IMMIGRATION AND LABOR MARKET IMBALANCES: IMPLICATIONS FOR POLICY REFORM

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OVERVIEW

The labor market in the United States today is extremely tight. The latest data suggest that there are approximately 4 million more job openings than the number of unemployed workers actively seeking employment — this figure had been as high as 6 million in 2022. While some of this shortfall is likely pandemic related, the number of job openings exceeded the number of unemployed workers actively seeking employment in the two years prior to the onset of COVID-19, for the first time since the beginning of the job openings data in 2000.

This report considers whether an expansion of the working-age population via reform in immigration policy is appropriate, by examining the literature on the net benefits of immigration and then focusing on four key worker groups: construction, food, care, and STEM (as a proxy for advanced manufacturing and green technology). The analysis determines whether labor shortages prevail in each of the worker groups and whether immigrants of various educational attainment levels might fill any observed supply/demand imbalances over the next decade.

An extensive literature exists on the net benefits of immigration; the net benefit to the native population is referred to as the "immigration surplus." At issue are considerations of overall economywide benefits versus benefits to native workers, whether net benefits accrue to business owners or workers, and fiscal implications. Perhaps unsurprisingly, the literature suggests that the strongest case for immigration is if policy focuses on immigrants that are highly educated and skilled. However, a case can also be made for admitting low-skill immigrants if this is done in a way that does not generate a net fiscal burden for the country. One possibility would be through legally enforceable temporary work visas.

The concept of a persistent labor market "gap" is inconsistent with the neoclassical notion of labor market responses and wage flexibility since markets respond to wage pressure. This is clearly happening in today's labor market, though not at a pace that is satisfactory to all participants. Shortages present in portions of the economy can conceptually be eliminated over time with relative wage adjustments and the acquisition of requisite skills. Still, it is apparent that gaps can prevail as these adjustments occur — regional preference or other frictions may impede adjustments. Of course, increases in labor costs have implications for business owners and consumers as the markets respond to wage pressures.

In order to understand labor market conditions in the four worker groups, the current literature and posted industry reports were examined. Then a quantitative analysis was undertaken using forecasts of employment in each of the four worker groups and projections of the working-age population, overall and for six categories of educational attainment. The results provide a glimpse at where labor gaps may exist, serving as a guide to understanding which worker groups might benefit the most from immigration reform.

LITERATURE REVIEW OF THE ECONOMIC AND FISCAL EFFECTS OF IMMIGRATION

The scholarly literature of theoretical and empirical studies of the economic impacts of immigration is vast. Not surprisingly, there have been many surveys of this literature. George Borjas, perhaps the most prolific and recognizable scholar in the area, has summarized much of this literature himself — for example, in his 2014 book *Immigration Economics*, a graduate-level text which covers many of his most important contributions, and in a more recent paper published in a 2021 collection of essays titled *Prospects for Economic Growth in the United States.* There are two massive surveys of the literature which reflect the views and contributions of dozens of immigration scholars—one published by the National Research Council in 1997 and one from the National Academies of Science, Engineering and Medicine edited by Blau and Mackie in 2017.

The purpose of this section is to summarize the primary findings of immigration research as reviewed in the above-mentioned surveys. This is intended to be a nontechnical paper. The intuition and logic behind the conclusions will be provided, but there will be no formal derivation of results. Also, no links or references to primary sources are included as these are available in the four surveys of the literature cited above.

The conclusions reviewed will be those that are useful for informing a debate on what kind of immigration policy would best serve the national economic interest of the United States. Not that they are unimportant topics, but there will be no discussion of how immigration policy in a receiving country would affect the economies of sending countries, or of what kind of immigration policy would best meet global humanitarian goals.

Summary

Economic theory clearly indicates that immigration will create both economic winners and losers. Native workers in competition with immigrants will suffer wage declines while others, including owners of business capital and possibly other groups of native workers, will enjoy increases in incomes. Impacts on wages and the return to capital will be larger in the short run than in the long run. Adjustments in the supply of capital, the spatial location of native workers and firms, and the occupational fields chosen by native workers will serve to attenuate the impacts of immigration. There will be permanent effects on the relative wage structure, however, if the distribution of skills among immigrants differs from the skill mix of native workers.

The task of using data to statistically identify the effect of immigration on the wages of native workers is a challenging one. In geographic cross-section studies, there is a problem of disentangling the effects of immigrant supply on wages from the effect of wages on immigrant supply. Over time wage impacts become muted by the location decisions and occupational choices of native workers. Given these complexities, it is not surprising that the empirical literature on how immigration has affected wages in the United States has produced a wide range of estimates.

Empirical studies generally have found immigration to have had a small impact on the average wages of broadly defined groups of native workers, particularly when impacts are assessed over a period of 10 years or more. There is stronger evidence of negative wage effects within

subgroups of the native population. Those who appear to have been most negatively affected are previous immigrants, blacks with no more than a high school education, and native-born Hispanics, especially those with poor English language skills.

Empirical evidence on the wage impacts of high-skill immigration is mixed. Some studies have found a negative effect on wages of native high-skill workers, while others have found that immigration has served to increase the wages of high-skill natives. The theoretical expectation of how native wages should be affected by high-skill immigration is unclear. Increases in labor supply lower wages. But native wages could increase if highly educated and knowledgeable immigrants, through their interactions with natives, directly increase the productivity of U.S. workers.

Immigration is said to serve the national interest of the receiving country if the collective real income gains in the native population exceed the collective real income losses. The net benefit to the native population is referred to as *the immigration surplus.* Studies that are purely data based are too limited and incomplete to provide estimates of the sign and size of the U.S. immigration surplus. Empirical studies focus on the wage losses suffered by native workers in competition with immigrants, with little or no information on the income gains enjoyed by other groups. Estimates of the net benefits of immigration are made using simulations from theoretical models that are calibrated to best fit actual data or results from data-based statistical analyses.

The following is a list of principal conclusions from model simulations.

- It is important to distinguish the immigration surplus from gross domestic product (GDP). Immigration may substantially increase the value of domestic production and yet provide a very modest net gain to the collective incomes of existing residents. Simulations using a simple model with homogeneous labor and a fixed capital stock are instructive. In the year 2017, immigrants represented 16.6 percent of the U.S. workforce. Based on the model, their presence in the economy served to increase GDP by 11.9 percent, or $2,322 billion. However, $2,266 billion of the increase in GDP was paid to immigrants for the services of their labor. The difference between the two numbers — the immigration surplus — was only $56 billion.
- If the skill mix of immigrants matches the skill mix of the existing workforce, there is no long-run benefit to the existing population from having immigration. The long-run immigration surplus in this case is zero. The long-run immigration surplus will be positive, however, if the share of the immigrant workforce that is high skill (low skill) differs from the high-skill (low-skill) share of the native workforce.
- Immigration policies that maximize the immigration surplus are those at the extremes, where immigrants are primarily either high skill or low skill. In the short run, because of capital-skill complementarities, optimal policy tends to favor high-skill immigration. In the long run, it is optimal to choose immigrants with skills that best complement (are most dissimilar to) natives. For countries that are abundant in high-skill workers, this means primarily selecting low-skill immigrants.
- Even if an optimal immigrant skill mix is selected, the net benefits of immigration are likely to be small, in both the short run and long run. For example, in his long-run simulations, Borjas (2014) finds that the largest net benefit from immigration in the amount of 15 percent of the U.S. workforce is realized if immigrants are all low skill, but

the gain is less than 1 percent of GDP. For nationals to receive more significant net gains from immigration, it is necessary that there be other sources of economic gain for the country, such as favorable knowledge or productivity spillovers from immigrants who work in the domestic economy, or positive fiscal effects as would arise if immigrants pay more in taxes than they receive in government services.

Knowledge spillovers refer to the informal sharing of ideas and the learning that takes place through face-to-face contact and interaction. Conclusive causal evidence of knowledge spillovers is difficult to obtain. But there is much anecdotal support for the idea in case studies of innovation clusters such as Silicon Valley. There is also statistical evidence that is strongly suggestive of knowledge transfers, such as the repeated finding in wage studies of wages earned by an individual depending not only on personal productivity characteristics such as years of schooling and work experience, but also on the average level of educational attainment of the population in the local area in which the worker resides. Urban theorists such as Jane Jacobs and Ed Glaeser have argued that the primary economic contribution of cities is the advance in innovation made possible from the transmission of ideas and knowledge that is facilitated when people live and work in close proximity to one another. As a practical point for policy, immigrants most likely to generate valuable knowledge spillovers are those with advanced degrees, particularly in STEM (science, technology, engineering, and mathematics) fields.

Conclusions regarding the size of the immigration surplus noted above did not factor in the possibility that immigrants, through the taxes they pay and the public services they receive, may generate a fiscal burden or a fiscal windfall for existing residents. Fiscal impacts represent an additional channel through which immigration can affect the national economic welfare.

The most important factor determining the sign and size of the fiscal impact is the level of education of the newly arrived immigrant. Fiscal impact estimates from a recent study suggest that if all of the country's immigrants in the year 2017 had been college graduates, the disposable aggregate income of the native population would have been $237 billion higher. This compares with an estimate of $25-to-$46 billion for the long-run immigration surplus that would be realized if immigrants were all high skill. These calculations suggest that fiscal considerations should play an important role in immigration policy decisions that are oriented to the national economic interest.

Given the large size of the U.S. economy, the country stands to gain little from immigration that simply replicates the skill mix of the native workforce. Because of the possibility of human capital spillovers and favorable fiscal impacts, the strongest case for immigration is if policy is heavily oriented to immigrants that are highly educated and skilled. A case can also be made for admitting low-skill immigrants if this is done in a way that does not generate a net fiscal burden for the country, such as might be achieved through term employment arrangements.

Wage and Distributional Effects of Immigration: Theory

The direction and size of the effect immigration has on wages in the host country depends on the extent to which immigrant workers substitute for or complement existing workers. Wage impacts will tend to be larger in the short run than in the long run. Adjustments in the supply of capital,

the spatial location of native workers and firms, and the occupational fields chosen by native workers will attenuate the wage impacts of immigration.

The Simple Case of Homogeneous Labor

The simplest theoretical analysis of the economic impact of immigration assumes that labor is homogeneous and that immigrant workers are perfect substitutes for native workers. The supply of native workers is assumed to be fixed. Labor is combined with capital to produce a single good under conditions of constant returns to scale. In the short run, the supply of capital is fixed. In the long run, international capital flows serve to adjust the domestic capital stock to maintain a fixed global return on capital. This model has been used extensively by George Borjas in his writings on the economic effects of immigration (for example, see Borjas (2014)).

In the short run, with a fixed capital stock, immigration must reduce the wages of native workers. Under the assumption of constant returns to scale, labor and capital are complements. The increase in national employment brought about by immigration raises the demand for capital, causing an increase in the return to capital. Immigration is an economic event with inexorable consequences for the distribution of national income. Native workers will suffer a loss in income, while owners of capital will benefit.

How much wages fall in response to an inflow of immigrant workers depends on the elasticity of substitution between labor and capital. In the special case where the elasticity of substitution is assumed to be one (the Cobb-Douglas case), the model is sufficiently tractable to provide detailed simulation results with a minimal amount of additional information. The elasticity of response in the market-clearing wage to changes in the supply of labor is minus capital's share of national income. For the United States, this is roughly -0.3. Given the size of the national economy, as measured by GDP, and the share of immigrants (the foreign-born population) in the domestic workforce, it is easy to use the model to calculate the short-run impact of immigration on GDP, the incomes of native workers, and the incomes of owners of capital. An illustrative set of calculations from Borjas (2021) is provided in Table 1. The data used are for 2017. In that year, U.S. GDP was $19.5 trillion and the immigrant share of the workforce was 16.6 percent.

The numbers in Table 1 refer to the simulated impact on the U.S. economy of immigration which expands the workforce by 16.6 percent. The analysis assumes a fixed capital stock. Immigration of this size would be expected to lower the wage incomes of native workers by $567 billion. This represents a loss equal to 2.9 percent of 2017 GDP, or 4.7 percent of what the model suggests native labor income would have been without immigration. These losses are more than offset by gains in the incomes of capital owners equal to $623 billion. The increase in capital income is 3.2 percent of 2017 GDP, or 12.1 percent greater than what, according to the model, capital income would have been without immigration.

According to the theoretical simulations, immigration serves the national economic interest of the receiving country in the sense that the gains to owners of capital exceed the losses suffered by native workers. The net gain, referred to by Borjas as "the immigration surplus," is only $56.4 billion, however, or 0.3 percent of GDP. Immigration in an amount that increases the workforce by 16.6 percent does result in considerably more domestic production. GDP is 11.9 percent greater. However, $2,266 billion of the $2,322 billion gain in GDP represents payments to

TABLE 1
THE SHORT-RUN IMPACT OF IMMIGRATION ON THE ECONOMY OF THE UNITED STATES IN 2017

	Billions of Dollars	Share of Gross Domestic Product
Loss to Native Workers	$566.9	2.9%
Gain to Native Firms	623.3	3.2
Immigration Surplus	56.4	0.3
Total Increase in Gross Domestic Product	2,322.3	11.9
Earnings of Immigrants	2,265.9	11.6

Source: Borjas (2021, Table 4.2, p. 90).

immigrants for the services of their labor. The difference between these two numbers — the immigration surplus — is only $56 billion.

The simulation results presented in Table 1 are derived from a highly simplified model of the economy and should not be regarded as highly accurate. There are some important lessons in the results, however, including expectations of likely orders of magnitude:

- Immigration the size of the foreign-born share of the U.S. workforce in 2017 can be expected, at least in the short run, to have had important effects on the distribution of income, generating sizeable income gains for some groups and sizeable losses for others.
- Theory suggests that immigration serves the national interest by generating more gains than losses. However, the net gains are likely to be small in comparison to the size of the distributional effects. For nationals to receive significant net gains from immigration, it is necessary that there be other sources of economic gain for the country, such as favorable knowledge or productivity spillovers from immigrants who work in the domestic economy, or positive fiscal effects as would arise if immigrants pay more in taxes than they receive in government services.
- It is important to distinguish GDP from gross national product (GNP). Immigration may substantially increase the value of domestic production and yet provide very modest gains in the collective incomes of pre-existing residents. The difference represents income received by immigrants. Immigration may yield large world welfare gains that accrue primarily to the immigrants themselves.

The analysis provided so far is conditioned on the assumption that the capital stock is fixed. Theoretically, what should happen if the world's capital stock adjusts to equalize returns to capital across countries? The results are clear. In the short run, immigration raises the return to domestic capital. This will serve to attract foreign capital inflows in an amount sufficient to bring the return to capital in the domestic economy back to its original level. The ratio of economywide labor to capital, which was initially increased by immigration, should fall over time until it drops back to its initial value. Wages of native workers will be boosted by the capital inflows and return to their original level. In the simple model with homogenous labor, immigration has no long-run effect on either the wages of existing workers or the return to capital. In the long run, the immigration surplus is zero.

Heterogeneous Labor

Workers are not identical, of course, but differ in important ways in terms of skill and overall value to employers, whether they be native workers or immigrant workers. When recognizing the heterogeneity of labor, the economic effects of immigration are seen to depend on the skill mix of immigrants. The few general theoretical conclusions that can be drawn are stated and derived in Borjas (2014, pp. 66-69). An appropriately defined "average" labor input must be complementary with capital. Thus, in the short run, immigration with a skill mix that resembles the skill mix of the existing workforce is likely to lower wages across all skill groups and increase the return to capital. On the other hand, if immigration is concentrated in a particular skill group, wages in that specific skill group will fall, but what happens to wages in other groups and the return to capital will depend in a complicated way on how substitutable or complementary these inputs are for or with the skill group whose supply has increased because of immigration.

The long-run effects of immigration also depend on the skill mix of immigrants. If immigration increases the supplies of all types of labor by the same percentage, then capital inflows will return all wages to their original levels, as in the case of homogeneous labor. However, if the skill mix of immigrants is very different from the skill mix of the existing workforce, there will be permanent long-run changes in the wage structure of the economy. If immigrants are exclusively low skill, for example, wages of existing low-skill workers will be lower in the long run as well as the short run.

More detailed theoretical results are possible if the model is simplified to involve only three inputs — low-skill labor, high-skill labor and capital — and if the assumption is made of "capital-skill complementarity." There is a long empirical literature, especially from studies of manufacturing production, that supports the notion that capital generally substitutes for low-skill labor but is complementary with high-skill labor. Machines and software that automate the workplace eliminate the need for workers who perform routine mental or physical tasks but increase the value of workers who are more creative and engaged in problem solving. A complete analysis of the three-input model with capital-skill complementarity is provided in Blau and Mackie (2017, pp. 133-141). Notable results follow.

If there is a relatively high degree of substitutability and a low degree of complementarity between low-skill labor and both high-skill labor and capital, then immigration which is heavily skewed toward low-skill workers will have small effects on the demands for high-skill labor and capital. In the short run, immigration of low-skill workers will raise high-skill wages and the return to capital, but not by much. In comparison, immigration that is focused on high-skill labor will have larger effects on the demand for capital and increase the return to capital by a larger amount. In the long run, therefore, there will be greater inflows of foreign capital in response to immigration if the immigrants are high skill than if they are low skill.

The assumption of capital-skill complementarity also implies that any given increase in the domestic capital stock increases the demand for high-skill labor by a greater amount than it increases the demand for low-skill labor. In the case where immigration is primarily high skill,

long-run adjustments in the capital stock may greatly attenuate the short-run negative effect of immigration on high-skill wages.

Table 2 shows the results of numerical simulations carried out by Borjas (2014) using a standard competitive labor market model with capital and five categories of labor, as defined by level of educational attainment. The results are conditional on specific assumptions made about degrees of substitutability and complementarity between the inputs. Nevertheless, the results are instructive. The column of the table labeled "supply shift" shows, by level of educational attainment, the percentage increases in U.S. labor supplies that occurred because of immigration over the period from 1990 to 2010.

The other columns of the table shows the theoretically calculated effects of that immigration on wages in each educational group, both in the short run and the long run. The table confirms the well-known fact that U.S. immigration has been bimodal with respect to skills, measured here by educational attainment. The largest percentage increases in labor supplies are for workers who did not complete high school and for workers with graduate degrees. In the short run, with a fixed capital stock, wages in all groups fall because of immigration. Not surprisingly, the largest declines are for workers without a high school degree and workers with a post graduate degree. Immigration increases the return to domestic capital (not shown), causing foreign capital to be reallocated to the U.S. economy. This serves to reverse partly or completely the initial wage declines. In the long run, the wages of high school dropouts fall 3.1 percent and the wages of workers with post-graduate degrees decline 0.9 percent. The wages of those with only a high school degree or less than four years of college rise slightly after allowing for complementarities and adjustments in the capital stock.

