

Science, Technology, Engineering, and Mathematics (STEM) Career Attractiveness¹

Andjelka Kelic

Aldo Zagonel

Critical Infrastructure Modeling & Simulation, Sandia National Laboratories²

PO Box 5800, MS 1137, Albuquerque, NM 87185-1137

Tel: (505) 844-5266 / Fax: (505) 284-3850

akelic@sandia.gov, aazon@sandia.gov

Abstract

A system dynamics model was developed in response to the apparent decline in STEM candidates in the United States and a pending shortage. The model explores the attractiveness of STEM and STEM careers focusing on employers and the workforce. Policies such as boosting STEM literacy, lifting the H-1B visa cap, limiting the offshoring of jobs, maintaining training and a combination of strategies are explored as possible solutions.

The system is complex, with many feedbacks and long time delays, so solutions that focus on a single point of the system are not effective and cannot solve the problem. A deeper understanding of parts of the system that have not been explored to date is necessary to find a workable solution.

Keywords: STEM, education

INTRODUCTION

This work was prompted by the National Academies' report, "Rising Above the Gathering Storm," follow-on discussions, and workshops that highlight concerns regarding the decline and potential shortage of science, technology, engineering and mathematics (STEM) candidates in the US educational system. The concern is that the decline is likely to result in a shortage of a STEM educated domestic labor force and a loss of US competitiveness in STEM-related fields.

Reasons cited for the cause of the shortage vary widely depending on the sector that they originate in. There are also competing viewpoints on whether a shortage of STEM workers even exists. Business and academia claim that there is an inadequate supply of STEM workers, while STEM workers [1] and economic indicators [2] disagree.

¹ The research described in this paper was funded by The Boeing Company, Principal Investigator Michael Richey, under CRADA/PTS agreement number 1651.16.00.

² *Sandia* is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The system that produces a STEM educated workforce consists of local and federal government, K-12 education, higher education, the STEM workforce and employers as large stakeholder groups. The goal of all of these stakeholders is to produce people educated in STEM that enter and stay in the STEM workforce. Prior modeling efforts focused heavily on the K-12 education portion of the system (see [3] and [4]). The Boeing/MIT model and the Raytheon model described in [3] explore teacher salary in comparison with the salary for STEM educated people in industry along with teacher quality and quantity. The Raytheon model touches on higher education and the entry of the STEM literate into the workforce, but does not explore those segments in detail. In order to gain a better understanding of the system as a whole, the work described in this document focused on the STEM workforce and employers, with a lesser focus on higher education through the idea of the attractiveness of STEM as a career. The other stakeholders are included, but not modeled in detail.

Figure 1 shows the different sectors that comprise the system that results in skilled people in the STEM workforce and where some of the modeling efforts have focused. The sectors are: K-12 education, higher education, STEM workforce, local government, federal government, and employers.

Grey depicts sectors that are touched on, green sectors have been covered in some detail, black sectors have not been covered, and blue sectors are covered in the current work. The red item -- “attractiveness of STEM careers” -- is the focus of the current model. In order to explore the attractiveness of STEM careers factors that affect the STEM workforce, employers, and the federal government need to be examined in more detail than has been done in past models. The work explores the possible causes of the disparate viewpoints on whether there is a shortage, potential causes, and potential solutions.

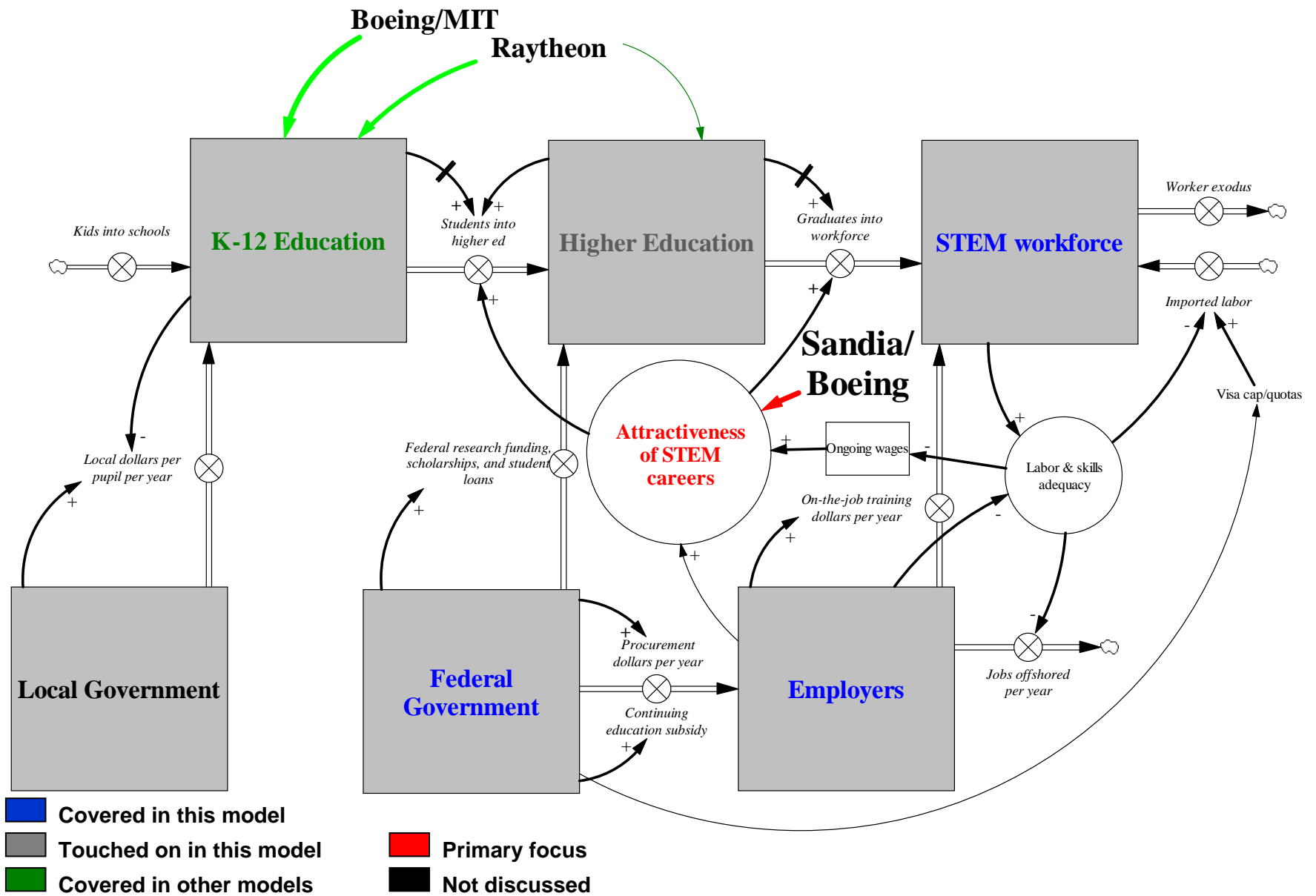


Figure 1: Stakeholder Groups and Focus of Work

MODEL OVERVIEW

The model was designed to capture the movement of students through the educational system and into the workforce, focusing primarily on the attractiveness of STEM, or the factors that cause students to choose STEM as a degree field and subsequently continue on into a career in STEM. The model also explores employers and job availability from the perspective of the economics of the firm, including the pressure to cut costs to be globally competitive by offshoring jobs, and cutting funding to continuing education initiatives. Firms in the model also have the ability to hire foreign workers through the H-1B visa program as a way to augment the size of the workforce.

Figure 2 shows the factors that affect attractiveness of STEM in the model. Attractiveness of STEM careers is affected by wages and risk perception of STEM as a career. The risk perception of STEM careers is in turn affected by STEM job tenure, the amount of employer-supplied continuing education, and offshoring. The attractiveness of STEM careers affects both the people seeking employment in STEM and the number of high school graduates deciding to enter STEM degree fields.

