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# How do Immigration and Technological Growth Affect One Another? Providing Guiding Principles for Policymakers

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## Providing Guiding Principles for Policymakers

By Nate Karren

# Intro

Beginning in World War II, the US and Mexico struck an agreement called the Bracero program in which agricultural workers were able to temporarily relocate from Mexico to the US to help aid with labor shortages. During the 1960s, the Bracero program abruptly ended. Suddenly, abundant immigrant labor disappeared, and farmers turned to better machines to keep production going.[1] Many economic models assume innovation grows with higher populations, but terminating the Bracero program was a striking counter-example suggesting the opposite was true. However, many of the most tech-forward companies in the US were founded by immigrants, or children of immigrants (Apple and Google, for example), especially those in Silicon Valley.[2] With real-world examples suggesting both positive and negative correlations between immigration and tech, it's critical to figure out exactly what their relationship is. Without a clear picture of how these interact, well-intentioned policy could harm the future of US tech development.

To assist policymakers in knowing how best to act, this article seeks to answer the question, "How do immigration and technological innovation affect one another?" This is done by thoroughly reviewing existing research and drawing conclusions and policymaking strategies from the lessons learned. By better understanding this relationship, the US can move forward confidently in its ability to achieve long-term economic growth.

The research shows the pattern between immigration and tech growth is more nuanced than a simple statement of positive or negative correlation. They can be complements and substitutes for one another depending on the field and the skill level of the labor force. Because the research often uses education as a measure of skill, this paper will refer to immigrants with at least a bachelor's degree as "high-skill" and immigrants with less education as "low-skill".[3] For high-skilled work, immigration and technology display a complementary relationship. In other words, with an increase in high-skilled immigration, patenting quantity also increases. These immigrants also bring spillover effects that benefit professionals around them, further encouraging innovation. This will be discussed in more detail later. In low-skill jobs, technology

[1] San, "Labor Supply and Directed Technical Change: Evidence from the Termination of the Bracero Program in 1964."
[2] "Silicon Valley's New Immigrant Entrepreneurs."
[3] Gaining more education can help one become more "skilled", but that is beyond the scope of this paper.

and immigration complement one another, but can also displace one another. This is generally seen through the use of automation and robots. While this kind of substitution may affect the high-skilled, it disproportionately affects low-skilled immigrants. Because the research often uses education as a measure of skill, this paper will refer to immigrants with at least a bachelor's degree as "high-skill" and immigrants with less education as "low-skill." Gaining more education can help one become more "skilled," but that is beyond the scope of this paper.

This article is structured to highlight how the relationship between immigration and technology changes based on the skill level of the labor force in a particular field. The research is divided into high-skill and low-skill sections. A third section discusses current policies and proposes strategies with these lessons in mind.

# The Relationship between Immigration and Tech Growth

## High-Skilled Immigrants Develop Technology

Research shows that high-skilled immigration complements tech development in several ways. These can be summarized as specialization, patenting booms, spillover effects, and employment opportunities - each explored in more detail in this section. When educated scientists and engineers move to the US, they bring their specialized expertise. Without strong family ties in their new country, they can move from city to city, bringing booms in patenting rates. Additionally, their presence and mentorship can spur others to further innovation. The following studies each provide evidence of immigrants' effect on technological growth and support one another in their findings.

### Specialization

In their 2020 study, Bahar et al. found immigrants increased the number of patents in their home country's specialty when they moved to a new host country. For example, if Taiwan specializes in semiconductors, a Taiwanese scientist immigrating to the US will help increase semiconductor patents. This study found doubling the number of inventors makes a country 50 to 60% more likely to specialize in the same kind of tech as the inventors' home. Doubling inventors also correlates with higher annual patenting rates by 29 to 43%. This is significant evidence that migrant inventors spread ideas and knowledge across borders.[4] High-skilled immigrants complement tech development with their specialized knowledge and mobility.

[4] Bahar, Choudhury, and Rapoport, "Migrant Inventors and the Technological Advantage of Nations."

## Booms and Breakthroughs

High-skilled immigrants help provide patenting booms in areas experiencing breakthroughs. William Kerr found mobile immigrants contribute to such booms by studying the Immigration Act of 1990. Before this act, US immigration policy imposed strict quotas on how many workers could enter the country at a time. The Immigration Act raised quotas and "...dramatically released pent-up immigration demand from [scientists and engineers] in constrained countries".[5] These immigrants were finally allowed to enter the US and move to the development hotspots in their respective fields, propelling innovation. By only considering the top 1% of most cited patents as breakthroughs and requiring a city to have at least 10 of these high-quality patents to be considered a breakthrough site, Kerr filtered out noise that could skew his results. Through carefully filtered data, he also concluded that high-skilled immigrants bolster invention.

