.756*** (0.098) 1 1 3.499 7.168 5.791 3.957 6.233 2.99 1.862	Base 1.739*** (0.258) 2.705*** (0.434) 2.864*** (0.529) Base 0.101 (0.047) -0.766*** (0.069) -0.766*** (0.003)

Note: The table reports least squares estimates of Equations (4), (5), (6), and (7). Different combinations of experience, age, year, and immigration status fixed effects are applied in the model. Year dummies are included in all three steps but excluded from the table for the sake of brevity. The following notation is used for α_{sa} that are recovered in Step 2: $s = \{1,2\}$ represent "experienced" and "less experienced," respectively; $\alpha = \{1,2,3,4\}$ represent age groups 14–19, 20–39, 40–59, and greater than 60. Standard errors are in parentheses.

***Denote significance at the 1% level.

most previous studies of nonagricultural less-skilled workers. An exception would be the study by Hotchkiss and Quispe-Agnoli (2013), who found similarly low degrees of substitution for workers in Georgia. Overall, our estimates of σ_i implies that (1) native and immigrant farmworkers are far from being perfect substitutes and are unlikely to compete for similar agricultural jobs and (2) authorization to work in the United States does not make an immigrant a closer substitute to a native farmworker relative to an unauthorized immigrant farmworker. Our estimates are consistent with and supportive of Hertz (2015), who found limited impact of legalization of unauthorized farmworkers on total farm labor supply and wage differentials between authorized and unauthorized farmworkers.

6.2 Estimates of elasticity of substitution across different age groups (σ_{A}) and α_{sa}

After obtaining σ_p , it is possible to estimate the elasticity of substitution across different age and skill groups following Step 2 (estimating Nest Level 2 to obtain elasticity of substitution across different age groups, σ_A) and Step 3 (estimating Nest Level 1 to obtain elasticity of substitution between different skill groups, σ_s). Tables 3 and 4 summarize the complete set of estimates for the three key substitution elasticities for labor differentiated by legal status, age, and skill level.

Note that estimating σ_A in Step 2, and σ_S in Step 3 using Equations (5) and (7) provide updated sets of estimates of σ_I previously estimated in Step 1. This procedure serves as an implicit robustness check of model specification and the estimated coefficients on the relative labor supply of unauthorized immigrant, authorized immigrant, and citizen farmworkers from Step 1. We find that the estimated (negative inverse) elasticity of substitution between unauthorized immigrant, authorized immigrant, and citizen farmworkers remains virtually unchanged in all three nests in both Tables 3 and 4. In particular, the coefficient of $-1/\sigma_I$ tends to be relatively stable in the experience nesting structure varying from -0.443 to -0.454 (Table 4) than in the task-type nesting structure varying from -0.475 to -0.619 (Table 3). This might be attributable to the fact that farmwork experience is closely associated with age. Once the hierarchical structures of experience–age are determined, farmworkers are relatively homogenous within each experience–age cell, yielding less noise in estimating $-1/\sigma_I$.

The estimated negative inverse elasticity of substitution across the different age groups $(-1/\sigma_A)$ is -0.57 in Model B (Table 4) and -0.3.8 in Model A (Table 3), implying elasticities of substitution, σ_A , moving from 1.76, when experience is used to define skill groups, to 2.61, when task type is used to define skill groups. Age differences appear to matter less for substitution within a particular task group than a particular experience group or a particular education group. This result is consistent with observations from the NAWS data that farmworkers tend to be homogeneous in their ages within a given task group. With four age cohorts, our elasticity of substitution estimates across different age groups, σ_A , is slightly smaller than those reported in the literature for nonfarm labor using finer age cohorts and education to approximate skill levels (Card and Lemieux, 2001; Manacorda et al., 2012; Ottaviano and Peri, 2012). For instance, Manacorda et al. (2012) obtained a point estimate of 5 for the elasticity of substitution across seven different age groups. Card and Lemieux (2001) found an estimate of 4.5 with a similar grouping of age cohorts. The middle point of the estimated range by Ottaviano and Peri (2012) across eight experience groups under different nesting structures is 5. In

general, increasing the number of age groups in the analysis reduces the difference between age groups, leading to a larger substitutability across different age groups. On the other hand, substitution between older and younger farmworkers may be smaller than that reported in the literature for nonfarmworkers due to the nature of crop farmwork; most crop-farming tasks are labor-intensive tasks that typically demand endurance levels correlated with younger age. For example, a younger fruit picker is unlikely to be substitutable with a much older harvester.

While the age-fixed effects (α_{sa}) are slightly different between Model A and Model B, both models consistently demonstrate that the productivity of different age groups first increase and then decrease as age increases, yielding a U-shaped relationship within both less-skilled and skilled groups (regardless of skill measure). However, the two major age groups (20–39 and 40–59) have relatively higher productivity in the low-skilled groups, indicated by higher values of α_{22} and α_{23} (recall that in both models, skilled workers constitute the base group). The negative coefficient in front of the unauthorized immigrants' dummy indicates that being unauthorized reduces the relative skill wage premium.