TABLE 2
SIMULATED WAGE IMPACT ON EXISTING WORKFORCE OF UNITED STATES IMMIGRATION INFLOWS FROM 1990 THROUGH 2010

		Wage Effects	
Educational Attainment	**Supply Shift**	**Short Run**	**Long Run**
Total of All Workers	10.6%	-3.2%	0.0%
Less Than High School Graduate	25.9	-6.2	-3.1
High School Graduate	8.4	-2.7	0.4
Some College	6.1	-2.3	0.9
Bachelor's Degree	10.9	-3.2	-0.1
Graduate Degree	15.0	-4.1	-0.9

Note: The existing workforce consists of both natives and immigrants residing in the United States in 1990. The short-run simulations assume that the capital stock is constant; the long-run simulations assume that the return to capital is constant.

Source: Borjas (2014, Table 5.2, p. 114).

Other Long-Run Adjustments

Changes in the size of the domestic capital stock represent only one of the important ways in which the economy will adjust over time to immigration. Other adjustments are also likely to occur, and these too will serve to mitigate the short-run impacts of immigration. One category of adjustments involves geography. If immigrants choose to locate disproportionately in certain cities, some native workers may move to other cities where there are greater employment opportunities and higher wages. Firms may also choose to relocate to cities where immigrants have increased labor supplies. Each of these forms of spatial adjustment will moderate the size of the economic impacts in immigrant cities and spread these effects out across the country, e.g., a broader group of cities will experience a fall in wages among native workers who are in direct or indirect competition with immigrants.

Another form of labor-market adjustment involves niche occupational choices made by native workers. If immigrants have relatively poor English fluency or poor communication skills, at least for an appreciable time after arriving, native workers may choose specialty fields which place a high value on communication. A native worker in computer science may choose an applications-based area which requires more contact and interaction with clients. A native engineer may choose to go into management. A quantitatively talented native student may choose to pass up engineering altogether and go into a quantitative business field like finance. Of course, these kinds of occupational adjustments do not fully allow native workers to avoid the negative wage effects associated with immigration, since their choices will cause them to congest, at least to some extent, their newly chosen fields.

Price Effects

Immigration will cause relative prices to fall for goods that are intensive in the use of skills which immigrants provide and to rise for goods that use intensively skills not provided by immigrants and which, therefore, have become more scarce. This is especially true for services that are traded mostly in local rather than global markets. These relative price changes will generate an economic gain or loss that is separate from those generated by wage and income changes. Native workers or business owners who spend an unusually large amount on services that have become cheaper will realize an additional boost in the purchasing power of their incomes. Those who spend a lot on services whose prices have risen will suffer a real income loss from these price changes. As a concrete example, high-income households spend a relatively large fraction of their budget on prepared meals, household cleaning services, and landscaping services. These are the kind of services which low-skill immigrants make cheaper. Thus, the real income gains from the price effects of low-skill immigration are likely to accrue more to native high-income than low-income households.

Increasing Returns to Scale, Knowledge Spillovers

The theory reviewed so far has assumed that there are constant returns to scale in production and that immigrants have no direct influence on the productivity of existing workers. If a larger labor force, and the larger capital stock which will eventually follow, allow the economy to operate more efficiently, or if immigrants contribute to the skills of native workers by sharing their ideas and knowledge, then immigration can have a much larger positive effect on the economic welfare of the native population.

One source of greater efficiency from a larger population involves the provision of public goods such as government administration, the court system and national defense. In larger economies, these costs can be spread over more taxpayers. Government spending on many public services falls as a share of GDP as population increases. Another source of efficiency from larger scale involves what economic geographers refer to as agglomeration economies. Immigration may lead to a larger concentration of people in urban areas. This can yield economic benefits by increasing the variety of goods and services available to consumers, by creating thicker labor markets, especially markets for specialized labor, and by supporting a greater division of labor and markets for specialized suppliers.

With a population over 330 million, the United States would not seem to be suffering from unexploited scale economies. It might be more likely that there would be diseconomies associated with a larger population. If immigration increases ethno-linguistic diversity in the country, this could lead to more intractable political disputes over government policy and, as studies suggest, suboptimal provision of public goods such as infrastructure and public education. If some natural resources (such as water) are underpriced, a larger population will exacerbate the welfare losses associated with this market failure.

Immigrants may directly increase the productivity of native workers through knowledge spillovers. This refers to the informal sharing of ideas and the learning that takes place through face-to-face contact and interaction between people. Urban theorists such as Jane Jacobs and Ed Glaeser argue that the primary economic contribution of cities is the advance in innovation made possible from the transmission of ideas and knowledge that is facilitated when people live and work in close proximity to one another. The lore of Silicon Valley as a center for advancement in information technology includes stories of social and chance encounters between engineers and technical workers who, by sharing ideas outside of the workplace, are able to solve problems more quickly and move the industry ahead. Immigrants most likely to provide valuable knowledge spillovers are those with advanced degrees, particularly in STEM fields.

Empirical Evidence on the Wage Impacts of Immigration[1]

U.S. immigrants, legal plus illegal, have concentrated most heavily in low-skill occupations. Because of this, most empirical studies have focused on determining whether immigration has had an identifiable negative effect on the wages of low-skill native workers. Since the introduction of the H-1B visa program, however, the character of U.S. immigration has changed in an important way to include some very highly educated and skilled workers, particularly in STEM occupations. There is now an emerging literature on how this new immigration has affected the occupational choices and wages of highly educated natives.

The task of using data to statistically identify the effect of immigration on the wages of native workers is a challenging one. There are subtle and sometimes unmeasurable differences between natives and immigrants, making it less clear which groups of native workers are in close competition with immigrants. Over time wage impacts become muted by the relocation decisions of workers and firms and by the occupational choices of native workers. In geographic cross-section studies, there is a problem of disentangling the effects of immigrant supply on wages

[1] This section draws heavily from Blau and Mackie (2017, Ch. 5) who provide a comprehensive recent review of the empirical literature on the wage impacts of U.S. immigration.

from the effect of wages on immigrant supply. Given all these complexities, it is not surprising that the empirical literature on how immigration has affected wages in the United States has produced a wide range of estimates.

A literature survey published by the National Research Council in 1997 concluded that U.S. immigration up to that point had had small adverse effects on the wages of competing native workers. With only a few exceptions, studies had found the relationship between immigration and native wages to be numerically small and statistically weak. This was true regardless of the skill or demographic makeup of native workers. The only category of native workers whose wages seemed to be significantly depressed by immigration was earlier waves of immigrants.

A survey published in 2017 by the National Academies of Science concluded that while more recent studies had also generally found a small overall impact of immigration on the native wage, particularly when impacts were assessed over a period of 10 years or more, there was stronger evidence of significant negative impacts within subgroups of the native population. In addition to previous immigrants, groups identified as having suffered a statistically and numerically significant wage loss because of immigration include native high school dropouts, black men and women with only a high school degree, and native-born Hispanics, especially those with poor English fluency.

Empirical evidence on the wage impacts of high-skill immigration is mixed. Some studies have found a negative effect on wages of native high-skill workers, while others have found that immigration has served to increase the wages of high-skill natives. The theoretical expectation of how native wages should be affected by high-skill immigration is unclear. Increases in labor supply lower wages, of course. But native wages could increase if highly educated and knowledgeable immigrants, through their interactions with natives, directly increase the productivity of U.S. workers. Because foreign-born high-skill workers are highly represented in science and engineering occupations, recent research also has focused on whether this new immigration has increased the rate of innovation in the United States.

Education and Occupation Groups With Large Immigrant Shares

When looking for groups whose wages are most likely to be negatively affected by immigration, it is useful to begin with data on the share of the foreign-born population in workforce categories defined by level of educational attainment and occupation. Table 2 as reviewed earlier shows how U.S. immigration, legal plus illegal, has increased the relative labor supplies of workers with less than a high school education and of workers with advanced degrees. Overall, immigration over the period from 1990 to 2010 increased the U.S. workforce by 10.6 percent. But immigrant flows had above-average effects on labor supplies at the two extremes of the education spectrum — increasing the workforce of those without a high school degree by 25.9 percent and of those with advanced degrees by 15.0 percent. These relative shifts in labor supply would be expected to lower the wages of native high school dropouts and, apart from possible knowledge spillovers, lower the wages of natives with more than a four-year college education.

Table 3 shows information from 2009 through 2011 on immigrant shares of the U.S. workforce by detailed occupation. The occupations listed are those with an immigrant share of at least 30 percent. Not surprisingly, the occupations with high immigrant shares are primarily low skill.

They include agricultural workers, housekeepers, grounds maintenance workers, construction laborers, and cooks. A few high-skill occupations also make the list: selected life and physical science occupations, and software developers. Table 3 is based on data from a study by Camarota and Ziegler (2013). The authors conclude in their study that "there aren't many jobs that immigrants have that natives won't do." In the occupation with the highest immigrant share, "graders and sorters of agricultural products," still 37 percent of members are natives.

TABLE 3
IMMIGRANT SHARE OF SELECTED OCCUPATIONS, 2009 THROUGH 2011

Occupation	Immigrant Share	Total Number of Workers*
Graders and Sorters, Agricultural Products	63.3%	80,182
Miscellaneous Personal Appearance Workers	59.4	271,199
Sewing Machine Operators	52.3	230,289
Miscellaneous Agricultural Workers, Including Animal Breeders	52.2	917,214
Tailors, Dressmakers, and Sewers	52.1	89,296
Maids and Housekeeping Cleaners	48.9	1,668,312
Drywall Installers, Ceiling Tile Installers, and Tapers	47.4	176,532
Medical Scientists and Life Scientists, All Other	45.9	131,664
Miscellaneous Media and Communications Workers	45.8	96,856
Packers and Packagers, Hand	41.9	523,066
Taxi Drivers and Chauffeurs	41.8	366,993
Roofers	40.3	255,096
Painters, Construction and Maintenance	39.6	641,927
Physical Scientists, All Other	39.5	190,787
Carpet, Floor, and Tile Installers and Finishers	39.3	196,802
Packaging and Filling Machine Operators and Tenders	38.7	300,163
Laundry and Dry-Cleaning Workers	37.8	225,038
Butchers and Other Meat, Poultry, and Fish Processing Workers	37.4	285,952
Grounds Maintenance Workers	36.4	1,491,666
Software Developers, Applications and Systems Software	36.2	910,611
Chefs and Head Cooks	35.9	368,335
Bakers	34.6	211,071
Construction Laborers	34.1	1,894,638
Electrical, Electronics, and Electromechanical Assemblers	34.0	174,549
Helpers, Construction Trades	33.8	82,181
Brickmasons, Blockmasons, and Stonemasons	33.6	188,896
Dishwashers	32.8	342,171
Cement Masons, Concrete Finishers, and Terrazzo Workers	32.0	83,240
Parking Lot Attendants	31.7	89,796
Miscellaneous Food Preparation and Serving Related Workers	30.8	393,689
Cooks	30.5	2,462,845

* Sum of employed and unemployed workers, immigrants plus natives.

Note: Of the 472 detailed civilian occupations for which immigrant shares were estimated, this table shows the 31 occupations with an immigrant share of at least 30 percent and a total number of employed and unemployed workers of at least 80,000.

Source: Camarota and Ziegler (2013).

Natives and Immigrants as Imperfect Substitutes Within Skill Groups

One of the difficulties involved in analyzing the economic impact of immigration is that employers do not always value equally immigrants and natives with similar measured characteristics. An empirical finding first published in 1978 and confirmed in studies as recent as 2015 is that the return in U.S. labor markets to work experience and education is lower for immigrants than it is for natives. A given level of education received in a foreign country is valued less by U.S. employers than is the same level of education completed in the United States. An implication of these results is that immigrants may compete most closely with natives in skill groups with somewhat less work experience and fewer years of schooling.

Another way in which immigrants may not substitute perfectly for natives involves English language fluency and communication skills, characteristics that often cannot be measured and controlled for in studies. Differences in language skills between immigrants and natives have been shown to influence occupational specialization. Native-born workers are more highly represented in occupations where communication is important. A study of occupational choice among immigrants and natives with graduate degrees found that immigrants tend to choose occupations that are highly quantitative while natives specialize in fields where communication skills are important.

Spatial Studies of Wage Impacts From Immigration

Spatial studies estimate immigrant-driven wage impacts by correlating changes in wages that occur in subnational labor markets (usually metropolitan areas) with changes in immigrant density in those areas. For the estimated coefficient to represent a causal relationship from immigration to wages, econometric methods must be used to identify immigrant inflows that are exogenous and not the result of wage changes themselves. Since immigrants are likely to settle in areas that have experienced a positive economic shock and high wage growth, a simple regression of wage changes on changes in immigrant levels will deliver a coefficient that has a positive bias — one that reflects the causal effect of wage changes on immigrant supply as well as the causal effect of immigrant supply on wages.

A standard econometric solution to this problem is to find another variable — an "instrumental variable" — that is correlated with the size of immigrant inflows into an area but is not correlated with factors other than labor supply that may cause wages to change. The instrumental variable then can be used to redefine an immigration variable that is stripped of the effect that wage changes have on immigrant inflows. The estimated coefficient for this redefined variable will more accurately reflect the causal effect that changes in immigrant levels have on wages. The most common strategy in spatial immigration studies is to use as an instrument data on historical settlement patterns. Immigrants tend to locate where there are already groups of co-nationals, to take advantage of pre-existing employment and social networks and to enjoy access to a wider variety of cultural goods. Past concentrations of home-country nationals will be correlated with future inflows to the area but are not likely to be correlated with future shocks that affect wages and employment.

A more potentially intractable problem with spatial studies is that over time, interregional flows of labor and capital may diffuse the wage impacts of immigration across the entire nation. Native workers living in areas most directly affected by immigrant arrivals may leave the area. Their

entry into other local labor markets will spread out the negative wage effects of immigration. This reduces the cross-sectional variation which spatial analysis is designed to exploit. Several empirical studies suggest that this theoretical process of local labor market arbitrage is highly imperfect. Nevertheless, because of these long-run adjustments, the spatial approach may tend to underestimate the national effect that immigration has on wages.

Spatial studies use either educational attainment or occupation to define wage changes for a particular skill group. Because of data limitations, however, changes in immigrant penetration often are based on measures of total immigration into an area. The strongest expectation of a negative effect of immigration on wages in a particular skill group is when immigration increases labor supply only in that skill group. If immigrant inflows involve many skill categories at the same time, there will be complementary effects as well as substitution effects, and the direction of effect on wages in a particular skill group is unclear. The estimated wage effect on that group will be an average of immigrant impacts across many skill categories.

Spatial studies that focus on wages of native low-skill workers have generated a wide range of results, from impacts that are moderately negative to impacts that are close to zero. A 1991 study by Altonji and Card is notable for its pioneering application of the econometric technique of instrumental variables to control for the confounding effects that wage changes have on local area immigrant supply. The study used education to define skill categories and measured wage changes over a period of 10 years. Altonji and Card found that immigration had significantly lowered the average wages of native high school dropouts, with a 1 percentage point increase in the immigrant share of the population reducing wages of native dropouts by 1.2 percent. More recent studies, however, have found smaller wage effects, with many concluding that U.S. immigration has had no discernable effect on average low-skill wages. Negative wage effects have been found on a more consistent basis for subgroups of native low-skill workers. Those who appear to have been most negatively affected are previous immigrants, blacks with no more than a high school education, and native-born Hispanics, especially those with poor English language skills.

Wage Impact Studies That Use the Skill Cell Approach

Another type of empirical study of how immigration affects native wages relies not on geographical variations in wage changes and immigrant levels but on national level variations in these variables across skill categories, or "skill cells." Skill cells usually are defined by level of education and years of work experience. The correlation coefficient obtained in this analysis measures the average direct effect that changes in immigration levels in a given skill category have on wages earned by workers in that skill category. Unlike spatial studies, there are no cross effects in these estimates. There are no potential complementarities involving workers with different skills, only substitution effects. Because of this empirical design, there is a clearer theoretical expectation of a negative wage impact associated with increases in immigration. Skill cell studies are more likely to find negative wage effects, and they do.

George Borjas pioneered the use of the skill cell approach in immigration impact research. In his 2003 study, skill cells were formed using four educational groups – those who did not complete high school, high school graduates, some college, and at least a four-year college degree. In addition to education, skill levels were based on eight experience levels: 1-to-5 years, 6-to-10

years, etc. up to 36-to-40 years. An observation consists of decadal natural log changes in weekly wages and in the percentage of immigrants in the workforce of men in a given skill category. The simple correlation in a scatterplot of data from 1980-to-2000 indicates that wages of male workers fall by 3-to-4 percent when immigration increases the workforce by 10 percent.

In a more recent paper, Llull (2015) noted that the characteristics of immigrants arriving in the United States were not random but were influenced by changes in national labor market conditions and wages. He developed an instrumental variable to control for this endogeneity problem using results from a cross-country analysis of determinants of immigration. The immigration variable used in his skill cell analysis is the number of immigrants of a given skill type that would be predicted from international conditions. When this instrumental variable was used, the estimated negative wage impact from immigration tripled in size. Llull's study provides the most negative estimate of wage effects of any published study.

Impacts From High-Skill Immigration

The skill mix of U.S. immigration has changed in an important way in recent decades with an increase in the number of very highly educated and skilled immigrants, an increase made possible in large part because of the H-1B visa program. There are now a disproportionate number of foreign-born workers in occupations such as computer software developers, computer systems analysts, electrical engineers, medical scientists, physicians, and university faculty. Some studies have concentrated on the usual question of whether this new immigration has reduced the wages of or crowded out employment of natives in these occupations. But because of the importance of science and engineering in modern innovation, there is the added question of whether high-skill immigration has increased the rate of economic growth in the country.