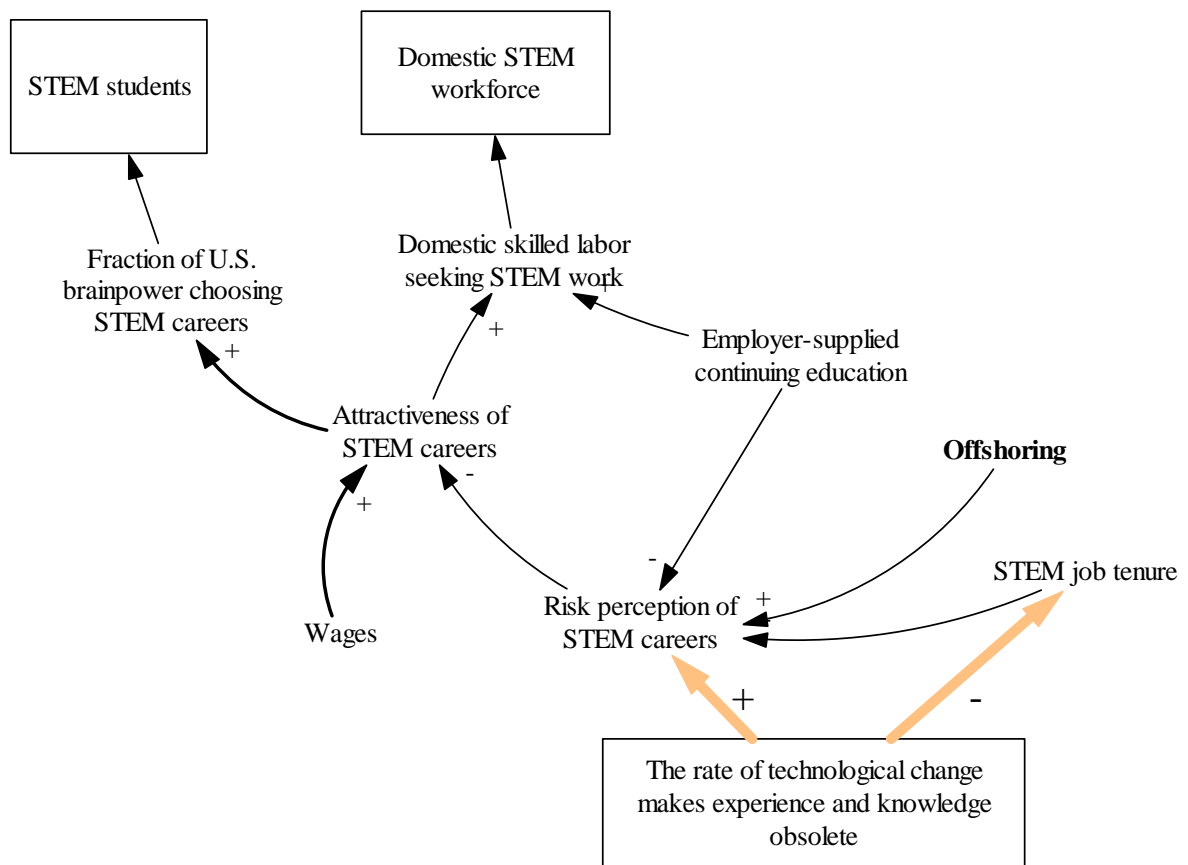


Figure 2: Attractiveness of STEM

From the perspective of the workforce, the model looks primarily at wages and the risk perception of STEM as a career as factors that influence attractiveness. While many

other factors may play into whether STEM is considered attractive, these were chosen as the factors to model because they are the indicators that can easily be observed by people choosing whether to enter into STEM fields. The risk perception of the career is governed by job availability and job stability – e.g. can a person with a STEM degree get a job? Will that person still have a job in a few years?

The workforce in the model is broken up into both entry level and higher level workers. Similar factors affect both of these pools of labor. Their differences will be discussed in detail in the model results section.

Figure 3 shows the factors included in the model that affect job availability and the efforts of firms to economize to become globally competitive. When wages begin to rise, as they would in a shortage of available labor, firms have several options to cut costs and economize. In the model, the available options are cutting the amount spent on continuing education and offshoring of jobs. The decision to economize by cutting the amount of continuing education available links back to the attractiveness of STEM as shown in Figure 2 by increasing the risk perception. This in turn reduces the number of people in the workforce, reducing the adequacy of the labor pool and triggering the desire to hire foreign labor.