6.3 Estimates of elasticity of substitution across different skill groups (σ) and κ,

The estimated elasticities of substitution between less-experienced and more-experienced groups are 1.42 (Table 4), indicating that there is limited substitutability between the two experience groups, and farm experience is an important factor that differentiates farmworkers. Conversely, in Model A presented in Table 3, the estimated elasticity of substitution between two task groups (less-skilled manual tasks vs. semi-skilled and skilled tasks) is 4.81, indicating that the two task groups are relatively more substitutable in comparison with the two experience groups. One reason for this result is that experience in farmwork is closely tied to worker's age, and younger crop workers are not easily substitutable with older workers due to labor-intensive characteristic of crop-farming tasks. The estimated elasticity of substitution between the two educational groups (Table B1 in Appendix B) is 2.45, which is only slightly higher than what is typically found in the labor literature on nonfarm labor, an estimate between 1 and 2 (e.g., Ciccone and Peri, 2005).¹⁴

The skill-biased technological change coefficient κ_1 estimated from Equation (7) in Step 3 was negative in Model B with experience skill proxy (Table 4), but was positive for in Model A with task type (Table 3). Shifts in the production technology tend to favor crop workers in semiskilled and skilled tasks over workers conducting manual labor tasks (Model A, Table 3), yet tend to favor younger (or less-experienced) farmworkers over older (or more experienced) farmworkers by increasing their relative productivity.

7 Conclusions

The large share of unauthorized immigrant workers in the farm labor force has made immigration policy a major issue for the U.S. agricultural sector. As debates for immigration reform

¹⁴ The elasticity of substitution in the alternative model using education as a skill proxy and two immigration categories based on birthplace is about 2.09, which is even closer to the upper boundary of the estimates in (nonfarm) labor literature (Table B2 in Appendix B).

continue, policy makers find themselves having to address agricultural employers' concerns about finding and keeping the labor they need while also making sure that any changes to the flow of immigrant farmworkers do not negatively impact the economic opportunities of native farmworkers. Therefore, whether native farmworkers are substitutes for immigrant farmworkers in the United States is an important question with significant implications for the design of immigration policies. If immigrant and native farmworkers are perfect substitutes in employment, then public pressure will likely drive policy to enact legislation that protects U.S. citizens and stems the flow of immigrant workers. If, however, immigrant and native farmworkers are imperfect substitutes, then the inflow of foreign-born farmworkers would not be harmful to economic gains of native farmworkers. In the second case, legalization of undocumented immigrant farmworkers or bringing in temporary foreign workers through federal visa programs, such as the H-2A guest workers program, could potentially benefit agricultural employers by complementing the population of existing domestic farmworkers.

Using type of farm tasks performed, farmwork experience and formal education as three alternative proxies for farmworkers' skill levels, we aggregate individual wage and employment information from the NAWS data over the period from 1989 through 2012 into different skillage-year cells. Our study is the first in proposing task type and number of years in farmwork as two additional measures besides formal education to approximate skill groups in the agricultural sector. We use two alternative legal status classifications under which we define native versus immigrant workers. The first classification divides farmworkers into three legal status groups: citizens, authorized immigrants, and unauthorized immigrants. The second classification is based on birthplace, where native farmworkers are defined as U.S.-born farmworkers and immigrants are defined as foreign-born workers. Regardless of which definition of immigration status is used in the analysis, we find limited substitutability between immigrant and native farmworkers under all alternative skill measures. The estimated elasticity of substitution across different immigration status groups is not sensitive to our choice of skill groups and is stable across different nesting structures. Within a specific age-skill cell, the point estimate of the elasticity of substitution between immigrant and native workers is near 2 (2.11 for age-task, 2.2 for age-experience, and 2.07 for age-education cells), which is far smaller than those reported in the literature for low-skilled nonfarm sectors. The estimated elasticity of substitution suggests that there are limited possibilities to substitute between native and immigrant farmworkers (whether authorized or unauthorized). Wage differentials between native and immigrant farmworkers are most likely driven by productivity differences between these groups, suggesting that the removal of unauthorized immigrant workers from the labor market is unlikely to increase opportunities for native workers. This finding is consistent with Clemens et al. (2018) who demonstrated that the exclusion of Mexican bracero farmworkers has little effect on the labor market for U.S. domestic farmworkers. Similarly, low substitutability between native and authorized immigrant workers implies that increased inflow of authorized immigrant farmworkers through, for example, the H-2A guest worker program is unlikely to have a negative effect on the employment of U.S. citizen farmworkers.

