The Potential Impact of Changes in Immigration Policy on U.S. Agriculture and the Market for Hired Farm Labor

A Simulation Analysis

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Abstract

Large shifts in the supply of foreign-born, hired farm labor resulting from substantial changes in U.S. immigration laws or policies could have significant economic implications. A computable general equilibrium (CGE) model of the U.S. economy is used to evaluate how changes in the supply of foreign-born labor might affect all sectors of the economy, including agriculture. Two scenarios are considered: an increase in the number of temporary nonimmigrant, foreign-born farmworkers, such as those admitted under the H-2A Temporary Agricultural Program, and a decrease in the number of unauthorized workers in all sectors of the economy. Longrun economic outcomes for agricultural output and exports, wages and employment levels, and national income accruing to U.S.-born and foreign-born, permanent resident workers in these two scenarios are compared with a base forecast reflecting current immigration laws and policies.

Keywords: farm labor, farmworkers, immigrant, immigration, H-2A program, computable general equilibrium (CGE) model, agriculture, authorized, unauthorized

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Summary

What Is the Issue?

This report explores the possible economic implications of large shifts in the supply of foreign-born, hired farm labor that could result from substantial changes in U.S. immigration laws or policies. Hired labor (including contract labor) is an important input to U.S. agricultural production, accounting for about 17 percent of variable production expenses and about 40 percent of such expenses for fruits, vegetables, and nursery products. Over the past 15 years, roughly half of the hired laborers employed in U.S. crop agriculture have lacked the immigration status needed to work legally in the United States. Thus, changes in immigration laws or policies could lead to markedly different economic outcomes in the agricultural sector and the market for hired farm labor. The same is generally true for other economic sectors that rely on large numbers of unauthorized workers.

To examine how large changes in the supply of foreign-born labor would affect U.S. agriculture, we considered two hypothetical scenarios: (1) a 156,000-person increase in the employment of temporary nonimmigrant agricultural workers, such as those now participating in the H-2A Temporary Agricultural Program; and (2) a 5.8-million-person decrease in the total number of unauthorized workers in all sectors of the economy, including agriculture. These scenarios (15-year projections) are not intended to precisely represent the effects of any specific policy proposals. Instead, they provide an opportunity to consider the economic impacts of sizable changes in the supply of foreign-born farm labor.

What Did the Study Find?

The expanded employment of temporary nonimmigrant agricultural workers would lead to a longrun relative increase in agricultural output and exports. The increases are generally larger in labor-intensive sectors, such as fruits, tree nuts, vegetables, and nursery products. By year 15 of the increased farm labor supply scenario, these four sectors experience a 1.1- to 2.0-percent increase in output and a 1.7- to 3.2-percent increase in exports, relative to the base forecast. Less labor-intensive sectors, such as grains, oilseeds, and livestock production, tend to have smaller increases, ranging from 0.1 to 1.5 percent for output and from 0.2 to 2.6 percent for exports. While agricultural output and exports would increase, the real wages of agricultural workers would decrease by 4.4 percent in the long run, relative to the forecasted wage with no policy-induced labor supply change. Increased employment of temporary nonimmigrant agricultural workers would have little effect on the nonagricultural economy, since hired farmworkers make up a small share of the U.S. workforce.

By contrast, a large reduction in the number of unauthorized workers in all sectors of the U.S. economy would lead to a long-run reduction in output and exports in both agriculture and the broader economy, relative to forecasted levels with no policy-induced change in unauthorized labor supply. Fruits, tree nuts, vegetables, and nursery production are again among the most affected sectors, with longrun relative declines from 2.0 to 5.4 percent

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in output and from 2.5 to 9.3 percent in exports, depending on the modeling assumptions. These effects tend to be smaller in other, less labor-intensive parts of agriculture—a 1.6- to 4.9-percent decrease in output and a 0.2- to 7.4-percent decrease in exports. Real agricultural wages would rise, on average, from 3.9 to 9.9 percent in the long run, relative to the forecasted wage with no policy-induced labor supply reduction. Since unauthorized farmworkers would be in much shorter supply, their wages would increase from 13.6 to 39.8 percent.

Decreasing the size of the unauthorized labor force would reduce the aggregate level of economic production and slightly lower the income that accrues to complementary, U.S.-owned factors of production, such as capital and skilled labor. The lost income would be only partially offset by higher real wages for U.S.-born and foreign-born, permanent resident workers employed as hired farm laborers or in other lower paying occupations where unauthorized workers were formerly more prevalent. In the long run, overall gross national product accruing to the U.S.-born and to foreign-born, permanent residents would fall by about 1 percent, compared with the base forecast. The number of U.S.-born and other permanent resident farmworkers would increase, but not by an amount sufficient to fully offset the decrease in the employment of unauthorized farmworkers. Among the additional U.S.-born and other permanent resident farmworkers are some people who lost (slightly) higher paying jobs as the economy contracted due to the decreased supply of unauthorized labor in all sectors of the economy. This downward shift in occupational composition reduces the *average* real wage of all U.S.-born and other permanent resident workers—agricultural and nonagricultural—from 0.3 to 0.6 percent compared with the base forecast, even as real wages rise in many lower paying occupations.

How Was the Study Conducted?

The authors employed a modified version of the U.S. Applied General Equilibrium (USAGE) Model, a recursively dynamic, computable general equilibrium (CGE) model of the U.S. economy developed by Peter Dixon and Maureen Rimmer of Monash University in Australia and adapted to the U.S. context in collaboration with the U.S. International Trade Commission (USITC). Data for the base year (2005) came from the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). Model structure, extensions, and data sources are summarized in the main text of the report and discussed in greater detail in the appendix.

The model generated a set of 15-year projections for three scenarios:

- Base forecast: Current laws, programs, policies, and trends are assumed to remain in effect, generating a baseline against which the alternative scenarios will be evaluated.

- Simulation 1: The quantity of labor supplied annually to agriculture by people without the U.S. immigration status of permanent residency is assumed to increase by about 30,000 workers in year 1, with the additional number of temporary nonimmigrant agricultural workers rising to about 150,000 in year 15. By comparison, 68,088 positions in the H-2A program (the current avenue by which nonimmigrant workers can

be employed in U.S. agriculture on a temporary basis) were certified in fiscal year (FY) 2011.

- Simulation 2: The total number of unauthorized workers in all sectors of the economy, both agricultural and nonagricultural, is assumed to decrease by 5.8 million by year 15 of the forecast, a 40-percent reduction compared with the base forecast. This change corresponds to about 3 percent of the projected size of the total U.S. workforce in year 15.

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Introduction[1]

Large shifts in the supply of foreign-born farm labor, such as those that might result from substantial changes to U.S. immigration laws or policies, could have significant effects on production costs in U.S. agriculture. Hired labor (including contract labor) accounted for about 17 percent of the sector's variable production expenses and even higher proportions in more labor-intensive sectors, such as vegetables (35 percent), nursery products (46 percent), and fruits (48 percent), according to 2006-10 Agricultural Resource Management Survey (ARMS) data (fig. 1).[2]

Many workers employed by U.S. agriculture lack the immigration status needed to work legally in the country. According to the U.S. Department of Labor's National Agricultural Workers Survey (NAWS), about half of the hired workers in U.S. crop agriculture over the past 15 years were unauthorized, with most of these workers coming from Mexico (Carroll et al., 2011).[3] Farmworkers, however, accounted for 4 percent of the 8.3 million unauthorized immigrants in the U.S. labor force as of March 2008, according to estimates by Passel and Cohn (2009). Many of the unauthorized workers employed outside of agriculture worked in construction, leisure and hospitality, cleaning and maintenance, and other service industries.[4]

The Federal Government's H-2A Temporary Agricultural Program "establishes a means for agricultural employers who anticipate a shortage of domestic workers to bring nonimmigrant foreign workers to the U.S. to perform agricultural labor or services of a temporary or seasonal nature" (U.S. Department of Labor, Employment and Training Administration, 2009). Although the H-2A program is the only program of its type currently in effect for U.S. agriculture, participation is customarily low relative to the size of the unauthorized workforce. In fiscal year (FY) 2011, determinations were issued for 7,361 applications to the H-2A program. Of these, 7,000 applications were certified. Most employers requested multiple workers, as the 7,000 certified applications corresponded to 68,088 positions in the agricultural workforce (U.S. Department of Labor, Employment and Training Administration, 2012). Over the past 5 fiscal years, the number of positions certified has fluctuated between 68,088 and 86,100 (U.S. Department of Labor, Employment and Training Administration, 2012, 2010).

H-2A employment represented less than 10 percent of the U.S. farm labor force during 2007-11, compared with the average annual number of hired farm and service workers in agriculture as tallied by USDA's National Agricultural Statistics Service (2007-11). The limited use of the H-2A program has been attributed to a variety of causes. Dairy, livestock, and nursery operations, which tend to need year-round labor, are largely precluded from participating since the program is only for temporary or seasonal workers. In addition, prospective employers may be discouraged by some program requirements, such as providing housing to H-2A workers and paying them the highest of the Federal or State minimum wage, the prevailing hourly or piece rate, the agreed-upon collective bargaining rate, or the adverse effect wage rate (AEWR). AEWRs are "the minimum wage rates the [U.S. Department of Labor] has determined must be offered and paid by employers to H-2A workers and workers in corresponding employment

[1]In this report, we use the following terminology to describe U.S. immigration status. "U.S.-born" refers to people born in the United States. "Foreign-born, permanent resident" refers to people born outside the United States who have the official U.S. immigration status of permanent resident and, thus, are legally allowed to work in this country. We sometimes use the term "authorized" to refer to these two groups of people. "Foreign-born, not permanent resident" refers to people born outside the United States who lack the status of permanent residency. Most of the people in this group are not authorized to work legally in the United States, and we refer to them as "unauthorized." However, temporary, nonimmigrant workers, such as those in the H-2A Temporary Agricultural Program, also fall into the category of foreign-born, not permanent resident. These workers are authorized to work in the United States on a temporary basis but do not have the immigration status of a permanent resident.
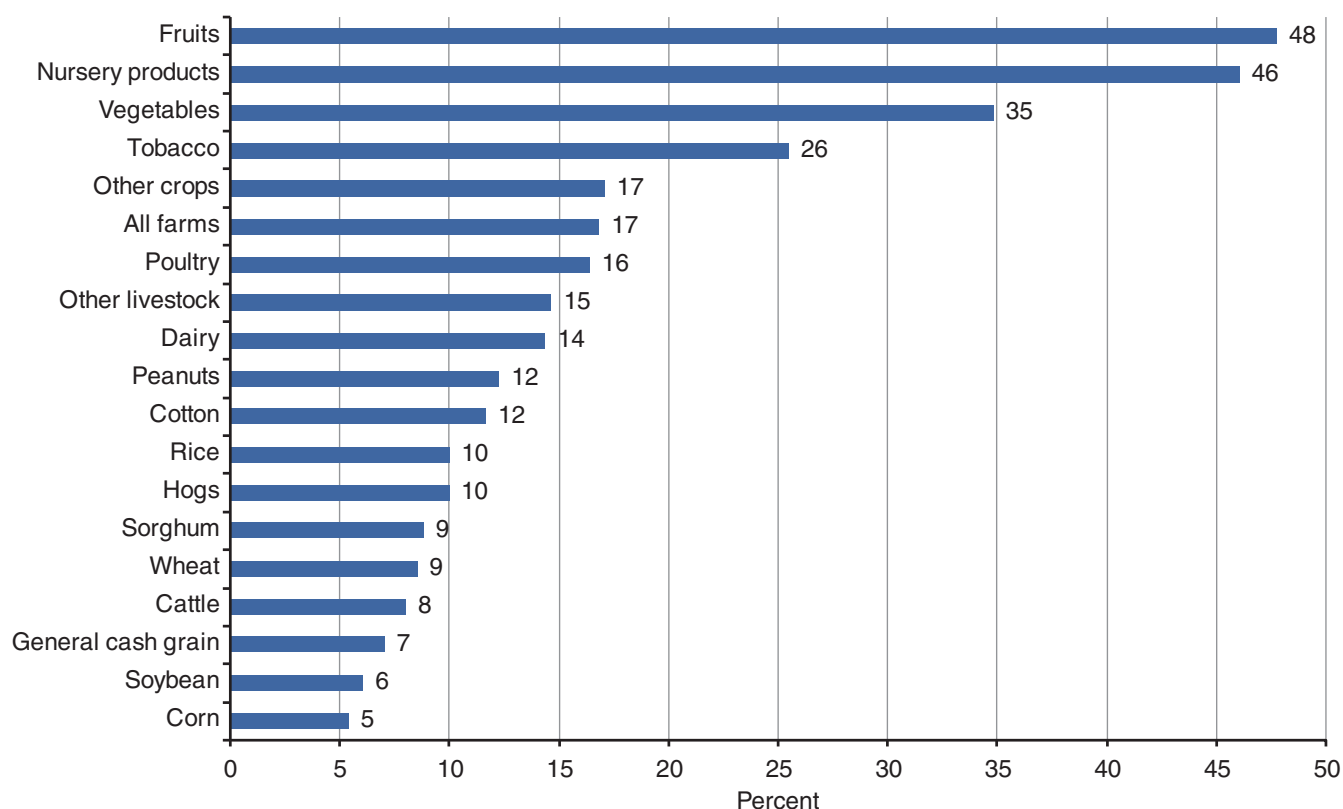
[2]Wages for field and livestock workers in October 2011 averaged $10.57 per hour, not counting meals, housing, and other benefits (USDA, National Agricultural Statistics Service, 2011).

