This is to certify that the
thesis entitled

INTERNATIONAL TRADE, LABOR MARKET STRUCTURE
AND THE ORGANIZATION OF PRODUCTION

presented by

NICHOLAS SLY

has been accepted towards fulfillment
of the requirements for the

PhD degree in Economics

Carl Davidson
Major Professor's Signature

May 6, 2009
Date

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.
MAY BE RECALLED with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE

INTERNATIONAL TRADE, LABOR MARKET STRUCTURE, AND THE ORGANIZATION OF PRODUCTION

By

Nicholas Sly

A DISSERTATION

Submitted to
Michigan State University
In partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Economics

2009

ABSTARCT

INTERNATIONAL TRADE, LABOR MARKET STRUCTURE, AND THE ORGANIZATION OF PRODUCTION

By

Nicholas Sly

This dissertation examines microeconomic aspect of international trade flows in a general equilibrium environment. The primary focus is on firm behaviors such as technology choice, the decision to export, product scope, and extensive export margin. The influences of structural features of the labor market often overlooked are emphasized. These include worker heterogeneity, labor market mobility, and the matching behavior of workers. Considering the manner in which firms engage domestic and foreign product markets, as well as labor markets, provides new insights into the nature of international trade.

The first chapter considers firm technology and export decisions in an environment where labor market mobility is significant and costly. I find that Job and Worker turnover have opposing marginal effects on firm behavior; high job turnover deters firms from adopting the best available technologies, while high worker turnover leads to a greater share of firms using the best production modes. As a result industries with relatively high worker turnover exhibit larger export intensity, lower wage inequality, and spread the gains from trade among a larger share of the workforce.

Chapter 2 demonstrates the importance of worker behavior in trade adjustment. Heterogeneous workers from matches endogenously, each vying for the best jobs and best partners. As international markets become more integrated, workers recognize that export opportunities become larger while domestic markets experience greater competition from foreign firms. Both cause the labor market to reorganize as workers seek out new matches in order to secure export opportunities or avoid unemployment. The post-trade liberalization allocation of the labor market is shown to be more efficient in terms of aggregate productivity. Furthermore, labor market adjustments result in infra-marginal changes in firms, as all firms experience changes in productivity through new management.

Chapter 3 focuses on the how cross-country differences in the degree of heterogeneity in labor endowments and the size of factor endowments jointly describe the pattern of world trade. The theory makes two key predictions. First, high levels of dispersion in ability within labor endowments make the costs of sub-optimal matching more severe in terms of aggregate productivity. Second, high levels of dispersion make poor matching outcomes less likely to occur. These predictions are evaluated using data about international technology differences and cross-country differences in educational attainment. Dispersion is shown explain much of cross country differences in total factor productivity. Furthermore, information about trade flows reveals that accounting for the level of dispersion in labor endowments improves the ability of the Heckscher-Ohlin-Vanek theorem to explain factor trade based on the endowment sizes alone.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter1
Labor Market Turnover, Firm Technology Choice, and Trade Preferences[1]

ABSTRACT: Firms choose to adopt one of several available technologies and hire managers who are heterogeneous with respect to skill. The labor force of each firm changes over time because workers who quit must be replaced, and because jobs destroyed by capital failure must be updated. Job turnover and worker turnover are both costly. Because of variation in turnover costs across technologies, differences in labor market turnover rates have consequences for the rate at which certain technologies are adopted. Job and worker turnover have opposing marginal effects on a firm's choice of technology, highlighting the importance of relative turnover rates, rather than just total levels. High job turnover limits industry adjustment to trade and may lead to an anti-trade preference among a large share of the skilled workforce.

1 Introduction

Many characteristics of a firm, such as productivity, factor payments, and export status, result from its choice of technology. Since workers are employed to utilize the firm's chosen technology, the selection process cannot be free from labor market influences. The focus here is how labor market turnover, meaning both worker and job turnover, affects a firm's choice to adopt one of several available technologies. With an understanding of how individual firms respond to the costs of creating and continually staffing jobs on their production lines, I will examine the impact industry specific turnover rates have on equilibrium outcomes such as income distribution, market concentration, aggregate productivity and prices. The importance of labor market turnover on the behavior of firms also has consequences for industry adjustment to trade liberalization, and trade preferences of workers.

While little is known about how turnover affects the organization of the firm, several micro-data studies from the last two decades have demonstrated the nature of turnover in labor markets. Davis, Haltiwanger and Schuh (1996), DHS from this point forward, characterizes job turnover within U.S. manufacturing industries. They find that in nearly all industries a remarkably large number of jobs are being created and destroyed simultaneously. From 1973 to 1988, between 11% and 19% of the workforce was reallocated across production locations.

Observed job flows are distinct from worker flows since workers often leave jobs when the firm continues to offer an employment opportunity. Burgess, Lane, and Stevens (2000), BLS, call the worker movements into and out of employment that are in excess job turnover "churning" in the labor market. Using employer level data to parse the contributions of worker versus job turnover they find "...a considerable amount of labor reallocation, primarily due to churning." Even for surviving jobs the supply side of the labor market is mobile, causing firms to have to recruit a sizable portion of its labor force continually.

Besides the large magnitudes of job and worker turnover which pervade all industries, DHS and BLS also find significant variation in both turnover rates across industries. So to the extent that firms respond to turnover costs, industrial organization can vary widely because of mobility in the labor market. In addition to the individual features of job and worker turnover, the relationship between them is important. While both job and worker turnover rates are on average large with significant variation, they need not be related. The determinants of job turnover, or demand side turnover, are not the same as the determinants of worker turnover, reallocation from the supply side of the labor market. In fact BLS confirm that churning rates have only a weak correlation with job turnover rates[2]. These facts suggest that worker and job turnover are distinct economic events to which firms will respond independently.

Many firms that manufacture similar goods use different methods of production, and hire different types of workforces. Doms, Dunne and Troske (1997) find that the firms which use newer technologies employ larger management teams, more educated or skilled workers, and pay higher wages. The systematic pattern of technology choices and hiring decisions indicates that while firms within industries are heterogeneous, much of their differences are rooted in endogenous choices rather than random differences. Firm technology choice is a key determinant of other organizational choices and seems a goods place to begin to examine the consequences of labor market turnover in product markets.

A strong relationship exists between international trade and productivity. Going forward, firms which export are typically more productive and use better technologies, Bernard and Jensen (1999). And going backward, trade causes productivity gains at aggregate and individual plant levels. At the industry level productivity increases through a reallocation of production toward the most efficient firms, Pavcik (2002), and at the plant level through technology and skill upgrades, Fernandes (2007). There is also mixed evidence for learning-by-exporting as a source of improved firm productivity, among others see Blalock and Gertlet (2004) and Clerides, Lach, and Tybout (1998). Labor market turnover can play an important role in the trade and productivity story by restricting or enhancing each of these avenues for trade adjustment. The amount of job and worker reallocation influence the share of firms which adopt each technology initially, and the number of firms who update their technology after trade liberalization.

Turnover influences firm behavior because creating and filling employment positions are costly activities. Here I assume jobs using better technologies are more expensive to create. Firms in a skill intensive sector choose which technology to adopt, thus what type of jobs to offer. The workforce of an individual firm consists of a single manager with a particular skill and a measure of identical labor. Managers use their skill to take advantage of better technologies to improve labor efficiency. High skilled managers are better at implementing technologies during production. Firm heterogeneity arises within industries both because of endogenous technology choices and exogenous managerial skill differences.

Each period after production a fraction of jobs are destroyed by capital failure. Regardless of how productive a technology is at some point it breaks down or becomes obsolete. When firms update their production lines they must pay to create new jobs using the adopted technology. In line with the findings in DHS, job destruction and creation are persistent events; they are not temporary shutdowns or start-ups of activity. Destroyed jobs require new investments before labor is able to generate output. Even though a firm continues to offer certain jobs over time, its labor force may need to be reconstituted when a fraction of all workers quit. They might quit to have children, retire, or relocate when a spouse changes jobs. These components of job and worker turnover are outside the control of the firm.

In the following period firms update their production lines according to their chosen technology and fill open employment positions generating industry-wide job and worker turnover. The role turnover plays is only to reallocate the labor force. Labor productivity does not evolve with greater employment tenure and a technology maintains constant productivity throughout the duration it is used. That is to say the marginal productivity of a firm depends only on the technology chosen and the skill in which it is employed; the incidence of labor turnover has no impact on marginal productivity.

High job destruction rates mean that firms have little time to recover their investment in technology, causing fewer firms to offer jobs using better, but more expensive, technologies. When worker quit rates are high firms expect to have to pay to recruit workers more often. As a result more firms adopt better technologies to maximize worker productivity during their relatively short tenure[3]. The opposite influences of job and worker turnover is an important feature of the model. While total levels of turnover imply certain costs and thus hiring decisions by firms, the relative levels of worker and job turnover are key in determining the allocation of labor to firms using different technologies.

Better technologies raise the productivity of labor, increasing the amount of revenue from which managers can capture rents. The demand for high-skilled relative to low-skilled managers is greater in industries where more firms adopt the best available technologies. Higher demand for a particular skill group implies a larger rent that managers receive from each unit produced. As a result, industries in which more firms adopt the best technologies will exhibit greater wage (per unit) and total income inequality. Considering the response of firms to turnover costs, industries with relatively high worker turnover (low job turnover) have greater income inequality.

Labor market turnover rates have consequences for the trade preferences of skilled workers in each industry. Trade costs exclude some firms and managers from participating in international markets. A reduction in trade costs lowers the demand for managers who are not skilled enough to use better technologies; as a result their nominal wages fall. Turnover rates determine the share of managers who face potential losses by influencing the share of firms which adopt less productive technologies. Firms pass along costs to consumers, so the pattern of job and worker turnover determines if nominal wage reductions equate to real wage losses. Anti-trade preferences are more common among skilled workers, and more likely to occur, when total labor turnover is low, but job turnover is relatively higher.

Much of the literature on technology adoption has focused on how firms will choose a continuous degree of specialization in production. In Acemoglu, Antràs, and Helpman (2007) and Yang and Borland (1991) firms can raise productivity by spreading the production process over many specialized intermediate suppliers in environments with incomplete contracts and transaction costs. Becker and Murphy (1992) show how coordination costs and the general knowledge available in the economy limit the optimal degree of specialization. The analysis here is closely related to Manasse and Turrini (2001) and Yeaple (2005). Managerial skill interacts with technology to increase productivity, and following Yeaple firms make endogenous choices about which technology to employ[4].

The topics examined here are also related to a literature that investigates the role of labor market turnover in open economies. Cuñat and Melitz (2006) show how differences in labor market flexibility across countries can lead to a pattern of comparative advantage based on turnover rates. Davidson *et al.* (1999) and Davidson and Matusz (2005) show how comparative advantage and the pattern of trade is related to turnover rates when there are frictions in the labor market. While these previous papers have emphasized how labor market turnover influences the allocation of resources across sectors, the focus here is how turnover rates affect the allocation of resources within sectors.

Trade preferences, observed as votes or campaign contributions have been used to test results from traditional trade theories.[5] Magee *et al.* (2005) are the first to examine the role of turnover in determining trade preferences. Using job turnover rates as a proxy for labor market mobility the authors show that PAC contributions are consistent with predictions from the Heckscher–Ohlin–Samuelson model, when there is high job turnover, and the Ricardo–Viner model, when there is low job turnover. I show here that both the relative levels, and total levels, of worker and job turnover have important consequences for trade preferences because they impact the size and allocation of welfare gains of freer trade.

The rest of the paper proceeds as follows: section 2 describes the model. Section 3 solves for the stationary equilibrium and discusses the effects of turnover on industry characteristics. Section 4 demonstrates how relative turnover rates impact the gains from trade, and trade preferences of workers employed in export industries. Section 5 concludes.

2 Model

2.1 Demand

Consumers have identical preferences for goods X and Y. Good Y is a homogeneous low-skill good. The skill intensive good X is a composite of a continuum of available varieties. Each consumer has Cobb-Douglas preferences over the goods X and Y and CES preferences for the varieties of X.

$$\begin{aligned} U &= (1-\beta)\ln Y + \beta \ln X \text{ , where} \\ X &= \left[\int_0^N x(i)^\alpha di\right]^{1/\alpha} \quad \text{and } \sigma = \frac{1}{1-\alpha}. \end{aligned} \tag{1}$$

Given these preferences consumers will spend a portion β of their income on varieties of X. The elasticity of substitution between varieties of X is σ.[6] As shown by Dixit and Stiglitz (1977) the consumption of varieties of X can be modeled by considering the composite good X that has a price equal to the index that is a weighted average of the price of each variety,

$$P_X = \left[\int_0^N p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}. \tag{2}$$

Let E represent total expenditure. Good Y is the taken as the numeraire so that demand for good Y is given by

$$Y = (1-\beta)E \tag{3}$$

and the demand for each variety of X is

$$x(i) = \left(\frac{\beta E}{P_x}\right)\left(\frac{p(i)}{P_x}\right)^{-\sigma}. \tag{4}$$

2.2 Workers

Each country is endowed with two types of infinitely-lived workers: a mass L of laborers and a mass M of managers. Laborers are identical and supply a unit of time inelastically. Labor cannot take advantage of better technologies absent a manager. Each laborer can produce a single unit of Y, or any variety of X, when not working under a manager.

Managers supply a unit of time for production and are heterogeneous in their skill level, given by s, for implementing technologies. The skill of each manager is observable but exogenous to the hiring firm. Skill intensity in the X sector refers to the ability of managers to use their skill to organize production in a way that improves labor productivity. Managers in the X sector provide only supervising services. No manager can improve labor productivity in the perfectly competitive Y sector, and so works alone producing output according to her skill level. The distribution and density of managerial skill are $G(s)$ and $g(s)$, respectively, and have support $(0, \infty)$.

The markets for managers and laborers are perfectly competitive. Since laborers have the same opportunities regardless of the sector in which they are employed, and regardless of the technology adopted by their employer, labor wages will not vary across individuals. Differences in managerial ability will lead to dispersion in skilled wages.

2.3 Production

Firms are free to enter both industries. Entry consists of adopting a production technology, and in the skilled sector hiring a workforce simultaneously. There is only one available technology for good Y. If the firm enters the X industry then it produces a unique variety using one of two available technologies: H, for "high-tech" and L for "low-tech". The "high-tech" method of production can be thought of as a greater division of the production process so that when manufacturing output, labor benefits from specialization. Each firm in the X sector hires one manager and as many laborers as needed.

Adopting the Y technology is costless. To create a job opening a firm must pay F_L per position when using technology L and F_H per position when using technology H. The natural assumption is $F_L < F_H$. All labor is qualified to use the Y technology but there are costs, k, to recruiting and training labor to use either technology in skilled X sector. Job creation and recruiting costs are given in terms of output that must be produced but cannot be sold, as is standard.

The productivity of labor within a firm in the high-skill sector depends on the skill of the manager hired and the technology the firm adopts. Labor does not benefit from using better technologies separate from the skills of a manager. In essence, unsupervised labor uses technologies with a skill level $s = 0$. A manager using the L or H technology can increase the productivity of any size of labor force, or work alone employing her skill level, s, using the Y technology. So, each worker using technology $j \in \{Y, L, H\}$, under the supervision of a manager with skill s, can produce $f_j(s)$ units of output.

More skilled managers have comparative advantage in employing better technologies. When using the same technology, the labor force with the more skilled manager is more productive; i.e. $f_j(s)$ is increasing and continuous in s. When using different technologies with a manager of the same skill level, the labor force using the better technology is more productive. The following two conditions summarize the characteristics of the technologies.

$$\begin{aligned} f_Y(0) &= f_L(0) = f_H(0) = 1, \text{ and} \\ \frac{\partial f_H(s)}{\partial s}\frac{1}{f_H(s)} &> \frac{\partial f_L(s)}{\partial s}\frac{1}{f_L(s)} > \frac{\partial f_Y(s)}{\partial s}\frac{1}{f_Y(s)} > 0 \end{aligned} \tag{5}$$

2.4 Turnover

Industry X faces two sources of labor market turnover that occur exogenously after production: worker quits and job destruction. Workers leave employment positions for various personal reasons that are unrelated to the wage paid by the firm. Here workers do not quit to engage in rent seeking behavior[7]. Job destruction occurs due to exogenous capital failure. Technologies wear out or become obsolete after some time and must be replaced, however their productivity is constant until the point of failure.

In a single interval of time jobs are destroyed with a constant probability δ. Creating new jobs entails opening new positions using the firm's technology at a cost of F_j per position, and training new workers to employ the technology at a cost of k per position. Some workers quit their jobs even when the firm continues to offer the employment opportunity. When a fraction γ of a firm's labor force quits replacement workers must be trained at a cost of k per worker.

The skill of the manager is constant and technologies maintain their productivity regardless of job duration. Therefore, firm productivity is not affected by the tenure of the worker or age of the technology; the implication being that turnover does not affect productivity at the margin. Applying the law of large numbers to each firm, δ of all the jobs at a firm will be destroyed and γ of the firm's surviving jobs will need to be restaffed when employees quit; of course when new jobs are created to replace one where a worker simultaneously quit, the firm only has to pay to recruit one worker. So the expected turnover costs to the firm that hires a manger of skill s to use technology j, and hires the optimal size of labor force $l(s,j)$, are

$$\left[\delta\left(F_j+k\right)+\gamma k-\delta\gamma k\right] l(s,j). \tag{6}$$

There is no turnover in the Y industry. Though turnover in the Y industry may exist the purpose here is to examine how turnover rates affect firm behavior within a sector, holding the turnover rates of all other sectors constant. Firms in the Y industry produce a homogeneous product with a costless technology, so they do not face any chance of becoming obsolete or having to pay to replace capital. And since labor market turnover is taken to be exogenous for any industry, it need not be modeled explicitly in the Y industry.[8]

3 Equilibrium

I will focus on the derivation of a stationary equilibrium in a closed economy. Industry Y is perfectly competitive in its production of the numeraire good. Hence the marginal revenue in each period for a firm in the Y industry is constant and equals 1. Industry X is monopolistically competitive, giving rise to the well know revenue function for a firm producing variety i,

$$r(i)=\left(\beta E P_X^{\sigma-1}\right) p(i)^{1-\sigma} \tag{7}$$

As is standard, these firms will charge a price equal to a fixed markup over per unit costs. The markup is $\frac{1}{\alpha}$. Define the per unit costs of producing with technology j as C_j for $j\in\{Y,L,H\}$. Under the supervision of a manger with skills s, a labor can produce $f_j(s)$ units of output. Labor is paid a wage v and managers are paid

$W(s)$ by the firm. Thus the per unit cost of production satisfies $l(s,j)\, f_j(s) C_j = vl(s,j) + W(s)$; the total output of the the firm times the per unit costs equal total production costs.

3.1 Wages

Since good Y is the numeraire, and the productivity of labor without a manager is one unit of output, a perfectly competitive market will result in a labor payment of $v = 1$. Differences in skills result in differences in managerial opportunities which lead to dispersion in skilled wages. The distribution of wages for skilled activities depends on the allocation of managers across different technologies.

Free entry by firms and a perfectly competitive market for skilled activities ensure two features of the skilled income distribution must hold: the skilled wage per unit of output is constant and is increasing in the skill of the manager. Each laborer has the same outside option regardless of the technology adopted by their employer, so the surplus generated by increased labor productivity must be captured by either the firm or the manager. With free entry in the X sector, fear of other firms poaching the manager erodes the ability of the hiring firm to capture any of this surplus. Hence the manager is paid the whole of the increase in each laborer's productivity from implementation of the firm's technology. The manager applies her skills to the entire labor force, extracting the same wage from each unit of output. Managerial wages are increasing in skill because better managers generate more output.

Managers recognize that their wages depend crucially on the productivity of labor under their supervision. Therefore every manager will prefer a job using the best technology. Firms observe the distribution of managerial skill and will make its hiring and technology choices optimally. Each firm will try to hire the manager with the highest skills to manage its production lines. In the perfectly competitive manager market the combination of managers looking for jobs using the best technology available, and firms trying to hire a manager with the most skill, leads to a equilibrium where managers are positively assorted across technologies based on skill. For a given manager with skill level s, using technology j, there will be no other managers with a skill level less than s using a more efficient technology than j in equilibrium. The most skilled workers will find jobs managing a firm that uses the best available technology. The least skilled workers will be self-employed in the Y sector.

As managers in the skill intensive sector capture the rents created when they increase labor productivity, the firm's average production costs do not change. Any potential savings on labor wages are paid in full to the manager. Then any two firms using the same technology have the same unit costs, regardless of the skill of the manager hired. That is to say $C_j = l\,(s,j)\,v + W(s)/l\,(s,j)\;f_j(s)$ is constant over s for all firms that use technology j. Unit costs vary across technologies H and L because of the difference in returns to skill across technologies.

3.2 Allocation of Managers to Technologies

Define S_1 as the most skilled manager working in the Y industry and S_2 as the least skilled manager employed by an H type firm in the X industry. A manager with skill level S_1 is indifferent between the wages she earns in the Y sector or managing a firm using the L technology. A manager with skill level S_2 is indifferent between the wages she earns using the L or H technology. Consistent with positive assortative matching, all managers with skill less than or equal to S_1 work in the Y sector and all managers with a skill level above S_2 use the H technology.

Firms which adopt the L technology will hire workers such that $s \in (S_1, S_2)$ if they exist. Firms using the L technology will arise in equilibrium only if the fixed cost savings relative to the best technology $(C_H F_H l\,(s,H) - C_L F_L l\,(s,L))$ are large enough, and the demand for X is large enough. From this point forward I assume the more interesting case where costs and the size of the market are such that L type firms appear in equilibrium.

Rearranging the expression for unit costs, C_j, for each technology gives the skilled wage distribution over skill, s,

$$W(s) = \begin{cases} f_Y(s)C_Y, & 0 \leq s \leq S_1 \\ l(s,L)\left[f_L(s)C_L - 1\right], & S_1 \leq S \leq S_2 \\ l(s,H)\left[f_H(s)C_H - 1\right], & S_2 \leq s \end{cases} . \tag{8}$$

Marginal revenue in the perfectly competitive Y industry is 1, and because the cutoffs S_1 and S_2 are defined such that the worker is indifferent between the wages she earns using either technology, the unit costs can be written[9]

$$\begin{aligned} C_Y &= 1 \\ C_L &= \left(\frac{f_Y(S_1) + l(S_1,L)}{l(S_1,L)\,f_L(S_1)}\right) < 1 \\ C_H &= \frac{l(S_2,L)\,f_L(S_2)}{l(S_2,H)\,f_H(S_2)}\left(\frac{f_Y(S_1) + l(S_1,L)}{l(S_1,L)\,f_L(S_1)}\right) + \frac{l(S_2,H) - l(S_2,L)}{l(S_2,H)\,f_H(S_2)} < C_L \end{aligned} \tag{9}$$

These last two expressions completely describe the skilled wage distribution in equilibrium given the allocation of managers to each technology. The two skill cutoffs are obtained from equilibrium conditions in the Y and X industries. Specifically the market clearing condition for Y and the free entry condition for firms in the X industry.