The estimated elasticity of substitution across the four age groups varies from 1.53 to 2.61, depending on the skill measure used in the preceding nest. The estimated elasticity of substitution between less-educated and more-educated farmworkers is 2.45 and is close to that reported in the literature for nonfarm labor. The estimated elasticity of substitution between

less-experienced and more-experienced farmworkers is 1.42, and the estimated elasticity of substitution between workers conducting less-skilled manual labor tasks and semi-skilled or skilled tasks is 4.81. The relatively low substitution possibilities between less- and more-experienced farmworkers are likely due to correlation between age and experience; older crop workers may not easily replace younger crop workers due to the labor-intensive nature of crop-farming tasks that require endurance. This result may have potential policy implications for employment of older, "settled" migrant farmworkers who have been in the United States for more than 10 years, on average.

Regardless of our choices of skill measures and nesting structures, our estimate for the elasticity of substitution across different legal status groups of farmworkers within a given age-skill cell proves to be robust and is consistently estimated to be around 2. The insensitivity of the substitution elasticity across different immigration status groups may indicate that immigration status is a relatively stand-alone characteristic in the nesting structure, while skill and age groups tend to be more closely interrelated. The substitution elasticities computed in this study for citizen, authorized immigrant, and unauthorized immigrant farmworkers from various age and skill groups would be better interpreted as long-run aggregate elasticities of substitution. It is worth noting that the theoretical model is static and the relative labor supply is assumed constant across time (inelastic labor supply). These elasticities 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 farmworker may have picked apples in Michigan before migrating down to Florida to harvest strawberries and then up to North Carolina to pick blueberries. Nonetheless, our long-run aggregate elasticity estimates still serve as a valuable reference point for the effects of immigrant farm labor on local agricultural markets.

Overall, we find little evidence that immigrant (both unauthorized and authorized) farmworkers significantly impact the employment of native farmworkers across different age and skill levels. Limited substitutability between authorized immigrant and citizen farmworkers found in this study has implications for the agricultural guest workers program and its future revisions. Given the limited substitutability of authorized immigrant farmworkers with citizen farmworkers combined with the tightening labor supply in the agricultural sector, policy makers may need to rethink the elements of the agricultural guest worker program that can hamper the inflow of authorized immigrant workforce into the U.S. agricultural sector. Providing easier access to the pool of authorized immigrant farmworkers through federal guest worker programs will help the U.S. agricultural sector stay competitive without threatening the employment opportunities of domestic (native) farmworkers. Our empirical finding that the degree of substitution between unauthorized immigrant farmworkers and citizen farmworkers is also small has similar implications for policies concerning undocumented farmworkers, including ongoing legislative debates and proposals on legalization of unauthorized agricultural workers who have been in the country for a certain period of time (e.g., the 2017 "Blue Card" proposal). The limited substitutability among unauthorized immigrant, authorized immigrant, and citizen farmworkers implies that providing current undocumented workers a path to legal status through a federal immigration reform is unlikely to have significant negative consequences for citizen or authorized farmworkers.

Declarations

Availability of data and material

The datasets generated and/or analyzed during the current study are available at www.doleta.gov/naws/

Competing interests

The IZA Journal of Development and Migration is committed to the IZA Guiding Principles of Research Integrity. The authors declare that they have no competing interests.

Authors' contributions

XW developed the model, analyzed the NAWS data, interpreted findings, and prepared the initial manuscript. GO interpreted results, and was a major contributor in writing the manuscript and designing legal status and skill measures used in the empirical analyses. ZG and FR contributed to interpretation of the results and revision of the manuscript. All authors read and approved the final manuscript.

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References

- Altonji, J. G.; D. Card; (1991): The Effects of Immigration on the Labor Market Outcomes of Less-Skilled Natives, in: Abowd, J.; R. Freeman (eds.), Immigration, Trade, and Labor. Chicago: The University of Chicago Press, 201-234.
- Autor, D. H.; L. F. Katz; M. S. Kearney (2008): Trends in U.S. Wage Inequality: Revising the Revisionists. The Review of Economics and Statistics 90(2), 300-323.
- Autor, D. H.; F. Levy; R. J. Murnane (2003): The Skill Content of Recent Technological Change: An Empirical Exploration. The Quarterly Journal of Economics 118(4), 1279-1333.
- Borjas, G. J. (2003): The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market. The Quarterly Journal of Economics 118(4), 1335-1374.
- Borjas, G. J. (2015): The Slowdown in the Economic Assimilation of Immigrants: Aging and Cohort Effects Revisited Again. Journal of Human Capital 9(4), 483-516.
- Card, D. (2009): Immigration and Inequality. The American Economic Review 99(2), 1-21.
- Card, D.; T. Lemieux (2001): Can Falling Supply Explain in the Rising Return to College for Younger Men? A Cohort-Based Analysis. The Quarterly Journal of Economics 116(2), 705-746.
- Caponi, V.; M. Plesca (2014): Empirical Characteristics of Legal and Illegal Immigrants in the USA. Journal of Population Economics 27, 923-960.
- Cattaneo, C.; C. V. Fiorio; G. Peri (2013): What Happens to the Careers of European Workers When Immigrants 'Take Their Jobs'? The Journal of Human Resources 50(3), 655-693.
- Chassamboulli, A.; G. Peri (2015): The Labor Market Effects of Reducing the Number of Illegal Immigrants. Review of Economic Dynamics 18(4), 792-821.
- Ciccone, A.; G. Peri (2005) Long-Run Substitutability Between More and Less Educated Workers: Evidence from U.S. States, 1950–1990. The Review of Economics and Statistics 87(4), 652-663.
- Clemens, M. A.; E. G. Lewis; H. M. Postel (2018): Immigration Restrictions as Active Labor Market Policy: Evidence from the Mexican Bracero Exclusion. The American Economic Review 108(6), 1468-1487.
- DOL [U.S. Department of Labor] (2019): National Agricultural Workers Survey (NAWS). https://www.doleta. gov/naws/. Accessed 25 March 2019.