[3]Similar, survey-based information on legal immigration status was not available for hired workers in the livestock sector. Foreign-born persons—authorized and unauthorized—accounted for a large share of the workforce in U.S. agriculture and related industries: about 71 percent of workers in crop agriculture during 2007-09 (Carroll et al., 2011), 41 percent of workers on dairy farms in 2008 (Rosson et al., 2009), and 36 percent of workers at meat processing plants in 2008 (Kandel, 2011).

[4]Passel and Cohn (2011) estimated that 11.2 million unauthorized immigrants were living in the United States as of March 2010 and that 8.0 million of these immigrants were in the U.S. labor force.

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Figure 1
Labor expenses as a percentage of total variable expenses in U.S. agriculture, by production specialization, 2006-10 average

Source: USDA, Economic Research Service and National Agricultural Statistics Service, 2006-10 Agricultural Resource Management Survey data.

for a particular occupation and area so that the wages of similarly employed U.S. workers will not be adversely affected" (U.S. Department of Labor, Employment and Training Administration, 2011b). In general, the AEWR for each region (or State) "is equal to the annual weighted average hourly wage rate for field and livestock workers (combined) for the region, as published annually by the U.S. Department of Agriculture (USDA)" (U.S. Department of Labor, Employment and Training Administration, 2011b). For 2012, the AEWRs range from $9.30 per hour (Arkansas) to $12.26 per hour (Hawaii) and average $10.40 per hour for the 50 States (U.S. Department of Labor, Employment and Training Administration, 2011a).

Given the desire of many Americans to control illegal immigration, the limited use of the H-2A program and the continuing practice of employing unauthorized farmworkers combine to make addressing the issue of unauthorized farmworkers one of the more important agricultural policy challenges of the early 21st century. As discussed below, a number of relevant legislative proposals are currently being debated, some that would increase the availability of temporary nonimmigrant agricultural labor and others that would make it more difficult to hire unauthorized workers. We considered the economic implications of two hypothetical scenarios:

- An increase in the employment of temporary nonimmigrant agricultural workers, such as those admitted under the current H-2A program; and

- A decrease in the number of unauthorized workers available to work in all occupations (agricultural and nonagricultural).

These scenarios were not intended to represent the outcomes of any specific policy proposals. Instead, they provided an opportunity to consider the economic impacts of significant changes in the supply of foreign-born labor.

To conduct this analysis, we employed a modified version of the U.S. Applied General Equilibrium (USAGE) Model, a recursively dynamic, computable general equilibrium (CGE) model of the U.S. economy. This model offered several important advantages over other methods that addressed similar questions in the past. First, it treated authorized and unauthorized labor as separate factors of production and modeled employers' ability to substitute between them. Second, unlike partial equilibrium models, the USAGE Model can estimate the impact of large changes in unauthorized labor supply on macroeconomic outcomes, such as national income and the exchange rate, which in turn affect domestic and foreign demand for agricultural output.

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Recent Legislative Proposals

Over the past decade, the U.S. Congress has debated a variety of changes to U.S. immigration law as it relates to foreign-born farmworkers. Some of these proposals would create additional opportunities for persons from other countries to work legally in U.S. agriculture, while others propose different approaches to the enforcement of existing U.S. immigration restrictions.

The Agricultural Job Opportunity Benefits and Security Act (AgJOBS)—a compromise negotiated by worker advocates and farm employers in December 2000—is an example of one proposal that would create additional opportunities for foreign-born farmworkers. The AgJOBS proposal was last introduced as a standalone bill in the 111th Congress but not enacted into law. Currently, AgJOBS is contained within the Comprehensive Immigration Reform Act of 2011, a bill introduced in the 112th Congress.

Among its main provisions, AgJOBS would grant a temporary nonimmigrant visa to up to 1.35 million people who could document a certain amount of past experience as U.S. farmworkers and provide them and their families with the opportunity to apply for permanent residency status if they performed additional farmwork in the United States. In addition, AgJOBS would modify some aspects of the H-2A program. For instance, it would allow employers to make cash housing assistance payments in some cases instead of physically providing worker housing, and it would freeze the AEWR in each State at its level as of January 1, 2011. If the U.S. Congress does not establish a new wage standard for the H-2A program within 3 years of the bill's enactment, then the AEWR would rise at the same rate as the 2-year average of the consumer price index, but not by more than 4 percent per year.

Measures intended to enforce existing U.S. immigration restrictions using different methods also have been proposed. The Legal Workforce Act (H.R. 2885), also introduced in the 112th Congress, would require all employers—agricultural and nonagricultural—to use E-Verify to confirm the employment eligibility of their new hires. E-Verify is an Internet-based system operated by the U.S. Department of Homeland Security in partnership with the Social Security Administration that compares information reported by the employees on their Form I-9 (Employment Eligibility Verification) with Government records. Currently, the Federal Government requires the use of E-Verify for all Federal contractors and most subcontractors but does not mandate its use by all private-sector employers. Several States do require E-Verify, however, including Arizona, Alabama, Mississippi, and South Carolina. Utah requires that all private-sector employers use one of several methods to confirm employment eligibility, with E-Verify being one of the specified options; Georgia will require similar verification by 2013 for businesses with 11 or more employees.

Within the E-Verify process, employees whose Form I-9 information does not match Government records receive a "Tentative Nonconfirmation." Such employees have the right to challenge this result within 8 workdays, and while the challenge is underway, employers are not allowed to dismiss the employee, reduce the employee's work hours, or limit the employee's training. If the information discrepancies are not resolved, the employee receives a "Final Nonconfirmation" from E-Verify, and the employer must dismiss the

employee. At present, 96.9 percent of employees whose employment eligibility was checked using E-Verify were confirmed almost immediately (U.S. Department of Homeland Security, 2011a).

The proposed Legal Workforce Act would give agricultural employers 36 months to comply with the E-Verify mandate. Some farm groups, however, are concerned that mandating use of E-Verify without creating some sort of new program for foreign-born agricultural workers would raise labor costs sharply, adversely affecting many farm employers.

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Research on Previous Immigration Policy Changes[5]

The termination of the Bracero Program in 1964, the passage of the Immigration Reform and Control Act of 1986 (IRCA), and contemporary interest in immigration have prompted several waves of research on the role of foreign-born labor in the U.S. economy. This research provided key insights into the economics of hired farm labor in the United States and supported the modeling work presented here.

The Bracero Program, in effect from 1942 to 1964, evolved from a series of bilateral agreements between the U.S. and Mexican Governments to become the largest U.S. agricultural guestworker program to date. In Spanish, the word "bracero" comes from "brazo," the word for arm, and refers to a day laborer or strong-armed individual. The Bracero Program recruited millions of Mexicans to work on U.S. farms; participation peaked in 1956 at 445,000 workers. In a study of seven U.S. States that were the destination for about 90 percent of all braceros, Morgan and Gardener (1982) found that the program boosted total farm employment by 26 percent and reduced agricultural wages by 9 percent.

Another study of the Bracero Program (Wise, 1974) provided early estimates of the responsiveness of U.S. farmworkers to wage changes. Growers argued that U.S.-born workers would not accept the jobs formerly held by braceros at any reasonable wage, while then Secretary of Labor W. Willard Wirtz held that more U.S. labor would be forthcoming if growers paid higher wages. In a study of California's strawberry and melon sectors, Wise concluded that the elasticity of supply of U.S.-born farm labor was roughly 3—meaning that a 1-percent increase in wages would lead to a 3-percent increase in the availability of U.S.-born workers.[6] He estimated that, without the braceros, employment of U.S.-born farmworkers in the California strawberry sector would have been 51 percent higher and wages would have been 12 percent higher; in the melon sector, employment and wages would have been 261 percent and 67 percent higher, respectively.

When the Bracero Program ended, however, farmers did not simply switch to an entirely U.S.-born labor force of the same size. Instead, the employment of unauthorized farmworkers increased, wages rose, and advances in mechanization greatly reduced the labor requirements for some crops. Martin (1998) noted: "The removal of unauthorized or guest workers from the farm workforce rarely prompts U.S. workers to replace them. The more common response is for growers to demand fewer workers, often by mechanizing hand-harvest tasks." The development of the tomato harvester, along with the development of uniformly ripening tomatoes, for example, meant that the tomatoes could be harvested in a single pass through the field using much less labor. Martin and Calvin (2010) summarized the lessons learned in this industry as they apply to the current debate about how labor-intensive agriculture would adjust to higher labor costs:

> "First, most analysts conclude that farmers will mechanize or reduce production before raising wages high enough to induce U.S. farm workers into the fields, highlighting the fact that the major responses to

rising wages in the farm labor market are on the demand rather than the supply side of the labor (Huffman, 2007; Martin, 2009). Second, those closest to the industry were unable to predict the speed of the adjustments that occurred. Third, the government played a critical role in speeding mechanization via research funding" (Martin and Calvin, 2010).

IRCA provided an opportunity for unauthorized immigrants to gain temporary legal residency in the United States and then to apply for permanent residency status by demonstrating that she or he had either lived in the United States continuously since before January 1, 1982, or worked in U.S. agriculture for at least 90 days in the year prior to May 1986. Roughly 2.7 million people legalized their immigration status by these two channels (Rytina, 2002).

