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Hiring College Graduates to Flip Hamburgers: An Endogenous Theory of Professionalization

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An Endogenous Theory of Professionalization**

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Hiring College Graduates to Flip Hamburgers: An Endogenous Theory of Professionalization

Abstract

In this paper, we offer an endogenous theory of professionalization and ever-higher degree attainment. We theorize that higher education is a self-driving growth engine. We introduce two endogenous mechanisms that act on the education enterprise, causing the number of educated people to increase dramatically with relatively short-term changes in the job market. Using an illustrative dynamic model based on simple rules of degree attainment and job selection, we argue that these self-driving growth engines are adequate to over-incentivize degree attainment, and can affect the match between supply and demand for college-educated labor. We also show that the mechanisms magnify effects of short-term recessions or technological changes, and create long-term waves of mismatch between workforce and jobs. The implication of the theory is degree inflation, magnified pressures on those with lower degrees, underemployment, and job market mismatch and inefficiency.

Keywords: Education sector, inefficiency, education mismatch, public policy, bullwhip effect

“Everyone has a right to a university degree in America, even if it’s in Hamburger Technology.”

Clive James

Can we claim that the education industry is now providing a more effective and efficient service to the entire population of K-Graduate School students? At least across the developed world, educational attainment levels have been increasing continually. By comparing the education levels of different age groups, we see a clear indication of the growing trends. In 2011, 82% of the 25-34 age group of OECD countries had completed upper secondary education or higher, compared to 64% of the 55-64 age group, showing close to a 30% increase in the portion of the population with upper secondary education or higher (OECD, 2013). This trend continues into tertiary education, where in 2011 some 39% of the 25-34 age group had completed tertiary education, compared to 24% of the 55-64 age group (OECD, 2013). The increasing trend has even gone above the PhD level, and now years of postdoctoral work are becoming commonplace for many newly minted PhDs. The number of postdocs in U.S. institutions has more than tripled in the past 30 years (National Science Foundation, 2011). The demand for higher education has also increased, as shown in the number of applications for graduate programs in U.S. universities: a rise from 955,000 applicants for graduate programs in 1991 to 1.768 million in 2010 (FASEB, 2012). The overall trend is the growth of degree attainment.

The growth in higher education is in line with educational policies in developed countries. Governments have increasingly encouraged the pursuit of education to spur economic growth, raise productivity, and increase innovation and the general wellbeing of society (Te Riele & Crump, 2003). However, these policies include several inherent assumptions about the demand for more educated workers and the education industry. In fact, there is evidence for the opposite: inefficiency in labor markets and education systems.

Take the STEM (Science, Technology, Engineering, and Math) workforce as an example. On the one hand, there have been arguments claiming a shortage of STEM workers in the United States; evidence of this shortage includes the higher salaries and benefits for STEM professionals. The arguments have prompted various government initiatives to incentivize foreign workforce immigration (U.S. House of Representatives, 2012). On the other hand, many STEM graduates have difficulty finding jobs that match their training, and there is an abundant supply of STEM PhD graduates who cannot land academic positions (Larson et al., 2013).

Educational attainment and general job market needs do not appear to be closely matched. Data show that the average duration of the job candidate interview process roughly doubled between 2010 and 2013 at major companies such as General Mills and Southwest Airlines, indicating the difficulty of finding a proper match for open positions (Rampell 2013a). Furthermore, many people are employed for jobs that do not require the level of education they attained: college graduates performing jobs that do not require a Bachelor's degree, or PhD graduates taking master's-level jobs, and postdoctoral work becoming a common practice for getting an academic position (Battu and Sloane, 2000). With the U.S. national student debt growing to \$1.2 trillion and two thirds of U.S. college graduates leaving school with some level of debt (an average borrower will graduate with \$26,600 in debt), there remains a puzzle regarding the incentives and mechanisms behind increasing degree attainment (Chopra, 2013; Institute for College Access and Success, 2012). These patterns make us doubt whether the efficiency and effectiveness of the education sector are truly increasing, and raise a question: *What are the drivers of increased degree acquisition?*

This paper offers a coherent dynamic theory of educational attainment and inefficiency in education systems. We develop a mathematical model and conduct simulation-based analyses to

explain how degree attainment can get triggered endogenously and how the supply of a highly degreed workforce may not necessarily follow market demand. The theory has policy implications for improving performance of the education industry.

1. BACKGROUND: Complexities and Mismatch in STEM workforce

Ideally, the trend toward increased educational attainment in the workforce should be linked to demand for a more educated workforce due to an increasingly complex technological world. Let us take Moore's law (Moore, 1965) as a description of technological growth: Moore's Law says, roughly, that the power of computers doubles approximately every two years. This law has been operating at least since 1958, indicating 28 doublings of computers' abilities. If there is such a rapid growth in technological capabilities, one might conclude that complexities of production lines and factories that produce such devices should increase at the same pace and so too should the need for a more highly educated workforce. Put simply, new technological advancements require a more educated workforce. This argument implies that higher degree attainment is a rational response to such a need. We call this theory an exogenous theory of degree attainment; it is a theory that links an increase in workforce development to market forces outside of the education system.

An exogenous theory succeeds in following the overall trend of degree growth, and partially succeeds in explaining the increasing need for STEM graduates in the United States. However, there are various indicators that make us doubt whether the growth in educational attainment is really driven by our increasingly complex technology-driven society. For example, the existing mismatches in the job market signal an inefficient education and degree attainment system or marketplace. In 2010, the Bureau of Labor Statistics (BLS) reported that there are 28.6 million

jobs requiring a college degree, but at the same time the number of people with a bachelor's degree and higher in the workforce was around 43.8 million (Bureau of Labor Statistics, 2013b); Bureau of Labor Statistics, 2010). Figure 1 shows the increasing gap over the past two decades between the number of employed people with bachelor's degree and the number of jobs that require such degrees. Were the rise in degree attainment a response to the need in labor force and growth in technological capability, one would expect more educational training to lead to a better match between supply and demand of degrees.

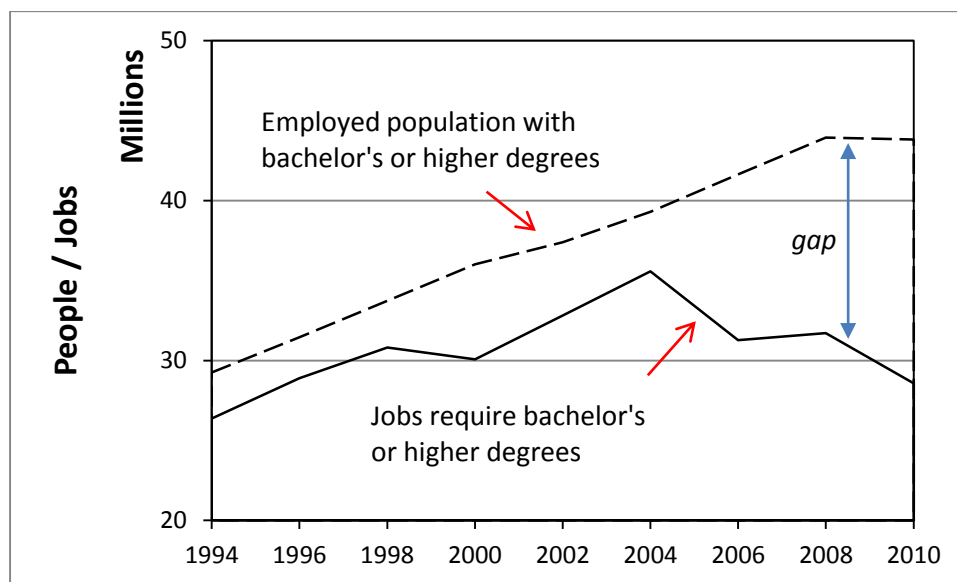


Figure 1. Increasing gap in the employment levels of bachelor's degree holders or higher in the civilian labor force compared with the employment opportunities requiring bachelor's degree or higher between 1994 and 2010 (Source: Bureau of Labor Statistics).

There is evidence that workers are hired into jobs that do not require their current educational credentials. For example, the college degree is becoming the new high school diploma and a new minimum requirement for even the lowest-level jobs (Rampell 2013a). While in 1970, less than 1% of taxi drivers and 2% of firefighters had college degrees, now more than 15% have college credentials in both jobs (Veddar et al., 2013). The mismatch between education and a job's "actual" requirement is not limited to college degree holders. At the PhD

level, spending time as a postdoc now greatly improves one's chances when applying for a tenure-track position in academia, a practice not as common even a decade ago. Looking at our home university, the Massachusetts Institute of Technology, the number of tenured faculty has stayed relatively constant at 1,000 for the past three-plus decades. However, the number of postdocs employed has more than tripled over the same time period, and currently there are about 1.3 postdocs per faculty member (National Science Foundation, 2011).

Veddar et al. (2013) estimate that about half of employed college graduates are in jobs that require less than a four-year college education; of these, about 5 million are in jobs that do not require even a high school education. They report that more than 14 percent of waiters, bartenders, and counter and sales clerks hold college degrees. The exogenous theory does not explain these patterns (Will, 2014).

In this paper, however, we provide a different theory, an endogenous theory (Richardson, 2011) which characterizes the situation. We theorize that higher education is a self-driving growth engine. We introduce two different endogenous mechanisms that act on the education enterprise, where the number of degree holders can increase dramatically with small changes in the job market.

2. THE ENDOGENOUS THEORY

In the following section, we discuss briefly the theory of endogenous growth in degree attainment, and describe two major mechanisms that are rooted in the education system and lead to the growth in degree attainment. We provide more in-depth arguments in the subsequent sections by developing a dynamic model and analyzing simulation results.

