This document provides a sketch of solutions to the exam. The provided solutions are intended as a guide to answering the questions, and are not meant as exhaustive. The written solutions would have to be worked out more completely.

Draft your responses with an eye to clarity of exposition and structure as well as to showing your understanding of the concepts learned in class. Link the problem at hand to economic theory. You are free to make any reasonable assumptions that help you in answering, as long as you are specific and explicit.

Make sure to *pace yourself*. You may choose to work on the questions in a different order.

Massive Open Online Courses

For the past couple of years, online learning has greatly expanded as an alternative to regular schools and universities. Massive, open, online courses, or MOOCs, have become hugely popular. Players in this industry, such as the Khan Academy, Coursera, or edX, have millions of registered learners. The *New York Times* declared 2012 "the year of the MOOC." Some characteristics of MOOCs that are relevant for an economic analysis are:

- They are "massive," meaning that there is hardly a limit to how many people can use the same material that was generated once. This would lead to a steadily declining per/user cost schedule as the number of users increases. Think of a natural monopoly like railroads.
- Some internet courses are taught by the very best professors in the field, at top institutions such as Harvard and MIT. There is no restriction on where students have to be to engage with content from those elite institutions.
- MOOCs mostly focus on adult self-learners, but there are also courses that are appropriate for elementary and secondary school students, such as the Khan Academy (teaching math from grade 3-level and up).
- Some courses lead to certification, while others do not come with a diploma at the end.

Questions

1. Use the classical Ben Porath human capital model to analyze how two aspects of MOOCs influence optimal individual demand for education.

   Questions 1.a) to 1.c) are below. You may use the following:
   The optimal share of time in schooling in period t by individual i is S^*_{it}:

$$S^*_{it} = \left[\frac{\beta_{t+1}}{\beta_t} \frac{\alpha}{1+\rho} \frac{1}{H_{it} + \gamma_t/\beta_t} \left(A_i H_{it} E_{it}\right)^{\alpha} \right]^{\frac{1}{(1-\alpha)}},$$

   where

   - β_t and β_{t+1} are the wage-returns to human capital in periods t and $t+1$,
   - H_{it} is i's human capital in period t,
   - A_i is personal initial learning ability,
   - E_{it} are public inputs (for ex. expenditures) into schooling in period t,
   - γ_t is the direct cost of schooling in period t,
   - α is the parameter of the human capital production function, ρ is the discount rate.

   (1.a) **Cost of schooling:** A successful MOOC teaches many students from a single set of content. We would expect this MOOC to be cheaper per student than a teacher that teaches to a single class.

   How does a decreased cost influence demand for education? (Stay within the model for individual demand here—do not analyze competition between online and regular courses.)

   Solution:

   - A very clear prediction from Ben-Porath: With a lower marginal cost of schooling (γ_t), everyone's optimal schooling increases. Put differently: at a lower price, individual demand for schooling is higher.
   - Analytically, we see that the partial derivative has to be negative, so at *lower* cost, optimal schooling S^*_{it} is greater:

$$\frac{\partial S^*_{it}}{\partial \gamma_t} = \frac{-1}{1-\alpha} \left(H_{it} + \gamma_t/\beta_t\right)^{\frac{-1}{1-\alpha}-1} \left[\frac{\beta_{t+1}}{\beta_t} \frac{\alpha}{1+\rho} \left(A_i H_{it} E_{it}\right)^{\alpha} \right]^{\frac{1}{(1-\alpha)}},$$

   (1.b) **Public inputs on schooling** Alternatively, one could imagine teachers in regular classrooms use content from MOOCs as additional material.

i. How would demand for schooling change if we interpret this as in increase in resources put into education (E_{it} in the model)?

ii. Would the response be homogenous across the population, or would a specific group of students react more strongly? Use the following derivative.

$$\frac{\partial S_{it}^*}{\partial E_{it}} = \frac{\alpha}{(1-\alpha)} E_{it}^{\frac{\alpha}{(1-\alpha)}-1} \left[\frac{\beta_{t+1}}{\beta_t} \frac{\alpha}{1+\rho} \frac{1}{H_{it} + \gamma_t/\beta_t} (A_i H_{it})^{\alpha} \right]^{\frac{1}{(1-\alpha)}}$$

