A Simple Model of Globalization, Schooling and Skill Acquisition

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Abstract: We develop a model of schooling and skill acquisition, highlighting informational asymmetries that distort the incentives to educate. A key feature of our model is that education acts simultaneously as a signaling device and as a method for workers to enhance their productivity. We show that when firms can only imperfectly screen workers, the result is an economy in which too many workers purchase schooling and too few workers devote sufficient effort to their coursework to qualify for the high skill labor pool. We then examine how greater openness to international markets alters the skill mix of the domestic workforce and show that greater openness usually eases one labor market distortion while making the other distortion worse. Globalization impacts educational behavior and labor market outcomes differently as the extent of firms engaged in international markets varies.

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I. Introduction

It is often argued that the key to individual success in a globalized economy lies in higher education. From a national perspective, a highly educated workforce is seen as an essential component needed to maintain international competitiveness and foster economic growth. Yet, the educational process is complex, requiring a variety of individual choices, and the manner in which globalization affects those choices is not well understood. In this paper we develop a simple model of schooling and skill acquisition, highlighting informational asymmetries that distort the incentives to educate. We then examine how greater openness to international markets alters the skill mix of the domestic workforce, given that worker schooling and skill acquisition decisions are not perfectly observed by firms.

The notion that educational choices might be distorted is not new. Forty years ago Ivar Berg (1970) and Richard Freeman (1975, 1976) argued that `too many' Americans seek a college education. More recently, Charles Murray, in *Real Education: Four Simple Truths for Bringing America's Schools Back to Reality* (2009), pushed this same idea, arguing that the marginal student in college today would be much better off going to a trade school.[1] For anyone who has taught at a large state university and dealt with students who rarely come to class and seem to devote almost no effort to the educational process, this sentiment probably rings true. On the other hand, we often hear that firms are complaining that they cannot find enough high-skilled workers to fill available positions. For example, in a 2012 survey the ManpowerGroup found that 34% of employers across the globe report that they are having difficulty filling positions due to a lack of available talent among the labor force. In a 2012 study by the McKinsey Global Institute it was concluded that "[i]n advanced economies, demand for high-skilled labor is now growing faster than supply…," so the shortage of high skill workers may actually be growing.

These anecdotal pieces of evidence are seemingly at odds with one another. How can it be that there are simultaneously 'too many' workers earning advanced degrees in school, yet there are 'too few'

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[1] In an interview with the *New York Times*, Murray argued "there are very few unemployed first-rate electricians. I can get a good doctor in a minute and a half. Getting a really good electrician – that's hard." -- see Solomon (2008) for additional details. Carneiro, Heckman and Vytlacil (2011) provide evidence consistent with Murray's claims that the marginal return to college is often well below the average return. They argue that policies that expand college enrollment induce "students who should not attend college to attend it. Too many people go to college."

high-skill workers available for hire? We argue that such a market condition can arise if the efforts that workers put forth during school, and hence the benefits of their high skills to productivity, are not perfectly observed when firms screen applicants. If high skill workers cannot perfectly distinguish themselves from low skill workers that obtained schooling solely as a signaling device, then the problem of adverse selection arises in the labor market. Firms compensate for the lack of information about skills by offering wages that reflect the average productivity of the educated workers, rather than their marginal productivity. As a result, too many low aptitude workers choose schooling because the expected returns to education are higher than their individual productivity. Likewise, too few high aptitude workers put forth effort in school to enhance their productivity because the returns to education do not fully compensate them for being high skilled if there is imperfect screening. A key feature of our analysis is to model skill acquisition as simultaneously a signaling device and a mode for workers to enhance their productivity, which allows us to rationalize the opposing views of the labor force as having both too many workers obtaining advanced degrees, and too few high skill workers.[2,3]

Globalization has long been recognized as a mechanism that shifts the relative demand for skilled workers, and thus the expected returns from education and skill acquisition. Hickman and Olney (2011) provide direct evidence that the offshoring of local production, and international migration into local labor markets, both induce U.S. workers to enroll in post-secondary education institutions. Atkin (2012) provides empirical evidence that young Mexican workers respond to increased export opportunities for low-skill occupations by reducing their enrollment in school, whereas greater export opportunities for

[2] Fang (2006) uses a structural model to quantify the relative importance of signaling motives versus productivity enhancements in explaining the college wage premium among US workers. He finds that *both* motives contribute substantially to the incentives of workers to seek education.

[3] Our approach here is different from the empirical literature on over-education, as indicated by the qualifications of *individual* workers that are in excess of their specific job requirements. As an example, as of 2010, the Bureau of Labor Statistics reported that over 17 million Americans with college degrees are employed in positions that require a lower level of skills than those associated with a college degree. More details can be found in Matgouranis (2010) who reports that: 29.8% of flight attendants, 24.5% of retail salespersons, 21.6% of customer service representatives, 15.2% of taxi drivers, and 13.9% of mail carriers hold college degrees. For a recent review of the literature on mismatches between worker skills and job tasks see Leuven and Oosterbeek (2011). Our analysis of educational behavior when there are informational asymmetries across the entire market is distinct from, but complementary to, the studies of mismatch and coordination problems for individual workers.

high-skill occupations increase the acquisition of schooling among Mexican workers. There is similar evidence in Falvey, Greenaway, and Silva (2010) of skill-upgrading among Portuguese workers as international competition intensifies. It is clear that the expansion of the global economy influences the schooling and skill acquisition of native workers. However, it is unclear if changes in the educational behavior of workers following episodes of globalization mitigate, or exacerbate, the distortions present when firms screen worker skills imperfectly. Our goal here is to examine the impact of increased trading opportunities on (i) the decisions of workers to go to school, and (ii) the decisions of workers to obtain high levels of skill, when workers have more information about theirs skills than hiring firms.

To analyze the impact of globalization on the mix of worker skills, we build a two-sector model with perfectly competitive markets. Workers differ in aptitude and can choose to go to school to become a low-skill worker, and subsequently choose whether to put forth effort to become a more productive high-skill worker. Both schooling and effort are costly, and the costs are each declining in the innate aptitude of workers. The schooling decisions of workers are observed through the earning of a degree, however the efforts of workers toward improving their productivity are not observable. Firms can screen for high skill workers, but the screening technology is imperfect.

In one sector of the economy, output is produced by identical firms using unskilled labor, while the other good requires skilled labor, and can be produced using two different technologies: one is a *basic* technology that requires low-skilled labor and the other is a *modern* technology that requires high-skilled workers. Firms that adopt the basic technology hire less productive workers but also pay lower wages so that firms of both types can co-exist in equilibrium. We show that when there are heterogeneous firms, who differ in the skill intensity of their production techniques, the autarky and open economy equilibria are unique – even when worker skills are not perfectly observed. Given the differences in the relative demand for skills across firms we are also able to derive monotone comparative statics, and characterize the impact of international trading opportunities on schooling and skill acquisition by domestic workers.

The ability to flexibly choose the skill intensity of their production techniques gives firms an additional margin, besides adjusting wages, on which they can respond to information asymmetries.

Adjustments in the equilibrium demand for skill across firms erode the potential for multiple equilibria. In previous analyses of imperfect labor markets, where workers use education to both signal skills and enhance productivity, multiplicity of equilibria has generally made it difficult to characterize equilibrium outcomes, at least without imposing structural assumptions.[4] Instead we simply rely on the empirically relevant assumption that firms differ in their choice of production techniques across skill, even within narrowly defined industries.[5] Importantly, the propensity of firms to adjust their production techniques in order to absorb changing supplies of educated workers is consistent with the evidence in Ciccone and Peri (2011). Although the labor market allocation under asymmetric information is unique, the choices to obtain schooling and acquire high skills are still distorted.

Changes in trading opportunities impact the educational behavior of workers by shifting the relative demand for skills across industries and across firms. There is strong evidence that firms face a fixed cost to gain access to world markets; e.g., Roberts and Tybout (1997). As a result firms with different productivities face varying incentives to take advantage of export opportunities. We show that the impact of greater access to foreign markets on skill-acquisition behavior can vary according to the share of firms engaged in export activity. In an equilibrium in which only a share of the most productive firms export, globalization induces more workers to obtain high skills. However, when a relatively large share of firms export, greater market access benefits firms that hire both low and high skilled workers, so that the incentives to obtain high skills at the margin can be generally larger or smaller. In terms of schooling, we find that greater export opportunities *always* exacerbate the over education decision by inducing more workers to obtain low skills. We also investigate the implications of increased import

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[4] The potential for multiple equilibria in the presence of asymmetric information has long been recognized. The classic treatment of this issue is from Wilson (1980). Rose (1993) numerically examines the potential for multiple equilibria in adverse selection settings like those studied by Wilson. Even abstracting from the possibility to signal the market, several well-known distributions of unobserved quality (i.e., worker ability) generate multiple equilibria, including the normal distribution that accords well with the 'Bell Curve' often used to describe student performance. A recent analysis where workers acquire schooling to both signal skills and enhance their own productivity is Blankenau and Camera (2006), who demonstrate that generally there are multiple stationary equilibrium.

[5] Doms, Dunne and Troske (1997) demonstrate that firms within U.S. manufacturing industries differ according to the skill intensity of their production techniques. It is also worth noting that there is substantial evidence that exporting firm differ in skill intensity (Bernard and Jensen 1999) and that changes in international competition impact the relative demand for skills within and across firms within industries (Pavcnik 2003 and Fernandes 2007).

penetration for education decisions and find that since increased import competition reduces the relative demand for skilled workers, this mitigates the problem of over-education, but discourages workers from obtaining high skills.

The potential for information problems to distort labor market outcomes and educational decisions has long been recognized and often studied. Spence (1973) first described the role of costly education to signal skill when firms have less information about worker skills. The role of education as a signal is complementary to the traditional role of education for productivity enhancement studied by Becker (1964) and Mincer (1974).[6] There are few analyses that nest both the signaling and productivity enhancing roles of education, which may be an important oversight given the evidence in Fang (2006) that both the signaling and productivity enhancing motives to educate are quantitatively important in explaining the college premium among the US workforce. Moreover, by allowing education to act simultaneously as a signal and to improve productivity, we show that is generally wage dispersion among workers who are observed by firms (and econometricians!) to have similar skill sets. Lemieux (2006a,b) demonstrates that much of the ubiquitous rise in wage inequality over the last four decades is concentrated within educational groups, rather than wages rising across educational attainments. He also provides evidence that residual wage variation among post-secondary educated workers has risen, which he argues is best explained by an empirical model with heterogeneous returns to education. Incorporating both signaling and productivity motives for educational allows us to capture this feature.[7]

Many facets of the global economy are intimately connected to the distribution of worker skills in each country. Yet, the common approach it to treat the distribution of skills as a fixed endowment within countries, and as an innate characteristic of workers. There are a few notable exceptions. The classic

[6] Here we note that our view of the productivity enhancements that workers receive by exerting effort are general at the sector or aggregate level, rather than being firm-specific. Acemoglu and Pischke (1998) have analyzed the human capital accumulation decision when skills can be general or particular to a specific employer.