- **Duffield, J. A.; R. Coltrane** (1992): Testing for Disequilibrium in the Hired Farm Labor Market. American Journal of Agricultural Economics 74(2), 412-420.
- Dustmann, C.; U. Schonberg; J. Stuhler (2017): Labor Supply Shocks, Native Wages, and the Adjustment of Local Employment. The Quarterly Journal of Economics 132, 435-483.
- Emerson, R. D.; N. Iwai (2014): Assessing Agricultural Labor Markets for Specialty Crops. Final Report, University of Florida.
- Employment and Training Administration [ETA] (2014): The National Agricultural Workers Survey. ETA, Washington, DC. http://www.doleta.gov/agworker/naws.cfm. Accessed 7 November 2017.
- Fisher, D. U.; R. D. Knutson (2012): Uniqueness of Agricultural Labor Markets. American Journal of Agricultural Economics 95(2), 463-469.
- Gonzalez-Barrera, A. (2015): More Mexicans Leaving than Coming to the US. Pew Research Center, Washington, DC.
- Goos, M.; A. Manning (2007): Lousy and Lovely Jobs: The Rising Polarization of Work in Britain. Review of Economics and Statistics 89(1), 118-133.
- Guan, Z.; F. Wu; F. Roka; A. Whidden (2015): Agricultural Labor and Immigration Reform. Choices 30(4), 1-9.
- Gunter, L. F.; J. C. Jarrett; J. A. Duffield (1992): Effect of U.S. Immigration Reform on Labor Intensive Agricultural Commodities. American Journal of Agricultural Economics 74(4), 897-906.
- Hertz, T. (2015): Authorizing the Unauthorized: Labor Market Consequences for Crop Farm Workers. United States Department of Agriculture, Economic Research Service (USDA-ERS), Washington, DC.
- Hotchkiss, J. L.; M. Quispe-Agnoli (2013): The Expected Impact of State Immigration Legislation on Labor Market Outcomes. Journal of Policy Analysis and Management 32(1), 34-59.
- Kaushal, N.; Y. Lu; N. Denier; J. S. Wang; S. J. Trejo (2016): Immigrant Employment and Earnings Growth in Canada and the USA: Evidence from Longitudinal Data. Journal of Population Economics 29, 1249-1277.
- Lewis, E. (2005): Immigration, Skill Mix, and the Choice of Technique. Working Paper 05-8, Federal Reserve Bank of Philadelphia.
- Manacorda, M.; A. Manning; J. Wadsworth (2012): The Impact of Immigration on the Structure of Wages: Theory and Evidence from Britain. Journal of the European Economic Association 10(1), 120-151.
- Martin, P. (2003): Promise Unfulfilled: Unions, Immigration, and the Farm Workers. Ithaca, NY: Cornell University Press.
- Martin, P. (2017): Trump, Immigration, and Agriculture. Choices 32(1), 1-5.
- Ottaviano, G. I. P.; G. Peri (2006): Rethinking the Effect of Immigration on Wages. NBER Working Paper 12497, National Bureau of Economic Research, Cambridge, Massachusetts.
- Ottaviano, G. I. P.; G. Peri (2012): Rethinking the Effect of Immigration on Wages. Journal of the European Economic Association 10(1), 152-197.
- Passel, J. (2006): The Size and Characteristics of the Unauthorized Migrant Population in the U.S. Estimates based on the March 2005 Current Population Survey. Washington, DC: Pew Hispanic Center.
- Passel, J.; D. Cohn (2016): Overall Number of U.S. Unauthorized Immigrants Holds Steady Since 2009. Washington, DC: Pew Hispanic Center.
- Pena, A. A. (2010): Legalization and Immigrants in U.S. Agriculture. The B.E. Journal of Economic Analysis and Policy 10(1), 7.
- Roka, F. M.; R. D. Emerson (2002): Demographics, Income, and Choices: Seasonal Farmworkers in Southwest Florida, in: Findeis, J. L.; A. M. Vanderman; J. M. Larson; J. L. Runyan (eds.), Dynamics of Hired Farm Labor: Constraints and Community Responses. Wallingford, UK: CABI, 57-66.
- Taylor, E. J. (2010): Agricultural Labor and Migration Policy. Annual Review of Economics 2(1), 369-393.
- Watson, P. S.; K. Castelin; P. Salant; J. D. Wulfhorst (2012) Estimating the Impacts of A Reduction in the Foreign-Born Labor Supply on A State Economy: A Nested CGE Analysis of the Idaho Economy. The Review of Regional Studies 42, 51-74.
- Zahniser, S.; T. Hertz; P. Dixon; M. Rimmer (2012): The Potential Impact of Changes in Immigration Policy on U.S. Agriculture and the Market for Hired Farm Labor: A Simulation Analysis. ERR-135. United States Department of Agriculture, Economic Research Service (USDA-ERS), Washington, DC.