Solution:

- i. Demand for schooling would increase, because the production function has a built-in complementarity between time inputs into schooling and public inputs. Thus, a given minute spent in schooling is now more effective in producing human capital with the higher-quality online courses.
- Analytically: In the original equation for S_{it}^*, E_{it} enters positively. Alternatively, use the derivative with respect to E_{it}. All ingredients in the first derivative shown are *positive*, so demand for schooling increases.
- ii. The response would not be homogenous. The magnitude of the response is defined by the first derivative $\frac{\partial S_{it}^*}{\partial E_{it}}$. This is unambiguously increasing in A_i, therefore high-ability students would react more strongly to the increase in quality. This results from a similar complementarity in production as between schooling inputs and public inputs, just between ability and public inputs.
- Other sources of heterogeneity could be parameters such as β_t, β_{t+1}, etc., but here they do not have a person-specific subscript i. The response magnitude is ambiguous with respect to H_{it}.

(1.c) Discuss briefly why the Ben-Porath model is appropriate to study MOOCs.

Solution:

- Ben-Porath is mainly a model of time investment, which is the main ingredient to MOOCs.
- This is a model that is best used to analyze adults who make their own decisions (not necessarily in intergenerational context). Most learn-

ers in MOOCs are self-directed independent learners, therefore the assumption of independent decision-making sounds appropriate.

- Unfortunately, Ben-Porath assumes the ability to perfectly smooth consumption, which we may not want to assume.

2. The Economist writes on January 12, 2017: "Besides costs, the second problem for MOOCs to solve is credentials. Close colleagues know each other's abilities, but modern labour markets do not work on the basis of such relationships. They need widely understood signals of experience and expertise, like a university degree or baccalaureate, however imperfect they may be. [...] The MOOCs' answer is to offer microcredentials like nanodegrees and specialisations."

   Credentials are often provided after students pay a fee, and after going through an exam or test of their learning outcomes.

   Use sorting models to analyze this topic.

   (2.a) What is the basic framework and assumptions in which Spence developed his 1973 signalling model? What was the objective?

Solution:

- Asymmetric information about worker quality, employer does not observe quality at all/ever.
- Other assumptions: only 2 types of workers, high/low ability. Productivity increases with ability. Wages are set by firms in a perfectly competitive environment. The cost of education is decreasing in ability. Education itself is not productivity-enhancing, and thus not a reason for higher wages.
- Objective: to show that even in complete absence of actual learning/ human capital acquisition in schooling, there could be an apparent "return" on the labor market to a degree.
- Condition for the separating equilibrium to occur: obtaining the signal is costlier to low-ability individuals than high-ability individuals, but it is not too costly: The wage differential (resulting from productivity differences that can be rewarded in a separating equilibrium) is large enough to outweigh the cost of investing in the signal for the high-ability individuals.

(2.b) Very briefly highlight which key ingredient of the model is alluded to in the quote from the Economist.

Solution:

- "know each other's abilities" - asymmetric information. The Economist makes it sound like modern labour markets suffer more from this inability to know a worker's quality before hiring him.

(2.c) Why are credentials necessary at all? Which conditions could make credentialling less important?

Solution:

- They are necessary because saying one has enrolled in a MOOC is cheap talk, costless, and a worthless signal. Enrolling is costless. Anyone can claim so. Therefore, employers do not value enrollment as a signal.
- Credentials work because they are costly. Here, we have two types of costs actually: a monetary one, and the learning and effort cost of preparing for and taking an exam.
- Conditions to make credentialling less important:
  - Showing completion in another way: proving to employers the skills one has through examples of work, screenshots of homeworks, etc.
  - Selection into more difficult courses, and proving completion in these alternative ways
  - If employers could learn about their employees ability more quickly, the employee would be willing to engage in costly learning even without a credential.
  - This last point will go in the direction of screening. Employers could give exams to applications to select them on basis of demonstrable skills.