3.2.1 Y Market Clearing Condition

The total demand for the low skill good is $Y = (1-\beta)E$. There is no saving in the stationary equilibrium so total expenditure in the economy is equal to the sum of total skilled wages and all labor earnings. Given the skilled wage distribution above for the mass of workers M, and the mass of laborers L, total expenditure (E) in this economy is[10]

$$E = M\left(\begin{array}{c}\int_0^{S_1}[f_Y(s)]\,dG(s) + \int_{S_1}^{S_2} l\,(s,L)\,[f_L\,(s)\,C_L - 1]\,dG(s) \\ + \int_{S_2}^{\infty} l\,(s,H)\,[f_H(s)C_H - 1]\,dG(s)\end{array}\right) + L$$

$$= M\left(\begin{array}{c}\int_0^{S_1} f_Y(s)dG(s) + \int_{S_1}^{S_2} C_L l\,(s,L)\,f_L\,(s)\,dG(s) + \\ \int_{S_2}^{\infty} C_H l\,(s,H)\,f_H(s)dG(s) - \int_0^{\infty} l\,(s,\cdot)\,dG\,(s)\end{array}\right) + L \qquad (10)$$

Now, the total payments to workers in the Y industry is the sum of skilled and labor wages: $M\int_0^{S_1} f_Y(z)dG(z) + L - \int_0^{\infty} l\,(s,\cdot)\,dG\,(s)$. When the Y market clears, total expenditure on good Y equals total payments to workers in the industry, or

$$\left(\frac{\beta}{1-\beta}\right)\frac{1}{C_L}\left\{\int_0^{S_1} f_Y(s)dG(s) + \int_0^{\infty} l\,(s,\cdot)\,dG\,(s) + \frac{L}{M}\right\} =$$
$$\int_{S_1}^{S_2} l\,(s,L)\,f_L\,(s)\,dG(s) + \frac{C_H}{C_L}\int_{S_2}^{\infty} l\,(s,H)\,f_H(s)dG(s) \qquad (11)$$

3.2.2 Free Entry Condition in X Sector

The second equilibrium condition is derived from the free entry conditions for L and H type firms. The value of entry into the X industry is equal to the stream of expected profits earned from entry, less sunk entry costs. The probability of job survival is $(1-\delta)$ and the probability of having to replace a worker for a surviving job is γ. Hence,

$$V^e(s) = -C_j\left[F_j + k\right] l\left(s,j\right) + \max_j \int_0^\infty \exp(-\rho t)\left(r_j - l\left(s,j\right) - W(s) - C_j\left\{\left[\delta\left(F_j + k\right) + \gamma k - \delta\gamma k\right] l\left(s,j\right)\right\}\right) dt$$

At low levels of discounting the fixed barrier to entry is uninhibiting, leading firms to earn zero profits in equilibrium. For monopolistically competitive firms the zero profit condition takes the following form, where revenues are a constant mark-up expected turnover costs:

$$r_j = \sigma C_j\left[\delta\left(F_j + k\right) + \gamma k - \delta\gamma k\right] l\left(s,j\right). \tag{12}$$

The relationships between output and revenue for any two firms with H and L technologies are functions solely of their unit costs. As can be derived from (4) and (7),

$$\frac{x_H}{x_L} = \left(\frac{C_H}{C_L}\right)^{-\sigma} \text{ and } \frac{r_H}{r_L} = \left(\frac{C_H}{C_L}\right)^{1-\sigma} \tag{13}$$

Then combining (12) and (13) yields

$$\frac{r_H}{r_L} = \left(\frac{C_H}{C_L}\right)^{1-\sigma} = \frac{C_H\left[\delta\left(F_j + k\right) + \gamma k - \delta\gamma k\right] l\left(s,H\right)}{C_L\left[\delta\left(F_j + k\right) + \gamma k - \delta\gamma k\right] l\left(s,L\right)} \tag{14}$$

The free entry condition for both L and H type firms is fulfilled by skill cutoffs that meet the condition above, or

$$\frac{C_H}{C_L} \equiv \left(\frac{\left[\delta\left(F_H + k\right) + \gamma k - \delta\gamma k\right] l\left(S_2,H\right)}{\left[\delta\left(F_L + k\right) + \gamma k - \delta\gamma k\right] l\left(S_2,L\right)}\right)^{\frac{-1}{\sigma}} \tag{15}$$

3.2.3 Equilibrium Allocation of Managers to Technologies

An equilibrium allocation of managers to technologies occurs when both the Y market clearing condition and free entry condition are satisfied. Thus the equilibrium values of S_1 and S_2 occur at the intersection of equations (11) and (15); these conditions are illustrated in Figure 1.1. The opposing slopes of the two conditions guarantee that the equilibrium is unique.

Total differentiation of the market clearing condition for Y shows that $\frac{ds_1}{ds_2} < 0$. The requisite skills needed to obtain a management job at a high tech firm is inversely related to the necessary skill level to find a job at any firm in the X industry. The inverse relationship between the skill cutoffs has an intuitive justification. As more firms adopt the best technology (S_2 falls) average labor productivity rises in the skill intensive sector, increasing total income. When income rises so does spending on good Y, which increases the demand for the low skill good (S_1 rises).

The free entry condition is upward sloping; $\frac{ds_1}{ds_2} > 0$. When the value of S_1 is low there are many firms operating in the X sector. With a large amount of variety for consumers and greater competition in the market firms can only justify entry if they can capture enough market share. Adopting the best technology makes a firm's particular variety relatively less expensive to produce and able to be sold at a low price. Hence a low value of S_1 must be associated with relatively greater number of firms using the best technology; i.e. low value of S_2.

3.3 Turnover Effects

3.3.1 Turnover & Allocation of Managers

Now we can address specifically the questions of this analysis: how is firm behavior regarding technology choice affected by labor market turnover rates? Notice that the free entry condition in (15) is a function of the labor market turnover rates γ and δ, while the Y market clearing condition is not. The equilibrium allocation of managers responds to turnover costs via the entry channel only. Differentiating we obtain

$$\frac{\partial\left(\frac{C_H}{C_L}\right)}{\partial\delta} = (F_L - F_H)\left(\frac{1}{\sigma}\right)\left(\frac{\delta(F_L+k)+k\gamma-\delta\gamma k}{\delta(F_H+k)+k\gamma-\delta\gamma k}\right)^{\frac{1-\sigma}{\sigma}} \times \left(\frac{\gamma k l(S_2,H)\, l(S_2,L)}{(\delta(F_H+k)+k\gamma-\delta\gamma k)^2}\right) < 0$$

$$\frac{\partial\left(\frac{C_H}{C_L}\right)}{\partial\gamma} = (F_H - F_L)\left(\frac{1}{\sigma}\right)\left(\frac{\delta(F_L+k)+k\gamma-\delta\gamma k}{\delta(F_H+k)+k\gamma-\delta\gamma k}\right)^{\frac{1-\sigma}{\sigma}} \times \left(\frac{\delta k l(S_2,H)\, l(S_2,L)}{(\delta(F_H+k)+k\gamma-\delta\gamma k)^2}\right) > 0$$

An increase in job turnover rates shifts the entry condition downward, raising the skill requirement for being hired to manage the best technology. $\left(\frac{dS_2}{d\delta} > 0\right)$. In industries where job turnover is more likely, the expected stream of income coming from a job using either technology is shortened, giving firms less time to recover their sunk investment costs. Only the most skilled managers increase labor productivity enough to justify the expense of the H technology.

Worker turnover rates have the opposite effect of reducing the skill requirement of the best technology $\left(\frac{dS_2}{d\gamma} < 0\right)$. Industries with higher worker turnover rates have higher expected future costs of using either technology because firms will have to pay to recruit workers more often. As a result more labor will be allocated to the H technology.

Worker and job turnover rates have opposite effects on the adoption of technologies specifically because of how they affect the relative shares of worker and job turnover costs, as compared to the firm's total turnover costs, associated with using each technology. The right hand side of (15) is the ratio of the expected total turnover costs for firms using the H and L technologies. Higher expected turnover entails higher costs of using any technology. But since creating an H type job is more expensive, higher job turnover rates make the H technology relatively less appealing. On the other hand, firms using either technology face the same expected worker turnover costs per position. When worker turnover costs are higher, the relative difference in costs between H and L technologies is smaller. At high levels of worker turnover both technologies become more similar in terms of total turnover costs, inducing a larger portion of firms to choose the lower unit cost (H) technology.

There does not seem to be any comprehensive empirical assessment of the relative size of these costs. Richer models of the costs associated with job and worker turnover might yield different or more interesting results. However regardless of the specification of turnover costs across technologies and workers the key determinant is the relative cost shares of worker turnover and job turnover associated with either technology. As we will see, the relative cost shares of labor market turnover have far reaching consequences for wages, industry productivity, market concentration and trade adjustment.

For the rest of this article I will use the response of the equilibrium cutoff values S_1 and S_2 to describe how labor market turnover shapes the equilibrium. Using the fact that the Y market clearing condition is upward sloping, each turnover rate has the opposite effect on the allocation of managers between sectors: $\frac{dS_1}{d\delta} < 0$ and $\frac{dS_1}{d\gamma} > 0$. The first proposition summarizes the relationship between the turnover rates and the equilibrium allocation of managers to technologies. The results are illustrated in Figure 1.2.

Proposition 1 *A higher job turnover rates raises S_2 and reduces S_1. A higher worker turnover rate decreases S_2 and raises S_1.*

3.3.2 Turnover & Firms in the Skill Intensive Sector

Average productivity and the distribution of sales across firms in the X industry depend on the relative number of firms that adopt each technology. The total number of firms in the X industry determines product variety, and average sales concentration. Together the total number of firms and relative number using each technology determine aggregate prices. From the fact that the equilibrium cutoffs S_1 and S_2 are inversely related we know that as more firms adopt the best technology, fewer firms enter using the second best technologies, and visa versa. Proposition 1 shows how the relative adoption of each technology depends on labor market turnover rates. So to describe response of product variety, sales concentration and prices to turnover, what remains to be demonstrated is how the total mass of firms using each technology depends on expected turnover costs.

The market clearing conditions for both L and H type varieties establish how many firms adopt either technology in the skill intensive sector. In a stationary equilibrium the number of firms is constant over time. Total production in a single time period by H type firms is $M \int_{S_2}^{\infty} f_H(s)\, l(s,H)\, dG(s)$. Output by firms using the H technology either goes to cover job creation costs, worker recruitment costs, or to market. A fraction δ of active jobs are destroyed every period and the same number of jobs are created in the next period at a cost of F_H units of output per position. Each new job created by a firm using the H technology must be filled by a new worker. Employment positions within the firm may survive, though the firm will have to replace any workers who quit. Each worker that must be recruited costs the firm k units of output. The remaining output of the firm is sold to consumers. Using $\widetilde{X_j}$ and $\widetilde{l(j)}$ to denote respectively the output and number of workers employed by a representative firm using technology j, the market clearing condition for H type varieties is

$$N_H\left(\widetilde{X_H}+\left[\delta\left(F_H+k\right)+k\gamma-\delta\gamma k\right]\widetilde{l\left(H\right)}\right)=M\int_{S_2}^{\infty}f_H(s)l\left(s,H\right)dG(s) \tag{16}$$

By similar construction for L type firms, and using the fact that $\widetilde{X_j}=(\sigma-1)\left(\left\{\delta\left(F_j+k\right)+k\gamma-\delta\gamma k\right\}\widetilde{l\left(j\right)}\right)$, we can write

$$N_H = \frac{M}{\sigma\left(\left[\delta\left(F_H+k\right)+k\gamma-\delta\gamma k\right]\widetilde{l\left(H\right)}\right)}\int_{S_2}^{\infty}f_H(s)l\left(s,H\right)dG(s), \quad \text{and} \tag{17}$$

$$N_L = \frac{M}{\sigma\left(\left[\delta\left(F_H+k\right)+k\gamma-\delta\gamma k\right]\widetilde{l\left(L\right)}\right)}\int_{S_1}^{S_2}f_L(s)l\left(s,L\right)dG(s).$$

N_j is the total number of firms which adopt technology j in equilibrium. The first term in the equations in (17) reflects the labor market turnover costs expected upon entry. As is natural, higher turnover costs lead to less entry of firms using any technology. The second term on the right hand side of equations (17) indicate the relative adoption of each technology.

As more firms adopt the best technology the distribution of sales becomes more skewed towards the largest firms in the industry. This happens first because as more managers and labor begin using better technologies, they become more efficient during production. The productivity gain to these workers from a better technology is reflected in the price charged by the firm. A lower price allows firm which adopt the H technology to increase market share. Furthermore as more firms adopt the best technology total income rises. Large firms, that employ the best technology initially, can expand production as other firms upgrade their technology because of increased demand. Both reallocations imply larger market shares held by the largest firm in an industry.

Total labor market turnover costs are important determinants of the average sales concentration among firms by limiting market participation. But the relative costs of worker and job turnover affect how the distribution is skewed toward firms using either technology. Then turning to the role turnover plays in firm entry, and on technology choices from proposition 1, the following results are obtained.

Proposition 2 *The average sales concentration is increasing in both the job turnover and worker turnover rates of an industry. Industries with higher job turnover (larger* δ*) will have a less skewed distribution of sales across firms. Industries with higher worker turnover (larger* γ*) have a more skewed distribution of sales across firms.*

Given the differences in the productivity of labor using each technology, changes in the proportion of firms which adopt either technology have implications for aggregate industry productivity. Adoption of the H and L technologies by firms are inversely related so an increase in the share of firms which adopt the best technology necessarily raises average productivity in the industry. Using the response of firms to labor market turnover, average productivity depends on turnover rates in the following way.

Proposition 3 *Average labor productivity is higher (lower) in industries with relatively higher worker (job) turnover, and is lower in industries with higher levels of total labor market turnover.*

Turnover is costly and so hinders firm productivity. However, higher worker turnover could possibly result in greater average productivity. Though there is no advantage to worker-firm separation embedded in the model the allocation of managers to technologies is improved with relatively high mobility in the supply side of the labor market. Job turnover always has negative effects of average productivity since it is costly and discourages firms from adopting better technologies.

3.3.3 Turnover & the Income Distribution

Each laborer makes the same wage regardless of the technology he is using. Managers capture the surplus created by increased labor productivity which varies across skill level and technology used. Technological adoption has already been shown to depend on labor market turnover rates. This section explores how firm responses to turnover rates influences the income distribution.

The perfectly competitive market for skills ensures that every manager using a particular technology earns the same wage per unit of output. Then besides the direct effect of changing the allocation of managers to technologies, turnover rates have an indirect effect on the skilled wage distribution by influencing the per unit skilled wage. Even the wages of those managers who use the same technology at various levels of job and worker turnover will respond to changes in technological adoption. Managers supply their services inelastically but the rate at which each technology is used affects the relative demand for certain skill levels.

Combining the two components of the skilled wage distribution in (8) and (9) gives the income distribution as a function of a particular manager's skill level, and the equilibrium skill cutoff values.

$$W(s)=\begin{cases} f_Y(s), & 0<s\leq S_1 \\ l(s,L)\left[f_L(s)\left(\frac{f_Y(S_1)+l(S_1,L)}{l(S_1,L)f_L(S_1)}\right)-1\right], & S_1\leq s\leq S_2 \\ l(s,H)\left[\begin{array}{c} f_H(s)\frac{l(S_2,L)f_L(S_2)}{l(S_2,H)f_H(S_2)}\left(\frac{f_Y(S_1)+l(S_1,L)}{l(S_1,L)f_L(S_1)}\right) \\ +\frac{l(S_2,H)-l(S_2,L)}{l(S_2,H)f_H(S_2)}-1 \end{array}\right], & S_2\leq S \end{cases} \tag{18}$$

In order to fully characterize the effects of labor market turnover on income distribution there are five different classes of skills to consider: those who remain employed as managers by each of the three firm types regardless of turnover rates, and those near each cutoff skill level that get sorted into managing a different technology for various turnover rates. As the two equilibrium cutoffs adjust managers with skills near the cutoffs will have the most severe changes in income; the technology she uses changes and the return to her skill using that technology changes. Since S_1 and S_2 always move in opposite directions we can discuss the each type of turnover more conveniently in terms of the number of managers who will find employment at L type firms. Job and worker turnover either increase or decrease the size of this "middle class".

High worker turnover results in a smaller "middle class". ($\frac{dS_2}{d\gamma} < 0$ and thus $\frac{dS_1}{d\gamma} > 0$.) Workers at the upper fringe of the middle class for low worker turnover rates can find work at H type firms, where they earn higher wages, when worker turnover rates are higher. Subsequently, the lower fringe of the middle class is allocated to the low skill sector at higher worker turnover rates, resulting in lower income. Worker turnover benefits the top of the skill distribution at the expense of low skilled managers.

Now consider the workers who obtain jobs managing a labor force using the same technology for various levels of job and worker turnover. The price of the low skill good Y is taken as the numeraire so income from that sector fixed and equal the manager's total output when self-employed. Now consider skilled wages of those who are employed by L type firms for any level of job/worker turnover, the perennial middle class. The premium paid per unit of output at L type firms is decreasing in skill requirement for managing the L technology.

In an industry with relatively high worker turnover. The resulting high value of $S_1$and the associated low value of S_2 mean that fewer firms demand managers with moderate skills. The lower demand results in a lower skilled wage per unit. In a similar manner, the premium paid to managers at firms that adopt the H technology is decreasing in S_2. As more firms adopt the best technology in response to high worker turnover, demand for the highest skills increases, raising the premium paid per unit of output to the highest skilled managers.

All together the impact of firm technology choices on the skilled income distribution and results in proposition 1 make clear predictions about how labor market turnover affects income inequality[11].

Proposition 4 *Industries with relatively higher worker turnover exhibit greater income inequality across skill. Industries with relatively higher job turnover exhibit less income inequality across skill.*

The last proposition demonstrates how the distribution of nominal income is influenced by the relative levels of job and worker turnover. However the impact of worker turnover on real income cannot be described in general. A larger share of people using the more advanced H technology raises total productivity and thus total income. However if greater adoption of the best technology results from relatively higher worker turnover costs, then it is not clear if real income increases. Presumably higher turnover costs get transferred to consumers via aggregate prices. The next section explores the relationship between labor market turnover has with welfare and prices.

3.3.4 Turnover & Welfare and Prices

The ambiguous effect of total worker turnover rates on real income also means that the effect on social welfare is ambiguous. Turnover in this model is solely a cost burden to the economy. A social planner would prefer to let the initial efficient allocation of managers across technologies and labor hiring decisions be maintained. So the statement above that the effect of worker turnover is ambiguous should be interpreted that one cannot say in general whether a higher level of worker turnover raises welfare; what is clear is that at the same level of *total* turnover costs, a relatively large *share* of turnover costs coming from worker turnover is more favorable.

Real wages depend both on income and prices. So far I have shown how nominal wages, that is wages in terms of the price of Y, are related to labor market turnover. The aggregate price index for the X industry can shed light on the labor market conditions under which real wage gains and welfare gains are most likely. Every firm in the skill intensive sector charges the same markup over unit costs, so from equation (2)

$$P_X = \frac{1}{\alpha}\left(N_H C_H^{1-\sigma} + N_L C_L^{1-\sigma}\right)^{1/1-\sigma}.$$

Substituting for the equilibrium number of firms from (17) and simplifying using the market clearing condition for Y the price index of X can be written.

$$P_X = \frac{1}{\alpha}\left\{\frac{\sigma(1-\beta)\left[\delta(F_H+k)+k\gamma-\delta\gamma k\right]\widetilde{l(L)}}{\beta M}\right\}^{\frac{1}{\sigma-1}}$$
$$\times\left\{C_L^{-\sigma}\left[\int_0^{S_1} l(s,Y)\,f_Y(s)dG(s)+\int_0^{\infty}\widetilde{l(s,\cdot)}dG(s)-1\right]\right\}^{\frac{1}{1-\sigma}}.$$

The first term in braces is increasing in both turnover probabilities. This is the "level effect" of higher turnover. Firms pass these costs along to consumers. The second term in braces is decreasing in S_1. Thus it is the case that the efficiency gains from greater use of the best technology outweigh the losses in variety. This is the "share effect" of relatively higher turnover costs from either job or worker reallocations. Since S_1 increases with the amount of worker turnover, the share effect is positive for total welfare. High job turnover rates necessarily increases prices since fewer high-tech firms will operate in equilibrium. Thus relatively higher worker turnover rates may induce price savings if total turnover is low, but job turnover always causes prices to rise.

3.4 Worker Quits and Skill

So far the assumptions about the costs associated with labor market turnover have been that high-tech jobs are more expensive to create than low-tech jobs, and that all workers are equally likely to quit their jobs. Even though worker turnover is exogenous we can examine other models of worker quits that may be more empirically relevant or intuitively satisfying. In this section I assume that labor working for less skilled managers are more likely to quit. Specifically, a firm that hires a manager of skill level s faces the probability $\gamma(s)$ that each laborer will quit his job before the next period, where $\gamma'(s) < 0$. Thus in addition to being less productive when working under a less skilled manager, labor quits cause turnover costs to be higher at firms which hire low skilled managers.

Note that since managers capture all of the surplus from increased productivity, quits by laborers working under low skilled managers cannot be interpreted as rent seeking behavior. Labor earns the same wage regardless of productivity. Even so, there is at least anecdotal evidence that labor is less likely to quit when worker for better management. This section provides an examination of how robust the previous results are to various models of job and worker turnover.

Compared to the previous discussion, correlation in worker quit rates and managerial skill affects the *ex-ante* entry and hiring decisions by firms because the expected turnover costs per position will depend on the skill of the manager that is hired, not just the technology adopted. The equilibrium conditions used before need to be modified slightly to account for the relationship between skill and probability of worker quits. Still assuming that market size and fixed costs are such that in equilibrium there are firms who choose to adopt less productive technologies, equation (15) becomes

$$\frac{C_H}{C_L} \equiv \left(\frac{[\delta(F_H + k) + k(1-\delta)\gamma(S_2)]\, l(S_2, H)}{[\delta(F_L + k) + k(1-\delta)\gamma(S_2)]\, l(S_2, L)} \right)^{\frac{-1}{\sigma}}.$$

Relative to the case with no correlation between skill and quits, the ratio of total turnover costs between the H and L technologies decrease more sharply in skill. The reason being that as skill rises, worker turnover falls, and so differences between turnover costs between the H and L technologies become increasing dependant on the differences in job creation costs, F_j. As before, at low levels of worker turnover the best technology appears relatively more expensive.

When making comparisons across industries based on labor market turnover with correlated skill, the way that quit rates differ is important. A "high worker turnover" industry could mean that at all skill levels quit rates are higher, or that quit rates decrease slower with skill. To consider both cases suppose that the probability of worker quits in a "high worker turnover" industry is affine transformation of $\gamma(s)$ (quit rate in a "low worker turnover" industry) of the form $a + b\gamma(s)$, where $a > 0$ and $b \geq 1$.

Quit rates between the high and low turnover industries differ by the same *absolute* amount for any level of managerial skill if b is held constant across industries but a differs. Expected turnover costs for each technology in the high turnover industry are shifted upward. But if the strength of the correlation between skill and worker quit rates varies across industries, then the high turnover industry can be characterized by a higher value of b. Differences in the correlation of skill and quit rates will cause expected turnover costs for each technology to rotate around the point where $S_2 = 0$. This equilibrium condition and the impacts of higher worker turnover of both types are depicted in Figure 1.3.

Regardless of the specification of high worker turnover in a particular industry, the result is the same. Higher worker turnover reduces the requisite sill level for using the best technology. High worker turnover reduces the relative cost differences between the H and L technologies, causing more firms to adopt the best technology. The previous results are robust to an inverse relationship between managerial skill and quit rates.

3.5 Discussion

The model laid out above makes several assumptions about the interactions of technology, labor and managerial skill. Some are made for analytical convenience and are not crucial to the results obtained. In this section I delineate which features of the model can be generalized and which are necessary the results obtained.

First, the assumption that labor cannot take advantage of better technologies absent a manager simply pins down outside opportunities of labor. If laborers could take advantage of better technologies during their then the economy would require a rationing rule for who is hired by firms using the best technologies. Since labor is homogeneous an arbitrary rule would not affect firm technology choice at the margin. The need for skilled oversight to take advantage of better technologies is not a crucial feature of the model.

Next, skill intensity in the X sector describes the ability of managers to lend their skills to labor working under their supervision. Restricting managers to be self-employed in the Y sector guarantees that at least some managers seek employment in the skilled sector. If there were no differences in skill intensity between sectors, then all managers would seek employment in the perfectly competitive Y sector. In the perfectly competitive Y sector managers capture rents from increased productivity while facing a constant marginal revenue curve, rather than a decreasing one in the X sector. Requiring self-employment in the low skill sector is a simplifying assumption to guarantee that all technologies are adopted in equilibrium. However, the marginal impact of labor market turnover on firm technology choice is not contingent on this assumption.

Neither the partial interactions of labor and technology, nor labor and skills, have an impact on the marginal behavior of firms regarding technology choice. Thus the key feature of the model must be the interaction of managerial skills and technology. The ability of more skilled workers to apply technologies more efficiently results in the particular allocation of factors during production discussed above. I now turn to the description of that allocation in a open economy and discuss how labor market turnover rates influences industry adjustment to trade and trade preferences of skilled workers.

4 Open Economy

Several studies have established the link between the export status and the productivity of a firm. Since a firm's productivity is partially a result of its choice of technology, we can extend that link to labor market turnover. The trading environment that I will consider here is between two identical countries so that wages are equalized, and Y is not traded in equilibrium. Intraindustry trade in the X industry occurs as consumers desire foreign varieties.

Potential exporters face variable iceberg transportation costs τ and fixed exporting costs F_x if they choose to serve foreign markets. For any optimally chosen size of labor force[12] assume the beachhead costs satisfy

Condition 1

$$[\delta(F_H + k) + (1-\delta)\gamma k]\, l\,(s, H) > F_x \tau^{\sigma-1} > [\delta(F_L + k) + (1-\delta)\gamma k]\, l\,(s, L)$$

The implication is that only firms using the best technology export in equilibrium, regardless of job and worker turnover costs. This restricts the analysis to the more empirically relevant scenario where the most productive firms export while the less productive do not. Because of differences in a manager's skill, the firms using the same technology produce different levels of output. It may be possible that fixed exporting costs are such that some firms using the same technology choose to export and others do not. However the condition on fixed costs given above allows firms to respond to trade liberalization via technology choice, generating an avenue for labor market turnover to shape economic outcomes.

