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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, and affects wage inequality both within and across educational groups.

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1. 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 (2009) continued to push this idea, arguing that the marginal student in college today would be much better off going to a trade school.[1] Consistent with these views, Carneiro et al. (2011) provide evidence that the marginal return to college is often well below the average return. They show that policies expanding college enrollment induce "students who should not attend college to

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[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.

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attend it. Too many people go to college." On the other hand, we often hear that firms are complaining that they need more high-skilled workers to fill available positions. Popular reports from the 2012 *Talent Shortage Survey Research Results,* ManpowerGroup and the McKinsey Global Institute cite concerns of employers across the globe that difficulties in filling positions are due to a lack of available talent among the labor force, and further contend 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. In line with this perspective, Autor et al. (2003); Goos et al. (2009) and Acemoglu and Autor (2011) document that the demand for occupations with high cognitive and skill requirements has risen substantially in US and Europe over the last several decades, due to technological changes in production methods and increased foreign sourcing of routine tasks that require low/moderate skill levels.

These features of worker schooling behavior 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' 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 both 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. Consistent with our analysis here, Atkin (2012) provides empirical evidence that export activities are not always biased toward high skill workers, and thus global integration may actually reduce educational attainment. Specifically, he shows that young Mexican workers respond to increased export opportunities for low-skill occupations by reducing their enrollment in school, whereas greater export opportunities for high-skill occupations increase the acquisition of schooling among Mexican workers. 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 their skills than 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: the *basic* technology utilizes low-skilled labor but the *modern* technology 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 of firms can co-exist in equilibrium. We show that when there are heterogeneous firms, differing in the skill intensity of their production techniques, the autarky and open economy equilibria are unique – even when worker skills are not perfectly observed.

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

[2] Fang (2006) uses a structural model to quantify the relative importance of signaling motives and productivity enhancement in explaining the college wage premium in the US and finds that *both* motives contribute substantially to educational incentives. Similarly, Lange (2007) estimates the speed of employer learning about worker attributes and finds both signaling and productivity enhancement are persistent motives that influence educational behavior.

[3] Our approach here is different from the empirical literature on over-education, as indicated by the qualifications of *individual* workers that exceed specific job requirements. As an example, as of 2010, the BLS 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.

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). We note that, although the market allocation under asymmetric information is unique, educational behavior is still distorted. A key advantage of our simple perfectly competitive model is that we can provide a welfare analysis of educational behavior in an open economy absent other distortions.

Changes in trading opportunities impact educational behavior by shifting the relative demand for skills across industries and firms. There is strong evidence that firms face fixed costs to gain access to world markets, so that firms with different productivities face varying incentives to export. As a result, the impact of greater access to foreign markets on skill-acquisition 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, partially alleviating the inefficiency in skill acquisition behavior. 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 are smaller; in that case globalization exacerbates inefficient skill acquisition behavior. The different impacts of globalization, as relatively more or less firms engage in export activity, highlight how the impact of international trading opportunities differs from skill-bias technological change. When few firms export, greater trade opportunities are isolated among those that hire the most skilled workers to use the best technologies, and so globalization induces skill-biased technological change, as in Acemoglu (2003). However, when many firms can profitably enter export markets, including those that use less productive technologies and employ relatively low skill workers, globalization increases the demand for both low and high skill workers. In this case, exporting activity is not skill-*biased*. In terms of schooling behavior, we find that greater export opportunities *always* exacerbate the over education distortion by inducing more workers to use schooling simply as a signal.

Changes in educational behavior in an open economy reflect the manner in which wages adjust in equilibrium. Here we highlight that – because workers that use education as a signal are indistinguishable to firms (and econometricians!) from those that use schooling for productivity enhancement – the impacts of globalization on wage inequality manifest both within and across educational groups. Lemieux (2006a, 2006b) demonstrates that much of the ubiquitous rise in wage inequality over the last four decades is concentrated *within* education groups, in addition to change in the skill premium *across* education groups. 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 education allows us to capture this relevant feature.[6]

In the next section we discuss related literature on educational behavior with asymmetric information, as well as related literature on globalization. In Section 3 we develop our simple two-sector a model of worker educational behavior with imperfect screening and in Section 4 we derive the autarky equilibrium with adverse selection in the labor market. In Section 5 we turn to the global economy and consider how export opportunities influence educational behavior of domestic workers. Section 6 considers the alternative case where firms in the skilled sector face import competition. The final section offers a conclusion.

2. Related literature

The potential for information problems to distort labor market outcomes and educational decisions has long been recognized. Spence (1973) first described the role of costly education as a signal for 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).[7] There are few analyses that include both the signaling and productivity enhancing roles of education (see Blankenau and Camera, 2006) for an important exception. Regev (2012) allows employers to learn, albeit imperfectly, about the amount of human capital a worker obtained while in school.

[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 et al. (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; Fernandes, 2007).

[6] As we do here, Blankenau and Camera (2006) show that imperfect information about worker skills can lead to adverse selection, with over education, under accumulation of skills, and wage dispersion among similarly skilled workers. However they assume that the demand for skills and technologies across agents are fixed, and find that there are multiple equilibria, complicating policy analysis. Also, their analysis is silent on the role of globalization in influencing labor market outcomes. Krugman (2000) exploits the potential for multiple equilibria generated by asymmetric information in labor markets with adverse selection 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.

[7] 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.

Importantly, in Regev's analysis human capital accumulation from schooling is probabilistic, whereas we model the choice to exert effort while in school to accumulate further capital. This additional skill acquisition behavior in our model is important, as we show that globalization or changes in the relative demand for skills have distinct effects on schooling versus skill acquisition decisions of workers. Understanding the distinction between schooling and skill acquisition is crucial 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. Similarly, Lange (2007) estimates an upper bound of 15–40% on the value of schooling that is due to signaling, supporting the idea that both motives, and hence both behaviors, are empirically relevant.