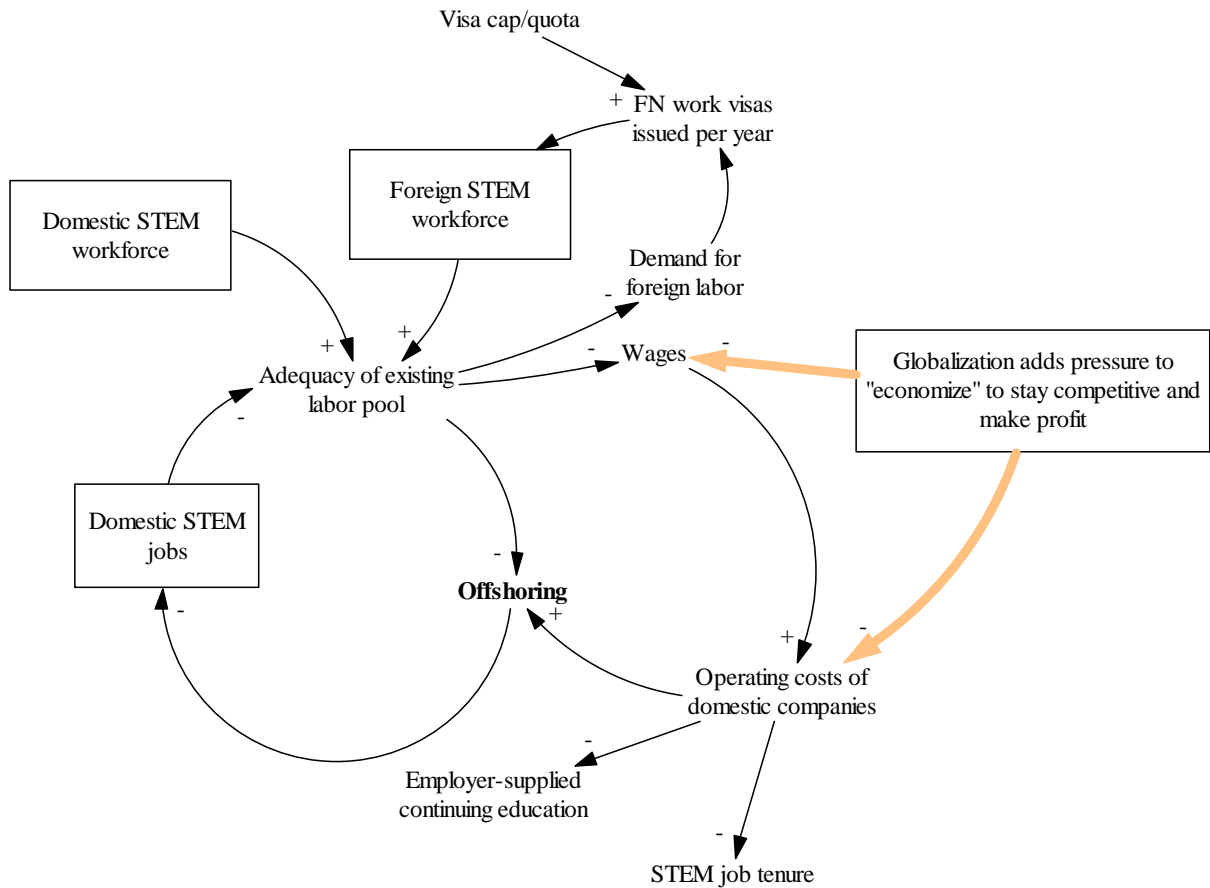


Figure 3: Pressure to economize

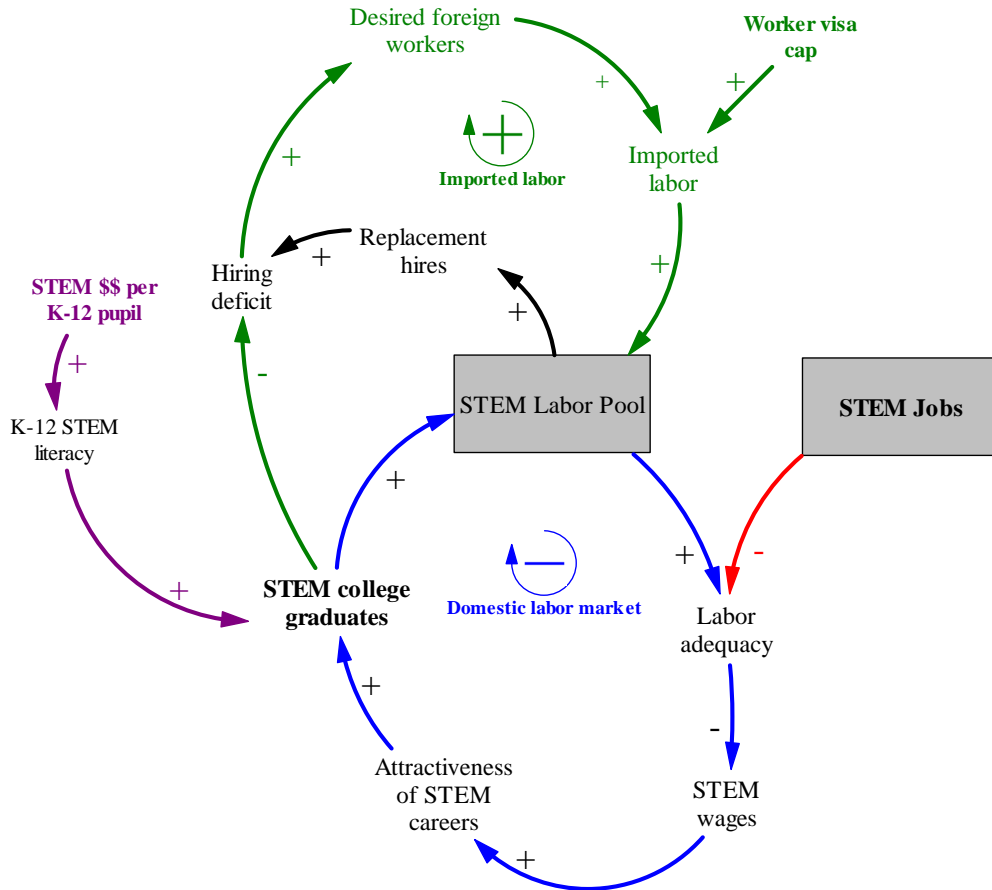


Figure 6: Importation of foreign labor causal diagram

An additional way to reduce operating costs that is captured in the model is to cut back on corporate-sponsored training. The model assumes that the maximum amount of corporate provided training is 80 hours per year with an average of 40 hours per worker per year.

Reduced training shortens the lifetime of entry-level workers' STEM skills, particularly in a fast-changing technological environment. Without retraining employees, employers are implicitly opting for replacing the workforce more frequently with a fresh batch of college graduates with up-to-date skills. This results in a "revolving door" of entry level positions and lower perceived STEM career stability as shown in Figure 7.

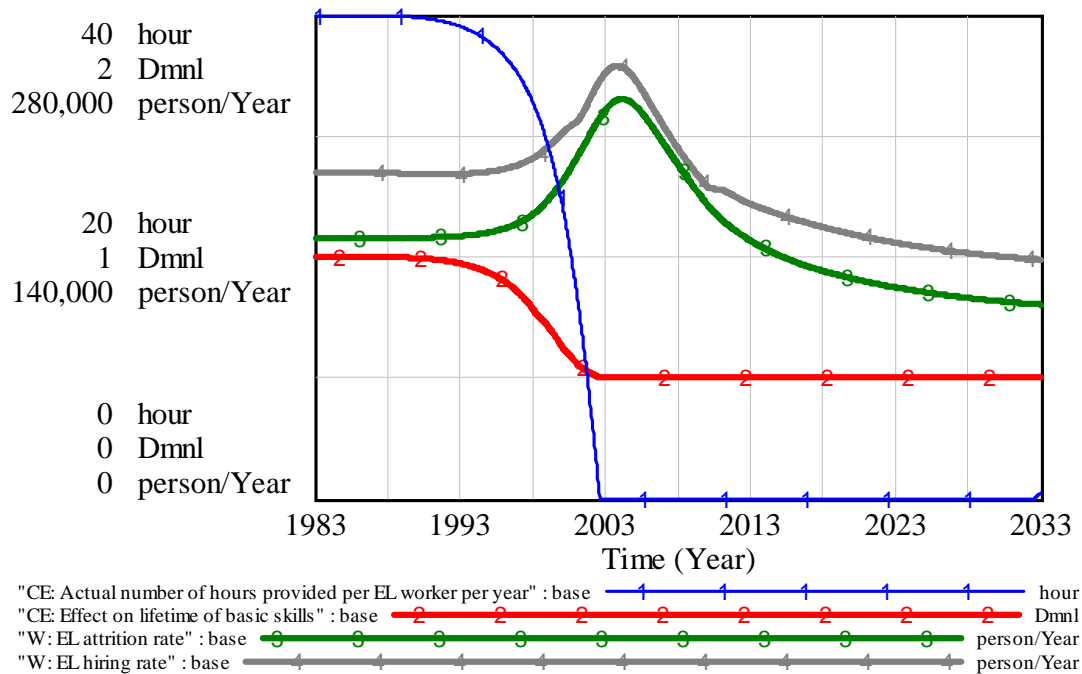


Figure 7: Entry level revolving door: base run

Figure 8 adds the continuing education and offshoring loops to the diagram. As wages go up, pressure to economize also goes up and the willingness to allocate funds to corporate sponsored training goes down. This causes the length of lifetime of skills to go down along with the number of people eligible for jobs and the size of the labor pool. As the skills lifetime of current workers deteriorate, their length of stay in the job goes down, and they need to be replaced with new entry level workers.

Employers can also offshore entry level jobs to places where people with basic skills are more affordable in response to rising wages. As a result, the pool of domestic jobs available at the entry level decreases. Offshoring of jobs becomes more attractive as domestic wages increase. At a particular threshold it becomes more economical to offshore jobs which causes the required size of the domestic labor pool to decrease and helps hold wages down.