To solve for the open economy we can proceed in the exact same manner as in section 3 where the closed economy equilibrium was characterized. The wage distribution is still described by (8) and (9). Since Y is not traded in equilibrium the market clearing condition is unaffected. The difference is that firms in the X industry now face export opportunities. The zero profit conditions for H type firm must include trade costs. So (15) becomes

$$
\begin{aligned}
\frac{C_H}{C_L} &= \left(\frac{[\delta(F_H+k)+k\gamma-\delta\gamma k]\, l\,(S_2,H)+F_x}{[\delta(F_L+k)+k\gamma-\delta\gamma k]\, l\,(S_2,L)\left(1+\tau^{1-\sigma}\right)}\right)^{\frac{-1}{\sigma}} \\
&= \left(\frac{[\delta(F_L+k)+k\gamma-\delta\gamma k]\, l\,(S_2,L)}{[\delta(F_H+k)+k\gamma-\delta\gamma k]\, l\,(S_2,H)+F_x}\right)^{1/\sigma}\left(1+\tau^{1-\sigma}\right)^{\frac{1}{\sigma}}
\end{aligned}
\tag{19}
$$

and the number of firm using the H technology is

$$
N_H = \frac{M}{\sigma\,[\delta(F_H+k)+k\gamma-\delta\gamma k]\, \widetilde{l\,(H)}+F_x}\int_{S_2}^{\infty} l\,(s,H)\, f_H(s)dG(s)
$$

4.1 Gains from Trade & Openness

Yeaple (2005) studied how firms which do not face the prospect of labor market turnover will adjust their technology choice in response to a multilateral reduction in trade barriers. Lower trade costs reduce the skill requirement for managers to find jobs using the best technology, and raise the skill requirement for participation in the skilled sector. That is, more production in the X sector occurs at H-type firms, the firms in the X industry with the lowest productivity shut down, and the Y sector expands as trade raises aggregate income. (When τ is reduced, S_2 falls and S_1 rises.)

The reallocation of economic activity within the skill intensive sector toward the most productive firms increases income inequality, raises average productivity, and reduces the price of the composite skilled good P_X. Nominal skilled wages, which are skilled wages in terms of the labor wages, of managers with jobs implementing the L technology fall, and rise for managers using the H technology. Skilled wages respond this way to trade liberalization because export opportunities raise the demand for high skilled managers, while demand for workers who are not skilled enough to export will fall. With the effects trade liberalization well understood in the literature what remains is to examine how labor market turnover amplifies or dampens these effects.

Job destruction has been shown to deter firms from adopting the best available technologies. Since the reallocation of production toward more efficient organizations is the key source of adjustment, the incidence of job turnover diminishes the skilled sector's response to freer trade. With high job turnover few firm adopt the technologies that would grant export opportunities. Furthermore, as trade is liberalized fewer firms upgrade their technologies in high job turnover industries.

To see this consider equation (19). By differentiating with respect to τ we can show the effects of trade liberalization on the adoption of each technology. The question of interest here is how the effects of trade liberalization are influenced by turnover rates. So differentiating again with respect the labor market turnover rates the next result is established.

Proposition 5 *Adjustments to trade liberalization are smaller for industries with a higher job turnover rate and a lower worker turnover rate.*

Proof. The second order derivative with respect to the industry job destruction rate[13] is

$$\frac{\partial^2\left(\frac{C_H}{C_L}\right)}{\partial\tau\partial\delta} = \left(\frac{\gamma k\left(F_L - F_H\right) - F_x\left(F_L + k - \gamma k\right)}{\left(\left[\delta(F_H + k) + k\gamma - \delta\lambda k\right] l\left(S_2, H\right) + F_x\right)}\right)\left(\frac{C_H}{C_L}\right)$$
$$\times\left(\frac{l\left(S_2, H\right) l\left(S_2, H\right)\tau^{-\sigma}\left(1+\tau^{1-\sigma}\right)^{-1}}{\left[\delta(F_L + k) + k\gamma - \delta\gamma k\right] l\left(S_2, L\right)\sigma^2}\right) < 0$$

■

Proposition 6 compliments previous new trade theory literature on the effects of reducing trade costs in industries with heterogeneous firms. In Melitz (2003), Manasse and Turrini (2001), and Yeaple (2005) reducing trade costs generates gains by directing production toward more efficient facilities, driving out less efficient production and expanding export opportunities to take advantage of economies of scale. Expected labor market turnover costs at high and low productivity facilities are key to establishing the magnitude of the reallocation of production when trade costs fall. Given the amount of, and variation in, worker and job turnover observed across industries, and the differences in costs that may arise across countries due to policy, turnover can play an important role in an economy's response to trade liberalization.

4.2 Trade preferences

Trade induces a reallocation of production to the most efficient firms and managers. With lower trade barriers managers that do not participate in export markets lose in terms of their nominal wages as the demand for their services falls. Total levels of labor market turnover are reflected in prices. As a result the total levels of worker and job turnover influence changes in real skilled wages due to trade liberalization. In this section I consider the effect trade has on real wages to determine the trade preferences of workers.

Labor market turnover influences trade preferences along two dimensions. The size of real wage gains/losses from trade depend on industry turnover rates. Also, an industry's levels of job and worker turnover determine the share of workers who stand to gain or lose from free trade. So turnover can affect the intensity of trade preferences as well as the extent to which trade is favored or opposed.

First consider the trade preferences of laborers and the least skilled managers in each economy. Labor wages are always equal to the numeraire. Trade does not change the employment opportunities for labor because they earn the same wage regardless of their employer. Because Y is not traded in equilibrium, the nominal wages of the least skilled managers who are self-employed in the Y sector do not change either. Trade does not affect the nominal wages of labor or the least skilled managers, but since P_X falls with trade liberalization, these workers always gain from trade.

Now consider managers employed in the skill intensive X sector. Trade liberalization provides better export opportunities for the highest skilled managers. As demand for high skills rise, so do the nominal wages earned by managers at exporting firms. Price reductions further imply that high-skilled managers always gain in real terms when trade barriers fall. Managers in the X sector who are relatively low-skilled may not benefit from trade since they will not participate in foreign markets. Demand for these mangers who cannot export fall, and so do their nominal wages. However aggregate prices fall, so the effect on the real wage of the moderately skilled is uncertain.

Nominal wage reductions will result in real wage losses for the moderately skilled when trade generates only small price reductions. At low levels of both job and worker turnover the share of total output sold in the market (rather than covering turnover costs) is higher, putting downward pressure on prices. So if consumers initially face low prices because of low turnover costs, trade liberalization results in only small price reductions[14].

Besides total turnover rates, the relative levels of job and worker turnover have implications for how prices respond to trade. When the skilled sector in the foreign country exhibits high job turnover, only a few products will be available for import. The aggregate price index for the skill intensive good is decreasing in the number of varieties available. Therefore relatively high job turnover causes the price savings of trade to be small. Hence in a symmetric trading environment moderately skilled managers will be more opposed to trade when employed in industries with low levels of both worker and job turnover, but relatively higher job turnover.

Having established when the middle class of managers is likely to lose from trade, what is left to examine the number of managers who stand to lose, the extensiveness of anti-trade preferences. Wage reductions occur among the moderately skilled with trade liberalization because they are employed by firms which adopt technologies that exclude them from export opportunities. So the extent to which each technology is used in an industry is the crucial factor for determining the fraction of managers who stand to lose from trade.

Again using proposition 1, relatively high job turnover increases the share of managers using the L technology. Of course trade induces some firms to begin offering jobs using the best technology. But with high job turnover the number of new H-type jobs created after liberalization is small. Hence job turnover increases the share of managers exposed to the perils of trade, and discourages firms from offering jobs that would save them. The next proposition summarizes the relationship between the pattern of labor market turnover and trade preferences.

Proposition 6 *Real wage losses from trade are more likely for some skilled workers, and more common across skilled workers, in sectors with low levels of labor market turnover but with relatively higher job turnover.*

Even in this simple model of exogenous turnover the influence of turnover costs on firm technology choice suggests an intuitively appealing relationship between labor market mobility and trade preferences. Firm responses in technology choice to trade liberalization are less harmful when workers are more mobile, have less loyalty to their employers, or can be replaced at low cost. When jobs survive for only a short time or costs of restructuring production are high, fewer workers stand to gain from trade.

5 Conclusion

Creating and continually staffing employment positions are costly activities for firms. Given the observed levels of job and worker reallocation these costs are likely to have a significant impact on firm behavior. In an economy populated by firms which are heterogenous largely by choice, systematic variation in turnover rates across industries suggests that the role of labor mobility should not be ignored. Moreover, job and worker turnover are distinct economic events. Except in a knife-edge case, where the cost share of each source of turnover is the same for all technologies, firms will respond differently to the prospects of replacing jobs and replacing workers.

When jobs using the best technology are more expensive to create, higher levels of job destruction reduce the incentive of firms to adopt state of the art production techniques. High job turnover increases income inequality, reduces average industry productivity, and skews the sales concentration. High job turnover also limits export participation and industry adjustment to trade.

The pattern of labor market turnover in an industry shapes trade preferences. A large share of the skilled workforce is made worse off relative to the rest of the population by international trade when there is high job turnover. Moreover, the chance freer trade harms these workers in terms of their real wage is greater when there is little turnover in the labor market, but job turnover is relatively high.

Notes

[1]JEL Classification: F16

[2]Even the little correlation that is observerd may be overstated due to measurement error.

[3]This will be shown to be true when worker quits are uncorrelated with managerial skill, and inversely related with skill because in equilibrium only less skilled workers use "low" technologies.

[4]The extention of Yeaple (2005) to production by firms with many employees in crucial. First, one worker producing a fixed amount of output means that the firm faces no marginal decision with regard to quantitiy or prices. The result of fixed price mark-ups over units costs from monopolistic competition and CES preferences does not hold. The firm will sell the worker's output for the maximum price consumers will pay for the given quantity.

Second, with only one worker, job destruction results in destruction of the firm. The sunk entry cost would have no effect on firm behavior is subsequent time periods. In a large firm model, the law of large numbers suggests a pseudo-fixed cost equal to the incidence of job turnover costs. Thus free entry would lead to firms earning zero profit in equilibrium

[5]See Magee (1980), Irwin (1996), Beaulieu and Magee (2004), and Balistreri (1997), among others.

[6]By assumption $\sigma > 1$ so that all varieties have positive demand. This also implies that $\rho \in (0, 1)$.

[7]In equilibrium, the allocation of workers to firms using each technology will be perfectly positively assorted based on skill. There will be no better opportunities for a worker to earn higher wages, and hence no endogenous reason to quit.

[8]Again, see Davis, Haltiwanger and Schuh (1996) and Burgess, Lane, and Stevens (2000) for evidence that turnover rates are heterogenous across industries. Varia-

tion does not imply independance necessarily but interindustry links in firm/worker turnover rates are outside the scope of this paper.

[9]Again note that the inequalities result from the assumption that each technology is adopted by at least some firms. If the sizes of the labor force at each type of firm were constant, then the inequalities would obtain from the assuptions on the comparative advantage given to skilled workers using better technologies. High demand for X is reflected in the size of the labor force used by firms in the X industry relative to Y.

[10]The term $l(s, \cdot)$ represents the optimal labor hiring decision of the a firm with a manager of skill s, given the optimal choice of technology. This a simplification of notation where is should be understood that $\int_0^\infty l(s, \cdot)\, dG(s) = \int_{S_1}^{S_2} l(s, L)\, dG(s) + \int_{S_2}^{\infty} l(s, H)\, dG(s)$.

[11]The distribution of skilled income is given in nominal terms. But since labor wages are equal to the numeraire good, these results are true when considering both labor and skilled managers working in an industry.

[12]I have reverted to the parameterization where worker quits are uncorrelated with skill. As shown in the previous section, only the magnitude of the results to be derived are affected by a correlation between worker turover and manger skill.

[13]Following from proposition 1 the effect of the worker turnover rate is the opposite of the job turnover rate.

[14](Prices are reduced by free trade, $\frac{dP_X}{d\tau} < 0$, and $\frac{dP_X}{d\tau}$ is larger in magnitude for larger values of δ and γ.)

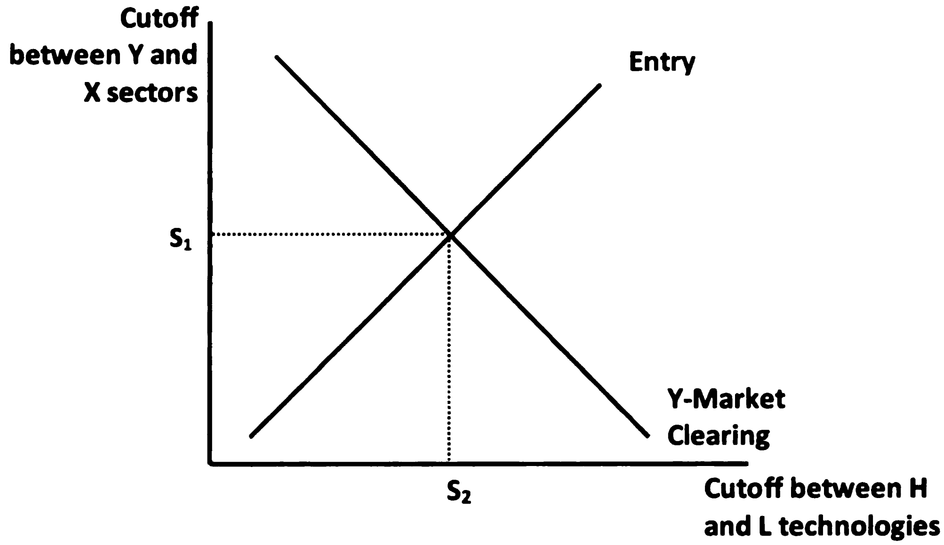

Figure 1.1: Equilibrium Allocation of Managers to Technologies

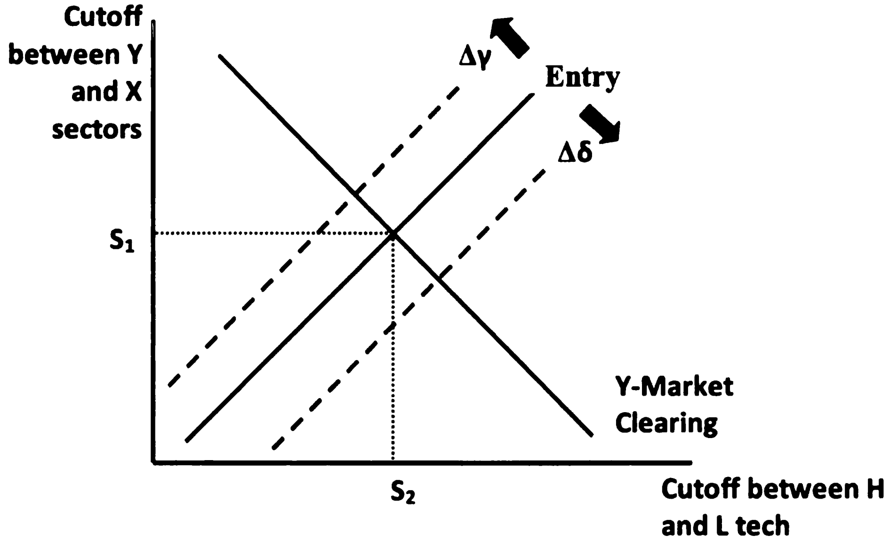

Figure 1.2: Effects of Labor Market Turnover Rates on Technology Adoption

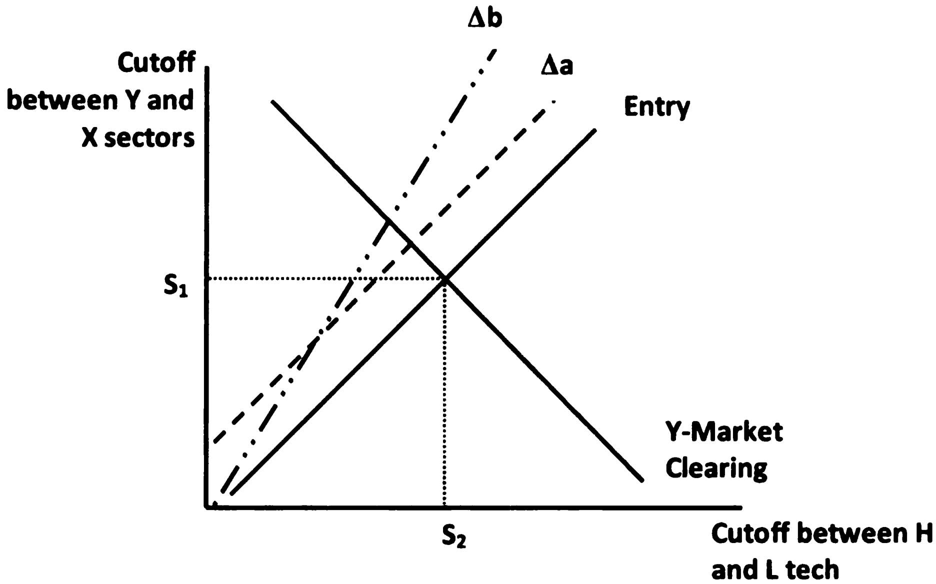

Figure 1.3: Equilibrium Technology Adoption with Correlation between Quit Rates and Managerial skill

Chapter2
International Trade, Wages, and Unemployment with Endogenous Firm Scope[15]

ABSTRACT: Heterogeneous managers match and supervise production of multiple goods. Managerial skill improves labor productivity, so long as efficiency wages deter shirking. Trade liberalization eases the efficiency wage constraint, thereby raising total employment and labor wages. Trade rationalizes production in three ways. Firms become more specialized by dropping marginal product lines. Production is reallocated within industries toward the most efficient firms. Also trade rationalizes the matching behavior of managers, leading to improved team formation. Overall wage inequality rises as trade costs fall. There are workers who may benefit from trade even though workers with higher skill may lose.

6 Introduction

Two common assumptions in the trade literature are that firms produce a single product and use factors that are fully employed. Though such models have provided great insights about the nature of open economies, even casual observation leads to the conclusion that unemployment and multi-product firms are persistent features of any economy. While nearly all firms produce many differentiated products, they vary in both their product scope and productivity. These differences across firms are likely to result from endogenous choices made by rational economic agents.

Separate lines of literature have examined the impact of trade liberalization on firm scope and the effects trade has on unemployment in environments with heterogeneous firms. However, a link between features of structural unemployment and firm scope has been left unexplored. Here I consider how firms choose the number of products to manufacture given that unemployment persists because labor wages must be high enough to deter shirking. In addition I examine how the choice of skilled workers to match determines how firms within an industry initially organize, and shapes the distribution of firm productivity. Trade has a direct effect on the incentives of labor to shirk and the matching behavior of managers. In response to a change in the nature of worker supply after liberalization, firms adjust their product scope, hiring decisions and factor rewards. Moreover, managers rethink their pre-liberalization partnerships leading to changes in industrial organization.

Few firms produce only a single product and multi-product firms seem quite concerned with the specific portfolio of products that they offer. Firm behavior across product lines has been shown to respond to both internal and external influences. Bernard, Redding and Schott (2008) document the degree of product switching by multi-product firms and the share of production taking place at multi-product plants. Using 5-digit SIC classifications to identify different products they find that 87% of US manufacturing takes place at plants which produce multiple products, half of whom alter their product mix every five years. The decision to add or drop a product is often made for reasons particular to a firm/product pairing. Turning to external forces, Bernard, Jensen and Schott (2006) provide evidence that plants alter their product mix when exposed to foreign competition. Baldwin and Gu (2006) also find that lower tariffs cause plants to reduce the level of diversification in production but note that exporter plant size does not seem to respond to changes in tariffs.

Political discussions of international trade center on either unemployment or job quality. Trade can improve, or harm, the economic opportunities of workers in three ways. First, international market size could impact the probability that each worker is employed at all. Second, for those who are employed trade may alter the type of job they obtain. Third, even the workers who retain a certain job type will feel the effects of globalization if the rest of their employer's workforce responds to trade liberalization. These issues have been explored previously in Davidson, Martin and Matusz (1999), Itskhoki and Helpman (2007), Matusz (1986) and (1996), Davidson and Matusz (2004), Felbermayr, Prat, and Schmerer (2008), Davis and Harrigan (2007), and elsewhere.

Careful examination of the relationship between trade and labor market outcomes must account for the relationship that globalization has with both sides of the labor market: supply and demand. The emphasis of much of the literature falls on the effects of reduced trade costs on the organization of production, with labor market outcomes resulting from only changes in firm behavior. Worker behavior is left out of the analysis. This sort of "partial-partial equilibrium analysis" misses half of an economy's trade adjustment[16]. Commodity prices and export opportunities are key determinants of worker supply. Endogenous worker responses to trade liberalization can play an important role in shaping firm organizational design, overall industrial organization and labor market outcomes.

Besides multi-product firms and unemployment, another key feature of any economy is heterogeneous production. Within narrowly defined sectors firms differ in the number of products that they offer (Bernard, Redding and Schott (2008)), in the types of workers that they hire, technologies that they employ (Doms, Dunne, and Troske (1997)), in productivity and in export status (Bernard and Jensen (1999)). Given the observed patterns of heterogeneity across each of these dimensions, I take the skill of managerial teams to be the underlying source of firm differences, as in Lucas (1978) and Rosen (1981). A key difference in the approach taken here is that, while the distribution of individual managerial talent is exogenous, the distribution of the skill of management teams available for hire is endogenous. Heterogeneity results from both endogenous matching behavior and exogenous skill differences[17].

In order to address the relationship between trade, worker supply, and the organization of production, I amend the model set forth in Matusz (1996). He incorporates efficiency wages into a monopolistic competition model with intraindustry trade. Laborers make a supply decision in the form of whether or not to shirk, as firms have imperfect monitoring abilities. In each economy a single final good is produced using the set of domestic and foreign intermediate products available. An increase in the number of available intermediates allows for greater specialization, and hence greater efficiency, in the production of the final good.

Heterogeneous intermediate firms have a core variety which they can modify to supply additional varieties to the market. Each firm is most productive in manufacturing its core variety. Labor efficiency suffers when producing additional varieties because of a greater need for modification. Given diminishing returns to scope, market demand, labor wages and management skill, each firm determines its scope endogenously.

Each economy is endowed with a set of managers who are heterogeneous with respect to their ability to improve labor productivity, given that shirking is deterred. Firms hire two managers and assign one to supervise labor in performing assembly tasks associated with developing the core variety and one to modification activities necessary to produce additional varieties. As managers cooperate in production of all the firms varieties, they share the firm's operating profits. Differences in the skill intensity of "scope tasks" and "scale tasks" lead to matches between heterogeneous managers, while complementarity leads to positive assortative matching. Given profit opportunities and the set of potential matches, skilled individuals form management teams endogenously.

Trade liberalization induces adjustments in production both across firms and within firms. The introduction of additional foreign intermediate varieties allows for greater efficiency in the production of the final good. This gain in efficiency increases real wages and relaxes the efficiency wage constraint. Slack in the efficiency wage constraint and better access to foreign markets encourages firms to hire additional labor. Additional labor demand bids up labor wages inducing a reallocation in production. In the face of higher labor costs the least productive firms are forced to exit and surviving firms shed marginal product lines. A greater share of production takes place at the firms with the best management teams, who concentrate on their core specialties, thereby increasing aggregate productivity.

This sort of marginalization of production across and within firms is similar to results obtained in Melitz (2003), Bernard, Redding and Schott (2006), Eckel and Neary (2008), and Nocke and Yeaple (2006). A significant difference being that changes in firm scope and industry organization come at the behest of both firm *and* worker response to trade liberalization. The most prominent departure from previous work is the role that international markets play on the manner in which firm management organizes initially.

Globalization induces adjustments in managerial matching. As the least efficient management teams exit, the highest skilled member of those pairs, who initially would only accept high skill intensity positions, now are willing to accept a less skill intensive position as opposed to unemployment. In light of a new group of managers who offer to take low skill jobs, every other manager rethinks her current partnership. Each manager vies for one of the relatively higher skilled managers willing to take a low skill intensity job. All surviving firms realize a change in management. Some individual managers feel the effect of trade via the type of job they acquire, and all feel its effects through the skill of the partner with whom they match in equilibrium.

When two managers attempt to match with a particular individual, the higher skilled of the two will always win the bidding contest. So as trade induces relatively higher skilled managers to begin accepting low skill intensity jobs, they will match with the best available partners. Adjustments in managerial matching due to trade lead to more positively assorted matches. Increased segregation generates productivity gains within the top firms, but losses among the bottom firms. The rationalization of matches at the largest firms may cause them to further diversify, despite the partial influence of trade to reduce product scope. The complete economic response to trade is the sum of the effects of matching, firm selection and product selection.

Both changes in production and changes managerial matching have consequences for total welfare. Even though trade reduces labor productivity partially through changes in management at smaller firms, in the aggregate these losses are dominated by the productivity gains from (1) the reallocation of production across firms toward larger firms, (2) the specialization within firms through decreased product scope, and (3) increases in the quality of management at larger firms. Thus open economies enjoy greater economic welfare.

At a minimum globalization has a marginal impact on matching outcomes by forcing some mangers to take low skill positions. But trade can have a drastic impact on the formation of management teams by inducing some managers to actually prefer low skill positions, if doing so guarantees the opportunity to export. Only the most efficient firms can penetrate foreign markets. So if there is a shift in matching behavior in order to secure export status, preferences will shift toward matching with higher skilled partners. Whether the result of changes in matching outcomes or overall matching behavior, trade causes matches between managers to be more positively assorted. The effects of shifts in matching behavior are magnifications of the effects due to marginal adjustments in matching outcomes.

The matching outcome in the manager market is crucial to the skilled wage distribution. For either job type, better partners result in better wages. More segregated matches after trade is liberalized increase the wages of the top managers but reduces the wages of the lower skilled. Real wage losses are more likely when matching preferences shift than when there are only marginal adjustments to matches.