Appendices

Appendix A: Theoretical model

A competitively produced agricultural good, *y*, is assumed to follow a nested CES production function with heterogeneous labor inputs.

$$y_t = A_t \left(\theta_t L_{1t}^{\rho} + L_{2t}^{\rho} \right)^{\frac{1}{\rho}} \tag{A1}$$

where L_{st} with s = (1,2) denotes the aggregate labor inputs with two different skill levels, s, at time t, where 1 denotes skilled labor and 2 denotes less-skilled labor. Workers with different levels of skills within each skill group are implicitly assumed to be perfect substitutes in the theoretical model. This assumption is relaxed in the empirical analysis by introducing disaggregated experience, task, and education groups. A_t captures the time-varying Hicks-neutral technological change, and θ_t is the time-varying skill-biased technological change of skilled workers.

The first nest provides the elasticity of substitution between skilled and less-skilled labor: $\sigma_s = \frac{1}{1-\rho}$. Empirically, we use three different variables to capture *skill* (*S*): farmwork *experi-*

ence, type of *task* performed (in the main text), and formal *education* level (in Appendix B).

Within the second nest, both skilled and less-skilled labor inputs are modeled as a CES combination of a set of age-specific labor inputs:

$$L_{st} = \left(\sum_{a} \alpha_{sa} L_{sat}^{\eta}\right)^{\frac{1}{\eta}}, s = (1,2) \tag{A2}$$

where *a* denotes different age groups within each skill group, *s*. The elasticity of substitution between worker groups with different age and skill levels is given by $\sigma_A = \frac{1}{1-n}$.

Within the third and final nest, farmworkers with different immigration statuses are further categorized as different labor inputs. For mathematical simplicity, the theoretical model only considers two immigration statuses as implications of the model do not change with the number of legal status groups considered. Specifically, each skill–age-specific labor input, L_{sat} , is further partitioned into *native* and *immigrant* categories according to the following equation:

$$L_{sat} = \left[\beta_{sat}^{N} \left(\mathbf{L}_{sat}^{N} \right)^{\delta} + \beta_{sat}^{M} \left(\mathbf{L}_{sat}^{M} \right)^{\delta} \right]^{\frac{1}{\delta}}$$
(A3)

where *N* stands for native workers, and *M* is immigrant workers. β_{sat}^N and β_{sat}^M reflect efficiencies of native and immigrant workers within each skill–age group, respectively. The elasticity of substitution between immigrants and natives is given by $\sigma_I = \frac{1}{1-\delta}$. If $\delta = 1$, then immigrant and native farmworkers are considered to be perfect substitutes.

The term *native* is used to refer to two (related) nonimmigrant groups, both of which are considered in the empirical analyses. In alternative empirical models, we consider both *citizens* (i.e., U.S.-born and naturalized citizens) and *U.S.-born* farmworkers (i.e., U.S. citizen by birth only) as *natives*. We present substitution elasticities for both cases: Citizens versus authorized or unauthorized immigrants in the main text, and U.S.-born versus immigrants in Appendix B. Specifically, the nesting structure in the main empirical application includes *three* immigration statuses: *Citizens, authorized immigrants* (holders of green cards and other work

authorization visas), and *unauthorized immigrants* (persons with no legal documentation or with expired visas).

Consider the following cost minimization problem,

$$\min_{L_{sat}^{N}, L_{sat}^{M}} \sum \left(w_{sat}^{N} L_{sat}^{N} + w_{sat}^{M} L_{sat}^{M} \right)$$

subject to

$$y_{t} = A_{t} \left(\theta_{t} L_{1t}^{\rho} + L_{2t}^{\rho} \right)^{\frac{1}{\rho}}$$
(A4)

$$L_{st} = \left(\sum_{a} \alpha_{sa} L_{sat}^{\eta}\right)^{\frac{1}{\eta}}, s = 1, 2 \tag{A5}$$

$$L_{sat} = \left[\beta_{sat}^{N} (\mathbf{L}_{sat}^{N})^{\delta} + \beta_{sat}^{M} (\mathbf{L}_{sat}^{M})^{\delta}\right]^{\frac{1}{\delta}}$$
(A6)