Among studies of the wage impact of U.S. high-skill immigration, two papers by Peri et al. (2015) are notable in finding a significant positive impact on wages of native high-skill workers. In a broad study of STEM occupations, the authors found that an increase in the number of foreign-born STEM workers that increased a city's total employment by 1 percent served to increase the real wages of college-educated natives by 7-to-8 percent and increase the real wages of natives with less than a college education by 3-to-4 percent. In another paper, the authors focused on computer-related occupations and found that H-1B entrants into these occupations complemented rather than displaced natives. The complementarities found in these two studies are consistent with the idea that, through their interaction with natives, high-skill immigrants directly increase the productivity of natives, especially high-skill natives.

Not all studies have found beneficial impacts on natives from high-skill immigration. In looking at the earnings of doctorate holders by field of discipline, Borjas (2009) found that a 1 percent change in labor supply through immigration was associated with a -0.2 percent to -0.3 percent change in the earnings of native doctorate holders. In a more focused study, Borjas and Doran (2012) found that the arrival of 336 Soviet mathematicians following the breakup of the Soviet Union caused many American mathematicians to move into lower-quality institutions and out of active publishing.

Charles Jones has estimated that one-half of the growth in U.S. total factor productivity in recent decades is associated with the employment of scientists and engineers. Given the prevalence of

science and engineering backgrounds among highly educated immigrants, it is reasonable to wonder whether the new high-skill immigration has had an impact on the rate of innovation in the United States. What is clear is that, based on measures such as patents per capita, high-skill immigrants are more innovative than their native peers. This is not because they are inherently more innovative but because they are more heavily represented in science and engineering occupations.

The question is whether the presence of high-skill immigrants in the country has raised the overall rate of innovation or simply caused a displacement of natives from innovative activity. Borjas and Doran (2012) found that the arrival of Russian mathematicians after the Cold War reduced the research of American mathematicians to such an extent that U.S. mathematical research stayed constant. On the other hand, in a broader study, Hunt and Gauthier-Loiselle (2010) found in analyzing panel data across states from 1950 to 2000 that inflows of high-skill immigrants — those either working in science and engineering fields or having at least a bachelor's degree — significantly increased overall patenting per capita. A 1 percentage point increase in the population's share of high-skill immigrants increased patents per capita by 9-to-18 percent depending on the econometric technique used in the analysis.

What matters, of course, is not patenting activity but productivity. To explore the link between immigration and overall productivity, Peri (2012, 2015) used measures of state-level total factor productivity (TFP) to estimate the effect of immigrant science and engineering workers on TFP. He found that this kind of immigration increases TFP.

Is Immigration in the National Economic Interest? The Immigration Surplus

Like other economic shocks or events, immigration creates winners and losers. Native workers in close competition with immigrants suffer wage declines while others, including owners of business capital and possibly other groups of native workers, enjoy increases in incomes. Immigration is said to serve the national economic interest if the collective gain in the incomes of the winners exceeds the collective income loss suffered by losing groups. The net change in the aggregate real income of natives has been referred to by George Borjas as the "immigration surplus."

Purely data-based empirical studies are too limited and incomplete to provide estimates of the sign and size of the U.S. immigration surplus. Empirical studies focus on the wage losses suffered by native workers in competition with immigrants, with little or no information on the income gains enjoyed by other groups. As expressed by Borjas (2014, p.153) "estimates of the economic benefits from immigration are not estimates in the sense that the researcher used actual data and computed the various gains and losses, but rather they are the result of a calibration exercise of some economic model." To the extent possible, the various parameters in these models are based upon actual data or data-based statistical analyses. But the models themselves build in a very specific and highly structured logic of how immigration affects wages and incomes of native groups.

Review of Findings From the Model With Homogeneous Labor

An earlier subsection provided a summary of results from a theoretical analysis of the impact of immigration on native incomes in the case where all workers were identical. The analysis has

broader relevance in that the conclusions also will apply to economies with heterogeneous labor if the skill mix of immigrants is similar to the skill mix of native workers. Here are some conclusions from this model that are important for the question of how immigration affects the national economic welfare:

- In the short run, with a fixed capital stock, immigration reduces the wages of existing workers and increases the incomes of owners of capital. There are both losers and winners, but the results are not a wash. There is a net national economic gain in the sense that the gains in capital income will exceed the losses suffered by native workers. This conclusion is completely robust in that its validity does not depend on the particular values for the model's parameters. Immigration serves the national interest in the short run.
- The size of the immigration surplus varies directly with the size of the drop in wages. The larger is the loss to existing workers, the larger is the immigration surplus.
- Estimates made with the simple model suggest that while the distributional effects of immigration may be large, the immigration surplus is likely to be small. Calculations made by Borjas (2021) indicate that immigration which increases the U.S. workforce by 16.6 percent generates an immigration surplus of only 0.3 percent of GDP.
- In the long run, when foreign capital inflows bring both wages and the return to capital back to their original values, the immigration surplus goes to zero. There is no net benefit to the native population from immigration, only a larger economy. The conclusion of a zero immigration surplus in the long run is special to this model. Other models, even ones with constant returns to scale but a recognition of heterogeneity in labor, suggest that the long-run immigration surplus is likely to be positive. A conclusion from the simple model that does generalize is that long-run adjustments to immigration such as international movements of capital tend to reduce the size of the immigration surplus.

The Immigration Surplus in a Model With Heterogeneous Labor

Theoretical models become increasingly difficult to solve and interpret as they are expanded to embrace more real-world detail. A manageable model which provides insights into a potentially richer set of impacts from immigration assumes that there are two types of labor — low-skill labor and high-skill labor. These two types of labor are combined with capital to produce a single good under conditions of constant returns to scale. This model has been used by Borjas (2014) to estimate the effects of immigration on U.S. national economic welfare. Table 4 summarizes his findings.

In his simulations, Borjas defines high-skill labor as workers with more than a high school education. Low-skill workers are those with a high school education or less. Within education groups, immigrants are assumed to be perfect substitutes for native workers. The model is calibrated using data from the 2000 Census. The share of the native workforce that is high skill is 61.4 percent. The high-skill share of immigrant workers is 48.9 percent. Thus, in relation to native workers, immigrants are relatively low skill. But the immigrant workforce is diverse in skill levels, with large numbers of both high-skill and low-skill workers. The overall share of immigrants in the workforce is 15 percent. GDP is assumed to be $15 trillion.

TABLE 4
SIMULATED IMMIGRATION SURPLUS IN A MODEL WITH TWO SKILL GROUPS

Share of Immigrants Who Are High Skill	Short-Run Impact		Long-Term Impact	
	Billions of Dollars	Share of GDP (%)	Billions of Dollars	Share of GDP (%)
48.9%	35.6 – 74.7	0.24 – 0.50	2.6 – 4.8	0.02 – 0.03
0%	67.6 – 135.2	0.45 – 0.90	62.4 – 115.8	0.42 – 0.77
100%	112.1 – 201.8	0.75 – 1.35	24.7 – 45.8	0.16 – 0.31

Note: Each cell of the table shows a range of results that corresponds to a range of estimates of factor price elasticities found in the empirical labor literature. High-skill labor is defined as workers with more than a high school education. Based on data from the 2000 Census, the high-skill share of the native workforce is 61.4 percent. The simulations assume that immigrants represent 15 percent of the workforce and that gross domestic product is $15 trillion.

Source: Borjas (2014, Table 7.1, p. 158).

Parameters that play an important role in the simulations are own factor-price elasticities for high-skill and low-skill labor (i.e., the percentage change in a given wage brought about by a 1 percent change in factor supply). In his simulations, Borjas considers a range of possible factor-price elasticities as suggested by the empirical labor literature. The elasticities he uses have the feature that the demand for skilled labor is more wage inelastic than is the demand for unskilled labor. The assumption of a relatively inelastic demand for skilled labor implies that skilled labor is more complementary with capital than is unskilled labor. This reflects the widely supported hypothesis of capital-skill complementarity.

The first line of Table 4 provides estimates of the immigration surplus based on the actual skill mix of the U.S. immigrant workforce. The skill mix of immigrants is not appreciably different from the skill mix of native workers. Estimates of the immigration surplus are then similar to the estimate in Table 1 for the simple case of homogeneous labor. The short-run surplus is very small, ranging from $36 billion to $75 billion in an economy with a $15 trillion GDP. In the long run, the immigration surplus is essentially zero. The lesson here for immigration policy is that unless there are efficiency advantages to having a larger economy, the existing resident population stands to gain little to nothing economically from immigration that simply replicates the skill mix of the native workforce.

The second and third lines of Table 4 show what happens to the immigration surplus when immigrant workers are either all low skill or all high skill. The short-run estimates of the surplus increase by a factor of two to three, now ranging in size from $68 billion to $202 billion. These are not large numbers when considering both the size of the economy and the size of the underlying immigrant workforce (equal to 15 percent of the total U.S. workforce). Nevertheless, the gains in national economic welfare are significantly greater when the skill mix of immigrants is specialized rather than diversified.

In Borjas' simulations, the short-run immigration surplus is larger if immigrants are exclusively high skill than if they are all low skill. Because of assumed capital-skill complementarities, the rise in the return to capital and the value of the capital income component of the immigration

surplus will be larger if immigrants are high skill than if they are low skill. It can also be shown that a given percentage increase in the number of high-skill workers raises the wages of low-skill workers by more than the same percentage increase in the number of low-skill workers raises the wages of high-skill workers (Blau and Mackie, p. 184).

As expected, estimates of the long-run immigration surplus are uniformly smaller than the short-run estimates. Adjustments in the capital stock serve to diminish the size of both the wage impacts and the net benefits of immigration. Table 4 reveals an interesting conflict in optimal immigration policy depending on whether the objective is to maximize short-run national economic welfare or long-run economic welfare. Whereas the short-run immigration surplus is maximized by admitting only high-skill immigrants, the long-run surplus is larger if immigrants are exclusively low skill. Long-run adjustments in the supply of capital eliminate the importance of capital-skill complementarities. What then dominates the choice between skilled or unskilled immigrants is the fact that the native workforce is assumed to contain more skilled than unskilled workers. Unskilled immigrants are more complementary with (dissimilar to) a skilled native workforce (Borjas 2014, p. 157).

The following summarize the principal insights from the model with heterogeneous labor:

- If the skill mix of immigrants matches the skill mix of the existing workforce, there is no net benefit to the existing population from having immigration. The long-run immigration surplus in this case is zero.
- The long-run immigration surplus is positive, however, if the share of the immigrant workforce that is high skill (low skill) differs from the high-skill (low-skill) share of the native workforce.
- Immigration policies that maximize the immigration surplus are those at the extremes, where all immigrants are either high skill or low skill. In the short run, because of capital-skill complementarities, optimal policy tends to favor high-skill immigration. In the long run, it is optimal to choose immigrants with skills that best complement (are most dissimilar to) natives. For countries that are abundant in high-skill workers, this means primarily selecting low-skill immigrants. The opposite is true for countries that have an abundance of low-skill workers.
- As in other analyses, long-run impacts on wages and the immigration surplus are smaller than short-run impacts.
- Even if an optimal immigrant skill mix is selected, the net benefits of immigration are likely to be small, in both the short run and long run.

Other Factors Influencing the Effect Immigration Has on National Economic Welfare

The theoretical models that have been used to simulate the effects of immigration on the economic welfare of the native population assume that there are constant returns to scale and that immigrants have no direct impact on the productivity of native workers. In addition, the analysis has been phrased in terms of incomes gross of taxes and transfers. There has been no recognition of the possibility that immigrants, through the taxes they pay and the public services they receive, may generate either a fiscal burden or a fiscal windfall for existing residents. These assumptions go a long way toward locking in the result that the net benefits of immigration, while positive, will be relatively small. A relaxation of these assumptions, on the other hand, opens up the possibility of a much larger immigration surplus.

Immigration increases the scale of production in the domestic economy, both directly from the increase in labor supply and over time as more of the world's capital stock is allocated to the host country. There are well-known circumstances under which increases in scale may bring about greater economic efficiencies in a country — so-called cases of "increasing returns to scale." For example, there are efficiencies to be realized when the fixed costs of certain public goods such as government administration, the court system, and national defense are spread out over more taxpayers. Immigration also may help countries realize agglomeration economies — efficiencies related to the development of thick markets in urban areas. There are many historical examples of increasing returns to scale from immigration, from the settlement of unpopulated regions to the consolidation of small countries into nation states. The United States, however, with a population now over 330 million, would not seem to be in need of greater scale to help realize these kinds of efficiencies.

Immigrants may directly increase the productivity of native workers through knowledge spillovers. This refers to the informal sharing of ideas and the learning that takes place through face-to-face contact and interaction. Conclusive causal evidence of knowledge spillovers is difficult to obtain. But there is much anecdotal support for the idea in case studies of innovation clusters such as Silicon Valley. There is also statistical evidence that is strongly suggestive of knowledge transfers—for example, the repeated finding in wage studies that the wages earned by an individual depend not only on personal productivity characteristics such as years of schooling and work experience, but also on the average level of educational attainment of the population in the local area in which the worker resides. As a practical point for policy, immigrants most likely to generate valuable knowledge spillovers are those with advanced degrees, particularly in STEM fields.

Another factor with potential significance for the size of the immigration surplus involves the fiscal effects of immigration — the financial impact on existing residents if immigrants contribute less or more in taxes than they receive in public services. This is the topic of the next subsection.

The Fiscal Impact of Immigration

The analysis of the immigration surplus in the prior subsection did not factor in the possibility that immigrants, through the taxes they pay and the public services they receive, may generate a fiscal burden or a fiscal windfall for existing residents. Fiscal impacts represent an additional channel through which immigration can affect the national economic welfare. A detailed and carefully prepared set of estimates of fiscal impacts has been developed recently by a panel of immigration scholars who contributed to a 2017 report from the National Academies of Science. Their work builds upon methodologies developed 20 years earlier in connection with a similar report published in 1997 by the National Research Council.

The task of estimating the fiscal consequences of immigration is a challenging one, involving difficult conceptual issues and a great deal of economic data. Here are some of the key assumptions made by the National Academies of Science (NAS) research group:

- In their forward-looking calculations, the NAS decided that the important fiscal question to answer was what the total net contribution or burden of a newly arrived immigrant

would be including the net fiscal impact of the immigrant's descendants. In data that provide a fiscal snapshot at a moment of time, immigrant households often come out as a net burden because they have young children in public schools. A more complete picture of an immigrant's fiscal impact would include not only the costs of educating his or her descendants, but the taxes generated when the descendants begin working. To this end, the NAS research group decided to measure the net fiscal impact of an immigrant and descendants over a 75-year horizon using standard methods of present value discounting.

- Most services provided by the government are driven by population. Simple average cost pricing is a reasonable way of measuring the costs of providing these public services to immigrants. There may be some public services, however, that resemble pure public goods, where consumption is nonrival and there are very low marginal costs of extending services to a larger population. Far and away the most important example of a pure public good is the national defense. The NAS group prepared two sets of fiscal impact estimates, one in which a subset of federal expenditures was assumed to be for pure public goods, with services extended to immigrants at no additional cost, and another set of impacts in which average cost pricing methods were used for all government expenditure categories.
- Extremely important to the forward-looking estimates of the NAS is the future budget of the federal government. When the budget is in deficit, the average resident of the country imposes a net fiscal burden. The NAS research team considered two alternative future budget scenarios — one based on the annual long-term budget outlook of the Congressional Budget Office (CBO) and another which the team referred to as the "business-as-usual" (BAU) fiscal outlook. In the BAU forecast, taxes per capita and expenditures per capita in categories other than demographically sensitive ones were assumed to grow at a real annual rate of 1 percent, the assumed rate of long-run productivity growth. In the BAU forecast, no legislated fiscal changes, such as an increase in the Social Security retirement age or a sunsetting of tax cuts, were included. Future federal budget balances were more negative and future public debt levels were higher in the BAU scenario than in the CBO forecast scenario.

Key results from the NAS fiscal study are shown in Table 5. The estimated fiscal impact of an immigrant depends upon age at arrival and level of education. The numbers shown in the table are based upon averages across all immigrants in the population circa 2012. The estimates are of fiscal impacts consolidated across all levels of government. The various estimates are significant in size and range from highly negative to strongly positive, depending on the characteristics of the immigrant and the assumptions made. The net present value over the 75-year period of taxes paid minus cost of public services provided is some $60,000 to $80,000 higher if the assumption is made that expenditures for the national defense need not increase to accommodate additional immigrants. The net present value is greater by $100,000 or more if the more fiscally prudent forecast of the CBO is used rather than the BAU forecast.

The most important factor determining the sign and size of the fiscal impact is the level of education of the newly arrived immigrant. For example, in cases where the average immigrant generates the largest fiscal burden (BAU budget forecast and average cost pricing for all public goods), the net present values range from -$301,000 for immigrants who arrive without a full high school education to +$236,000 for immigrants with a graduate degree. The size of the

TABLE 5
LONG-RUN FISCAL IMPACT OF IMMIGRATION
(In 2012 Dollars)

Educational Attainment	CBO Long-Term Budget Outlook*	Business-as-Usual Budget Forecast
Zero Marginal Cost of Providing Pure Public Goods to Immigrants		
Total of All Workers	$58,000	$-36,000
Less Than High School Graduate	-196,000	-219,000
High School Graduate	-47,000	-112,000
Some College	99,000	-10,000
Bachelor's Degree	280,000	123,000
Graduate Degree	547,000	318,000
Average Cost Pricing of Pure Public Goods		
Total of All Workers	-5,000	-119,000
Less Than High School Graduate	-259,000	-301,000
High School Graduate	-109,000	-193,000
Some College	34,000	-96,000
Bachelor's Degree	216,000	39,000
Graduate Degree	485,000	236,000

* CBO: Congressional Budget Office

Note: Estimates of 75-year net present value flows for consolidated federal, state, and local governments by level of education, for two future budget scenarios and varying treatment of public goods.

Source: Blau and Mackie (2017, Table 8-12, pp. 430-433).

estimated impacts clearly reveal a very important potential role for fiscal considerations in immigration policy decisions that are oriented to the national economic interest.

Using the same quadrant of numbers, suppose that instead of the actual educational makeup of immigrants, the country had selected only immigrants with a bachelor's degree. The net present value of the fiscal impact of an average immigrant would shift from -$119,000 to +$39,000, for a net increase of $158,000. With an annual rate of discount equal to 3 percent, the annuity equivalent of this present value would be $5,320. Following Borjas (2021, p. 108), there were 44.5 million immigrants in 2017. If all of these immigrants had been college graduates, the disposable aggregate income of the native population would have been $237 billion higher. This compares with an estimate of $25-to-$46 billion higher cited previously in Table 4 for the long-run immigrant surplus that would be realized if immigrants were all high skill.