Managerial wages also depend on market share and export status. Better trading opportunities benefit the best management teams through the reallocation of production; with heterogeneous matching the best teams are not composed entirely of the most able managers. The group of relatively low skill managers employed by exporting firms will benefit from trade, while some higher skilled managers with skill intensive positions at non-exporters will be harmed.

The combined effect of adjustments in the management and adjustments in production lead to an ambiguous effect of trade on the wages for all but the most skilled. The highest skilled workers always gain from trade and as a result overall wage inequality rises. The pattern of rising wage inequality that emerges post trade liberalization is one of less within-firm wage dispersion and more inequality across firms for workers with similar skill. These predictions are consistent with Dunne *et al.* (2004) who document the contributions of within-firm and across firm wage dispersion for production and non-production workers in the US. In addition moderately skilled workers may gain from trade, although the likelihood of benefiting from globalization is not necessarily increasing in skill.

Labor always benefits from trade. The introduction of foreign varieties and the rationalization of domestic production lowers prices thereby increasing the real wage. Increased labor demand further bids up nominal wages and raises total employment. Thus labor benefits from free trade because of better compensation while employed, and from shorter expected durations of unemployment.

The next section describes the model of labor and goods markets. Section 3 discusses the matching behavior of potential managers and derives an open economy equilibrium. Section 4 discusses the impact of a reduction in trade costs on production, managerial matching and labor market outcomes. Section 5 concludes.

7 Model

7.1 Production

The world consists of two countries. Each economy produces a single final good Y using the set of available intermediate goods from domestic firms, χ, and exported by foreign firms, χ_{ex}^{*}. (An asterisk denotes a foreign variable.) Because firms produce multiple products the mass of varieties of intermediates available, χ, is greater than the mass of active firms determined below. The final good is assembled costlessly by combining intermediates according to the production function

$$Y = \left(\int_{\chi} x_j^{\theta} dj + \int_{\chi_{ex}^{*}} x_j^{\theta} dj \right)^{1/\theta} \quad , \ \theta \in (0,1) \quad . \tag{20}$$

Each intermediate good is produced by a firm, which may produce multiple intermediate varieties, using labor and managerial skill. There are two necessary tasks that must be performed by a firm producing any intermediate variety. First, labor must be used to assemble a "core" intermediate that represents the firm's base product in which it has the most expertise. This task is called an assembly activity. Each unit of output produced, of any variety, requires one efficiency unit of labor to perform the necessary assembly activities.

Second, if the firm produces multiple varieties additional labor must be used to alter the characteristics of its core intermediate to contribute to the production of Y. This task is called a modification activity. The further a particular intermediate variety is from a firm's core variety, the more labor that must be used in modification activities for that specific variety. For simplicity I assume that if a firm produces a mass of intermediates N, indexed by their distance from the core variety at $n = 1$, then the variety $n \in [1, N]$ requires n efficiency units of labor to perform the requisite modification tasks. Modification activities are particular to the characteristics of each specific intermediate good. Producing additional varieties has no effect on the efficiency of labor in the production of the firm's inframarginal varieties.

The labor pool has mass λ. The productivity of labor in performing both activities is normalized to unity. That is, each laborer supplies a single unit of efficiency labor of his own accord. Each economy is also endowed with a mass μ of heterogeneous agents who differ in their skill, s, for managing labor. A manager can improve the productivity of labor in performing either assembly or modification activities according to her skill level[18]. While working under a manager of skill s each laborer supplies $m(s)$ efficiency units of labor to completing modification activities and $f(s)$ efficiency units of labor to performing assembly activities. More skilled managers are better at increasing the productivity of labor; $m'(s) > 0$ and $f'(s) > 0$. The distribution of managerial skill is given by $G(s)$ with support $(0, \overline{S}]$, and $\overline{S}$ can be arbitrarily large.

Managerial tasks differ in their skill intensity. I assume, without loss of generality, that the assembly task is more skill intensive[19]; that is $\frac{\partial f(s)}{\partial s}\frac{1}{f(s)} > \frac{\partial m(s)}{\partial s}\frac{\tilde{N}}{m(s)}$. If a firm hires two managers of different skill[20], then the optimal strategy will be to assign the more skilled manager to the more skill intensive task of improving labor productivity in completing assembly activities. The labor needed to produce one unit of variety n, which is a measure $n-1$ from a firm's core competency, produced under the supervision of managers with skill s' and s'', where $s' < s''$, is given by

$$l(n) = \left[\frac{n}{m(s')} + \frac{1}{f(s'')}\right]. \tag{21}$$

7.2 Demand

The composite final good Y is the numeraire. Combining intermediates according to (20) yields a cost function for Y given by

$$C\left(\vec{P},Y\right)=\left(\int\limits_{\chi}P_j^{\frac{\theta}{(\theta-1)}}dj+\int\limits_{\chi_{ex}^{*}}P_j^{*\frac{\theta}{(\theta-1)}}dj\right)^{\frac{(\theta-1)}{\theta}}Y \tag{22}$$

The total sets of available intermediates from domestic and international firms are endogenously determined by the number of active domestic firms, foreign exporters, and the number of intermediates that each firm produces and exports. An intermediate firm faces a demand for each individual variety n of

$$D_n=Y\left(\int\limits_{\chi}P_j^{\frac{\theta}{(\theta-1)}}dj+\int\limits_{\chi_{ex}^{*}}P_j^{*\frac{\theta}{(\theta-1)}}dj\right)^{\frac{-1}{\theta}}p\left(n\right)^{\frac{1}{\theta-1}}+$$

$$I\left(n\right)\left[Y^{*}\left(\int\limits_{\chi^{*}}P_j^{*\frac{\theta}{(\theta-1)}}dj+\int\limits_{\chi_{ex}}P_j^{\frac{\theta}{(\theta-1)}}dj\right)^{\frac{-1}{\theta}}p^{*}\left(n\right)^{\frac{1}{\theta-1}}\right].$$

The variable $I\left(n\right)$ is an indicator which equals 1 if the firm exports variety n and 0 if it does not.

7.3 Firm behavior

The gain in efficiency in producing the final good from having a greater mass of intermediate varieties guarantees that no firms will enter and produce the same intermediate goods. Also each firm is small relative the whole market and so takes the prices of other varieties as given. Similarly the firm can ignore the effect that its own additional production lines have on the demand for its inframarginal products.

The profit function for an intermediate firm is equal to the revenues from all of its product lines (N), for all units of each variety sold $(x(n))$, less labor costs per unit of output of each variety (at labor wages ω), beachhead costs for the firm (β) and per product (γ) if the firm exports, and total wages paid to managers for services on all varieties $\left(W_m \text{ and } W_f\right)$. Implicitly defined for the skill of managers hired, the profit function is

$$\Pi = \int_1^N [p(n) - \omega l(n)]\, x(n)\, dn + \int_1^{N^*} I(n) \left\{ [p^*(n) - \omega l^*(n)]\, x^*(n) - \gamma \right\} dn - I(1)\,\beta - W_m - W_f$$

Managers perform identical tasks across all intermediate varieties produced by the firm, and so their compensation (described in detail below) does not affect firm behavior at the margin. Each firm maximizes profit by choosing the price it charges for each intermediate variety, and the total number of varieties to manufacture. Of course the optimal choice of scope and price depend on the skill the managers hired. The first order condition for the domestic price charged by a firm with managers of skill s' and s'', with $s' < s''$, is

$$p(n) = \frac{\omega}{\theta} l(n) = \frac{\omega}{\theta} \left[\frac{n}{m(s')} + \frac{1}{f(s'')} \right]. \tag{23}$$

Each firm charges a fixed mark-up over marginal costs, which are a function of labor wages, ω, and labor productivity, the term in brackets. The first-order condition for the optimal firm scope shows that firms add production lines until the marginal intermediate variety yields zero additional profits.

$$\left[p\left(N\left(s', s''\right)\right) - \omega l\left(N\left(s', s''\right)\right) \right] x\left(N\left(s', s''\right)\right) = 0 \tag{24}$$

Free entry guarantees that prices and scope are chosen optimally[21] and that all revenues accrue to either labor or managers. Then using (23) and (24) the total labor demand of a firm with managers $s'$and s'', with $s' < s''$, is

$$L\left(s', s''\right) = \int_{1}^{N\left(s', s''\right)} l\left(n\right)\left[x\left(n\right) + x^{*}\left(n\right)\right] dn$$

Full labor employment in this economy would be $\int_{\chi} l_j dj = \lambda$, where the labor demand for all intermediates produced in each country required use of the entire labor pool. However the interest here is in equilibria where $\int_{\chi} l_j dj < \lambda$.

7.3.1 Export Choice

If an intermediate firm exports it must pay a fixed cost β to acclimate itself to foreign markets and γ to prepare each of its products for use in foreign production of the final good. In addition the firm must pay iceberg transportation costs on each unit of output exported. For a single unit of a specific variety to arrive in a foreign market an exporter must produce and ship $\tau > 1$ units. Fixed exporting costs have no effect on the marginal behavior of firms, and as a result a firm that charges a price p in the domestic market will charge τp in the foreign market.

Each intermediate firm must decide whether or not to export at all, and if so which products to sell overseas. Average fixed exporting costs are decreasing in the number of products exported because the firm must only make the investment to learn about foreign markets once. Because of the need for modification, each firm experiences diminishing returns to scope. The trade-off between reduced costs of market penetration and diminishing profits defines a firm's optimal export strategy. A firm that makes N intermediate varieties will be an exporter if, for at least one

$n \in [1, N]$, the follow criterion is satisfied

$$\int_{1}^{n} [p^* (n) - \tau l (n)] \, x^* (n) \geq \beta + \gamma n \tag{25}$$

Upon entering a foreign market the firm must determine its extensive export margin. The firm chooses the number of products to export by comparing marginal operating profits from exporting an additional product and the marginal cost of adapting the product to the tastes of foreign consumers. So a firm will export the varieties $[1, N_{ex}]$, where N_{ex} satisfies

$$[p^* (N_{ex}) - \tau l (N_{ex})] \, x^* (N_{ex}) = \gamma. \tag{26}$$

Of course $N_{ex} \leq N$. Figure 2.1 shows the optimal scope and extensive export margin established in (25) and (26). Firms that do not export would have an operating profit curve that lies entirely below the line representing fixed exporting costs. As drawn the firm in Figure 2.1 would not choose to export only its core products, even though it produces them most efficiently. For this firm, decreasing average fixed costs to penetrate foreign markets is crucial in the decision of whether or not to export. The last thing to notice about Figure 2.1 is that because managerial skill is relatively more important for intermediates that require more modification, firms with better management are more likely to export and will export a greater range of intermediate goods. That is, better management shifts the operating profits curve for a firm up. Also better management reduces the firm's incidence of diminishing returns to scope, which would be illustrated by less curvature in the operating profits curve.

7.4 Factor Markets

7.4.1 Efficiency Wages and Labor

Managerial skill improves labor productivity so long as labor is putting forth effort. Working on any task, at any level of productivity, is onerous so that each laborer has an incentive to shirk his duties while enjoying wages. Firms pay efficiency wages, ω, that are higher than the opportunity cost of effort and fire labor caught shirking. The benefit of higher wages and the threat of unemployment deter shirking in equilibrium.

The model of the labor market is set in continuos time. Labor who put forth effort still face the probability $b > 0$ that their employment will be terminated exogenously. Employees who shirk their duties are caught with probability $q > 0$. Note that these probabilities (particularly q) are not functions of managerial skill. The role of skill in this model is only to improve labor productivity in the performance of certain tasks. Regardless of skill in supervising modification activities or assembly activities, all managers can monitor labor with the same ability.

Labor can be in one of three possible states: employed and putting forth effort, employed and shirking, or unemployed. Laborers are risk neutral and find jobs at an endogenously determined rate e. All laborers discount the future at a rate $\rho > 0$, and the disutility of effort is $d > 0$. The asset value equations for being in each state are

$$\begin{aligned}
\rho V_e &= \omega - d + b\left(V_u - V_e\right) \\
\rho V_s &= \omega + (b+q)\left(V_u - V_s\right) \\
\rho V_u &= e\left(V_e - V_u\right)
\end{aligned}$$

Shirking is avoided in equilibrium so long as the expected lifetime utility of shirking today is less than the expected utility associated with putting forth effort, that is $V_e \geq V_s$. Profit maximizing firms will pay efficiency wages just high enough to deter shirking so that $V_e = V_s$, or

$$\omega = d\left(\frac{\rho + b + q + e}{q}\right) \tag{27}$$

In a steady-state equilibrium the flows of labor into and out of employment are equal. Since shirking is deterred in equilibrium, the flow out of employment comes only from exogenous layoffs. A fraction b of the total number of workers employed, $\int\limits_{\chi} l_j dj$, transition out of employment, while a fraction e of the pool of unemployed labor, $\lambda - \int\limits_{\chi} l_j dj$ finds a job. Thus in a steady state

$$e = b\left(\frac{\int\limits_{\chi} l_j dj}{\lambda - \int\limits_{\chi} l_j dj}\right) \tag{28}$$

7.4.2 Managerial Earnings

Production occurs as managers cooperate in the performance of specific tasks, supervising either modification or assembly activities. Firms cannot capture any surplus generated from production because of free entry. Were any economic value retained by a firm, a competitor could poach the firm's management by offering marginally better pay. So total managerial earnings are the operating profits (revenues net labor costs and exporting costs if applicable) from all of the firm's varieties. Operating profits for a firm which employs managers with skill s' assigned to modification activities, skill s'' assigned to assembly activities, and produces $N(s', s'')$ varieties of intermediate goods, are

$$\pi\left(s', s''\right) = \int_{1}^{N\left(s',s''\right)} \left(p\left(n\right) - \omega\left[\frac{n}{m\left(s'\right)} + \frac{1}{f\left(s''\right)}\right]\right) x\left(n\right) dn +$$

$$\int_{1}^{N\left(s',s''\right)^{*}} I\left(n\right)\left[\left(\tau p\left(n\right) - \tau\omega\left[\frac{n}{m\left(s'\right)} + \frac{1}{f\left(s''\right)}\right]\right) x^{*}\left(n\right) - \gamma\right] dn - I\left(1\right)\beta$$

Note that the first argument in $\pi\left(\cdot\right)$ refers to the skill of the manager assigned to modification tasks, and the second argument to the manager assigned to assembly activities.

The coalition of managers must decide how to divide the sum of operating profits among themselves. Here I use the Shapley Value to determine the allocation of operating profits across the two managers. Each manager earns the average of her marginal contribution to the coalition. That is, each manager earns the average of operating profits when working with another skilled manager, and operating profits when her counterpart's labor activities are unsupervised.

When working alone, a manager of skill s' assigned to modification activities generates $\pi\left(s', 0\right)$ in operating profits, and an assembly manager of skill s'' generates $\pi\left(0, s''\right)$. Therefore a modification manager contributes $\pi\left(s', 0\right)$ to the coalition without a partner, and $\pi\left(s', s''\right) - \pi\left(0, s''\right)$ working with her partner. Then taking averages, managerial earnings for the modification manager and assembly manager (using a similar derivation) are respectively

$$W_m\left(s', s''\right) = \frac{1}{2}\left\{\pi\left(s', 0\right) + \pi\left(s', s''\right) - \pi\left(0, s''\right)\right\} \tag{29}$$

$$W_f\left(s', s''\right) = \frac{1}{2}\left\{\pi\left(0, s''\right) + \pi\left(s', s''\right) - \pi\left(s', 0\right)\right\} \tag{30}$$

8 Equilibrium

8.1 Managerial Matching

Two important features of the allocation of operating profits to management in (29) and (30) determine managerial matching behavior. First, as a manager's own skill level increases so does the opportunity cost of not cooperating with a second manager. Put another way, the managerial compensation functions are supermodular[22]. Each manager's earnings increases with the skill of her partner. As a result the equilibrium matching pattern is some type of positive assortative matching where, all else equal, each manager prefers a relatively higher skilled partner.

Second, managerial compensation depends not only on the skills of the two managers but also the task to which each is assigned. Still assuming (WLOG) that the assembly task is more skill intensive, if two managers of the same skill match and cooperate in production, the manager assigned to supervise assembly activities will earn a strictly greater wage than the manager assigned to modification activities. In a homogeneous match the manager assigned to the less skill intensive task would prefer to match with a marginally less skilled worker to obtain a more lucrative skill intensive management position. Therefore, with a continuous distribution of skill, equilibrium matches will be heterogeneous[23].

A tendency towards positive assortative matching leads to equilibria that are more segregated; managers matching with others who have similar skill. The returns from the skill of a partner encourage behavior that leads to segregated matches. On the other hand post-match task assignment across different skill intensities encourages behavior that leads to heterogeneous matches. The particular matching outcome sustained in equilibrium depends on the primitives of the model: the skill distribution, world market size, fixed exporting (beachhead) costs and variable trade costs. The interest here is on trade costs. An important distinction exists between shifts in the matching regime sustained in equilibrium, and marginal adjustments in matching outcomes within a particular regime, that occur at the behest of trade liberalization.

All matching regimes are characterized by a degree of segregation. Given the complementarity of managerial skill, a more diffuse skill distribution induces behavior that leads to a more segregated matching regime (see Kremer and Maskin (1996) and Legros and Newman (2002)). The reason being that a more diffuse distribution of skill means that *ceteras parabis* heterogeneous matches will occur between managers with greater differences in skill. Complementarity makes such matches less viable even when differences in the skill intensity of managerial tasks exist.

Larger international markets increase the opportunity costs of rejecting higher skilled partners (in order to obtain skill intensive jobs), especially when doing so excludes a manager from export opportunities. Trade costs have a similar effect as international market size on the equilibrium matching regime. Both beachhead and variable trade costs limit participation in foreign markets and lower the operating profits of exporting. Reduced trade costs increase the incentives of managers to overcome the expense of penetrating foreign markets; for some managers this may mean accepting less skill intensive jobs in order to match with partners that allow for profitable exports. Hence lower trade costs can lead to adjustments in matching regimes towards one which is more segregated.

Since there are may potential matching patterns, the procedure here will be to derive the effects of trade liberalization in the context of a particular matching regime. Then given the discussion above, describe the new equilibria obtained after trade costs fall and the economy moves across matching regimes. I choose the most extreme form of heterogeneous matching where every manager strictly prefers to obtain the skill intensive position within her employing firm, regardless of export opportunities afforded at a given level of trade costs, and for all potential skill levels of partners. As each manager seeks the most skill intensive of the two available job types, the distribution of skill will be completely bifurcated with respect to task assignments. The top half of managers will obtain the most skill intensive jobs. The most skilled manager in the economy will attract the most skilled partner who takes a low skill intensity position; this must be the median worker[24]. Then as all managers vie for the best partners, matches are positively assorted across the median. This matching regime has been labelled *median matching.*

8.2 Median Matching Equilibrium

The next step is to derive the endogenous distribution of management skill employed in a median matching regime. The set of managers that are employed in equilibrium must be rational in terms of entry and consistent with median matching. The lowest skilled manager to find a job, S_L, will obtain a low skill intensity position supervising modification activities. In a median matching regime the S_L manager will be matched with a median-skilled manager, S_M, who performs assembly services. Entry by a firm which hires managers S_L and S_M must be rational given fixed entry costs F, and the exogenous probability that a firm breaks apart[25], b. So,

$$V^{Entry} \equiv \int_0^\infty \exp(-bt)\Pi\left(S_L, S_M\right) dt - F \geq 0 \tag{31}$$

and in equilibrium (31) holds with equality.

A median-skilled manager could also obtain a job supervising modification activities while working with the highest skilled manager in the economy, $\overline{S}$. Therefore, in equilibrium the median worker must be indifferent between her compensation as a modification manager and an assembly manager.

$$W_m\left(S_M, \overline{S}\right) - W_f\left(S_L, S_M\right) \equiv 0 \tag{32}$$

The equilibrium conditions (31) and (32) can be plotted in a two dimensional skill space with the vertical axis representing the skill level of the manager assigned to the skill intensive task (assumed to be the assembly manager) and the horizontal axis representing the skill level of the manager assigned to the low skill intensity task. Both curves are monotonically decreasing; i.e. $\frac{dS_m}{dS_L} < 0$. Furthermore, the entry condition is everywhere steeper than the wage indifference condition (see appendix). Hence, these two determine a unique equilibrium pair S_L and S_M.

Since labor is identical across all firms, the distribution of managerial skill employed in equilibrium ($G(s)$ over $[S_L,\overline{S}]$), and the pattern matching between managers (median matching) completely describe the set of intermediate good firms active in equilibrium. From this point forward I simplify the notation by indexing each firm by its highest skilled manager so that the distribution of active firms is written $G(s)$ with the endogenously determined support $[S_M,\overline{S}]$. It should be understood that a firm of skill s refers to a firm with a modification manager of skill $\varphi(s)$ and an assembly manager with skill s where $\varphi(\cdot)$ is the one-to-one correspondence of matches across the median with $\varphi'(\cdot) > 0$.

8.3 Labor Market Equilibrium

A steady-state equilibrium in the labor market is characterized by an efficiency wage that deters shirking and a level of unemployment. Combining (27) and (28) the relationship between the efficiency wage and unemployment rate is given as a function of the set of intermediate firms active in the domestic country. Then denoting a representative domestic firm with management skill S_R, an equilibrium in the labor market must satisfy

$$\omega = d + \left(\frac{\rho}{q} + \frac{b}{qu(S_R)}\right) d. \tag{33}$$

The unemployment rate[26], $u\left(S_R\right)=\left(\lambda-\frac{\mu}{2}L\left(S_R\right)\right)/\lambda=\left(\lambda-\int\limits_{\chi} l_j dj\right)/\lambda$, depends on both the number of firms and the representative skill level which determines firm size. The number of firms is increasing in the mass of potential managers, μ, and the average size of firms in increasing in the skill level of the representative firm, S_R. And so the unemployment rate is decreasing in both μ and S_R. From (33) the efficiency wage paid to laborers is decreasing in the unemployment rate (increasing in μ and S_R) because longer spells of unemployment entail greater opportunity cost of shirking, diminishing the need for higher wages. The LL curve in Figure 2.3 traces the set of efficiency wage and representative firm skill pairs that are consistent with a steady-state equilibrium where shirking is deterred, given the distribution of firm productivity in a median matching regime.

8.4 Goods Markets Equilibria

An equilibrium in the final and intermediate goods markets consists of intermediate firms setting prices that satisfy (23) and choosing a scope of intermediates according to (24), equilibrium matching by managers determined by (31) and (32) in a median matching regime, and cost minimization in the Y sector according to (22). Substituting the individual firm prices into the cost function of Y in (22) gives the zero-profit condition for the Y sector.

$$1=\left[\int\limits_{\chi}\left(\frac{\omega l_j}{\theta}\right)^{\frac{\theta}{\theta-1}}dj+\int\limits_{\chi_{ex}^{*}}\left(\frac{\omega l_j}{\theta}\right)^{\frac{\theta}{\theta-1}}dj\right]^{\frac{\theta-1}{\theta}} \tag{34}$$

Instead of using the cost for each intermediate product, averaging the zero profit condition across all firms yields a simple expression for the relationship between labor wages and representative skill level of active management teams. The representative firm from the mass of $\frac{\mu}{2}$ management teams produces $N(S_R)$ varieties of intermediate goods which require and average of $\tilde{N}(S_R)$ efficiency units of labor for modification. The firm sells its goods at an average price of $\frac{\omega}{\theta} l\left(\tilde{N}(S_R)\right)$. Rewriting the zero profit condition for Y, given the optimal behavior of intermediate firms and the equilibrium distribution of active management teams, equilibrium in the goods market must satisfy

$$\omega = \frac{\mu}{2}^{\frac{1-\theta}{\theta}} \theta \left[\tilde{N}(S_R)\, l\left(\tilde{N}(S_R)\right)^{\frac{\theta}{\theta-1}} + \tau^{\frac{\theta}{\theta-1}} \tilde{N}(S_R^*)\, l\left(\tilde{N}(S_R^*)\right)^{\frac{\theta}{\theta-1}} \right]^{\frac{1-\theta}{\theta}}. \quad (35)$$

8.5 Full Equilibrium

The closed economy is in full equilibrium when both labor markets and goods markets are in equilibrium. A matching equilibrium occurs at the intersection of the entry condition in (31) and the median indifference condition in (32), as in Figure 2.2. Given the distribution of active firms and management teams the labor market and goods markets are in equilibrium when both (33) and (35) are satisfied. For given factor endowments λ and μ, an equilibrium is a unique efficiency wage, unemployment rate and a median skill level. The median skill level implies a certain profile of firms that can be summarized by a representative skill level. Figure 2.3 illustrates the equilibrium in the goods and labor markets.

9 Trade

9.1 Liberalization and Adjustment in Production

Regardless of the trading opportunities of an economy labor must be deterred from shirking in order for production to take place. Changes in trade costs have no impact on the labor market equilibrium conditions. However the equilibrium conditions for the intermediate product and final goods markets in (35) are dependant on the level of trade costs. Lower variable costs result in lower costs of imported intermediates and, because of selection into export markets, a greater number of foreign intermediates available for domestic production. Both act to lower production costs of the final good. Zero profits in the final good sector are restored only by an increase in labor wages. The shift in the goods market equilibrium condition resulting from trade liberalization is illustrated in the second diagram in Figure 2.4.