## Spillover Effects & Employment

Immigrant scientists further complement tech by encouraging their peers to innovate. Hunt and Gauthier-Loiselle, like Kerr, used patenting data to investigate these spillover effects. They found that as the number of immigrant scientists in an area increased, so did the number of patents per capita. This encourages higher inventing rates among native scientists, as well. Hunt and Gauthier-Loiselle write, "Even immigrants who do not patent themselves may increase patenting by providing complementary skills to inventors, such as entrepreneurship." [6] While much growth comes directly from the actions of high-skilled immigrants, here the literature finds that simply their presence in an area can catalyze invention. This is in direct support of Kerr's research regarding breakthrough sites.

Stuen et al. further study positive spillover effects through high-skilled immigration in tech. They examined the effect of each international student on the number of articles written for science and engineering (S&E) journals. The authors found that foreign-born students were more likely to pursue and earn higher degrees in science and engineering, outnumbering native students. Therefore, they had a more significant impact on publication numbers than native students.[7] Stuen et al. argued that this was due to the quantity of international students rather than an innate ability to produce more. This agreed with Hunt and Gauthier-Loiselle's findings that the number of immigrants mattered.[8]

AnnaLee Saxenian found supporting evidence that mobile immigrants provide opportunities and tech development. In her study of Silicon Valley, she illustrated how various policy changes affected the region. Loosening immigrant restrictions always saw labor force booms, primarily from Taiwanese, Chinese, and Indian scientists. As these faced challenges to their career development, they began to network with one another, building up new businesses.[9] As

[5] Kerr, "Breakthrough Inventions and Migrating Clusters of Innovation."
[6] Hunt and Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?"
[7] Stuen, Mobarak, and Maskus, "SKILLED IMMIGRATION AND INNOVATION: EVIDENCE FROM ENROLLMENT FLUCTUATIONS IN U.S. DOCTORAL PROGRAMS."
[8] Hunt and Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?"
[9] Kerr, "Breakthrough Inventions and Migrating Clusters of Innovation."

Saxenian learned from Silicon Valley, some of the most tech-forward enterprises in the nation were founded by Chinese or Indian immigrants.[10]