The Lagrangean for the optimization problem is

$$\mathcal{L} = \sum \left(w_{sat}^{N} \mathbf{L}_{sat}^{N} + w_{sat}^{M} \mathbf{L}_{sat}^{M} \right) - \lambda \left[A_{t} \left(\theta_{t} L_{1t}^{\rho} + L_{2t}^{\rho} \right)^{\frac{1}{\rho}} - y_{t} \right]$$
(A7)

Taking derivatives with respect to the two labor inputs L_{sat}^N and L_{sat}^M yields the following first-order conditions:

$$\begin{cases} \frac{\partial \mathcal{L}}{\partial L_{sat}^{N}} = 0\\ \frac{\partial \mathcal{L}}{\partial L_{sat}^{M}} = 0 \end{cases} \Rightarrow$$
(A8)

$$\begin{cases} w_{sat}^{N} - \lambda \frac{1}{\rho} A_{t} \Big[\theta_{t} L_{1t}^{\rho} + L_{2t}^{\rho} \Big]^{\frac{1}{\rho^{-1}}} \theta_{st} \rho L_{st}^{\rho-1} \frac{1}{\eta} \left(\sum_{a} \alpha_{sa} L_{1at}^{\eta} \right)^{\frac{1}{\eta^{-1}}} \alpha_{sa} \eta L_{sat}^{\eta-1} \frac{1}{\delta} \Big((L_{sat}^{N})^{\delta} + \beta_{sat} (L_{sat}^{M})^{\delta} \Big)^{\frac{1}{\delta^{-1}}} \beta_{sat}^{N} \delta (L_{sat}^{N})^{\delta-1} = 0 \\ w_{sat}^{M} - \lambda \frac{1}{\rho} A_{t} \Big[\theta_{t} L_{1t}^{\rho} + L_{2t}^{\rho} \Big]^{\frac{1}{\rho^{-1}}} \theta_{st} \rho L_{st}^{\rho-1} \frac{1}{\eta} \left(\sum_{a} \alpha_{sa} L_{1at}^{\eta} \right)^{\frac{1}{\eta^{-1}}} \alpha_{sa} \eta L_{sat}^{\eta-1} \frac{1}{\delta} \Big((L_{sat}^{N})^{\delta} + \beta_{sat} (L_{sat}^{M})^{\delta} \Big)^{\frac{1}{\delta^{-1}}} \beta_{sat}^{M} \delta (L_{sat}^{M})^{\delta} = 0 \end{cases}$$
(A9)

The first-order conditions require that wages of native and immigrant farmworkers be equal to their marginal products:

$$\begin{cases} w_{sat}^{N} = \lambda A_{t}^{\rho} y_{t}^{1-\rho} \theta_{st} L_{st}^{\rho-\eta} \alpha_{sa} L_{sat}^{\eta-\delta} \beta_{sat}^{N} (L_{sat}^{N})^{\delta-1} \\ w_{sat}^{M} = \lambda A_{t}^{\rho} y_{t}^{1-\rho} \theta_{st} L_{st}^{\rho-\eta} \alpha_{sa} L_{sat}^{\eta-\delta} \beta_{sat}^{M} (L_{sat}^{M})^{\delta-1} \end{cases}$$
(A10)

Plug in $\sigma_s = \frac{1}{1-\rho}$, $\sigma_A = \frac{1}{1-\eta}$, and $\sigma_I = \frac{1}{1-\delta}$ in previous equations and rewrite them as

$$\begin{cases} w_{sat}^{N} = \lambda A_{t}^{1-\frac{1}{\sigma_{s}}} y_{t}^{\frac{1}{\sigma_{s}}} \theta_{st} L_{st}^{\frac{1}{\sigma_{s}}-\frac{1}{\sigma_{s}}} \alpha_{sa} L_{sat}^{\frac{1}{\sigma_{s}}-\frac{1}{\sigma_{s}}} \beta_{sat}^{N} (L_{sat}^{N})^{\frac{1}{\sigma_{t}}} \\ w_{sat}^{M} = \lambda A_{t}^{1-\frac{1}{\sigma_{s}}} y_{t}^{\frac{1}{\sigma_{s}}} \theta_{st} L_{st}^{\frac{1}{\sigma_{s}}-\frac{1}{\sigma_{s}}} \alpha_{ea} L_{eat}^{\frac{1}{\sigma_{s}}-\frac{1}{\sigma_{s}}} \beta_{eat}^{M} (L_{sat}^{M})^{\frac{1}{\sigma_{t}}} \end{cases}$$
(A11)