The new equilibrium occurs where the shifted GG curve and LL curve intersect. Holding managerial matches fixed liberalization increases the skill level of the management team at the representative firm. The increase in average labor productivity for a fixed set of employed managers has two potential sources: a greater share of production is taking place at firms who hire superior management teams, or firms have dropped fringe product lines which are produced less efficiently. In fact, both occur as a result of trade liberalization.

Lower trade costs increase foreign demand for the varieties exported by domestic firms, causing these firms to expand the scale of production. The introduction of more foreign intermediates into the domestic market lowers the relative demand for the varieties produced by non-exporters, who respond by contracting the scale of production. Because the most efficient firms are those which export, the result is a larger share of production taking place at firms with better management.

Adjustments to production also occur within each firm, even without changes in management. Higher labor wages reduce the profitability of all product lines for both exporting and non-exporting firms. Non-exporters drop marginal varieties that are not profitable in the face of foreign competition and higher labor wages. Exporters are also induced to shed products in the face of higher labor costs, even though liberalization induces firms to export a larger fraction of the varieties it produces.

As these firms drop the products that they make with the least efficiency, average labor productivity rises. The next proposition summarizes the findings on the effect of trade on the nature of production.

Proposition 7 *Holding fixed the set of managers employed, trade induces an increase in average productivity both across firms and within firms. After liberalization a larger share of production takes place at the most efficient firms and all firms devote a larger share of resources to the production of varieties in which they are most efficient.*

9.2 Liberalization and Labor Market Outcomes

Production of the final good is less costly in an open economy. An increase in the real wage eases the efficiency wage constraint, and together with the fact that a representative firm has greater productivity, firms demand more labor. Increased demand bids up nominal labor wages, further benefiting labor. Besides better compensation when working, spells of unemployment are shorter. At a higher real wage the opportunity cost of being caught shirking is much higher. So firms can hire more labor and feel confident that laborers will exert themselves during production. Hence all laborers benefit from higher wages and lower unemployment, as in Matusz (1996).

9.3 Liberalization and Adjustment in Management

Trade Liberalization causes a reallocation of production towards firms which employ better managers. Smaller market shares and higher wages force the least productive management teams out of the industry altogether. The breakup of low skilled teams causes a change in the matching outcome in the entire manager market. The lowest skilled managers can no longer find partners and become unemployed. But their high-skilled counterparts seek out new matches, accepting low skill intensity positions if they must. The small group of managers now willing to accept low skill positions causes every other manager to rethink their current partnership.

Equilibrium in the manager market in a median matching regime occurs when entry is rational and the median manager is indifferent between a low-skill and high-skill intensity position given her potential matches. The equilibrium condition on entry shifts up when trade is liberalized because at higher wages better management is needed to survive. The level of trade costs also has an impact on the incentive compatibility constraint for the median skill level. Better export opportunities increase the operating profits from participating in international markets. Furthermore lower market shares for domestic firms reduce the incentive to accept low skill partners. Each of these incentives cause the equilibrium condition on the median manager in equation (32) to shift up. The size of the shift in the incentive compatibility constraint is larger than the shift in the entry condition because it accounts for both higher wages and better export opportunities. The first diagram in Figure 2.4 shows the unambiguous effect of trade on the matching outcome in a median matching regime.

Lower trading barriers cause matches to become more positively assorted. The managers with skill above the median level obtain partners ordered higher in the skill distribution, while lower skilled managers (if still employed) must accept partners lower in the skill ordering. Those with skill slightly above the initial median level obtain better partners, but switch to low skill intensity jobs, per the incentive compatibility constraint on the median manager. By accepting the low skill intensity job they gain access to foreign demand and avoid unemployment. The managers with the lowest skill continue to exit the industry and the remaining managers continue to reform teams until equilibrium is restored. The effect of trade on the median matching outcome is depicted in Figure 2.5.

Each manager's skill level is fixed, so when one firm shuts down the managers who remain above the median skill level obtain a partner who is the next highest in the ordering of skill to her initial partner. However the cardinal change in skill depends on the overall distribution of managerial ability. The next potential partner could have significantly more skill than the pre-liberalization partner, or could have exactly the same skill level if there are many identical managers. Because of complementarity of skill in production, more positively assorted matches result in higher average productivity.

In a peculiar case, where more than half of the set of managers have identical ability with at least some managers of greater skill, trade results in a change in matching outcomes that produces results akin to Melitz (2003). With endogenous matching, trade liberalization results in the top skilled managers finding partners that are ordered higher in the skill distribution. But if there is no difference in their partners' cardinal ability[27], then there is no change in the skill of the management teams which are active in equilibrium both pre- and post-liberalization. Yet trade improves overall productivity by driving the least efficient firms out of the industry and allowing the most efficient firms to expand production.

In the previous section the effect of trade liberalization on the share of production taking place at the most productive firms, and the level of diversification within firms, leads to an equilibrium in which the representative firm appears to be managed with greater skill. Now considering the general equilibrium adjustment to trade, all firms still operating are in reality managed by higher skilled teams. Endogenous adjustments to matching in the manager market, and the resulting distribution of firm productivity, might overturn previous conclusions about the effect of trade on firm scale and scope reported in Proposition 1, as well as in Bernard, Redding and Schott (2006), Nocke and Yeaple (2006) and Eckel and Neary (2008). The partial effect of trade is to rationalize production both across firms and within firms. However the change in the initial formation of firms causes matches to occur between partners with more similar skill levels. Better management leads to greater diversification, even when trade reduces the profitability of marginal product lines.

To this point I have discussed the effect that trade has on the matching outcomes holding the behavior of managers constant. Specifically I have assumed that a median regime occurs in equilibrium because of every manager's preference to obtain a high-skill intensity position regardless of export opportunities. Depending on the skill distribution, lower trade costs might cause managers to reprioritize and seek participation in international markets, no matter the skill intensity of the job obtained. When the behavior of managers changes, the entire matching regime shifts.

Although the matching regime sustained in equilibrium depends on the underlying distribution of managerial skill, the impact of trade on the matching regime (if any) is clear. The firms that are able to export are those that have the best management teams. So if managers change their behavior, their preferences will always shift toward higher skilled partners, rather than skill intensive jobs. Managers will be more positively assorted and the complementarity of skill in production implies that the new regime will lead to a population of firms with higher average productivity. Davidson, Matusz and Shevchenko (2008) show in a search environment that free trade can change the behavior of workers so they begin to reject less efficient technologies. Their result is similar to shifts in matching preferences but only accounts for two worker types, rather than a continuum of skill levels.

To compare changes in matching outcomes within a regime to shifts across matching regimes consider how each affects the ordinal differences in the skill of the partner matched with the highest skilled manager, $\overline{S}$. Looking within a regime, the exit of a single firm allows her to match with the manager who has the next highest skill of her previous partner. But a change in preferences towards export opportunities increases the desire of others to match with a manager with high skills such as $\overline{S}$. The shift in preferences works to her advantage and she may be able to obtain a match with a manager ordered several places higher than her pre-liberalization match. Marginal adjustments in matching outcomes within a regime, and regime shifts due to matching behavior, have the same qualitative result: active management teams with higher average productivity. Although, changes in matching regimes induce a much greater reallocation of resources. The next proposition summarizes the effect of trade on the formation of management teams.

Proposition 8 *Lower trade costs cause management teams to be more positively assorted and thus raise aggregate productivity. The impact of trade is much larger if managers change their behavior and prioritize export opportunities over job type.*

The rationalization of matches between manager leads to changes in the distribution of firms that is consistent with the evidence. As demonstrated in Head and Ries (1999), the number of firms active after trade liberalization falls, and the remaining firms are larger on average. Furthermore Nocke and Yeaple (2006) show that the shape of the distribution of firm productivity changes as the world economy becomes more integrated. Specifically they show that the distribution of firm sales within U.S. industries have become less skewed as trade costs have fallen, i.e. the largest firms do not lie as far ahead of their competitors when operating in industries with more trade exposure. Nocke and Yeaple also consider multi-product firms in their explanation of the "globalization-skewness puzzle". Yet their model predicts a negative correlation between a firm's scale and scope. Bernard, Redding and Schott (2006) find a positive relationship between a firm's extensive and intensive margins when looking at US manufacturing.

Adjustment in firm management across the industry has far reaching consequences for the distribution of firm productivity. Furthermore a reduction in the skewness of the productivity distribution is consistent with adjustments to matching outcomes in a median matching regime for many common skill distributions. When the median of the skill distribution lies near a mode, the top managers will match with a commonly occurring skill type. Globalization allows the top managers to begin matching with those ordered higher in the skill distribution. But with so many potential matches with similar skill levels, the top managers enjoy only modest gains in the cardinal ability of their partners.

The managers who lie above the median skill level, but not at the top of the skill distribution, will also match with managers ordered higher in the skill distribution. The increase in their partners' cardinal abilities will be much greater because they were matched will less commonly occurring skill types. The most productive firms are those that employ the best managers. Since these firms experience only modest gains in productivity from increases in matches, relative to less efficient firms, trade liberalization initiates a shift in the distribution of firm productivity that is less skewed, as in Nocke and Yeaple (2006).

9.4 Liberalization and Wage Inequality

9.4.1 Inequality across Skill Levels

There are two reasons that trade costs affect the income distribution within a particular matching regime. First, trade liberalization causes a reallocation of production towards the best management teams. The increase in the relative demand for the managers who export changes the distribution of income. Second, the formation of management teams is affected by trade costs. Each manager's compensation depends on the skill of her partner, so changes in matching outcomes also affect the income distribution. The full response of wages to trade depends on the joint responses along these two avenues.

Better export opportunities increase the operating profits for firms efficient enough to access foreign demand. However increased foreign competition reduces the relative demand for intermediates produced by non-exporters. The wages paid to the best management teams increase relative to wages paid to non-exporting teams. In a median matching regime teams are formed by heterogeneous managers. Thus relatively higher wages paid to exporting teams are not concentrated among a conjoined skill group. The highest skilled workers above the median join with the highest skilled workers below the median and engage foreign markets. Holding matches constant, the least skilled managers who are still above the median (these are the managers with skill intensive positions at non-exporting firms) are harmed by trade, even though managers with less skill gain. The next lemma summarizes the effect that trade has on the income distribution via the reallocation of production across firms.

Lemma 1 *Trade causes a reallocation of production across firms. The effects on the income distribution is for some managers above the median skill level to lose, while some below the median will gain. Furthermore the most skilled managers, who obtain skill intensive positions at exporting firms, gain relative to all other managers.*

As some firms drop out of the industry each manager rethinks her current partnership and the result is a new matching outcome that is more positively assorted. Any manager who still obtains a high-skill intensity job after a reduction in trade costs will be matched with a higher skilled partner. Likewise, all managers with low-skill intensity jobs will have lower skilled matches than their pre-liberalization partner. The subsequent impact on wages is clear. Better matches result in better wages.

Lemma 2 *The effect of changes in the matching outcome due to trade liberalization is that the top of the skill distribution benefits from better matches, while the bottom half of the distribution loses.*

In order to describe the total impact of trade on the income distribution in a median matching regime there are four classes of skill to consider; managers are divided by the median skill level and a threshold separating non-exporters from exporters on either side of the median. Of course these partitions are determined endogenously, but considering the impact of trade within each class of skills is a convenient way to expose the impact of trade on wage inequality. The overall effect is derived from the combination of the previous two lemmas.

The most skilled workers, above the median and export threshold, benefit from trade because of both better matches and greater demand for their exported products. Those managers above the median skill level who do not export are harmed by foreign competition and decreased market share, but they do benefit from better matches. The net effect on the real wage of managers above the median who do not export is ambiguous. However, their wage definitely decreases relative to those at the top of the skill distribution.

Managers below the median have low skill intensity positions. If they are employed by an exporting firm, then greater export opportunities tend to increase their wages. However the rationalization of matches lowers their wages. Again, the net effect on the wages of exporting managers in low skill intensity positions is ambiguous; depending on trade-off between higher export profits and matching with a lower skilled partner. Their wage decreases relative to the top of the skill distribution necessarily. Finally, the least skilled managers are harmed by trade both because of decreased demand for their products and because of worse matching outcomes. Trade harms the lowest skilled managers in terms of their real wage. Altogether the effect of trade on the income distribution is stated in the next proposition.

Proposition 9 *Trade increases overall income inequality. In terms of the real wage, the least skilled managers lose, the most skill managers gain, and the impact on those with moderate skills is ambiguous. Yet all managers lose relative to the top of the skill distribution.*

An interesting result is the likelihood that a manager benefits from trade is not necessarily increasing in her skill level. If adjustments in matching outcomes are small then managers with skill intensive jobs who do not export are likely to oppose trade liberalization, while some workers with less skill would support freer trade. Individual trade preferences depend on both the characteristics of the individual manager and with whom she works.

Clearly the response of matching behavior to trade liberalization is an important avenue for productivity gains and the shape of the skilled wage distribution. If trade initiates a shift in the matching regime towards one that is further segregated, wage inequality increases much more drastically. As higher managers begin to accept low skill positions, export profits are concentrated among only the highest skilled managers. Lower skilled managers are more likely to be excluded from export profits because of relatively lower skilled partners. Whether due to changes in matching outcomes or matching preferences, trade initiates a change in the skilled distribution toward one that is more unequal. Changes in the behavior of managers cause larger shifts.

9.4.2 Inequality within Firms

The previous discussion of wage inequality was concerned with wages across skill levels. Trade also causes changes in the relative wages within firms. As trade changes the operating profits of a particular firm, those gains and losses would be distributed across management teams. However the composition of managerial teams changes as trade costs are reduced. Within a particular matching regime globalization leads to matches which are more positively assorted. Furthermore, if trade induces a change in matching behavior, a new regime emerges in which all managers prefer higher skilled partners. In either case management teams form between managers with more similar skills. As a result within firm wage inequality falls. The impact of trade on the income distribution described here, with higher wage inequality across firms and skill levels within industries but less inequality within firms, is consistent with Dunne *et al.* (2004).

10 Conclusion

Worker behavior has far reaching consequences for production and labor market outcomes in general equilibrium. The choices of laborers to provide effort shape firm organizational design and lead to unemployment. The decision of managers to match is a key determinant of industry organization. With self-selection of firms into export markets, endogenous formation of management teams can be an important avenue for trade adjustment.

A reduction in transportation costs enlarges markets for only those firms productive enough overcome trade costs. As a result worker preferences for job type become secondary to securing export status. Even the managers who have no hope of engaging foreign consumers place less value on obtaining a particular job type, because the alternative may be unemployment.

Modeling worker behavior is challenging technically, but the implications of trade exposure for firms and workers may run opposite. Traditionally trade is thought to cause agents to lean down and become more competitive. For firms this may mean paring down the scope of activities that take place with its boundaries. For workers this means dropping low ability partners, leading to better performing teams. The partial incentive of firms to specialize may be eclipsed by improvements in team formation.

Chapter 2 Appendices

Appendix A-Task Assignment of Heterogeneous Managers

The optimal strategy of a firm that hires mangers with two different skill levels is to assign the more skilled manager to the task that uses her skill most intensively. The function of each manager is to improve labor productivity in the performance of a specific production task. So the intensity with which a managers skills are used depend on both the increase in each laborer's efficiency in performing the requisite task and the amount of labor benefiting from skilled oversight. I define the more skill intensive task to be the one that has the higher percentage increase in labor productivity from additional skill, weighted by the unit labor requirement. That is, the assembly task is more skill intensive for a firm that produces N varieties of intermediates, with an average requirement of $\widetilde{N}$ efficiency units of labor for modification activities, if

$$\frac{1}{f(s)}\frac{f'(s)}{f(s)} > \frac{\widetilde{N}}{m(s)}\frac{m'(s)}{m(s)}. \tag{A.1}$$

Note that the modification task is more likely to be skill intensive at a firm that produces a greater number of products (RHS is increasing in $\widetilde{N}$). As intuition suggests, a firm that produces a greater range of products will devote more labor to modification activities. So, even if the modification task is relatively easy ($\frac{m'(s)}{m(s)}$ is low) there may be a large amount of labor that benefits from managerial skill. Another key feature of condition A.1 is that given the skill of each manager, product market characteristics influence task assignment; the reason being that N is chosen endogenously. As firms change their product scope and scale the ranking of the skill intensity of each task might reverse. Therefore a manager may be reassigned to different tasks when her employer adjusts its scope, even when the skill of her partner remains constant.

Given this definition of skill intensity it still remains to be shown that the optimal strategy of a firm is to assign the more able manager to the skill intensive task. To do this I will show that operating profits increase more from a marginal improvement in the skill of the manager assigned to the skill intensive task. Without loss of generality assume that the assembly task is more skill intensive given firm scope; this is the condition in A.1.

The operating profits of a firm that hires two managers of skill s are $\pi(s,s) = \int_1^{N(s,s)} [p(n) - \omega l(n)]\, x(n)dn$. Exporting profits are omitted without effect. After substituting the optimal price charged by firms and consumer demand, the increase in profits from a marginal increase in the skill of the assembly manager is

$$\pi_2(s,s) = \int_1^{N(s,s)} C(\overrightarrow{P},Y)\omega^{\frac{\theta}{\theta-1}} \left[\frac{n}{m(s)} + \frac{1}{f(s)}\right]^{\frac{\theta}{\theta-1}-1} \frac{f'(s)}{f(s)^2} dn \tag{A.2}$$

and the increase in operating profits from a marginally more skilled modification manager is

$$\pi_1(s,s) = \int_1^{N(s,s)} C(\overrightarrow{P},Y)\omega^{\frac{\theta}{\theta-1}} \left[\frac{n}{m(s)} + \frac{1}{f(s)}\right]^{\frac{\theta}{\theta-1}-1} \frac{m'(s)\,n}{m(s)^2} dn. \tag{A.3}$$

Firms will assign the more skilled worker to the skill intensive task (assembly task by assumption) if doing so generates more profits. Averaging across all product lines the criterion is

$$C(\overrightarrow{P},Y)\omega^{\frac{\theta}{\theta-1}} \left[\frac{\tilde{N}}{m(s)} + \frac{1}{f(s)}\right]^{\frac{\theta}{\theta-1}-1} \frac{f'(s)}{f(s)^2} >$$
$$C(\overrightarrow{P},Y)\omega^{\frac{\theta}{\theta-1}} \left[\frac{\tilde{N}}{m(s)} + \frac{1}{f(s)}\right]^{\frac{\theta}{\theta-1}-1} \frac{m'(s)\,\tilde{N}}{m(s)^2}$$

or

$$\frac{1}{f(s)}\frac{f'(s)}{f(s)} > \frac{\tilde{N}}{m(s)}\frac{m'(s)}{m(s)}.$$

Q.E.D.

Appendix B-Equilibrium in a Median Matching Regime

A matching equilibrium occurs in a median matching regime when entry (Φ_1) is rational and the median manager's incentive compatibility constraint (Φ_2) is satisfied. The equilibrium conditions are

$$\begin{aligned}\Phi_1 &\equiv \int_0^\infty \exp(-bt)\Pi(S_L, S_M)\,dt - F = 0 \\ \Phi_2 &\equiv W_m\left(S_M, \overline{S}\right) - W_f(S_L, S_M) = 0\end{aligned}$$

First, the implicit function theorem verifies that both conditions are downward sloping; $-\frac{\partial\Phi_1/\partial S_M}{\partial\Phi_1/\partial S_L} < 0$ and $-\frac{\partial\Phi_2/\partial S_M}{\partial\Phi_2/\partial S_L} < 0$. Then the equilibrium defined by Φ_1 and Φ_2 is unique only if one condition is everywhere steeper than the other. I will show that Φ_1 always more steeply sloped.

From Appendix A we know that

$$-\frac{\partial\Phi_1/\partial S_L}{\partial\Phi_1/\partial S_M} = -\frac{\pi_1(S_L, S_M)}{\pi_2(S_L, S_M)} > -1 \tag{B.1}$$

Now substituting the managerial compensation function into condition Φ_2 we obtain

$$\begin{aligned}\Phi_2 = \frac{1}{2}\{\pi(0, S_M) + \pi(S_L, S_M) - \pi(S_L, 0)\} \\ - \frac{1}{2}\left\{\pi(S_M, 0) + \pi\left(S_M, \overline{S}\right) - \pi\left(0, \overline{S}\right)\right\}.\end{aligned} \tag{B.2}$$

and using the implicit function theorem to derive the slope of Φ_2 we have

$$-\frac{\partial\Phi_2/\partial S_L}{\partial\Phi_2/\partial S_M} = \frac{-\left[\pi_1\left(S_L, S_M\right) - \pi_1\left(S_L, 0\right)\right]}{\pi_2\left(0, S_M\right) + \pi_2\left(S_L, S_M\right) - \pi_1\left(S_M, 0\right) - \pi_1\left(S_M, \overline{S}\right)}. \qquad \text{(B.3)}$$

From B.1, Φ_1 is every where more steeply sloped than Φ_2 only if the equation in B.2 is greater than -1, which is easily verified.

$$\begin{aligned}
&\left[\pi_1\left(S_L, S_M\right) - \pi_1\left(S_L, 0\right)\right] + \\
&\qquad\left[\pi_2\left(S_L, S_M\right) - \pi_2\left(0, S_M\right)\right] + \\
&\qquad\qquad\left[\pi_1\left(S_M, \overline{S}\right) - \pi_1\left(S_M, 0\right)\right] > 0.
\end{aligned}$$

Q.E.D.

Notes

[15]JEL Classifications: F16, L23, J21

[16]The term "partial-partial equilibrium" was coined by Rothschild (1973) as quoted by Davidson and Woodbury (2002)

[17]Davidson, Matusz and Shevchenko (forthcoming) contains a similar feature where heterogenity obtains from endogenous technology choices and exogenous worker-firm matches. Also in Yeaple (2005) heterogenity is the result of exogenous skill differences and endogenous technology choice.

[18]Production requires at least one manager to be hired. A single manager can apply her skills to only one production activity. In the absense of a manager specifically assigned to either task each laborer contributes his single efficiency unit of labor, i.e. $m(0) = f(0) = 1$.

[19]See the appendix for a discussion of skill intensity of the tasks.

[20]As will be shown, firms will always recruit managers of different skill in equilibrium.

[21]Firms cannot strategically choose scope or price to attract a particular management team. Free entry means that managers who are not working for firms selecting price and scope based on (23) and (24) could be poached by entering firms that can offer better compensation.

[22]This is not the same condtion as supermodularity of the profit function, even though it is a direct result of it.

[23]For a discussion of matching regimes see Legros and Newman (2002) and (2007).

[24]I assume an equal measure of workers on either side of the median, each including a median-skilled worker.

[25]Firm destruction leads to labor/firm break up. Labor takes this probability into account when making the decision whether or not to shirk. See the asset value equations for labor in the previous section.

[26]Unemployment of managers is ignored as they are small relative to the entire workforce. The set of managers who are not employed is determind endogensously and is given by $\int_0^{s_L} \mu dG(s)$.

[27]For managers with the same cardinal ability the ordering is arbitrary.