Mechanism 1: Pipeline Cascading Effect

It is no surprise that many popular charts and analyses show that obtaining a university degree boosts the chances of getting a job. In the United States, there is significant evidence that unemployment is more prevalent for those with lower skills, education, and experience. For example, the unemployment rate in 2012 was 12.4% for those who did not complete high school, compared to 8.3% for those who completed high school and 4.5% for those with a bachelor's degree (Bureau of Labor Statistics, 2013a).

The push to remain competitive in the job market increases demand for educational attainment. Looking at data from the recent 2008 recession, college graduates are the only employment group that has more people employed in April 2013 than before the recession began (Rampell 2013b). However, over the same time period, the majority of the jobs created are low-skilled and low-wage jobs in food and retail services (Rampell 2013b). This suggests that bachelor's degree holders have a competitive edge over their less-educated peers and that employers are hiring college graduates for jobs that do not require college-level skills. Another study of U.S. employers in 2009 showed that they tended to place a greater emphasis on hiring those with additional qualifications, such as a bachelor's degree from a four-year college, and less emphasis on hiring those with a high school education, compared to before the economic downturn (Hart Research Associates 2010).

Suppose there are two subsets of a population, people who do not have any college level degree (group 1), and people with a college degree (group 2). When the number of job candidates in group 2 is more than the number of available jobs that require such a degree, some of them move down to lower-paid positions that do not require the degree. As college degree holders take jobs that do not require a college degree, fewer jobs are available for the other

subpopulation, group 1, thus increasing unemployment in this subpopulation. This implies that group 1 needs additional educational certification to remain competitive but does not necessarily need to acquire any additional training and skills for the sought-after job.

Now, let us take a holistic approach: If we have n steps of educational attainment, we can divide the workforce population to n subpopulations based on their latest degree attainment. Suppose each of the n layers has $X=10\%$ more qualified people than available jobs, and for simplicity suppose that the same number of jobs are available at each level. Then, at top level n , all jobs are filled by the top qualified, and the remaining top qualified people take 10% of the jobs at level $n-1$. That leaves only 90% of $n-1$ level jobs for the people qualified directly for these jobs. So, all of these 90% are taken by level $n-1$ people, who also take 20% of the $n-2$ level jobs. The level $n-2$ people take all 80% of their available jobs but an additional 30% take level $n-3$ jobs, and so on and so on. The entire mechanism results in a snowballing, reinforcing cascade, pushing otherwise qualified individuals into lower and lower job categories, as evidenced by Battu and Sloane (2000). In response, we obtain a feedback loop with considerable incentive to move up the education ladder and attain higher degrees. The entire push-down and then feedback-up processes, which we label as “the cascading effect,” may result from certification and not from job qualifications *per se*.

Mechanism 2: Pipeline Reinforcing Effect

Education costs have been continually growing and academic institutions have tried various strategies to protect their institutions financially. Greater revenues can be achieved by increasing tuition and admitting more students. Between 1967 and 2010, the total undergraduate enrollment in degree-granting institutions tripled from 6 million to 18 million (Snyder and Dillow, 2012). More students require a larger teaching workforce, and the abundant supply of PhD students and graduates give universities the opportunity to hire them into temporary teaching positions at lower costs. Thus, while the full-time-equivalent (FTE) student-to-faculty ratio hovered around 16:1 between 1976 and 2009 (Snyder and Dillow, 2012) the share of part-time faculty (adjuncts) increased from around 24% to 42% over approximately the same period (Curtis and Thornton, 2013). Meanwhile, tenured and tenure-track faculty dropped from around 45% of instructional staff to less than one-fourth. This points to an increasing trend of hiring PhDs into non-tenure track academic positions to maintain the FTE student-to-faculty ratio (Curtis 2013).

An American Association of University Professors' survey found that the median pay rate per course is \$2700 for a part-time faculty member (Curtis and Thornton, 2013). Even for a full-load of 8 courses, the salary for part-time faculty would range from \$18,000 at associate's degree colleges to around \$30,000 at private doctoral universities, which is less than one-third of the salary for a full-time tenured or tenure-track faculty member at the same institutions (Curtis and Thornton, 2013).

In many organized labor forces, this labor-cheapening strategy would have been forbidden as an unfair labor practice. With an increase in the number of doctorates, many of those desiring tenure-track academic positions end up being employed instead in lower paying, non-tenure track positions. For example, the number of engineering PhDs in non-tenure positions in

academia has increased by about 60% in the past 10 years (National Science Foundation, 2011). With this additional workforce, education enterprises have been able to expand their capacity and admit more students, reinforcing the sheer number of educated people. With the increase in low-paid positions displacing work traditionally occupied by tenure-track professors, the university's production capacity for all degree levels also increases.

Furthermore, professors who would like to focus more on research activities can buy out their teaching load, and universities can then hire lower-waged lecturers and postdocs to teach a variety of courses, especially undergraduate courses. This displaces the time professors had to spend on lecturing, and allows them to focus instead on research. A byproduct of research activities is the training and production of PhD students, leading both to more PhD admissions and PhD graduates. Again, we see here a positive feedback loop.

We argue that the described mechanisms can magnify small exogenous shocks in the job market and result in long-term lasting waves of an abundant educated workforce, demand for higher education, and mismatch between job market requirements and workforce degree attainment.

In the following sections, we implement the model using a dynamic framework and further develop the theory to capture effects of small shocks to the system, representing short-term economic downturns, and changes in distribution of jobs, representing technological shifts in workplaces. The model demonstrates how short-term economic downturns affect not only the current time period, but also have repercussions on the composition of the labor workforce. It also shows how a technological shift in the market can over-incentivize the workforce to acquire more training.

3. MODELING

Building on other dynamic models of higher education (e.g., Kennedy, 2011; Larson and Gomez, 2012; Ghaffarzadegan et al., 2013) we develop a system dynamics model of the workforce and credential-based job market. We explore the effects of the described mechanisms under two simulation scenarios: 1) a short-term economic downturn, and 2) a technological shift that permanently changes the distribution of education requirements.

We represent the workforce population in an aggregated pipeline where people move within the pipeline as they receive more education. Each step in this pipeline will represent a subpopulation of the workforce. The population of the pipeline increases as new people enter the pipeline and decreases as people leave the pipeline due to retirement or for other personal reasons. The model is based mainly on three major rules:

- *Matching*: In each time period, the active workforce population is matched to the available jobs. The workforce population is evaluated based on their highest level of education. If the number of jobs is less than the number in the workforce, some people will not find jobs and some will take jobs for which they are overqualified. In this model, we assume that people in the workforce prefer to take jobs that match their credentials (i.e., their education degree), the ones with higher degrees have competitive advantage over the ones with lower degrees, and people cannot take jobs that require higher degrees than what they have attained.
- *Education for current workforce*: In each time period, there is a normal ratio of people who join an education program to receive more education. In addition, we include a decision making rule to represent job market-related incentives for education: when one does not find a job, he/she has more incentive to obtain education to improve his/her

competitiveness in the job market. We see this trend most prominently during economic recessions. For example, data from the Graduate Management Admission Council (GMAC, 2011) have shown that the MBA application volume follows the inverse of the business cycle.¹

- *University expansion:* We assume a portion of people at the end of the pipeline who do not find a fitting job take temporary academic positions such as teaching positions. This, in the real world, is analogous to PhD graduates taking temporary lecturer positions. These positions are economical for universities. In the past 35 years, due to hiring PhD graduates for part-time faculty positions, the ratio of adjunct faculty members to total faculty has increased from around 24% to 42% (Curtis and Thornton, 2013).

In the following section, we discuss these rules and represent them within the model structure. All formulation details and parameter values are presented in the Appendix. The goal of our simulation experiments is to offer a coherent and empirically testable theory regarding the dynamics of unemployment and underemployment as affected by education. The model represents a hypothetical context; we make no claim that it depicts detailed U.S. or other labor markets precisely. Rather, we seek to understand first-order dynamics, given our postulated assumptions.

3.1. Workforce pipeline

¹ Application volumes to full-time MBA programs in 2001-2002 increased, when the economy slowed, and dropped off during the recovery in 2004-2005. Similarly, when the global recession began in 2007, full-time MBA applications increased in 2008 and peaked in 2009, and have since decreased during the recovery. This trend is reflected in enrollment trends as well: in 2010, there were over 8 million students over the age of 25 enrolled in higher education institutions, 1.2 million more than in 2007 (Cowan and Kessler, 2013).

For n steps of degree attainment, the workforce population can be divided into n subpopulations based on each individual's highest attained degree. Subpopulation i will represent people whose highest degree is the degree level i . Let W_i represent the active workforce in the i th subpopulation. The pipeline also includes people who are in schools receiving more education, and therefore are not active in the market. We represent number of students who are attaining the i th level degree as S_i . Similarly, let J_i represent number of jobs that require at least degree i of education.

We can write:

$$\text{Total "active" workforce} = W_1 + W_2 + \dots + W_i + \dots + W_n$$

$$\text{Total students} = S_2 + S_3 + \dots + S_i + \dots + S_n$$

$$\text{Total jobs} = J_1 + J_2 + \dots + J_i + \dots + J_n$$

In the interest of parsimony, let us analyze the system for $n=3$, as Figure 2 depicts. In this model, we have three different subpopulations of active workforce (boxes in grey: W_1 , W_2 , and W_3), and two stages of education (boxes in white: S_2 , and S_3) working as transition stages between W_1 to W_2 , and W_2 to W_3 , respectively. To offer a concrete example for this categorization, W_1 can represent people with a high school degree, and W_2 and W_3 can represent two stages of education such as undergraduate and graduate degrees. In this example, S_2 will be undergraduate students and S_3 will be graduate students.