Two major concerns about IRCA with respect to hired farm labor were that the legalization of previously unauthorized farmworkers would increase their mobility in the labor market, leading to an exodus out of agriculture, and that IRCA's enforcement provisions would limit access to new immigrant labor. Studies that addressed this question include Duffield (1990), Gunter et al. (1992), and Duffield and Coltrane (1992). These papers offered a review of published estimates of labor supply and demand elasticities for the U.S. farm labor market and presented new estimates of these parameters. Longrun labor supply elasticities ranged between 0.71 and 1.55, while the longrun elasticity of labor demand was observed to be rising over time (in absolute terms); Duffield and Coltrane's preferred estimate of this latter parameter, based on data from 1948-89, indicates that a 1-percent increase in the real wage leads to a 3.14-percent reduction in the quantity of labor demanded in the long run. As we will show, these elasticities are generally consistent with our simulation results.

Gunter et al. considered a scenario whereby IRCA caused labor supplied to agriculture to fall by 10 percent and then estimated the consequences for wages, employment, and output in fruit and vegetable production. Their model looked at longrun effects, taking into account substitution between capital and labor, changes in output demand that would occur if higher costs led to higher output prices, and the elasticity of labor supply (treating all hired labor as a single input, regardless of nationality). They found that a 10-percent reduction in labor supply raised wages by 5.1 percent, reduced agricultural employment by 6.2 percent, and reduced output by 3.4 percent.[7] They then refined these estimates for a set of 11 individual commodities and found that wages rose by 4.4-5.1 percent, depending on the crop; employment fell by 4.0-10.9 percent; prices rose by 0.2-2.2 percent; and farm output fell by 0.4-4.3 percent.

Gunter et al. concluded that "only minor changes in fruit and vegetable production would result from an IRCA-induced labor supply decrease." In particular, total fruit and vegetable output was still projected to grow by 12.1 percent over 5 years, compared with 16.0 percent in the absence of the labor shock, because they forecasted that consumer demand for fruits and vegetables would continue to grow at the same rate as during 1983-87.

The decrease in farm labor availability contemplated by Gunter et al. never materialized, as illegal immigration continued and even accelerated.

[7]These numbers were calculated from the results reported in table 3 of Gunter et al. and reflected the difference between projected outcomes under two scenarios: one involved steady consumer demand growth with no labor supply shock, and the other assumed the same rate of demand growth but also reduced labor supply by 10 percent.

Although IRCA included penalties for farmers who "knowingly" hired unauthorized workers, it did not require farmers to verify the authenticity of the documents their workers presented to establish their legal status (Martin and Calvin, 2010). The subsequent proliferation of false documents drew congressional attention in 1996, resulting in the development of systems that allow employers to check the authenticity of documents provided by newly hired workers. These pilot projects have since evolved into E-Verify.[8]

The most recent wave of research on unauthorized farmworkers includes the work of Martin and Calvin, already mentioned, and analyses by Devadoss and Luckstead (2008), Rosson, et al. (2009a), the American Farm Bureau Federation's Economic Analysis Team (2006), and Ruark and Moinuddin (2011). In their study of California vegetable production, Devadoss and Luckstead argued that there was virtually no displacement of domestic workers by foreign-born workers: "[T]he addition of one new immigrant displaces only 0.0123 domestic workers, and wage reduction is inconsequential." They noted that, since only about 5 percent of workers in California vegetables were U.S.-born, even large percentage increases in their employment would correspond to small absolute numbers. However, since foreign-born workers accounted for roughly 95 percent of the workforce during the period that Devadoss and Luckstead studied, it is unlikely that the presence of such workers had only inconsequential effects on wages. A simple static shortrun model with the labor supply elasticity set at 0.5 and the demand elasticity set at 2 (in absolute value), which were the parameters employed by Devadoss and Luckstead, predicts that a 10-percent increase in total labor supply would lead to a 4-percent reduction in wages and an 8-percent increase in total employment.[9]

Most research supports the conclusion that the elasticity of labor supply that governs the response of U.S.-born farmworkers is well below infinity. Hence, large reductions in the size of the foreign-born workforce would not be offset simply by equally large increases in the employment of U.S.-born farmworkers. Instead, the reductions would lead to some combination of higher wages, increased employment of U.S.-born and other authorized workers, reduced farm output, and, in all likelihood, advances in mechanization over the long run.

Rosson et al. (2009) illustrated the importance of foreign-born workers to the U.S. dairy industry through the use of an input-output model of the U.S. economy. In a simulation whereby the number of foreign-born workers (both authorized and unauthorized) employed in the dairy sector was reduced by 50 percent, the authors found that U.S. milk production decreased by 7.9 percent. This study did not consider, however, the extent to which departing foreign-born workers could be replaced by further mechanization, U.S.-born workers, or some combination of the two. Indeed, the study was grounded in the assumption that the quantity of U.S.-born labor for the dairy industry remained constant.

The American Farm Bureau Federation's Economic Analysis Team (2006) considered a scenario whereby U.S. agriculture no longer had access to "migrant workers," who were defined as "foreign-born workers who travel to the U.S. for employment in the agricultural sector." This study also made no distinction between authorized and unauthorized workers. Based on a simple

[8]The U.S. Department of Homeland Security, Citizenship and Immigration Services (2011b) offers a chronological summary of the major milestones in the development of E-Verify.

[9]The change in the equilibrium wage in response to a supply shift is given by: $\%\Delta W = -\%\Delta L_S / (\varepsilon+\gamma)$ where W is the wage, L_S is labor supply, ε is the elasticity of labor supply, and γ is the elasticity of labor demand. The change in employment is then: $\%\Delta W*\gamma$.

comparison of agricultural and nonagricultural wage data, the authors concluded that in such a scenario, the wages of hired farmworkers would need to rise by 16-47 percent for agricultural employers to attract replacement workers from other occupations requiring similar skills. The authors then assumed that about 10-20 percent of financially vulnerable growers of fruits, vegetables, and nursery products would be forced to exit the sector because of this wage increase, without a clear explanation of how this percentage was obtained. When the authors conducted their study, about 10 percent of all U.S. fruit, vegetable, and nursery product growers were classified as financially vulnerable, according to 2003 ARMS data, so the number of growers assumed to depart the sector would correspond to about 1-2 percent of all fruit, vegetable, and nursery product growers.[10] Total U.S. agricultural output was projected to fall by approximately 3-6 percent in the long run.

Similarly, Ruark and Moinuddin (2011) imagined replacing unauthorized farmworkers with U.S.-born workers at higher wages and then calculated the implications of this increase in labor costs for agricultural profit margins. They concluded that farm profits were high enough to absorb the additional costs associated with replacing the unauthorized labor force. The authors noted that U.S.-born workers earned 18-22 percent more than unauthorized workers and assumed that adequate numbers of additional U.S.-born workers could be recruited at this wage. This argument, however, rested on the assumption that the supply elasticity of U.S.-born labor to farming was nearly infinite: with no change in the wage rate currently offered to U.S.-born workers, hundreds of thousands more could be recruited. This assumption is contradicted by the empirical evidence cited earlier, implying that Ruark and Moinuddin's estimates of the hypothetical increase in labor costs and its effects on farm profitability and output are too low.[11]

As mentioned previously, some State Governments have mandated the use of E-Verify by private-sector employers; quantitative evaluations of these mandates are now emerging. Lofstrom et al. (2011) studied the effects of the 2007 Legal Arizona Workers Act (LAWA)—a State law that mandates the use of E-Verify by all Arizona employers and imposes sanctions on employers who hire unauthorized workers. Lofstrom et al. compared population and employment levels in Arizona before and after the law's passage with those in a group of control States that displayed similar economic trends prior to 2007. They found that wage and salary employment of Hispanic noncitizens, many of whom were unauthorized, dropped by approximately 56,000 post-LAWA, but that self-employment by Hispanic noncitizens, either as independent contractors or as laborers in the informal sector, increased by about 25,000. The authors found no clear evidence that LAWA either hurt or benefitted competing authorized workers. Although results specific to agriculture were not reported, these findings suggest that broader mandated use of E-Verify by private sector employers could have significant effects on the farm labor market.

The final set of studies that we reviewed examined the impact of immigration on local labor markets and the economy as a whole but did not look specifically at agriculture. Longhi et al. (2008) discussed dozens of relevant studies with widely varying conclusions; the opposite sides of this debate are exemplified by Borjas and Katz (2007) and Ottaviano and Peri (2008). Borjas and Katz found no net effect of immigration between 1980 and 2000 on average

[10]ERS classifies financially vulnerable farms as having negative net cash income and a debt-to-asset ratio greater than 0.4. ERS's most recent research on the financial outlook for the U.S. farm sector (Park et al., 2011) indicated that, as of December 31, 2010, 2 percent of all U.S. farms were financially vulnerable. This was the lowest level ever recorded by ERS. Moreover, most of these vulnerable farms were classified as residential/lifestyle operations, or small family farms (gross farm sales less than $250,000), where the operator reports a major occupation other than farming (Hoppe and Banker, 2010).

[11]A detailed critique of Ruark and Moinuddin appears in Knutson and Fisher (2011).

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wages of U.S.-born workers, but they found a strong negative effect for those without a high school diploma, whose wages fell by 4.8 percent. By contrast, Ottaviano and Peri argued that, on balance, immigrants complement the U.S.-born workforce, promoting capital investment and allowing U.S.-born workers to fill higher paying jobs. They concluded that immigration between 1990 and 2006 raised average wages of U.S.-born workers by 0.6 percent. Strikingly, Ottaviano and Peri found positive wage effects of immigration even for the least educated U.S.-born workers. However, they also found that new immigrants reduced the wages of previous immigrants by 6 percent.

Research Methods

We employed a modified version of the U.S. Applied General Equilibrium (USAGE) Model, a recursively dynamic, computable general equilibrium (CGE) model of the U.S. economy developed by Peter Dixon and Maureen Rimmer of Monash University in Australia and adapted to the U.S. context in collaboration with the U.S. International Trade Commission (USITC). The model's origins, structure, and data sources are described in detail in the appendix. Here, we summarize the model's key features that must be understood to interpret our results.

A CGE model is "a system of equations that describes an economy as a whole and the interactions among its parts" (Burfisher, 2011). CGE modeling may be contrasted with partial equilibrium analyses, which examine markets for individual goods, services, or factors of production under the assumption that the policy change in question is not large enough to have an appreciable effect on the overall economy. When the macroeconomic repercussions of economic policy changes cannot be ignored, such as with our decreased unauthorized labor supply scenario, CGE modeling is necessary.

At the heart of any CGE model is a social accounting matrix (SAM) that describes the monetary flows within an economy between buyers and sellers, including industries that buy intermediate inputs from each other, and quantifies the public, private, and foreign sources of demand for national output. For our purposes, the key linkages are between the markets for various factors of production, between different economic sectors (agricultural and nonagricultural), and between the U.S. economy and the rest of the world.

Three important features of the USAGE Model distinguish it from other methods used to address this issue:

- The model treats authorized and unauthorized labor as distinct factors of production and contains a parameter (an elasticity of substitution) that determines the willingness of employers to substitute between them. In both the Ottaviano/Peri and Borjas/Katz papers, data limitations prevented an explicit differentiation between authorized and unauthorized foreign-born workers. The inconsistent results between the two studies stemmed from how the researchers treated capital stock adjustments, substitution between workers with varying levels of education and experience, and substitution between immigrant and nonimmigrant labor. The USAGE Model incorporates Ottaviano and Peri's estimated elasticity of substitution between domestic and foreign-born labor but reaches conclusions similar to those of Borjas and Katz with regard to the impact of immigration on low-wage U.S.-born workers, including farmworkers, because authorized and unauthorized labor are assumed to be close substitutes in the model.