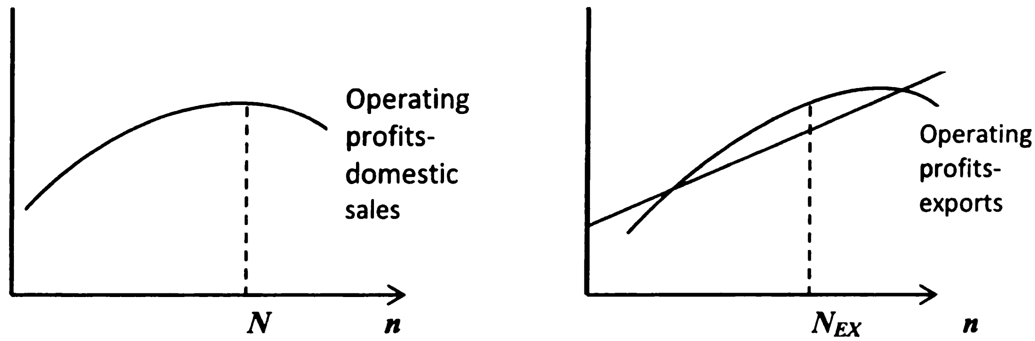

Figure 2.1: Firm Product Scope and Extensive Export Margin

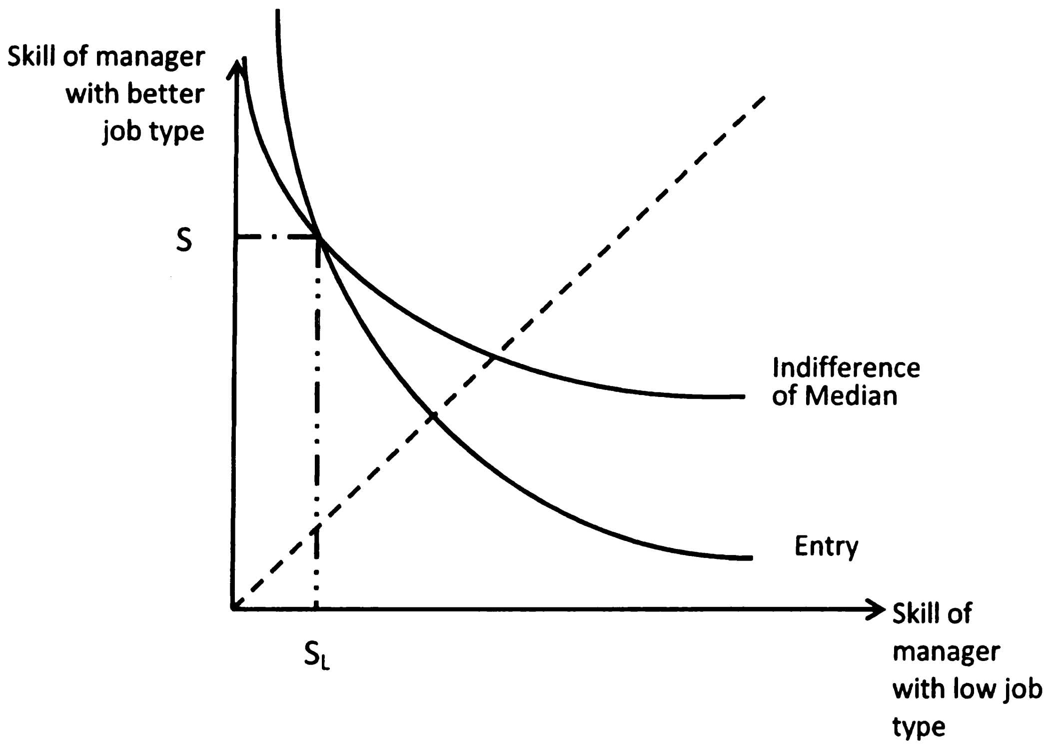

Figure 2.2: Determination of Employed Managers and Task Assignments

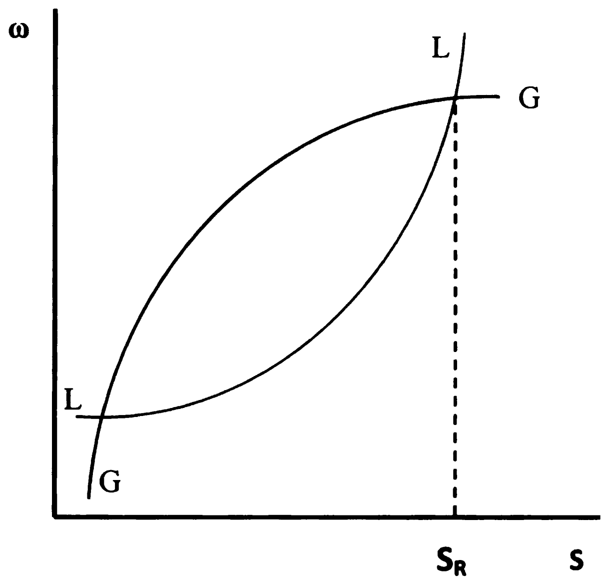

Figure 2.3: Labor Market Equilibrium

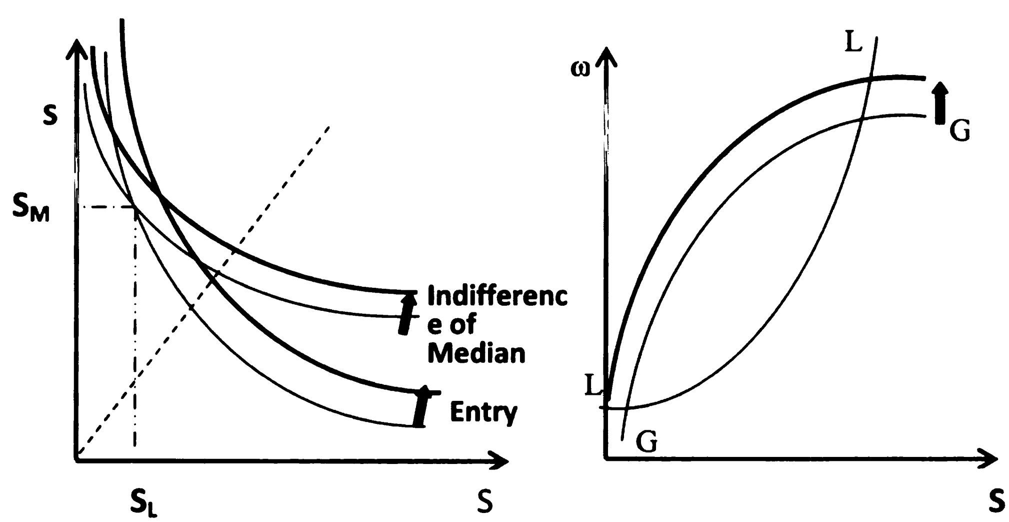

Figure 2.4: Effects of Trade Liberalization

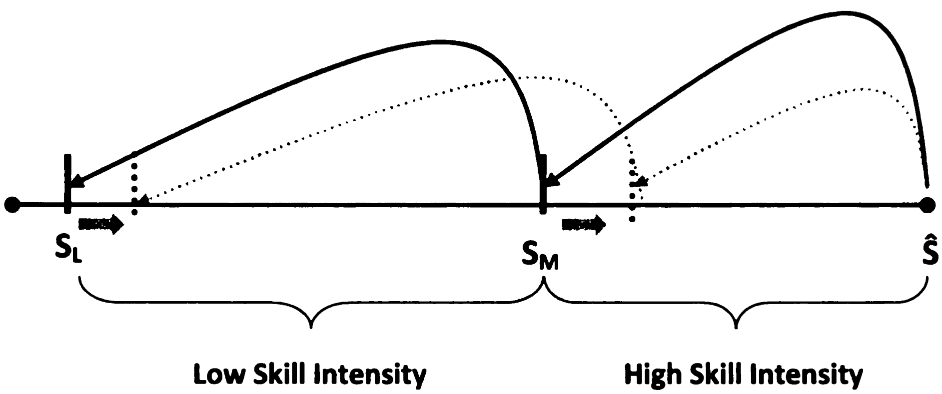

Figure 2.5: Adjustments in Matching Outcomes within a Median Matching Regime

Chapter3
HOV and the Distributions of Factor Endowments

ABSTRACT: The shape of the distribution of labor endowments impacts aggregate productivity when markets fail to organize labor effectively. Variation in the level of dispersion in labor endowments across countries lead to Ricardian productivity differences. These productivity differences impact the pattern of comparative advantage that arises from relative factor supplies. Using information about the overall shape of labor endowments, rather than just cumulative levels, improves the ability of the HOV model to predict the pattern of world factor trade. Countries export their abundant factors as long as they can organize labor effectively. However, estimating unexplained international productivity differences better accounts for the volume of world factor trade; a result that could possibly be due to attenuation and omitted variable biases derived from estimating the shape of labor endowments.

11 Introduction

Heterogeneity, or diversity, in endowments influences aggregate productivity when labor fails to organize effectively. In countries with diffuse distributions of labor ability the cost of poor organization can be severe. An endowment with relatively more workers with different levels of ability increases the potential for poor matching and productivity losses. As a result countries with relatively large supplies of labor may not posses comparative advantage in labor intensive goods when high levels of dispersion erode productivity. If all countries have inherent problems organizing labor the pattern of comparative advantage that arises is determined by the entire shape of labor endowments, rather than just the cumulative mass of labor which reside across borders.

I present a simple model with complemetarities between labor ability in the production process so that an allocation of labor into teams with self-matching is the most productive. That is, all teams should be comprised of workers with identical ability. The production process is divided into two labor tasks, one more difficult than the other. Performing the more difficult task is more important to the production process. As team members negotiate over wages after production, the worker who performed the more difficult task is in a stronger bargaining position, and thus earns a discretely higher wage. Laborers pursue the wages guaranteed by better task assignments by sacrificing match quality. Every worker is willing to accept marginally less skilled partners for discretely higher wages associated with good assignments. The behavior of individual workers causes the labor matching market to fail to deliver the most productive allocation in all countries. Productivity differences across countries and the pattern of comparative advantage depend on the severity of the matching market failure.

Greater dispersion in labor endowments creates the potential for large productivity losses; the realization of such losses is dependant on the vigor with which labor pursues good task assignments. I derive two types of results that predict the impact of dispersion on total factor productivity. First, if preferences for particular assignments are very strong (i.e. wages differ significantly across tasks) then very poor matches will be consummated. As a consequence, countries with larger amounts of dispersion will exhibit lower productivity. I call this the Matching Outcome Effect. Consider an example where the production of T-shirts requires one worker to supervise production and a second worker to advertise the shirts for sale to retailers. Suppose that the production manager is more vital to the operation. All else equal workers prefer to be hired as production managers, even if that means being matched with a slightly less skilled advertiser. In countries that have relatively more high skilled production managers and relatively more low skilled advertisers, aggregate productivity will be lower. There will be too many workers chasing the benefits of the good task assignments instead of productive matches.

The second prediction concerns individual matching behavior when the workers do not favor task assignments strongly over quality partners. Again in countries with high levels of dispersion there is greater potential for large mismatches. But, if preferences for job types are relatively weak then individuals are not willing to accept very poor matches. In this case workers prefer to be part of the best team rather than be the star of a mediocre team. I refer to this as the Matching Regime Effect. Using the example of production managers and advertisers, there may be some workers who can find employment as production managers but only by matching with very poor advertisers. In that case the production managers is entitled to a larger share of a very small amount of profit. Instead it might be optimal to seek employment as an advertiser with a more profitable firm.

These seeming contradictory implications of dispersion hinge in the relative benefits of task assignments and potential match quality. I find that in those countries with relatively low levels of dispersion the first effect dominates. Higher dispersion erodes average factor productivity in countries with still relatively tight endowments of labor ability. Among countries with very high levels of dispersion, those with most heterogeneity exhibit the highest productivity as the Matching Regime Effect dominates. Among the possible shapes of labor endowments the optimal level of dispersion is zero, yet those countries with already high levels of dispersion may be willing allow human capital accumulation to be concentrated among a small class of workers as doing so would increase their productivity.

With the estimated impact of dispersion on productivity I am able to estimate unit factor requirements across countries. Using trade and production data from the OECD STAN database for 23 countries I measure world factor trade accounting for the different production technologies implied by the different shapes of endowments. Information on the distributions of labor ability across countries are derived from the Barro and Lee (2000) CID database on education attainment. I find that the productivity effects of dispersion explain much of the observed deviations from the HOV prediction. That is to say, countries export their abundant factors, as long as they can organize labor effectively. Furthermore I find that information about the shape of endowments can describe world factor trade patterns just as well as estimated unexplained productivity differences, i.e. estimated Hicks-neutral technology differences. Information about the shape of labor endowments has more difficultly explaining factor trade volumes, although this result could be an artifact of statistical biases that arises because the shape of endowments are measured imperfectly, and features such as skewness are omitted.

Others have suggested that the problem of organizing labor effectively can explain much of international differences in productivity and trade patterns. Clark and Feenstra (2003) find that world trade during the period between 1910 and 1990 is best explained by differences in countries' abilities to use labor and technologies effectively. They argue that easier transmission of technologies and information made the best technologies more readily available the world over, but some countries failed to absorb new technologies as well as others. While Clark and Feenstra infer from trade patterns expected in an HOV environment that differences in the effectiveness of labor are the responsible for cross-country productivity differences, I combine information about both trade and labor endowments to establish a causal link between the organization of labor and aggregate productivity. Adler (2009) demonstrates that even small deviations from optimal matching between firms and workers can lead to large reductions in aggregate productivity. He cites matching frictions and crony capitalism as reasons that matching markets may fail to deliver the most productive allocation and explain international differences in TFP. Li (2001) argues that while long-run productivity growth can only be explained by technological innovation, the cross-section of international productivity differences are largely due to differences in the organization and effectiveness of domestic labor forces. He shows that growth among Chinese factories between 1980 and 1991 is best explained by better organization of labor to tasks and a greater amount of labor effort.

International trade theory has recently begun to explore the role that features of factor distributions, other than aggregate supply, have on trade patterns. Grossman and Maggi (2000) find that the degree of heterogeneity across countries can independently grant comparative advantage in certain sectors. Countries with homogeneous populations specialize in goods with complemetarities in production, and diverse countries specialize in goods that reward individual talent. Similarly Bougheas and Riezman show that differences the distribution of human capital leads to trade between countries with similar aggregate endowments. They focus on the implications of trade based on the shapes of distributions of endowments has on income inequality. In Grossman (2004) imperfect labor contracts provide an avenue for the degree of heterogeneity to influence the pattern of comparative advantage. All of these models consider trade between countries with similar aggregate endowments, abstracting from potential interaction between diversity and aggregate supply. Ohnsorge and Trefler (2007) consider labor who differ along two dimensions, rather than a single attribute such as ability. They provide an excellent analysis of how the joint distribution of worker capacities influences trade patterns and highlight the importance of the cross-correlation between different worker attributes. However they abstract from the impact that variation of individual attributes on international trade patterns[28]. Here my goal is provide an examination of how aggregate supply and the amount of diversity jointly confer comparative advantage, demonstrating the relevance of the Heckscher-Ohlin model in a world with heterogeneity.

In Davidson, Martin and Matusz (1999) the severity of labor market failures determines the pattern of comparative advantage across countries. Search frictions vary across countries and industries so that countries specialize in producing in industries that reflect their relative efficiency of organizing labor during production. Cuñat and Melitz (2007) look to labor market institutions and the degree of flexibility in the labor market to determine the pattern of trade. I introduce a market failure that influences the allocation of labor that is common to all countries and industries. The pattern of comparative advantage is driven by relative factor supplies and the shape of labor endowments, rather than the structure of the labor market.

The most relevant theoretical framework to this analysis is found in Costinot (2009). He provides sufficient conditions on aggregate production functions for factor abundance to translate into comparative advantage. The key is log-supermodularity: it must be that *relatively* more of a particular factor used in production implies *relatively* more output. The matching environment here provides micro-foundations for an aggregate production function based on the formation of teams. His analysis provides a generalized interpretation of my theoretical predictions and empirical findings. If preferences for particular task assignments are strong, then the aggregate production function is not log-supermodular. As a result factor abundance does not necessarily confer comparative advantage. The microeconomic explanation being that poor matches are formed and productivity suffers.

There is of course a long literature which scrutinizes the HOV model theoretically and empirically, uncovering paradoxes and mysteries along the way. The initial wave of research built statistical techniques for examining the validity of the HOV prediction that countries export their abundant factors, each rejecting the model in turn. See Leontief (1953), Bowen et al. (1987), Maskus (1985) among many others. Trefler (1995) was the first to show that the volume of predicted trade is far below predicted levels given relative factor endowment. In a recent contribution Trefler and Zhu (2006) define the factor content of trade in a manner that is both Vanek relevant and consistent with trade in intermediates in and international technology differences. Trefler and Zhu (2000) argues convincingly that the HOV model is still valuable given the need to account for productivity differences, as suggested by Trefler (1993) and Davis and Weinstein (2001).

The next section describes world endowments, production and the trading environment. In section 3 I establish that domestic matching markets necessarily fail when a certain type of job provides a discretely higher wage, all else equal. Section 4 relates the level of dispersion to the costs of market failures in terms of aggregate productivity. I then empirically evaluate the role that dispersion plays in the determining world factor trade. Section 5 describes the data on production technologies, world trade, and the shape of endowments. Section 6 estimates productivity differences across countries and shows that dispersion is able to explain much of the international differences in TFP. Also, the shape of the labor endowments is shown to strengthen HOV predictions of world factor trade. Section 7 concludes.

12 Model

12.1 Production

The world economy is comprised of many countries labeled $1...C$, which each use labor and capital services to produce output in several industries labeled $1...N$. Consumers in all countries have identical homothetic preferences. With free trade in competitive markets every country faces the same prices for each sector given by p_i. Within each industry labor services, l, and intermediate capital goods, k, are combined to manufacture output according to $l^{\beta_i}k^{1-\beta_i}$ for $i = 1...N$. Production in any industry requires both labor and capital (i.e. $\beta_i \in (0,1)\ \forall i$). Furthermore production benefits from (1) the cooperation of labor in the completion of specific tasks and (2) the specificity of capital to the skills of workers. Though self employment is possible, the complementarities that manifest through division of labor allow for more efficient production.

The Vanek prediction is that countries will export a factor if they are abundant in that factor relative to the world endowment. With team production of labor services and intermediate capital goods, the amount of each factor a country uses in production of per unit of output also depends on the organization heterogeneous workers into matches. I will discuss raw factor endowments first and then the organization of teams. Capital is an *ex ante* homogeneous and divisible factor that can be modified to suit the needs of any industry, and the skills of any worker. Total capital endowments K^c vary across countries. Each country's endowment of labor is populated by a mass L^c of heterogeneous individuals who differ according to their ability, a, in performing labor tasks. The distribution of labor ability, given by $G_c(a)$ over the interval $[\underline{a}, \overline{a}]$ for country c, can vary across countries in two ways. Countries may have different different levels of human capital per capita. Also countries can vary according to their level of dispersion about the mean according to the following definition.

Definition 1 *Country i is said to have a more diffuse distribution of human capital than country j (both with mean ability $\widehat{a}$) if $\frac{G_i(a)}{G_i(a')} < \frac{G_j(a)}{G_j(a')}$ for $a > a' > \widehat{a}$ and $\frac{G_i(a)}{G_i(a')} > \frac{G_j(a)}{G_j(a')}$ for $\widehat{a} > a' > a$.*

Variation in the level of dispersion in labor endowments across countries satisfies the monotone likelihood ratio property about the mean. A more dispersed endowment of labor is characterized by relatively more labor with extreme levels of skill above and below the mean. This is a stronger condition that stochastic dominance, as discussed in Costinot and Vogel (2009), because it describes the relative abundance of each level of ability, rather than just the cumulative degree of abundance across abilities.

Team production divides labor services into two distinct tasks with different skill intensity. Laborers with ability a_1 and a_2 combine their effort according to the production function $l(a_1, a_2) = a_1^{\theta} a_2^{1-\theta} + a_1^{\theta} + a_2^{1-\theta}$ with $\theta \in \left(\frac{1}{2}, 1\right)$. When θ is close to 1, a single member of the team carries a large burden during production, while her partner contributes little. As θ approaches $\frac{1}{2}$ production uses each team member more equally. Although the production framework for labor services implies a degree of cooperation between worker, the model is meant to apply generally to circumstances where workers perform their respective tasks in isolation. Consider an example of the retail sale of T-shirts. There is no reason to think that workers who manufacture shirts must interact with advertisers, however they benefit from each others' efforts. Team production need not be interpreted as production by a single economic agent such as a firm. Rather laborers that perform each task should be considered independent utility maximizers who exchange their tasks in a market.

Capital endowments are comprised of raw materials that are *ex ante* homogeneous. To be used in production capital must be transformed into intermediates which are relevant to the skills of each labor team. Forging capital into intermediates is costly; these costs are larger for teams comprised of workers with different levels of ability. Only one design of intermediates is necessary for homogeneous teams. If teammates have different abilities, then capital must be modified further so that both workers can take full advantage. Team members with large differences in their abilities require use more units of raw capital to manufacture relevant intermediates. To be explicit, if one unit of capital is allocated to a team comprised of workers a_1 and a_2 then the amount of intermediate capital goods available for production is $k = 1 - \tau \left| a_1 - a_2 \right|$.

This style of team production has several important features. First, production at the industry level exhibits constant returns to skill. For any industry if the amount of capital employed were doubled and the exact number and composition of labor teams were duplicated, the industry would double its output. The second crucial feature of production is that industry output depends on not only the aggregate amount of labor ability employed in each industry; the matching of workers according to their abilities is an important determinant of productivity. Complementarities in worker skill and the need for intermediate capital goods that are relevant to the skills of workers imply that productivity is the greatest when all workers self-match; that is the labor market is perfectly segregated according to skill.

Third, the total supply of labor services by any pair of workers depends on the task to which each worker is assigned. If matches form between heterogeneous agents[29], then output is maximized when the most able of a pair of workers is assigned to the skill intensive task. Fourth, the design of intermediate goods to be specific to the skills of the workers using them is not meant to imply any sort of bias[30]. Intermediate capital goods are generated at a disaggregated level based on the skills of individual teams rather than the labor market in general.

Based on this (admittedly stylized) production function countries will exhibit greater productivity when domestic markets allocate relatively skilled workers to difficult tasks, and similarly skilled laborers into teams. Poor matching outcomes can erode both labor and capital productivity[31]. Thus the avenue for skill dispersion to influence the factor content of trade to be examined here is the impact dispersion has on the allocation of domestic workers into matches and to tasks. The matching behavior of workers is driven by the desire to earn high wages.

12.2 Labor Wages

Total production is determined by the composition of teams and task assignments of labor. As a result wages are a function of (1) a worker's own ability, (2) partner's ability, and (3) task assignment. Competitive markets, and free trade equalize the price of labor services, ω, across countries[32]. The total payments for labor services must further be divided among the pair of workers. I use the Shapley Value to determine the *ex post* division of surplus as in Hart and Moore (1990) and Acemoglu, Antràs and Helpman (2007). Since payments are made after production occurs, no laborer has a claim to the surplus earned by other teams. During negotiation team members first have a claim to the surplus generated solely by their own actions, and then must divide an surplus that arose from cooperation. Therefore laborers earn the average of their marginal contribution to the production of labor services.

Labor with skill level a, performing a task designated by θ, and matched with a worker of ability $m(a)$ will earn

$$w(a, m(a), \theta) = \frac{1}{2}\omega a^{\theta} + \frac{1}{2}\omega\left[a^{\theta} m(a)^{1-\theta} + (a^{\theta} + m(a)^{1-\theta}) - m(a)^{1-\theta}\right]$$

The first term represents the marginal contribution of a worker with ability a to production when working alone and the second term is worker a's marginal contribution to the team when paired with a laborer with ability $m(a)$. The term $\frac{1}{2}$ is included to average the two terms. Simplifying provides labor wages expressed as

$$w(h, m(h), \theta) = \omega a^{\theta} + \frac{1}{2}\omega a^{\theta} m(a)^{1-\theta} \tag{36}$$

This determination of labor wages exhibits several intuitive properties. First, all else equal a laborer's wage is increasing in her own skill level because higher skill leads to more production. Second, a laborer's wage is increasing continuously in the ability of her partner. A better partner leads to greater output of total labor services from the team, and a greater amount of surplus to be divided. Third wages are discretely higher when assigned to perform the skill intensive task. A worker who is relatively important in the production process contributes more on average, and so extracts more surplus ex post. Fourth, wages are increasing in the market price for labor services ω, since each worker receives a portion of the total surplus to labor services that is to be divided. Larger payments for labor services result in higher wages for both members of the team.

The last feature of wages is that by assuming a structured division of surplus among workers I have assumed the labor market environment to be one of non-transferable utility (NTU). Workers cannot make side payments to each other. The next section discusses the matching of laborers and task assignments. Assuming NTU is not without consequence for the allocation of labor to tasks and into matches.

It is important to keep in mind to style of team production that motivates the assumptions about production and wage bargaining. Although all goods require a pair of specific labor tasks to be completed, there is no reason to think that workers interact, cooperate, are part of a single institution (i.e. firm), or even know the identity of one another. They can simply offer their services, "meet" in a market setting, join with capital and engage in production. The dislocation of laborers geographically within borders, or practically during production reduce the likelihood of side payments. Thus the contractual obligation of laborers to divide surplus according to the Shapley Value is taken as a primitive of the model.

The fact that labor wages increase in ability, partner's ability, the price of labor services, and skill intensity task assignments all seem like plausible relationships. However there is a subtle distinction to draw between the manner by which each component influences wages. Being paired with a high ability worker increases the gross amount of surplus to be divided among a team. So wages are increasing in $m(a)$ and ω because they increase the total size of the pie to which a worker has a partial claim.

On the other hand a worker being more skilled herself, or having to perform the more difficult task, entitles her to a greater share of the payments to the team. Greater ability and good jobs increase the size of the piece of the pie awarded. The next section describes the behavior of workers. This distinction between wage increases via entitlement to a share of a large *sum* of monies versus a larger *share* of the monies divided among the team will be crucial to the endogenous formation of teams.

Workers face a trade-off between obtaining good task assignments and obtaining good matches. A last point before describing the allocation of labor is that even though production with "self-employment" is possible wages are always higher when paired with another worker because of complementarities between skill in production and the division of surplus between team members.

13 Allocation of Labor

Labor is fully mobile across industries, can perform any and all tasks in the economy (albeit with differing success), and form matches voluntarily. Labor services are divisible so that a team could potentially "be employed", or sell their services, in multiple sectors. Given the manner of wage negotiations outlined above, all else equal, each laborer would prefer to match with the highest skill partner, and perform the task that makes the most use of her abilities. However such desires are not feasible. As all workers compete for the best jobs with the best coworkers, many will be crowded out. The allocation of labor has three components (1) the set of workers performing high or low skill intensive tasks, (2) the specific matches between partners, and (3) the allocation of labor across sectors.

13.1 Task Assignment

With heterogeneous labor the assignment of workers across tasks has important consequences for total output. Labor services are produced more efficiently when the most able worker in a match is assigned the more difficult task. When making matching decisions, utility maximizing agents force the allocation of heterogeneous team members to tasks to be the most productive; otherwise they would seek optimal matches elsewhere.