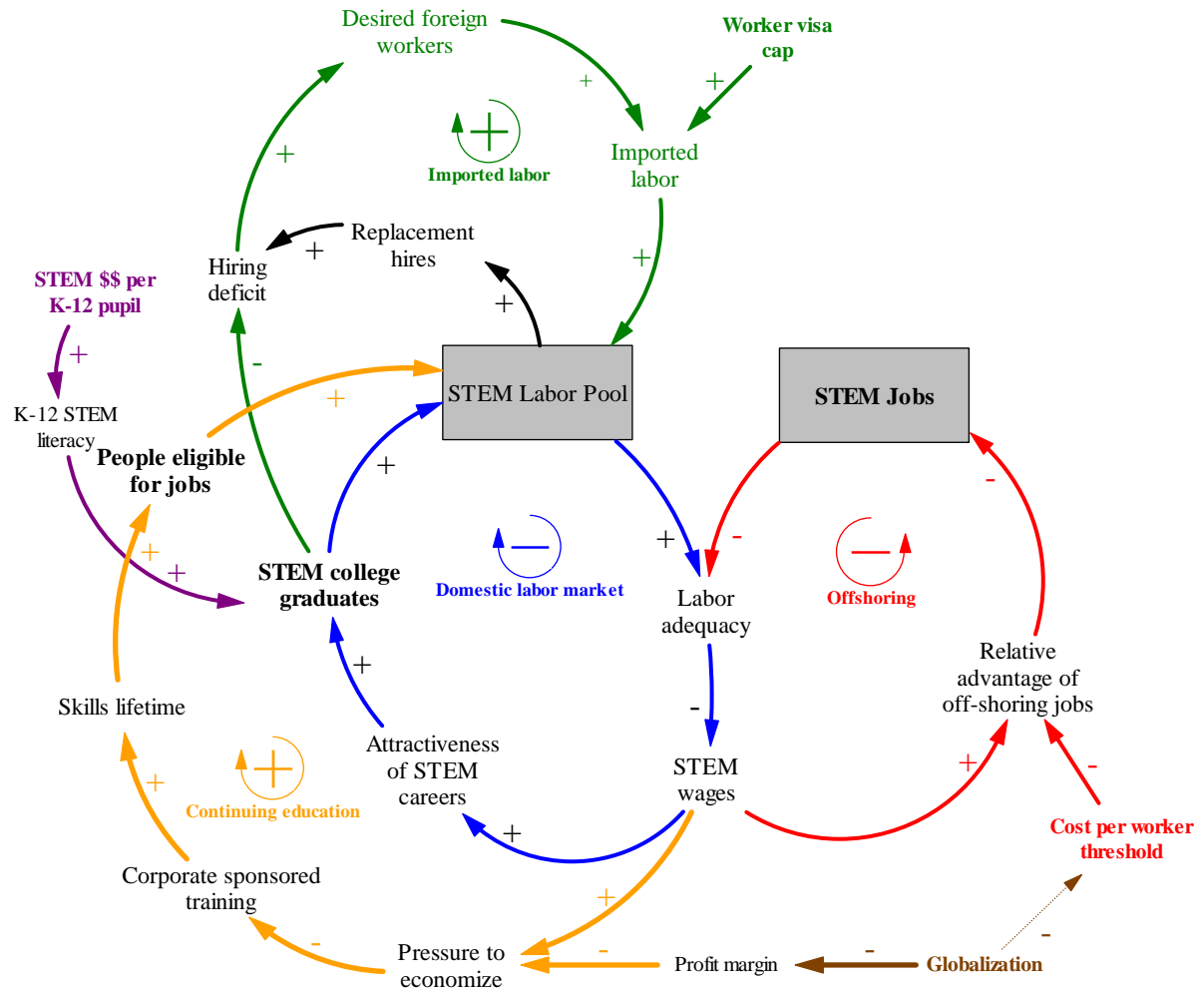


Figure 8: Offshoring causal diagram

The overall attractiveness of the STEM field is a composite measure made up of wages, the likelihood of getting an entry level job, offshoring, promotion potential, and career potential. In the base run, initially the attractiveness of STEM rises due to increasing entry level wages and a high likelihood of getting a first job. As shown in Figure 9, eventually attractiveness falls because those factors are not sustainable due to declining tenure in entry level jobs and loss of domestic jobs due to offshoring.

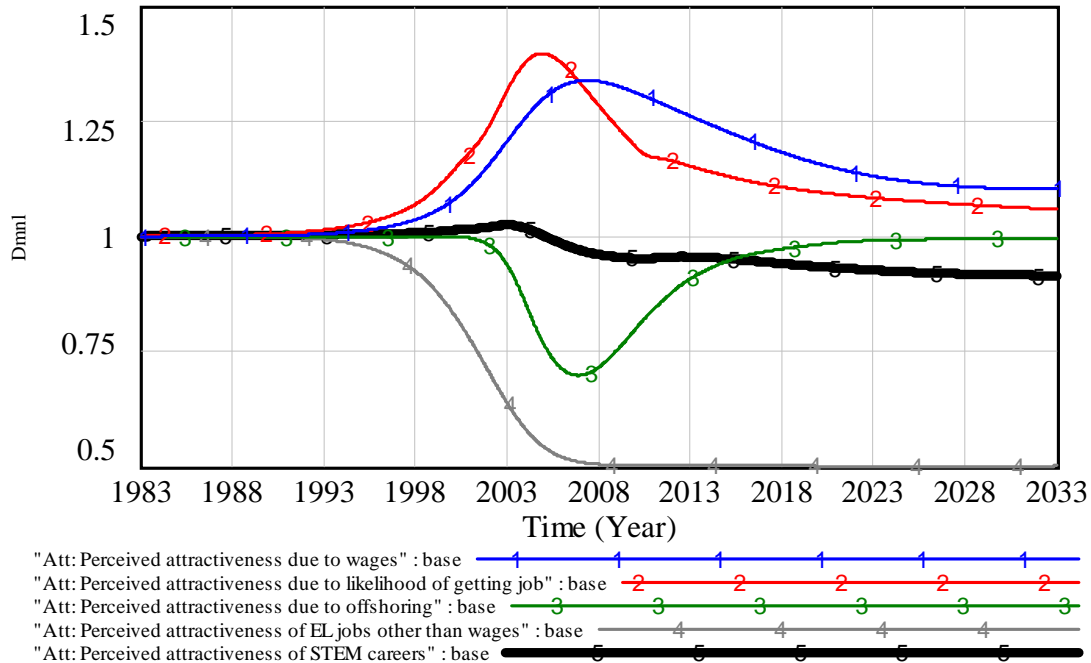


Figure 9: Attractiveness of STEM careers: base run

The factors as discussed to this point apply to entry level jobs. Similar effects occur in higher level jobs. As the rate of people with basic degrees becoming obsolete rises; many choose to retrain themselves by joining a higher-level graduate program. As a result, the number of people with basic degrees eligible for entry-level positions falls drastically as shown in Figure 10.

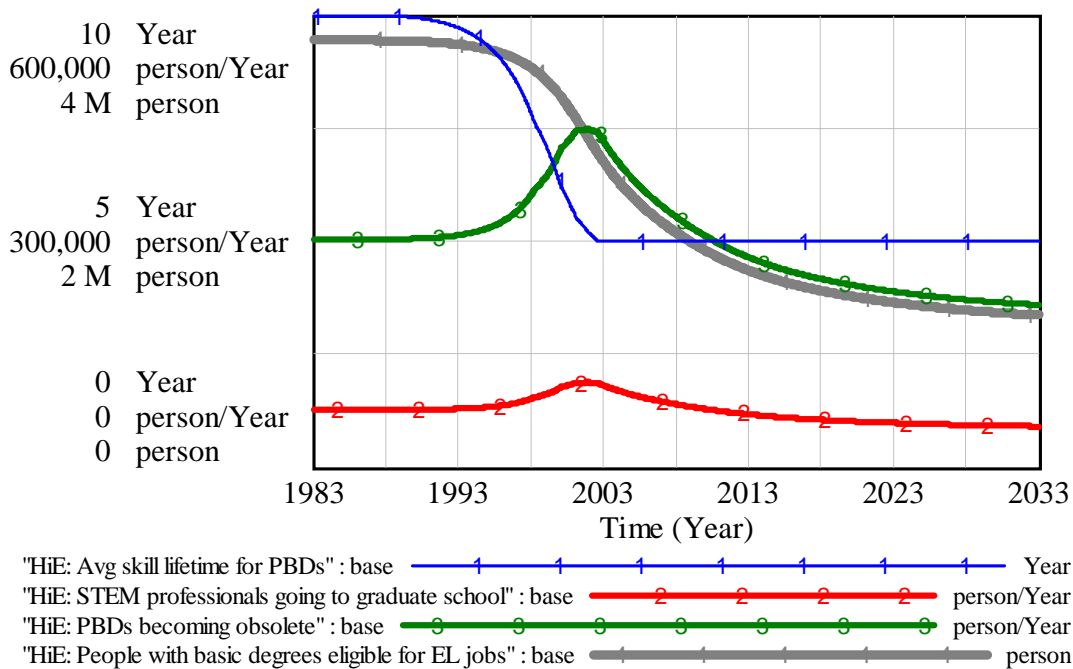


Figure 10: Deteriorating skills: base run

As those deciding to stay in the STEM field choose to pursue graduate programs to maintain or augment their skills, enrollment, attendance and graduation from higher-level programs rises. This creates an increase in the supply of people with advanced degrees and a resulting surplus of higher-level labor, the red line in Figure 11. This increase is not sustainable, since the number of people with undergraduate degrees is declining. The blue line in the figure depicts the shortage of entry level labor. The shortage becomes less severe as domestic entry level jobs are offshored and never replaced. Currently, there is both a shortage of entry level labor and a surplus of people seeking higher level jobs. The model captures the opposing viewpoints of employers and STEM workers.