- The model also takes into account linkages between agriculture and the rest of the U.S. and global economy, allowing us to assess the effect of changes in immigration policy on domestic and international demand for agricultural output. Most static analyses hold output prices fixed or, as with Gunter et al., assume that output demand grows steadily and is

not affected by the policy-induced changes in the supply of unauthorized labor.

- Finally, the model explicitly represents the markets for farm labor, capital, land, and output as endogenous variables, unlike Ruark and Moinuddin, whose estimated wage changes were imposed exogenously and who made the assumption that farm output was unchanged.

The USAGE Model is not the only CGE model that has been used to evaluate the economic impacts of changes in the supply of foreign-born labor. For instance, a global CGE model of bilateral migration flows associated with the Global Trade Analysis Project (GTAP) (Walmsley et al., 2007) examined the economic gains from relaxing the restrictions of developed countries to temporary workers from the developing countries. Unlike the USAGE Model, this model has not yet been fully applied to U.S. agriculture, although work is underway by Remble and Keeney (2011) to apply the CGE modeling approach of Walmsley et al. to determine how an increase in the supply of foreign-born workers might offset a decrease in U.S. domestic farm supports.

We began our analysis by using the USAGE Model to generate an economic forecast for the 15-year period that followed the base year, which was 2005. We will refer to this forecast as the "base forecast." It represents a prediction of how the economy would evolve under current laws and policies. We then implemented the labor supply changes described below and compared the resulting scenarios with the base forecast. Model results are expressed as percentage differences between the base forecast and the scenarios, and these differences are interpreted as the effects of the labor supply changes, which are assumed to be the results of unspecified changes in policy. The 15-year forecast was long enough to enable the model to achieve a new, long-term equilibrium and to express fully the economic effects of the scenarios.

Like many CGE models, the USAGE Model assumes that markets are sufficiently flexible to ensure that all labor and capital resources are nearly fully employed in the long run. This means that the simulations reported here do not apply to the current economic environment, in which roughly 8 percent of the workforce is unemployed. Instead, they describe a hypothetical, longrun situation in which the U.S. economy is much closer to full employment and has an unemployment rate of about 5 percent.[12]

To adapt the USAGE Model to the study of immigration, Dixon and Rimmer (2008, 2009) used estimates of unauthorized migration from Van Hook et al. (2005) to disaggregate the workforce into three categories based on immigration status:

- U.S.-born: native U.S. citizens;

- Foreign-born, permanent resident: those with permanent U.S. residency status and are, thus, legally authorized to work in the United States; and

- Foreign-born, not a permanent resident: those without permanent U.S. residency status.

Most people in this third category are not legally authorized to work in the United States. For this reason, we sometimes used the term "authorized" to refer to people in the first and second categories and "unauthorized" to refer

[12]In the short run, the model used a dynamic approach to adjust wage rates in response to gaps between the demand for and supply of different types of labor. This permitted some deviation from near-full employment. We reported only long-run results (15 years after a significant policy shock), by which time near-full employment had been restored.

to people in the third category. The third category, however, also includes foreign-born persons with nonimmigrant visas, such as H-2A workers, who are legally authorized to work in the United States during a specified time period but do not have permanent U.S. residency status.[13]

Within the USAGE Model, members of the labor force can participate in one of three economic activities:

- Employment in the United States in one of the model's 50 occupations;

- Unemployment in the United States; and

- Employment outside the United States.

The supply of labor to each U.S. occupation is determined by the occupation's real wage rate and an occupational preference matrix that represents the relative utility that workers in a specific category would obtain from employment in a particular economic activity in the upcoming year. Categories of workers and economic activities are both defined by birthplace, immigration status, and occupation (e.g., foreign-born, permanent resident, hired farmworkers in the United States).

The occupational preference matrix is a novel feature of the USAGE Model and plays a central role in the policy simulations examined here. For a given category of worker, a high preference is assigned to the current occupation so that nearly all people employed in a given occupation in 1 year offer to work in that same occupation in the following year; these incumbents are also first in line for available jobs in that occupation. Smaller positive values are assigned to alternative occupations with similar skill requirements as the current occupation. By increasing (decreasing) the preferences of unauthorized workers for particular occupations, we were able to increase (decrease) the supply of unauthorized labor to those occupations, without altering the *ex ante* real wage. More information about the changes made to this matrix to implement the two scenarios follow, and detailed, technical descriptions of the matrix and its function are available in the appendix or in Dixon and Rimmer (2010, 2008).

The impact of changes in labor supply depends on a number of important parameters, two of which we modified to conduct sensitivity analyses of the enforcement scenario. The first parameter determines how changes in relative wages alter the willingness of workers to supply labor to different occupations. The elasticity of substitution for a particular category of workers (say, foreign-born, permanent resident) between earning a dollar in a specific pair of occupations is defined as:

Workers' elasticity of substitution between occupations i and j

$$= -\frac{\text{Percentage change in}\left(\dfrac{\text{Quantity of labor supplied to occupation } i}{\text{Quantity of labor supplied to occupation } j}\right)}{\text{Percentage change in}\left(\dfrac{\text{Real wage in occupation } i}{\text{Real wage in occupation } j}\right)}$$

In keeping with prior work by Dixon et al. (2011), this parameter was set equal to 2.0 for all pairs of occupations for both the increased farm labor supply scenario and the "standard parameters" version of the decreased unauthorized labor supply scenario. Thus, a 1-percent increase in the ratio of the real wage of occupation *i* relative to *j* would lead to a 2-percent increase in the ratio of the quantity of labor supplied to occupation *i* relative to *j*. As demonstrated below, this setting generated supply elasticities for U.S.-born and foreign-born permanent residents to agricultural activities that were consistent with econometric estimates.

We conducted a sensitivity analysis to address the assertion that U.S.-born workers find certain jobs currently filled by unauthorized workers to be undesirable and that farm employers would find it difficult to replace their unauthorized workers. Specifically, we considered the impact of a less elastic labor supply (i.e., one that was less responsive to changes in the real wage) by estimating a variant of the decreased unauthorized labor supply scenario where the above parameter was reduced from 2.0 to 0.5. With a lower willingness to substitute between occupations, larger increases in the real wage are necessary to draw U.S.-born and foreign-born, permanent resident workers into the jobs vacated by unauthorized workers.

The second parameter we modified in our sensitivity analysis was the employers' elasticity of substitution between unauthorized and authorized labor, defined as:

Employers' elasticity of substitution between unauthorized and authorized labor

$$= - \frac{\text{Percentage change in } \left(\dfrac{\text{Quantity of unauthorized labor demanded}}{\text{Quantity of authorized labor demanded}} \right)}{\text{Percentage change in } \left(\dfrac{\text{Real wage for unauthorized labor}}{\text{Real wage for authorized labor}} \right)}$$

This elasticity is a characteristic of the economy's production function and, thus, influences labor demand rather than labor supply. In our second variant of the decreased unauthorized labor supply scenario, we reduced the employers' elasticity of substitution between unauthorized and authorized labor from 5.0 to 2.0, to capture the possibility that employers treat the two types of labor as more differentiated factors of production.[14] We also used the lower parameter of 0.5 to govern the workers' elasticity of occupational substitution on the labor supply side. In this variant of the decreased unauthorized labor supply scenario, a loss of unauthorized labor results in larger real wage increases for the remaining unauthorized workers and smaller real wage increases for U.S.-born and foreign-born, permanent resident workers.

[14]The appendix explains how the elasticities of substitution between labor provided by persons of different immigration statuses were selected.
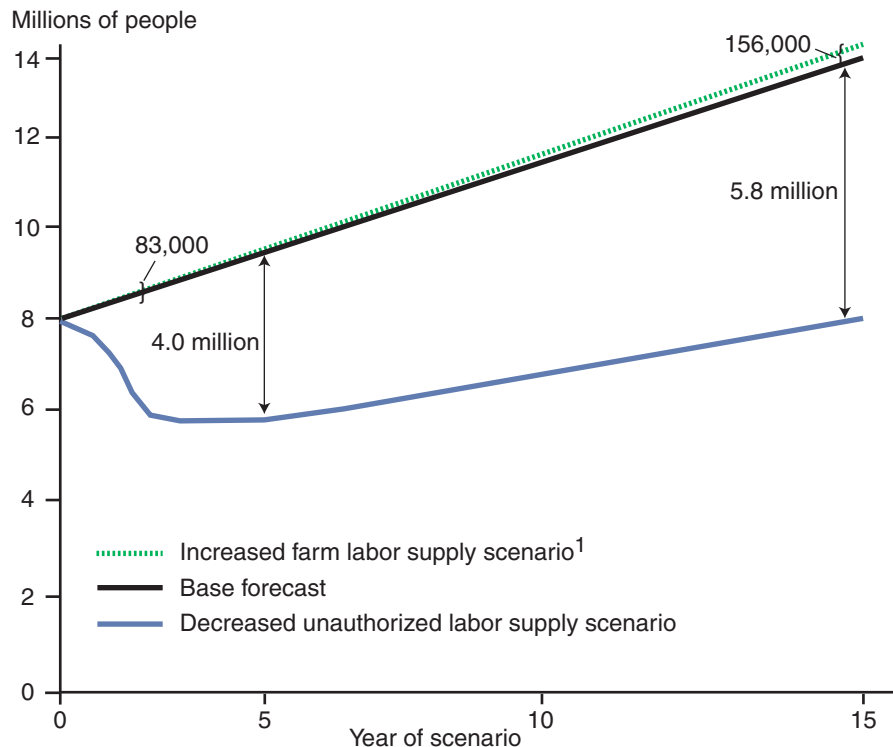
Simulations

Our first simulation—the increased farm labor supply scenario—considered the economic impact of increased employment of temporary nonimmigrant agricultural workers brought about by unspecified changes to the H-2A program or a similar program. As mentioned previously, the additional temporary nonimmigrant agricultural workers associated with this simulation are included in the category of foreign-born people without U.S. permanent residency status. The H-2A program authorizes participating workers to enter the United States temporarily with a nonimmigrant visa, but H-2A workers do not have the opportunity to apply for permanent residency by virtue of participating in the program. Moreover, a typical H-2A worker may not be a perfect substitute for a typical foreign-born farmworker with permanent residency (e.g., the two groups of workers may have different skills and abilities).

The scale of the increase in the farm labor supply was chosen to correspond with an approximate quadrupling of participation levels in relation to the H-2A program. In FY 2005, which roughly corresponded with the USAGE Model's base year of 2005, 48,336 positions were certified under the H-2A program (U.S. Department of Labor, Employment and Training Administration, 2006). We increased the number of temporary nonimmigrant agricultural workers by 30,000 in year 1 of the simulation and by 83,000 in year 2. By year 15, the number of additional workers of this type reached 156,000 (fig. 2). This represents a 32.4-percent increase in the long-run number of foreign-born farmworkers without permanent residency status.[15]

[15]The number of workers in the USAGE Model is measured in terms of full-time equivalents (FTEs—2,000 hours per year), while a position certified in the H-2A program may not precisely correspond to 1 FTE.

Figure 2
Impact of labor-supply scenarios on the number of workers without permanent residency

Millions of people

[1]Includes additional temporary nonimmigrant agricultural workers.

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While we did not specify a particular policy change that led to increased employment of temporary nonimmigrant agricultural workers, we did allow the market for hired farm labor to adjust in the model without reference to the H-2A program's current legal wage requirements. To generate the necessary increase in labor supply, we altered the occupational preferences of foreign-born workers and new labor market entrants who were not currently in the United States, so that they derived higher utility from employment as U.S. farmworkers. The increased preference for employment as a U.S. farmworker was phased in over the first 2 years of the scenario and was perceived by foreign-born workers and new labor market entrants who were not currently in the United States as equivalent to a 28.6-percent increase in earnings.