[7] As we do here, Blankenau and Camera show that imperfect information about worker skills can lead to adverse selection, with over education, under accumulation of highly productive skills, and wage dispersion among similarly skilled workers. However they assume that the demand for skills across agents are fixed, and find that there are multiple equilibria, complicating any policy analysis. Also, their analysis is silent on the role of globalization in influencing labor market outcomes.

treatment of endogenous human capital accumulation with international trade is in Findlay and Kierzkowski (1983), which examines the educational behavior of workers across countries that differ in their relative factor endowments. Falvey *et al.* (2010) extends the open economy analysis with endogenous human capital choices and shows that trade also interacts with worker ages in the choice to go to school.[8] Perhaps the most closely related analysis of international trade with endogenous human capital acquisition is Vogel (2007). He investigates trade and human capital accumulation with information problems that generate moral hazard issues. As with all the previously mentioned analyses, education is purely productivity enhancing, allowing skilled managers to better detect the efforts of subordinate employees, and he specifically does not investigate adverse selection problems associated with the educational behavior not being perfectly observed. Our inclusion of education as a signaling device into the analysis is novel to the literature on trade and educational behavior.[9]

In the next section we develop a simple two-sector a model of worker educational behavior with imperfect screening of worker skills. In Section 3 we derive the autarky equilibrium with adverse selection in the labor market, and examine the relative effects of educational policies directed at altering schooling and skill acquisition behavior. In section 4 we turn to globalization policies and consider how import penetration influences educational behavior of workers. Section 5 considers the case where firms face in the skilled sector face export opportunities. The final section concludes.

[8] In addition, Bougeas *et al.* (2011) consider the role of educational policies in determining comparative advantage, and thus trade patterns, across countries. As in our analysis, Blanchard and Willmann (2011) allow for more than just a binary choice of whether or not to obtain schooling, and show that trade opportunities can lead to polarization of the labor force. Krugman (2000) exploits the potential for multiplicity of equilibria generated by asymmetric information in labor markets to explain rapid changes in wage inequality observed across several countries in recent decades, as an alternative to other mechanisms such as globalization or skill-biased technological change.

[9] The interaction between trade and education has also been applied to New Growth Theories to examine the link between globalization and differences in development across countries; see for example Wood and Ridao-Cano (1999) and Redding and Schott (2003). However, none of these models consider education a signaling device, as opposed to productivity enhancement. The distinction we draw between signaling and productivity enhancing motives for education may be important to new growth theories, given the evidence in Bils and Klenow (2000) that differences in educational attainment explain little of the variation in growth rates across countries.

2. The Model

Our model consists of two types of workers, those born with innate academic aptitude and those born without it, but this feature is private information. Prior to seeking a job, workers with academic aptitude can choose to obtain an education and become either low or high skilled, knowing that firms imperfectly screen for their productivity as skilled workers at the time of hiring. Firms must choose between the skill-intensive and unskilled sectors of the economy in which to operate, and within the skilled sector firms must select among two production technologies, which differ in skill intensity. All output is sold in perfectly competitive markets. This section provides details about the model.

2.1 <u>Consumer Preferences</u>: All consumers have identical homothetic preferences over two goods X and Y. We set Y as the numeraire and denote p as the price of X.

2.2 <u>Worker Education</u>: Each country is endowed with a measure U of workers *without* an aptitude for education. We assume that these workers do not purchase schooling, either because they cannot earn the grades required to get into college or because they lack access to the resources needed to cover the cost of education. We classify them as unskilled workers. There is also a measure S of workers that vary in aptitude, a, to perform in school. The distribution of innate aptitude across all S workers is assumed to be uniform over $[0, S]$. Workers with an aptitude for education can choose whether or not to go to school.

Unskilled workers are able to produce Y but do not have the skills required to use any of the technologies available to produce X. In contrast, all workers born with academic aptitude are qualified to use a basic technology to produce X. In addition, those with aptitude who purchase schooling and exert sufficient effort to their coursework can produce X using a more sophisticated technology (more details on the X sector technologies are provided below). Because aptitude and effort are not observable, firms using the basic technology will not be able to distinguish unskilled workers from those with aptitude absent any signal (i.e., a degree), and without screening firms using the more sophisticated technology will not be able to distinguish those who put in effort into their coursework from those who do not.

We assume that the cost of schooling, $C_S(a)$, is decreasing and convex in worker aptitude, and given in terms of disutility. Workers with aptitude can purchase schooling and earn a degree, regardless of the effort that they devote to their coursework. Since the degree is observable schooling serves as a signaling device that allows workers with aptitude to distinguish themselves from unskilled workers. However, schooling alone does not increase productivity. Workers who put forth no effort during their education remain low-skilled workers. However, workers who put forth a unit of effort in school enhance their productivity and become a high-skilled worker. The disutility from effort, $C_E(a)$, is also decreasing and convex in ability. We denote the endogenous mass of low-skill workers who do not put forth effort as S_L, and denote the mass of high-skill workers by S_H.

2.3 Worker Screening & Wages: Workers signal that they attended school by showing their degree to firms, which verifies that they are not unskilled. However, the effort exerted while in school is not observable. As a result firms cannot perfectly distinguish between more productive high- skilled workers and less productive low-skilled workers upon hiring. To keep the analysis tractable, we assume that upon the completion of schooling, workers take a test with the results observable by all firms.[10] Those who pass the test reveal themselves as highly productive skilled workers and are eligible for high-skilled employment; whereas those who fail the test are classified as low-skilled applicants. High skilled workers, who exerted effort during school, pass the test with probability $\lambda \leq 1$, while any low skill worker that did not exert effort fails the screening test. Note that in the case of $\lambda = 1$ the screening process is perfect, otherwise it is imprecise. A popular example of a screening test administered to workers upon recruitment is the Wonderlic Cognitive Ability Test. For several decades the 'Wonderlic' has been a screening device used in occupations ranging from executives to general clerical work, and across many industries including healthcare, finance and even professional sports. The exam takes 12 minutes to administer and so provides a low-cost, albeit imperfect, signal of worker skills.

[10] Equivalently, we could assume that after schooling workers can either pass or fail the exam regardless of which firm administers it. In this sense there is no reason that a worker would try to repeat the screening exam. Such strategic motives would complicate our analysis further by introducing another dimension of asymmetric information. Our current set-up allows us to focus on the problems caused by the fact that student effort and ability cannot be observed in the cleanest possible environment.

Firms hire from competitive labor markets and compensate workers based on their performance on the screening exam. Those who pass the screening exam reveal themselves as high-skill workers and are paid a wage w_H. Workers who do not pass the screening exam, either because they are low skilled or misidentified high skill workers, are each paid a wage w_L. Although firms cannot distinguish between low and high skill workers that fail the exam, the wage that they pay, w_L, will account for their differences in productivity on average. Unskilled workers are paid a wage w_U.

2.4 <u>Labor Demand & Production</u>: Good Y is produced using only unskilled labor with each worker producing one unit of output. All firms producing Y are identical and since Y is the numeraire, the equilibrium unskilled wage must satisfy $w_U = 1$. Good X is produced using only skilled labor, so that workers must have a degree to be hired.

There are two technologies available that can be used to produce the skilled good. Firms are free to enter and adopt either production mode. The first technology, which we refer to as *basic*, allows firms to produce X using low-skilled or high-skilled labor, with a low-skilled worker producing b units of output and a high-skilled worker producing θb units with $\theta > 1$. However, workers produce output in teams and individual productivity is not observable – thus, all workers employed by basic firms are treated the same. Since wages are determined in a competitive market and the productivity of workers is fixed for any level of output, basic firms produce output at constant marginal cost; however they also face a capacity constraint of $\bar{x}_b$units. The second technology, which we refer to as *modern*, requires high-skilled labor. Each high-skilled worker can produce $h > \theta b$ units of X and firms that adopt the modern technology can produce at constant marginal cost up to a capacity constraint of $\bar{x}_m > \bar{x}_b$. The capacity constraint is used to capture the notion of increasing marginal costs for the firm, and is a common device used in the industrial organization literature on Bertrand (pricing) games.

The assumptions that $h > \theta b$ and $\theta > 1$ reflect the benefits of schooling and effort to worker productivity. The differences in productivity are partially offset by differences in the costs of adoption. The basic technology requires a fixed investment F_b, while the modern technology requires a cost

$F_m > F_b$, each given in terms of additional units of the numeraire good that must be purchased to setup a firm. Our interest is in studying a menu of technologies that are skill biased. The assumption $h > \theta b$ also implies that high skill workers have comparative advantage using the modern technology. Moreover, it should be the case that turning one high-skill worker into a low-skill worker should increase the expected total output produced by basic firms, which will be the case if $b > (1-\lambda)\theta b$. These assumptions about the relative productivity of workers imply that the basic technology is biased toward low skill workers, while the modern technology is biased toward high skill workers. Differences in the skill intensity of modern or basic technologies, even within narrowly defined sectors, are consistent with the evidence in Doms, Dunne and Troske (1997).

Given that the modern technology requires high-skilled workers, firms that adopt this technology will only hire applicants who pass the screening exam. These firms pay a wage w_H with each employee generating h units of output; thus the marginal cost for modern firms is given by $\frac{w_H}{h}$. Alternatively, firms can adopt the basic technology and hire workers from the pool of low-skilled applicants.[11] Without the ability to distinguish low from high-skilled workers in pool of applicants that fail the screening exam, all workers at basic firms are paid the same w_L. The imperfect screening technology implies that there are $(1-\lambda)S_H$ relatively productive high-skill workers in the low-skill applicant pool who each generate θb units of output, and S_L available workers who produce b units of X. Then, for basic firms the expected output generated by workers hired from the low-skill applicant pool is

(1) $$\phi \equiv \frac{b[S_L+\theta(1-\lambda)S_H]}{S_L+(1-\lambda)S_H}.$$

It follows that the marginal costs for the typical basic firm are $\frac{w_L}{\phi}$.