To see this consider a team comprised of labor with abilities a' and a'' with a'

$< a''$. Suppose worker a'' is assigned to the relatively easy task $(1-\theta)$. Now consider a worker with ability $a^* \in (a', a'')$. If worker a^* is matched with a worker of ability greater than a'' then there is potential to for a'' to raid the team as she can offer a better match, and no worse task assignment to the partner of a^*. Both opportunities would benefit the partner of a^* as wages are increasing in partner's ability and task assignment.

If a^* is matched with a worker of ability less than a''there is potential to for a'' to raid the team as she can offer a better match, and no worse task assignment to a^*. Again both would bring higher wages to a^*, and so the raid by a'' would be successful. In either case raiding would be optimal since a'' would obtain a better partner, and thus a better wage. Matches with inefficient task assignments are not stable because the more able member of the team could always find a better match elsewhere. Therefore the following result is obtained.

Proposition 10 *With continuum of labor ability, if teams are comprised of heterogeneous laborers, matches are stable only if the more able member of the team performs the more skill intensive task (denoted θ).*

Laborers face a trade-off between task assignment and match quality. Proposition 1 tells us that the only way to guarantee a better task assignment is to accept a match with a partner who has lower ability. Each laborer must weigh the benefits from efficient production against enhanced bargaining power when considering potential matches. This result has limited scope in that it only describes task assignment between a specific pair of workers, rather than types of labor in each country assigned to each task in equilibrium. At this point all we know is that relatively able labor will perform more difficult task in a stable environment with heterogeneous matches.

13.2 Matching Outcomes

Matching between agents in each industry occurs endogenously, without frictions or costs. Holding task assignments fixed, the wages of all labor are increasing in the ability of their partners. To be more specific the payoff functions for laborers in (1) are supermodular. At an aggregate level labor can be divided into two groups that must have equal measure: workers willing to accept a low skill task, and the workers who obtain high skill intensive task assignments. Supermodularity of the wage function (wage increasing in partner's ability) implies that the pattern of matching between these two groups will be positive assortative matching[33] (PAM). Competition for matches leads high ability workers to match with relatively high ability workers, and low types to match with relatively low types.

This is a one-sided matching context, with labor forming teams based on a single characteristic, ability. However it can be useful to think of it as a two-sided matching problem occurring in two stages. First, laborers decide if they are willing to accept a poor task assignment in anticipation of their match in the next stage. Second, matches form based on the abilities of workers in each group. Without knowing the exact distribution of ability in each country we cannot derive the equilibrium matching pattern in general. This is because we cannot describe the sets of workers within each country willing to accept poor task assignments. What can be inferred from the complementarity of worker abilities in wages is that once the sets of labor willing to be assigned to each task are determined, in the second stage workers will match positively.

Even though an equilibrium in the first stage cannot be derived for arbitrary distributions there are still regularity conditions that must be satisfied for an equilibrium to exist. Such restrictions provide at least some insight about how workers decide which type of task to pursue. First, proposition 1 guarantees that for any pair of workers the most able member of the pair will receive the better task assignment. The most able worker in each country will always perform difficult tasks and visa versa for the least able member in each country. Second, because team production always yields higher wages than self employment, all production occurs in teams. Therefore the measure of workers who choose to perform either task must have equal measure. Third, the properties of the wage function imply the second stage allocation of labor into matches will be positively assorted. Given the many potential matching regimes that can arise in the first stage, it is worthwhile to describe a few examples and the conditions under which they may arise.

13.2.1 Possible Matching Regimes

The most extreme form of positive assortative matching is perfect segregation, or self-matching. In the perfect segregation matching regime nearly every laborer would be paired with one who has the same skill level[34]. Complementarity in production implies that self-matching is the matching regime that leads the greatest aggregate productivity. However perfect segregation cannot arise in equilibrium in the present context because laborers have strict preferences for a particular job type because of the improved bargaining position it guarantees. Consider any homogeneous match in a perfectly segregated matching regime. The laborer assigned to the low skill task could earn a discretely higher wage by matching with a marginally less skilled partner because doing so guarantees a better task assignment (Proposition 1). The continuity of labor abilities ensures there is a marginally less skilled worker performing the low skill task. Moreover, a self-matched worker assigned arbitrarily to the low skill task could obtain a better wage by matching with a higher skilled partner, while still performing the low skill task. With self-matching across all levels of ability, labor who receive poor task assignments will always be able to find either better task assignments or marginally better partners elsewhere. Thus we have the following result:

Proposition 11 *If there is a continuum of abilities in each country, the allocation of labor into matches will be such that all matches form between heterogeneous laborers.*

Propositions 1 and 2 point to the heart of the analysis here. Because of the way labor contracts are written in each country, all individuals are willing to forgo the labor allocation which is most productive at the aggregate level in order to secure private benefits. The matching market fails to deliver the optimal outcome because labor wages only give partial weight to total production. The severity of this market failure in terms of aggregate productivity is determined by how strongly labor will pursue the good jobs. Put differently, the potential productivity losses are greater when labor are willing and able to find poor matches.

Even though the most productive allocation can never be reached, some countries may be able to operate closer to the productivity frontier than others. Total production receives at least partial weight in the matching behavior of labor. At some point the loss in productivity losses of poor match quality becomes so great that labor may begin to accept less skill intensive positions. To see this formally consider the change in wages a worker receives for matching with a less able partner in order to obtain a better task assignment. Define $\frac{\Delta w(\cdot)}{\Delta \theta}$ as the private benefit of pursuing a better task assignment.

$$\frac{\Delta w\left(\cdot\right)}{\Delta\theta} = w(a, \widetilde{m\left(a\right)}, \theta) - w(a, m\left(a\right), 1-\theta) \tag{37}$$

where $\widetilde{m\left(a\right)}$ is the match that a worker of skill a obtains if he finds a job performing the skill intensive task. A worker would only choose to reject a good match and take high skill task assignment if this expression were positive. Substituting the expression for wages into (37) yields

$$\frac{\Delta w\left(\cdot\right)}{\Delta\theta} = \left[\omega a^{\theta} + \frac{1}{2}\omega a^{\theta}\widetilde{m(a)}^{1-\theta}\right] - \left[\omega a^{1-\theta} + \frac{1}{2}\omega m(a)^{\theta}a^{1-\theta}\right] \tag{38}$$

Clearly the gain from switching to a better task assignment is smaller as the ability of the match one obtains by switching is lower; $-d\,\frac{\Delta w(\cdot)}{\Delta\theta}/dm(a) < 0$. As match quality deteriorates $\frac{\Delta w(\cdot)}{\Delta\theta}$ will eventually become negative, and labor will no longer reject good matches for the sake of good task assignments. As more more groups of abilities experience negative values of $\frac{\Delta w(\cdot)}{\Delta\theta}$ the matching regime will be characterized by more segregation.

By way of example consider a worker who has the choice of being hired as a production manager, the skill intensive task assignment, but only by pairing with a low ability advertiser. The performance of the advertiser could be so poor that the production manager would rather given up her job and match with a better partner, even if that means becoming a advertising executive herself.

The opposite extreme of perfect segregation is a pattern called median matching. This occurs when all labor in the industry are willing to sacrifice match quality to obtain good task assignments. That is, better task assignments lead to higher wages for all potential matches ($\frac{\Delta w(\cdot)}{\Delta\theta} > 0$ for all a). More intense competition for task assignments comes at the cost of match quality. Thus median matching is the least productive allocation of labor into matches. In equilibrium only half of laborers can actually obtain the better of the two assignments, as the measure of workers performing either task must be equal. Proposition 1 dictates that those above the median skill level will perform the more difficult tasks and visa versa. The matching regime will still exhibit positive assortative matching between those assigned to either task. Hence labor will match positively across the median. The most able laborer in each country will match with the most able person willing to accept the low skill task assignment: this is the median skilled laborer as everyone at or below the median is crowded out of high skill task by more able labor.

In the next section we will derive in impact of greater dispersion in a country's skill endowment on match quality. Dispersion influences matches in both stages of the matching game by first influencing the set of workers willing to accept each task assignment, and second influencing the pair of abilities that form matches holding labor assignments to tasks fixed. I will refer to the impact of dispersion on the range of workers assigned to each task in the first stage as the *Matching Regime Effect* and the impact of dispersion on the specific pair of abilities that form teams in the second stage as the *Matching Outcome Effect.*

13.3 Allocation across Industries

Labor services are employed by all industries. The market for labor services clears when there is zero excess demand ($z_i(\omega)$) in all industries at price equal to ω. The last equilibrium condition that must be satisfied is full employment of labor services. Note that this is not necessarily the same as full employment of labor; constant return to scale in the production of labor services, and no barriers or frictions in the labor market, ensure that full employment of labor will be obtained. Define $I(\cdot)$ as an indicator function that equals 1 if its argument is an laborer who obtains a skill intensive task assignment and zero otherwise. The industry-level and country-level equilibrium conditions are respectively

$$\begin{aligned} z_i(\omega) &= 0 \text{ for industries } i = 1...N \\ L^c &= \int_{\underline{a}}^{\overline{a}} I^c(a) \left[a^\theta \widetilde{m(a)}^{1-\theta} + a^\theta + \widetilde{m(a)}^{1-\theta} \right] \end{aligned}$$

14 Distribution of Labor

Positive assortative matching is an ordinal mapping of labor performing either task to one another. Aggregate productivity depends on the cardinal abilities of workers who form matches. Therefore the overall distribution of labor ability has first-order implications for productivity by either influencing the matching regime which arises in equilibrium or influencing the matching outcomes within a particular regime.

14.1 Dispersion & Matching Outcomes

Recall that dispersion as given in definition 1 is identical to imposing likelihood ratio dominance about mean. In a country with a more diffuse distribution there are increasingly more workers with abilities away from the mean. Consider any worker with above average ability. In a country which has a more dispersed endowment of labor there are relatively more workers with even greater ability. That is to say relatively able labor who are native of countries with diffuse labor endowments face more intense competition for the best matches. Holding task assignment fixed, each laborer above the mean is ordered lower when ranked according to ability against others performing the same task. Positive assortative matching then implies that the matches obtained by above average workers in diffuse countries are less than or equal to the quality of matches in countries with relatively tight labor endowments. The implication for productivity is given in the following lemma.

Lemma 1 *Holding task assignments fixed, labor with above average ability will form less productive matches in countries with more dispersed endowments of labor*

The converse is true for abilities below the mean. For abilities below the mean there are relatively more labor with even lower ability in countries with dispersed labor endowments. These low skill agents could potentially be better off when competing for matches in diffuse labor endowments. However better matches for low skill workers results in lower productivity at the aggregate level; the gain in the match quality of low ability workers limits the degree to which a diffuse country can exploit complementarities in production or take advantage of abundant factor supplies.

Lemma 2 *Holding task assignments fixed, labor with below average ability form less productive matches in countries with more dispersed endowments of labor*

Both lemmas are made with the caveat that task assignments are held fixed. They only apply when the same groups of labor pursue each task assignment for various levels of dispersion. Recall that workers pursue good task assignments as long as $\frac{\Delta w(\cdot)}{\Delta \theta}$, the private benefit from doing so, is positive. If there are any workers on the margin ($\frac{\Delta w(\cdot)}{\Delta \theta}$ near zero) then dispersion may also shift the matching regime, as will be discussed shortly. Proposition 2 ensures that all matches will form between workers of different abilities because every worker is willing to sacrifice match quality at least to a small degree. Lemmas one and two demonstrate that as long as labor still seek the private benefits which accompany good jobs, their willingness to accept poor matches has greater consequences in countries with more dispersed labor endowments.

Together lemmas 1 and 2 describe impact of dispersion of a country's labor endowment on the quality of matches. Relating matching outcomes to productivity in an environment with complementarities between skill in both labor and capital productivity, the following result is obtained.

Proposition 12 *(Matching Outcome Effect) If the benefits of good task assignments are large, then countries with greater dispersion in their labor endowment will exhibit lower productivity in terms of factor usage.*

14.2 Dispersion & Matching Regimes

Labor wages can be split into two components: half of wages are derived from individual contributions and bargaining power, and half are derived from the amount of team production. While full weight is not given to team production erosion of match quality can be severe enough to eclipse the benefits from better task assignments. The private benefits of good task assignments decreases as match quality worsens $\left(\text{recall that } -d\frac{\Delta w(\cdot)}{\Delta \theta}/dm(a) < 0\right)$. In countries with more diffuse labor endowments, those with above average ability face more competition from above for good matches. Competition for matches among relatively skilled workers reduces the premium earned from good task assignments. Eventually the productivity losses may become severe enough that some skilled workers are willing to forgo better task assignments and seek better partners.

Lemma 3 *Labor with above average ability are more willing to accept high quality matches over good task assignment in countries with dispersed labor endowments.*

Even though workers who are relatively skilled have an advantage *ex ante* in securing good jobs (Proposition 1), they may not choose to exercise that advantage when competing in a matching market with diffuse supply of partners.

As high ability labor begin to accept poor task assignments, matching outcomes of those with below average ability must also adjust. When relatively able workers begin matching with even more able workers, they are unavailable as partners to the relatively low skilled. On one hand, competition among those willing to perform low skill task intensifies. On the other hand, opportunities to perform high skill tasks become available as there must always be an equal measure of labor performing each task. Both lead below average workers to pursue good task assignments. Those who do so must match with labor of even lower ability for their partnerships to be stable (Proposition 1). Responding to the behavior of relatively able workers, the impact of dispersion on relatively low ability workers is summarized in Lemma 4.

Lemma 4 *Labor with below average ability are more likely to obtain good task assignments and form high quality matches in countries with dispersed labor endowments.*

From an individual perspective some skill levels may earn higher or lower wages in countries with different levels of dispersion based on their specific matching outcome and task assignments. But the emphasis here is on aggregate matching outcomes and the consequences for productivity. Lemmas 3 and 4 indicate that greater levels of high levels of dispersion diminish the benefits derived from having more negotiating power and thus alter matching behavior. Stronger emphasis on team production leads to more segregated matching patterns. When the patterns of task assignments differ across countries dispersed labor endowments have the following impact of aggregate efficiency.

Proposition 13 *(Matching Regime Effect) If dispersion alters the pattern of task assignments across countries, then countries with greater dispersion will exhibit greater productivity in all sectors.*

14.3 Discussion

Several partial results have been derived above and a discussion of them together is prudent. First, proposition 1 demonstrates that worker preferences for specific job types necessarily cause the matching market to fail to deliver the efficient outcome. In the model laid out above preferences come from the inherent bargaining power associated with each assignment. There are several other features of labor payments that may distort the allocation of ability during production[35]. Information asymmetries may exist and one job type may come down on the better end of negotiations when effort or productivity are not observed perfectly. Non-pecuniary benefits such as health care plans, contract length, or organizational authority can influence preferences over jobs. Certain professions, or positions within companies, may grant better social status. In any event, certain benefits attached to only a faction of jobs available inhibits the ability of the market to organize labor effectively.

With complementarities between worker abilities in production the severity of failure in the matching market is measured by the degree of heterogeneity in matches. Dispersion in labor endowments create the possibility of drastic productivity losses because of the relatively larger shares of workers of different ability. That is, matching outcomes have the potential to be worse in dispersed endowments. Proposition 3 demonstrates that when market failures are persistent (i.e. preferences for task assignments are strong), countries with more diffuse distributions do indeed suffer in terms of productivity. This result must be reconciled with the finding in Proposition 4 which states that greater dispersion with a country provides incentives to labor in that country to make decisions about task assignments which improve total productivity.

The two seemingly contradictory predictions influence productivity through different mechanisms. Whereas dispersion makes market failure more costly, dispersion also makes severe market failures less likely to occur. Therefore it is an empirical question whether or not dispersion in labor endowments influences total factor productivity across countries or over which ranges dispersion it is detrimental/beneficial; the next section tries to answer this question.

15 Data

The goal here is to provide a complete test of HOV predictions of the factor content of trade accounting for the influence of skill dispersion in a country's labor endowment. In order to perform complete tests data on technology, trade and endowments are needed from each country. These data come from the 2005 edition of the Organization for Economic Cooperation and Development STAN database. Reported are labor and capital usages, gross output, value added and bilateral trade data for 25 industries in the manufacturing and non-manufacturing sectors. Observations are taken from the year 1995 for 23 countries[36]. Although the coverage of this data set is quite extensive, there are missing data problems for production and factor requirements in many industries and countries. The data appendix describes the data set in more detail and also the methodology used to impute missing observations.

Information on the distribution of skill in each country are from Barro and Lee (2000) data set at the Center for International Development which reports educational attainment levels across countries every 5 years. For the year 1995 the percentage of the population over the age of 15, in each country, which attain one of four levels of education are observed; the levels are No Schooling, Primary Attained, Secondary

Attained, Higher than Secondary education attained. Note that these group are mutually exclusive in that the percentage to the population with Secondary Attained is the percentage whose maximum level of education is secondary school. These data provide very detailed information about the composition of the labor force in each country, yet still suffer two important limitations.

First, the mapping of education into human capital is not evident. It is not clear which levels of education provide the most marketable skills to workers. Therefore I will construct estimates of the labor endowment in each country (in terms of total ability or total Human Capital Accumulation) under the assumptions of increasing, decreasing and constant returns to education. The one restriction that I impose is that all countries education systems yield the same returns from each level of education attained[37]. Specifically let NE^c denote the percentage of the population in country c which has no education. Similarly define P^c, S^c, B^c as the percentages of the population in country c which attained primary, secondary, and beyond secondary education levels respectively. I normalize human capital endowments by assuming that uneducated labor have zero human capital. Thus the total human capital endowment per capita in country c is given by

$$\begin{aligned} HCA^c &= P^c * (1) + S^c * (2) + B^c * (3) \text{ under Constant Returns} \\ HCA^c &= P^c * (1^2) + S^c * (2^2) + B^c * (3^2) \text{ under Increasing Returns} \\ HCA^c &= P^c * (\sqrt{1}) + S^c * (\sqrt{2}) + B^c * (\sqrt{3}) \text{ under Decreasing Returns} \end{aligned}$$

A second gap in the data is that the levels of education are not observed by age group. Were it the case that information about age were available the estimates of human capital accumulation could be refined to include a degree of experience. Higher levels of education concentrated among a young group in one country would plausibly indicate a lower level of human capital accumulation than a country where the same percentage of workers have been educated, but also have the benefit of years of experience. These two limitations notwithstanding, information on educational attainment within each country shed light on the differences in the composition of labor endowments across countries.

The last piece of information to be included in the estimates of factor productivity and factor trade is the amount of dispersion in each country's labor endowment. If every individual in an economy were to attain the same level of education, then each share of the population should have an equal share of the total human capital endowment. For example, in a country with no dispersion in the distribution of ability any 25% of the population should have 25% of the total human capital endowment. The percentage of the population which completes each level of education are observed and total human capital accumulation can be estimated. Therefore the level of dispersion in each country can be represented by a pseudo-Gini coefficient. For each level of educational attainment, I compute the difference between the equal share of human capital and the actual amount of human capital accumulated by all workers at or below each level of education. For example, dispersion in the labor endowment of country c, under constant returns to education, is

$$gD^c = \{NE^c * HCA^c\} + \{(NE^c + P^c) * HCA^c - [P^c * (1)]\} + \\ \{(NE^c + P^c + S^c) * HCA^c - [P^c * (1) + S^c * (2)]\}$$

Measures of dispersion under increasing and decreasing returns are calculated in a similar manner. The first term in braces represents the fact the in country c a percentage of workers NE^c accumulated no human capital. Yet if the human capital were equally divided among labor they would have accumulated $NE^c * HCA^c$ units. Likewise the second term in braces demonstrates that if labor who received only primary education or less were to have an equal share of the human capital accumulated in country c they would have $(NE^c + P^c) * HCA^c$ units. Instead labor with primary education or less received only $P^c * (1)$ units with constant returns to education. The third term in braces has an identical interpretation.

If all workers in a country attained the same level of education, say secondary, then the measure of dispersion in that country would be given by

$$gD^c = HCA^c - S^c * (2^2) = S^c * (2^2) - S^c * (2^2) = 0.$$

Clearly the pseudo-Gini measure of skill dispersion is larger as different shares of workers receive different levels of education. Table 3.1 reports the estimates of per capita human accumulation and measures of dispersion for each country.

16 Empirics

Two types of statistical tests are necessary to evaluate the impact of dispersion of labor endowments on the factor content of trade. As suggested by the Trefler (1993) and Davis and Weinstein (2001) technology differences across countries are central to factor content studies. The theoretical framework provided above describes how dispersion influences productivity (i.e. technology) across countries when matching markets fail to deliver efficient allocations. This is the first statistical test performed below. Clearly, the modes of production across countries influence the factor content of the goods they send abroad. The second set of tests examines whether or not the degree of labor heterogeneity influences factor trade patterns in a manner consistent with the benchmark HOV prediction. The link between factor supplies and factor trade is tenuous at best. Additional information about endowments, such as dispersion, allow a more precise line to be drawn between endowments and trade.

This section first provides evidence that Hicks-neutral technology differences exist between countries. Then the degree of labor heterogeneity is shown to explain much of these differences. The evidence suggests that matching outcomes are worse in countries with high levels of dispersion, consistent with the notion that labor has strong preferences for job types. Third, I construct technology matrices for each country derived from their measured level of dispersion. Combined with bilateral trade data, these technology matrices provide estimates of the world factor trade. Next, observed factor trade and factor endowments are measured against HOV predictions. In the end I find that information about all features of the shape of labor endowments together can tell much of the story of international trade flows.

16.1 Technology Differences and Dispersion

Let A be the common $N \times f$ matrix of factor requirements so that A_{if} is the amount of factor f (labor or capital) needed to produce a single unit of output in industry $i = 1...N$. If all countries used the same technologies then we would observe $A_{if}^{c} = A_{if}^{c'}$ for all countries. Following Davis and Weinstein (2001) suppose that factor usages are observed imperfectly and that such measurement error is distributed log-normal with mean zero. Moreover, countries may use the commonly available technology with differing levels of efficiency. If these productivity differences are Hicks-neutral, then factor usages would differ proportionally from a common technology[38]. Accounting for measurement error in each country across factors and industries, denoted as ξ_{if}^{c}, and productivity differences each country, given as Θ^{c}, factor usages in country c are centered around the common technology matrix A with elements A_{if} that satisfy

$$A_{if}^{c} = \Theta^{c} A_{if} \xi_{if}^{c}$$

Technology differences Θ^{c} and the common available technology can be estimated in log form by running the following regression, with $\theta^{c} = \ln \Theta^{c}$, $\epsilon_{if}^{c} = \ln \xi_{if}^{c}$, and

$\mathbf{A}_{if} = \ln A_{if}$

$$\ln A_{if}^{c} = \theta^{c} + \mathbf{A}_{if} + \epsilon_{if}^{c} \tag{39}$$

In order to estimate (39) a normalization is required. As is standard I use the United States as the basis of comparison by setting $\theta^c = 0$ (equivalent to $\Theta^c = 1$). Also I weight each observation by the square root of the log of value added in each industry to account for heteroscadasticity that arises because large sectors are likely to be measured more precisely. Table 3.2 reports the estimates of technology differences. To no surprise there is significant variation across countries. Belgium, Canada, Finland, France, Netherlands, Norway, Sweden and the United States are indistinguishable in terms of productivity and are more productive than every other country. Korea is the least productive of the sample, requiring approximately of six and a half times as much of each factor to produce the same amount of output. Australia, Hungary and Poland also exhibiting severe productive deficiencies.

Having established that international technology differences exist, the next step is to relate the degree of heterogeneity, or dispersion, in labor endowments to overall productivity. Rather than estimate country-fixed effects as in (39) we will use the pseudo-Gini coefficients as measures of dispersion in labor endowments and human capital accumulation per capital as a measure of average ability across countries. The theoretical framework above does not specify a functional relationship between factor requirements and dispersion. Furthermore, the theoretical characterization of dispersion hold average ability fixed. The impact of dispersion on technological efficiency, controlling for the average level of ability, and using higher polynomials approximate the impact of dispersion, can be estimated in reduced form by the following regression.

$$\ln A_{if}^{c} = \beta_1 gD^c + \beta_2 \left(gD^c\right)^2 + \beta_3 HCA^c + \mathbf{A}_{if} + \psi_{if}^{c} \tag{40}$$

If preferences for good job types weigh heavily on labor behavior, then dispersion has an adverse effect on productivity. Evidence of strong preferences for jobs would be positive coefficients on the dispersion measures. The corresponding estimates of the Matching Outcome Effect would be $\beta_1 + 2\beta_2 gD > 0$. While a high level of dispersion raise the potential costs of failures in the matching market, it also makes them less likely to occur. More efficient matching regimes may arise in countries with high levels of dispersion. Estimates of the partial effect of dispersion would be less than zero if the Matching Regime Effect dominated.

The theory fails to return sharp predictions characterizing the role that dispersion plays. Both positive and negative estimates have explanations within the framework above. Difficulty would only arise if no significant estimates were returned. An inability to find a relationship between the degree of labor heterogeneity and productive efficiency could be due to the Matching Outcome Effect and Matching Regime effect cancelling each other out on average, or could be due to the fact that the notion that dispersion is economically important is non-sense. To make matters worse imperfect measurement of dispersion and average ability in labor endowments will tend to bias the estimated impact of dispersion toward zero.