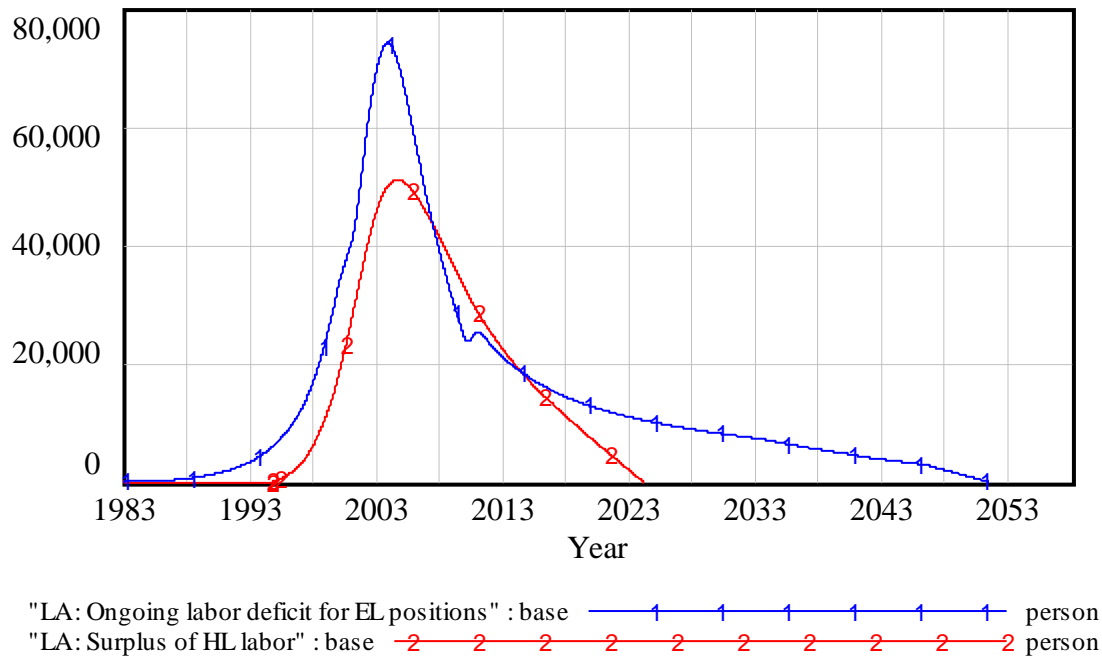


Figure 11: Entry level deficit and higher level surplus: base run

POLICY OPTION IMPLEMENTATIONS

The model allows for the exploration of several different proposed policy solutions. This section describes the implementation of the examined policies in the model. The policy options include lifting of the H-1B visa cap, boosting STEM literacy, curbing the offshoring of jobs, and maintaining training.

Lift H-1B visa cap

This run assumes that there never was a visa cap. Therefore, the entry-level labor gap can be covered via importation of labor. Normally, policy changes are enacted in the current or subsequent years. However, since the base run shows the limiting effect of the cap happening between 2001 and 2009 the effects of removing the cap are more easily seen if it is not included initially. The cap is a temporary limiting factor and could happen at any

point, thus eliminating it altogether can show whether the cap itself is beneficial or harmful to the pool of STEM candidates.

Boost literacy

This policy entails raising the level of literacy in K-12 education to its 1983 value. To achieve this result, an immediate increase in STEM resource adequacy is used to correct for the steady deterioration portrayed in the base run scenario.

It takes 10-15 years to achieve the intended objective of the policy, because it takes 12 years to move an entire cohort of children through basic education at the new resource level. Children who are partway through the process cannot “catch up” due to existing deficiencies unless additional resources are put in place to help them do so. This policy corrects for the “assumed scenario” of what is causing the STEM problem: deterioration in science and math education originating in basic education. The number of people considering STEM degrees does not return to pre-decline levels until 15 years after resource adequacy is boosted to its pre-decline level.

Curb offshoring of jobs

This policy does not eliminate offshoring of jobs, but curbs it significantly (“willingness to offshore entry level jobs is changed from 1 to 0.1). Similar to the implementation of the policy to lift the visa cap, this policy is in place throughout the simulation to better visualize its full potential effect. This policy would require incentives from the federal government or changes in laws to implement.

While the rate of jobs being offshored is significantly reduced, this rate is sustained over a longer period of time and, eventually, is greater than in the base run. Thus, in the very long run, curbing offshoring will tend towards a similar number of accumulated job losses.

Maintain training

This policy maintains the amount of “corporate-sponsored” continuing education throughout the simulation for both entry-level and higher-level workers. In other words, it guarantees that employers will not curb training to economize on operating costs whenever labor costs increase (nor increase training if wages fall and there is some surplus money in the operating budget).³

POLICY COMPARISONS

This section compares the effects the various policies have on key variables of interest.

³ The policy implies the existence of a financial mechanism to create and maintain this incentive, such as a governmental subsidy or tax benefit, just as the policy of curbing offshoring of jobs would also require some sort of incentive mechanism to achieve its intended goal.

Boosting STEM literacy in basic education is the only policy that will reestablish the original level of interest in STEM degrees and careers by high-school graduates as shown in Figure 12. Students considering STEM degrees in the model are all students with adequate levels of STEM literacy. Since the model has no feedback mechanisms into STEM literacy, no other policy can have as dramatic an effect. The other policies can only affect people that have the necessary levels of STEM literacy already.

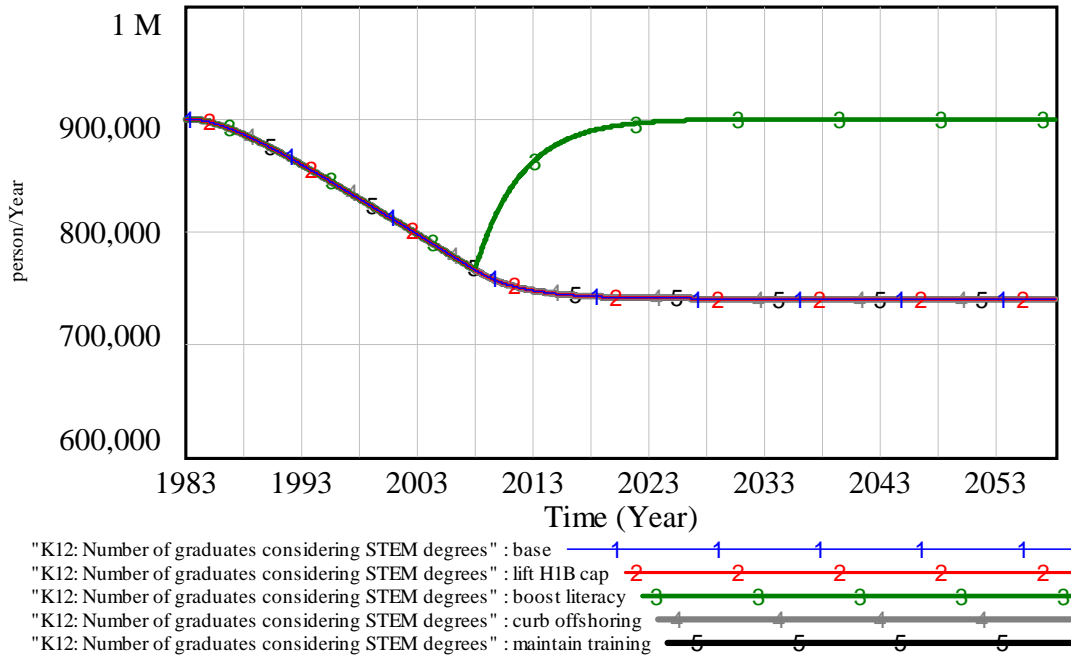


Figure 12: High school graduates considering STEM degrees

If the attractiveness of the STEM field could alter the students’ literacy or ability to excel in science and math K-12 education then the feedback into the K through 12 portion of the model could be closed and other policies could change the number of STEM eligible graduates. However, attractiveness does not have this affect and only “curbing offshoring” and “maintaining training” are able to enhance the attractiveness of the STEM field and career as shown in Figure 13.

If the feedback existed, an isolated effort to increase STEM literacy in K-12 education would likely be ineffective, because it does not address the problem of “perceived unattractiveness” of this field due to factors explored further below. Students would be better equipped for STEM careers but not be inclined to pursue them.

Successful curbing of offshoring of jobs quickly increases the attractiveness of the STEM career, whereas sustained corporate-sponsored continuing education increases it over the longer time horizon.

Curbing the process of offshoring jobs alone is not a sustainable strategy to maintain the attractiveness of the field, whereas continuing education does sustain gains in perceived attractiveness.

Lifting the H-1B visa cap does little to improve attractiveness as compared to the base run. In the short term, it makes the field even less attractive to the pool of high-school graduates deciding on what degrees to apply for in college.