Many facets of the global economy are intimately connected to the distribution of worker skills in each country. Yet, the common approach is to treat the distribution of skills as a fixed endowment within countries, or as an innate characteristic of workers. There are a few notable exceptions. The classic treatment of endogenous human capital accumulation with international trade is in Findlay and Kierzkowski (1983). Subsequently, open economy analysis with endogenous human capital choices have shown that trade also interacts with features such as worker ages, national education policies, credit constraints, or diversity of occupations in the choice to go to school (see Falvey et al., 2010; Bougheas et al., 2011; Bougheas and Riezman, 2012; Moro and Norman, 2010; Ranjan, 2001; Blanchard and Willmann, 2011). Perhaps the most closely related analysis of international trade with endogenous human capital acquisition is Vogel (2007). He investigates trade patterns with human capital accumulation with information problems that generate moral hazard issues. As with the previously mentioned analyses, education is purely productivity enhancing, allowing skilled managers to better detect the efforts of subordinate employees. He does not investigate adverse selection problems associated with imperfect observation of educational behavior. Our inclusion of education as a signaling device into the analysis is novel to the literature on trade and educational behavior.[8]

3. 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. The assumption of perfect competition is made for tractability and, more importantly, so that we can highlight the distortions generated by asymmetric information about worker skills without having to worry about how they interact with distortions tied to imperfect competition in the product market.[9] In addition, the perfectly competitive framework allows us to derive analytic results in a very general setting.

3.1. Consumer preferences

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.

3.2. Worker education

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 frequency distribution of aptitude for these workers is $G(a)$ over $[0, \overline{a}]$ so that $G(\overline{a}) = S$. Workers with an aptitude for education 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, basic firms will not be able to distinguish unskilled workers from those with aptitude absent any signal (i.e., a degree), and without screening modern firms will not be able to distinguish those who put in effort into their coursework from those who do not. Fig. 1 illustrates the sorting of workers across sectors and technologies.

[8] 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 (e.g., Wood and Ridao-Cano, 1999; Redding and Schott, 2003). However, none of these models consider education a signaling device. 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.

[9] In Appendix B, we provide an alternative version of our model that allows for monopolistic competition and show that all of our key comparative statics results generalize to this alternative market structure.

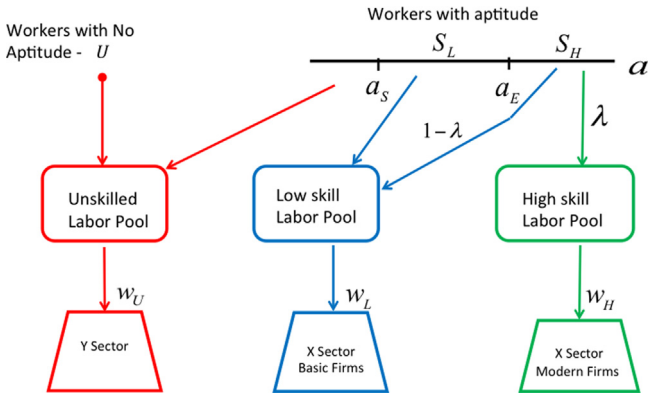

Fig. 1. Sorting of worker aptitudes across technologies and sectors of employment.

We assume that the cost of schooling, $C_S(a)$, is decreasing and convex in aptitude, and given in terms of disutility. Workers with aptitude can purchase schooling and earn a degree, regardless of the effort devoted 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, but those who put forth a unit of effort in school enhance their productivity and become high-skilled workers. The disutility from effort, $C_E(a)$, is also decreasing and onvex in aptitude. 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.

3.3. Worker screening and 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. We assume that upon the completion of schooling, workers take a test with the results observable by all firms. 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.

Popular examples of screening tests administered upon recruitment are the Wonderlic Cognitive Ability Test or the Armed Forces Qualification Test (AFQT). 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 professional sports. The exam takes 12 min to administer and so provides a low-cost, albeit imperfect, signal of worker skills. Similarly, scores on the AFQT are often used by employers to infer potential differences in productivity among otherwise identical workers. More recently, commercial options such as the Collegiate Learning Assessment are being adopted by a large number of institutions to measure the value added for students obtained from higher education. Although such screening options are available, Lange (2007) estimates that there is persistent expectation error about worker productivity after 3 years of employment; his estimates imply that it takes about 26 years on the job to reduce expectation error about worker productivity to less than 10% of its initial value. In other words, the mechanisms that firms can use to screen workers are effective, yet imperfect.

Firms hire 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. Those who fail 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 will account for their differences in performance on average. Unskilled workers receive wage w_U.

3.4. Labor demand and production

Only unskilled labor is used to produce Y, 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 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 produces $h > \theta b$ 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, and is a common device used in the industrial organization literature on Bertrand games.

The assumptions that $h > \theta b$ and $\theta > 1$ reflect the benefits of schooling and effort to worker productivity. Differences in productivity across technologies 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.[10] Our interest is in studying a menu of technologies that are skill biased: note that 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 is the case if $b > (1-\lambda)\theta b$. These assumptions about relative productivity 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 et al. (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 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 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 X, 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

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

It follows that the marginal costs for the typical basic firm are w_L/ϕ.

4. Autarky

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

4.1. Product market equilibrium

Free entry in X sector implies that both basic and modern firms must earn just enough profit to cover the fixed cost of adopting their technology. In autarky this implies

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

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

where p denotes the price of X. Note that since price exceeds marginal cost, all firms produce at capacity. Next, if we use N_b (N_m) to denote measure of firms that adopt the basic (modern) technology; and use E to denote total expenditures by consumers, then equilibrium in the market for X requires[12]

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

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

[10] As in Helpman et al. (2010), we assume that firms cover fixed costs by using unskilled labor. This assumption does not play a critical role in our analysis. We could assume that they are covered with skilled labor (as in Yeaple 2005) without altering our results. We prefer our approach because it makes the skilled labor market clearing conditions more tractable.

[11] Basic firms could also choose to hire high skill workers that pass the screening exam. However, we show in Appendix A that such behavior could only arise for a knife-edge set of parameters (see Result A.2 in Appendix A).

[12] Since each unskilled worker produces one unit of Y, market clearing for Sector Y requires $Y(p,E) = U + S - S_L - S_H$; however, Walras' Law assures us that this equilibrium condition is redundant.

4.2. Labor market equilibrium

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:

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

$$\lambda S_H=\frac{\overline{x}_m}{h}N_m. \tag{6}$$

In (5) and (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 product of labor demand per firm and the measure of firms of each type.