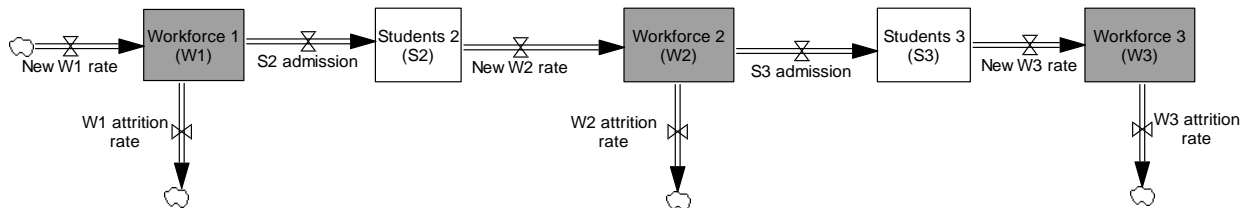


Figure 2. Stock-Flow representation of workforce group i

We assume, in each time period, a constant flow of people enter W_1 . In each period, some members of the W_1 workforce exit the pipeline due to retirement or other personal reasons (W_1 attrition rate), some stay in the active workforce population, and some decide to obtain more education (S_2 admission). People in the S_2 stage receive more education and enter the W_2 subpopulation with a delay representing the time it takes to earn the degree. People who newly join W_2 may move to S_3 (immediately or with a delay) to obtain more education, or may stay in W_2 until retirement. In this simple model, W_3 is the end point, while in reality the pipeline may have additional stages (such as postdoctoral trainings).

3.2. Matching mechanism

We intuitively expect that the distribution of workforce and jobs do not necessarily match. Consequently, in each subpopulation, we may have unemployed (people who do not find a job) and underemployed people (people who take jobs for which they are overqualified). Figure 3 depicts how jobs are taken by different subpopulations in our model. In the figure, while the workforce moves from left to right (from W_1 to W_3), jobs are distributed from right to left (from J_3 to J_1).

In this model, we first estimate the shortage in the number of jobs for the most-educated workforce (W_3). The shortage is represented by the variable *Job discrepancy 3*. It is basically the difference between the number of people in the subpopulation and the number of jobs. For positive values, this variable indicates that there are people in the subpopulation W_3 who do not find a job fitting their level of educational attainment.

A portion of the people who do not find a fitting job remain unemployed (in the figure: U_3) and a portion become underemployed taking J_2 level jobs (in the figure: UD_3). The

remaining J_2 level jobs (in the figure, J'_2) will be taken by W_2 . Similarly, unemployment and underemployment are calculated for the rest of the pipeline.

3.3. Education for current workforce

In each time period, a portion of the population decides to pursue higher education and move up the pipeline. In addition to societal and personal reasons that incentivize higher education, one reason for receiving more education is to get a better job. The latter motivation makes more sense in particular when one's chance of employment significantly increases by obtaining more education. Figure 3 includes job market incentives to pursue education.

We formulate the tendency to seek an education level (represented by S_2 application rate and S_3 application rate in Figure 3), as a function of normal rate of education and job discrepancy, the latter representing job market incentives to study more. The normal rate represents all other personal and social incentives and is set to create a net-flow of people who replace the ones permanently exiting the workforce. In our model, university admissions (S_2 admission and S_3 admission) are constrained by university capacities (C_2 and C_3).

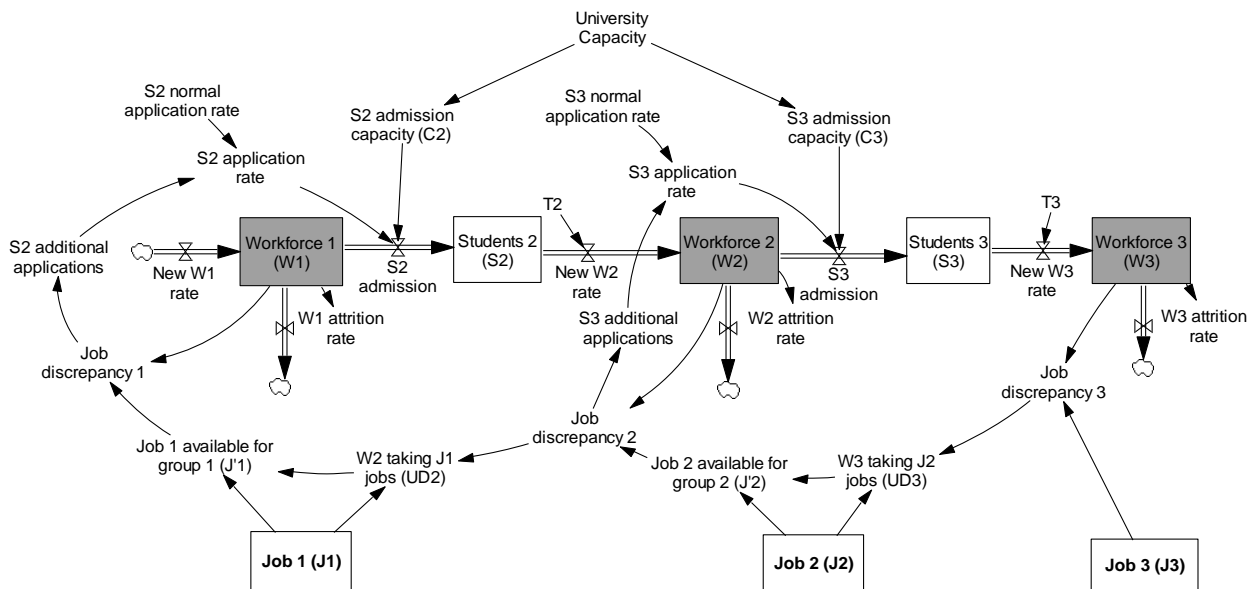


Figure 3. Flows and distribution of workforce and jobs

The links from job discrepancies (*Job discrepancy 1* and *Job discrepancy 2*) to university admissions (S_2 and S_3) close several feedback loops as presented in Figure 3. For example, as we face more job shortages for group 1, *Job discrepancy 1* increases, and there is more incentive to pursue education among W_1 . Therefore, S_2 admission rises. As more W_1 leaves to attain S_2 education, W_1 declines, in turn compensating for job shortages (a short-term balancing loop). However, in a longer time period, as the number of people in W_2 increases, more of them take J_1 jobs, fewer jobs become available for W_1 , and more individuals of W_1 obtain education, adding to the W_2 subpopulation (a reinforcing loop). A simulation analysis of the interactions between these reinforcing and balancing loops can reveal which ones are dominant.

3.4. University Capacity Dynamics

Universities tend to expand their capacities by hiring the most-educated subpopulation for temporary teaching positions. We formulate *University Capacity* as a function of *permanent positions* and *temporary positions*. We assume a constant value for *permanent positions*, and formulate temporary positions as a function of job discrepancy in the most-educated subpopulation. In our model, temporary positions are taken by people in the workforce group W_3 who do not find a fitting job. Figure 4 shows the resulting feedback structures.

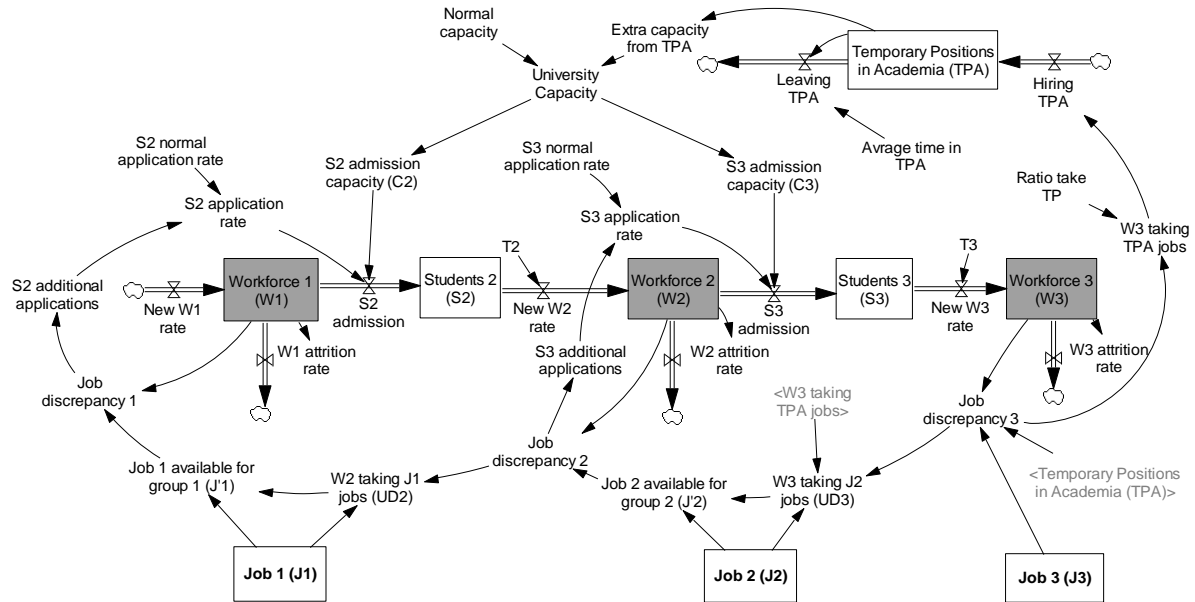


Figure 4. Temporary positions in universities and resulting feedback loops

In this figure, as more people obtain the highest degree, some are offered temporary positions in academia contributing to training more S_2 and S_3 students (reinforcing loops). However, these positions decrease the number of people in W_3 who need to take J_2 level jobs, which in turn raises jobs that are available for W_2 people (a balancing loop). The ratio of people who take temporary positions is also a parameter in our sensitivity analysis below.