(2.d) Think about empirical tests of signalling versus human capital models.

Does the "need for credentials" prove that there is no human capital gain from MOOCs?

Could a simple comparison between earnings of individuals who completed certified courses, and individuals who completed courses that do not give a credential

at the end, be a test of signaling versus human capital models?

Solution:

- The need for credentials arises from asymmetric information, not because there is no human capital gain.
- If completing a credentialled course is more expensive in terms of direct costs and time costs, and less so for highly-able, then the credential could serve as a sorting tool to separate high-ability individuals from low-ability individuals.
- If we really found 2 courses that provide the same learning experience, and both students actually completed the course, they would both have the same human capital gain from the course. Only one would have the signal. One would be tempted to compare their wages, and conclude that a signal is important if the person who completed the expensive credentialled course has higher earnings than the non-credentialled completer.
- But there are two problems with this: a) selection, and b) being sure that a non-credentialled person actually completed a course with the same learning effort.
- a) The simple comparison suffers from selection into different types of courses. We worry that one reason to choose to do a non-credentialled course is that there is no pressure to actually exert a lot of learning effort. Skating by with a minimum is costless, since there is no test at the end. Therefore, one should expect there to be a quality difference ex ante between individuals who choose to follow a credentialled vs non-credentialled course.

  We would instead need other reasons that force students into one/the other type of course. These could be credit constraints (as long as they are independent of learning ability etc.), or simply the offering of 2 versions that is temporally or spatially different between otherwise similar individuals.
- b) Non-credentialled courses suffer from non-completion. Therefore, the human capital gain may be lower in those classes relative to classes with a test at the end. That means we would compare someone with both human capital gains and a degree to someone with neither of the

two. This would not allow us to learn about human capital versus signalling either.

- Furthermore, the two individuals may be employed at different types of employers, and the employer difference may be a third reason for different wages that is unrelated to the signalling/human capital story. If less productive firms employ workers without a diploma, the non-credentialled workers' earnings will be lower not directly because they cannot signal, but because they work in different firms.

3. For this final question, we contrast the return from completing a class in two different settings: a regular program at Harvard, vs. one of their online classes.

(3.a) What is the main difference between taking an online class from Harvard and (being allowed to) enrolling in regular Harvard and taking a physical class there? How would the difference be reflected in wage returns?

Solution:

- Keyword: selection. Anyone can take the online class, whereas only a select few are admitted into regular Harvard.
- The selection effect means that the students in physical Harvard are of higher quality, ceteris paribus. Even if both classes have the exact same learning gain, they increase their Human Capital with the same amount, we could expect a difference in earnings between students in the two classes. The selected students have not only shown learning gain from the class, but also that they are of high quality even without that gain. We would expect the return to be much higher from regular/physical Harvard classes.
- Finally, note that there is also a price tag difference between the two. Tuition is much higher in physical Harvard.

(3.b) One reason why returns to a class (or degree) from Harvard are generally high is that they supposedly have the world's best professors. Discuss what you know about teacher value added, and how it would apply to the two types of courses.

Solution:

- Teacher value added has been shown by Chetty and coauthors to identify true quality differences between teachers. These quality differences causally lead to greater learning in students, and have large long-term effects on educational outcomes. These educational outcomes then translate into better labor market outcomes, as would be predicted by the human capital model.
- There is, however, more variation within schools than across schools. Translated to Harvard, this would suggest that while the average Harvard professor may have higher value-added than an average professor, there will also be lower-value-added professors at Harvard.
- Furthermore, we know from recent work by Kirabo Jackson that teachers also vary in their value-added in another domain than just academic outcomes, namely in building their students' socio-emotional skills. The correlation between the two types of value-added is low. At the same time, this second type of value-added of teachers also has independent returns in terms of academic gains and labor market outcomes.
- To the extent that the *same* professor teaches the physical and the online class, the learning gain from students should be the same.
- There is, however, a potential difficulty with translating a value-added score from a physical classroom to the online class: if the teacher's value added stems at least partly from classroom management and a direct interaction with students, and not only the presentation of material, value added in the two environments would not be perfectly correlated.