4.3. Equilibrium educational behavior

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

$$C_S(a_S)=w_L-1. \tag{7}$$

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

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

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:

$$S_L=G(a_E)-G(a_S) \tag{9}$$

$$S_H=S-G(a_E) \tag{10}$$

Accordingly, total unskilled employment can be expressed as $U+S-S_L-S_H$.

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

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

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.

4.4. Determining the autarky equilibrium

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 p. Thus, it is sufficient to show that, given optimal education behavior of workers and technology adoption by firms, 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

$$\begin{aligned}\frac{X}{Y}&=\frac{\overline{x}_bN_b+\overline{x}_mN_m}{U+S-S_L-S_H-N_bF_b-N_MF_M}\\&=\frac{b[(G(a_E)-G(a_S))+(1-\lambda)\theta(S-G(a_E))]+(S-G(a_E))\lambda h}{U+G(a_S)-b(F_b/\overline{x}_b)[(G(a_E)-G(a_S))+(1-\lambda)\theta(S-G(a_E))]-\lambda h(F_M/\overline{x}_M)(S-G(a_E))}\end{aligned} \tag{12}$$

where the second equality follows from substituting (1), (5), (6), (9) and (10). Note that relative supply is solely as a function of a_S and a_E, given the parameters of the model. Thus, the relative supply curve 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

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

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

It will be useful to note that responses 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:

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

Eq. (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).

Eq. (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 low-skilled labor pool, ϕ. Hence w_L rises, and this reduces the relative benefit from exerting effort. As a result, a_E must rise to restore the equality in (14).

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 Appendix A (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 $L_j \equiv \partial L/\partial a_j$ and $H_j \equiv \partial H/\partial a_j$ for $j = S, E$. From (13) and (14) we have

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

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

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

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

High skill workers are more productive using any technology in sector X, and low skill workers are more productive than unskilled workers. Hence, 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 acquiring 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. Given a downward sloping relative demand curve, we then obtain a unique relative price level p, which Lemma 1 assures is associated with a unique set of educational behaviors.[13]

[13] To see that equilibrium is truly unique, we note that the intersection of Relative Supply and Relative Demand yields a unique p. Given p, (13) and (14) give us unique cut-off values as reported in Lemma 1. Once we have the cut-off values, (9) and (10) give us unique values for S_L and S_H, which then yield ϕ via (1). Equilibrium wages then follow directly from (2) and (3), and then (5) yields N_b and (6) yields N_m. Finally, (11) gives E.

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.*

A unique equilibrium is determined even when education acts to both signal skills and to enhance productivity. Previous analyses of labor markets with adverse selection have typically found the possibility of multiple 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 (e.g., Blankenau and Camera, 2006; Krugman, 2000). A key distinction of our analysis that leads to a unique equilibrium, despite imperfect information about workers' skills and signaling behavior, is that we allow firms to select technologies with different skill intensities. The ability to choose the skill intensity of their production technique offers firms an additional margin, besides adjusting wages, on which they can respond to information asymmetries, which erodes the potential for multiple equilibria. Importantly, this mechanism matches the evidence in Ciccone and Peri (2011) that firms absorb changes in the supply of skilled labor by altering their production techniques, and that this adjustment takes place across firms within the same industry.

5. The open economy: export activity

Consumers in all countries share identical homothetic 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 given on world markets at p^*. Our primary interest is in the impact of greater export opportunities in the skill-intensive sector on educational choices. Thus, in this section we first consider an economy in which some domestic firm may want to export, given that $p^* > p$. We address import competition in the skill intensive sector (i.e., $p^* < p$) in the next section.

As is the standard approach, 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 $(p^* - p)\bar{x}_b$. Hence, modern firms have a stronger incentive to export, consistent with the large body of evidence that exporters typically dominate domestic firms in term of size and productivity. 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.

The distinction between each type of equilibrium is important for two reasons. First, it 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). Second, it allows us to characterize the impact of export activity in terms of relative skill-bias. 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. Since modern firms hire only the highest skill workers, it is clear that globalization favors high skill workers relatively more in case (a) than in cases (b) and (c). As a result, globalization does not always induce skill-biased technological adoption. Instead, it is the extent of firms that actively export that determines how they each adjust production modes, and thus determines how workers respond when making skill acquisition decisions.

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. Note that 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 only 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 in the open economy. Also the autarky equilibrium conditions must be adjusted to accommodate the existence of fixed exporting costs. We turn first to the case where some modern firms export, while all basic firms sell domestically.

5.1. Modern firms indifferent between foreign and domestic market

Modern firms will split across serving either the domestic or foreign market if $p = p^* - (F_x/\bar{x}_m)$. We denote the endogenous 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:

$$F_m + F_x = \left(p^* - \frac{w_H}{h}\right)\bar{x}_m. \tag{15}$$

With a fraction of modern firms exporting, 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

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

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

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 (15), 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 Eqs. (13) and (14) in the case in which some modern firms choose to export:

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

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

5.2. Modern firms export while domestic firms do not export

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 (15) 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 domestic supply equals demand; that is,

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

The other equilibrium conditions are defined as under autarky. Reducing the model's supply-side to two equations characterizing schooling and skill acquisition behavior yields

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

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

5.3. Basic firms indifferent between foreign and domestic market

If any basic firm exports, then the relatively more productive modern firms will find export opportunities more valuable, and will serve only foreign markets. Basic firms are indifferent between exporting and selling domestically 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_b. With only a fraction of basic firm selling domestically, and all modern firms exporting, domestic market clearing requires

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

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

$$F_b + F_x = \left(p^* - \frac{w_L}{\phi}\right)\bar{x}_b. \tag{16}$$

The remaining free entry conditions are (2), which must hold for basic firms that sell domestically, and (16), 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

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

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

5.4. Open economy equilibrium with export activity

Fig. 2 illustrates Relative Supply for a small country with the potential to export skill intensive goods. The dashed line indicates Relative Supply under autarky. In the case where $p > p^* - (F_x/\bar{x}_m)$, no firm exports and the domestic supply is the

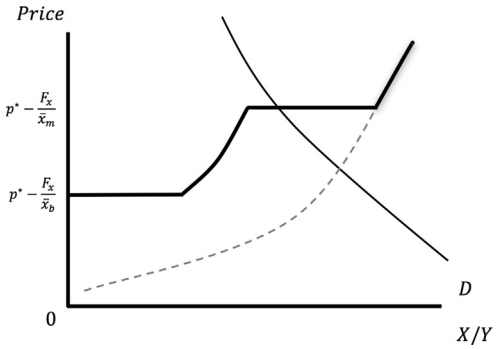

Fig. 2. Equilibrium in a small exporting country.

same as under autarky. As p decreases, modern firms become indifferent between exporting and serving the domestic market. The flat portion of relative supply is where $p = p^* - (F_x/\bar{x}_m)$, corresponding to type (a) equilibria. The intersection of the relative demand curve for domestic consumers along the flat portion of the supply curve determines the fraction of modern firms that export.