The described model can be simulated after parameterization. Consistent with the goal of our simulation, which is to offer a coherent theory to understand first-order dynamics (rather than an empirical replication of a specific market), we set the model parameters. Details of the formulations and parameter values are documented in the Appendix.

4. SIMULATION

As stated, we conduct two experiments with the model, each representing one of the scenarios. In each experiment, an exogenous shock is introduced to the system and we then examine how the system reacts to those shocks. The exogenous shock for the first experiment is

a short-term decline (negative pulse) in the number of jobs, and in the second experiment it is a shift in the distribution of jobs while keeping the total number of jobs constant.

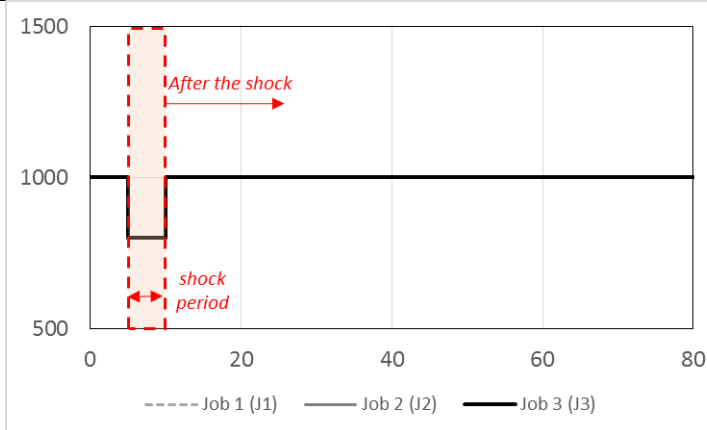
We assume that in the steady state in each of the three subpopulations there is an active workforce of 1,000 people. We also assume that for each subpopulation there are 1,000 jobs (an active workforce totaling 3,000 people, and 3,000 jobs). Thus, initially, no unemployment or underemployment exist. We first conduct the experiments with the model for a specific set of parameters and then conduct a broader sensitivity analysis with changes to the major parameters.

4.1. Experiment 1: a short-term economic downturn and loss in number of jobs.

Let us assume at $t=5$ that there is a 20% shortage in the number of jobs at all levels due to a short-term economic recession for 5 years, and then at $t=10$ we go back to the initial number of 3,000 jobs and remain there. We expect the workforce to react to the shock, and in the recession period some people lose jobs, some take jobs for which they are overqualified to avoid unemployment, some remain unemployed, and some pursue more education to improve their chances of getting a job. One might think that after job market recovery at $t=10$, the system should return very quickly to its stage prior to the recession, with everyone having an appropriate job. Our simulation result does not support this intuition. Figure 5a shows how the shock is entered to the model as input; Figure 5b shows simulation outputs.

(a) Experiment 1 Input

Distribution of Jobs in Different Time Periods



(b) Experiment 1 Output

Distribution of the Workforce in Different Time Periods

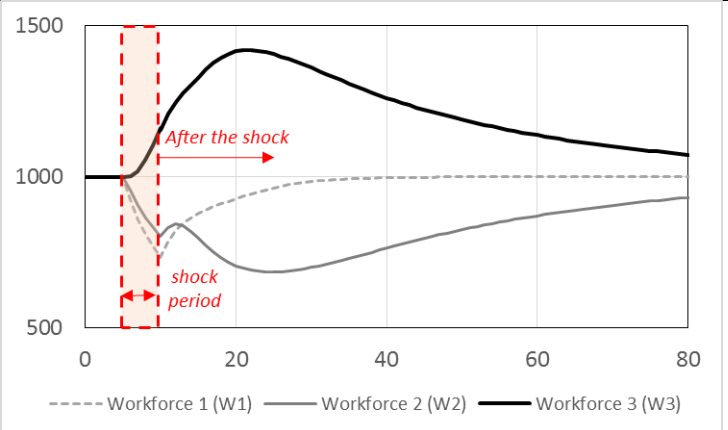


Figure 5 – Effects of a pulse decline in number of jobs available at $5 \leq time \leq 10$ (a) on the distribution of workforce overtime (b)

As the figure shows, the 20% shock during $5 \leq time \leq 10$ creates overshoot and undershoot in the workforce numbers in different groups. The number of the most-educated population increases beyond the equilibrium value and shows an overshoot pattern. The distribution of the workforce also changes, and for a long time we see a non-uniform distribution with a shortage of people in the middle-skilled workforce. As the figure shows, changes in the distributions of the workforce last for a long time before the distributions eventually return to the steady state.

As a measure of efficiency, we are interested in measuring the mismatch between education and job types in each group and capturing the ratio of people who take jobs for which they are overqualified. The measure of mismatch, M_i , is defined as the ratio of people in group W_i who do not find a J_i type of work:

$$M_i = \frac{\text{Max}(\text{Job discrepancy } i, 0)}{W_i}$$

Figure 6 shows the trend of the mismatch for each workforce group during the recession and for a long time after.

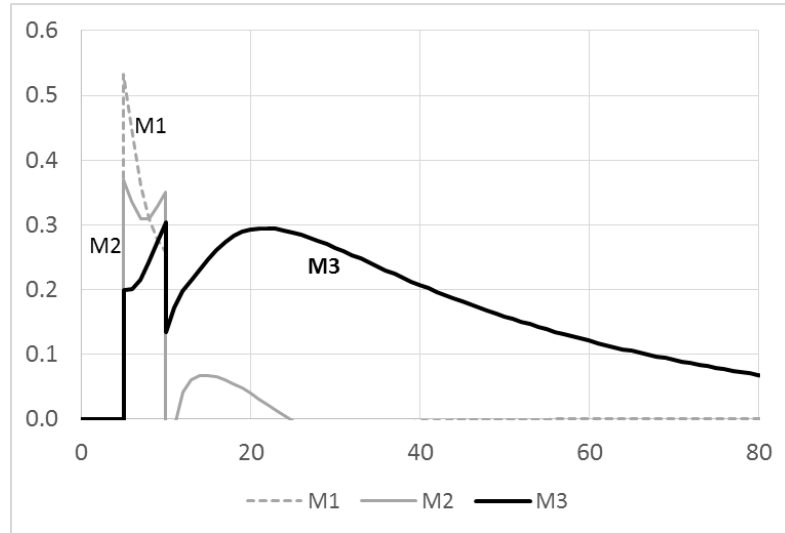


Figure 6: Mismatch index in each workforce subgroup as results of a short-term recession between $t=5$ and $t=10$.

As the figure shows, there are two different trends of mismatch: one short term as a quick response to the recession, and one long term. In the short run, the lower-skilled workforce experiences most of the economic recession burden and people with higher skills take their jobs (see M_1). In the long run, however, as people respond to the recession and try to move up the workforce pipeline, the ones with higher education experience more mismatch and

underemployment (see M_3). Due to the flow of the workforce to attain more education, the mismatch remains in the system long after the recession, until the overeducated workforce retires from the pipeline.

Let us recall that the entire recession is operationalized as a short-term pulse function and that the number of jobs returns to its previous stage at $t=10$, so the second wave of pressure on the workforce comes as an endogenous response to the flow of the workforce. In other words, around $t=10$ and $t=30$, the job market for the highly educated population has become tight due to internal feedbacks within the workforce and education system.

Overall, the change in the distribution of the workforce causes many people to take jobs for which they are overqualified, an indicator for lack of efficiency in the system. One can imagine how the most-educated population will feel around $t=20$: “*The economic recession finished 10 years ago, jobs are back, but somehow we still feel recessionary pressures!*” Seeing a small picture of the entire system, the most-educated group may not even agree that the economic recession is gone and their past response to acquire education is the source of the new job market pressures.

4.2. Experiment 2: an upward shift in the distribution of jobs.

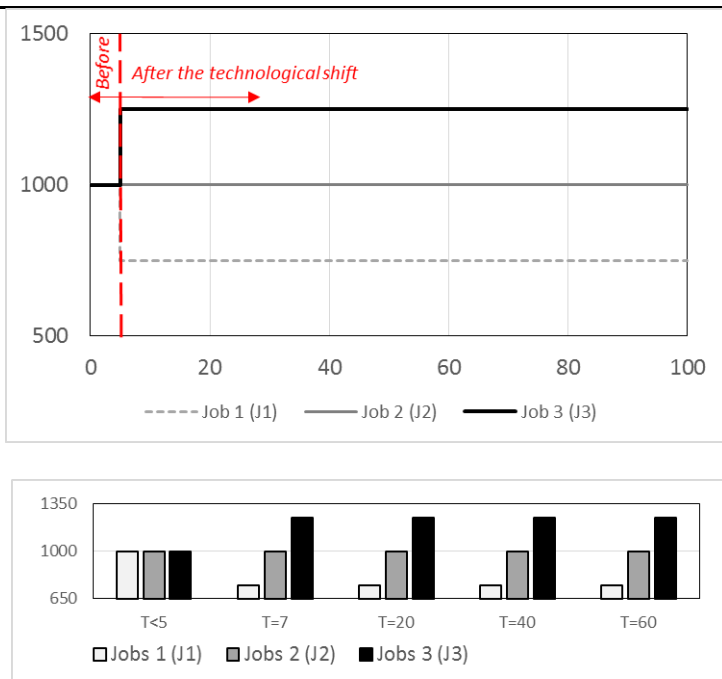
Let us represent technological shifts in the society by changing the distribution of the jobs at $t=5$ to create greater demand for higher levels of education. In this simulation experiment, the numbers of jobs in each category changes from $J_1=J_2=J_3=1,000$ jobs to $J_1=750$, $J_2=1000$, and $J_3=1250$ at $t=5$ and stays the same thereafter. The total number of jobs before and after the exogenous shock is the same (total of 3,000 jobs), and the only change is the distribution in favor of the most-educated group of the population. We expect the shock to provide more incentives

for the workforce to attain higher degrees, and would like to examine the transition to the new steady-state condition. Figure 7a shows how input to our model is formulated, and Figure 7b shows the effects on the workforce population.