[11] Basic firms could also choose to hire high skill workers that pass the screening exam. However, this behavior would only arise in equilibrium for a knife-edge set of parameters such that $\frac{F_m}{\bar{x}_m} = \frac{F_b}{\bar{x}_b}$, which would subsequently imply that all firms are identical in terms of productivity. Specifically, if the higher fixed costs of the modern technology are exactly offset by the higher capacity, relative to the basic technology, then free entry of firms implies that it must also be that all firms have the same marginal costs $\frac{w_H}{h} = \frac{w_L}{\phi_b}$. Bernard *et al.* (2003) provide broad evidence that US firms differ in terms of labor productivity, and there is robust evidence of heterogeneous firm productivity in other countries as well. As our interest is in the empirically relevant case where firms differ in terms of their technologies and productivities, we restrict our attention to the case such that $\frac{F_m}{\bar{x}_m} \neq \frac{F_b}{\bar{x}_b}$.

3. Autarky

We are now in position to describe the equilibrium conditions for our model when the economy is closed. Our derivation proceeds in reverse order of the model above: we begin with product market clearing conditions, then characterize equilibrium in labor markets, and then determine equilibrium educational behavior of workers.

3.1 <u>Product Market Equilibrium</u>: Free entry in the *X* sector implies that both basic and modern firms must earn just enough profit to cover the fixed cost of adopting their technology. In the autarkic equilibrium this means that we must have

(2) $$F_b = \left(p - \frac{w_L}{\phi}\right)\bar{x}_b$$

(3) $$F_m = \left(p - \frac{w_H}{h}\right)\bar{x}_m$$

where p denotes the competitively determined price of X. Note that since price exceeds marginal cost for all firms, they all produce at their respective capacities. Next, if we use N_b and N_m to denote measures of firms that adopt the basic and modern technologies, respectively; and use E to denote total expenditures by consumers, then equilibrium in the market for *X* requires

(4) $$\bar{x}_m N_m + \bar{x}_b N_b = X(p, E)$$

The left-hand-side of (4) gives total production while the right-hand-side is total demand for X.

3.2 <u>Labor Market Equilibrium</u>: We now turn to the labor markets, starting with the markets for skilled workers. Equating supply with demand for each skill level yields the following equilibrium conditions

(5) $$S_L + (1-\lambda)S_H = \frac{\bar{x}_b}{\phi} N_b,$$

(6) $$\lambda S_H = \frac{\bar{x}_m}{h} N_m.$$

In (5)-(6), the left-hand-side gives the size of the skilled applicant pool for firms using the respective technology. The right-hand-side is simply the labor demand per firm times measure of firms of each type.

3.3 <u>Equilibrium Educational Behavior</u>: For a worker with aptitude a, the benefit of purchasing schooling without devoting any effort to coursework is that this qualifies them for a low-skilled job that pays w_L, as compared to taking an unskilled job that pays $w_U = 1$. The cost of schooling to this worker is $C_S(a)$. Thus, if we let a_S denote the ability level of the worker who is just indifferent between purchasing schooling and taking an unskilled job, a_S must satisfy

(7) $$C_S(a_S) = w_L - 1.$$

All workers with $a < a_S$ strictly prefer unskilled employment. Workers with $a \geq a_S$ obtain schooling and must also decide whether to devote effort to their coursework. The cost of exerting enough effort to qualify for a high-skilled job is $C_E(a)$ and the benefit is that doing so increases your earnings from w_L to w_H, provided that you pass the screening test, which happens with probability λ. Thus, a worker with ability level a_E is just indifferent between exerting a unit of effort and no effort when a_E satisfies

(8) $$C_E(a_E) = \lambda(w_H - w_L).$$

Given the distribution of worker aptitude, we can define the masses of low and high skill labor supplies using the respective cutoffs for educational behavior:

(9) $$S_L = a_E - a_S$$

(10) $$S_H = S - a_E$$

Finally, total expenditure by workers, E, is equal to their total income which is

(11) $$E = [S_L + (1-\lambda)S_H]w_L + \lambda S_H w_H + [U + S - S_L - S_H]\ ,$$

where the first term is income from low-skilled employment, the middle term is income from high-skilled employment and the last term is income from unskilled employment.

3.4 <u>Determining the Autarky Equilibrium</u>: This simple model consists of 11 unknowns, w_L, w_H, a_E, a_S, S_L, S_H, N_m, N_b, E, p and ϕ, that define the closed economy equilibrium, which is determined by (1)-(11). Our first goal is to show that in spite of the informational asymmetries, the autarkic equilibrium is unique. Given that preferences are homothetic, we know that the relative demand curve is downward sloping in relative prices. Thus, it is sufficient to show that the relative supply curve is upward sloping.

With both types of technologies adopted in the skilled sector, the Relative Supply for goods X and Y for the closed economy is given by

(12) $$\frac{X}{Y} = \frac{\bar{x}_b N_b + \bar{x}_m N_m}{U + S - S_L - S_H - N_b F_b - N_M F_M} = \frac{[(S-a_S)+(1-\lambda)(S-a_E)\theta]b + (S-a_E)\lambda h}{U + a_S - \frac{F_b}{\bar{x}_b}[(S-a_S)+(1-\lambda)(S-a_E)\theta]b - \frac{F_M}{\bar{x}_M}(S-a_E)\lambda h}$$

where the second equality follows from substituting (1), (5), (6), (9) and (10). Note that the relative supply is solely as a function of a_S and a_E, given the exogenous parameters of the model. Thus, the relative supply of goods in (12), for a given price p, is determined completely by the aptitude cutoffs for schooling and skill acquisition.

To examine the relationships between the cutoffs a_S and a_E and relative prices we reduce the supply side of the model to two equations in two unknowns; substituting (2), (3), (5), (6), (9) and (10) into equilibrium conditions for optimal schooling and skill acquisition behavior in (7) and (8) yields

(13) $$L(a_S, a_E) \equiv C_S(a_S) - \left(p - \frac{F_b}{\bar{x}_b}\right)\phi(a_S, a_E) + 1 = 0$$

(14) $$H(a_S, a_E) \equiv C_E(a_E) - \lambda\left[\left(p - \frac{F_m}{\bar{x}_m}\right)h - (p - \frac{F_b}{\bar{x}_b})\phi(a_S, a_E)\right] = 0$$

Note that the response of the productivity of basic firms to changes in schooling and skill acquisition among the workers at the margin are given by the following the partial derivatives:

$$\phi_S \equiv \frac{\partial\phi}{\partial a_S} = \frac{\phi - b}{S_L + (1-\lambda)S_H} > 0 \qquad \phi_E \equiv \frac{\partial\phi}{\partial a_E} = \frac{-(\theta-1)(1-\lambda)b(S_L+S_H)}{[S_L+(1-\lambda)S_H]^2} < 0.$$

Equation (13) defines the ability of the marginal low-skilled worker for any given a_E. This curve is upward sloping in (a_S, a_E) space for any p. The logic is straightforward – an increase in a_E means that there are fewer high-skilled workers, and this lowers the average productivity for workers in the low-skill pool, ϕ, thereby reducing the low-skill wage. With fewer high skill workers to free ride off of in the low skill labor pool, there is less incentive to acquire schooling; a_S must rise to restore the equality in (13).

Equation (14) defines the ability of the marginal high-skilled worker for any given a_S. This curve is also upward sloping in (a_S, a_E) space and the logic is similar. An increase in a_S means fewer low-skilled workers and this pushes up the average productivity of the workers in the low-skilled labor pool, ϕ. Hence the low-skilled wage rises, and this reduces the relative benefit from exerting effort. As a result, a_E must rise to restore the equality in (14). Figure 1 illustrates the two conditions characterizing equilibrium educational behavior.

There are two concerns in characterizing the autarky labor market equilibrium with imperfect screening of worker skills. First, with two upward sloping relationships that characterize schooling and skill acquisition behaviors in (13) and (14), one might expect that a given p might be associated with multiple values of the cutoffs for educational behavior, (a_S, a_E). However, we show in the appendix (see Result A.1) that $H(\cdot)$ is less steeply sloped than $L(\cdot)$ for any (a_S, a_E). This gives us the following lemma.

Lemma 1: *Any relative price level p is associated with a unique pair of cutoffs in worker aptitudes, (a_S, a_E), that define the mass of workers that obtain schooling and acquire high skills, respectively.*

The second concern regarding multiplicity is that, even though there is a unique set of educational choices across workers for any *p*, differences in educational behavior across a range of potential prices may still cause the relative supply curve to be downward sloping, resulting in multiple equilibria. Thus, we must also be concerned with how changes in prices influence educational behavior.

Lemma 2: *An increase in the relative price of the skilled good, p, leads to an increase in the mass of workers that obtain schooling, and an increase in the mass of workers that obtain high skills.*

In order to prove Lemma 2 we must determine the impact of a change in *p* on the educational choices of workers. To do so, we define $L_j \equiv \frac{\partial L}{\partial a_j}$ and $H_j \equiv \frac{\partial H}{\partial a_j}$ for *j = S, E.* From (13) and (14) we have

$$L_S = C_S'(a_S) - \frac{W_L}{\phi}\phi_S < 0 \qquad \text{and} \qquad L_E = -\frac{W_L}{\phi}\phi_E > 0$$

$$H_S = \frac{\lambda W_L}{\phi}\phi_S > 0 \qquad \text{and} \qquad H_E = C_E'(a_E) + \frac{\lambda W_L}{\phi}\phi_E < 0$$

For later use, we define $D \equiv L_S H_E - H_S L_E > 0$, where the inequality is derived in the proof of Lemma 1 in the Appendix. Then straightforward differentiation of (13) and (14) yields the results we need:

$$\frac{da_S}{dp} = \frac{\phi H_E - \lambda(h-\phi)L_E}{D} < 0 \qquad \text{and} \qquad \frac{da_E}{dp} = \frac{\lambda(h-\phi)L_S - \phi H_S}{D} < 0\ .$$

Since high skill workers are more productive using any technology in the skilled sector, and low skill workers are more productive than unskilled workers, the result in Lemma 2 implies that an increase in *p* leads to an increase in the relative supply of goods. Each new worker who purchases schooling shrinks the supply of *Y* by one unit while increasing the supply of *X* by *b* units; and each new worker who acquires high skills pushes *X* up by $h - b$ if they pass the screening test and are employed by a modern firm and by $\theta b - b$ if they fail the screening test and take a job with a basic firm. Thus, relative supply is upward sloping. Given a downward sloping demand curve, we then obtain a unique relative price level p, which Lemma 1 assures is associated with a unique set of educational behaviors among workers.