At lower values of p, between $p^* - (F_x/\bar{x}_m)$ and $p^* - (F_x/\bar{x}_b)$, 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. In this region, higher prices induce more basic firms to enter and sell domestically, regardless of the adverse selection problem. As p drops further to $p^* - (F_x/\bar{x}_b)$, 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 domestic demand – that is, the intersection of the relative demand curve on the flat portion of supply pins down γ_b. Note that in Fig. 2 we have illustrated demand conditions such that a type (a) equilibrium occurs.

5.5. Export activity and education behavior

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. Note that in both of those cases, the domestic price p is completely determined by p^*, F_x and the capacity constraints. This feature makes cases (a) and (c) more tractable than case (b). We therefore deal with the more complex case (b) last and relegate some details of the case to Appendix A.

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

$$\frac{da_S}{dF_x} = \frac{1}{D}\left\{ -\frac{\phi}{\bar{x}_m} H_E + \frac{\lambda(h-\phi)}{\bar{x}_m} L_E \right\} > 0 \tag{17a}$$

$$\frac{da_E}{dF_x} = \frac{1}{D}\left\{ \frac{\phi}{\bar{x}_m} H_S - \frac{\lambda(h-\phi)}{\bar{x}_m} L_S \right\} = \frac{1}{D\bar{x}_m}\left\{ -C_S'(a_S) + \frac{\lambda h w_L}{\phi}\phi_S \right\} > 0 \tag{18a}$$

Falling trade costs benefit modern firms that are exporting and initially they earn higher profits. As new modern firms subsequently enter, the demand for high skill workers rises, and so does w_H. Anticipating better employment opportunities, more students exert effort, which increases the measure of highly skilled workers.

Intuitively, 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 rise. 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 demand for low skill workers. As low skill wages rise, more workers find it optimal to obtain schooling. Equilibrium is reestablished when p rises enough to make modern firms indifferent between exporting and selling their goods domestically.

Moving to case (c), both modern and basic firms have an incentive export so that trade liberalization is unequivocally not skill-biased. Note that in case (c) skilled wages are $w_H = (p^* - ((F_m + F_x)/\bar{x}_m))h$ and $w_L = (p^* - ((F_b + F_x)/\bar{x}_b))\phi$. To determine the impact of trade on educational choices we differentiate (13c) and (14c)

$$\frac{da_S}{dF_x} = \frac{1}{D}\left\{ -\frac{\phi}{\bar{x}_b} H_E + \lambda\left(\frac{h}{\bar{x}_m} - \frac{\phi}{\bar{x}_b}\right) L_E \right\} = \frac{1}{D}\left\{ -\frac{\phi}{\bar{x}_b} C'_E + \lambda\frac{h}{\bar{x}_m} L_E \right\} > 0, \quad \text{and} \tag{17c}$$

$$\frac{da_E}{dF_x}=\frac{1}{D}\left\{-\frac{\phi}{\bar{x}_b}H_S+\lambda\left(\frac{h}{\bar{x}_m}-\frac{\phi}{\bar{x}_b}\right)L_S\right\}=\frac{1}{D}\left\{-\lambda\left(\frac{h}{\bar{x}_m}-\frac{\phi}{\bar{x}_b}\right)C_S'+\frac{\lambda W_L}{\phi}\phi_S\right\}\gtrless 0. \tag{18c}$$

Eq. (17c) indicates that a reduction in trade costs results in more workers in school. As more basic firms begin exporting, new basic firms enter to serve the domestic market, increasing the demand for low-skilled labor and pushing up w_L. Intuitively, better job opportunities result in more workers that pursue schooling.

Eq. (18c) indicates that as F_x falls, there are generally two opposing effects. First, since all firms benefit from lower trade costs, both w_L and w_H rise. The high-skill wage rises at rate $h/\bar{x}_m$, and, holding ϕ fixed, w_L rises at rate $\phi/\bar{x}_m$. If $h/\bar{x}_m > \phi/\bar{x}_m$ then $w_H - w_L$ increases, and since the return to effort is tied to this difference, more workers put in effort while in school. This effect is captured by the first term on the right-hand-side of (18c). Second, as more low-ability workers purchase schooling, ϕ falls and this puts downward pressure on w_L. This effect, which is captured by the second term on the right-hand-side of (18c), increases the return to effort.[14]

Importantly, both effects work in the same direction if $(h/\bar{x}_m) > (\phi/\bar{x}_b)$. It is worth noting that $\bar{x}_m/h$ and $\bar{x}_b/\phi$ are 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 $(h/\bar{x}_m) < (\phi/\bar{x}_b)$. 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 acquiring high skills. This result is in stark contrast to case (a) where only high skill workers benefit from trade liberalization and so skill acquisition behavior increases.