The NAS report also provides a breakout of fiscal impact estimates by level of government — federal and state/local combined. The results show that almost all the positive fiscal impacts accrue at the federal level. Descendants' impacts at the state and local level are mostly negative because these governments must pay the costs of education for young immigrants who are still dependents and for the native-born children of new immigrants. Working immigrants pay state and local taxes, but these revenues are not large enough to offset the cost of educating their children.

In addition, the NAS report indicates that there is not as wide a range in the present value of tax revenues by education group at the state and local level as there is at the federal level. State and local governments rely less heavily on income taxes. Sales and property taxes are less correlated with education than are income taxes. This suggests that higher levels of education among immigrants, while a revenue windfall for the federal government, would not be as helpful to the budgets of state and local governments.

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SUMMARY OF LABOR MARKET WORKER GROUP GAP FINDINGS

The analysis of labor market imbalances in each of four worker groups — construction, food production and processing, care, and STEM — is based on both a review of current industry reports and a subsequent empirical comparison of industrial and occupational employment projections (demand) by skill level in each of the four worker groups of interest, coupled with a projection of the working-age population (supply) by educational attainment. A summary of each of the worker groups follows.

Construction

A high percentage of the workers are immigrants and noncitizens. Many are undocumented. Educational attainment is very low. Currently, there is a shortage relative to trend and reported by industry sources. The latter expect the shortage to worsen through 2028 due to the 2021 infrastructure legislation. However, Lightcast projects a steady decline in the growth rate from above the economywide average to well below. As a result of the drop off in federal funding after 2028, the gap likely will narrow. Only a small shortfall of 1 percent is projected in 2033, with gaps only among the less educated.

Food Production and Processing

A high percentage of the workers are immigrants and noncitizens. Many are undocumented. Educational attainment is very low. Currently, industry sources report a shortage in the agricultural portion of this worker group, but not in the manufacturing portion. However, for the entire group, the comparisons to 2019 and to trend are mixed, not strongly supportive of a shortage. Lightcast projects a steady growth rate at somewhat below the economywide average. A small shortage is projected in 2033, with gaps only among the less educated.

Care

The percentage of the workers who are immigrants and noncitizens is not much different from the economywide average, though by occupation the percentage of immigrants is above average. Educational attainment is somewhat below average. The literature review did not provide consistent evidence of a shortage. Currently, there is a shortage relative both to 2019 and to trend. Lightcast projects the growth rate to continue to be above the economywide average. A large shortage is projected in 2033, the largest among the four worker groups. Gaps are projected primarily in the moderate attainment categories of high school graduate, some college, and associate degree.

STEM

The percentage of the workers who are immigrants is above the economywide average. Educational attainment is far above average. The literature review did not provide consistent evidence of a shortage. Currently, there is a shortage relative to trend based on the occupational definition but not the industrial definition. Lightcast projects the growth rate to slow but to continue to be above the economywide average. A moderately large shortage is projected in 2033. with gaps only among those with at least a bachelor’s degree.

LITERATURE REVIEW OF THE SUPPLY AND DEMAND FOR WORKERS IN FOUR WORKER GROUPS

A review of the reports and literature on sectoral and occupational employment gaps reveals a wide array of discussion points. First, there appears to be no uniform approach to measuring employment gaps. There are sectoral and occupational employment forecasts from both government and industry sources to proxy demand. Predictions for decades into the future of the size of the working-age population provide supply estimates. A comparison of predicted trends in these measures would seem to offer a glimpse at future labor market conditions.

However, wide and persistent aggregate disparities between the measures of demand and supply seem inconsistent and unrealistic. Conceptually it is unlikely that demand would persistently outstrip supply since the demand for goods and services is ultimately driven by the supply of consumers, which, in turn, is of course highly correlated with the size of the working-age population. According to February 2023 data from the U.S. Bureau of Labor Statistics (BLS), there were 9.9 million job openings but only 5.9 million unemployed workers, suggesting that even in the aggregate labor market, shortfalls can prevail at least in the short run.

While it is unlikely that an aggregate persistent imbalance would prevail over an extended period, sectoral shortages could conceptually exist until labor force participation rates, skill imbalances, and/or relative wages adjust to eliminate them. Moreover, institutional, legal, and/or regional location constraints might impede progress toward these labor market adjustments, making short-to-medium-term shortages a very real prospect in some sectors of the labor market. Numerous published and Internet-posted reports suggest that sectoral shortages of workers exist, especially in this post-pandemic era.

In reviewing the literature, it is important to consider the organization releasing the reports. Some actors in sectoral labor markets have incentives to inflate perceptions of labor market shortages. Since businesses benefit from access to quality labor at affordable wage rates, fostering a belief that more employment applications are needed is clearly in the interest of the business community. Educators and certification providers, both public and private, are in the business of training prospective workers, so projections of worker shortages are conducive to maintaining persistent student interest. Media and policy think tanks are eager to convey these messages that are perceived to be in the public interest.

Definition of Worker Groups

The focus of this analysis is to examine labor market growth trajectories in certain portions of the labor market and investigate whether revisions in immigration law might be needed to meet the demand for workers. The Migration Policy Institute was interested in examining five segments of the labor force: advanced manufacturing, green technology, care work, food production and processing, and construction. The last three of these can be easily defined both industrially — using the North American Industry Classification System (NAICS) — and occupationally, using the Standard Occupational Classification (SOC):[2]

[2] The NAICS and SOC are organized hierarchically. In the NAICS, sectors have a two-digit code, subsectors a three-digit code, industry groups a four-digit code, and industries a five- or six-digit code. In the SOC, a major group code ends in 0000, a minor group code ends in 000, a broad occupation code ends in 0, and a detailed occupation ends in a nonzero.

- Construction. By occupation, construction consists of all occupations in the minor groups 47-1000 construction supervisors, 47-2000 construction trades workers, 47-3000 helpers to the construction trades, and 47-4000 other construction workers. By industry, the entire construction sector (23) is included.
- Food Production and Processing: By occupation, food production and processing consists of all occupations in the minor groups 45-1000 farming supervisors, 45-2000 agricultural workers, and 51-3000 food processing workers. By industry, food production and processing consists of all industries in the subsectors 111 crop production, 112 animal production and aquaculture, 114 fishing, hunting and trapping, 115 support activities, 311 food manufacturing, and in industry group 3121 beverage manufacturing.
- Care: By occupation, care consists of all occupations in major group 31-0000 healthcare support, and occupation 39-9011 childcare workers. By industry, food production and processing consists of all industries in subsector 623 nursing and residential care facilities, and in industry groups 6241 individual and family services, and 6244 child care services. The care worker group does not include the professional and technical portions of healthcare.

The other two desired segments of the labor force are problematic since they are not defined in either the SOC or NAICS:

- Advanced manufacturing is defined as the use of innovative technology to improve products and processes, and to create new products. However, essentially every manufacturing industry has some degree of innovation. Some manufacturing industries obviously are more "advanced," but there is no standard definition of these industries.
- Green technology is defined as any technology intended to reduce the impact of humans on the environment. Like advanced manufacturing, green technology is in use across many industries; while some industries are more obvious choices, no standard definition exists.

Simply focusing on advanced manufacturing and green technology businesses also ignores the fact that many large conventional businesses across the spectrum (even some traditional fossil fuel companies or traditional automobile manufacturers) have product and service divisions devoted to innovation and green technology.

A review of workforce needs of companies labeling themselves as advanced manufacturing or green technology reveals needs for workers with such skills as analytical, science, engineering, and critical thinking. These businesses compete for the traditionally limited supply of science, technology, engineering, and mathematics (STEM) workers of all types as well as individuals trained in basic business management and operations skills. Instead of attempting to define advanced manufacturing and green technology by occupation and industry, the fourth worker group is defined as STEM. Appendices A and B provide the lists of occupations and industries included in the STEM worker group.

Actual and Projected Employment

In addition to a literature review, this section presents employment estimates and projections for each of the four worker groups, defined both by occupation and by industry, with comparisons to the overall U.S. economy. The source of the data is Lightcast, which provides estimates from 2001 through 2022 and projections from 2023 through 2033. A description of Lightcast's

estimates and projections is provided in Appendix C. The forecasts are of net employment growth; labor needs will be greater due to workers retiring or otherwise leaving the workforce.

Using Lightcast's data, several simple analyses were conducted for the entire national workforce and for each of the four worker groups, both industrially and occupationally:

- A comparison of employment in 2022 to the pre-pandemic level in 2019.
- A comparison of employment in 2022 to what the level would have been had the growth rate from 2020 through 2022 been equal to that from 2017 through 2019. This is referred to as the "trend" analysis.
- The annual average growth rate in employment between 2011 and 2022, which are comparable years of two economic cycles.
- The projected annual average growth rate between 2022 and 2033.

The results are presented in Table 6.

Construction

The total number of workers in construction in 2022 was nearly 9.6 million based on the industrial definition and 7.3 million based on the occupational definition.[3] A review of the current literature on the construction worker group suggests that, based on an October 17, 2022 report from McKinsey & Company (https://www.mckinsey.com/industries/public-and-social-sector/our-insights/will-a-labor-crunch-derail-plans-to-upgrade-us-infrastructure), there were approximately 440,000 job openings (as of mid-2022) in the construction sector and that the recently passed infrastructure legislation (the Bipartisan Infrastructure Law signed in November 2021) will generate demand for "some 300,000 additional workers across the construction value chain peaking in 2027-28." The assessment by McKinsey is echoed by numerous other reports that describe shortages being driven by "great resignation" pressures induced by the pandemic, ability to find higher paying jobs elsewhere, an aging construction workforce, and a decline in the number of new immigrants.

The latter factor is important to an industry in which more than 25 percent of the workforce is foreign born. A report by the Center for American Progress (https://www.americanprogress.org/wp-content/uploads/2021/02/EW-Construction-factsheet.pdf) notes the reliance on foreign-born workers in construction. It estimates, based on an analysis of American Community Survey (ACS) microdata merged with zip code information, that nearly 1-in-4 of the foreign-born construction workers are undocumented. The Center for American Progress estimates suggest that some 450,000 foreign-born construction workers may be illegally participating in the labor market, which creates adverse pressures and inefficiencies of its own. This equates to approximately 6 percent of the construction workforce, as measured occupationally, consisting of undocumented workers.

[3] The occupational and industrial totals should not be expected to be the same. In the case of the construction and food production and processing worker groups, the industrial total is considerably greater than the occupational total, reflecting that these industries also employ workers in other occupations, such as business and finance. In contrast, in the care and STEM worker groups, employment is greater using the occupational definition than the industrial definition. These groups are well defined occupationally, but are not as well defined industrially.

TABLE 6
U.S. EMPLOYMENT ESTIMATES AND PROJECTIONS BY WORKER GROUP
(Number in Thousands)

	Total Economy	Construc-tion	Food	Care	STEM
Occupation					
2022	166,731	7,290	1,938	8,724	9,531
2022 Versus 2019*					
Number Difference	-388	-101	-23	-132	287
Percent Difference	-0.2	-1.4	-1.2	-1.5	3.1
2022 Versus Trend**					
Number Difference	-7,077	-652	2	-795	-415
Percent Difference	-4.2	-8.9	0.0	-9.1	-4.4
Annual Average Growth Rate					
2011 to 2022	1.1	1.4	0.8	1.8	2.1
2022 to 2033	1.0	0.8	0.8	1.7	1.4
Numeric Change, 2022 to 2033	18,357	633	176	1,777	1,626
Industry					
2022	166,731	9,574	3,926	7,102	8,592
2022 Versus 2019*					
Number Difference	-388	193	67	-312	698
Percent Difference	-0.2	2.1	1.7	-4.2	8.8
2022 Versus Trend**					
Number Difference	-7,077	-709	-47	-729	-22
Percent Difference	-4.2	-7.4	-1.2	-10.3	-0.3
Annual Average Growth Rate					
2011 to 2022	1.1	2.4	1.0	1.8	2.6
2022 to 2033	1.0	0.8	0.8	1.7	1.5
Numeric Change, 2022 to 2033	18,357	827	370	1,475	1,546

* The percentage is calculated relative to 2019 employment.
** The trend is calculated as the growth rate from 2017 through 2019. The percentage is calculated relative to 2022 employment.

Source: Calculated from Lightcast data (www.economicmodeling.com).

Relative to the pre-pandemic employment level of 2019, construction employment in 2022 was approximately 200,000 greater defined by industry, but the occupational level was 100,000 short. Relative to the trended figure for 2022, actual employment in 2022 was significantly lower, both occupationally and industrially (see Table 6). This supports the findings of McKinsey and numerous industry reports that there is a shortage of construction workers, amid documented evidence of housing shortages and significant infrastructure investments set to pressure the labor market in the next several years.

Construction's annual average employment growth rate between 2011 and 2022 was higher than that of the total economy, especially using the industrial definition. However, construction's growth rate is predicted to slow between 2022 and 2033, to a somewhat lesser rate than the overall economy.

Food Production and Processing

The total number of workers in food production (agriculture) and processing (manufacturing) in 2022 was 3.9 million based on the industrial definition and 1.9 million based on the occupational definition. There are no reports documenting any discernable shortage of workers in food manufacturing. However, industry-sponsored reports from the Farm Bureau (https://www.fb.org/focus-on-agriculture/labor-shortages-continue-to-impact-farmers) and Agamerica (https://agamerica.com/wp-content/uploads/2019/12/farm_labor_shortage_digest.pdf) suggest a significant labor shortage in agriculture. Reasons for the shortage may include preferences, especially among younger Americans, to live in urban rather than rural settings; the opportunity to earn higher wages in other occupations/industries; reduced access to migrant workers; and complaints about existing H-2A visa rules and regulations (the H-2A program is for temporary agricultural workers).

A recent report from the U.S. Department of Agriculture (https://www.ers.usda.gov/topics/farm-economy/farm-labor/#legalstatus) based on surveys of farm workers estimates that some 40 percent do not have legal work status. While difficult to verify, there are plenty of reports and anecdotal evidence that corroborates numbers of this magnitude. Since an unknown number of foreign-born workers use fraudulent workforce identify information, it is possible that the share of undocumented workers in agriculture — especially where H-2A visas are not accepted — is even higher.

As seen in Table 6, food production and processing's employment in 2022 was not much different than in 2019 or what it would have been in 2022 based on the trend rate, suggesting that little, if any, labor shortage currently exists. Employment in food production and processing rose at a rate a little less than that of the overall economy between 2011 and 2022; growth rates between 2022 and 2033 are not expected to be much different.

Care

As defined for this report, the care worker group had employment in 2022 of 7.1 million based on industrial data and 8.7 million based on occupational data. This definition may not be consistent with literature reports, some of which separately identify healthcare, childcare, and eldercare. Those reports on healthcare may include health professionals and technicians, while only healthcare support workers are included in the definition used for this report. The challenge in analyzing potential shortages in the care workforce stems from the complex nature of the labor market demands spanning healthcare, childcare, and eldercare. Moreover, the current situation is no doubt clouded by the impact of the pandemic.

Numerous industry reports, including an assessment presented at the World Economic Forum (https://www.weforum.org/agenda/2023/01/medical-recruitment-crisis-davos23/), suggest current and impending shortages in care workers, most notably in healthcare. Indeed, the Davos analysis predicts a 10 million global healthcare worker shortfall by the end of the decade, though most of the deficiency is expected to occur in low- and middle-income countries.

Industry reports note the need for over a million new healthcare workers in the United States by the end of the decade, with many requiring advanced technical skills — presumably, these more-skilled workers are outside the definition of care used in this report. The need for less-skilled

workers prevails in eldercare and childcare. Foreign-born workers fill positions in the care workforce across all skill levels.

The Center for American Progress (https://cdn.americanprogress.org/content/uploads/2021/01/01114813/EW-CareEconomy-factsheet.pdf) reports that, based on estimates from ACS surveys, that some 5 million workers in the U.S. labor market are undocumented, with nearly 150,000 undocumented workers in the care industry filling jobs in childcare and eldercare.

Two factors particularly affect the current employment level in childcare. First, the tight overall job market provides opportunities to find higher-wage jobs in other industries/occupations. Second, a considerable number of families have decided to take on childcare responsibilities themselves, enabled by more workers working from home. In eldercare, the pandemic resulted in a reduction in the number employed. It is difficult to know how many of the positions will be refilled in the short term as the pandemic left such a deep imprint, with the fatality rate among elderly cohorts extremely high. It is likely that the aging of the baby-boom generation over the next two decades will increase demand for eldercare workers.

As demand for eldercare workers grows, immigrant workers could conceptually fill many of the positions. According to an AARP report (https://www.aarp.org/caregiving/basics/info-2022/in-home-caregiver-shortage.html), more than one-quarter of direct care workers and over 30 percent of nursing home workers are immigrants. An in-depth study by the Brookings Institution (https://www.brookings.edu/blog/up-front/2022/11/04/the-role-of-immigrants-in-the-market-for-elder-care/) finds reduced demands for long-term institutional eldercare in regions where there is greater access to immigrant homecare workers. This suggests immigrants may be filling homecare roles in important ways.

Based on the definition of the care worker group used for this report, the number employed in 2022 was less than in 2019 and considerably lower than the trended number for 2022 (see Table 6), suggesting that a worker shortage is present. The employment growth rate between 2011 and 2022 in the care worker group was higher than the overall rate and is expected to continue to be higher between 2022 and 2033.

STEM

Based on the definition used for this report, STEM employment in 2022 was 8.6 million industrially and 9.5 million occupationally. Most STEM jobs require moderate-to-high skill levels. Since no standard definition of the STEM worker group exists, there are inconsistencies in reports analyzing the STEM workforce. For example, the National Science Foundation (https://ncses.nsf.gov/pubs/nsb20212) uses a very broad definition of STEM, suggesting that it accounts for nearly 1-in-4 workers. Due to its broad definition, the National Science Foundation states that a significant number of STEM workers have technical skills but not a bachelor's degree.

In contrast, a 2021 study by the Seidman Institute (https://ccpr.wpcarey.asu.edu/sites/default/files/stemstates02-21.pdf) using the same occupational definition as used in this report indicates that STEM accounted for only 5.5 percent

of the workforce in 2019, though because of STEM's high wages, its share of aggregate earnings was 10.2 percent. Using a somewhat different definition, the BLS (https://www.bls.gov/emp/tables/stem-employment.htm) reported that STEM accounted for 6.2 percent of U.S. employment in 2019 based on occupational data.