Proposition 1: *When there are firms with heterogeneous productivities operating in the skill intensive industry, the autarky equilibrium is unique even when worker skills are not perfectly observed by firms.*

Previous analyses of labor markets with adverse selection have typically found multiple possible equilibria, each of which imply different worker outcomes and potentially different output prices. This multiplicity makes it difficult for the models to consistently match stylized facts about labor markets, and hinders any policy analysis. Yet, these analyses generally abstract from technological differences and open economy issues. One advantage of our framework is the ability to analyze worker signaling behavior via education, technological adoption and international trade simultaneously in simple general equilibrium framework. Moreover, we obtain a unique equilibrium allocation when education acts to both signal skills and to enhance productivity, which encompasses a rich set of worker behaviors on the supply side of the market.

3.5 Education Policies in the Autarky Equilibrium: Policies designed to influence educational behavior are ubiquitous. The US offers the Stafford loan program to reduce to cost of borrowing funds for post-secondary educational purposes, and in 2012 updated the Workforce Investment Act to provide federal funds for job training. Other countries have similar policies that target the educational behavior individuals on the cusp on entering the workforce. Policies that change the cost of schooling obviously have an impact on worker educational behavior, but subsequent changes in technological adoption and hiring by firms imply that such policies have general equilibrium consequences. And, even though Proposition 1 ensures that the closed economy equilibrium is unique with imperfect screening of worker skills, the equilibrium adjustments to policy change are distorted.[12] We close our discussion of the autarky model by examining the effects of such policies on the domestic supply of goods and on relative prices.

[12] One of the major advantages of assuming that product markets are perfectly competitive is that it allows us to avoid the product market distortions that arise in the presence of monopolistic competition, and focus solely on the asymmetric information problem in the labor market.

To clearly identify educational policies we rewrite the cost of schooling as $\eta C_S(a)$ and the cost of effort as $\delta C_E(a)$. Policies that target educational outcomes directly can then be examined by considering changes in η and δ. Consumer preferences are unaffected by educational policies, and so we need only consider how to costs of education influence the supply side of the model. Differentiating optimal educational behavior of workers in (13) and (14) for any given price level, p, yields

(15) $$\left.\frac{da_S}{d\eta}\right|_p = \frac{-C_S(a_S)H_E}{D} > 0 \quad \text{and} \quad \left.\frac{da_E}{d\eta}\right|_p = \frac{C_S(a_S)H_S}{D} > 0 .$$

A reduction in the cost of schooling induces more workers to attend school and more workers to put effort into their coursework at any given price level. The first result follows directly from the cost reduction, whereas the second result stems from the fact that as more low aptitude workers attend school average productivity for low-skilled workers falls. This triggers a drop in w_L, which raises the expected return from effort. With a_E and a_S both falling, relative supply will increase unless there is a substantial drop in low-skill productivity. However, an argument identical to the one used to prove that the relative supply curve is upward sloping can be used to rule this out. In short, a reduction in the cost of schooling shifts relative supply out to the right.

A similar analysis allows us to derive the impact of a change in the cost of effort. We obtain

(16) $$\left.\frac{da_S}{d\delta}\right|_p = \frac{C_E(a_E)L_E}{D} > 0 \quad \text{and} \quad \left.\frac{da_E}{d\delta}\right|_p = \frac{-C_E(a_E)L_S}{D} > 0 .$$

A reduction in the cost of effort results in more students acquiring high skills. As the measure of high-skill workers rises, and as some of these workers fail the screening test, productivity at basic firms increases. This triggers an increase in the low-skill wage, w_L. A higher low-skill wage induces more low aptitude workers to purchase schooling. So, just as with a reduction in the cost of schooling, lower costs of effort shift relative supply out to the right. These two sets of results imply the following result.

Proposition 2: *Lower costs of schooling and effort reduce the autarkic price of the skill intensive good.*

Another way to interpret the result in Proposition 2 is that educational polices that target the cost of schooling and effort can independently grant a country comparative advantage in producing skill intensive goods. Bougeas *et al.* (2011) also highlights the potential for governments to influence trade patterns through education policies, but do not suggest what market failures would justify policy intervention. Here a government may introduce policies to mitigate the problem of imperfect screening of worker skills. Yet, it is important to recognize that such policies can have subsequent impacts on trade patterns. In the next section, we focus on the open economy in more detail.

4. The Open Economy: Import Penetration

Consumers in all countries share identical Cobb-Douglas preferences over X and Y. Hence, the only differences between the autarky and open economy models are due to the supply side of the model; in the open economy with costly trade, firms may adjust the technologies they adopt and workers may adjust their educational behavior. We consider the response of a small economy to trade openness, where the relative price is fixed on world markets at p^*. In this section we consider the possibility that the domestic economy can import skill intensive goods from the foreign firms with $p^* < p$. In the next section we turn to the case in which $p^* > p$ so that some domestic firms may want to export.

Opening the domestic market to foreign producers when $p^* < p$ changes the relative supply of goods to consumers in the domestic market. Instead of the upward sloping supply curve that reflects the behavior of domestic firms, a small importing country faces a flat supply curve at p^* as it can purchase the X at the fixed world price p^*. Figure 2 illustrates the open economy equilibrium for a small importing country. The dashed line represents the autarky relative supply curve, while the solid flat line at $p^*$is the supply curve for the domestic market as it can purchase the skilled good from global markets.

As the home country begins to import X, rather than buying from domestic producers, workers recognize that demand for their skills diminishes, and adjust their educational behavior accordingly. In proving Lemma 2 we derived the relationship between exogenous changes in prices and worker educational behavior. Similar adjustments take place when import penetration in the skill intensive sector reduces p^*: that is, fewer workers will obtain schooling and fewer workers will pursue high skills. This reduction in educational attainment as the relative demand for skilled labor diminishes is consistent with the evidence in Atkin (2012); Mexican workers are more likely to drop out of secondary education when the arrival of local unskilled manufacturing employment opportunities is relatively small.[13]

The individual educational behavior of workers reflects their rational responses to changes in job prospects. However, in the aggregate educational choices are distorted by the imperfect screening of skills by firms.[14] So the question remains whether the reduction in schooling and skill acquisition following import penetration mitigates or exacerbates these distortions. The efficient outcome for this small open economy corresponds to an equilibrium in which no information problems exist (i.e. $\lambda = 1$). The distortions in educational behavior can then be characterized by examining deviations from the first-best outcome; that is we differentiate the equilibrium conditions in (13) and (14) with respect to λ, and consider the limiting case of full information as λ approaches one. Differentiating we obtain

(17) $$\frac{da_S}{d\lambda} = \frac{w_L}{D\phi}\left\{C_e'(a_e)\phi_\lambda + (w_H - w_L)\phi_E\right\} \gtreqless 0,$$

(18) $$\frac{da_E}{d\lambda} = \frac{1}{D}\left\{L_S(w_H - w_L) - \frac{w_L}{\phi}\phi_\lambda C_S'(a_S)\right\} < 0$$

where $\phi_\lambda \equiv \frac{\partial\phi}{\partial\lambda} = \frac{S_H(\phi - b\theta)}{S_L + (1-\lambda)S_H} < 0$. Equation (18) gives us one of our fundamental results – imperfect screening leads to an inefficiently low level of skill acquisition. As λ falls below one and screening gets less precise, the return to effort, and hence skill acquisition, declines. As a result, a_E rises and the supply of high-skilled workers falls. The effect of imperfect screening on schooling behavior is given in (17); the first term in brackets is positive while the second term is negative, indicating that imperfect screening has an ambiguous effect on the level of schooling obtained among the labor force. On one hand, as λ falls there are fewer high-skill workers taking the screening test, and this means less free riding off of their higher productivity. On the other hand, as λ falls the probability that a high-skilled worker will fail the test rises, and this increases the return to schooling for low-ability workers. Since these two effects work

[13] As Atkin (2012) argues, the arrival of manufacturing jobs presented employment opportunities predominantly for unskilled labor, wherein 80% of workers in those positions possessed less than a high-school degree in 2000.

[14] A large empirical literature has documented the feature of 'over-education' in labor markets, as indicated by individual workers acquiring schooling that is in excess of what is required to qualify for their current job. Here, imperfect screening of worker skills may lead to some high-skill workers to obtain jobs that do not fully complement their skills. We note however that workers take this possibility into account when choosing which skills to acquire. See Leuven and Oosterbeek (2011) for an overview of the 'over-education' literature.

in opposite directions, the overall level of schooling purchased can generally be too high or too low. We note, however, that as λ approaches one, ϕ_E becomes arbitrarily small. This implies that when screening is sufficiently precise, equilibrium will be characterized by over-education. Thus, we have

Proposition 3: *If worker screening is imperfect, then workers will under-invest in skill acquisition relative to the first-best outcome. In addition, if screening is sufficiently precise, the overall workforce will over-invest in schooling.*

Note that for a screening technology that is sufficiently precise, the educational behavior of workers is consistent with the criticism that too-many people go to college put forth by Berg (1970), Freeman (1975, 1976) and Murray (2009). Also, note that there is over-investment in schooling because the expected return to education is greater than the return for those workers who are at the margin of whether go to school. Consistent with feature, Carneiro, Heckman and Vytlacil (2011) provide evidence that average return to college is much higher than the marginal return to for workers considering whether to enroll. Given this evidence, we take a sufficiently precise screening technology to be the empirically relevant case, and focus on equilibria with over-investment in schooling from this point forward.

Combining the insights from Lemma 2 and Proposition 3, we have the following result

Proposition 4: *Globalization that results in greater import competition in the skill intensive sector (i) exacerbates the distortion in the investment in skills, so that fewer individuals exert effort to become high skill workers; and (ii) mitigates the distortion in the investment in schooling, so that fewer workers go to school.*

Changes in educational behavior reflect the impact of import competition on relative wages. More workers will go to school as low-skill wages rise, while fewer put forth effort as high-skill wages fall in equilibrium. Then, given the result in Proposition 4, we can derive the implied changes in income inequality directly.