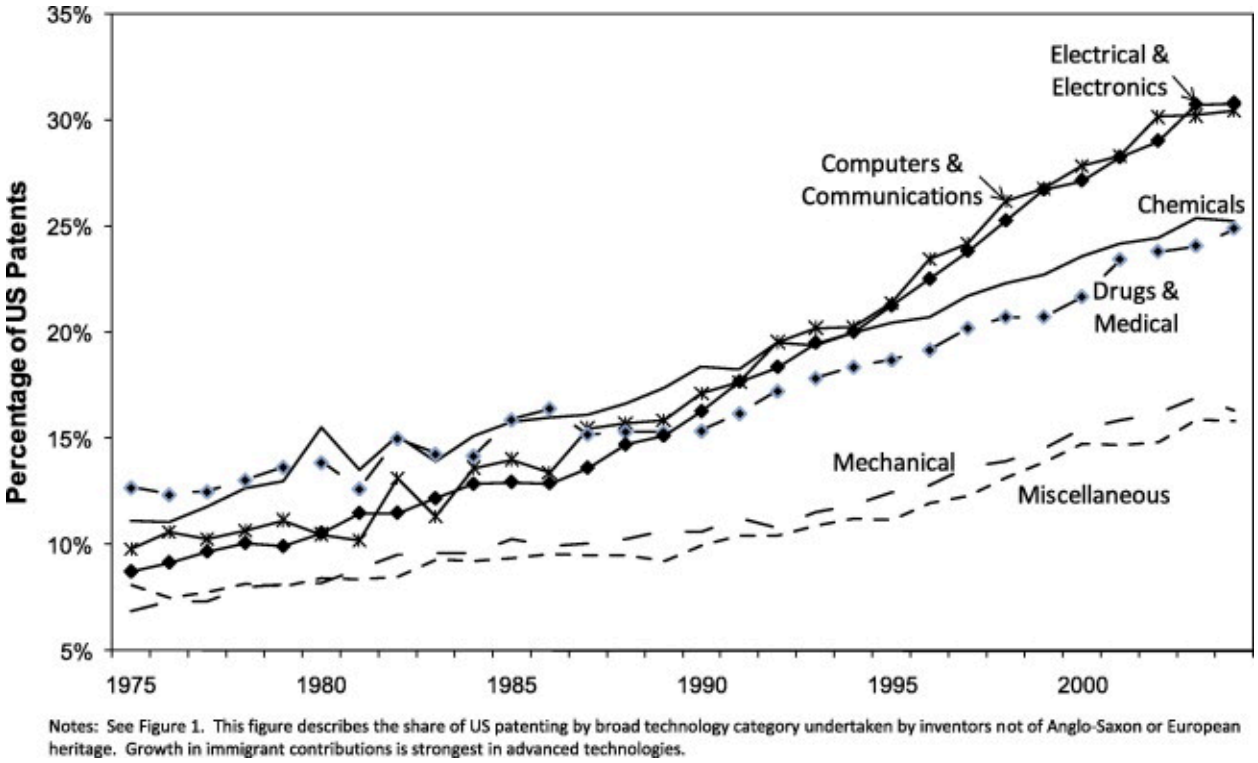
## High-Skill Takeaway

Together, the studies mentioned above show that high-skilled immigrants complement tech growth. Bahar et al. found immigrants are crucial to spreading specialized knowledge across borders.[11] Kerr found that immigrants can move around to keep breakthroughs going.[12] Hunt and Gauthier-Loiselle concluded immigrant scientists and engineers promote higher patents-per-capita.[13] Stuen et al. showed international students publish more in S&E journals.[14] Saxenian's case study showed when the US allowed more high-skilled immigrants to enter the country, the result was more innovation and entrepreneurship, the benefits of which are still being seen today.[15]

During these notable examples, immigration spikes after policy reforms signified a higher demand for American jobs than the US supplied. There were unrealized gains that these reforms were able to capture, which are paying off in the long run with immigrant entrepreneurship.

As tech is an ever-expanding sector, specialized knowledge brought by mobile immigrants helps speed it up even faster. In Saxenian's words, "Not only are skilled immigrants highly mobile, but the technology industries in which they are concentrated are the largest and fastest-growing exporters and leading contributors to the nation's economic growth".[16] So when expert immigrants move to where they can add the most value, they promote innovation breakthroughs. Because of the complementarity between high-skilled workers and tech growth, rates for both can grow together.[17] Kerr provided a graph of how the share of immigrant patents has grown since 1975, shown below. A clear upward trend shows that immigrant inventors have contributed more to innovation over time.

[10] "Silicon Valley's New Immigrant Entrepreneurs."
[11] Bahar, Choudhury, and Rapoport, "Migrant Inventors and the Technological Advantage of Nations."
[12] Kerr, "Breakthrough Inventions and Migrating Clusters of Innovation."
[13] Hunt and Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?"
[14] Stuen, Mobarak, and Maskus, "SKILLED IMMIGRATION AND INNOVATION: EVIDENCE FROM ENROLLMENT FLUCTUATIONS IN U.S. DOCTORAL PROGRAMS."
[15] "Silicon Valley's New Immigrant Entrepreneurs."
[16] "Silicon Valley's New Immigrant Entrepreneurs."
[17] Lewis, "Immigration and Production Technology."




Kerr, 2010. Fig. 2. Immigrant ethnic contributions by technology

People propel growth, and their ideas advance the range of possibilities. By collecting as many of the best minds as possible (natives and immigrants), the US can better boost tech growth rates and thereby improve the quality of life for all within its borders.[18]

The main takeaway is that in the arena of high-skilled immigrants, there is a strong relationship between immigration rates and tech growth. Immigration is an invaluable tool for long-term economic growth as high-skilled scientists and engineers have a strong, positive effect on technological development.

While high-skilled immigrants influence tech development, low-skilled immigrants also play a crucial role. This is examined in the following section.

## Low-Skilled Immigrants and Tech Expansion

The majority of the literature covering low-skill immigration targets wages (Lafortune et al. 2015, Jones 2020, for example). There is much less focus on how low-skill immigration interacts with tech growth. However, the studies that do look at low-skilled immigrants and tech provide a valuable illustration of how they interact. Research finds that low-skill and tech can still complement each other. This is consistent with economic theory as it expects labor to become more productive with the right tools. Interestingly, research found that low-skilled immigration can even accelerate the pace at which certain technologies are spread. What low-skilled

[18] Brunello, Garibaldi, and Wasmer, “Higher Education, Innovation and Growth.”

immigrants experience more than high-skilled immigrants, however, is the risk of being replaced by tech. The following case studies establish both complementarity and substitution depending on the sector.