STEM workers earn above-average wages and generally report lower-than-average unemployment rates. The STEM workforce consists of disproportionately few minority workers and disproportionately high numbers of foreign-born workers, especially among STEM workers with doctoral degrees. A report from the American Immigration Council (https://www.americanimmigrationcouncil.org/research/foreign-born-stem-workers-united-states) notes that foreign-born workers have increased significantly as a share of STEM workers in the past several years.

Over the past several decades, numerous reports have documented the need to upgrade the U.S. STEM workforce to keep pace or compete with growth in the technical capabilities of world economies. The skill demands of STEM are widely documented, as is the potential for reaping significant wages.

A contrarian voice among these reports comes from Ron Hira, a political science associate professor at Howard University (https://www.linkedin.com/pulse/stem-workforce-shortages-myth-ron-hira). Hira questions the "myth" of the alleged shortage of STEM workers and has voiced concerns about the "exploitation" of foreign technology workers. Hira argues that BLS forecasts of employment demand have an historically poor record. He also argues that neither reported statistics on unemployment nor wages in various STEM occupations provide substantive evidence of a shortage of workers. Hira points to the large steady supply of new talent being produced by U.S. universities and a deep pool of available foreign-born talent qualified to fill many positions.

Based on the definition used for this report, STEM employment in 2022 was substantially higher than 2019, but industrial employment was slightly lower and occupational employment was approximately 400,000 lower relative to the trended figure for 2022, providing a mixed picture on whether a labor shortage currently exists.

STEM's share was predicted by the BLS to rise to nearly 6.6 percent in 2031, with an increase of 1.064 million workers over the 12 years, from a 2019 base of 9.880 million. Using the STEM definition used in this report and forecasts from Lightcast, STEM employment increased at a rate substantially greater than that of the overall economy between 2011 and 2022; between 2022 and 2033 STEM's growth rate is predicted to slow but still be above average (see Table 6).

QUANTITATIVE ANALYSIS OF LABOR GAPS IN FOUR WORKER GROUPS

This section presents quantitative and descriptive analyses of the U.S. labor market, focused on the economic contributions of immigrants and the predicted worker shortfall in each of the four worker groups. Results are based on the five-year publicly available microdata from the American Community Survey for 2017 through 2021. In addition, the analysis in this section uses Lightcast's projections of employment growth and the U.S. Census Bureau's population forecasts.

Broad Patterns in the U.S. Labor Market

This subsection reports U.S. data calculated from 2017-through-2021 ACS microdata. Unless otherwise noted, the universe consists of labor force participants (both employed and unemployed) between the ages of 16 and 67.

Participation in the Labor Force

Table 7 presents basic descriptive statistics of participation in the U.S. labor force, shares of the population, and educational attainment by race/ethnicity. Overall, the U.S. labor force was predominantly white (57.4 percent), followed by Hispanic (20.0 percent) and black (12.2 percent). Participation in the labor force did not vary to a great extent by race/ethnicity. Hispanics participated at a high rate (76.6 percent), while white individuals did so at the lowest rate (68.3 percent). Female participation was uniformly lower than male participation, with a minimum of 63.8 percent for white females and a maximum of 74.5 percent for females of other races (i.e., not white, black, Asian, or Hispanic).

Table 8 provides labor force statistics by immigration status. Immigrants, one-half of whom are naturalized U.S. citizens, constituted 13.2 percent of the U.S. labor force. The labor force participation rate of immigrants was 2.7 percentage points lower than natives, due to a substantially lower participation rate among female immigrants. The latter could constitute a

TABLE 7
DESCRIPTIVE STATISTICS OF THE U.S. LABOR FORCE BY RACE/ETHNICITY

	White	Black	Asian	Latino	Other
Share of Total Labor Force	57.4%	12.2%	5.7%	20.0%	4.7%
Share of Labor Force Who Are Immigrants	3.6	10.6	61.2	29.8	7.7
Share of Labor Force Who Are Not Citizens	1.4	4.1	24.8	18.5	3.5
Share of Labor Force by Educational Attainment:					
Less Than High School Graduate or Equivalent	28.1	36.3	30.6	50.8	48.8
High School Diploma or Equivalent	17.8	20.6	9.9	18.7	13.6
Some College, No Degree	16.3	18.8	9.8	13.7	14.2
Associate Degree	7.4	6.4	4.9	4.7	5.2
Bachelor's Degree	19.2	11.3	24.3	8.3	11.7
Graduate Degree	11.2	6.7	20.5	3.7	6.5
Labor Force Participation Rate	68.3	70.8	72.0	76.6	76.8
Female Labor Force Participation Rate	63.8	70.4	66.3	71.1	74.5

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

TABLE 8
DESCRIPTIVE STATISTICS OF THE U.S. LABOR FORCE BY IMMIGRATION STATUS

	Native	Immigrant
Share of Total Labor Force	86.8%	13.2%
Share of Labor Force Who Are Not Citizens	0.0	50.1
Share of Labor Force by Educational Attainment:		
Less Than High School Graduate or Equivalent	35.9	27.0
High School Diploma or Equivalent	17.2	20.8
Some College, No Degree	16.0	13.1
Associate Degree	6.5	6.1
Bachelor's Degree	15.7	18.1
Graduate Degree	8.7	14.8
Labor Force Participation Rate	71.1	68.4
Female Labor Force Participation Rate	67.8	58.9

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

valuable area of opportunity in terms of the economic contribution of immigrants to the U.S. economy, though doubtless some female immigrants who are not in the labor force are undocumented.

Educational Attainment[4]

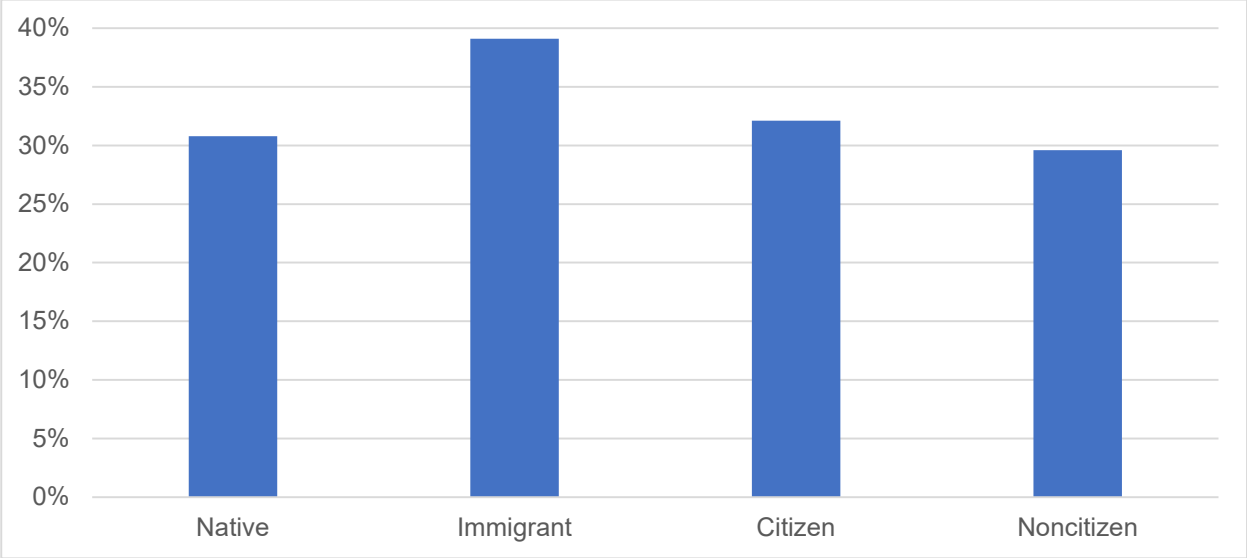
Notable differences exist across racial/ethnic groups in terms of educational attainment: 50.8 percent of Hispanics who were in the labor force did not complete high school, whereas only 28.1 percent of white individuals did not. College completion also varied considerably: from a low of 8.3 percent for Hispanics and 11.3 percent for blacks, up to 24.3 percent for Asians. Worthy of note is that slightly more than 1-in-5 Asians completed graduate studies compared to only 3.7 percent of Hispanics and 6.7 percent of blacks.

Immigrant workers completed on average more years of education than natives: the fraction of immigrants not graduating from high school was somewhat lower, but the shares with bachelor's degrees and graduate degrees were higher, as seen in Table 2.[5] As seen in Chart 1, the percentage with a college degree (sum of associate, bachelor's, and graduate degrees) was 39.1 percent among immigrants and 30.8 percent among natives. The share with college degrees was higher among citizens (32.1 percent) than noncitizens (29.6 percent). Because the overall educational attainment of immigrants is a weighted average of citizens and noncitizens, this breakdown illustrates the high level of skill that immigrant citizens bring to the economy.

[4] The U.S. Census Bureau typically reports educational attainment of the population 25 or older. In this section, educational attainment is reported for labor force participants between the ages of 16 and 67. The inclusion of teenagers in particular increases the share who are not high school graduates and lowers the shares of the higher attainment categories.

[5] Again, the inclusion of teenagers affects these proportions.

CHART 1
PROPORTION OF THE U.S. LABOR FORCE WITH AT LEAST AN ASSOCIATE DEGREE BY IMMIGRANT STATUS AND CITIZENSHIP STATUS



Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

Immigrant Share

Of those in the workforce between the ages of 16 and 67, a high 61.2 percent of Asians were immigrants. The share was 29.8 percent for Hispanics, as seen in Table 1. Only 3.6 percent of whites identified as immigrants. The share of foreign-born U.S. residents who are naturalized citizens varies by race/ethnicity, but the share who were not citizens was highest for Asians (24.8 percent), followed by Hispanics (18.5 percent).

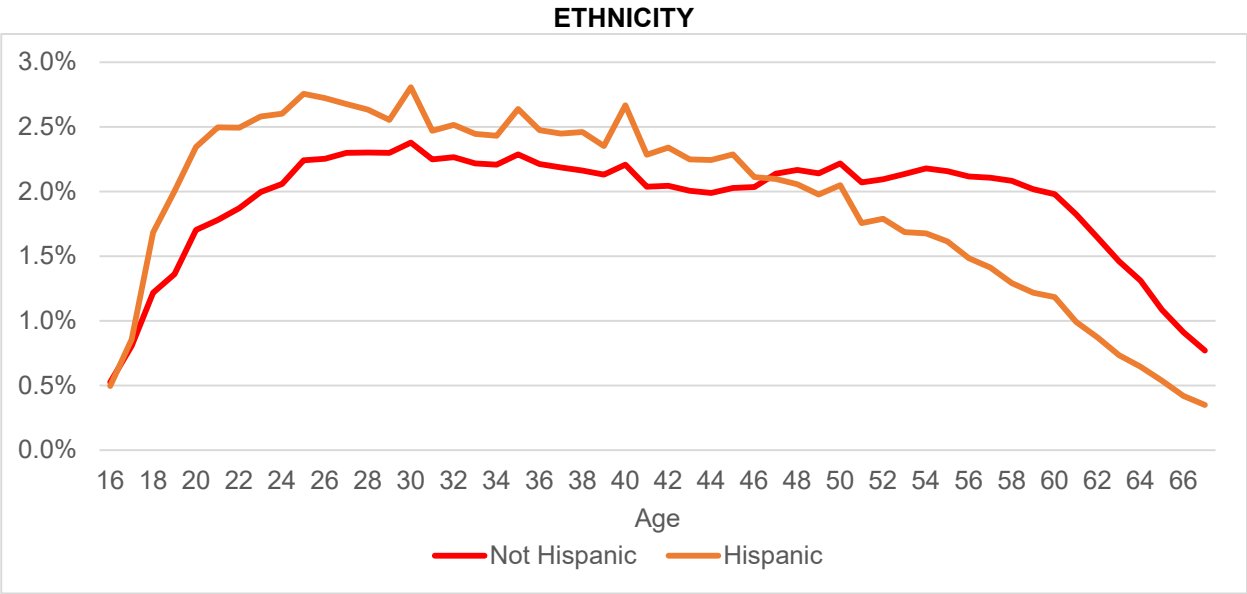
While the foreign-born share was much higher for Asians than for other racial/ethnic groups, the number of foreign-born Asians was less than the number of foreign-born Hispanics. Among those 18 or older (not just those in the labor force), there were 18.6 million foreign-born Hispanics, 11.5 million foreign-born Asians, and 7.5 million foreign-born non-Hispanic whites.

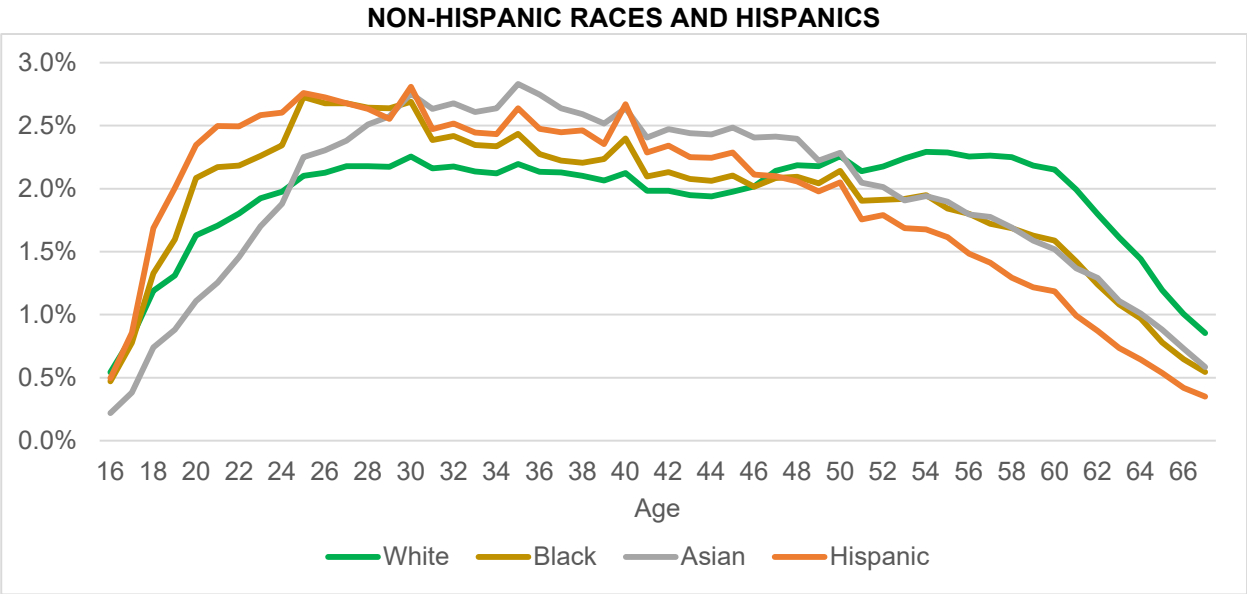
Age Distribution

Chart 2 shows the age distribution of individuals between 16 and 67 years of age who were in the labor force from 2017 through 2021, by ethnic and racial identity. The top graph of Chart 2 compares Hispanics against non-Hispanics irrespective of race. Hispanic labor force participants were younger than non-Hispanic participants, with a higher share at each age from 17 through 46. The bottom graph plots the distribution of age of non-Hispanic whites, blacks, and Asians, as well as Hispanics. The latter group was the youngest overall, followed by blacks.

The age distribution by immigrant status and citizenship status of *all people* between the ages of 16 and 67 is displayed in Chart 3. A higher proportion of immigrants than natives were between

CHART 2
AGE DISTRIBUTION OF THE U.S. LABOR FORCE BY RACE AND ETHNICITY
(Share of Racial/Ethnic Total)

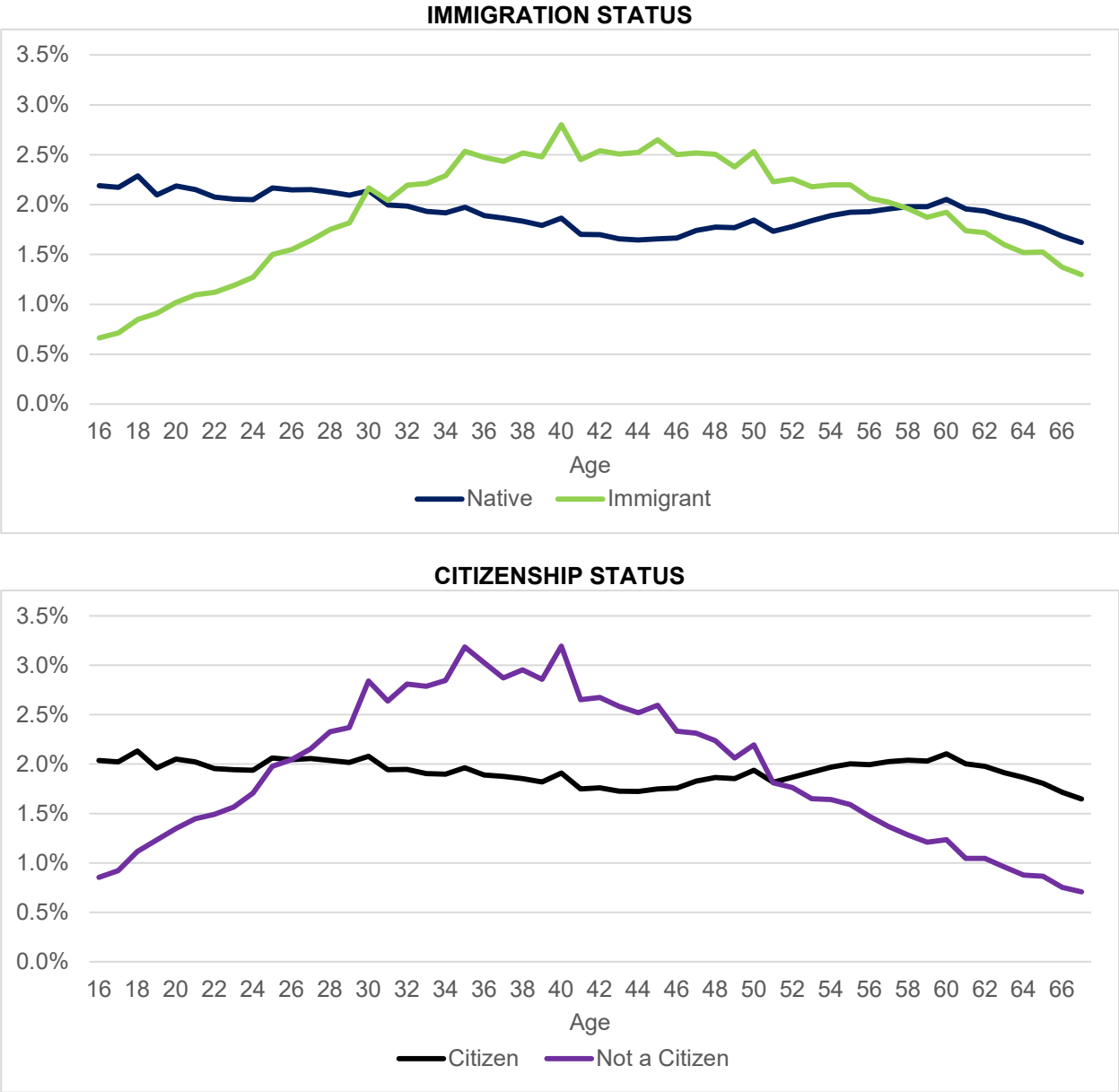




Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

CHART 3
AGE DISTRIBUTION OF U.S. RESIDENTS BY IMMIGRATION STATUS AND CITIZENSHIP STATUS
(Share of Immigration Status/Citizenship Status Total)



Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

the ages of 32 and 57. Similarly, a higher proportion of noncitizens than U.S. citizens were between the ages of 27 and 50. Prime working age is often defined as from 25 through 54 years of age.