Finally, we turn to the intermediate case (b), in which a reduction in trade costs also triggers an adjustment in the domestic price. This case is best analyzed in two steps. First, let F_x fall, holding p fixed. We then allow p to adjust to its new equilibrium level. The reduction in trade costs makes exporting more profitable for modern firms, inducing new entry of modern firms. The resulting increase in demand for high-skill workers pushes up w_H, increasing the expected reward from effort. As a result, more workers acquire high-skills. The increase in S_H increases ϕ, the average productivity for basic firms (from Eq. (1)), and the fact that more educated workers are now putting in effort means that the pool of low-skilled workers must shrink. As ϕ rises with p held constant, w_L must rise by the same amount to restore equality in (2). The higher low-skilled wage leads more workers to purchase schooling (from Eq. (7)) somewhat moderating the shortage of low-skilled workers. With a shortage of low-skilled workers, there must be a reduction in the measure of basic firms to restore equilibrium in that labor market (from Eq. (5)). With fewer basic firms, production of X for the domestic market falls, putting upward pressure on p. The results with respect to the cut-off values can be confirmed by differentiating (13b) and (14b) with p held fixed to obtain $(da_S/dF_x) = (\lambda h L_E/\bar{x}_m D) > 0$ and $(da_E/dF_x) = (-\lambda h L_S/\bar{x}_m D) > 0$. Thus, initially the reduction in F_x leads to an increase in both schooling and skill acquisition.

Now, let p rise to its new equilibrium level. 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, additional workers purchase schooling, reinforcing the initial increase in schooling. 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, counteracting the initial increase in skill-acquisition. Combining the two steps, we see that a reduction in trade costs must lead to an increase in schooling but the impact on skill-acquisition is ambiguous[15] — perhaps not surprisingly, case (b) gives us results that are a mix of what we find in cases (a) and (c). It is worth emphasizing that in case (b), as in case (c), the benefits of trade liberalization are not entirely biased toward high skill workers, and to the incentive to obtain high skills may be generally higher or lower with trade barriers are reduced.[16]

The two propositions below, which focus on cases (a) and (c), summarize the differential effects of export activity as the extent of exporting varies, given that modern firms are larger than modern firms.

Proposition 2. *Suppose that $p^* > p$ and that in the initial equilibrium only some modern firms export. Then if the cost of exporting falls then the measure of workers that obtain schooling and the measure of workers that acquire high skills both increase.*

Proposition 3. *Suppose that $p^* > p$ and that initially both modern and basic firms are engaged in export activity. Then if the cost of exporting falls, the measure of workers that obtain schooling increases. Moreover, if labor demand for each modern firm exceeds labor demand for each basic firm, then for a sufficiently precise screening technology, the measure of workers that acquire high skills falls.*

The results on schooling described in Propositions 2 and 3 is the same for all possible equilibrium types, and matches the empirical evidence for the consequences of trade liberalization. Atkin (2012) finds robust evidence of greater schooling

[14] 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 (18c) vanishes.

[15] More formally, differentiating (13b) and (14b) with p endogenous yields $(da_S/dF_x) = (1/D)\{(\partial p/\partial F_x)\phi C_E'(a_E) + \lambda(h/\bar{x}_m)L_E\} > 0$ and $(da_E/dF_x) = (-\lambda/D)\{C_S'(a_s)((h/\bar{x}_m) + (\partial p/\partial F_x)\phi) - (h/\bar{x}_m)(W_L/\phi)\phi_S\} \gtrless 0$

[16] Skill-biased technical change in our model would be equivalent to a reduction in F_m, the cost of adopting the modern technology. Straightforward differentiation of (13) and (14), versions a, b or c, reveal that a reduction in F_m *always* results in more workers purchasing schooling and more workers acquiring high-skills. Thus, only in case (a) is a reduction in trade costs qualitatively identical to skill-biased technical change.

among workers across cohorts of Mexican students as skilled employment opportunities in export sectors grow. 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 that bids up wages for workers who attend school.

5.6. Export activity and efficiency of education behavior

The individual educational behavior of workers reflects their rational expectations regarding job prospects. However, in the aggregate educational choices are distorted by the imperfect screening of skills by firms.[17] 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, or if trading opportunities exacerbate them.

The efficient outcome for an economy corresponds to an equilibrium in which no information problems exist (i.e. $\lambda = 1$). Hence, the distortions in educational behavior can be characterized by examining how schooling and skill acquisition behavior adjusts as an economy deviates from the first-best outcome. Recall that optimal educational behavior in the open economy is given by (13a–c) and (14a–c) for the corresponding exporting equilibrium. For the sake of exposition, here we characterize distortions in educational behavior at the two extreme cases (a) and (c) for exporting activity, but we show in Result A.3 in Appendix A that the same results are obtained in any open economy equilibrium. Differentiating the conditions for optimal educational behavior, (13a) and (14a) or (13c) and (14c), with respect to λ and considering the limiting case of full information as λ approaches one, we obtain

$$\frac{da_S}{d\lambda} = \frac{w_L}{D\phi}\{C_e'(a_e)\phi_\lambda + (w_H - w_L)\phi_E\} \gtreqless 0, \tag{19}$$

$$\frac{da_E}{d\lambda} = \frac{1}{D}\left\{L_S(w_H - w_L) - \frac{w_L}{\phi}\phi_\lambda C_S'(a_S)\right\} < 0 \tag{20}$$

where $\phi_\lambda \equiv (\partial\phi/\partial\lambda) = (S_H(\phi - b\theta)/S_L + (1-\lambda)S_H) < 0$. Eq. (20) 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. (i.e., a_E rises.)

The effect of imperfect screening on schooling is given in (19); 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 in opposite directions, the overall level on schooling 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 4. *If worker screening is imperfect in an open economy, then workers will under-invest in skill acquisition. 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 put forth by Berg (1970), Freeman (1975, 1976) and Murray (2009) that too many people go to college. 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 this feature, Carneiro et al. (2011) provide evidence that the average return to college is much higher than the marginal return for workers considering whether to enroll. Moreover, the Lange (2007) provides evidence that, while information problems are persistent, effective screening of workers' abilities occurs quite fast. 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.[18]

Information asymmetries about the skills of workers have long been known to distort education decisions and labor market outcomes. Yet, an important insight from Proposition 4 is that, when workers use education as both a signal and to enhance productivity, the single information problem that arises with imperfect screening of skills generates two separate distortions: over-investment in schooling as a signal, and under investment in skill-acquisition. These distorted outcomes persist whenever worker skills are imperfectly observed, yet the question remains whether integration into the global

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

[18] Lange (2007) and Kahn and Lange (2013) show that employers learn about worker productivity fairly quickly, albeit with persistent asymmetric information. The estimates in Lange (2007) suggest that half the expectation error surrounding worker performance is eliminated within 3 years. However, evidence in Kahn and Lange (2013) strongly suggests that wages differ from workers productivity all across the life-cycle as firms continuously gather information about worker productivity.

economy mitigates or exacerbates the inefficiencies in education behavior. The results in Propositions 2 and 3 for adjustments in educational behavior following trade liberalization, combined with the distortions in educational behavior described in Proposition 4, together imply that globalization has the following consequences:

Corollary 1.