The second simulation—the decreased unauthorized labor supply scenario— assumed that unspecified policy changes led to a decrease in the number of unauthorized workers in the U.S. economy. We assumed that the unauthorized labor force (farm and nonfarm) fell by 2.1 million people in absolute terms over the first 5 years of the scenario; compared with the base forecast for year 5, this represented a relative reduction of 4.0 million people (see fig. 2). Growth in the unauthorized workforce resumed thereafter, but at a slower pace than in the base forecast. By year 15, the projected unauthorized workforce had increased to 8.5 million people, compared with 14.3 million in the base forecast, or a difference of 5.8 million workers (40 percent).

We implemented this scenario by altering the preferences of foreign-born, unauthorized workers in two ways: people currently employed in their home countries and new labor market entrants born outside the United States offer a smaller quantity of labor to U.S. occupations, and unauthorized workers currently employed in the United States offer a larger quantity of labor to jobs in their home countries. This led to a reduction in the size of the unauthorized workforce that was large enough to have substantial effects on all sectors of the U.S. economy, not just agriculture. At the same time, this reduction fell short of assuming that there were no unauthorized workers in the U.S. labor force.

While the decreased unauthorized labor supply scenario was not intended to represent the impact of a specific policy change, we gauged the change in occupational preferences so that absolute, year-to-year decreases in the number of unauthorized workers took place in the first several years of the scenario, reflecting a policy change with the most dramatic effects on the labor market early on. The decreased preference for employment in any occupation in the United States was phased in over the first 2 years of the scenario and was perceived by unauthorized workers as equivalent to a 25-percent decrease in earnings. Moreover, the parameter that governed the proportion of unauthorized workers who returned to their home countries was doubled in each of the first 2 years of the scenario, effectively raising this proportion from 3 percent in the base year to 12 percent from year 2 forward.

Effects on the Labor Market

Table 1 illustrates how the two scenarios affect the agricultural labor market. The increased farm labor supply scenario led to a longrun increase in farm employment of 1.7 percent (43,600 full-time equivalents or FTEs), compared with the base forecast, and a 4.4-percent decrease in average farm wages.

Table 1

Long-run (15-year) changes in immigration levels, earnings per job, and employment in agriculture compared with base forecast

Variable	Increased farm labor supply scenario	Decreased unauthorized labor supply scenario		
		Standard parameters	Reduced elasticities of substitution:	
			Between occupations (labor supply)	Between occupations (labor supply) and between authorized and unauthorized (labor demand)
	Thousands			
Increase in temporary nonimmigrant agricultural workers	156	NA	NA	NA
	Millions			
Decrease in unauthorized workers, all occupations	NA	-5.8	-5.8	-5.8
	Percent			
Employment in agriculture:	1.7	-3.4	-4.8	-5.5
U.S.-born	-5.7	4.0	3.4	2.6
Foreign-born, permanent resident	-5.6	3.7	3.1	2.4
Foreign-born, not permanent resident[1]	32.4	-34.1	-38.7	-38.8
Wages in agriculture:	-4.4	3.9	8.0	9.9
U.S.-born	-3.4	3.3	7.4	5.6
Foreign-born, permanent resident	-3.4	3.3	7.5	5.6
Foreign-born, not permanent resident[1]	-10.0	13.6	19.7	39.8

NA = Not applicable.

[1]In the increased farm labor supply scenario, this group includes both unauthorized workers and the additional temporary nonimmigrant agricultural workers associated with the scenario.

The net wage change reflected a 10.0-percent decrease in the wages of workers without permanent residency status (whose supply increased) and a 3.4-percent decrease in average wages for all other workers. The fall in wages for U.S.-born and other permanent resident workers occurred because employers shifted employment toward less costly temporary nonimmigrant agricultural workers.

The net employment change reflected a 32.4-percent increase in the number of farmworkers who are not permanent residents, partially offset by reductions in the employment of U.S.-born and foreign-born, permanent resident workers. This net increase in employment occurred for two reasons. First, lower labor costs shifted the capital/labor ratio toward greater use of labor for a given amount of capital (the substitution effect). Second, the reduction in total costs caused farm output to expand, which increased demand for all factors of production (the scale effect).

In the increased farm labor supply scenario, the agriculture-specific change in labor supply was small enough to have no significant effect on national and international demand for farm output. As a result, we may use the realized

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wage and employment outcomes to calculate the effective longrun elasticities of labor supply and demand. For workers who were not permanent residents, the shift in supply lowered wages along the labor demand curve with a longrun elasticity of -3.24 (32.4 divided by -10.0), a figure similar to estimates from Gunter et al. (1992). As already noted, the increased supply of temporary nonimmigrant agricultural workers reduced the demand for U.S.-born and other permanent resident workers, lowering their wages along the labor supply curve. The longrun elasticity of supply was approximately 1.65 (-5.6 divided by -3.4), a figure close to published econometric estimates.

In the second column of table 1, using the standard parameters, the decreased unauthorized labor supply scenario reduced longrun farm employment by 3.4 percent (86,600 FTEs). This net effect was driven by a 34.1-percent reduction in the employment of unauthorized workers, which was partially offset by 3.7- to 4.0-percent increases in the employment of U.S.-born and foreign-born, permanent resident workers. Average farm wages rose by 3.9 percent, driven by a 13.6-percent increase in wages paid to unauthorized workers and smaller increases for the other two employment categories. As in the increased farm labor supply scenario, both wage and employment changes were most pronounced for the category of labor whose supply was altered by the policy change, with smaller spillover effects on workers in the other two categories. The longrun real wage increase for unauthorized farmworkers was larger than for U.S.-born and foreign-born, permanent resident farmworkers because the two are not perfect substitutes. When faced with a reduction in the supply of unauthorized labor, farm employers bid the real wages of unauthorized workers up by a larger margin than they raised real wage offers to U.S.-born and foreign-born, permanent resident workers to maintain the profit-maximizing level and composition of employment.

Reducing the workers' elasticity of substitution between occupations (third column of table 1) made it more difficult for farmers to replace the missing unauthorized labor in the decreased unauthorized labor supply scenario. Instead of rising by 3.3 percent, the wages of U.S.-born and foreign-born, permanent resident farmworkers now rose by 7.4-7.5 percent. Total farm employment fell by 4.8 percent, compared with 3.4 percent using the standard parameters.

In the final column of table 1, a lower elasticity of substitution between authorized and unauthorized labor reduced the willingness of farm employers to use authorized workers to replace unauthorized workers. As a result, the employment of U.S.-born and foreign-born, permanent resident farmworkers increased in the long run by just 2.4-2.6 percent, compared with 3.7-4.0 percent when the standard parameters were used. This alternative scenario was the most costly for agricultural employers: overall wages rose by 9.9 percent and employment fell by 5.5 percent. Note, however, that the predicted wage increase for unauthorized farmworkers was nearly 40 percent, which would result in their being paid more than U.S.-born and foreign-born, permanent resident farmworkers in the same agricultural sectors. This implausible outcome led us to conclude that an employers' elasticity of substitution between authorized and unauthorized workers of 2.0 was unrealistically low.

Effects on Agricultural Output and Exports

In the USAGE Model, growth in agricultural output is largely determined by the price elasticity of demand for each commodity, by the degree to which the policy change altered national income and the exchange rate, and by the degree to which changes in labor costs affected the total cost of production. Changes in labor costs, in turn, depend primarily on the share of labor, particularly unauthorized labor, in total costs: farm sectors that use a lot of labor reap the greatest cost savings when the supply of unauthorized labor increases and experience the greatest cost increases when the supply decreases.

Table 2 reports the change in the real value of agricultural output in the various scenarios. The impacts of the scenarios on output are expressed in terms of the longrun (15-year) percentage difference between real output in the scenario and in the base forecast. In the increased farm labor supply scenario, agricultural output experienced a longrun relative increase of 0.1-2.0 percent, depending on the sector. Output of labor-intensive commodities (e.g., tree nuts, cotton, fruits, vegetables, and greenhouse products) increased

Table 2

Long-run (15-year) changes in agricultural output compared with base forecast

Agricultural sector	Increased farm labor supply scenario	Decreased unauthorized labor supply scenario		
			Reduced elasticities of substitution:	
		Standard parameters	Between occupations (labor supply)	Between occupations (labor supply) and between authorized and unauthorized (labor demand)
		Percent		
Fruits	1.2	-2.0	-2.7	-3.5
Vegetables	1.2	-2.9	-3.7	-4.3
Greenhouse and nursery	1.1	-3.5	-4.5	-4.3
Tree nuts	2.0	-2.8	-4.2	-5.4
Feed grains	0.4	-2.5	-3.0	-2.8
Food grains	0.3	-2.6	-2.9	-2.7
Oilseeds	0.1	-1.7	-1.9	-1.6
Sugar crops	0.3	-2.2	-2.5	-2.4
Cotton	1.3	-3.4	-4.4	-4.7
Grass seeds	0.4	-2.9	-3.2	-2.9
Tobacco	0.3	-2.0	-2.2	-2.0
Miscellaneous crops	0.6	-3.1	-3.7	-3.6
Meat	0.3	-2.4	-3.1	-3.0
Poultry	0.2	-2.0	-2.5	-2.4
Dairy	0.3	-2.2	-2.5	-2.4
Miscellaneous livestock	1.5	-3.4	-4.9	-4.9

by about 1-2 percent, while output of less labor-intensive commodities (e.g., oilseeds, grains, and meat animals) expanded by less than 0.5 percent.

The decreased unauthorized labor supply scenario had significant macroeconomic repercussions—it altered national income and the foreign exchange rate. As a result, the scenario affected both domestic and foreign demand for agricultural products, whether they were labor-intensive or not. The magnitude of a sector's output decline depended on the elasticity of demand for its output and its exposure to foreign trade, in addition to the share of unauthorized labor in total costs. Depending on the sector, longrun agricultural output in this scenario fell by 1.7-3.5 percent compared with the base forecast.

Reducing the elasticities of substitution between occupations and between unauthorized and authorized labor generally amplified the magnitude by which agricultural output was reduced in the decreased unauthorized labor supply scenario. When we assumed that the parameter governing the elasticity between occupations was 0.5 instead of 2.0, each agricultural sector experienced a relative decrease in output that was about 0.6 percentage points larger, on average, than under the standard parameters. These larger decreases in output occurred because farm employers had to pay even higher real wages to attract U.S.-born and foreign-born, permanent resident workers to replace some of the unauthorized workers who left the United States. If we also reduced the employers' elasticity of substitution between unauthorized and authorized labor from 5.0 to 2.0, four agricultural sectors—fruits, vegetables, tree nuts, and cotton—experienced larger relative decreases in output.

Table 3 reports the change in agricultural exports. In the increased farm labor supply scenario, agricultural exports grew by 0.2-3.2 percent in the long run, while agricultural exports fell by higher percentages (0.8-6.3 percent) in the decreased unauthorized labor supply scenario (standard parameters). As mentioned previously, the latter scenario reduced the labor supply in all sectors of the economy. As a result, the supply curves for all U.S. exports shifted inward, which caused a terms-of-trade improvement and an associated appreciation of the real exchange rate. This outcome exerted additional negative effects on U.S. agricultural exports, beyond those caused by the reduction in the supply of labor to the sector. As with output, the decreased unauthorized labor supply scenario had a larger negative impact on exports when the workers' elasticity of substitution between occupations was set to a lower value. Similarly, sectors more intensive in unauthorized labor experienced greater long-run reductions in exports when the employers' elasticity of substitution between authorized and unauthorized labor was also lowered.