Chart 4 also presents the age distribution by immigrant and citizenship status, but is limited to individuals participating in the U.S. labor force. For the most part, the conclusions are similar to those of all individuals. As expected, the share of individuals in the labor force under age 20 is quite low for all groups, reflecting the pursuit of education by many members of these groups.

Chart 5 presents labor force participation rates by age. The native rate was somewhat higher than that of immigrants up to age 46. The participation rate of citizens was higher than that of noncitizens through age 62.

Sectoral and Occupational Employment of Immigrants

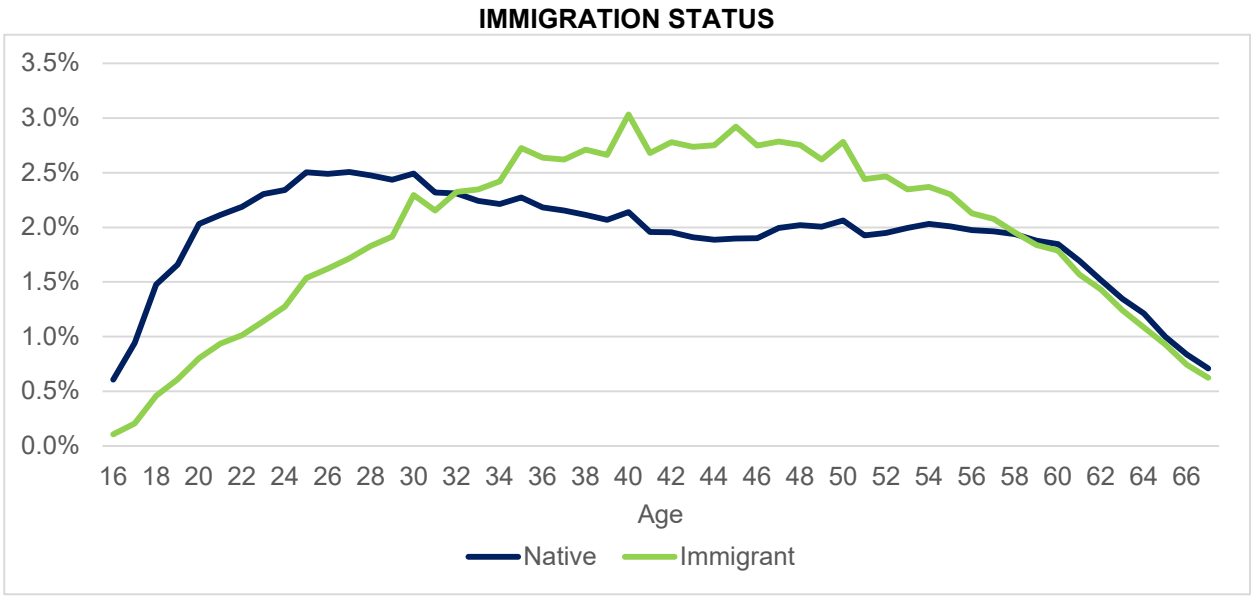
In the first graph of Chart 6, industrial activities with a high proportion of immigrant workers are displayed, topped by apparel manufacturing with an immigrant share of nearly 45 percent. Three of the top eight industrial activities are related to food production and processing. The second graph of Chart 6 shows occupational categories with a high proportion of immigrants. While some of the leading occupational categories mostly consist of lower-skilled workers, highly skilled workers predominate in others.

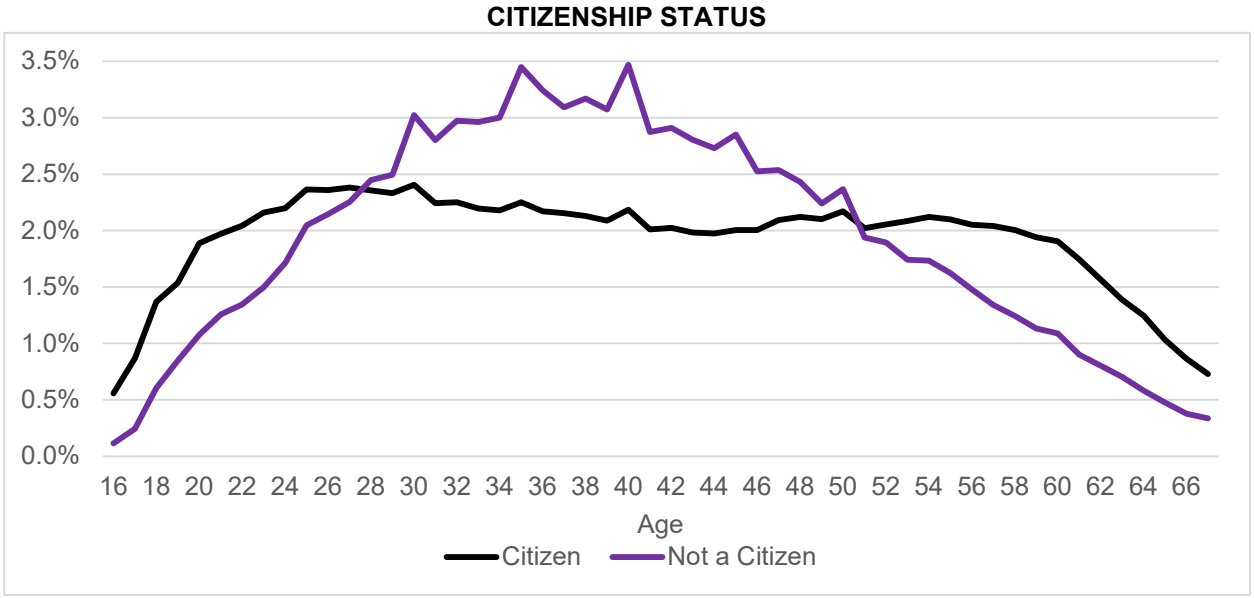
Chart 7 presents the industrial and occupational categories employing the largest number of immigrants. None of the leading industrial activities by number were among the leaders by proportion. In contrast, three of the occupational categories — building and grounds cleaning and maintenance; construction and extraction; and production — were among the leaders on both size and share.

Tables 9 through 12 present demographic characteristics of workers in the four worker groups of interest, for both the industrial and occupational definitions. Large sectoral and occupational subcategories of the worker groups also are displayed.

Construction. The statistics for the construction worker group are shown in Table 9. Construction was the largest of the four worker groups, accounting for 6.8 percent of total employment by the industrial definition and 4.9 percent by the occupational definition. Its workers were predominantly male: 89.7 percent industrially and 96.6 percent occupationally, compared to a male share of 52.9 percent of all U.S. employment. Hispanics were overrepresented: 29.7 percent industrially and 34.9 percent occupationally versus 17.7 percent of all workers. The construction worker group heavily employed immigrants, especially noncitizens: 17.2 percent industrially and 21.0 percent occupationally were noncitizens, each more than double the overall figure of 8.3 percent. The educational attainment of construction workers was below average. The share with a high school education or less was 57.5 percent industrially and 66.3 percent occupationally, compared to only 32.9 percent of all workers. Only 13.9 percent industrially and 6.7 percent occupationally had earned at least a bachelor’s degree, compared to 36.3 percent of all U.S. workers.

CHART 4
AGE DISTRIBUTION OF THE U.S. LABOR FORCE BY IMMIGRATION STATUS AND CITIZENSHIP STATUS
(Share of Immigration Status/Citizenship Status Total)

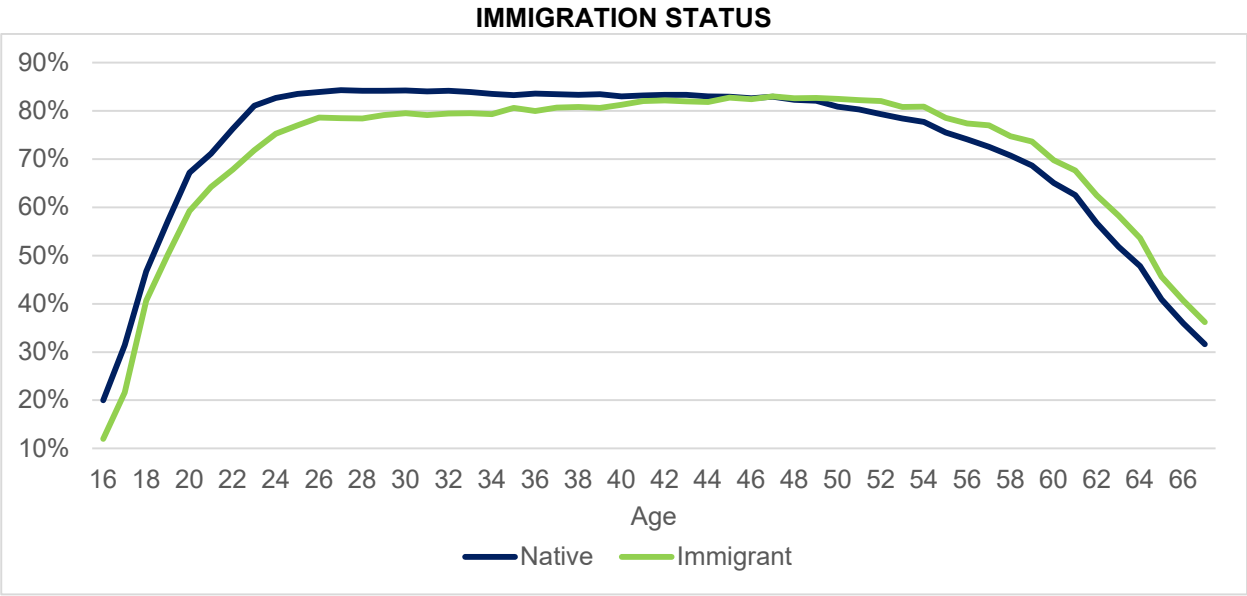


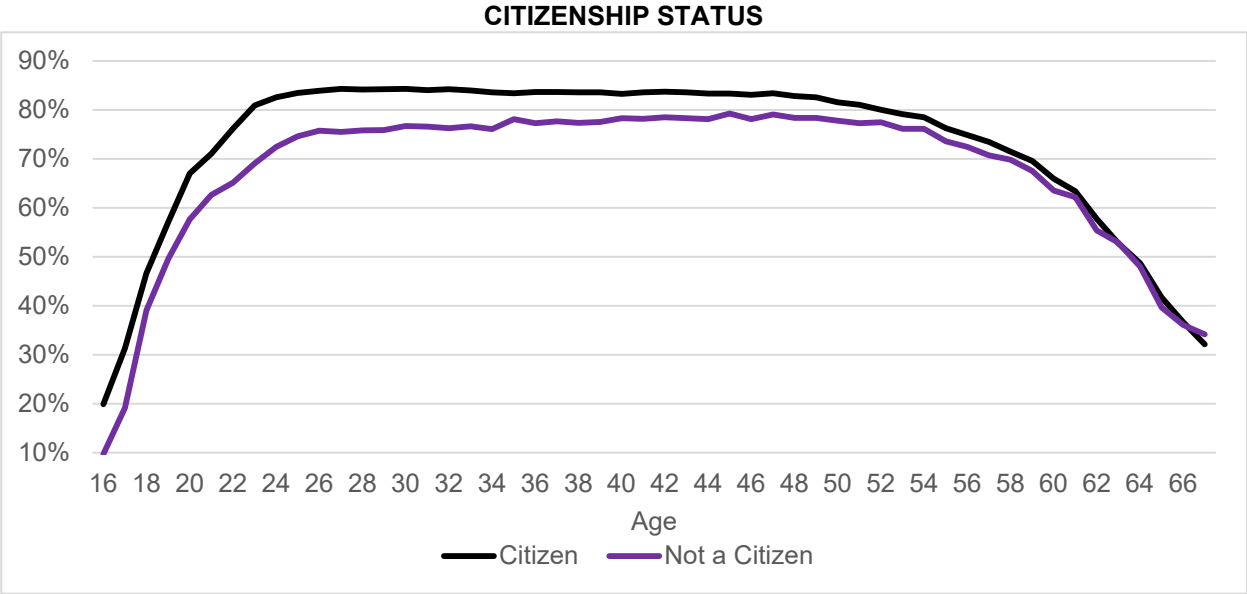


Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

CHART 5
U.S. LABOR FORCE PARTICIPATION RATES
BY IMMIGRATION STATUS AND CITIZENSHIP STATUS

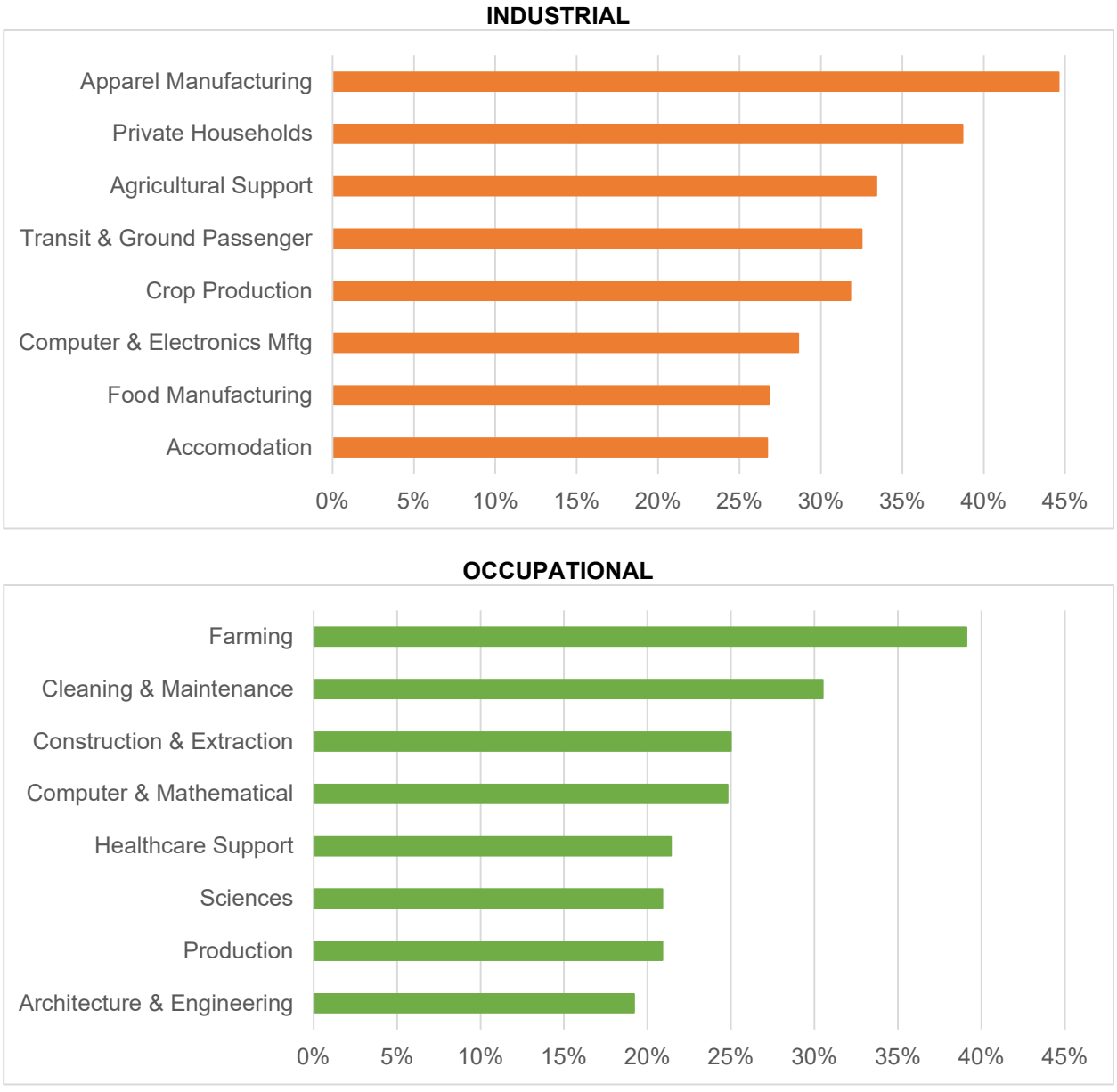




Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

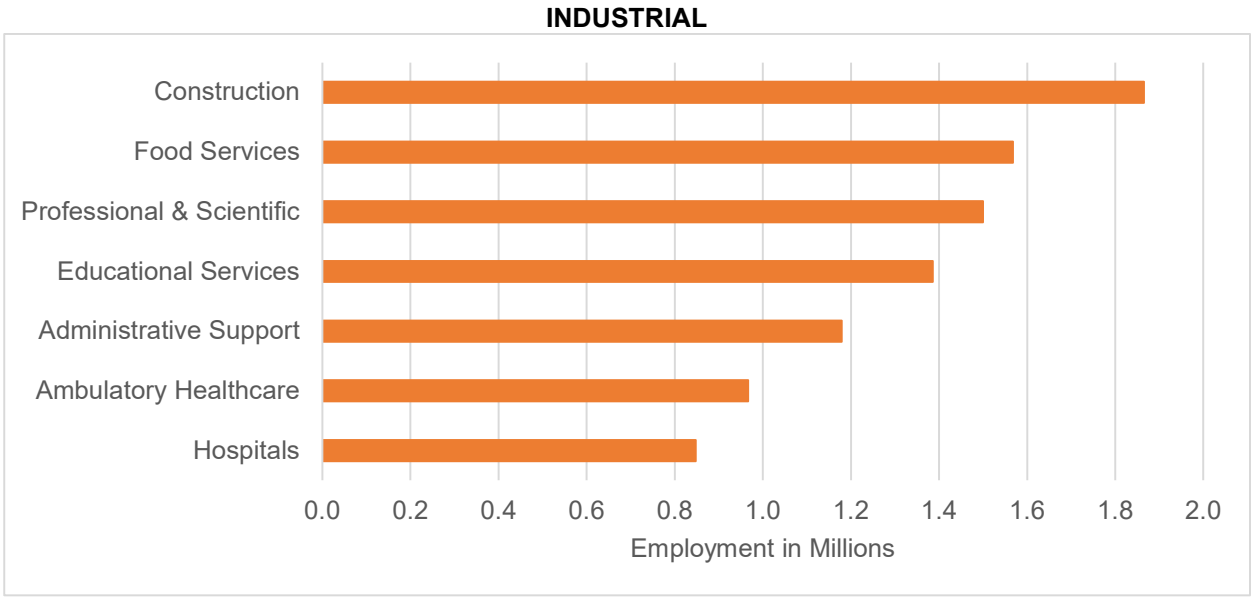
CHART 6
U.S. INDUSTRIAL AND OCCUPATIONAL CATEGORIES WITH THE LARGEST SHARES OF IMMIGRANT WORKERS