(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.*

5.7. Export activity, wages & inequality

Regardless of the distortions 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 can map the endogenous changes in worker educational behavior following trade liberalization directly into wage outcomes. Note that, because workers that use schooling as a signaling device and pass the screen exam are indistinguishable to firms (and econometricians) from those workers that use schooling to enhance productivity, trade liberalization has consequences for both across educational group wage inequality and within group wage inequality.

Corollary 2.

(i) *A reduction in the cost to access foreign markets always benefits low-skill wages relative to unskilled wages, regardless of the fraction of firms that export.*
(i) *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.*
(ii) *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 2 states that globalization has a non-monotonic impact on wage inequality. Helpman et al. (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 our framework the forces that drive these results are different, as are the implications. Reductions in the cost of exporting benefit modern firms disproportionally when only a small fraction of firms export. Since these firms primarily employ high skilled workers, they 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 basic firms to increase export activity. New basic firms must then enter to pick up the slack in the domestic product market. 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.

The wage effects described in Corollary 2 are also distinct in that export activity implies changes in inequality *both* within and across groups. High and low skill workers are observationally equivalent, so that an increase in w_H relative to w_L corresponds to an increase in residual wage dispersion among skilled workers, while changes in skilled wages relative to the unskilled wage correspond to shifts in inequality across skill groups. Notably, Card and Lemieux (1996) highlight that recent changes both the within and across skill group components of the wage distribution are substantial. 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 features are consistent the results in Corollary 2 where skilled workers are not able to perfectly distinguish themselves on the labor market. These facts, however, are inconsistent with models that assume that workers skills are perfectly observed, or assume that education serves only a single purpose for all workers.

6. The open economy: import penetration

Opening the domestic market to foreign producers when $p^* < p$ changes Relative Supply for the domestic market: instead of the upward sloping 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^*. Import competition differs from export activity in that

all domestic firms face similar competition from abroad. As a result, import competition in the skilled sector affects workers regardless if they use schooling as signaling device or to enhance productivity. As the home country begins to import X, both high and low skill workers recognize that demand for their skills diminishes, and adjust their educational behavior accordingly.

Optimal schooling and skill acquisition behavior for an economy that imports the skilled good satisfy (13) and (14) with $p = p^*$. Lemma 2 describes the relationship between exogenous changes in prices and worker educational behavior. Such 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.

It is straightforward to show that, as in the case of an exporting economy described in Proposition 4, workers in a country that imports the skilled good will over-invest in schooling and under invest in skill acquisition. (see Result A.4 in Appendix A). Thus we can readily describe how import competition tends to alleviate or worsen distortions in educational behavior. We obtain the following.

Proposition 5. *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.*

The reduction in educational attainment predicted in Proposition 5 is consistent with the evidence in Atkin (2012). As he 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. Subsequently he shows that Mexican workers are more likely to drop out of secondary education when the arrival of these local unskilled manufacturing jobs is relatively larger.[19]

Changes in educational behavior in Proposition 5 reflect the workers' responses to the impact of import competition on expected relative wages. More workers will go to school as low-skill wages rise, while fewer put forth effort as high-skill wages fall. Thus, given the results in Proposition 5 we can derive the implied changes in income inequality directly.[20]

Corollary 3. *Globalization that results in greater import competition in the skill-intensive sector reduces wage inequality among the domestic labor force both within and across educational groups.*

Again, our results for the impact of globalization on relative wages are distinct from previous analyses. Here, import competition shifts the distribution of wages *within* a group of workers that have the same observed level of education, as well as impacting wage inequality *across* skill groups and sectors of employment. Given the strong evidence of heterogeneous returns to education, it is important to recognize that globalization can impact these differential benefits of education for workers. And, given the large amount of variation in earnings among similarly skilled workers, it is also important to recognize that trading opportunities impact residual wage dispersion as well.

7. Conclusions

Is education the key to success for workers in an increasingly global economy? How much should workers invest in education? Should governments encourage the pursuit of skills as trade barriers fall? These broad economic questions can be difficult to answer given the complexities of the education process and the myriad 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 of labor markets: imperfect screening of skills by 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 to use education to acquire highly productive skills, but can increase the incentives 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

[19] Hickman and Olney (2011) provide complementary evidence that import competition in the low-skill sector with in the US (ostensibly from Mexico to a large degree) increases enrollments of US workers in higher education institutions.

[20] Formally this result is obtained from combining optimal education behavior from (7) and (8) with the relationship between given relative prices and education described in Lemma 2.

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 productivity.

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.

Finally, we should note that we have derived our result in, what has become, an unusual setting for trade models: perfect competition. This assumption has allowed us to derive analytic results with minimal structural assumptions.[21] The assumption of perfect competition has also played an important role in our welfare analysis since it allows us to study the distortions in educational decisions without having to worry about how they interact with distortions generated by imperfect competition that go hand in hand with any monopolistically competitive framework. However, we do not want to overemphasize the importance of this assumption. The forces that drive our results are compelling and quite general. We make this point by developing a monopolistically competitive version of our model in Appendix B, where we show that our comparative statics results generalize to the framework that has become standard in the literature on "new, new trade theory."