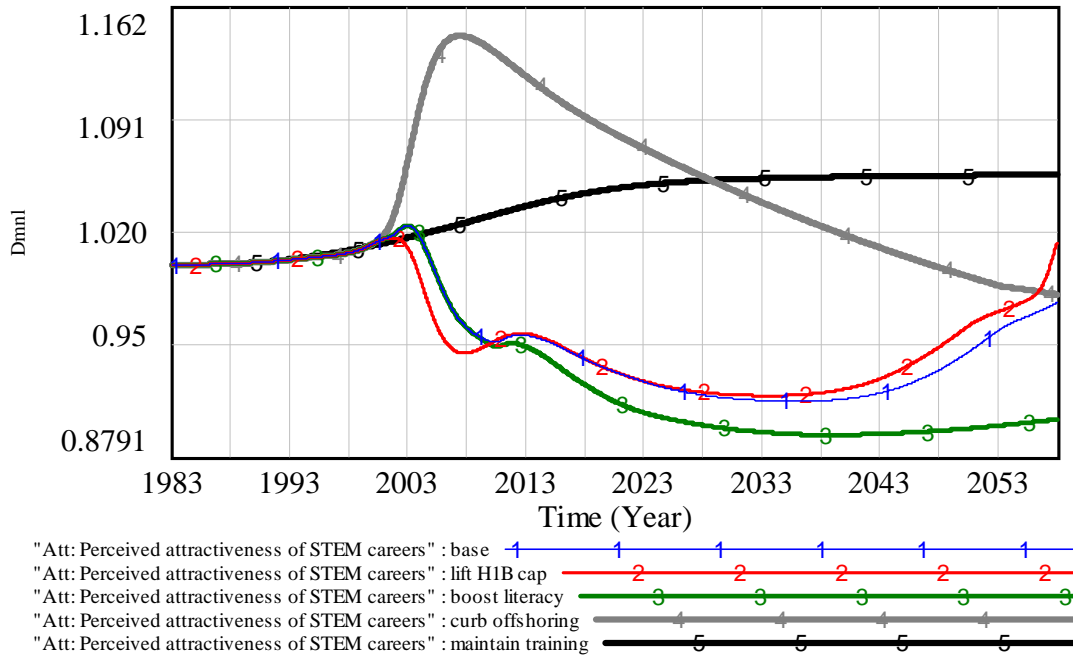


Figure 13: Attractiveness of STEM careers

None of the policies, used in isolation, can recoup and sustain gains in the falling graduation rates. Due to the “attractiveness” factor, curbing the offshoring of jobs does well in the short term, while maintaining training reverses the trend and sustains the level of college output in the labor market, albeit at a lower level.

For entry-level positions and workers, the policy to maintain training avoids a large labor deficit, while sustaining marginal wage increases as shown in Figure 14 and Figure 15. The only other policy that stands out from the base run is curbing the offshoring of jobs which boosts entry-level wages.

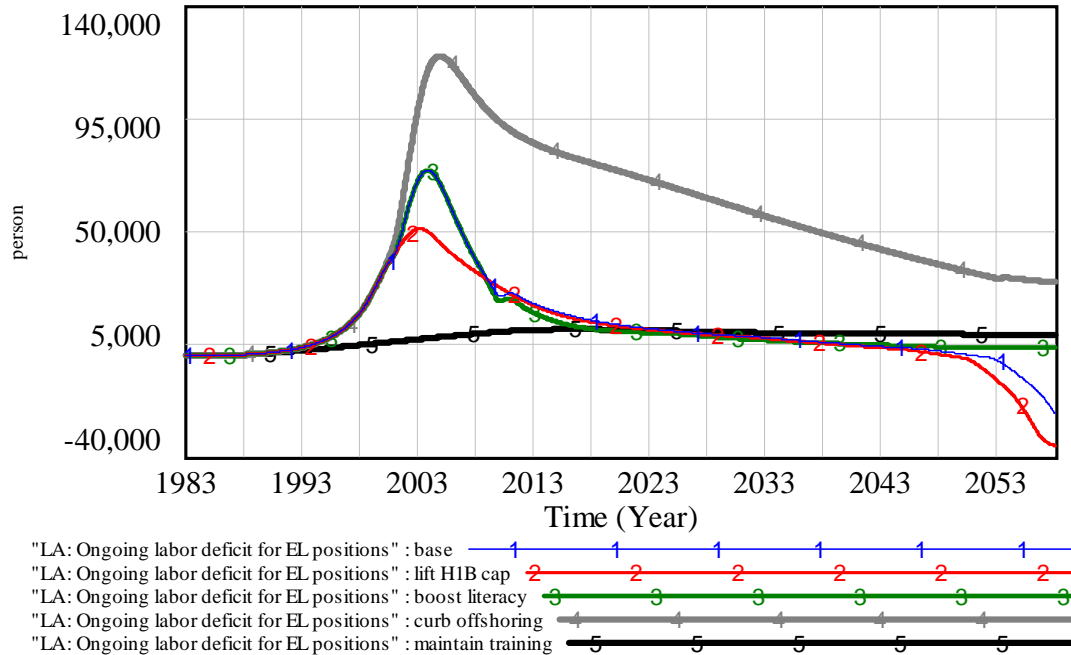


Figure 14: Entry level labor deficit

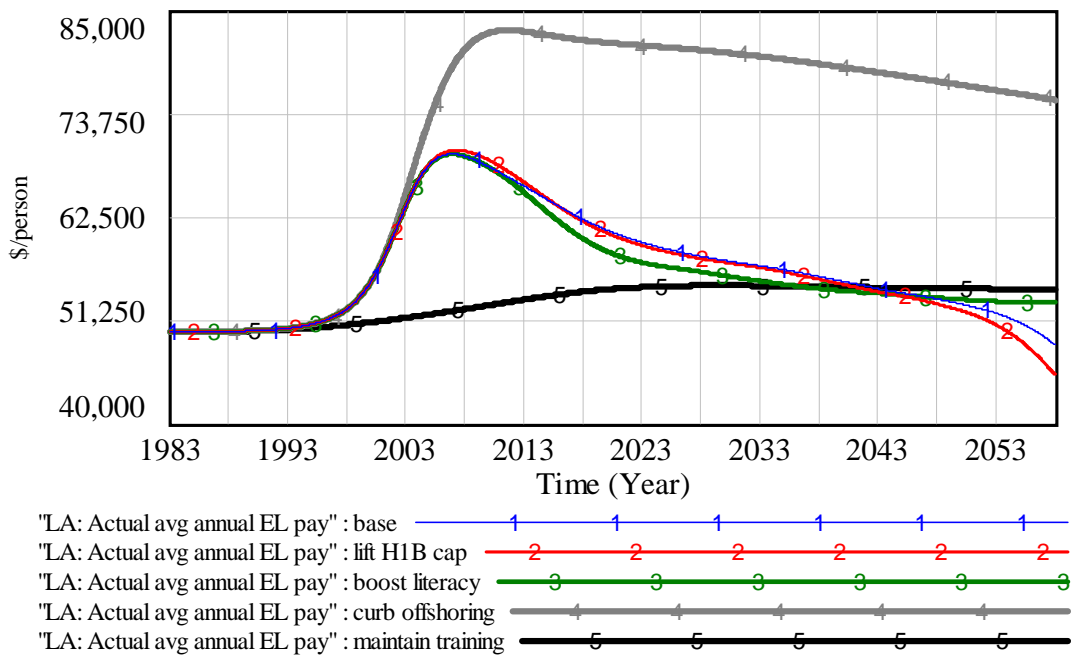


Figure 15: Average annual entry level salary

Similarly, for higher-level positions and workers, the policy to maintain a fixed amount of corporate-sponsored training avoids a labor surplus, while sustaining marginal wage increases (as opposed to observed losses in the base run) as shown in Figure 16.

Again, the policy curbing the offshoring of jobs stands out from the base run, but now with significant wage losses. For higher-level positions and workers, the policy boosting

STEM literacy in K-12 education also fares better than the base run, although also with wage losses.

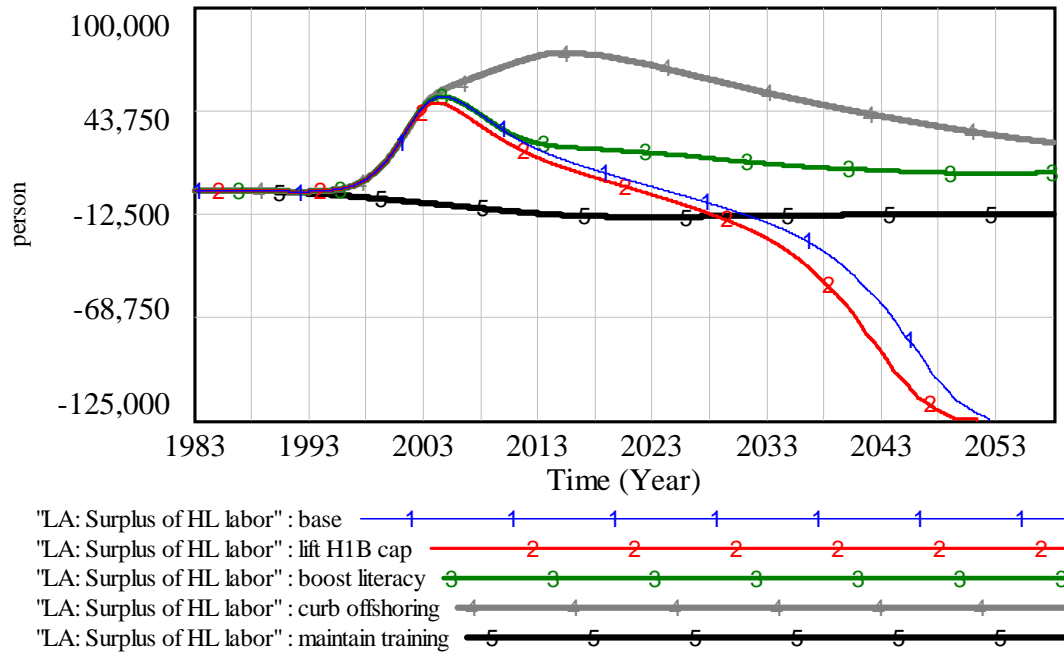


Figure 16: Higher level labor surplus

For employers, while wage increases for entry-level workers could be offset with wage decreases for higher-level workers, difficulties in filling entry-level vacancies would remain a problem with the policy of curbing the offshoring of jobs. Keeping jobs here and protecting the U.S. labor force would likely result in a two-fold increase in hiring delays for entry-level positions.