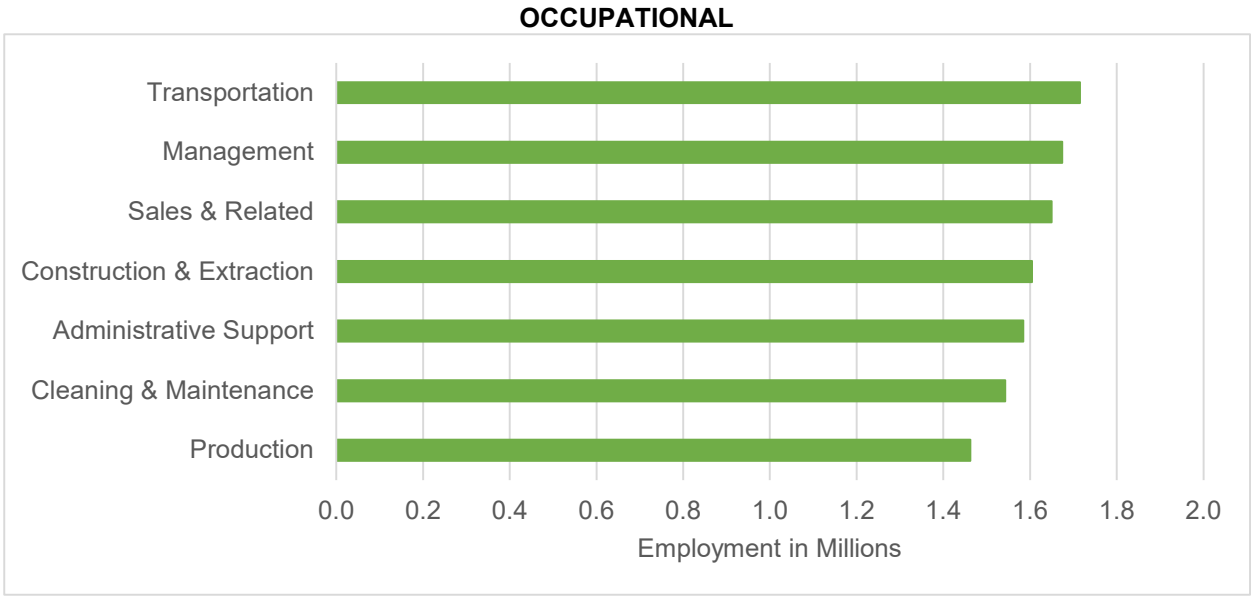


Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

CHART 7
U.S. INDUSTRIAL AND OCCUPATIONAL CATEGORIES WITH THE LARGEST NUMBER OF IMMIGRANT WORKERS





Note: age 16 through 67.

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

TABLE 9
DESCRIPTIVE STATISTICS OF THE CONSTRUCTION WORKER GROUP IN THE UNITED STATES

		Worker Group Total		Largest Industries			Largest Occupations		
	Overall Total	Industrial	Occupational	(1)	(2)	(3)	(a)	(b)	(c)
Total Employment (Millions)	158.27	10.75	7.78	10.75			7.78		
Share of Total Employment	100.00%	6.79%	4.91%	6.79%			4.91%		
Sex									
Male	52.91	89.68	96.64	89.68			96.64		
Female	47.09	10.32	3.36	10.32			3.36		
Race/Ethnicity									
White	61.36	60.53	54.90	60.53			54.90		
Black	11.36	5.07	5.82	5.07			5.82		
Asian	6.07	1.72	1.37	1.72			1.37		
Hispanic	17.66	29.72	34.91	29.72			34.91		
Age Group									
16 to 24	12.78	9.29	10.70	9.29			10.70		
25 to 54	64.19	69.02	69.41	69.02			69.41		
55 to 64	17.05	17.25	16.25	17.25			16.25		
65 or Older	5.98	4.44	3.63	4.44			3.63		
Immigrant Status									
Not an Immigrant	82.75	75.47	71.53	75.47			71.53		
Immigrant	17.25	24.53	28.47	24.53			28.47		
Citizenship Status									
Citizen	91.71	82.84	79.01	82.84			79.01		
Noncitizen	8.29	17.16	20.99	17.16			20.99		
Educational Attainment									
Less Than High School Diploma	8.75	19.08	23.41	19.08			23.41		
High School	24.17	38.38	42.85	38.38			42.85		
Some College	21.66	21.42	20.52	21.42			20.52		
Associate Degree	9.13	7.21	6.52	7.21			6.52		
Bachelor’s Degree	22.68	11.21	5.60	11.21			5.60		
Graduate Degree	13.61	2.70	1.10	2.70			1.10		

(1) construction sector
(a) construction and extraction occupational group

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

Food production and processing. This was the smallest of the four worker groups, accounting for 2.4 percent industrially and 1.0 percent occupationally of the nation's total employment (see Table 10). Though not to the degree of the construction worker group, food production and processing had a disproportionate share of male workers (68.9 percent industrially and 66.0 percent occupationally). Hispanics were overrepresented (29.9 percent industrially and 43.9 occupationally), as were immigrants and noncitizens, particularly based on the occupational definition. Educational attainment was below average, with a high proportion of the workers having no more than a high school diploma. The largest industrial components in order of employment were food manufacturing; crop production; and animal production and aquaculture. The largest occupational components were farming, fishing and forestry; and food processing.

Care. The care worker group employed nearly 4 percent of U.S. workers (see Table 11). It was dominated by female workers (82.8 percent industrially and 86.5 percent occupationally.) Whites were underrepresented and blacks were overrepresented. This worker group utilized immigrants and noncitizens at a rate not much different from the rest of the economy, though the immigrant share based on the occupational definition was above average. Educational attainment was not much different from the rest of the economy, though the shares of workers with some college or an associate degree were somewhat above average, while the shares with at least a bachelor's degree were somewhat below average. The largest industry components were social assistance, and nursing and residential care. The largest occupational component was healthcare support.

STEM. The STEM worker group employed 5.5 percent industrially and 4.4 percent occupationally of all U.S. workers. A disproportionately high share of the group's workers were male (66.1 percent industrially and 76.1 percent occupationally). Whites and especially Asians were overrepresented, whereas blacks and Hispanics were underrepresented (see Table 12). An above-average share of the workers were immigrants; a slightly above-average share of workers were noncitizens. A disproportionately high share of the workers were between 25 and 54 years of age. The educational attainment of STEM workers was far above average, with 70.9 percent industrially and 73.9 percent occupationally having earned at least a bachelor's degree. The largest industry component was professional, scientific, and technical services. The largest occupational component was computer and mathematical.

TABLE 10
DESCRIPTIVE STATISTICS OF THE FOOD PRODUCTION AND PROCESSING WORKER GROUP IN THE UNITED STATES

		Worker Group Total		Largest Industries			Largest Occupations		
	Overall Total	Industrial	Occupational	(1)	(2)	(3)	(a)	(b)	(c)
Total Employment (Millions)	158.27	3.80	1.62	1.72	1.04	0.54	0.89	0.73	
Share of Total Employment	100.00%	2.40%	1.03%	1.09%	0.66%	0.34%	0.56%	0.46%	
Sex									
Male	52.91	68.88	65.98	61.09	76.39	76.71	72.89	57.62	
Female	47.09	31.12	34.02	38.91	23.61	23.29	27.11	42.38	
Race/Ethnicity									
White	61.36	55.48	41.79	48.57	55.52	71.72	39.41	44.68	
Black	11.36	8.36	8.36	14.26	2.30	2.11	3.25	14.52	
Asian	6.07	3.50	3.45	5.72	1.42	1.05	1.31	6.02	
Hispanic	17.66	29.92	43.87	28.34	38.94	22.38	54.09	31.52	
Age Group									
16 to 24	12.78	12.03	17.28	11.94	11.83	14.48	17.91	16.50	
25 to 54	64.19	62.63	62.30	65.89	58.33	54.10	61.76	62.96	
55 to 64	17.05	18.38	15.34	18.21	19.02	19.98	14.66	16.16	
65 or Older	5.98	6.96	5.09	3.96	10.82	11.44	5.67	4.38	
Immigrant Status									
Not an Immigrant	82.75	73.17	60.87	72.26	67.56	80.48	54.07	69.07	
Immigrant	17.25	26.83	39.13	27.74	32.44	19.52	45.93	30.93	
Citizenship Status									
Citizen	91.71	81.25	70.25	82.82	74.06	85.07	62.00	80.21	
Noncitizen	8.29	18.75	29.75	17.18	25.94	14.93	38.00	19.79	
Educational Attainment									
Less Than High School Diploma	8.75	23.02	35.33	19.65	31.90	23.51	44.96	23.68	
High School	24.17	33.06	34.86	36.46	29.43	34.39	29.60	41.21	
Some College	21.66	18.33	16.68	19.51	15.56	18.00	13.12	20.98	
Associate Degree	9.13	7.12	5.40	6.79	6.95	7.72	4.18	6.88	
Bachelor’s Degree	22.68	14.40	6.41	13.31	13.15	13.43	6.74	6.00	
Graduate Degree	13.61	4.07	1.32	4.27	3.01	2.95	1.39	1.24	

(1) food manufacturing; (2) crop production; (3) animal production and aquaculture
(a) farming, fishing, and forestry; (b) food processing

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

TABLE 11
DESCRIPTIVE STATISTICS OF THE CARE WORKER GROUP IN THE UNITED STATES

		Worker Group Total		Largest Industries			Largest Occupations		
	Overall Total	Industrial	Occupational	(1)	(2)	(3)	(a)	(b)	(c)
Total Employment (Millions)	158.27	6.13	6.31	3.31	2.82		5.19	1.12	
Share of Total Employment	100.00%	3.87%	3.99%	2.09%	1.78%		3.28%	0.71%	
Sex									
Male	52.91	17.16	13.46	14.32	20.49		14.95	6.50	
Female	47.09	82.84	86.54	85.68	79.51		85.05	93.50	
Race/Ethnicity									
White	61.36	53.92	47.29	53.84	54.02		45.67	54.81	
Black	11.36	21.26	22.04	17.92	25.18		23.83	13.72	
Asian	6.07	5.14	6.15	5.05	5.25		6.62	3.92	
Hispanic	17.66	15.71	20.44	19.02	11.82		19.79	23.45	
Age Group									
16 to 24	12.78	13.86	17.76	14.00	13.70		15.20	29.68	
25 to 54	64.19	60.84	60.07	61.07	60.57		62.19	50.19	
55 to 64	17.05	18.00	16.05	17.07	19.08		16.50	13.99	
65 or Older	5.98	7.30	6.12	7.85	6.65		6.11	6.15	
Immigrant Status									
Not an Immigrant	82.75	82.08	77.49	81.95	82.22		77.26	78.55	
Immigrant	17.25	17.92	22.51	18.05	17.78		22.74	21.45	
Citizenship Status									
Citizen	91.71	93.09	90.69	92.74	93.48		91.17	88.45	
Noncitizen	8.29	6.91	9.31	7.26	6.52		8.83	11.55	
Educational Attainment									
Less Than High School Diploma	8.75	8.17	10.46	7.61	8.84		9.79	13.59	
High School	24.17	24.90	30.57	21.42	28.97		30.75	29.70	
Some College	21.66	24.47	31.67	23.06	26.13		32.08	29.78	
Associate Degree	9.13	12.10	12.96	10.33	14.17		13.61	9.94	
Bachelor's Degree	22.68	19.84	11.52	23.66	15.35		11.00	13.95	
Graduate Degree	13.61	10.53	2.82	13.92	6.54		2.77	3.05	

(1) social assistance; (2) nursing and residential care facilities
(a) healthcare support; (b) personal care and service

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

TABLE 12
DESCRIPTIVE STATISTICS OF THE STEM WORKER GROUP IN THE UNITED STATES

		Worker Group Total		Largest Industries			Largest Occupations		
	Overall Total	Indus-trial	Occu-pational	(1)	(2)	(3)	(a)	(b)	(c)
Total Employment (Millions)	158.27	8.68	6.94	7.32	0.58	0.39	4.30	1.33	0.85
Share of Total Employment	100.00%	5.49%	4.39%	4.62%	0.36%	0.25%	2.72%	0.84%	0.53%
Sex									
Male	52.91	66.05	76.08	66.86	54.12	70.05	75.22	86.30	74.57
Female	47.09	33.95	23.92	33.14	45.88	29.95	24.78	13.70	25.43
Race/Ethnicity									
White	61.36	65.85	62.91	66.43	59.29	65.15	59.44	70.30	69.89
Black	11.36	6.50	6.48	6.31	9.61	5.69	7.18	5.14	5.37
Asian	6.07	14.67	18.63	14.57	16.11	15.17	21.39	11.58	14.10
Hispanic	17.66	9.50	8.45	9.14	12.11	11.00	8.34	9.68	7.28
Age Group									
16 to 24	12.78	5.99	6.42	6.03	5.20	5.36	6.78	8.02	1.30
25 to 54	64.19	72.40	75.05	72.62	73.68	64.08	77.01	68.50	75.13
55 to 64	17.05	16.32	15.28	15.77	18.33	25.00	13.56	18.29	20.61
65 or Older	5.98	5.29	3.26	5.58	2.80	5.56	2.65	5.19	2.96
Immigrant Status									
Not an Immigrant	82.75	78.44	74.98	78.76	74.92	76.61	72.95	81.28	78.72
Immigrant	17.25	21.56	25.02	21.24	25.08	23.39	27.05	18.72	21.28
Citizenship Status									
Citizen	91.71	89.88	87.59	89.70	90.98	91.29	85.69	92.77	91.78
Noncitizen	8.29	10.12	12.41	10.30	9.02	8.71	14.31	7.23	8.22
Educational Attainment									
Less Than High School Diploma	8.75	1.46	0.85	1.21	2.60	3.36	0.85	1.06	0.54
High School	24.17	7.66	5.28	6.62	12.46	15.76	5.17	6.52	4.29
Some College	21.66	13.19	12.27	12.91	12.07	16.45	13.61	10.60	11.82
Associate Degree	9.13	6.85	7.72	6.73	5.60	9.97	8.04	8.97	6.93
Bachelor’s Degree	22.68	43.58	46.37	44.71	37.24	33.82	47.22	48.63	45.49
Graduate Degree	13.61	27.27	27.53	27.82	30.04	20.64	25.11	24.22	30.92

(1) professional, scientific, and technical services; (2) chemical manufacturing; (3) computer and electronic product manufacturing
(a) computer and mathematical; (b) architecture and engineering; (c) management

Source: Calculated from U.S. Department of Commerce, Census Bureau, American Community Survey, five-year estimates, 2017 through 2021.

Method for Projecting Labor Supply and Demand

In the rest of this paper, the balance between labor demand and supply in 2033 is projected for each of the four worker groups. To do so, labor demand comes from Lightcast's occupational and industrial employment forecasts. Lightcast provides projections of the number of workers through 2033 (but see the discussion in the last paragraph of Appendix C).

Overall, U.S. employment is projected to increase 4.0 percent between 2022 and 2033. Growth is expected to be below average in the construction (3.2 percent) and food production and processing (3.3 percent occupationally and 3.2 percent industrially) worker groups, but above average in the care (7.4 percent occupationally and 7.6 percent industrially) and STEM (6.2 percent occupationally and 6.6 percent industrially) worker groups.

The future supply of workers is based on working-age (age 16 through 67) population projections produced by the U.S. Census Bureau. Population projections by age are available for three scenarios from the Census Bureau: a baseline where no major changes to immigration policy occur, a high scenario that assumes a 50 percent increase in immigration, and a low-immigration scenario. Since the analysis discussed below finds labor supply to be less than demand overall and in each of the four worker groups based on the Census Bureau's baseline scenario, the low scenario is not used.

In addition to an overall assessment of the likely supply of, and demand for, labor by worker group, an assessment also is made by educational attainment, using the 2017-to-2021 American Community Survey's distribution of educational attainment over six attainment categories.

Projecting the supply-demand relationship requires strong assumptions:

- Projections of the working-age population are reasonably accurate.[6]
- Employment projections are reasonably accurate (see Appendix C).
- The distribution of educational attainment does not change over time.
- A surplus of workers with one educational attainment are not substitutable for a shortage of workers with another educational attainment. For example, if there is a shortage of workers with a four-year degree in the STEM worker group, one cannot expect workers with only a high school diploma to fill the open positions. Similarly, in the construction worker group, one cannot reasonably expect workers with a graduate degree to fill shortfalls in positions that do not even require a high school diploma.