Corollary 1: *Globalization that results in greater import competition in the skill intensive sector reduces wage inequality among the domestic labor force.*

Formally this result is obtained from combining optimal education behavior from equations (7), and (8) with the relationship between relative prices and education in Lemma 2. The cost of schooling and the cost of effort for the marginal workers must both fall as relative prices fall; this can only occur if w_L drops relative to 1 (the unskilled wage), so that low-skilled workers lose relative to unskilled workers, and if w_H falls relative to w_L, so that high-skilled workers lose relative to low-skilled workers. Thus, wage inequality falls as the relative price level drops, as would be the case for import competition in the skill intensive sector.

Our results for the impact of globalization on relative wages are distinct from previous analyses in which education is a simply a binary choice, or schooling and skill acquisition are ignored entirely. A change in wages of high skilled workers relative to low skill workers corresponds to a shift in the distribution of wages *within* a group of workers that have the same observed level of education, rather than *across* workers with different educational attainments. Lemiuex (2006a,b) documents broad evidence that recent episodes of rising wage inequality are concentrated among college educated workers, even within specific occupations and professions. He argues that an empirical model with heterogeneous returns across workers within educational groups best matches changes in the US income distribution between 1973 and 2005. Moreover, the evidence shows that while residual wage inequality increased for workers with post-secondary education, there is little change in the residual variation in wages for less educated workers. These facts are inconsistent with models that assume that workers skills are perfectly observed, or assume that education serves only a single purpose for all workers (i.e., solely to enhance productivity or signal ability.)

We close this section by showing that since our simple model takes into account two key features of the educational process, signaling and productivity enhancement, it allows for a fairly rich analysis of education policies in an open economy. We often hear policy makers emphasize the need for a highly educated workforce as a way to ensure growth and prosperity in a globalized economy. In 2012, the US reauthorized the Workforce Investment Act (WIA), which provides federal funding for job training and employment assistance. One of the major changes made to the original WIA of 1998 is that the use of federal funds must conform to best practices, such that expenditures must correspond to the most effective educational programs. Moreover, the reauthorization of the WIA in 2012 stipulates that measurements of effectiveness must take into account employer satisfaction of the skills and performance of workers, rather than simple graduation or employment rates of participant. Therefore, it is important to understand the different incentives for workers to pursue education (e.g., signaling versus productivity enhancement) as policies alter the costs of obtaining skills. Our framework is ideal for this purpose. In particular, we can use the results reported in (15) and (16) to assess the relative effectiveness of various policies in reducing the distortions in educational behavior.

We have previously shown in Proposition 3 and (15)-(16) that a lack of high-skilled workers can be addressed by instituting programs aimed at either lowering the cost schooling or effort. However, in addition to the monetary cost of such programs, (15)-(16) implies that there is an additional cost – lowering the cost of schooling and effort makes the over-education distortion worse. Thus, the relative effectiveness of these programs depends on the size of the benefit (i.e., the increase in the size of the high-skill workforce), relative to size of the new distortion created (i.e., the resulting increase in the measure of workers going to school).

To compare educational policies, we define B_δ and B_η as the reduction in a_E brought about by a marginal reduction in the cost of effort and schooling, respectively (the "B" is used to denote "benefit" of more workers becoming high skilled). From (15) and (16) we have

(19) $$B_\eta = \frac{H_S}{D} \quad \text{and} \quad B_\delta = \frac{-L_S}{D}$$

Comparing we see that $B_\delta > B_\eta$, since $-C_S'(a_S) > 0 > (\lambda - 1)\frac{w_L}{\phi}\phi_S$. Thus, the benefit from lowering the cost of effort is greater than the benefit from lowering the cost of schooling by the same amount.

We next want to compare the distortions generated by the associated fall in a_S triggered by the lower education costs. From (15) and (16), the decreases in a_S due to a marginal reduction in the costs of schooling and effort, respectively, are given by D_η and D_δ where

(20) $$D_\eta = \frac{-H_E}{D} \quad \text{and} \quad D_\delta = \frac{L_E}{D}$$

Comparing the distortions we see that $D_\delta < D_\eta$ if $-C_E'(a_E) > (\lambda - 1)\frac{w_L}{\phi}\phi_E$, which always holds for λ close to one. It follows that if screening is sufficiently precise, then the benefit of reducing the cost of effort exceeds the benefit from reducing the cost of schooling while also generating a smaller distortion.

As a result, policies that reward effort are relatively more effective. We can push this analysis further by noting that from (17) in an over-education equilibrium we have $-C_E'(a_E) > (w_H - w_L)\frac{\phi_E}{\phi_\lambda}$. Thus, a sufficient condition for policies that lower the cost of effort to be superior to those that lower the cost of schooling is $(w_H - w_L)\frac{\phi_E}{\phi_\lambda} > (\lambda - 1)\frac{w_L \phi_E}{\phi}$, or,

$$\frac{\lambda}{1-\lambda}\frac{w_H - w_L}{w_L} > -\frac{\phi_\lambda}{\phi}\lambda.$$

The right-hand-side of this condition is the elasticity of labor productivity at basic firms with respect to λ. This elasticity converges to zero as θ converges to one.[15] Thus, we have

Proposition 5: *If screening is sufficiently precise or if the productivity difference between high and low-skill workers employed by basic firms is sufficiently small, then education policies that reward effort are superior to those that lower the cost of schooling.*

There are several educational programs that are designed to limit the costs of either schooling or effort. For example, in the US the federal Stafford Loan Program provides lending at subsidized rates to students enrolled in accredited post-secondary education institutions. While the availability of lending is partly intended to ease credit constraints, an issue we do not focus on here, the facts that the interest payments are deductible from income taxes and that the rates are subsidized both imply that the program lowers the costs of schooling. On the other hand, a growing educational program called 'Flip Courses' directly targets the costs to students of putting forth effort.[16] Flipped courses take advantage of internet technology by having students watch pre-recorded lectures on the appropriate subject materials at a time convenient to them. Students then attend classes where the instructor gives individual attention to students about the questions they have from the lectures and leads interactive discussion of the materials. Proponents of 'Flip Courses' often argue that, by making lectures available online and making instructors more available to individual students, they allow students to potentially keep a job, manage family life and promote student engagement. In other words, these types of programs reduce the opportunity cost of effort in school. Of course, development of online course content requires funding. The WIA also

[15] This follows from the fact that $\phi_\lambda \equiv \frac{\partial \phi}{\partial \lambda} = \frac{s_H(\phi - b\theta)}{s_L + (1-\lambda)s_H}$; when $\lambda = 1$, we have $\phi = b$ so that $\phi_\lambda = 0$.

[16] For a brief introduction and discussion of Flip Courses see "Flipping the Classroom" in the *Economist* (9/17/11).

provides federal funding for initiatives to develop online job training services to facilitate student performance. The result in Proposition 5 states that policies that fund programs like 'Flip Courses,' which target the costs of effort, are more effective in alleviating the adverse selection problems in the labor market than polices that provide funds to individuals to simply obtain schooling.

5. The Open Economy: Export Activity

In this section we assume that $p^* > p$, so that domestic firms have an incentive to sell the skill intensive good to foreign consumers. Export activities differ from import competition in that it is typically the case that only a few firms export, while all firms in an industry face increased competition from greater import penetration. As is the standard approach when modeling export behavior, we assume that there is a fixed cost F_x of accessing world markets that must be paid to begin exporting. Modern firms that export gain $(p^* - p)\bar{x}_m$ by selling to foreign consumers, while basic firms gain $(p^* - p)\bar{x}_b$. The difference in capacity constraints (i.e., $\bar{x}_m > \bar{x}_b$) implies that modern firms have a stronger incentive to export, consistent with the evidence from many countries. There are three possible types of equilibrium that involve a positive level of export activity:

(a) $(p^* - p)\bar{x}_m = F_x$ — *In this case, modern firms are indifferent between exporting and selling domestically. No basic firms export.*

(b) $(p^* - p)\bar{x}_m > F_x > (p^* - p)\bar{x}_b$ — *In this case, all modern firms export but no basic firms export.*

(c) $(p^* - p)\bar{x}_b = F_x$ — *In this case, all modern firms export and basic firms are indifferent between exporting and selling domestically.*

When modern firms are indifferent between exporting and not exporting, an endogenously determined fraction of them will choose to sell to foreign consumers with the remaining firms serving the domestic market. Likewise, if basic firms are indifferent between domestic and foreign markets, the fraction of firms serving each destination will be endogenously determined. Although exporting firms are more productive on average, there is significant overlap in the observed productivities of exporters and non-exporters; see Bernard *et al.* (2003). Such overlap with exporters being more productive on average is consistent with cases (a) and (c) above. In case (b), all exporters exhibit greater productivity that all domestic firms. We take cases (a) and (c) to be the most relevant, but we will generally examine export activity and educational behavior across all possible equilibrium types.

Perhaps more importantly, the distinction between each type of equilibrium allows us to characterize the impact of export activity on educational behavior along the extensive margin; i.e., as more or fewer firms choose to export. In a type (a) equilibrium, a relatively small fraction of firms export as compared to type (b) equilibrium, while even more firms are engaged in exporting in a type (c) equilibrium. We show that the extent of firms that actively export is one key to determining how workers respond when making skill acquisition decisions. The different implications of few or many firms within an industry exporting are of particular interest because this extensive margin is an observable characteristic that varies across industries and countries, and so provides a potential strategy to identify the impact of trade on education when worker skills are imperfectly screened.

It will be convenient to derive the conditions that characterize educational behavior in each type of exporting equilibrium before we analyze the impact of trade liberalization. We turn first to the case were some modern firms export, while all basic firms sell domestically.

5.1.1 Modern Firms Indifferent between Foreign and Domestic Market: Modern firms will split across serving either the domestic or foreign market if $p = p^* - \frac{F_x}{\bar{x}_m}$. We denote the fraction of modern firms that export as γ_m. The productivity of basic firms is the same as in the autarky equilibrium, and again free entry drives profits to zero for all firms in the domestic market. However, there is an additional free entry condition for modern firms requiring that those that export also earn zero profits in equilibrium:

(21) $$F_m + F_x = \left(p^* - \frac{w_H}{h}\right)\bar{x}_m \; .$$

With a fraction of modern firms exporting their output, there is a smaller supply of X available to the domestic market. The product market clearing condition in (4) must be adjusted to account for this fact, with the new market clearing condition given by

(4a) $$(1 - \gamma_m)\bar{x}_m N_m + \bar{x}_b N_b = X(p, E) \; .$$

The definition of E in (11), along with (4a), allows us to solve for γ_m, given supply-side behavior.