Taking logarithms of the equations above results in the following wage equation for native and immigrant farmworkers for each skill–age–time group:

$$lnw_{sat}^{N} = lnB_{t} + \frac{1}{\sigma_{s}}lny_{t} + ln\theta_{st} + \left(\frac{1}{\sigma_{A}} - \frac{1}{\sigma_{s}}\right)lnL_{st} + ln\alpha_{sa} + \left(\frac{1}{\sigma_{I}} - \frac{1}{\sigma_{A}}\right)lnL_{sat} + ln\beta_{sat}^{N} - \frac{1}{\sigma_{I}}lnL_{sat}^{N}$$
(A12.1)

$$lnw_{sat}^{M} = lnB_{t} + \frac{1}{\sigma_{s}}lny_{t} + ln\theta_{st} + \left(\frac{1}{\sigma_{A}} - \frac{1}{\sigma_{s}}\right)lnL_{st} + ln\alpha_{sa} + \left(\frac{1}{\sigma_{I}} - \frac{1}{\sigma_{A}}\right)lnL_{sat} + ln\beta_{sat}^{M} - \frac{1}{\sigma_{I}}lnL_{sat}^{M}$$
(A12.2)

where lnB_t equals to $ln\lambda + \left(1 - \frac{1}{\sigma_s}\right) lnA_t$. Normalizing the coefficients such that $\beta_{sat}^N = 1$, $\beta_{sat}^M = \beta_{sat}$, and subtracting Equation (A9.2) from Equation (A9.1), we can derive the expression for the wage differentials between native and immigrant farmworkers in each skill-age-time cell (Manacorda et al., 2012).

$$ln\frac{W_{sat}^{N}}{W_{sat}^{M}} = -ln\beta_{sat} - \frac{1}{\sigma_{I}} \left(ln\frac{L_{sat}^{N}}{L_{sat}^{M}} \right)$$
(A13)

Denoting the immigration status by I, which takes on values N and M for native and immigrant status, respectively, the wage equations for native and immigrant farmworkers within each skill–age–time group can be written in the following compact form:

$$lnw_{sat}^{I} = lnB_{t} + \frac{1}{\sigma_{s}}lny_{t} + ln\theta_{st} + \left(\frac{1}{\sigma_{A}} - \frac{1}{\sigma_{s}}\right)lnL_{st} + ln\alpha_{sa} + \left(\frac{1}{\sigma_{I}} - \frac{1}{\sigma_{A}}\right)lnL_{sat} + ln\beta_{sat}^{I} - \frac{1}{\sigma_{I}}lnL_{sat}^{I}$$
(A14)

The relative wages of skilled labor with respect to less-skilled labor within the same age-immigration status, I = (N, M), at time t can be derived as

$$lnw_{1at}^{I} - lnw_{2at}^{I} = (ln\theta_{1t} - ln\theta_{2t}) + \left(\frac{1}{\sigma_{A}} - \frac{1}{\sigma_{s}}\right) (lnL_{1t} - lnL_{2t}) + (ln\alpha_{1a} - ln\alpha_{2a}) + \left(\frac{1}{\sigma_{I}} - \frac{1}{\sigma_{A}}\right) (lnL_{1at} - lnL_{2at}) + (ln\beta_{1at}^{I} - ln\beta_{2at}^{I}) - \frac{1}{\sigma_{I}} (lnL_{1at}^{I} - lnL_{2at}^{I})$$
(A15)

Letting $\theta_{1t} = \theta_t$ and $\theta_{2t} = 1$, and rearranging terms, we can rewrite Equation (A15) as $W^I = \theta_t = \theta_t$ and $\theta_{2t} = 1$, $L_{tr} = 1$ ($L_{tr} = L_{tr}$) 1 ($L_{tr}^I = L_{tr}$)

$$\ln \frac{W_{1at}}{W_{2at}^{l}} = \ln \theta_{t} + \ln \frac{\alpha_{1a}}{\alpha_{2a}} + \ln \frac{\beta_{1at}}{\beta_{2at}^{l}} - \frac{1}{\sigma_{s}} \ln \frac{L_{1t}}{L_{2t}} - \frac{1}{\sigma_{A}} \left(\ln \frac{L_{1at}}{L_{2at}} - \ln \frac{L_{1t}}{L_{2t}} \right) - \frac{1}{\sigma_{I}} \left(\ln \frac{L_{1at}}{L_{2at}^{l}} - \ln \frac{L_{1at}}{L_{2at}} \right)$$
(A16)

Appendix B: Supporting results and sensitivity check using alternative skill and immigration status classifications

Table B1 Estimated elasticities of substitution by immigration status, age, and skill (measured by education level)