Domestic wage increases for entry level workers, without a corporate commitment to (or government subsidy of) continuing education, are likely to lead to frequent replacement of the entry level workforce with recent college graduates to obtain new skills. This will allow employers to reallocate training dollars towards paying higher wages. As a result, the entry-level “revolving door” will spin faster, as observed in the higher number of job openings to be filled as shown in Figure 17.

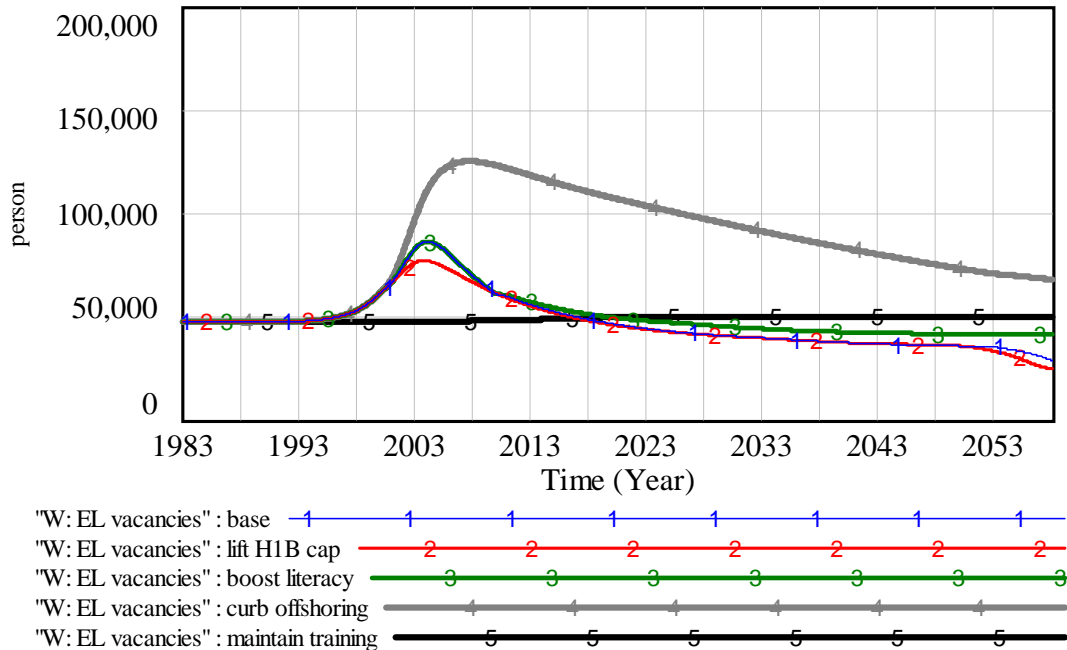


Figure 17: Entry level vacancies

Continuing education helps increase and sustain the attractiveness of the STEM field, despite decreased levels of math and science literacy in K through 12. An adequate supply of workers compared to jobs available reduces the need to import labor or to offshore jobs, particularly by avoiding inflationary wage gains. As a result, the policy that maintains training seems to fare better in keeping jobs here than the policy curbing the offshoring of jobs does as shown in Figure 18.

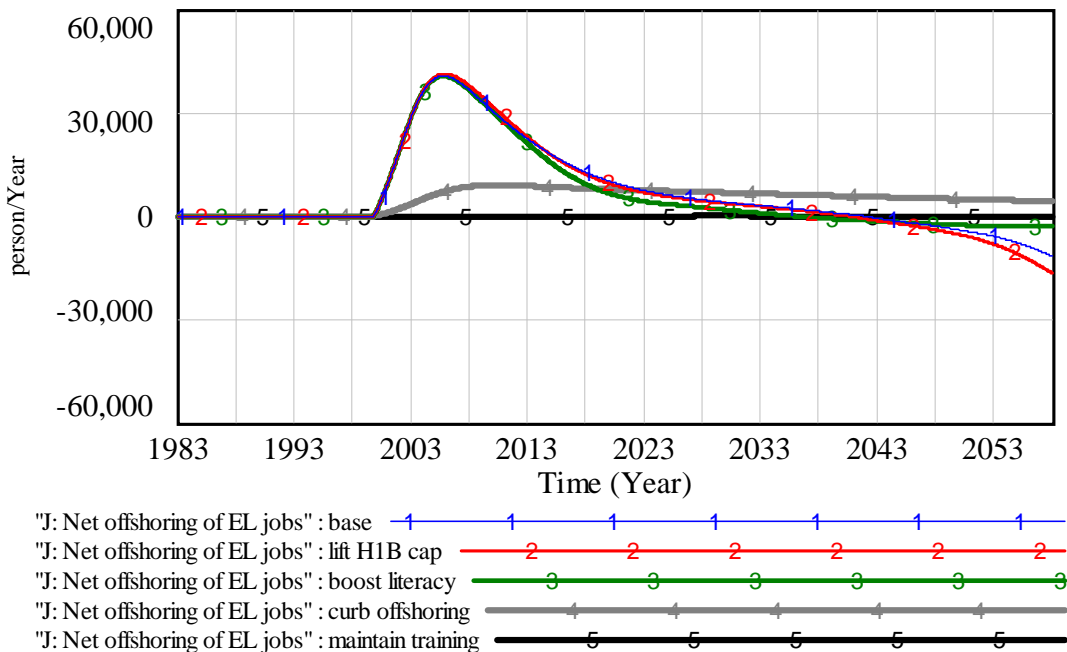
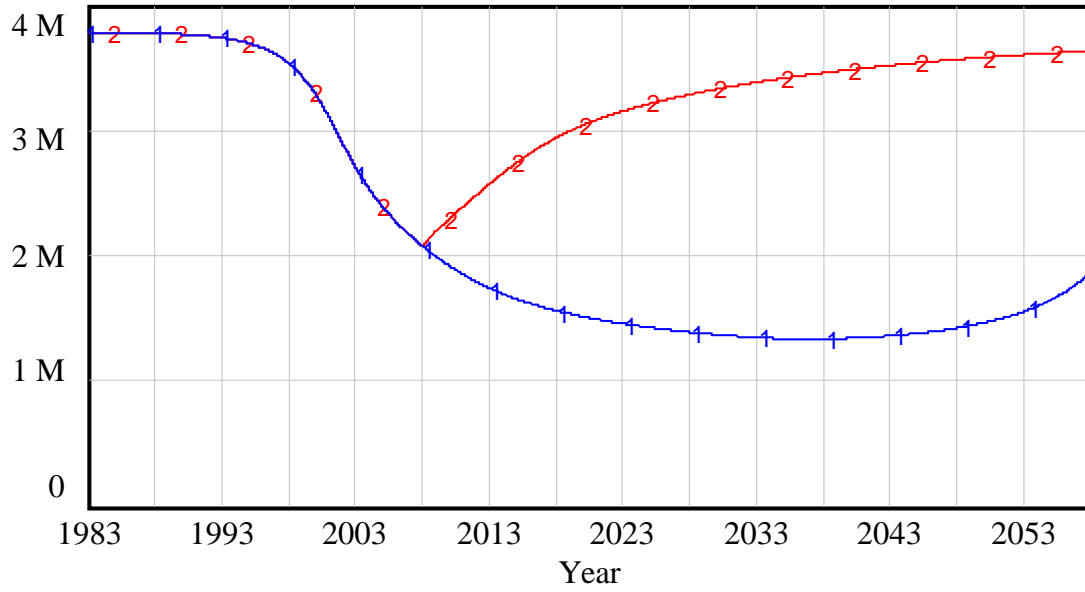