Appendix A

Result A.1

Our goal is to show that the H curve in Eq. (14) is is everywhere less steeply sloped than the L curve in Eq. (13). The slope of the H curve is $-H_S/H_E$ and the slope of the L curve is $-L_S/L_E$. 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

In the text, we are interested in equilibria in which all basic firms hire workers from the low-skill pool and all modern firms hire workers from the high skill pool. Of course, it may be possible to have an equilibrium in which basic firms hire from both pools and modern firms hire from only the high-skill pool, but here we show that such a circumstance can only arise in equilibrium for a knife-edge set of parameters. Suppose that some firms that adopt the basic technology choose to hire high skill workers who pass the screening exam, just as modern firms. Workers that pass the screening exam would only accept jobs at basic firms if they paid same wage as modern firms. Then in this case, the free entry condition for basic firms that hire a high skill workforce is given by

$$F_b = \left(p - \frac{w_H}{\theta b}\right)\bar{x}_b$$

and the free entry condition for modern firms remains Eq. (3). We can then use these two equations to solve for w_H and p in an equilibrium where basic firms also hire high skill workers. Specifically,

$$w_H = \theta b h \frac{F_m/\bar{x}_m - F_b/\bar{x}_b}{h - \theta b} \quad \text{and} \quad p = \left(\frac{hF_m/\bar{x}_m - \theta b F_b/\bar{x}_b}{h - \theta b}\right)$$

Note that high skill wages and prices in an equilibrium where basic firms recruit high skill workers are functions only of the parameters of the model. Put differently, such an equilibrium can only arise for a knife-edge set of parameters.

Result A.3

Proposition 4 states results about the (in) efficiency of schooling and skill acquisition behavior in an open economy. We now derive these results for each case in an economy that exports the skilled good ($p^* > p$), and for the case of import penetration ($p^* < p$).

[21] The only assumptions that we need under perfect competition are convex costs and homothetic preferences. To solve the monopolistically competitive version presented in Appendix B we need specific functional forms for preferences, costs and the distribution of academic aptitude. In addition, for the open economy version of the model we need to assume symmetric countries.

We begin with the exporting case (b), in which all modern firms export. Differentiating (13b) and (14b) and taking the limiting case of full information about worker skills yields

$$\lim_{\lambda\to 1}\frac{da_S}{d\lambda}=\frac{1}{D\phi}\left\{C_e'(a_e)\left(\frac{\partial p}{\partial\lambda}b+w_L\frac{S_HS_L(1-\theta)}{[S_L+(1-\lambda)S_H]^2}\right)\right\}>0 \quad \text{and}$$

$$\lim_{\lambda\to 1}\frac{da_E}{d\lambda}=\frac{1}{D}\left\{C_s'(a_s)\left([w_H-w_L]-\lambda\left[\frac{\partial p}{\partial\lambda}b+w_L\frac{S_HS_L(1-\theta)}{[S_L+(1-\lambda)S_H]^2}\right]\right)\right\}<0.$$

In other words, deviating from the first-best outcome, we find that workers pursue more schooling, with less skill acquisition, as described in Proposition 4.

Then note that for case (a) in an exporting economy, the term $\partial p/\partial\lambda$ equals zero and low skill wages are $w_L=(p^*-(F_b/\bar{x}_b))\phi(a_S,a_E)$, and the same inequalities above hold. Likewise, for case (c) in and exporting economy, the term $\partial p/\partial\lambda$ again equals zero and low skill wages are $w_L=(p^*-(F_b+F_x)/\bar{x}_b)\phi(a_s,a_E)$, so the inequalities above continue to hold. Finally, for the case of an importing economy, the term $\partial p/\partial\lambda$ equals zero, low skill wages are $w_L=(p^*-(F_b/\bar{x}_b))\phi(a_S,a_E)$, and high skill wages are $w_H=(p^*-(F_m/\bar{x}_m))h$, so that the inequalities above continue to hold.

Result A.4

With $p^*<p$, the equilibrium cut-off values are given by (13) and (14) with $p^*=p$. Differentiating (13) and (14) with respect to λ yields (15) and (16). The remainder of the argument is exactly as laid out in Section 5.4.

Appendix B

The purpose of this appendix is to provide an alternative version of our model set in a monopolistically competitive framework and explore the robustness of our comparative statics properties. As noted in the text, the advantage of perfect competition is tractability in a general setting. However, the cost is that it required us to set arbitrary limits on firm size. In the monopolistically competitive framework firm size will be endogenous, but the model does not yield analytic solutions. Instead, to solve the model numerically we will need to impose additional structure on preferences, the underlying distribution of worker ability, and the relative productivities of each technology. Our numerical solutions verify the robustness of our comparative statics results derived in the baseline model. Moreover, the monopolistically competitive model allows us to highlight that it is indeed the relative share of domestic firms engaged in the global economy that influences how worker educational behavior adjusts to trade liberalization, rather that the composition of trade within versus across industries.

As in, Yeaple (2005) we assume that preferences over X and Y are Cobb–Douglas with β denoting the fraction of income devoted to X, and that X is a composite good produced in a monopolistically competitive market with $X=[\int x(i)^\alpha di]^{1/\alpha}$, where i indexes variety and $\sigma=(1/(1-\alpha))>1$ is the elasticity of substitution across varieties. Given this set-up, the iso-elastic demand for variety i is given by $x(i)=(\beta E/P_x)(p(i)/P_x)^{-\sigma}$, where P_x is the price index for X. For profit maximization, all firms charge a price that is a fixed mark-up $(\sigma/(\sigma-1))$ over marginal cost, such that prices for basic firms and modern firms are $p_b=\sigma W_L/((\sigma-1)\phi)$ and $p_m=\sigma W_H/((\sigma-1)h)$, respectively. The corresponding price index is given by $P_X=\left\{N_bp_b^{1-\sigma}+N_mp_m^{1-\phi}\right\}^{1/(1-\sigma)}$. It follows immediately that profits are then $\pi_b=[\sigma W_L/(\sigma-1)\phi P_x]^{1-\sigma}(\beta E/\sigma)$ and $\pi_m=[\sigma W_H/(\sigma-1)hP_x]^{1-\sigma}(\beta E/\sigma)$. Setting these profits equal to the fixed costs of entry gives us the two free entry conditions that replace (2) and (3) in the baseline model. As for the labor market, labor demand for each firm is given by demand, $x(i)$, divided by productivity; thus, the labor market clearing conditions in (5) and (6) become $S_L+(1-\lambda)S_H=x(b)N_b/\phi$ and $\lambda S_H=x(m)N_m/h$, respectively. Finally, in solving the model we assume that the distribution of aptitude a is uniform on $[0,S]$; that $C_S(a_S)=\kappa_S/a_S$ for some κ_S; and that $C_E(a_E)=\max(\kappa_E-a_E,0)$ for some κ_E.