As the figure indicates, the workforce overreacts for a long time, and each group experiences overshoot or undershoot in different time periods until, after a long delay, it reaches equilibrium.

(a) Experiment 2 Input

Distribution of Jobs in Different Time Periods



(b) Experiment 2 Output

Distribution of the Workforce in Different Time Periods

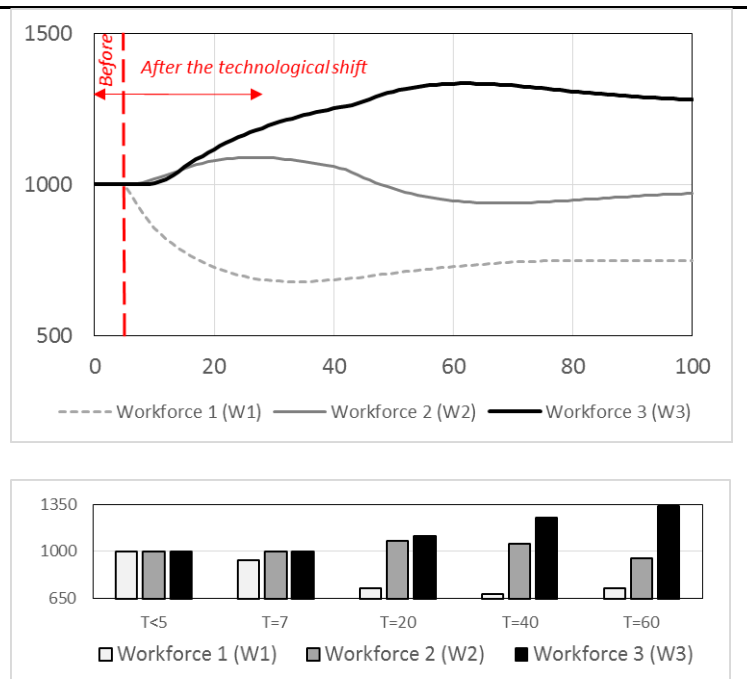


Figure 7: Magnified effects of a change in the distribution of jobs available from time = 5 representing a technological change (a) on the distribution of workforce overtime (b)

Figure 8 shows the trend of mismatch in different workforce subpopulations. The shift in technology first affects the lower-skilled workers (see M_1), but with delays two separate waves

emerge affecting other subpopulations (M_2 and M_3). It is interesting to note that the wave reaches the most-educated population (see M_3) when we do not see any mismatch among the least-educated population. We can imagine how the most-educated population will feel: *Technology has changed in favor of us, we responded intelligently and studied more, there are more jobs for us, but somehow it seems we have wasted our time and are taking jobs that do not require our education!* Seeing a small picture of the whole system, the most-educated group may not even agree that the number of jobs for the most-educated workforce has increased, and the mismatch comes as result of their “intelligent” reactions.

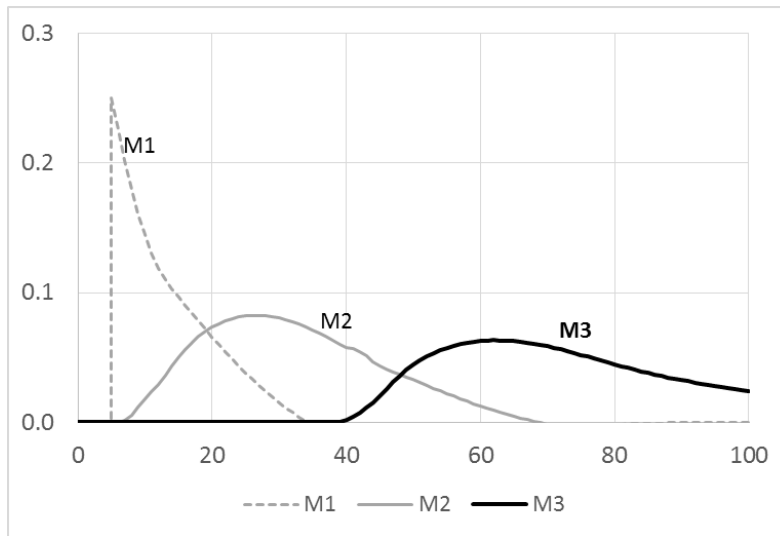


Figure 8: Mismatch index in each workforce subgroup as results of a shift in the distribution of jobs at $t=5$.

These two experiments simply represent a short-term decline in the number of jobs and a change in the distribution of jobs. In the real world, these changes can happen as results of short-term economic declines, technological shifts, or both. Our theory predicts long-term lasting effects that cascade to the most-educated population. The magnified effects go beyond short-term pressures and can create long-term waves in the job market that are reinforced

endogenously by delays and feedback loops. They eventually affect the most-educated population by causing them to take jobs for which they are overqualified.

The model is simple and is run with hypothetical parameter values to develop a coherent theory. However, sensitivity analysis on major parameters helps us generalize the arguments and find the conditions under which we might observe more endogenously generated mismatch.

4.3. Simulation for a larger range of parameters

We extend our analysis to a larger parameter space: experiment 1 with different sizes of economic shocks, and experiment 2 with different magnitudes of technological shifts, both in interaction with different values for temporary positions in academia.

First, we simulate the model for different values of short-term economic shocks ranging from 0% to 30% decline in the number of jobs for 5 years times different values of r . Figure 9 depicts a few selected simulation runs over time for 4 sizes of economic shocks (-5%, -10%, -20%, and -50% shocks in figures 9a, 9b, 9c, and 9d, respectively). Each graph shows the result of a different value for the ratio that take temporary positions ($r = 0, 0.01, 0.02, 0.05$ and 0.2). The $r = 0$ conditions represent the dynamics of economic shock in the absence of any temporary positions in academia. Higher values of r demonstrate the effects of adding these temporary positions.

In all simulation runs, we see the overshoot pattern in which the magnitude of the overshoot is higher for stronger economic shocks. However, r has an interactive effect: for smaller economic shocks (see Fig. 9a), we see that the magnitude of overshoot declines for higher values of r , implying that more temporary positions decrease the overshoot; for larger values of economic shocks (see Fig. 9d), the magnitude of overshoot increases with larger values of r . In addition, very large values of r help dampen the overshoot more quickly.