Economy-Wide Effects

The economy-wide effects of the scenarios are summarized in table 4. The first row of the table indicates the size of the economy, leaving out the earnings of workers who lack permanent residency status. This value measures the aggregate economic well-being of U.S.-born and other permanent residents. The increased farm labor supply scenario had negligible effects on this economy-wide measure, since the supply of foreign-born labor was increased only for the agricultural sector.

Table 3
Long-run (15-year) changes in agricultural exports compared with base forecast

Agricultural sector	Increased farm labor supply scenario	Decreased unauthorized labor supply scenario		
		Standard parameters	Reduced elasticities of substitution:	
			Between occupations (labor supply)	Between occupations (labor supply) and between authorized and unauthorized (labor demand)
		Percent		
Fruits	1.7	-2.5	-3.8	-4.7
Vegetables	2.7	-5.6	-7.4	-8.8
Greenhouse and nursery	3.1	-6.3	-9.3	-8.5
Tree nuts	3.2	-3.5	-5.6	-7.5
Feed grains	0.8	-3.9	-4.4	-3.9
Food grains	0.5	-3.0	-3.4	-3.1
Oilseeds	0.2	-0.8	-1.0	-0.3
Sugar crops	1.7	-5.0	-6.0	-5.9
Cotton	1.7	-3.6	-4.8	-5.1
Grass seeds	0.6	-3.2	-3.9	-3.1
Tobacco	0.7	-1.6	-2.2	-2.3
Miscellaneous crops	1.5	-4.7	-6.1	-5.9
Meat	1.9	-4.5	-6.4	-5.5
Poultry	0.7	-3.5	-4.5	-3.8
Dairy	2.3	-5.4	-7.4	-7.1
Miscellaneous livestock	2.6	-4.6	-7.2	-7.2

The decreased unauthorized labor supply scenario had a much larger effect on the economy since a far greater number of workers were involved. Gross national product (GNP), less wage payments to unauthorized workers, fell by about 1 percent over the course of the 15-year projection, relative to the base forecast. Dixon et al. (2011) explained the various economic channels by which the loss of unauthorized labor reduced the income accruing to U.S.-born and foreign-born, permanent resident workers and business owners:

- The economy-wide labor supply was reduced, leading to a decrease in the longrun level of production.

- Lower output reduced incomes to many other complementary factors of production, including capital, land, and U.S.-born and foreign-born, permanent resident workers in higher paying occupations.

- The negative longrun effect on incomes to U.S.-owned factors of production would be only partially offset by increased real wages for U.S.-born workers in lower paying occupations.

Note that nearly all U.S. workers in the USAGE model were employed in the base year and also in the long run of the scenario; there were no large pools of unemployed, permanent resident workers (either U.S.- or foreign-born)

Table 4

Long-run (15-year) changes in economy-wide outcomes for U.S.-born and foreign-born, permanent resident workers compared with base forecast

Variable	Increased farm labor supply scenario	Decreased unauthorized labor supply scenario		
			Reduced elasticities of substitution:	
		Standard parameters	Between occupations (labor supply)	Between occupations (labor supply) and between authorized and unauthorized (labor demand)
		Percent		
GNP less payments to persons without permanent residency status	0.1	-1.0	-0.9	-1.1
Employment:	0.02	-0.2	-0.1	-0.1
Hired farm labor*	-5.7	4.0	3.3	2.5
Other lower-paying occupations*	0.1	3.2	2.6	2.2
Higher-paying occupations	0.1	-0.7	-0.5	-0.5
Earnings per job:	0.03	-0.5	-0.3	-0.6
Hired farm labor*	-3.4	3.3	7.4	5.6
Other lower-paying occupations*	-0.001	1.7	4.5	3.4
Higher-paying occupations	-0.01	-0.2	-0.2	-0.6

GNP=Gross national product.

* = Occupations with average annual earnings below $20,000.

waiting to fill jobs vacated by unauthorized workers. Thus, the replacement farmworkers were drawn from other segments of the workforce—new entrants to the labor market, short-term and long-term unemployment, workers who switch occupations and become farmworkers in response to the changes in the relative wage, and workers displaced from other occupations as a result of the general economic contraction associated with the decreased unauthorized labor supply scenario.

The decreased unauthorized labor supply scenario also affected the occupational distribution of U.S.-born and foreign-born, permanent resident workers, which shifted toward more hired farm work and other lower paying occupations (less than $20,000 per year, on average), such as food service, childcare, and housekeeping, and away from higher paying occupations (a much larger category). Changes in occupational composition reduced the average real wage for U.S.-born and foreign-born, permanent resident workers, even as real wages rose in many lower paying occupations. Overall employment of such workers fell slightly because lower paid occupations had higher rates of turnover, which implied that the longrun, near-full employment equilibrium entailed a higher level of frictional unemployment.[16]

Real wages for U.S.-born and foreign-born, permanent resident workers in the decreased unauthorized labor supply scenario rose in hired farm labor and other lower paying occupations and fell in higher paying occupations.

[16]Frictional unemployment, also known as search unemployment, occurs during the period when workers are searching for an appropriate job vacancy, and employers are searching for an appropriate worker. Because this matching process is not instantaneous, frictional unemployment will exist even when there are sufficient vacancies to accommodate all job seekers.

Our parameter choices and the structure of the USAGE Model conform to what might be called the Borjas school (e.g., Borjas and Katz, 2007; Borjas et al., 2010), which contends that U.S.-born and foreign-born, permanent resident workers in lower paying occupations would see their real wages rise if there were fewer unauthorized workers in the country. The USAGE Model, however, could not address the possible relation between unauthorized immigration and high levels of unemployment among certain demographic groups of U.S.-born workers because the model did not distinguish among U.S.-born workers according to their demographic characteristics, such as educational level.

The sensitivity analyses revealed that reducing the elasticities of substitution between occupations and between authorized and unauthorized labor did not have a significant impact on the relative decline in GNP (net of payments to unauthorized workers) that occurred under the decreased unauthorized labor supply scenario. It did, however, affect the magnitude of the real wage and employment adjustments for lower paid workers. At lower elasticities of substitution between occupations, the wages of U.S.-born and foreign-born, permanent resident workers in lower paying occupations rose by more than twice as much as under the standard parameters. Reducing the employers' elasticity of substitution between authorized and unauthorized labor tempered these wage effects somewhat, because employers were less willing to use authorized workers to replace unauthorized workers.

Research Caveats

The USAGE Model accounted for many of the important linkages among sectors of the U.S. economy and between the U.S. economy and the rest of the world; however, there were aspects of U.S. agriculture and the market for hired farm labor that the USAGE Model did not fully capture:

- Our model did not differentiate between U.S. regions, between detailed individual commodities, or between key stages in the agricultural cycle, such as planting and harvesting. In reality, agriculture is a heterogeneous industry with distinctly local characteristics and seasonal patterns of production and input demand. With regional-level economic data, it would be possible to disaggregate the USAGE Model further to examine the impact of scenarios on the agricultural sectors of specific regions. Similarly, further disaggregation by commodity would identify subsectors within fruits or vegetables with very high shares of unauthorized labor costs. Such subsectors would probably be most affected by the scenarios considered here.

- Our model did not distinguish between hours worked by self-employed farm operators, most of whom are U.S.-born, and hours worked by hired wage and salary workers in agriculture. By treating these two as a single factor, the model effectively assumed that they were perfect substitutes in production within each immigration category, possibly leading to an overstatement of the U.S.-born employment response to a given wage increase in the decreased unauthorized labor supply scenario.

- Although the capital/labor ratio in each sector of our model was allowed to change and did change under the scenarios examined, the same set of production functions were used to represent agricultural output throughout the model's 15-year projection period. Since both of the scenarios assumed sustained changes in the supply of foreign-born agricultural labor, this representation may be unrealistic. For instance, a decrease in the supply of foreign-born farm labor (or greater uncertainty about its availability) would likely motivate growers to mechanize additional aspects of their operations and to adopt other labor-saving aids, such as conveyor belts and elevated work platforms (Calvin and Martin, 2010). In the context of our decreased unauthorized labor supply scenario, employment of U.S.-born and foreign-born, permanent resident farm labor might not increase as much if production functions were allowed to change.

- The USAGE Model did not allow people to change immigration status during the 15-year projection period. This limitation of the model prevented us from examining more precisely crafted immigration scenarios, such as what would happen to U.S. agriculture if H-2A workers became permanent residents.

- Finally, the USAGE Model assumed that all labor and capital resources were nearly fully employed in the long run. As a result, the simulations reported here do not apply to the current economic environment in which roughly 8 percent of the U.S. workforce is unemployed. Dixon and Rimmer (2011a, b) demonstrated that the USAGE Model can be adapted to better represent the current U.S. economy by relaxing the assumption

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that capital is fully employed at all times, and this approach could be applied in future research related to agriculture and the market for hired farm labor.

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Conclusions

This report illustrates some of the divergent economic interests at stake with respect to immigration and the market for hired farm labor. We evaluated two hypothetical scenarios: one in which the number of temporary nonimmigrant farmworkers roughly quadrupled in relation to its 2005 level, and one in which the supply of unauthorized labor in all sectors of the economy (including agriculture) decreased by 40 percent over the long term. Agricultural employers benefited from expanded employment of temporary nonimmigrant farmworkers, with the most labor-intensive agricultural sectors experiencing a longrun increase in output of 1-2 percent, compared with the base forecast. Accompanying this growth, however, was a 5- to 6-percent relative decrease in the number of U.S.-born and foreign-born, permanent resident workers employed in agriculture and a 3-percent relative decrease in the earnings of those who continued to work in the sector.

A 40-percent reduction in the number of unauthorized workers throughout the economy also had a marked, longrun impact on U.S. agriculture, causing a 2- to 5-percent relative decline in agricultural output; a 2- to 9-percent relative decline in farm exports, and a 3- to 7-percent relative increase in the wage rate for U.S.-born and foreign-born, permanent resident farm-workers. Moreover, this reduction in labor supply had negative effects on the overall economy. National income accruing to U.S.-born and foreign-born, permanent resident workers and to employers (in all sectors) contracted by 1 percent, compared with the base forecast, and the occupational distribution of the U.S.-born and foreign-born, permanent resident portions of the U.S. workforce shifted toward hired farm labor and other lower paying jobs. As a result, their average wages fell by about half of one percent in the long run, relative to the base forecast.

The CGE model allowed us to estimate the macroeconomic impact of a large reduction in the supply of unauthorized labor, which lowered domestic demand for agricultural output, strengthened the terms of trade and the exchange rate, and reduced U.S. agricultural exports. Sensitivity analyses suggested that our primary estimates of the impact of the decreased supply of unauthorized labor on agricultural output and exports may have been conservative. When we reduced the elasticity of labor supply by modifying the workers' elasticity of occupational substitution to represent limited interest in lower paying farm employment on the part of workers in other occupations, farm labor costs rose more rapidly and agricultural output and exports fell by a greater percentage. Reducing the employers' elasticity of substitution between authorized and unauthorized labor caused sectors that make extensive use of unauthorized labor to contract even further. In all cases, the decreased supply of unauthorized labor led to lower aggregate levels of agricultural employment and a shift toward more capital-intensive production in agriculture.