## Accelerating Tech Adoption

Take the Age of Mass Migration, for example. Between 1820 and 1920, the US experienced a huge immigration boom, which brought a surge of low-skilled workers. Here, Sukkoo Kim found that low-skilled immigration helped manufacturing spread nationwide. Due to a factory's ability to separate complex tasks into simple specialized actions, factories were able to fill out their vacant positions from the sudden excess of low-skilled immigrants. This spurred factory growth, helping factories pop up all over the country.[19] With the passage of the 1921 Emergency Quota Act, immigration was curtailed, and factory growth slowed.[20] This illustrated the complementarity between improved immigration rates and the spread of tech (the factory model, in this case) across America. As one increased, so did the other; as one was halted, the other dropped off.

## Substitution Creeps In

The spread of the factory model during the Age of Mass Migration is compelling evidence that immigration and tech still complement each other, even when the immigrant is high or low-skilled. However, low-skilled immigrants face a threat that isn't often faced by high-skilled labor: displacement by machines. Therefore, stating that low-skilled immigration speeds up tech use is inadequate. Instead, it is more accurate to say changes in low-skilled immigration rates affect tech use differently depending on the sector.

One study of automation shows that restricting immigration in the agricultural sector led to more tractor use. Here, scholars Lew and Cater found a convenient natural experiment in the Northern Great Plains region in the early 1900s, in which both sides of the US-Canada border were nearly identical. As a result, they were great counterfactuals for each other with the same labor force composition, climate, products, policy, geography, and adoption rates of tractors. The natural experiment began in the 1920s when the US and Canada diverged in their immigration policies - the US became more restrictive, and Canada became less so. From then on, the US adopted more tractors while Canada hired more immigrant workers.[21] Recalling how similar conditions were across the border before the policy change, Lew and Cater argued the policy change caused the shift in tractor adoption rates. This provided a compelling look at how technology can substitute for low-skilled immigrants. The substitution away from scarce immigrant labor in the US led to the proliferation of the tractor at a greater speed than if immigration rates never changed. Therefore, the lower the rate of low-skilled immigration, the higher the adoption rate of agricultural machines.

[19] Kim, "Immigration, Industrial Revolution and Urban Growth in the United States, 1820-1920."
[20] Kim.
[21] Lew and Cater, "Farm Mechanization on an Otherwise 'Featureless' Plain: Tractors on the Northern Great Plains and Immigration Policy of the 1920s."

Like the natural experiment in the Northern Great Plains, the end of the Bracero program in the 1960s was another great case study. Shmuel San studied the effects of ending the program and found "...the Bracero exclusion induced a sharp increase in innovation in technologies related to crops with a higher share of Bracero workers relative to crops with a lower share".[22] In other words, when immigrant labor was suddenly unavailable, farmers were forced to innovate new tech to keep up production. The jump in innovation is seen in the graphs below. This is strong supporting evidence that tech and immigration have a substitutive relationship in the agricultural sector.