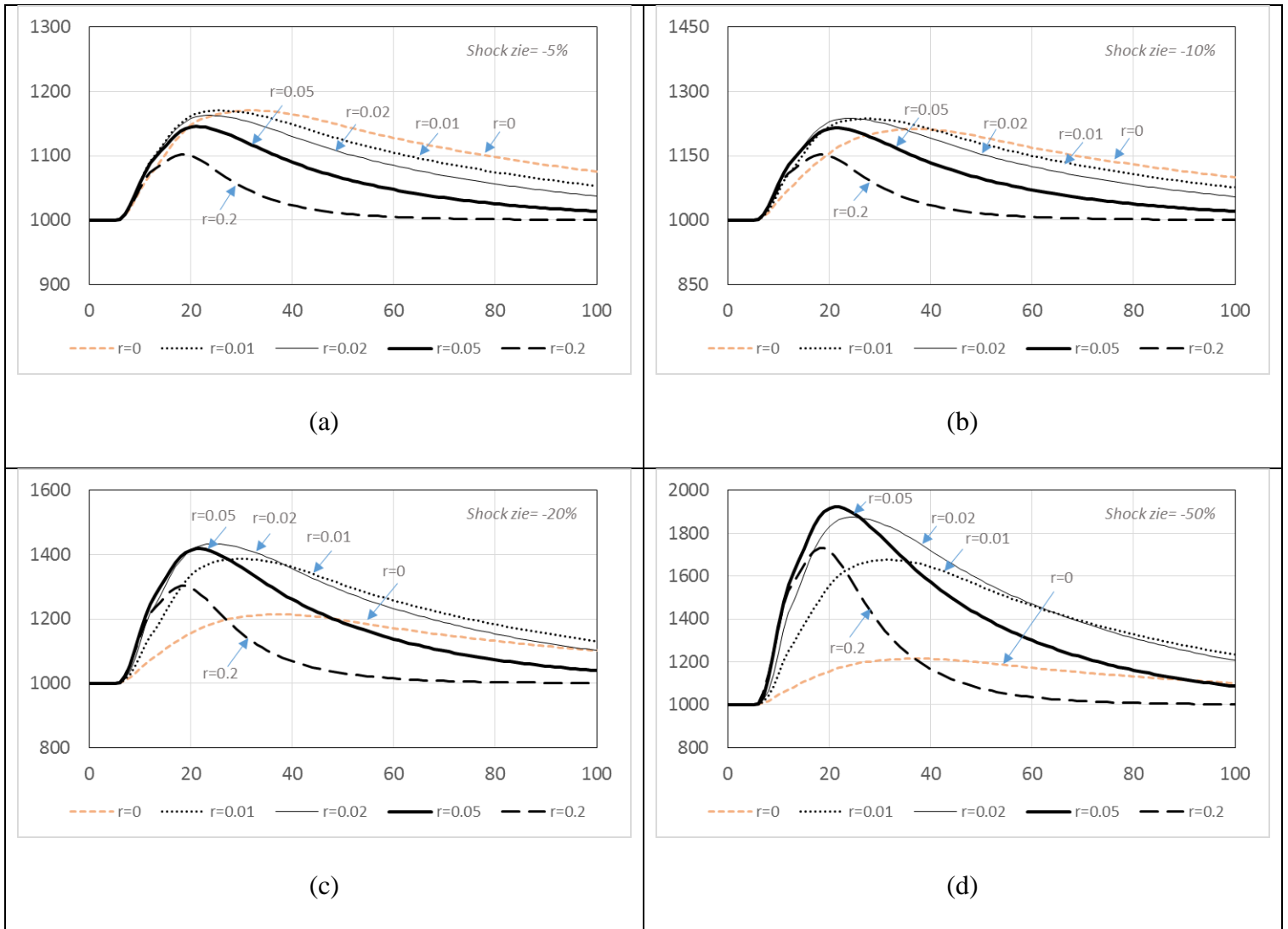


Figure 9: Number of the most-educated group (W_3) in different scenarios. Note: r represents the ratio of highly educated people who do not find fitting jobs and take temporary positions in academia.

For a systematic examination of the magnitude of overshoot in W_3 (the most-educated workforce) in different conditions, we can examine the ratio of the maximum magnitude of the long-term wave in W_3 to the same variable in the corresponding $r = 0$ condition. We name this variable *Normalized W_3 overshoot size*. Put simply, the *Normalized W_3 overshoot size* for shock size = -20% and $r = 0.05$ will show the ratio of the overshoot size in this condition to the

condition with shock size = -20% and $r = 0$. Higher values of the *Normalized W3 overshoot size* would mean we have had larger amplitudes in long-term waves. Figure 10 shows the results.

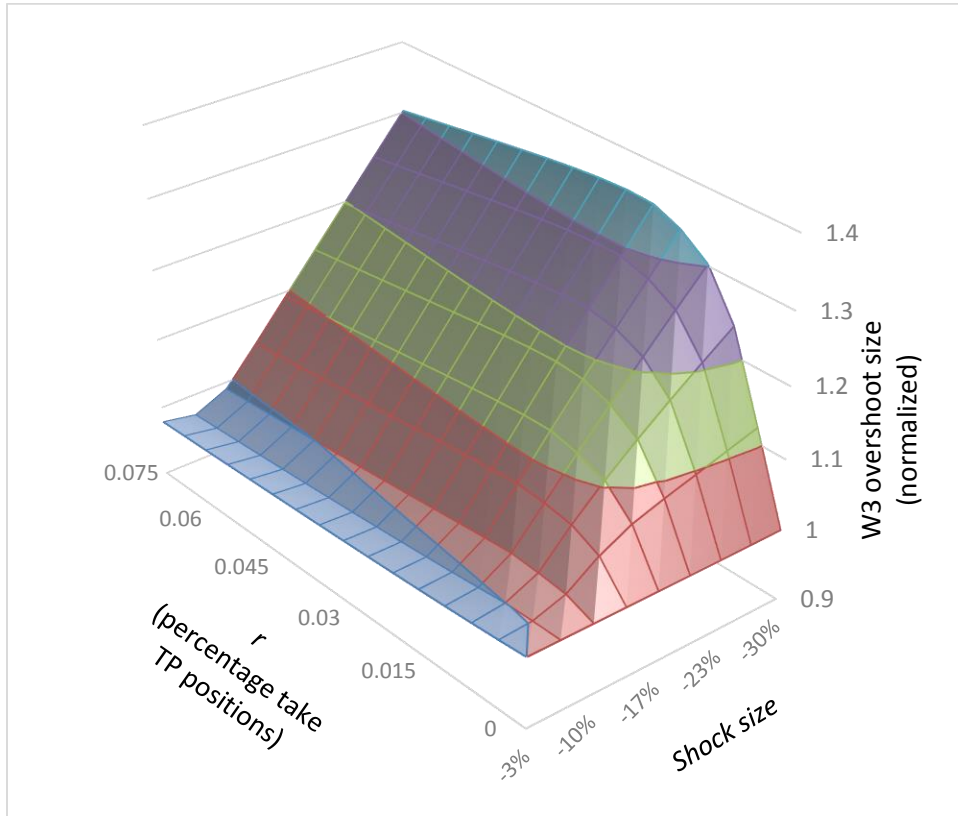


Figure 10: The size of overshoot in the number of the most-educated group (W3) for different values of short-term economic *shock size* vs. r (percentage of people taking temporary positions)

The results imply two major points. First, as we expect, larger short-term economic shocks result in larger mismatches in the highest-educated group. In the figure, as *shock size* increases we see a larger value for *W3 overshoot size*. Second, temporary positions in academia have interactive effects with the magnitude of long-term shocks, with a tipping point (Repenning et al., 2001; Rudolph and Repenning, 2002; Morrison 2012) after which the direction of effect of temporary positions on overshoot changes. In major recessions, as more people are hired into temporary academic positions (e.g., in the figure, see *Shock Size* = -30% and r between 0 and

0.03) we see that the long-term mismatch sharply increases. This is due to the dominance of the pipeline reinforcing effect that results in training more and more people in academia, with society ending up with an abundant number of highly educated people, more than what the job market desires. Notably, there is a tipping point after which the effect of r reverses. This is more apparent for smaller shocks: temporary positions help dampen economic shocks (e.g., in Fig. 10, see *Economic Shock Size* = -10% and r between 0 and 0.075). The reason is that these positions absorb people who do not find permanent jobs during short-term recessions, dampening the cascading effect and therefore mitigating what could have been extra pressure on the lower-educated population.

The bottom line is that for the range of parameters we tested, the endogenous growth in mismatch showed up, but the effect is worse for major recessions and during these the effects are likely to be magnified with temporary positions in academia. In smaller economic shocks, however, temporary positions can dampen the shocks, working as a buffer and absorbing highly educated people who otherwise would have taken the jobs of relatively lower-educated groups.

Next, we simulate the model for different values of the technological shift (the number of jobs taken from J_1 and added to J_3) times different values of r . Figure 11 depicts a few selected simulation runs over time for 4 sizes of technological shifts (25%, 30%, 32%, and 34% shocks in figures 11a, 11b, 11c, and 11d, respectively). Each graph shows the result of a different value for the ratio of people who take temporary positions ($r = 0, 0.01, 0.02, 0.05, \text{ and } 0.2$).

In simulation runs for $r = 0$, we see a goal-seeking pattern. As the value of r increases in Figs. 10a, b, and c, an overshooting pattern emerges in which the magnitude of the overshoot is higher for stronger economic shocks for two middle parameter values (30% and 32%, Fig 10b and 10c, respectively). This shows there is a window of parameters for technological shift within

which we see a large overshoot. In Figures 10a, b, and c, we can see the magnifying effect on overshoot of r . Higher values of r lead to a faster appearance of overshoot, and faster dampening.