To motivate trade, we assume that we have two countries that are identical in all aspects except for trade costs. Firms in the home country face a fixed cost of F_X to export while those in the foreign country face a analogous cost of F_X^*. We assume that Y is a non-traded good, so that all trade takes place in terms of varieties of X (i.e., intra-industry trade). Note that an increase in import penetration corresponds to a reduction in F_X^*, while greater export opportunities are generated by reductions in F_X.

Although the structure of the model here is quite similar to the case of perfectly competitive product markets, there are two key differences. First, in the perfectly competitive model all product market adjustment takes place via entry and exit of firms of different types given output per firm is fixed. In contrast, with monopolistic competition we get adjustments in firm size as well as entry and exit. Second, since firms will always serve their home market under monopolistic competition, we get a type (d) equilibrium that occurs if all trade costs are sufficiently low in which all firms export.

Our goal is to determine if the comparative static properties of the perfectly competitive model carry over to this framework. As with the competitive model, we find that increased import penetration always triggers reductions in the measures of workers who put forth effort to acquire high skills. Correspondingly, reductions in F_X^* always reduces wage inequality both within and across educational groups. As F_X^* falls more imports flow into the home market and the increased

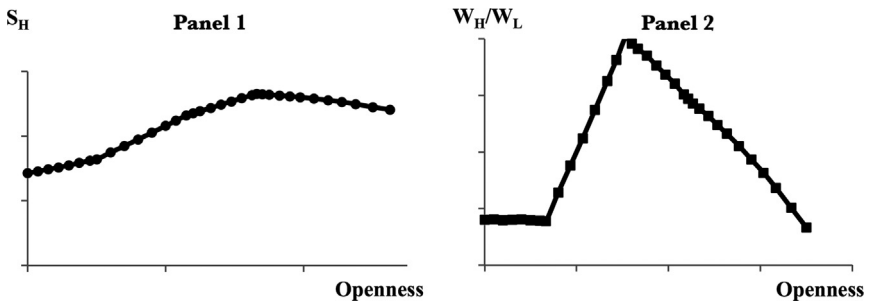

Fig. B.1. Numerical results for the labor market effects of trade with monopolistic competition.

competition lowers the profits firms earn from domestic sales, with modern firms suffering more severely since they produce relatively more output; i.e., both types of firms exit with a disproportionate amount of the exit coming from modern firms. The result is that both skilled wages fall relative to unskilled wages, with the gap between w_H and w_L shrinking.

Similarly, increased export activity has the same qualitative effect on education decisions and inequality as in the perfectly competitive model in that it (i) always generates more schooling; (ii) always increases inequality between unskilled and low skilled workers; (iii) has a non-monotonic effect on skill acquisition with more workers acquiring high skills when export activity is limited to modern firms and fewer workers acquiring skills when all firms are engaged in exporting; and (iv) has a non-monotonic effect on wage inequality between low and high-skilled workers. In addition, adjustments to changes in trade costs in type (b) equilibria are identical to what takes place in our baseline model. As trade costs fall, modern firms increase the amount shipped to the foreign market. This pushes up the demand for high-skill workers, causing w_H to rise and triggering an increase in the price that modern firms charge domestically. The increase in p_m shifts domestic demand towards the varieties produced by basic firms, causing new basic firms to enter.

The key difference between the two models is associated with adjustment in type (a) and (c) equilibria, where some firms go from serving only their domestic market to suddenly exporting as well. In a type (a) equilibrium a reduction in F_X causes some modern firms to start exporting. As they do, their demand for high-skill labor takes a discrete jump up and this pushes up w_H. However, in a type (a) equilibrium some modern firms serve only the domestic market and these firms are harmed by the increase in the high-skill wage. Thus, some of the modern firms that were serving the domestic market exit, a feature that does not arise under perfect competition. Reduced competition in the home market allows the remaining non-exporting modern firms to continue to break-even. The reduction in home market competition also triggers entry by basic firms, just as it does under perfect competition. Despite the different adjustment paths, in the end the fundamentals are affected just as they are in the baseline model: more output is produced by both types of firms with the share of output produced by modern firms increasing and w_H increasing more than w_L.

Adjustment within a type (c) equilibrium is analogous to a discrete jump in the demand for low-skilled labor that comes about as new basic firms start to export causing some non-exporting basic firms to exit. Note that such exit by basic firms does not occur in the baseline model and it has two important implications. First, it softens the increase in w_L that would occur without exit, and it triggers additional entry by new modern firms, putting additional upward pressure on w_H. As a result, in terms of educational behavior and wages, the comparative statics properties for case (c) are similar to those in cases (a) and (b) – lower trade costs result in more schooling and effort and greater wage inequality between high and low-skill workers. It is not until we move to case (d), in which all firms export, that we get the non-monotonic results that are consistent with case (c) under perfect competition. That is, in case (d), as trade costs fall there is a disproportionate amount of entry by basic firms, triggering a reduction in skill acquisition and a reduction in inequality among educated workers.

In Fig. B.1 we plot labor market outcomes obtained from numerical solutions to the model across various levels of trade costs. In panel 1 of Fig. B.1, we see the non-monotonic effect of changes in trade costs on skill acquisition, corresponding to differential effects of trade liberalization across equilibrium types. At high levels of trade costs (where only a few modern firms export) marginal reductions in trade costs induce more workers to become high skilled, while at low levels of trade costs (where all firms export) trade liberalization reduces the number of high skilled workers. Panel 2 likewise illustrates the non-monotonic effect of changes in trade costs on wage dispersion among educated workers. The underlying parameters used to generate Fig. B.1 are: $\sigma = 2$; $b = 1.4$; $\theta = 1.5$; $h = 2.5$; $\beta = .65$; $F_b = .08$; $F_m = .11$; $\kappa_S = .8$; $\kappa_E = 2.2$; $\lambda = .7$; and 33% of the population is born with academic aptitude. We carried out significant sensitivity analysis, especially with respect to the productivity parameters, the cost parameters and the screening parameter and identical qualitative results held for all values tested.

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