Alternative Model: Education is used as skill proxy							
	Step 1 Estimation:	Step 2 Estimation:	Step 3 Estimation:				
-	Three immigration groups	Four age groups	Two education				
(C	itizens, authorized immig.,	(14–19, 20–39, 40–59,	groups (≤6 yrs., and				
	unauthorized immig.)	and ≥60 yrs.)	>6 yrs. of schooling)				
Variable:	Major	coefficients of interest					
Citizen vs. authorized immigrants vs. u	nauthorized immig. (by age	and education)					
Coefficient (–1/ σ_{l})	-0.484*** (0.042)	-0.546*** (0.052)	-0.558*** (0.037)				
Elasticity (σ_i)	2.07						
Primary education and less vs. second	ary education and above (by	age)					
Coefficient $(-1/\sigma_{a})$		-0.653*** (0.154)	-0.591*** (0.085)				
Elasticity ($\sigma_{\rm c}$)		1.53					
Primary education and less vs. second	arv education and above (ad	(areaate)					
Coefficient $(-1/\sigma)$		9 9 ,	-0.408*** (0.074)				
Elasticity (σ)			2 45				
Elasticity (0 _s))ther coefficients	2.15				
	(other coefficients					
Education aummies:	0.70.4*** (0.1.01)						
Primary education and less	-0.704*** (0.121)						
Secondary education and above	Base						
Age group dummies:							
14–19	Base	Base	Base				
20–39	-0.107 (0.071)	-0.575*** (0.174)	-0.518*** (0.116)				
40–59	0.361*** (0.090)	-1.263*** (0.191))	-1.230*** (0.135)				
≥60	0.537*** (0.108)	-1.541*** (0.224)	-1.575*** (0.164))				
Legal status dummies:							
Citizens		Base	Base				
Authorized immigrants		-1.453*** (0.177)	-1.493*** (0.124)				
Unauthorized immigrants		-1.551*** (0.201)	-1.595*** (0.140)				
Recovered α in Step 2:							
α.	1.000						
α	1.966						
α_{12}	2.112						
α_{13}	1.598						
α_{14}	0.723						
α_{21}	1 414						
22 27	1.414						
<i>и</i> ₂₃	1.907						
<i>α</i> ₂₄	1.514						
Estimated κ_1 in Step 3:							
<u>K</u> 1			0.020*** (0.004)				
No. of observations	340	207	414				
R^2	0.723	0.733	0.700				

Note: The table reports least squares estimates of Equations (4), (5), (6), and (7). Different combinations of experience, age, year, and immigration status fixed effects are applied in the model. Year dummies are included in all three steps, but excluded from the table for the sake of brevity. The following notation is used for α_{sa} that are recovered in Step 2: $s = \{1,2\}$ represent "secondary education and above" and "primary education and less," respectively; $\alpha = \{1,2,3,4\}$ represent age groups 14–19, 20–39, 40–59, and greater than 60. Standard errors are in parentheses.

	Step 1 Estimation:	Step 2 Estimation:	Step 3 Estimation:
	Two immigration groups	Four age groups	Two skill groups
	by birthplace (U.Sborn	(14-19, 20-39, 40-59, 40-59)	(varies, see
	and foreign-born)	and ≥60 yrs.)	Delow)
Coefficient	1. Skill group	is approximated by task ty	/pe
U.Sborn vs. foreign-born (by age	and task)		
Coefficient (–1/ σ_{j})	-0.447*** (0.049)	-0.479*** (0.032)	-0.467*** (0.039)
Less-skilled manual vs. semiskilled	and skilled tasks (by age)		
Coefficient (–1/ $\sigma_{\!_{\!A}}$)		-0.348*** (0.071)	-0.354*** (0.077)
Less-skilled manual vs. semiskilled	and skilled tasks (aggregate)		
Coefficient (–1/ σ_{s})			-0.033 (0.058)
	2. Skill groups appi	roximated by experience i	n farming
U.Sborn vs. foreign-born (by age	and experience)		
Coefficient (–1/ σ_i)	-0.443*** (0.037)	-0.440*** (0.028)	-0.452*** (0.029)
Less-experienced vs. more experien	nced (by age)		
Coefficient (–1/ $\sigma_{\!_{\!A}}$)		-0.510*** (0.050)	-0.476*** (0.047)
Less-experienced vs. more experienced	nced (aggregate)		
Coefficient (–1/ σ_{s})			-0.597*** (0.094)
	3. Skill group	s approximated by educat	tion
U.Sborn vs. foreign-born (by age	and education)		
Coefficient (–1/ σ_{l})	-0.497*** (0.055)	-0.584*** (0.048)	-0.588*** (0.049)
Primary education and less vs. sec	ondary education and above (b	y age)	
Coefficient (–1/ $\sigma_{_{\!A}}$)		-0.563*** (0.078)	-0.529*** (0.064)
Primary education and less vs. sec	ondary education and m(aggre	gate)	
Coefficient (–1/ σ_{s})			-0.478*** (0.060)
Note: The table reports estimated	(negative inverse) substitutio	n elasticities from Equation	ons (4), (5), (6), and (7)

Table B2Estimated elasticities of substitution by *birthplace*, age, and skill (approximated by task type,
experience in farming, and education level)

Note: The table reports estimated (negative inverse) substitution elasticities from Equations (4), (5), (6), and (7) using birthplace as an alternative measure of immigration status. Standard errors are in parentheses. ***Denote significance at the 1% level.