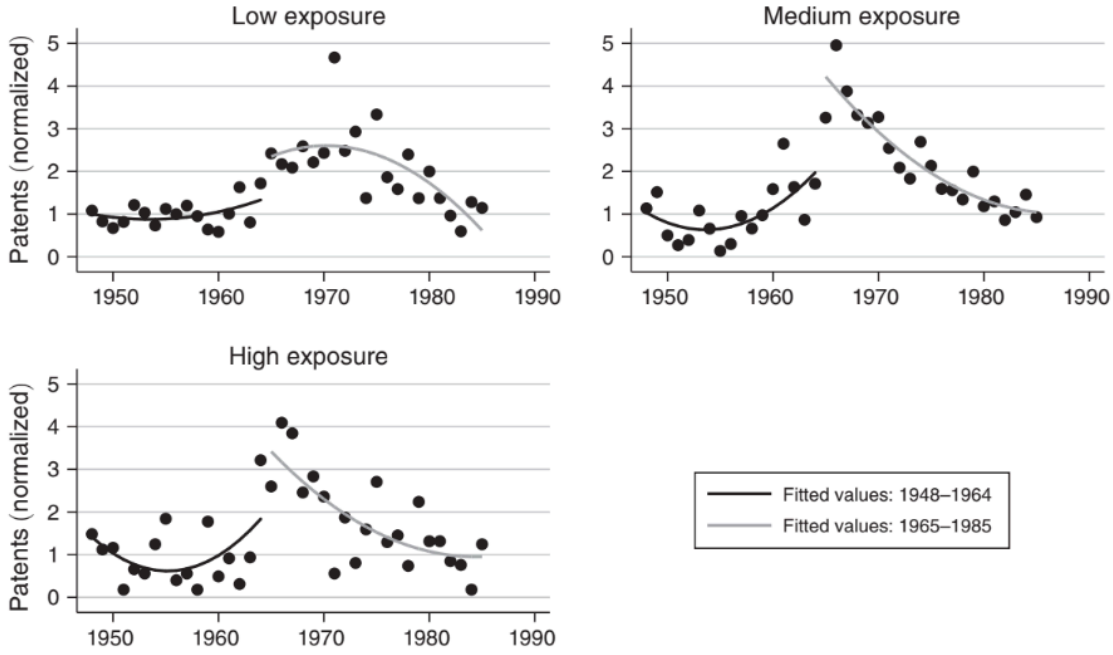



FIGURE 2. INVENTION OVER TIME FOR CROPS WITH LOW, MEDIUM, AND HIGH EXPOSURE TO THE BRACERO PROGRAM

*Notes:* Low exposure: six crops with at most 3.8 percent of foreign workers. Medium exposure: five crops with between 3.8–26.2 percent foreigners. High exposure: five crops with at least 26.2 percent foreigners. The normalized patents measure is the average normalized number of patents for the crops in the exposure group. Each crop-year observation is divided by the crop's pre-period (1948–1964) average number of patents per year.

San, 2023. Fig. 2. Invention over Time for Crops with Low, Medium, and High Exposure to the Bracero Program[23]

However, San quickly pointed out that tech is only sometimes an adequate substitute. After his analysis, San's results "...show that a negative shock to the supply of low-skilled labor, implied by immigration restrictions, is harmful to farm owners even in the medium and long run, despite

[22] San, "Labor Supply and Directed Technical Change: Evidence from the Termination of the Bracero Program in 1964."
[23] San.

the positive technology reaction".[24] Even though they could fill the void with tech, farmers' profits suffered in the long run without immigrants and all the benefits they bring to an economy.

| Case Studies | Manufacturing | Agriculture |
|---|---|---|
| **Changes in Low-Skilled Immigration Rates** | More immigrants, more factories | Fewer immigrants, more tractors/innovation |

Low-skilled immigrants know their substitutionary relationship with tech can also go both ways. Capital-skill substitutability is a big concern for those at the bottom of the vocational food chain as their jobs are being automated first. When looking at the effect of robot implementation on jobs, Mohsin Javed found that "...robot adoption leads to differential job losses for immigrants in the US, and the employment effect for immigrants is approximately 1.76 times that observed for natives… …the burden of robot adoption falls disproportionately on recent immigrants and foreign-born men and women".[25] Through his analysis, Javed concluded that automation affects different workers depending on their skill level. He argued that low-skilled workers are met with displacement while high-skilled workers enjoy productivity boosts and invent better tech.

Regarding the substitutional relationship, Lant Pritchett believes the US can bring in more low-skilled labor to benefit the country. Automation can displace low-skilled workers, but the relationship can work the other way, too. If the US loosens restrictions on immigration, Pritchett argues, then entrepreneurs can fill niches in the market with "the world's most abundant resource" instead of using time and money to innovate a redundant solution.[26] By filling specific needs with human labor instead of automation, the US can refocus its best minds to tackle issues that *can't* be solved with abundant human labor. For example, self-driving cars could easily be replaced with hired drivers. Meanwhile, innovators could focus their engineering expertise on energy abundance efforts, solving water desalination roadblocks, etc.

Like their higher-skilled counterparts, low-skilled immigrants bring other spillover benefits to those around them. During a recent interview, Pritchett argued that increasing immigration by almost 4 times what it is today would generate gains comparable to the total GDP of France. He claimed most of these gains would go straight into the immigrants' pockets, safeguarding against any further danger of inequality.[27] While this is a dramatic example of an immediate benefit, Pritchett's overall argument is tied back to the idea of stacking the deck for long-term growth. The US should not scale back any existing innovations but instead rework incentives going forward so that future inventions will be focused on more complex issues.