Our interest here is to derive the impact of exporting activity on worker educational choices. Regardless of the differences in the prices between foreign and domestic markets, workers make educational decisions based on relative wages. Of course global opportunities impact wage rates as some firms begin to sell output abroad. As before, we can reduce the supply-side of the model to two equations in two unknowns (a_E, a_H), which fully characterized educational behavior among the labor force in the open economy. Using the new free entry condition in (21), along with the free entry conditions in (2) and (3) and the worker indifference conditions in (7) and (8), it is straightforward to derive the counter-parts to equations (13) and (14) in the case in which some modern firms choose to export:

(13a) $$L^a(a_S, a_E) \equiv C_S(a_S) - \left(p^* - \frac{F_b}{\bar{x}_b} - \frac{F_x}{\bar{x}_m}\right)\phi(a_S, a_E) + 1 = 0$$, and

(14a) $$H^a(a_S, a_E) \equiv C_E(a_E) - \lambda\left[\left(p^* - \frac{F_m + F_x}{\bar{x}_m}\right)h - \left(p^* - \frac{F_b}{\bar{x}_b} - \frac{F_x}{\bar{x}_m}\right)\phi(a_S, a_E)\right] = 0 .$$

5.1.2 <u>Modern firms export while domestic firms do not export</u>: Modern firms never choose to serve the domestic market and basic firms never export if $(p^* - p)\bar{x}_m > F_x > (p^* - p)\bar{x}_b$. In this case, the free entry condition for exporting modern firms in (21) simply replaces the autarky free entry condition in (3). The market clearing condition for output must again be adjusted to accommodate the fact that no modern firm sells to domestic consumers. In a type (b) equilibrium it must be that

(4b) $$\bar{x}_b N_b = X(p, E),$$

so that domestic supply and demand are equal. The remaining equilibrium conditions are defined just as under autarky. Reducing the supply-side of the model to two equations yields

(13b) $$L^b(a_S, a_E) \equiv C_S(a_S) - \left(p - \frac{F_b}{\bar{x}_b}\right)\phi(a_S, a_E) + 1 = 0$$, and

(14b) $$H^b(a_S, a_E) \equiv C_E(a_E) - \lambda\left[\left(p^* - \frac{F_m + F_x}{\bar{x}_m}\right)h - \left(p - \frac{F_b}{\bar{x}_b}\right)\phi(a_S, a_E)\right] = 0 .$$

5.1.3 <u>Basic Firms Indifferent between Foreign and Domestic Market</u>: If any basic firm exports, then the relatively more productive modern firms will all export. Basic firms are indifferent between exporting and serving the domestic market if $(p^* - p)\bar{x}_b = F_x$. In this case, the free entry condition and market clearing condition must again be adjusted from those under autarky. We denote the fraction of basic firms that export under a type (c) equilibrium as γ_c. With only a fraction of basic firm selling domestically, and all modern firms exporting, the domestic market clearing condition is

(4c) $$(1-\gamma_b)\bar{x}_b N_b = X(p,E).$$

For basic firms that export there is still free entry, so profits are driven to zero such that

(24) $$F_b + F_x = \left(p^* - \frac{w_L}{\phi}\right)\bar{x}_b \ .$$

The remaining free entry conditions are (2), which must hold for basic firms that sell domestically, and (21), which must hold for modern firms. As before, the supply-side can be reduced to two equations that define the cutoff values a_S and a_E. The counterparts to (13) and (14) for a type (c) equilibrium are

(13c) $$L^c(a_S,a_E) \equiv C_S(a_S) - \left(p^* - \frac{F_b+F_x}{\bar{x}_b}\right)\phi(a_S,a_E) + 1 = 0, \text{ and}$$

(14c) $$H^c(a_S,a_E) \equiv C_E(a_E) - \lambda\left[\left(p^* - \frac{F_m+F_x}{\bar{x}_m}\right)h - \left(p^* - \frac{F_b+F_x}{\bar{x}_b}\right)\phi(a_S,a_E)\right] = 0.$$

5.2 <u>Relative Supply with Export Activity</u>: Figure 3 illustrates the relative supply curve for a small country with the potential to export skill intensive goods. The dashed line indicates relative supply under autarky. In the case where the domestic price is above $p^* - \frac{F_x}{\bar{x}_m}$ no firm exports, and the domestic supply is the same as under autarky. As p decreases, modern firms become indifferent between exporting and serving the domestic market. The flat portion of the relative supply curve is where $= p^* - \frac{F_x}{\bar{x}_m}$, corresponding to type (a) equilibria. The intersection of relative demand curve for domestic consumers along the flat portion of the supply curve determines the fraction of modern firms that export. At lower domestic price levels, between $p^* - \frac{F_x}{\bar{x}_m}$ and $p^* - \frac{F_x}{\bar{x}_b}$, all modern firms export and all basic firms serve the domestic market. The upward sloping portion of the relative supply curve at these price levels corresponds to type (b) equilibria (see result A.3 in the Appendix for a proof that supply is upward sloping in this region). In this region, higher prices induce more basic firms to enter and sell domestically, regardless of the adverse selection problem. As p drops to $p^* - \frac{F_x}{\bar{x}_b}$, basic firms become indifferent between serving the domestic and foreign markets. The flat portion of relative supply at this lower price level corresponds to the type (c) equilibria. In this case, the share of basic firms that export depends on the size of domestic demand – that is, the intersection of the relative demand curve on the flat portion of supply pins down γ_b. Note that in Figure 3 we have illustrated demand conditions such that a type (a) equilibrium occurs.

Proposition 6: *The relative supply curve for a small open economy in which $p^* > p$ is upward sloping. As a result, equilibrium is unique.*

5.3 <u>Export Activity, Educational Behavior and Inequality</u>: We are now in a position to investigate how the export behavior of domestic firms influences the decision of workers to obtain schooling and the decision of workers to acquire highly productive skills. We focus on the effects of trade liberalization characterized by a reduction in the costs to access foreign markers, F_x. To highlight the differential impacts of export activity on educational behavior as the extent of export participation varies, we begin by comparing the extreme cases (a) and (c), where relatively few or many firms serve foreign markets.

We begin by noting that in cases (a) and (c) the domestic price *p* is completely determined by p^*, F_x and the capacity constraints so that it is independent of λ. This feature makes cases (a) and (c) more tractable than case (b). In addition, since the proportion of firms that export is one of the keys to determining how workers respond when making skill acquisition decisions, and since this variable is at its extremes in cases (a) and (c), we focus most of our attention to these two cases. We report the results for case (b) and provide the intuition in the text, but relegate the details for that case to the Appendix.

In a type (a) equilibrium in which a fraction of the modern firms export, then the cutoff values a_S and a_E are determined by (13a) and (14a). Differentiating yields

(27a) $$\frac{da_S}{dF_x} = \frac{1}{D}\left\{-\frac{\phi}{\bar{x}_m}H_E + \frac{\lambda(h-\phi)}{\bar{x}_m}L_E\right\} > 0$$

(28a) $$\frac{da_E}{dF_x} = \frac{1}{D}\left\{\frac{\phi}{\bar{x}_m}H_S - \frac{\lambda(h-\phi)}{\bar{x}_m}L_S\right\} = \frac{1}{D\bar{x}_m}\left\{-C_S'(a_S) + \frac{\lambda h w_L}{\phi}\phi_S\right\} > 0$$

As trade costs fall it is the modern firms that benefit by exporting and initially earning higher profits. As new modern firms enter the demand for high skill workers rises, and so does the high skill wage.

Anticipating better employment opportunities, more students choose to exert effort which increases the measure of workers that become highly skilled.

A larger pool of high skilled workers also increases the measure of workers who fail the screening test, causing the average productivity of basic firms to also rise.[17] In addition, as more modern firms export, the supply of X to the domestic market falls, triggering an increase in the domestic price. These two effects both cause new basic firms to enter, which increases the demand for low skill workers. As low skill wages rise, more workers find it optimal to obtain schooling. Equilibrium is established when p rises enough to make modern firms indifferent between exporting and selling their goods domestically.

Next consider the case in which there are many firms involved in export activities. In a type (c) equilibrium firms using either technology may export, with basic firms indifferent between selling domestically and abroad. Thus, falling trade costs enlarge the market for all firms. To determine the impact of trade on educational choices we differentiate (13c) and (14c) and obtain

(27c) $$\frac{da_S}{dF_x} = \frac{1}{D}\left\{-\frac{\phi}{\bar{x}_b}H_E + \lambda\left(\frac{h}{\bar{x}_m} - \frac{\phi}{\bar{x}_b}\right)L_E\right\} = \frac{1}{D}\left\{-\frac{\phi}{\bar{x}_b}C'_E + \lambda\frac{h}{\bar{x}_m}L_E\right\} > 0 \text{ , and}$$

(28c) $$\frac{da_E}{dF_x} = \frac{1}{D}\left\{-\frac{\phi}{\bar{x}_b}H_S + \lambda\left(\frac{h}{\bar{x}_m} - \frac{\phi}{\bar{x}_b}\right)L_S\right\} = \frac{1}{D}\left\{-\lambda\left(\frac{h}{\bar{x}_m} - \frac{\phi}{\bar{x}_b}\right)C'_S + \frac{\lambda W_L}{\phi}\phi_S\right\}.$$

Equation (27c) indicates that a reduction in trade costs results in more workers purchasing schooling. A fall in trade costs results in more basic firms exporting. New basic firms must then enter to serve the domestic market, and this increases the demand for low-skilled labor, pushing up w_L. Better employment opportunities then increase the measure of workers that pursue schooling.