Our simulations did not consider how complementary programs that might accompany changes to immigration laws or policies would affect economic outcomes. Further advances in labor-saving agricultural technologies, for instance, might help agricultural employers adjust to a decrease in the supply of unauthorized labor. Future research using the USAGE Model will explore this possibility.

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Appendix: The USAGE Model and Its Application to Immigration

The United States Applied General Equilibrium (USAGE) Model is a recursively dynamic, computable general equilibrium (CGE) model of the U.S. economy. The model is based on an earlier CGE model of the Australian economy, known as the MONASH model (Dixon and Rimmer, 2002), which was adapted to fit the U.S. economy by Dixon and Rimmer in collaboration with the U.S. International Trade Commission (USITC).[1] This adaptation required the model's matrices of economic inputs and outputs across all industries and factors of production to fit the national accounts data of the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). Technical descriptions of the USAGE Model, including how it was adapted to study unauthorized immigration, can be found in Dixon and Rimmer (2002, 2008, 2009, 2010) and Dixon et al. (2008, 2011).

Principal features of the USAGE Model include:

- Modeling the accumulation of physical capital via a set of investment functions that are sensitive to rates of return;

- Tracking the accumulation of foreign debt, the balance of payments, and an aggregate representation of U.S. dollar-foreign currency exchange rates;

- Careful treatment of taxation, public expenditures, and the accumulation of public debt; and

- A dynamic model of wage-rate adjustment in response to gaps between the demand for and supply of labor.

The model was implemented in the RunDynam software program, version 3.2 (February 2009), developed at Monash University by the Centre of Policy Studies and Impact Project.

General equilibrium in the USAGE Model is based on supply and demand equations that are the results of optimizing decisions by firms, investors, consumers, and labor-force participants. Each industry chooses the composition of its outputs to maximize revenue from a given set of inputs and the composition of inputs to minimize the costs of producing any given set of outputs. The production functions that structure the industries' optimizations are constant-ratio-of-elasticity-of-substitution-homothetic (CRESH) over occupational labor input types and over primary factors of production (labor, capital, and land).[2] Intermediate commodities enter in constant-elasticity-of-substitution (CES) from across imported and domestic sources. Primary factors and commodity inputs are then combined using fixed coefficients (Leontief technology). Capital goods are created using CES technology over domestic versus imported sources and Leontief technology across commodities. The level of investment is based on expected rates of return, with expectations in this application based on past results. Consumers' utility functions are in the Klein-Rubin (or Stone-Geary) form, defined over commodities consumed, within which is nested a CES function defined over imported and domestic sources. Labor demand and labor supply functions are described in more detail below.

[1]U.S. International Trade Commission (2004, 2007, 2009) exemplify this collaboration.

[2]Labor of a given type is fully mobile across industries. Capital is industry-specific with the allocation of capital across industries adjusting in the long run through investment. Agricultural land is partially mobile among agricultural sectors with allocations responding to changes in relative rental values across agricultural activities.

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To use the USAGE Model to simulate the effects of a policy change or other shock, two model runs were needed: a base forecast and a policy simulation. To determine the effects of the scenarios, we compared the quantitative results of the policy simulations with those from the base forecast. We expressed model results as percentage differences between the base forecast and the scenarios, and these differences were interpreted as the effects of the policy change.

The base forecast was an economic forecast for the 15-year period that followed the base year (2005). This forecast offered a prediction of how the economy would evolve under current laws and policies, and it incorporated trends in technology, household preferences, international trade, and demographic characteristics. Most macroeconomic variables in the base forecast were exogenous so that their paths could be set in accordance with forecasts made by external macroeconomic specialists, such as those at the Congressional Budget Office (CBO).

Each simulation was a separate 15-year forecast in which the macroeconomic variables were permitted to evolve endogenously. In this simulation closure, the consumer price index was the numeraire, which means that changes in immigration policy were assumed to have no effect on the rate of inflation (or that the Federal Reserve compensated for any effects so that the rate of inflation was not altered). Further, we assumed that changes in immigration policy had no effect on technology or household preferences, which followed the same path as in the base forecast.

Public-sector expenditures and tax revenues were calculated to account for the differing consumption and savings patterns and for the differing demand for public services of authorized and unauthorized workers. Thus, changes in public-sector expenditures associated with increases or decreases in the number of unauthorized immigrants in the United States were accounted for. We then assumed that tax rates were adjusted so that the public-sector deficit followed the same path as in the base forecast.

To simplify the model's computation and interpretation, the nearly 500 nonfarm sectors in the original USAGE Model were aggregated and then collapsed into 49 sectors, while all 16 agricultural sectors in the model were retained in their full detail. Occupations were similarly redefined by preserving full detail for 45 occupations in which unauthorized immigrants were predominantly employed and collapsing the remaining occupations to just five broad categories. Appendix tables 1 and 2 list the economic sectors and occupations, respectively, within this compact version of the USAGE Model. Previous work by Dixon and Rimmer (2010) showed that the model's aggregate results were not appreciably altered by reducing the number of sectors and occupations in this fashion.[3]

[3]The smaller version of the USAGE Model used in this report is sometimes referred to as the Mini-USAGE Model or USAGE-M. We use the term "USAGE Model" to refer to this smaller model.

For our analysis, the model's base data were also revised to reflect more recently published agricultural trade and employment statistics for the base year. Data for 2005 from the Global Agricultural Trade System (GATS) of the U.S. Department of Agriculture's Foreign Agricultural Service were used in place of the model's original agricultural trade data, and data from USDA's Agricultural Resource Management Survey (ARMS) for average annual employment levels during 2004-06 were allocated across the USAGE Model's

Appendix table 1
Sectors in the USAGE Model

Agricultural sectors	Nonagricultural sectors	
Fruits	Forestry products	Manufacturing not elsewhere classified
Vegetables	Commercial fishing	Communications
Greenhouse and nursery	Agricultural, forestry, and fishing services	Utilities
Tree nuts	Landscaping and horticulture	Trading margin
Feed grains	Mining	Owner occupied dwellings
Food grains	Crude oil	Business and financial services
Oilseeds	Natural gas	Medical services
Sugar crops	Construction	Education
Cotton	Dairy and sugar products	Social services
Grass seeds	Meat products	Enterprise
Tobacco	Food manufacturing	Miscellaneous services
Miscellaneous crops	Tobacco products	Veterinary services
Meat	Apparel	Government services
Poultry	Textiles	Holiday
Dairy	Wood furniture	Foreign holiday
Miscellaneous livestock	Paper and publishing	Export tourism
	Chemicals	Other nonresidential
	Petroleum products	Auto rental
	Footwear	Railroad services
	Metal products	Passenger transportation
	Machinery	Trucking services
	Computers	Water transportation
	Electrical machinery	Air transportation
	Motor vehicles	Pipeline exchange
	Transportation equipment	Natural gas transportation

Number of workers in the base year of the USAGE Model, by labor-market function, birthplace, and immigration status

Labor-market function	Birthplace and immigration status			
	U.S.-born	Foreign-born, permanent resident	Foreign-born, not permanent resident	Totals
	Full-time person equivalents			
Automotive repair workers	656,208	84,776	61,816	802,799
Bricklayers and masons	118,325	11,450	46,645	176,420
Butchers and meat cutters	257,080	53,195	101,449	411,723
Carpenters	1,010,369	95,596	244,255	1,350,219
Carpet installers	118,131	19,145	46,101	183,377
Cashiers and other sales workers	2,961,866	337,299	199,790	3,498,956
Child care workers	1,059,279	139,274	81,542	1,280,096
Cleaners of vehicles and equipment	252,647	30,002	65,398	348,046
Concrete masons	133,574	18,889	55,111	207,574
Construction laborers	647,828	78,784	282,151	1,008,763
Construction supervisors	660,445	58,526	31,364	750,335
Construction trades helpers	284,251	19,945	124,732	428,928
Cooks	1,493,978	235,590	392,862	2,122,430
Dishwashers	336,989	34,856	135,516	507,361
Drywall installers	101,249	14,428	79,558	195,235
Food preparation supervisors	657,593	83,116	31,748	772,457
Food preparation workers	659,977	86,717	141,804	888,498
Food servers	1,848,847	133,289	167,686	2,149,822
Groundskeeping and maintenance workers	805,803	107,526	372,869	1,286,198
Housekeeping and cleaning workers	777,393	282,520	363,362	1,423,276
Industrial truck operators	513,228	56,877	65,393	635,497
Installation, maintenance, and repair helpers	121,596	9,117	32,678	163,392
Installation, maintenance, and repair workers	1,143,625	154,403	35,334	1,333,363
Janitors and building cleaners	1,788,887	302,330	298,745	2,389,963
Laundry workers	146,850	45,037	42,923	234,810
Miscellaneous agricultural workers	2,029,201	349,471	365,591	2,744,264
Miscellaneous food preparation workers	328,209	56,718	80,354	465,281
Miscellaneous production assistants	1,193,035	192,753	155,004	1,540,792
Nursing	1,720,380	344,375	74,223	2,138,978
Other construction workers	2,372,243	163,265	175,266	2,710,774
Other farm, food, or cleaning workers	1,597,065	212,850	141,166	1,951,081

Appendix table 2
Number of workers in the base year of the USAGE Model, by labor-market function, birthplace, and immigration status -- continued

Labor-market function	Birthplace and immigration status			
	U.S.-born	Foreign-born, permanent resident	Foreign-born, not permanent resident	Totals
	Full-time person equivalents			
Other low-paying production workers	286,472	46,660	41,048	374,180
Other production workers	5,144,004	734,707	362,349	6,241,060
Other service sector workers	73,565,492	8,565,302	418,478	82,549,272
Other transportation workers	2,192,129	279,151	96,181	2,567,462
Packing and filling machinery operators	235,467	63,450	113,098	412,016
Painters	289,825	44,861	137,035	471,721
Personal care workers	532,260	120,274	48,362	700,895
Plumbers	470,330	42,099	48,891	561,320
Production helpers	328,203	39,381	116,206	483,790
Retail sales workers	3,764,930	367,726	123,426	4,256,082
Roofers	96,808	11,843	52,696	161,347
Sewing machine operators	135,085	65,021	55,882	255,988
Shipping clerks	615,674	88,179	47,244	751,097
Stock clerks and order fillers	1,361,698	116,686	87,867	1,566,251
Transportation and packing workers	498,256	130,374	251,681	880,311
Transport drivers	2,797,472	284,676	160,171	3,242,319
Transportation laborers	2,079,621	139,841	212,559	2,432,021
Waiters	1,906,601	187,103	157,833	2,251,536
Welders	353,096	45,295	32,582	430,973
Employed outside United States	0	0	112,324,392	112,324,392
Short-term, unemployment in United States	7,352,260	908,135	365,920	8,626,314
Long-term, unemployment in United States	8,826,192	1,065,883	262,505	10,154,580
Total	140,628,026	17,158,766	120,008,842	277,795,634

Note: Sums may not total exactly due to rounding.
Source: Base data of USAGE Model, which were constructed using employment data by occupation and industry from U.S. Department of Labor, Bureau of Labor Statistics (2006) and birthplace and immigration status estimates from Van Hook et al. (2005). For more detailed information, see Dixon and Rimmer (2008).

farm sectors. The sectors in the ARMS data did not precisely match those in the USAGE Model, so we made some judgments to allocate the employment numbers. Minor adjustments to the employment data were required so that the data were consistent with the model's value-added numbers, which measured the contribution of each factor of production to the value of the final output, and so that the resulting base data included reasonable implied average wage rates and rates of return on capital.