[24] San.
[25] Javed, "Robots, Natives and Immigrants in US Local Labor Markets."
[26] Kurtz-Phelan, *Immigration Before Automation: A Conversation With Lant Pritchett*.
[27] Kurtz-Phelan.

### Low-Skill Takeaway

While the literature surrounding low-skilled immigrants mainly focuses on the effects of automation, it is clear that complementarity and substitution exist. Like their higher-skilled counterparts, low-skilled immigrants can enjoy boosted productivity through using tech and even accelerate the pace at which certain tech spreads. However, unlike the higher-skilled, they also have a substitutionary relationship with tech. The main takeaway is that changes in low-skilled immigration rates affect tech use differently depending on the sector. This framework helps explain the intersection between the two different arenas of immigration and technological growth.

| Effects of Immigration and Technological Growth on One Another | High-Skilled Immigration | Low-Skilled Immigration |
|---|---|---|
| **Technological Growth** | High-skilled immigration affects the number of patents and where a country specializes. | Low-skilled immigration can affect the speed at which specific tech is adopted. Automation disproportionately substitutes these immigrants. |

# Policymaking Strategies

## Expand Options for Permanent and Temporary Immigration

Currently, the US is facing a shortage of workers that can be filled with both natives and immigrants. Workers of all skill levels have a role in influencing technological progress in the US. High-skilled immigrants can share their expert knowledge, increase patent supply in science and engineering, and catalyze innovation among their native peers.[28] Meanwhile, low-skilled immigrants can accelerate the use of specific technologies and fill abundant job vacancies - allowing entrepreneurs to use their time and resources to make worthwhile developments instead of redundant tech.[29] Both high and low-skilled labor can bring value to the economy.

Improving options for temporary worker visas would be a big step forward. Some foreign-born workers only want to stay temporarily. They represent a whole demographic of workers eager to work in US-based jobs. They may offer significant gains for US GDP.[30] By blocking temporary worker programs, the US may miss out on the benefits these workers would otherwise bring to

[28] Bahar, Choudhury, and Rapoport, “Migrant Inventors and the Technological Advantage of Nations.”, Kerr, “Breakthrough Inventions and Migrating Clusters of Innovation.”, Hunt and Gauthier-Loiselle, “How Much Does Immigration Boost Innovation?”
[29] Kim, “Immigration, Industrial Revolution and Urban Growth in the United States, 1820-1920.”, *Lant Pritchett*.
[30] “Silicon Valley’s New Immigrant Entrepreneurs.”

the economy.[31] These would-be contributors will take their gains elsewhere. By loosening restrictions on temporary workers and permanent immigrants of all skill levels, the US can capture unrealized gains and innovations to stack its deck for long-term economic growth.

Another approach to increasing the stock of high-skilled STEM workers is to use subsidies to incentivize natives to specialize in tech fields. While improving education and training its scientists is critical for the US's long-term growth, subsidies risk sacrificing the long run for short-term gains. Subsidies would fill tech positions with people who may have a lower comparative advantage than experienced immigrants.[32] In Hunt and Gauthier-Loiselle's own words, "The additional natives drawn into science and engineering might have lower inventive ability than the excluded immigrants, and such natives might have contributed more to the US economy outside science and engineering." [33] By using subsidies to block high-skilled immigrants from entering the workforce, the US would miss out on the benefits described earlier. Instead, improving education while hiring high-skilled immigrants would help the US attract the best and brightest while producing the best and brightest.

## Promote Optional Practical Training and H-1B

One attractive option for prospective workers would be Optional Practical Training (OPT). While H-1B is already a known, longer-term option for immigrants who want to stay and work in the US, it is a lottery, making it difficult for an individual to secure their visa. Instead, OPT lets non-immigrants stay and work in the US for a time after completing a degree and allows a buffer (up to 3 years) for workers trying to get H-1B status. Researcher Pauline Khoo reports, "...international students do value work experience in the United States and make their schooling decisions on that dimension. Policies that restrict their ability to gain work experience will adversely affect their higher education enrollment in the US. These implications should be taken into consideration as policymakers consider suspending the OPT program".[34] OPT is an effective tool to boost international student enrollment and graduation in STEM fields, from bachelor's to doctorate.