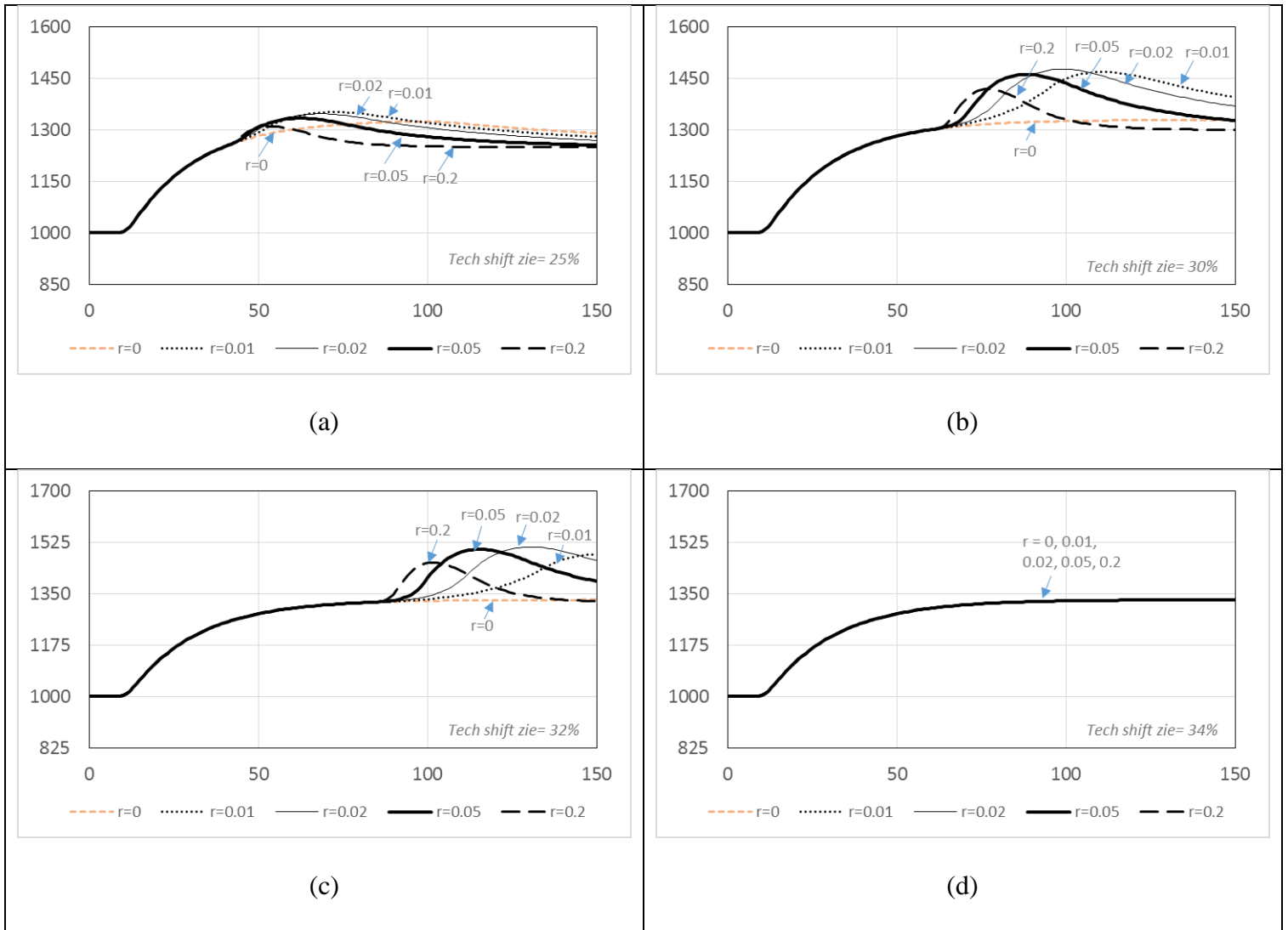


Figure 11: Number of the most-educated group (W3) in different scenarios. Note: r represents the ratio of highly educated people who do not find a fitting a job and take temporary positions in academia.

Figure 12 shows a more systematic comparison of the magnitude of overshoot in the number of the most-educated workforce. The figure shows that there is a window of parameter values for a technological shift to result in long-term waves of underemployment. Smaller technological changes will not result in overshoot in the system, and the workforce will slowly

adapt itself to the new equilibrium. However, as the shift passes a tipping point (in our model, 25%) and creates enough incentive to attain more education, more people go to schools and once the new wave of the students graduate, the job market ends up with an abundance of highly educated individuals. Notably, very large technological changes also will not result in mismatches for the highest-educated workforce. This is mainly due to absorbing all people who obtain education into new high-tech positions without allowing activation of the cascading effect.

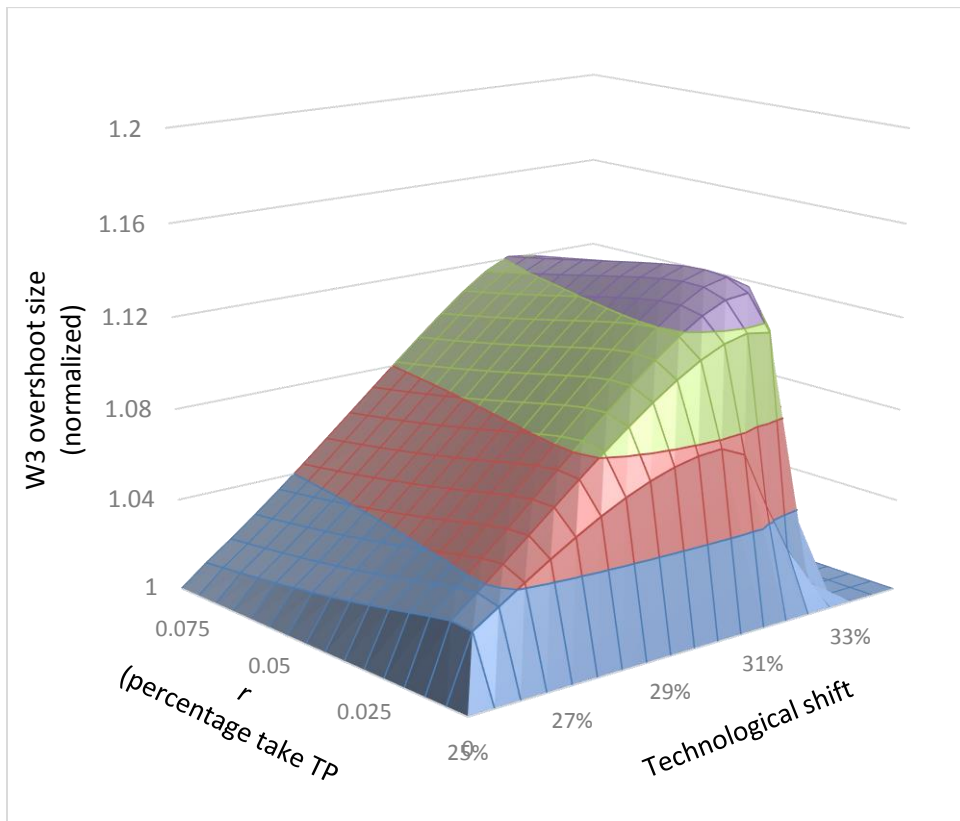


Figure 12: The size of overshoot in number of the most-educated group (W3) for different values of *technological shift* vs. *r* (percentage of people taking temporary positions)

The U-shaped effect of *r* is also worth mentioning. As people are hired into temporary positions ($r > 0$), the magnitude of overshoot increases until a tipping point, after which it

declines. This is related to the range of parameters in which the pipeline reinforcing effect becomes dominant over the buffering effect of temporary positions. While the actual values of this parameter are empirical questions, our model predicts that overshoot emerges in a specific range of technological shifts in the market.

5. DISCUSSION AND CONCLUSION

We presented a simple model to capture how feedback structures within labor and education sectors can lead to excess degree accumulation, magnified pressures on those with lower degrees, underemployment, and long-term pressures on people with higher degrees. We introduced two major feedback mechanisms that act on the education enterprise and cause the number of educated people to increase dramatically, with relatively short-term changes in the job market. First, we introduced a cascading effect that represents how job shortages throughout the pipeline cascade toward lower-skilled individuals as people with more education take jobs for which they are overqualified. The mechanism also creates incentives to move up the workforce pipeline. Second, we introduced a capacity reinforcing mechanism that results in increasing the population of PhDs by employing a portion of them in temporary academic positions. These two mechanisms create self-driving growth engines that are adequate to over-incentivize degree attainment, and can affect the long-term match between supply and demand for college-educated labor.

These mechanisms make the system vulnerable to small and short-term external shocks. As a result, we end up with individuals who attain higher degrees of education to take jobs that do not require these degrees, but give them a competitive advantage over people without those degrees. The implication is education system inefficiency; some waste their time in the education

system simply to obtain a degree they need to compete in the marketplace. In the real world, this means investing some of the most productive years of one's career during one's late 20s and early 30s in getting a degree to use for job hunting, with no use for the degree after taking the job other than ensuring a higher salary. At a societal level, the return on such an investment is questionable.

The feedback mechanisms described in this paper are not the only ones that exist and can intensify underemployment and mismatch in labor force. For example, there are dynamics on the labor force demand side that are triggered by employers. Job requirements can change based on social consensus about what type of people should perform which jobs. If a job is traditionally done by a worker with a master's degree, people can perceive the job as one that requires a master's degree. However, our perceptions about requirements are not fixed. Once the job is taken by higher degree holders, social mores can evolve towards the job requiring a higher degree. Employers can shift the requirements and begin to expect workers to have that higher degree. Looking back in the history of higher education in engineering schools, we see many faculty positions that were taken by experienced engineers with a bachelor or a master's degree, a practice that may seem strange in the 21st century.

The story does not end here. With an abundant number of job applicants, educational degrees now also act as a proxy for gauging dedication and overall capabilities. There is a high degree of uncertainty surrounding job candidates that is rarely revealed until they are hired. In such uncertain, subjective, and noisy environments, degrees can be seen as objective signals of capabilities. As a result, employers whose jobs typically have not required a degree are using degrees as a signaling mechanism to differentiate among applicants vying for the same position (Tyler et al. 2000). This effect should work stronger as other information cues become more

uncertain and as the number of applicants increases. The result is that the lengthy time spent on education gives a signal that could have been otherwise observed by patient employers in a few months after hiring a new employee.

We provide simulation-based evidence that for a wide range of parameter values the education system can create magnified pressures endogenously on those with lower degrees, and long-term waves of pressures on those with higher degrees. The main driver of these dynamic patterns is the structure of the system: the reinforcing loops to push down short-term job shortages to the lower-educated population and incentivize more education, and to take temporary positions in academia, adding to the capacity of universities and future outputs. Delays in attaining a degree also contribute to overshoot in workforce numbers for a limited number of jobs.

The behavior is similar to the bullwhip effect in supply chains and demand amplifications throughout supply chains (Lee et al., 1997; Sterman, 1989 and 2000; Andersen et al., 2000; Akkermans & Vos, 2003). It is shown that a small external shock (or just expecting a shock (Croson et al., 2014)) creates long-term waves of backlog and inventory, and overall inefficiency throughout the chain. In supply chains, however, providing clear information may help correct the bullwhip effect. Here, we cannot easily argue that the problem of self-driving growth engines in education stems solely from a lack of information. Individuals seeking fitting jobs face competitors with higher degrees, as if the rules of the game are changed. For example, it is getting much more difficult to argue that postdoctoral training is not necessarily required for an academic position, while a few decades ago such training were not at all common, and many newly minted PhDs would land tenure-track jobs immediately after graduation; today, universities take for granted that new hires should have years of postdoctoral training.