Labor Gaps

A labor "gap" occurs when the demand exceeds supply. A "surplus" exists when supply is greater than demand. As discussed earlier, economic theory suggests that wide and persistent aggregate disparities between labor demand and supply should not exist, though less lengthy shortages, especially in portions of the economy, certainly do occur. Economic theory indicates that some combination of the following will over time eliminate any gap:

[6] The Census Bureau's projections were created in 2017 based on the 2010 Census. As of the time of this writing, the Census Bureau has not yet released the 2020 census breakdown by age, sex, and race/ethnicity. There is the potential for important differences in the analysis once the new figures are released and the Census Bureau has updated its projections.

- An increase in the labor force participation rate — either by increasing the participation rate of natives or by increasing the number of working-age immigrants.
- An increase in wages.
- Workers gaining new skills in order to be able to fill the open positions.

Widespread labor shortages have occurred, largely due to demographic conditions. The entry into the workforce of the baby-boom generation coincided with an increase in the participation rate of women, causing unemployment rates to be high in the 1970s into the 1980s. Eventually, the economy expanded enough to employ these workers. In the 1990s, the baby-bust generation was entering the workforce, but there were not enough of them to fill the needs of the expanded economy. This was solved largely by an increase in the number of immigrants, many of whom were undocumented.

Currently, the overall economy has a shortage of workers. This seems to have been prompted by the pandemic-induced disruptions to the economy, but the retirement of some workers of the baby-boom generation also is playing a role. As discussed below, a widespread shortage of workers is projected in 2033 as well. According to the Census Bureau, the annual average growth rate of the working-age population is projected to be only 0.2 percent from 2022 through 2033. The continued retirement of the baby-boom generation likely is the cause of this slow growth and the projected labor gap. As in the 1990s, the most effective means of reducing this widespread labor gap is to increase the size of the workforce through immigration.

Because of the demographic nature of the current and projected gap, worker shortages in the economy as a whole likely are spread across all educational attainment levels. However, as discussed below, the gaps in any particular portion of the economy may be in only certain educational attainment categories, with surpluses existing in other attainment categories. In most cases, a surplus in the workforce of one attainment category cannot solve a shortfall in another attainment category.

Projected Labor Supply and Demand Balance

Projected labor gaps and surpluses overall and for each of the four worker groups are provided in Table 13 using both the baseline and high-immigration scenarios for the supply of labor. Using the baseline working-age population projection, a gap is projected overall and in each of the four worker groups. However, if immigration was allowed to increase by 50 percent, the overall gap would become a surplus, as would the gaps in the construction and food production and processing worker groups.

In each of the four worker groups, the gap is effectively larger than indicated by the overall figures in Table 13. In each group, sizable shortages are projected, even in the high-immigration scenario, in some educational attainment categories (see Table 14). This, as well as the projected overall surplus in the high-immigration scenario, suggests that simply allowing immigration to increase by 50 percent without reforms to the current immigration system will not solve the worker shortages in some portions of the economy and will create problems for native workers in other parts of the economy.

TABLE 13
PROJECTED U.S. LABOR GAPS AND SURPLUSES IN 2033

	Construc-tion	Food Production & Processing	Care	STEM	Overall Economy
Occupation					
Baseline Supply Scenario					
Number (000)	-76	-23	-463	-391	-1,948
Percent	-1.0	-1.2	-5.2	-4.0	-0.9
High Supply Scenario					
Number (000)	123	30	-225	-131	4,327
Percent	1.6	1.5	-2.5	-1.3	1.8
Industry					
Baseline Supply Scenario					
Number (000)	-98	-52	-387	-382	-1,948
Percent	-1.0	-1.3	-5.3	-4.4	-0.9
High Supply Scenario					
Number (000)	163	56	-193	-147	4,327
Percent	1.6	1.3	-2.6	-1.6	1.8

Note: A negative figure indicates a gap; a positive figure indicates a surplus.

Source: Calculated by authors.

Construction

Using the baseline supply scenario, a small gap of 1.0 percent (76,000 using the occupational definition and 98,000 using the industrial definition) is projected in 2033 in the construction worker group. However, if immigration were to increase by 50 percent, a surplus of 1.6 percent is projected.

Based on both the occupational and industrial definitions and both the baseline and high-immigration scenarios, employment gaps in the construction worker group are projected to be solely in the less than high school and high school graduate educational attainment categories.

Food Production and Processing

A small gap of 1.2 percent (23,000) is projected in 2033 in the food production and processing worker group using the occupational definition and the baseline supply scenario. A slightly larger gap is expected using the industrial definition. All of the gap likely will occur in the agricultural portion of this worker group. However, if immigration were to increase by 50 percent, a surplus of 1.5 percent occupationally and 1.3 percent industrially is projected.

As in the construction worker group, employment gaps in the food production and processing worker group are projected to be solely in the less than high school and high school graduate educational attainment categories based on both the occupational and industrial definitions and both the baseline and high-immigration scenarios.

TABLE 14
PROJECTED U.S. LABOR GAPS AND SURPLUSES IN 2033
BY EDUCATIONAL ATTAINMENT
(Number in Thousands)

BASELINE SCENARIO

Educational Attainment	Construction	Food Production & Processing	Care	STEM
Occupation				
Total	-76	-23	-463	-391
Not a High School Graduate	-784	-288	14	704
High School Diploma	-1,087	-184	-179	1,577
Some College	2	62	-364	773
Associate Degree	137	38	-321	195
Bachelor's Degree	845	161	161	-2,204
Graduate Degree	810	188	226	-1,436
Industry				
Total	-98	-52	-387	-382
Not a High School Graduate	-1,456	-1,084	-165	690
High School Diploma	-1,869	-447	-583	1,637
Some College	91	191	-849	777
Associate Degree	249	147	-328	94
Bachelor's Degree	1,664	649	765	-2,255
Graduate Degree	1,222	492	772	-1,326

HIGH-IMMIGRATION SCENARIO

Educational Attainment	Construction	Food Production & Processing	Care	STEM
Occupation				
Total	123	30	-225	-131
Not a High School Graduate	-766	-283	35	727
High School Diploma	-1,039	-171	-122	1,640
Some College	45	73	-312	829
Associate Degree	156	43	-299	219
Bachelor's Degree	891	173	215	-2,145
Graduate Degree	837	195	258	-1,401
Industry				
Total	163	56	-193	-147
Not a High School Graduate	-1,434	-1,074	-148	710
High School Diploma	-1,805	-421	-536	1,694
Some College	148	214	-807	828
Associate Degree	273	157	-310	116
Bachelor's Degree	1,724	673	809	-2,201
Graduate Degree	1,258	507	798	-1,294

Note: A negative figure indicates a gap; a positive figure indicates a surplus.

Source: Calculated by authors.

Care
Using the baseline supply scenario, a sizable gap of 5.2 percent (463,000) is projected in 2033 in the care worker group using the occupational definition. A similar gap of 5.3 percent is expected using the industrial definition. If immigration were to increase by 50 percent, the gap would narrow but still be 2.5 percent (225,000) occupationally and 2.6 percent (193,000) using the industrial definition.

Based on the occupational definition and both the baseline and high-immigration scenarios, employment gaps in the care worker group are projected in the moderate educational attainment categories of high school graduate, some college, and associate degree. Based on the industrial definition, a small gap is projected in the less than high school graduate category as well.

STEM
A moderately large gap of 4.0 percent (391,000) is projected in 2033 in the STEM worker group using the occupational definition and the baseline supply scenario. A gap of 4.4 percent is expected using the industrial definition. If immigration were to increase by 50 percent, the gap would narrow but still be 1.3 percent (131,000) occupationally and 1.6 percent (147,000) using the industrial definition.

Employment gaps in the STEM worker group are projected to be solely in the bachelor's degree and graduate degree educational attainment categories based on both the occupational and industrial definitions and both the baseline and high-immigration scenarios.

APPENDIX A: STEM OCCUPATIONS

Occupation	Description
	COMPUTER CATEGORY
11-3021	Computer and Information Systems Managers
15-1211	Computer Systems Analysts
15-1212	Information Security Analysts
15-1221	Computer and Information Research Scientists
15-1231	Computer Network Support Specialists
15-1232	Computer User Support Specialists
15-1241	Computer Network Architects
15-1244	Network and Computer Systems Administrators
15-1245*	Database Administrators; and Database Architects
15-1251	Computer Programmers
15-1256**	Software Developers; and Software Quality Assurance Analysts and Testers
15-1257***	Web Developers; and Web and Digital Interface Designers
15-1299	Computer Occupations, All Other
	MATH CATEGORY
15-2011	Actuaries
15-2021	Mathematicians
15-2031	Operations Research Analysts
15-2041	Statisticians
15-2098****	Data Scientists; and Mathematical Science Occupations, All Other
	ENGINEERING CATEGORY
11-9041	Architectural and Engineering Managers
17-2011	Aerospace Engineers
17-2021	Agricultural Engineers
17-2031	Bioengineers and Biomedical Engineers
17-2041	Chemical Engineers
17-2051	Civil Engineers
17-2061	Computer Hardware Engineers
17-2071	Electrical Engineers
17-2072	Electronics Engineers, Except Computer
17-2081	Environmental Engineers
17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors
17-2112	Industrial Engineers
17-2121	Marine Engineers and Naval Architects
17-2131	Materials Engineers
17-2141	Mechanical Engineers
17-2151	Mining and Geological Engineers, Including Mining Safety Engineers
17-2161	Nuclear Engineers
17-2171	Petroleum Engineers
17-2199	Engineers, All Other
	ENGINEERING TECHNICIAN CATEGORY
17-3011	Architectural and Civil Drafters
17-3012	Electrical and Electronics Drafters
17-3013	Mechanical Drafters
17-3019	Drafters, All Other
17-3021	Aerospace Engineering and Operations Technologists and Technicians
17-3022	Civil Engineering Technologists and Technicians
17-3023	Electrical and Electronic Engineering Technologists and Technicians
17-3024	Electro-Mechanical & Mechatronics Technologists and Technicians
17-3025	Environmental Engineering Technologists and Technicians
17-3026	Industrial Engineering Technologists and Technicians
17-3027	Mechanical Engineering Technologists and Technicians
17-3031	Surveying and Mapping Technicians
17-3098^	Calibration Technologists and Technicians; and Engineering Technologists and Technicians, Except Drafters, All Other

(continued)

APPENDIX A: STEM OCCUPATIONS (continued)

Occupation	Description
	SCIENCE CATEGORY
11-9121	Natural Sciences Managers
19-1011	Animal Scientists
19-1012	Food Scientists and Technologists
19-1013	Soil and Plant Scientists
19-1021	Biochemists and Biophysicists
19-1022	Microbiologists
19-1023	Zoologists and Wildlife Biologists
19-1029	Biological Scientists, All Other
19-1031	Conservation Scientists
19-1032	Foresters
19-1041	Epidemiologists
19-1042	Medical Scientists, Except Epidemiologists
19-1099	Life Scientists, All Other
19-2011	Astronomers
19-2012	Physicists
19-2021	Atmospheric and Space Scientists
19-2031	Chemists
19-2032	Materials Scientists
19-2041	Environmental Scientists and Specialists, Including Health
19-2042	Geoscientists, Except Hydrologists and Geographers
19-2043	Hydrologists
19-2099	Physical Scientists, All Other
	SCIENCE TECHNICIAN CATEGORY
19-4011^^	Agricultural Technicians; and Food Science Technicians
19-4021	Biological Technicians
19-4031	Chemical Technicians
19-4042	Environmental Science and Protection Technicians, Including Health
19-4045^^^	Geological Technicians; and Hydrologic Technicians
19-4051	Nuclear Technicians
19-4071	Forest and Conservation Technicians
19-4092	Forensic Science Technicians
19-4099	Life, Physical, and Social Science Technicians, All Other

* Combination of two Standard Occupational Classification (SOC) occupations: 15-1242 and 15-1243.
** Combination of two SOC occupations: 15-1252 and 15-1253.
*** Combination of two SOC occupations: 15-1254 and 15-1255.
**** Combination of two SOC occupations: 15-2051 and 15-2099.
^ Combination of two SOC occupations: 17-3028 and 17-3029.
^^ Combination of two SOC occupations: 19-4012 and 19-4013.
^^^ Combination of two SOC occupations: 19-4043 and 19-4044.

Sources: Lightcast (occupational classification adapted from Executive Office of the President, Office of Management and Budget, “Standard Occupational Classification Manual,” https://www.bls.gov/soc/2018/soc_2018_manual.pdf). Definition of STEM occupations produced by authors.

APPENDIX B: STEM INDUSTRIES

Industry	Description
	MANUFACTURING CATEGORY
325411	Medicinal and Botanical
325412	Pharmaceutical Preparation
325413	In-Vitro Diagnostic Substance
325414	Biological Product (except Diagnostic)
333242	Semiconductor Machinery
333314	Optical Instrument and Lens
333316	Photographic and Photocopying Equipment
334111	Electronic Computers
334112	Computer Storage Devices
334118	Computer Terminal and Other Computer Peripheral Equipment
334210	Telephone Apparatus
334220	Radio and Television Broadcasting and Wireless Communications Equipment
334290	Other Communications Equipment
334310	Audio and Video Equipment
334412	Bare Printed Circuit Boards
334413	Semiconductor and Related Devices
334416	Capacitor, Resistor, Coil, Transformer, and Other Inductors
334417	Electronic Connectors
334418	Printed Circuit Assembly (Electronic Assembly)
334419	Other Electronic Components
334510	Electromedical and Electrotherapeutic Apparatus
334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instruments
334512	Automatic Environmental Controls for Residential, Commercial, and Appliance Use
334513	Instruments and Related Products for Measuring, Displaying and Controlling Industrial Process Variables
334514	Totalizing Fluid Meter and Counting Devices
334515	Instruments for Measuring and Testing Electricity and Electrical Signals
334516	Analytical Laboratory Instruments
334517	Irradiation Apparatus
334519	Other Measuring and Controlling Devices
334613	Blank Magnetic and Optical Recording Media
334614	Software and Other Prerecorded Compact Disc, Tape, and Record Reproducing
336411	Aircraft
336412	Aircraft Engines and Engine Parts
336413	Other Aircraft Parts and Auxiliary Equipment
336414	Guided Missiles and Space Vehicles
336415	Guided Missile and Space Vehicle Propulsion Units and Propulsion Unit Parts
336419	Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment

(continued)

APPENDIX B: STEM INDUSTRIES (continued)

Industry	Description
	SERVICES CATEGORY
511210	Software Publishers
517312	Wireless Telecommunications Carriers (except Satellite)
517410	Satellite Telecommunications
517919	All Other Telecommunications
518210	Data Processing, Hosting, and Related Services
519130	Internet Publishing and Broadcasting and Web Search Portals
541330	Engineering Services
541340	Drafting Services
541360	Geophysical Surveying and Mapping Services
541370	Surveying and Mapping (except Geophysical) Services
541380	Testing Laboratories
541511	Custom Computer Programming Services
541512	Computer Systems Design Services
541513	Computer Facilities Management Services
541519	Other Computer Related Services
541620	Environmental Consulting Services
541690	Other Scientific and Technical Consulting Services
541713	Research and Development in Nanotechnology
541714	Research and Development in Biotechnology (except Nanotechnology)
541715	Research and Development in Other Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

Sources: Lightcast (industrial classification adapted from Executive Office of the President, Office of Management and Budget, “North American Industry Classification System,” https://www.census.gov/eos/www/naics/). Definition of STEM-intensive industries produced by authors.

APPENDIX C: LIGHTCAST EMPLOYMENT ESTIMATES AND PROJECTIONS

Lightcast (www.economicmodeling.com), formerly known as Emsi and Emsi Burning Glass, is a private-sector company that provides labor force and related data to subscribers. It is available for this project since Arizona State University is a subscriber. Available data from Lightcast include annual employment by industry and occupation, for the nation, states, counties, and metropolitan areas. Lightcast updates the data quarterly; the data used in this report come from Lightcast's first quarter 2023 data release. In addition to annual historical data back to 2001, Lightcast produces projections of employment annually, currently through 2033.

Lightcast uses a variety of sources, predominantly federal government agencies, to develop its historical data. A basic advantage of using Lightcast's data is that Lightcast imputes values for the large volume of data that are withheld by the federal government due to federal disclosure restrictions. Thus, figures are available for every industry and occupation.

Lightcast reports employment for each of four categories; the sum of the following three categories was used for this study:

- The first category corresponds to the Quarterly Census of Employment and Wages (QCEW), produced by the BLS, which is limited to wage and salary employees who are covered by the unemployment insurance program.
- The second category is wage and salary workers who are not covered by unemployment insurance. Those in the military and those working for railroads are in this category, as are some employees of the federal government, religious organizations, etc.
- The third category of self-employed workers includes those individuals whose self-employment constitutes a high proportion of their total earnings and working hours.

Lightcast's fourth employment category consists of self-employed workers who work limited hours on their own. Most counted in one of the first two categories; others may be largely retired.

Projections

Lightcast first produces employment projections by industry. According to Lightcast, "Projections are calculated for each 6-digit NAICS [industry] and county combination individually. For each county-industry combination, we begin with final Lightcast industry data and produce three 10-year projection lines based on 5, 10, and 15 years of historical employment data, respectively. We then project each of those trend lines forward 10 years into the future. The lines are simple projections of historical trends. The three projections, based on the various historical trend lines, are then combined into one projection. The projection line is damped, meaning that projected growth or decline is slowed a bit each year. Next, we make adjustments to outside sources. First, we adjust to the National Industry-Occupation Employment Matrix (NIOEM), another BLS dataset. We also adjust to long-term industry projections as published by each state." Staffing patterns (employment by occupation within each industry nationally) are used by Lightcast to convert the industry projections into occupational projections.

Lightcast's total employment projections were compared to other sources, including the BLS and IHS Markit (www.connect.ihs.com, part of S&P Global), another proprietary source of forecast data. Lightcast's projections of employment growth were far higher than those of the other sources and much higher than the historical record. However, it was not possible to use projections from these other sources instead of Lightcast's projections because the other sources do not provide projections at the detailed industry and occupation level that is necessary to define the four worker groups. Instead, Lightcast's projections of employment change between 2022 and 2033 overall and in each worker group were scaled down by a factor of 0.365 — the factor needed to equate Lightcast's overall projected employment change to that of IHS Markit.