H-1B has its merits, too. Despite many immigrants' difficulties with the program, it is a legitimate pathway to gain employment in the US. Raising the H-1B cap would allow more experts to contribute to the economy. This includes increasing the productivity of high-tech firms and helping younger firms bring in the talent they need to survive and compete against older firms.[35] Improving the availability of both the OPT and H-1B programs is a worthwhile change.

A 2010 study by Kerr and Lincoln provided more support for H-1B. They found that higher H-1B admissions were met with more immigrants working in science and engineering fields and that patenting by Chinese and Indian inventors increased. The authors concluded, "...immigrant

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[31] Kurtz-Phelan, *Immigration Before Automation: A Conversation With Lant Pritchett*.
[32] Hunt and Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?"
[33] Hunt and Gauthier-Loiselle.
[34] Khoo, "If You Extend It, They Will Come."
[35] Mandelman, Mehra, and Shen, "Skilled Immigration Frictions as a Barrier for Young Firms."

scientists and engineers are central to U.S. technology formation and commercialization. Immigrants represented 24% and 47% of the U.S. SE workforce with bachelor's and doctorate educations in the 2000 census, respectively".[36] The resulting uptick in immigrant patenting showed high demand for US jobs blocked by restrictive policy.

While arguing for the expansion of available H-1B visas, Kerr and Lincoln stated, "While the H-1B program does not have the size to dramatically alter aggregate levels of U.S. invention in the short run, it does have the size to substantially influence the growth rate of U.S. innovation…" It's a case of building a deck for long-term payoffs. The authors continued: "We conclude that total invention increased with higher admissions primarily through the direct contributions of immigrant inventors." [37] The more immigrant inventors were allowed into US jobs, the more they contributed to the tech world.

## Attract Experts for CHIPS

As Saxenian found, Taiwanese inventors were among the largest contributors to the success of Silicon Valley.[38] Additionally, Bahar et al. found bringing in experts helped boost patenting in their specialized fields.[39] Pursuing the options described above is in its best interest if the US wants to leverage the CHIPS Act to ensure semiconductor self-reliance. By attracting Taiwanese experts and improving pathways for them to enter the workforce, the US can set itself up for rapid growth in the semiconductor industry. Again, highly-skilled immigrants (and temporary workers) bring direct contributions and spillover effects that propel innovation even further.[40]

## Policy Takeaway

Improving domestic STEM personnel is a worthwhile goal, but training and employing new scientists and engineers takes time. In the meantime, bringing in high-skilled immigrants from abroad is the best way to catalyze invention while simultaneously stacking the US's deck for long-term tech growth. As the supply of experts in certain technologies (like semiconductors) is scarce, reducing the barriers they face when entering the country is crucial. Attracting experts will bring their knowledge and all the beneficial spillover effects of high-skilled immigration. The US should look to the global talent pool to permanently or temporarily fill its shortage of scientists and engineers.

# Conclusion

Immigration and technological growth affect each other in significant and nuanced ways. High-skilled immigrant scientists and engineers stand ready to launch innovation forward.

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[36] Kerr and Lincoln, "The Supply Side of Innovation: H-1B Visa Reforms and U.S. Ethnic Invention."
[37] Kerr and Lincoln.
[38] "Silicon Valley's New Immigrant Entrepreneurs."
[39] Bahar, Choudhury, and Rapoport, "Migrant Inventors and the Technological Advantage of Nations."
[40] Hunt and Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?"

Low-skilled immigrant workers stand ready to fill whatever market niches are appropriate, redirecting invention efforts toward other endeavors that can't be solved simply with more human labor.[41] Meanwhile, low-skilled immigration can also speed up the adoption of new, worthwhile innovations. Policymakers interested in promoting long-run economic growth and prosperity through initiatives like the CHIPS Act should use immigration's effects on tech as vital tools.

I recommend increasing accessibility to permanent programs like H-1B and expanding temporary work programs like OPT. These changes can better position the US to attract as many of the best minds as possible into its labor force. With them, these best minds bring expertise and entrepreneurship to benefit long-term tech growth efforts and catalyze immediate growth in S&E fields. Allowing for permanent or temporary low-skilled immigration also has a role to play. These workers influence how quickly technology use spreads from sector to sector, and their presence can help redirect high-skilled inventors toward efforts that aren't simply automation. Policymakers should focus on expanding permanent and temporary programs to capture the most value possible.

[41] *Lant Pritchett*.

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