Equation (28c) indicates that the impact on skill acquisition is unclear. To see why, note that in case (c) the skilled wages are fixed at $w_H = \left(p^* - \frac{F_m+F_x}{\bar{x}_m}\right)h$ and $w_L = \left(p^* - \frac{F_b+F_x}{\bar{x}_b}\right)\phi$. As F_x falls, there are two effects. First, since both basic and modern firms benefit from lower trade costs, both low and high skilled wages rise. The high-skill wage rises at rate $\frac{h}{\bar{x}_m}$, and, holding low-skill productivity fixed,

[17] We discuss productivity growth among basic firms in more detail in the next section.

w_L rises at rate $\frac{\phi}{\bar{x}_b}$. If $\frac{h}{\bar{x}_m} > \frac{\phi}{\bar{x}_b}$ then $w_H - w_L$increases, and since the return to effort is directly tied to this difference, more workers put in effort while in school. This effect is captured by the second term on the right-hand-side of (28c). However, as more low-ability workers purchase schooling low-skill productivity (ϕ) starts to fall and this puts downward pressure on w_L. This second effect, which is captured by the first term on the right-hand-side of (28c), increases the return to effort.[18]

Both effects work in the same direction if $\frac{h}{\bar{x}_m} > \frac{\phi}{\bar{x}_b}$; but the overall impact on skill acquisition is uncertain if the inequality is reversed. It is worth noting that $\frac{\bar{x}_m}{h}$ and $\frac{\bar{x}_b}{\phi}$ are simply the labor demands for modern and basic firms, respectively. Since more productive firms tend to be larger, this suggests that the empirically relevant case is $\frac{h}{\bar{x}_m} < \frac{\phi}{\bar{x}_b}$. Also note that when the screening technology is sufficiently precise, ϕ_S approaches zero, limiting any upward pressure on the incentives to obtain high skills as trade barriers fall. In other words, when there is extensive export activity across firms, trade liberalization is likely to reduce the measure of workers that acquire high skills. The following proposition summarizes the differential effects of export activity as the extent of firms serving foreign markets varies, given that modern firms are relatively larger than modern firms.

Proposition 7: *Suppose that $p^* > p$ and that the cost of exporting falls; then*

(i) if only some modern firms export, the measure of workers that obtain schooling and the measure of workers that acquire high skills both increase.

(ii) if both modern and basic firms engage in export activity, the measure of workers that obtain schooling increases.

(iii) if both modern and basic firms engage in export activity and labor demand for each modern firms exceeds labor demand for each basic firm, then for a sufficiently precise screening technology, the measure of workers that acquire high skills falls.

A similar adjustment takes place in the stark case where all modern firms export and all basic firms serve the domestic market. In a type (b) equilibrium, as F_x falls the profits that modern firms earn from exporting increases and this leads to entry. As w_H is bid up, more workers put in effort while in school, shrinking the low-skill labor pool. This creates excess demand for low-skill labor, which causes

[18] Note that this indirect effect is not present if $\theta = 1$, since low-skill productivity would then be fixed at *b;* in such a case $H_S = 0$ and the first term on the right-hand-side of (30) vanishes.

w_L to rise. As a result fewer firms adopt the basic technology. With less output available for the domestic product market, p must rise to restore equilibrium. Finally, the increase in p, along with a larger pool of high-skill labor, results in more workers purchasing schooling (the technical details for case (b) are presented as Result A.5 in the Appendix).

The impact of falling trade costs on the decision to acquire schooling as described in Proposition 7 is the same for all possible equilibrium types, and more importantly, the prediction matches the empirical evidence for the consequences of trade liberalization. Atkin (2012) finds robust evidence of greater schooling among workers as skilled employment opportunities in export sectors grow across cohorts of Mexican students. As he argues, the educational behavior of workers as export opportunities change reflects shifts in the expected labor market outcomes across educational attainments. This is precisely the mechanism at play here. Greater export opportunities in the skilled sector always lead to an increase in relative prices, which generates entry and bids up wages for workers who attend school.

We are interested not only in how worker educational behavior adjusts to changes in export activity, but whether such changes eliminate the distortions present when firms imperfectly screen worker skills. Again, we will consider differences in the extent of export activity across firms. Note that in cases (a) and (c) the domestic price p is completely determined by p^*, F_x and the capacity constraints across firms. Thus, small changes in λ do not alter prices in cases (a) and (c), and so the distortions in educational behavior described in (17) and (18) continue to apply. In other words, in an open economy with extensive or very limited export activity, too few workers will acquire high skills. Also, if the screening technology is sufficiently precise, too many workers purchasing schooling.[19] As we have argued above, the case where the screening technology is precise is consistent with the popular criticism of too many workers going to school, and the evidence that the returns to college at the margin are well below average returns. Moreover, the stylized fact common across many countries and industries is that

[19] Similar results hold for type (b) equilibria, although the proof is more complicated since changes in λ trigger in changes in p (in fact, the a decrease in λ causes p to fall and, in case (b), this harms only basic firms, resulting in fewer workers purchasing schooling and more students putting in effort – this moderates both the over-education and under-supply of high-skilled worker distortions -- see Result A.4 in the Appendix for details).

more productive firms tend to be relatively large. Thus, for the empirically relevant parameter restrictions, such that the screening technology is sufficiently precise, trade liberalization has the following consequences:

Corollary 2: *(i) If only some modern firms export, then a reduction in the cost of exporting exacerbates the schooling distortion and mitigates the distortion in skill acquisition behavior.*

(ii) When both modern and basic firms engage in export activity and labor demand for each modern firm exceeds labor demand for each basic firm, a reduction in the cost of exporting exacerbates the distortions in both schooling and skill acquisition behavior.

Regardless of the distortion surrounding educational behavior, workers choose to go to school and to acquire skills in anticipation of the wages they expect to earn as export opportunities in the skilled sector change. Thus, we have another corollary to Proposition 7 that characterizes the effect of export activity on wage inequality, considering the case of a sufficiently precise screening technology.

Corollary 3: *(i) A reduction in the cost to access foreign markets always benefits low-skill wages relative to unskilled wages.*

(ii) If only some modern firms export, a reduction in the cost to access foreign markets benefits high-skilled workers relative to low-skilled workers, so that inequality rises.

(iii) If both modern and basic firms engage in export activity and labor demand for each modern firm exceeds labor demand for each basic firm, a reduction in the cost to access foreign markets benefits low-skill worker relative to high-skill workers.

Generally, Corollary 3 states that globalization has a non-monotonic relationship with wage inequality. Helpman, Itskhoki and Redding (2010) and Egger and Kreickemeier (2012) have also emphasized the potential for globalization to increase or decrease wage inequality, depending on the extent to which markets are integrated. In their framework, openness increases inequality when the fraction of firms that export is small, and decreases inequality when that fraction is large. In our framework the forces that drive our results are somewhat different, as are the implications. Reductions in the cost of exporting benefit modern firms disproportionally when only a small fraction of firms export. And, since these are the firms that primarily employ high skilled workers, high skilled workers benefit the most from globalization. Low-skilled workers free ride off of the increased effort by high-ability students, and they gain at the expense of unskilled workers. However, when a large fraction of firms export, reductions in the cost of exporting lead to more entry by basic firms – they respond by increasing export activity; new basic firms must also enter to pick up the slack in the domestic product market as existing firms ship their goods to foreign consumers. When the fraction of firms that export is relatively high, the biggest beneficiaries of globalization are those employed by basic firms – that is, workers in the middle of the income distribution.

4.4 <u>Export Activity and Firm Productivities</u>: The previous section makes clear that greater import and export opportunities impact worker educational behavior. As a result, firms hire workers from a labor force that has a different composition of skills, and some firms may adjust their chosen technology as the economy moves to a new trade equilibrium. In any typical model with heterogeneous firms, a growth in the relative measure of firms that adopt the modern technology and recruit high skilled workers will improve the average productivity in the skilled sector. However, a distinct feature of our analysis with imperfect screening of skills is that productivity *within* basic firms also changes as workers adjust their educational behavior to new trade opportunities.

Bernard, Jensen and Schott (2006) show broad evidence of productivity growth within both domestic and exporting manufacturing firms in the U.S. over a decade-long period during which the trade barriers to Canada and Mexico fell significantly. As they argue, productivity growth *within* firms cannot be explained by greater adoption of highly productivity technologies *across* firms. Furthermore, productivity gains through greater technological adoption occur only at the margin; Lileeva and Trefler (2010) provide evidence that the benefits of technological improvements are limited to new exporters as trade barriers fall. Finally, Pavcnik (2003) shows that skill deepening among firms is not explained by greater technology adoption as trade barriers fall, consistent with the finding here that higher skills improve productivity within firms that continues to use a specific technology type. The potential for productivity gains within firms as trade barriers fall, and specifically the potential for gains within domestic firms, highlights the importance of considering mechanisms such as labor market imperfections like asymmetric information.[20]

[20] Sly (2012) also shows that some domestic firms can realize productivity gain through skill-upgrading as export opportunities grow, when workers compete over occupations that differ in skill intensity within different firms. Here

6. Conclusions

Is education the key to success for workers in an increasingly global economy? How much should workers invest in education? Should governments incentivize the pursuit of skills as trade barriers fall? These broad economic questions can be difficult to answer given the complexities of the educational process and the myriad of incentives that workers face prior to entering the labor force. Workers can use educational opportunities to qualify for employment, to signal ability to firms, or to improve their productivity, each decision in hopes of earning higher wages upon graduation. The choices workers make regarding schooling and skill acquisition are further complicated by two ubiquitous features across countries: imperfect screening of skills by hiring firms, and ever increasing global integration of national economies. In this paper we provided a tractable framework to analyze a rich set of educational behaviors in the global economy.

A key feature of this analysis is to incorporate both signaling and productivity enhancing motives for education simultaneously. More than simply providing realism, allowing both incentives to weigh on worker behavior allows us to match several stylized facts regarding educational attainments and labor market outcomes. For instance, we have shown that imperfect screening of worker skills by firms reduces the incentives of workers to use education to acquire highly productive skills, but can increase the incentives of works to use education to signal ability. This potential for 'too many' college educated workers and still 'too few' high skill workers corresponds to common criticisms of the distortions among the labor force of developed countries. Also, across several countries rising wage inequality in recent decades has been concentrated within groups of college educated workers. Such variation in wages among workers with similar observed educational attainments is inconsistent with education being solely a mechanism for workers to signal abilities, or solely to enhance their productivity.