Figure 18: Yearly offshored jobs





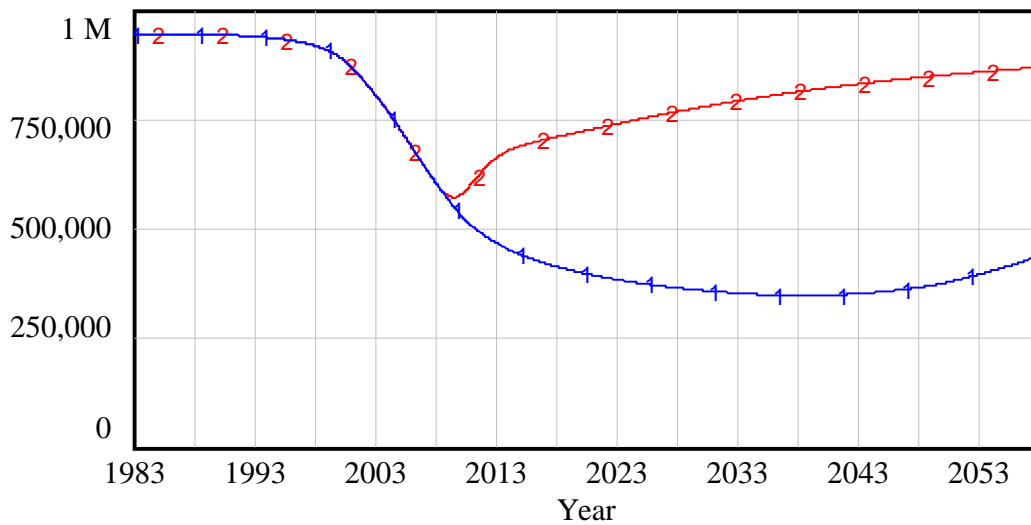
"HiE: People with basic degrees eligible for EL jobs" : base  person
 "HiE: People with basic degrees eligible for EL jobs" : min length of recovery  person

Figure 20: Entry Level Labor Pool





"W: EL domestic" : base  person
 "W: EL domestic" : min length of recovery  person

Figure 21: Domestic Job Availability

Figure 22 shows that initially attractiveness recovers with more jobs available for fewer applicants. However the rise in the labor pool causes increased competition for jobs and attractiveness to decline again. As the system balances itself out, attractiveness rises slowly, yet steadily. While this looks promising from the attractiveness viewpoint, the new equilibrium point has lower domestic job availability, which is detrimental to U.S. competitiveness in STEM-related fields.

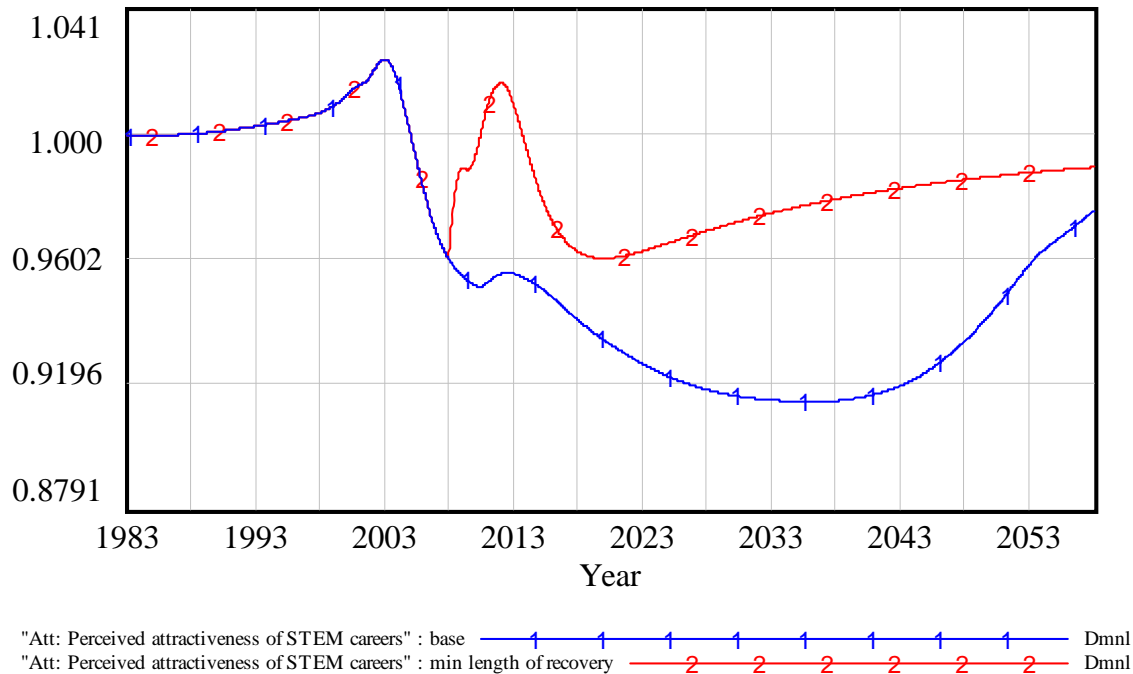


Figure 22: Attractiveness of STEM

CONCLUSIONS

The need to import skilled labor and offshoring of jobs are symptoms of inadequacy in the labor force, whether in sheer numbers or in skill sets. Fixing any individual symptom resulting from these inadequacies may produce favorable results initially that are not sustainable in the long term. In many cases they are likely to exacerbate the root problem – the U.S. is losing its relative advantage in STEM fields, both in terms of jobs and innovative minds, to the countries attracting those jobs and cultivating these minds.

Retraining and retooling the workforce, irrespective of cost, may be a strategy to deal with the STEM drainage. In order to avoid losing competitiveness in the global marketplace, particularly in the face of lower wages abroad, employers will need to receive subsidies or other financial incentives to sustain the level of training required for their workforce. Those who are temporarily out of employment should also have affordable access to retraining, particularly when technology and necessary knowledge is changing at a rapid pace.

If there is indeed degradation in math and science literacy in K-12 education, this root cause in the labor supply chain must be addressed. However, as observed in the simulation, even if a greater output of math and science wizards from high-school is created, it will not necessarily solve the problem. In order to create and maintain a healthy domestic STEM economy, something needs to be done to raise and sustain the attractiveness of the STEM field and careers. Otherwise, these high-school graduates will pursue other more attractive careers.

This analysis indicates that boosting STEM literacy in K-12 education, coupled with systematically retraining the labor force, creates a healthy, sustainable domestic STEM economy. It avoids the need for “hasty” importation of foreign labor and reduces the pressure to offshore jobs due to inflation in wages. Some offshoring of jobs will still occur, to the extent that there are lower wages abroad and current technology allows for remote production. The analysis also indicates that even this solution will take a long time to produce favorable results. Additional research is necessary to determine if additional solutions could shorten the time necessary for the system to recover. If the root causes of the STEM drainage problem are not addressed, offshoring of jobs, and the importation of skilled labor will continue to escalate.

FUTURE WORK

The model and analysis revealed additional areas where the attractiveness model could be modified or additional models developed to augment understanding of the problems and explore solutions for the STEM workforce system.

Future directions for the attractiveness model include:

- Grounding in available data
- Effects of attractiveness of STEM
 - On K-12 literacy or ability
 - On college graduates entering the field
- Effects of salary stagnation on attractiveness

Additional models that would aid with the exploration of the problem and potential solutions are:

- Role of higher education incentives (scholarships, research grants, etc) on perception and new career field creation
- Role of perception (from media) on interest in STEM education and career field (student perspective)

REFERENCES

1. “Policy and the STEM Workforce System,” STEM Workforce Data Project: Report #9, October 2007.
2. “Is There a Tech Talent Shortage?” Informationweek.com, January 7/14, 2008.
3. B.H. Wells, H.A. Sanchez, and J.M. Attridge. *Systems Engineering and the U.S. Education System*. INCOSE, 2008.
4. D. Sturtevant. *America Disrupted: Dynamics of the Technical Capability Crisis*. MS Thesis, Massachusetts Institute of Technology, September 2008.
5. “The H-1B Program and Labor Certification: Attestation and PERM,” National Bureau of Economic Research (January 18, 2008), Executive Summary