Furthermore, the abundance of PhDs (Larson et al., 2013) who decide to look for non-academic positions end up applying for different positions in research centers, many of which do not need their specific and narrow PhD training. However, these PhDs are likely to win the competition over applicants with master's degrees, persuading the latter that one needs a PhD to get any research position. And the story continues making a college degree a must for jobs that do not necessarily benefit from the type of training offered in colleges.

We tried to simplify the analysis by designing two clear experiments with the model. We investigated the effects of a pulse shock and a change in the distribution of jobs separately to capture effects of change in the average number of jobs and change in the distribution of jobs one at a time, while controlling for the other. In the real world, they are likely to happen concurrently. For example, there is no guarantee that for each W_1 job that disappears exactly one W_3 job emerges; in fact, one might expect that the number of high-tech jobs that are replacing former low-tech jobs is smaller. This adds to the magnitude of long-term waves throughout the education pipeline and makes the system more vulnerable. Overall, the education system seems to be in structural disequilibria (Teitelbaum, 2008).

The theory has several policy implications. First, while federal funding for short-term academic positions such as postdocs and temporary teaching positions might be helpful for current PhDs, it is not a proper policy from a big-picture perspective. These positions help PhD graduates have temporary jobs, but also free professors' teaching time, with the side effect of graduating more PhD students! Universities that offer course-release policies so faculty members can allocate a relatively small portion of their funding in exchange for not teaching also contribute to exacerbating this situation. More funding comes to the university, more PhD

scholarships are provided, and more PhDs will compete for a fixed number of academic positions.

Our study has several limitations. The model was offered to develop a theory, and as stated we made no claim that our simulation model precisely depicts detailed labor markets in the United States or elsewhere. Rather, we tried to understand first-order dynamics, given our postulated assumptions. Future models can address more layers of complexities and include more details. They can also be calibrated to reproduce real-world patterns and be validated against different cases (Groesser and Schwaninger, 2012).

Furthermore, our study focused on a specific type of mismatch. However, the problem of mismatch between education and job market goes much beyond the analysis in this study. Our model depicts a simple one-dimensional mismatch between the level of degree and job requirement; in the real world, there are multiple dimensions of mismatch between training and job requirements. For example, people may undergo training that lags behind technologies used in a given industry. The delay between education colloquia and industry needs may result in teaching techniques that are outdated. More elaboration on the dynamics of mismatch between education and industry is a future avenue of research.

In summary, we offered a new explanation for inefficiency in the education sector. We hypothesized that small economic changes in the market last for a long period, have magnified and immediate effects on the lower-educated workforce, and with a delay affect the most-educated group due to education escalation and the abundance of an overqualified workforce. In this context, people end up obtaining education only to have a competitive advantage during the hiring period, without any further use. The overall result is extra spending on education, a corresponding loss of working years, and an increase in student debt. Recalling our opening

quote from Clive James, investing significant time and money to learn Newton's force equations for rotating and falling circular objects does not seem to be an efficient strategy for better *hamburger-flipping*.

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Online Appendix: Detailed formulations

Formulations	Comment
<p>1. <u>Workforce</u></p> <p> $d/dt (W_1) = NW_1 - SAd_2 - EW_1$ $d/dt (W_2) = NW_2 - SAd_3 - EW_2$ $d/dt (W_3) = NW_3 - EW_3$ </p> <p style="padding-left: 40px;"> <i>W_i: Workforce with degree i;</i> <i>Initial values = 1000</i> </p> <p style="padding-left: 40px;"> <i>NW_i: New W_i Rate</i> <i>EW_i: Exit W_i rate</i> <i>SAd_i: Student Admission to pursue degree i</i> </p> <p> $NW_1 = 150$ $NW_2 = DELAY3(SAd_2, T_2)$ $NW_3 = DELAY3(SAd_3, T_3)$ </p> <p style="padding-left: 40px;"> <i>DELAY3: Third Order Delay,</i> <i>T₂ and T₃: Average time to graduate</i> </p> <p> $EW_1 = \alpha W_1$ $EW_2 = \alpha W_2$ $EW_3 = \alpha W_3$ $\alpha = 0.05$ $T_2 = 5$ $T_3 = 2$ </p>	<p><i>This set represents workforce with three stock variables, W₁, W₂, and W₃.</i></p> <p><i>Each stock increases as new people join and declines as people exit the workforce pipeline or, for W₁ and W₂, decide to pursue education (W₃ is assumed to be the end of the pipeline).</i></p>
<p>2. <u>Jobs</u></p> <p> $J_1 = 1000$ $J_2 = 1000$ $J_3 = 1000$ </p> <p style="padding-left: 40px;"> <i>J_i: Jobs that require degree i</i> </p> <p> $J'_1 = J_1 - UD_2$ $J'_2 = J_2 - UD_3$ </p> <p style="padding-left: 40px;"> <i>J'_i: J_i available for W_i,</i> <i>UD_i: Underemployment; W_i taking J_{i-1} jobs</i> </p> <p> $\Delta_1 = W_1 - J'_1$ $\Delta_2 = W_2 - J'_2$ $\Delta_3 = W_3 - J_3 - TPA$ </p> <p style="padding-left: 40px;"> <i>Δ_i: Job discrepancy i</i> </p>	<p><i>This set represents jobs and how they are distributed.</i></p> <p><i>It also estimates job discrepancies for each subpopulation, which represents the difference between number of jobs for a degree and number of people with that degree.</i></p>
<p>3. <u>Unemployment and underemployment</u></p> <p> $U_1 = \Delta_1$ $U_2 = \Delta_2 - UD_2$ $U_3 = \Delta_3 - UD_3$ </p> <p style="padding-left: 40px;"> <i>U_i: Unemployment</i> <i>UD_i: Underemployment; W_i taking J_{i-1} jobs</i> </p> <p> $UR = 0.9$ </p> <p style="padding-left: 40px;"> <i>UR: Max Under-employment ratio</i> </p> <p> $UD_2 = \text{Min}(\text{Max}(0, UR * \Delta_2), J_1)$ $UD_3 = \text{Min}(\text{Max}(0, UR * \Delta_3) - \text{Hiring TPA}, J_2)$ </p> <p style="padding-left: 40px;"> <i>Hiring TPA: W₃ taking temporary position in academia</i> </p>	<p><i>This set estimates unemployment and underemployment.</i></p> <p><i>Unemployment for W₁ is basically job shortage. For W₂ and W₃ it is equal to job shortage minus the number of people who take lower-level jobs (underemployment).</i></p> <p><i>UR represents underemployment ratio; the ratio of people that don't find a fitting job (Δ_i) and willing to take a lower level job, if available.</i></p>

<p>4. <u>Temporary Positions (TPA)</u></p> <p>$d/dt(\text{TPA}) = \text{Hiring TPA} - \text{Leaving TPA}$ TPA: Temporary Academic Positions Initial value = 0</p> <p>Hiring TPA = $r \cdot \max(0, \Delta_3)$ $r = 0.05$</p> <p>Leaving TPA = TPA/Time in TPA Time in TPA = 2</p> <p>$C_{\text{TPA}} = \text{TPA} \cdot \text{Average Cap Per TPA}$ Average Cap Per TPA = 20 C_{TPA}: Additional capacity due to hiring TPAs</p>	<p><i>This set represents temporary positions in academia, such as postdocs and lecturer positions. It is assumed the positions are for 2 year. And in the base run 5% of people in W3 that don't find a fitting job take temporary positions in academia.</i></p> <p><i>The capacity of university is assumed on average to increase 20 students per person hired in temporary position.</i></p>
<p>5. <u>Students</u></p> <p>$C = C_N + C_{\text{TPA}}$ $C_N = 150 \cdot 1.33$ $C_2 = kC$ $C_3 = (1-k)C$ $k = 2/3$</p> <p><i>C: Total university capacity;</i> <i>C_i: Capacity for admitting S_i</i></p> <p>$d/dt(S_2) = \text{SAd}_2 - \text{NW}_2$ $d/dt(S_3) = \text{SAd}_3 - \text{NW}_3$ <i>S_i: Students getting degree i</i> Initial values: $S_2(t=0) = 500$, $S_3(t=0) = 100$</p> <p>$\text{SAd}_2 = \text{Min}(C_2, \text{SAP}_2)$ $\text{SAd}_3 = \text{Min}(C_3, \text{SAP}_3)$ <i>SAP_i: Applications for college, degree i</i></p> <p>$\text{SAP}_2 = \text{SAP}_{2,N} + \text{SAP}_{2,\text{extra}}$ $\text{SAP}_3 = \text{SAP}_{3,N} + \text{SAP}_{3,\text{extra}}$</p> <p>$\text{SAP}_{2,N} = \text{Smooth}(-\text{EW}_1 + \text{NW}_1, T)$ $\text{SAP}_{3,N} = \text{Smooth}(-\text{EW}_2 + \text{NW}_2, T)$ $T = 3$ $\text{SAP}_{3,\text{extra}} = \beta \Delta_2$ $\text{SAP}_{2,\text{extra}} = \beta \Delta_1$ $\beta = 0.2$</p>	<p><i>This set represents applicants (SAP), admission rate (SAd), number of students (S), and graduation rate (NW) for two degrees.</i></p>
<p>6. <u>General</u></p> <p>TIME STEP = 0.015625 FINAL TIME = 150</p>	<p><i>Operational parameters for simulation.</i></p>