Worker skills are intimately linked with several aspects of the global economy, including the propensity of firms to export/import, the likelihood of being acquired by foreign multinationals, or even

basic firms realize improvements in productivity by hiring more highly skilled workers on average, even if all workers within the firm perform tasks with the same skill-intensity.

the potential to gain from international opportunities. We have shown that globalization can have a substantial impact on schooling and skill acquisition behavior among the domestic workforce. With imperfect screening of skills by firms, both the choices to go to school and to become high skilled are distorted. We have shown that while globalization can ease one of these distortions, it never alleviates both. Finally, our results demonstrate that the extent of firms engaged in international markets is a key fact in determining how workers respond to opening international markets.

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Appendix

Result A.1: Our goal is to show that the H curve is flatter than the L curve. The slope of the H curve is $\frac{-H_S}{H_E}$ and the slope of the L curve is $\frac{-L_S}{L_E}$. Thus, the H curve is flatter if

$$-\frac{H_S}{H_E} < -\frac{L_S}{L_E}$$

After substitution and cross-multiplication, this is equivalent to

$$D \equiv L_S H_E - H_S L_E = C_S^{'}(a_S)C_E^{'}(a_E) + C_S^{'}(a_S)\frac{\lambda w_L}{\phi}\phi_E - C_E^{'}(a_E)\frac{w_L}{\phi}\phi_S > 0$$

Which holds for all a_S and a_E. Thus, the H curve is flatter than the L curve and D > 0. #

Result A.2: We want to show that the Relative Supply curve is upward sloping. Substituting from (1), (5) and (6) into (12) we obtain

$$\frac{X}{Y} = \frac{b[S_L + (1-\lambda)S_H] + \lambda h S_H}{U + S - S_L - S_H}$$

Now use (9) and (10) to substitute for S_L and S_H and then collect terms to obtain

$$\frac{X}{Y} = \frac{S[\theta(1-\lambda) + \lambda h] - b a_S - [b(\theta - 1) + \lambda(h - \theta b)]a_E}{U + a_S}$$

Since $\theta > 1$ and $h > \theta b$, the rest of the proof follows directly from Lemma 2. #

Result A.3: Our goal is to show that relative supply is upward sloping for the range of prices that correspond to type (b) equilibria. In this case, relative supply is given by

(A.1) $\frac{X}{Y} = \frac{N_b \bar{x}_b}{U + a_S} = \frac{\phi[S_L + (1-\lambda)S_H]}{U + a_S} = \frac{b}{U + a_S}[S\theta(1-\lambda) - a_S + (1 - \theta(1-\lambda))a_E]$

Thus

$$\text{sign}\left[\frac{d\left(\frac{X}{Y}\right)}{dp}\right] = \text{sign}\left\{b[1 - \theta(1-\lambda)]\frac{da_E}{dp} - \left[b + \frac{X}{Y}\right]\frac{da_S}{dp}\right\}$$

Differentiating (13b) and (14b) yields

(A.2) $\frac{da_S}{dp} = \frac{\phi}{D}[H_E + \lambda L_E] = \frac{\phi}{D}C_E'(a_E) < 0$ and $\frac{da_E}{dp} = -\frac{\phi}{D}[H_S + \lambda L_S] = -\frac{\phi}{D}C_S'(a_S) > 0$

Since we have assumed that $1 > \theta(1-\lambda)$ (see p. 10-11), this completes the proof. #

Result A.4: Our goal is to analyze the impact of a change in λ for type (b) equilibria. We analyze the change in two steps. First, we allow λ to fall holding p constant; then, we allow p to adjust to its new equilibrium level. With p held fixed, the changes in the cut-off values from a fall in λ are given by (17) and (18). Thus, as λ falls we end up with fewer high-skilled workers and if the screening technology is sufficiently precise, more workers purchasing schooling. With more workers purchasing schooling, there is more output by basic firms, implying that X must rise; and with fewer unskilled workers, Y must fall – together this implies that X/Y rises so that the relative supply curve shifts out to the right (see below for a formal proof of this). This puts downward pressure on p. As p falls and we move down the new relative supply curve, the adjustments in the cut-off values are given in (A.1). As (A.1) indicates, the over-education problem is moderated as fewer workers purchase schooling and the distortion in effort is moderated as more students put in sufficient effort to qualify for the high-skill labor pool.

To prove that relative supply increases when λ falls, note that in a type (b) equilibrium relative supply is given by (A.1) in Result A.3 above. Differentiating with respect to λ yields

$$\text{sign}\left[\frac{d\left(\frac{X}{Y}\right)}{d\lambda}\right] = \text{sign}\left\{b[1 - \theta(1-\lambda)]\frac{da_E}{d\lambda} - \left[b + \frac{X}{Y}\right]\frac{da_S}{d\lambda} - b\theta S_H\right\} < 0;$$

Thus, as λ falls, relative supply on the domestic market increases. #

Result A.5: We want to examine how changes in F_x impact educational choices for type (b) equilibria – that is, for $p \in \left(p^* - \frac{F_x}{\bar{x}_b}, p^* - \frac{F_x}{\bar{x}_m}\right)$. Differentiating (13b) and (14b) yields

(A.3) $$\frac{da_S}{dF_x} = \frac{\lambda h L_E}{\bar{x}_m D} > 0 \quad \text{and} \quad \frac{da_E}{dF_x} = -\frac{\lambda h L_S}{\bar{x}_m D} > 0$$

Now, break down the move to the new equilibrium into two steps. First, let F_x fall, holding p fixed. The reduction in trade costs makes exporting more profitable for modern firms, inducing new entry. The increased demand for high-skill workers pushes up w_H and this increases the expected reward from effort. As a result, more workers acquire high-skills, as indicated the second result reported in (A.2). As the pool of high-skilled workers increases and some of these workers fail the screening test, ϕ rises and this leads to an increase in the measure of workers who purchase schooling. This explains the first result reported in (A.2). Thus, the initial impact from the reduction in trade costs is an increase in schooling and an increase in skill acquisition.

Now, let p rise to its new equilibrium level. The impact on the cut-off values can be found in (A.2) above. The increase in p increases the profits that basic firms earn by selling goods domestically and leads to greater demand for low-skill workers. As w_L rises, more workers purchase schooling, as indicated by the first result reported in (A.2). However, since these new low-skill workers do not put in effort, ϕ falls and this, along with the rise in w_L, reduces the expected reward from effort. This causes the pool of high-skilled workers to shrink a bit, as indicated by the second result reported in (A.2). But, since lower trade costs lead to an increase in exports, since all exports come from modern firms and since these firms use only high-skilled workers to produce output, the total net effect on the size of the high-skilled labor pool must be positive. Finally, combining the first result in (A.2) with the first result in (A.3) we see that the total measure of workers purchasing schooling must also rise.

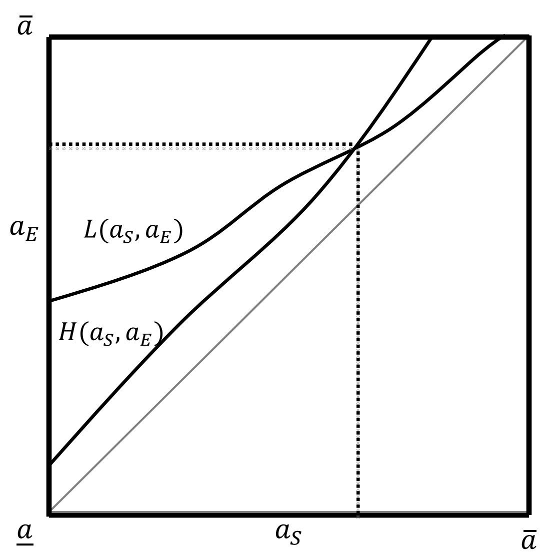

Figure 1: Equilibrium Education Behavior

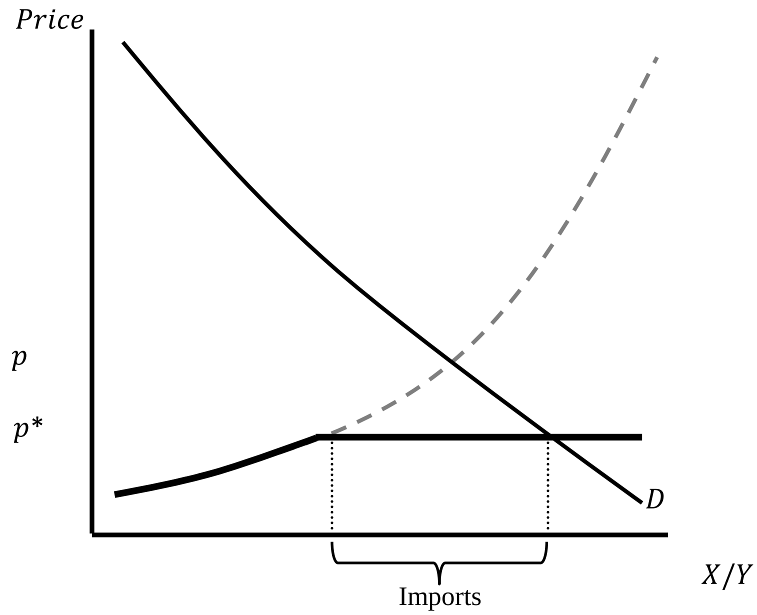

Figure 2: Equilibrium in a Small Importing Country

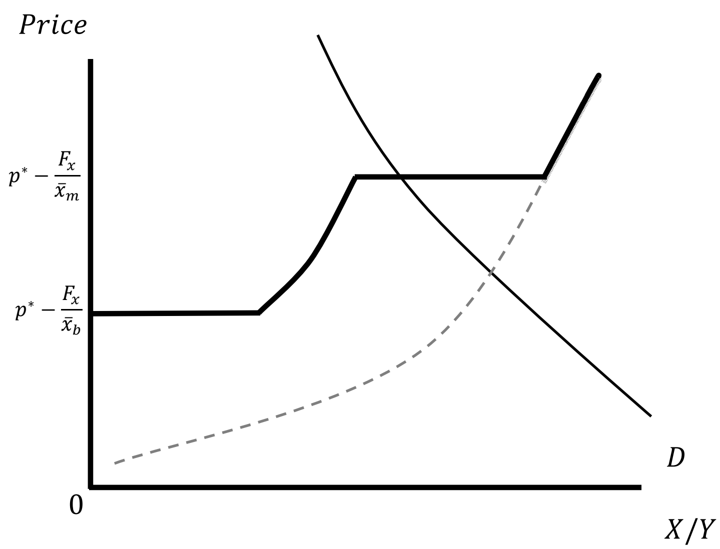

Figure 3: Equilibrium in a Small Exporting Country