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The USAGE Model's Labor-Market Module

The version of the USAGE Model used in this report contained a unique labor-market module that distinguished between authorized and unauthorized labor—that is, workers with and without the official U.S. immigration status of a permanent resident. An overview of how that module functions is presented here, and a more detailed technical explanation of the module, replete with lists of its component equations, is available in the appendix of Dixon and Rimmer (2010) and in section 3 of Dixon and Rimmer (2008).
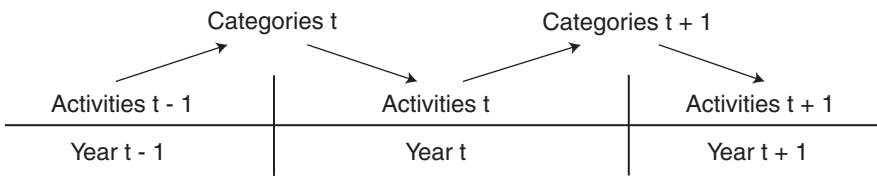
The main task of the labor-market module was to match categories of workers (rather than individual workers) to economic activities. Categories of workers (c) are defined by the worker's birthplace (United States or foreign), immigration status (permanent resident or not a permanent resident), and labor-market function in the *previous* year. The model identified six different labor-market functions in year t-1:

- Employment in the United States in one of 50 occupations;

- Shortrun unemployment in the United States; that is, unemployed for a substantial amount of year t-1 but not unemployed in year t-2;

- Longrun unemployment in the United States; that is, unemployed for a substantial amount of year t-1 and also of year t-2;

- Born in the United States and about to enter the workforce;

- Employment outside the United States; and

- Born outside the United States and about to enter the workforce.

In turn, economic activities (a) are defined by the worker's birthplace, immigration status, and labor-market function in the *current* year (appendix fig. 1). For any given category of worker (c), the number of workers that will perform a particular economic activity (a) in a given year is determined primarily by worker category c's supply of labor to activity a relative to the supply from other categories of labor, and by industries' demand for the labor services of particular occupations.

The extended workforce included all employed people and unemployed job-seekers in the United States, and foreign-born persons who were currently working outside the United States but could potentially work in the United States as an unauthorized worker. In addition, we assumed that 1 percent of

Appendix figure 1
Labor-market dynamics in the USAGE Model

Source: Dixon and Rimmer (2010).

people in every economic activity in year t-1 withdrew from the extended workforce at the beginning of year t, either through retirement or death.

Labor Supply From Workers to Activities

The model ensures that workers in a category defined by a particular birthplace and immigration status only make employment offers to economic activities with these same characteristics. For example, workers in the category of foreign-born, permanent resident construction laborers can only offer to supply labor to economic activities with the same characteristics (foreign-born and permanent resident). Most of these workers will offer labor to the economic activity of foreign-born, permanent resident construction laborer; that is, they will offer to continue their occupation from the previous year. Some workers, however, will offer to change their occupation in response to changes in relative wages, and a few will offer to be unemployed. In addition, a small percentage is "fired" each year, creating additional unemployment.

The labor supply of unauthorized workers was represented in a similar fashion. Most employed workers in the category of foreign-born, not permanent resident will offer to continue to work in the same U.S. occupation. Some unauthorized workers, however, will return to their home country and work there. In making these decisions, unauthorized workers compare wages outside the United States with U.S. wages for unauthorized workers.

Workers in category c (defined by birthplace, immigration status, and labor-market function) decide their offers to economic activity a (also defined by birthplace, immigration status, and labor-market function) for the year by solving a collective utility maximization problem where the objective is to maximize the sum of the activity's real, after-tax wage for all the workers in category c. Each category of workers treats earnings from different economic activities as imperfect substitutes; in other words, a dollar earned in a possible alternative economic activity is not valued as highly as a dollar earned in the current economic activity. The utility functions have a CES form, where the elasticity parameter reflects the willingness of workers to shift between economic activities in response to changes in after-tax earnings. The utility function for a particular category of workers c includes a vector of occupational preference variables that influence the utility derived by workers from earning money in activity a in year t. The changes in immigration flows modeled in our simulations were generated by manipulating these preferences, as noted in the main body of the report.

Labor Demand in the United States

The quantity of labor demanded by a specific industry in a given year is a function of the industry's capital stock; the overall real, pre-tax wage rate facing the industry; and other variables that influence the industry's demand for labor, such as technology and commodity prices. In this respect, the USAGE Model's representation of the labor market is similar to many other CGE models. The overall real wage rate is a weighted average of the real wage rates for the various types of labor employed by the industry.
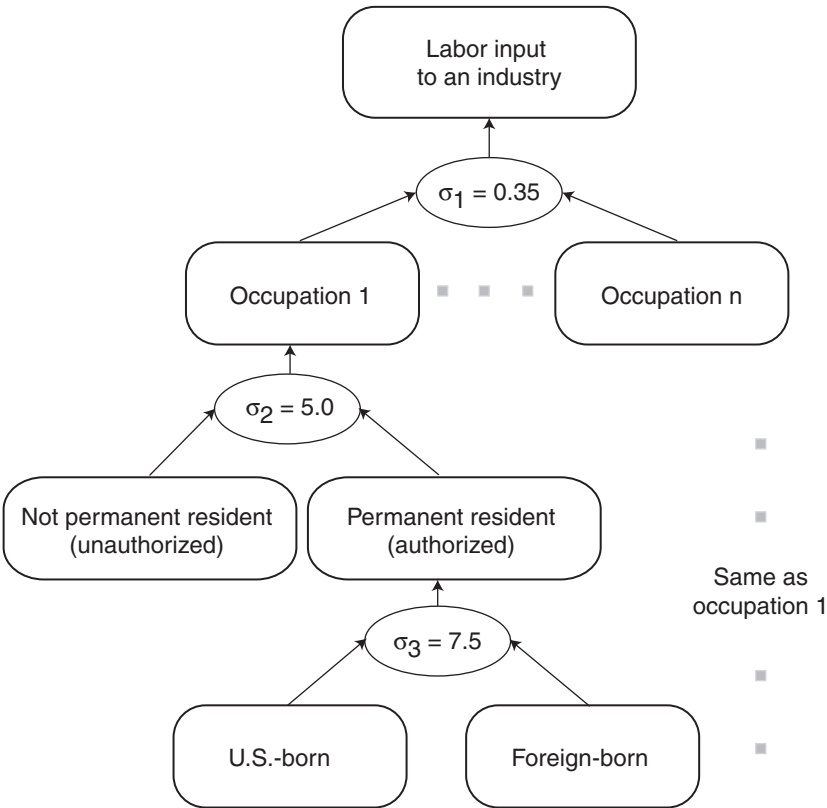
Within the industry's labor input, the demand for labor by birthplace, immigration status, and occupation is determined by a nested, CES,

cost-minimization problem (appendix fig. 2). The model assumes a high elasticity of substitution (7.5) between U.S.-born and foreign-born, permanent resident workers and a somewhat smaller elasticity of substitution (5.0) between authorized and unauthorized workers. The value for the elasticity of substitution between U.S.-born and foreign-born, permanent resident workers was suggested by the econometric estimates of Ottaviano and Peri (2006), while the elasticity of substitution between authorized and unauthorized workers in the same occupation was assumed to be somewhat lower since immigration status is an important attribute of the worker from the standpoint of most employers. Within the context of the model, a small reduction in the wage of unauthorized workers relative to that of authorized workers is sufficient to prompt employers to replace many of their authorized workers with unauthorized workers. The elasticity of substitution between occupations (0.35) was assumed to be low and was drawn from Higgs et al. (1981).

How Are Farmworkers Represented Within the Model?

Incorporating accurate information about the quantity of labor employed by U.S. agriculture was a challenging aspect of working with the USAGE Model. Base data from versions of the USAGE Model used in previous immigration studies (Dixon and Rimmer, 2008, 2009, 2010; Dixon et al.,

Appendix figure 2
Nested structure of the USAGE Model's calculation of each industry's labor input

σ = Elasticity of substitution.
Source: Dixon and Rimmer (2010).

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2008, 2011) indicated that 1.76 million persons, when measured in terms of full-time equivalents (FTEs—2,000 hours per year), worked in U.S. agriculture in 2005. Data from USDA's Agricultural Resource Management Survey (ARMS), by contrast, suggested that this figure was closer to 3 million FTEs.

The large difference between these two totals motivated us to modify the base data so that they more accurately represented the quantity of labor used in U.S. agricultural production. In the USAGE Model, the production functions in both the agricultural and nonagricultural sectors drew labor from each occupational category, but the main occupational category of interest with respect to agriculture was that of "miscellaneous agricultural worker." This category encompasses the labor of hired farmworkers as well as farm operators, spouses, and family members who work on the farm.

Modifying the USAGE Model's base data for agricultural labor took four major steps:

- ARMS data were used to calculate the average of the quantity of labor used annually in each agricultural sector during 2004-06. This total represents the sum of the labor time of primary operators, their spouses (if applicable), and any secondary operators, unpaid laborers, hired laborers, and contract laborers. For U.S. agriculture as a whole, this total accounted for about 3.1 million FTEs.

- The sectoral quantities of agricultural labor from ARMS were allocated to each agricultural sector in the USAGE Model. Since the agricultural sectors in the USAGE Model did not precisely conform to those in ARMS, we made some judgments as to how to perform this allocation. Overall, the quantities allocated closely corresponded with ARMS's aggregate employment data and approximated ARMS's sector-specific data, while maintaining the USAGE Model's value-added numbers and achieving reasonable implied average wage rates and rates of return on capital.

- The quantity of unauthorized labor employed in each sector corresponding to the ARMS data was estimated and then allocated to the agricultural sectors in the USAGE Model. Multiple data sources were used to produce these estimates. Using the ARMS data, the sum of the average annual quantities of hired labor and contract labor was calculated for each agricultural sector. We assumed that this sum represented the quantity of hired farm labor utilized by each agricultural sector. For agriculture as a whole, this sum accounts for roughly 816,000 FTEs. To estimate the quantity of hired farm labor supplied by unauthorized workers, we assumed that 52 percent of the hired farmworkers in crop agriculture and 27 percent of the hired farmworkers in livestock and dairy production were unauthorized. We made these assumptions based on data on unauthorized workers in crop agriculture from the U.S. Department of Labor's National Agricultural Workers Survey (NAWS) and data on noncitizen workers in livestock and dairy production from the Current Population Survey (CPS). Together, the quantity of hired farm labor in each sector multiplied by the estimated percentage of unauthorized workers gave us an estimated quantity of hired labor supplied by unauthorized workers in each agricultural sector. Agriculture as a whole accounted for about 359,000 FTEs of

unauthorized labor.[4] The sectoral estimates of unauthorized farm labor were then used as a guide to allocate these 359,000 FTEs across the agricultural sectors of the USAGE Model. Again, we made some assumptions about how to perform this allocation in order to maintain the model's value-added numbers and achieve reasonable rates of return to labor and capital. Earnings per FTE of unauthorized agricultural labor in the base year were set to be equal across all agricultural sectors.[5] We took this step because there was initially an implausibly large variation in earnings of unauthorized workers across sectors. The amount of average earnings per unauthorized FTE in agriculture (about $16,000) was applied to all agricultural sectors in the base year.

[4]This number is somewhat smaller than the figure of about 366,000 reported in appendix table 2 because the larger number includes workers in this occupation who are employed outside of agriculture.

[5]In the main body of the report, earnings per FTE are sometimes referred to as earnings per job.