Moreover, the pseudo-Gini coefficient derived from educational attainment levels does not correspond precisely to likelihood ratio dominance about the mean. Even if education were measured and mapped into human capital precisely, these measures of dispersion can only proxy for the sort of variation that impacts matching outcomes as described above. Fortunately the data do not succumb to the potential for ambiguity and return statistically and economically significant coefficients reported in Table 3.3.

The evidence supports the hypothesis that greater levels of dispersion labor endowments reduce aggregate productivity on average. Consistent with the theory above we can infer that labor exhibit strong preferences for particular job types. Initially there seem be more detrimental effects on efficiency from dispersion; $\beta_1 > 0$. Eventually losses in productivity begin to reverse $(\beta_2 < 0)$, plausibly due to shifts in matching regimes as potential losses in match quality become more severe. Countries with high levels of dispersion, specifically those with measures greater than 20.8 under constant returns, no longer suffer productivity losses from polarized labor endowments. As expected higher average levels of ability are associated with greater productivity.

The distribution of educational attainment in labor endowments appears to be a statistically significant determinant of productivity. Evaluating the economic significance of the parameters, even interpreting them clearly, is more difficult. Under constant returns to education the average measure of dispersion across countries is 19.5. Based on the estimates in Table 3.3, a 1% increase in measured dispersion leads to a 0.7% increase in unit factor requirement for the average country. This sort of estimate seems plausibly and economically significant. However the meaning of a 1% change in the measured level of dispersion is an ambiguous description of how the shape of labor endowments vary across countries. The ideal way to evaluate the importance of the shape of labor endowments would be to include both country fixed effects and the measures of dispersion and mean human capital accumulation. If the fixed effects estimates were estimated at zero, we could infer that productivity differences were explained entirely by the shape of factor endowments. Unfortunately there are not enough degrees of freedom to perform such a test.

A feasible alternative is to consider what would happen to factor requirement across countries if their labor endowments resembled the shape of the US labor endowment; recall that the Hick-neutral productivity differences in Table 3.2 are estimated relative to the United States. Korea, Australia and Poland are among the least efficient countries, with unit factor requirements approximately 6.5, 2 and 3 times that of the US respectively. If they were able to reduce the amount of dispersion (Korea: 21.2, Australia: 17.9 and Poland: 15.7) to the same level of the United States (12.5) then they could reduce their unit factor requirements in all industries significantly.

Based on the estimates in Table 3.3 they could almost surpass the United States, using about 15% less of each factor than required in by US industries. Estimates of the technological improvements that could be realized if the level of dispersion in labor endowments for each country were the aligned with the US are reported in Table 3.4. The estimates gravitate toward .85, suggesting that most countries could surpass the US in terms of productivity. However this is likely do to the fact that the US is an outlier in terms of dispersion. The OLS estimates of the partial effects of variation in levels of dispersion are likely to be imprecise when using the US as a basis of comparison.

Of course the most relevant way to evaluate the economic significance is to test if the information about dispersion and average levels of human capital explain international trade flows. This is the real focus of the paper and will be discussed in the next section. At this point it is worthwhile to discuss limitations of the estimation methodology used above. First, the shape of a distribution is described by more than a mean and level of dispersion (even if perfectly measured). Estimates of factor requirements and the coefficients for measured dispersion likely suffer omitted variable bias because features of labor endowments such as skewness are not included. Suitable measures for higher moments are difficult to construct in addition to dispersion because only four levels of educational attainment are available for each country.

16.2 Factor Content of Trade

In this section I test the validity of the Vanek prediction that countries will be net exporters (importers) of their abundant (scarce) factors, controlling for the effect of dispersion on unit factor demands. With international productivity differences the amount of each factor embodied in each unit sent abroad varies by exporter. Factor requirements are given by each country's technology matrix A^c. Let X^{cj} be the vector of exports from country c to county j. The factor content of exports, F^{cW}, from country c to the world, W, is then

$$F^{cW} = A^c X^{cW}$$

The amount of each factor imported by country c from country j is $F^{jc} = A^j X^{jc}$. Summing across exporters gives the total imports of both factors for country c. The net amount of factor trade for country c is given by

$$F^{cW} - \sum_{j \neq c} F^{jc} \tag{41}$$

Relative factor abundance is defined in the usual way. Country c is considered abundant in a particular factor if its endowment, V_f^c, relative to the world endowment, V_f^c, exceeds its share of world GDP, s^c. So relative factor endowments are given by

$$V_f^c - s^c V_f^c \tag{42}$$

The strict statement of the Heckscher-Ohlin-Vanek theorem is

$$V_f^c - s^c V_f^c = F^{cW} - \sum_{j \neq c} F^{jc} \tag{43}$$

If actual data on technologies are used and imports are proportional to GDP, then the Vanek prediction holds as an identity. I avoid this issue first because technologies are estimated rather than taken as observed. A second reason I am able to circumvent this problem is that I use bilateral trade data to measure international factor flows, as opposed to estimating exports based on relative GDP levels.

Tables 3.5, 3.6 and 3.7 provide results from several of the now standard tests of the HOV prediction in (43). The first, and one of the weakest, is the sign test based on the various specifications of technology and returns to education. To no surprise, assuming identical technologies causes the HOV theorem to perform poorly; the measured and predicted factor content of trade have the same sign only 26% of the time. Also in-line with previous findings, estimated Hicks-neutral technology differences across countries influence factor trade patterns. Accounting for such differences, factor endowments correctly predict that a country is a net exporter (importer) of its abundant (scarce) factor 43% of the time. The key question is whether or not the shape of labor endowments helps to predict the factor content of trade. Evidence from the sign test suggests that controlling for the mean, and level of dispersion, in labor endowments improves factor content predictions just as well as estimated productivity differences across countries; under constant returns to education the relative abundance of each factor predicts the sign on the measure factor content of trade correctly for 43% of country-factor pairs.

The primary weakness of the sign test is that it does not relate the magnitudes of relative factor endowments and measured factor trade. Larger degrees of relative factor abundance should be associated with larger amount of exports. The Spearman Rank tests evaluates this slightly stronger version of the HOV prediction. Factor endowments[39] across countries are ordered in terms of relative abundance. That ranking is compared to the ordering of factor trade volumes. Here estimated differences in the shape of endowments perform poorly compared to unexplained technology differences. In fact the amount of factor trade predicted by relative factor supplies and the shape of the labor distribution appear at best uncorrelated, and at worst negatively correlated, with observed factor flows.

The precise statement of the HOV theorem is an identity which can be tested by regressing the right-hand side of (43) on the left-hand side, as in Davis and Weinstein. The theory predicts a coefficient of one. Also the R^2 is an indicator of the amount of missing trade à la Trefler (1995). Results from this regression are in Table 3.7. Again we see that assuming identical technologies does poorly. Both estimated

Hicks-neutral technology differences and estimated differences based on the shape of labor endowments do much better, returning positive and significant relationships between predicted and measured factor trade. Neither returns an estimated coefficient statistically close to 1.

Using measures of dispersion and average ability help to explain the pattern of world factor trade pattern magnitude of factor trade. Estimated HNTD can better account for trade volumes. To see this note that the missing trade statistic (the R^2 from regression tests) is much greater under a the specification of HNTD.

As a robustness check I estimated technology differences that may be implied by differences in capital-labor ratios across countries which may cause them to operate in different cones of diversification. See Schott (2003). Using data on the relative sizes of factor endowments within a country in tandem with the shape of labor distributions improves the predictive power of the HOV theorem. The sign test is satisfied nearly 50% of the time and the rank test returns a positive and stronger correlation between predicted and measured factor trade volumes. However is it difficult to discuss the role of relative factor endowments in the current context. It is not clear from this analysis how labor would match and sort across different goods within industries; therefore it would be misleading to suggest that laborers in different countries appear to match in different diversification cones because capital-labor rations are relevant statistically. I leave such issues to future research.

17 Conclusion

The primary goal of this analysis has been to demonstrate that factor endowments still have an important role in the story of international trade. For some time factor supplies have taken a back seat to unexplained Ricardian productivity differences in the HOV literature. In world of heterogeneity and team production endowments must be considered as more than cumulative collections of factors. A richer characterization views endowments as distributions with shapes that reflect dispersion, mean, modal values, skewness and other moments. Moreover, the individual features of factor distributions interact to shape the pattern of world trade, rather than only influencing production independently.

Here I found that using information about both the mean and dispersion in labor endowments improves the ability of relative factor abundance to predict the direction of factor trade. Countries export their abundant factors as long as they can organize labor effectively. Benefits attached to particular job types makes the organization problem more difficult, and dispersion in labor endowments makes poor organization more costly. For most countries good job types are too enticing. Only in those countries with a very large degree of dispersion does individual matching behavior reflect the most productive allocation.

On the other hand the estimated impact of dispersion in labor endowments on productivity fails to accurately described factor trade volumes suggested by relative factor supplies. This could be due in part to the fact that some countries can organize labor for producing exports more or less effectively than production intended for domestic consumption. This result could also be due to statistical artifacts. As I have only incorporated two features of the shape of endowments, omitted features such as skewness may have biased estimates used to construct technology matrices across countries. There is also likely to be attenuation bias as the distribution of human capital is certainly measured with a degree of error. Yet, even through a biased lens, endowments seem to be an important component of international trade again.

Chapter 3-Data Appendix

17.1 Sources

The source of production, factor usages, value added and bilateral trade data is the 2005 volume, ed. 5, of the Organization for Economic Cooperation and Development STAN database. Observations are available at the industry level described in table A-1 and taken from the year 1995. Empirical tests of productivity differences make use of the information in 25 industries covering both manufacturing and service sectors. However, bilateral trade data for service sectors is incomplete; only an aggregate for all service industries is reported. The pattern of estimated productivity differences using only 15 manufacturing industries (those without an asterisk in table A-1) and the one service industry aggregate (sum of all industries with asterisk in table A-1) did not differ across countries from the estimates when all 25 industries were used. For both trade and production data the industry classifications are consistent with ISIC Rev. 3.

The data source for employment is the Number Engaged (EMPN) for each industry, which includes domestic production. Some variation in reporting employment data exists across countries. Most countries report a headcount of persons employed. However Austria, Canada, New Zealand, and Great Britain report the number of jobs in each industry. The national accounts of employment vary across countries, as hundreds or thousands of persons, and so a simple conversation is used to convert all employment data of all countries into a common unit of measurement.

Capital data are based on the national accounts of Gross Fixed Capital Formation (GFCF). Values are given in national currencies at current prices. Production and Value Added data are also given at current prices in national currencies. All these variable were converted to US dollars using 1995 exchange rates in the OECD Factbook 2008.

Bilateral Trade data are reported in thousands of US dollars. Both export and import data are available for each country but rarely correspond. For example the reported value of Australian imports of Wood Products and Cork from Belgium does not necessarily equal Belgian exports of Wood Products and Cork to Australia. Only the export data were used to construct bilateral trade flows as the reporting countries typically provides the free on board value of exports. Imports for a particular country and industry were then constructed by summing values of exports to that country in each industry, across all exporters.

Table A-1	
Industry Code	Description
105	Agriculture, Hunting Forestry & Fishing
1516	Food Beverage & Tobacco
1719	Textiles, Leather, & Footwear
2000	Wood Products & Cork
2122	Pulp, Paper, Printing & Publishing
2300	Coke Refined Petrol Products & Nuclear Fuel
2400	Chemical & Cleaning Products
2500	Rubber & Plastics
2600	Other Non-Metallic Products
2728	Basic & Fabricated Metals
2900	Machinery & Equipment NEC
3033	Electrical & Optical Equip.
3435	Transport Equipment

Table A-1 cont.	
3637	Manufacturing NEC
4041	Electricity, Gas, & Water Supply
4500*	Construction
5052*	Wholesale Trade & Repairs
5500*	Hotels & Restaurants
6064*	Transportation, Storage & Communication
6567*	Financial Intermediation
7074*	Real Estate & Renting Business
7500*	Public Admin, Defense & Compulsory Social Services
8000*	Education
8500*	Health & Social Work
9093*	Other Community, Social & Personal Services
	*-Industries for which trade data were not available.

The data on educational attainment are detailed in Barro and Lee (2000). The accompanying data set from the Center for International Development reports educational attainment levels across countries every 5 years. For the year 1995 the percentage of the population over the age of 15 in each country, which reaches each of four levels of education are observed; the levels are No Schooling, Primary Attained, Secondary Attained, Higher than Secondary education attained. Groups are mutually exclusive as they reflect the maximum level of education received by each person. Educational classifications are comparable across countries as they are based on the International Standard Classification of Education of 1976. For example Primary Schooling correspond to a particular set of topics or areas studied, rather than years of schooling. Education levels can be mapped into human capital more uniformly than if education levels were not universally defined.

17.2 Missing Data

Despite the wide coverage across and within countries, several data on capital, employment and production are missing. The following details which data were missing by country, industry and variable as well as other irregularities.

Australia

PROD-105, 4041, 4500, 5052, 5500, 6064, 6567, 7074, 7500, 8000, 8500, 9093

GFCF- 1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637

France

GFCF-2300 reported negative value set to zero

Hungary

GFCF- 1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637

Ireland

PROD- 105, 2300, 4041, 4500, 5052, 5500, 6064, 6567, 7074, 7500, 8000, 8500, 9093

EMPN-2300

Iceland

PROD-3033, 2900, 7500, 8000, 8500, 2300 reported zero value

GFCF- 1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637, 5052, 5500, 6567, 7500, 8000, 8500, 9093

EMPN-1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637

Korea

PROD-1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637, 5052, 5500

EMPN-2300, 2400, 2500

Norway

PROD-2300, 2400

EMPN- 2300, 2400

New Zealand

PROD-2300, 2400, 2500, 2900, 3033

EMPN- 1516, 1719, 2000, 2122, 2300, 2400, 2500, 2600, 2728, 2900, 3033, 3435, 3637

GFCF- 2000, 2122, 2300, 2500, 2900, 3033, 3435

17.3 Replacing Missing Data

Missing data were replaced in a two-step process similar to the methodology of Davis and Weinstein (2001). Using averages from countries for which observations were available for each industry, missing production data were replaced first, and then missing factor requirement data were replaced using worldwide averages based on either observed or imputed production values.

To be specific, let M^c denote the set of industries for which data are unavailable in country c, and let $\widehat{c}$ denote the set of countries for which production data are available for all industries i. The average share of total production that takes place in industry i worldwide is given by

$$ps_i = \frac{\sum_{1}^{\widehat{c}} PROD_i}{\sum_{1}^{i} \sum_{1}^{\widehat{c}} PROD_i} \tag{A.1}$$

In countries with missing production for at least one industry, the total value of production must also be estimated. Using the average production shares for each industry from equation A.1, the total share of production observed in each country is

$$so^c = \sum_{i \notin M^c} ps_i$$

and so total production in country c is approximated by

$$\widehat{PROD}^c = \frac{\sum_{i \notin M^c} PROD_i}{so^c}$$

Finally, missing production data are replaced by multiplying total production by the average share of production for missing industry $m \in M^c$.

$$\widehat{PROD}^c_m = ps_m \widehat{PROD}^c$$

The next step is to replace missing data for factor usages based on world averages. Let $\tilde{c}$ denote countries in which capital usage is available for a particular industry i. Then missing value of capital usage for industry i in country c was imputed using the average unit capital requirement of countries for which capital usage was observed in industry i. The following formula describes precisely how missing factor usages were imputed. Note that production values may be observed or estimated as described above.

$$GFCF_i^c = \frac{\sum_{k=1}^{\tilde{c}} GFCF_i^k}{\sum_{k=1}^{\tilde{c}} PROD_i^k} PROD_i^c \tag{A.2}$$

Similarly, missing labor data were replaced by

$$EMPN_i^c = \frac{\sum_{k=1}^{\tilde{c}} EMPN_i^k}{\sum_{k=1}^{\tilde{c}} PROD_i^k} PROD_i^c \tag{A.3}$$

17.4 Technology and Endowments

The technology matrix gives unit factor requirement for each industry[40]. The $N \times 2$ matrix of unit factor requirements for all N industries and 2 factors in country c is comprised of elements B_{if}^c for $i = 1 \ldots N$ and $f = L, K$. The elements B_{if}^c depend on the assumed specification of production. e.g. when no technology differences are allowed then

$$B_{if}^c = \exp\left(\mathbf{A}_{if}^c\right)$$

where $\mathbf{A}_{if}^c$ are the coefficients from running the regression in

Endowment data are given as the sum of each factor used across all industries for each location. Because the trade data are observed directly, and not constructed to conform to data identities such as full employment, no scaling of technologies or endowments is performed once missing data are replaced and technology calculated.

Notes

[28]In fact, the working paper version of this paper (NBER #w10959) claimed that these "are not particularly interesting parameters." I hope to show that if fact they are!

[29]Given the determination of wages in the non-transferable utility setting described below, all equilibrium matches will be heterogeneous.

[30]See Acemoglu (2007) for a theoretical treatment of equilibrium technological bias.

[31]Note that no assumptions are made about the relative magnitudes of losses in labor and capital efficiency. In the empirical section Hicks-neutral technology differences are used as a benchmark for discussing the influence that the shape of labor endowments has on productivity. Though capital and labor productivity can be influenced independently, such estimates are difficult to cast in term of previous literature. The goal here is to demonstrate that accounting for heterogeneity in endowments can do just as well as measured productivity differences at explaining trade flows.

[32]Davis and Weinstein (2001) demonstrated that the factor content of trade is best explained with a failure of FPE. Here it is unclear how the failure of FPE would impact matching behavior across countries. Such analysis is left for further research. To guage the empirical importance of heterogeneity in factor endowmence for the pattern of factor trade, I will use the traditional specification of the HOV equation with FPE as a benchmark.

[33]i.e. the matching correspondence $m(\cdot)$ is monotonic and increasing

[34]In general, not all workers with be matched with a partner of identical skill because the matching equilibrium must also satisfy the equal measure condition. The measure of workers with skill intensive task assignments must exactly equal the measure of workers with poor task assignments. Therefore for identical workers a, a small measure of these laborers may match with workers of infinitessimal differences in skill. See Legros and Newman (2002) and (2007) for further discussion. Similar

adjustments are necessary for all matching regimes as the equal-measure condition must always be satisfied. As this is only a technical adjustment with little impact on the overall allocation of matches the reader is again referred to matching literature for more details.

[35]Grossman (2004) discusses how imperfect labor contracts can influence the pattern of comparative advantage rather than generate Ricardian productivity differences.

[36]Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Hungary, Iceland, Ireland, Italy, Korea, Netherlands, Norway, New Zealand, Poland, Portugal, Sweden, and the United States

[37]The data on education across education in Barro and Lee (2000) conform to the International Standard Classification of Education (ISCED 1976). Primary schooling in each country cooresponds to the same information learned by students, rather than years of schooling, or within country definitions of levels. The adjustment so that levels of education match, rather than years of education, are also why the data reported in Barro and Lee may differ from national reports.

[38]Technology differences with respect to each factor cannot be estimated without restriction using the available data. With only a cross-section of countries and industries there are not enough degrees of freedom to estimate both country and factor fixed effects.

[39]To perform the Rank and Regression tests all observations of $V^c - s^c V^w$ and $F^{cW} - \sum_{j \neq c} F^{jc}$ are divided by σ_f so that they are expressed in common units across factors.

[40]To be specific, the labor requirement is how many hundreds of persons engaged needed to produce a \$1 million value of output in each industry and the capital requirement is the number of dollars worth of capital needed to produce \$1 worth of ouput, at current prices.

Table 3.1: Mean and Dispersion of Labor Endowments across Countries

	Constant Returns		Decreasing Returns		Increasing Returns	
Location	Dispersion (gD)	Mean Human Cap. Accum (HCA)	Dispersion (gD)	Mean Human Cap. Accum (HCA)	Dispersion (gD)	Mean Human Cap. Accum (HCA)
Australia	17.9	304.4	9.5	173.0	32.5	981.2
Austria	16.6	278.7	8.8	165.7	30.3	821.9
Belgium	23.7	269.8	12.2	162.3	44.5	793
Candada	18.5	331.7	10.0	180.6	31.8	1161.7
Germany	15.8	286.5	8.4	167.8	28.2	867.1
Denmark	17.7	277.1	8.9	165.1	34.7	816.9
Spain	21.5	256.3	10.9	158.4	41.9	712.1
Finland	17.2	284.8	8.8	167.5	33.0	859
France	20.1	261.5	10.0	160.2	40.5	736.5
Great Britain	22.4	271.1	11.5	162.8	42.0	796.7
Greece	22.1	255	11.4	158.0	42.0	705.6
Hungary	19.2	257.5	9.7	159.0	37.7	712.5
Ireland	19.4	284.4	10.2	167.1	35.5	864
Iceland	19.5	267.6	9.8	162.1	37.9	768.2
Italy	29.8	249.1	15.9	155.3	52.7	693.7
Korea	21.2	294.9	11.8	169.8	35.8	932.3
Netherlands	21.0	284.4	11.2	167.0	37.8	867.4
Norway	10.9	308	5.7	174.6	20.4	982.2
New Zealand	22.3	308.4	11.5	173.9	40.7	1019.8
Poland	15.7	266.2	8.0	161.9	30.1	750.4
Portugal	29.1	233.4	14.8	150.3	56.0	612.6
Sweden	14.7	299.4	7.8	171.8	26.7	940.4
USA	12.5	334.8	6.5	181.9	22.7	1164

Table 3.2: Estimated Hicks-Neutral Technology Differences (HNTD)

Country	θ	standard error	Implied Θ
Australia	0.784	0.0558**	2.19
Austria	0.148	0.0560**	1.16
Belgium	-0.081	0.0559	0.92
Canada	0.080	0.0554	1.08
Germany	0.162	0.0543**	1.18
Denmark	0.124	0.0565*	1.13
Spain	0.268	0.0552**	1.31
Finland	-0.003	0.0566	1.00
France	0.027	0.0546	1.03
Great Britain	0.114	0.0548*	1.12
Greece	0.536	0.0569**	1.71
Hungary	0.941	0.0577**	2.56
Ireland	0.107	0.0580*	1.11
Iceland	0.914	0.0668**	2.49
Italy	0.178	0.0548**	1.20
Korea	1.866	0.0575**	6.46
Netherlands	0.048	0.0556	1.05
Norway	-0.001	0.0581	1.00
New Zealand	0.269	0.0612**	1.31
Poland	1.084	0.0566**	2.96
Portugal	0.539	0.0574**	1.71
Sweden	0.071	0.0561	1.07
USA	0.000	...	1.00

**-indicates significance at 99% level, *-indicates significance at 95% level

Table 3.3: Impact of Dispersion and Average ability on Aggregate Productivity

	Constant Returns		
	β	**se**	**t-stat**
Dispersion	0.1270152	0.017053	7.45
Dispersion^2	-0.003057	0.0004043	-7.56
Mean HCA	-0.0026643	0.0006142	-4.34
R^2	0.945		
	Decreasing Returns		
	β	**se**	**t-stat**
Dispersion	0.2309423	0.0322655	7.16
Dispersion^2	-0.0101455	0.0014581	-6.96
Mean HCA	-0.007157	0.0019528	-3.66
R^2	0.945		
	Increasing Returns		
	β	**se**	**t-stat**
Dispersion	0.0612298	0.0092851	6.59
Dispersion^2	-0.0008458	0.000119	-7.1
Mean HCA	-0.0005997	0.0001136	-5.28
R^2	0.945		

Table 3.4: Productivity Differences imposing identical dispersion measures across countries (=US)

Location	Relative Productivity
Australia	0.83
Austria	0.85
Belgium	0.83
Canada	0.82
Germany	0.87
Denmark	0.83
Spain	0.81
Finland	0.84
France	0.81
Great Britain	0.82
Greece	0.81
Hungary	0.82
Ireland	0.81
Iceland	0.81
Italy	1.04
Korea	0.81
Netherlands	0.81
Norway	0.92
New Zealand	0.82
Poland	0.88
Portugal	1.00
Sweden	0.91
USA	1.00
average	0.85

Table 3.5: Sign tests of the HOV prediction

Specification	%-same sign
Identical Tech	26
Estimated HNTD	43
Est. Difference in V_L CR	43
Est. Difference in V_L IR	41
Est. Difference in V_L DR	41
Diff in V_L and K/L CR	48

Table 3.6: Rank tests of HOV prediction

Specification	ρ
Identical Tech	-0.10
Estimated HNTD	0.19
Est. Difference in V_L CR	-0.08
Est. Difference in V_L IR	-0.10
Est. Difference in V_L DR	-0.05
Diff in V_L and K/L CR	0.20

Table 3.7: Regression tests of the HOV prediction

Specification	β	p-val (β=1)	R^2
Identical Tech	-0.65	0.000	0.003
Estimated HNTD	0.63	0.003	0.39
Est. Difference in V_L CR	0.45	0.0002	0.2
Est. Difference in V_L IR	0.44	0.000	0.19
Est. Difference in V_L DR	0.44	0.001	0.19
Diff in V_L and K/L CR	0.39	0.000	0.15

References

Acemoglu, D., Antràs, P., and Helpman, E. (2007) "Contracts and Technology Adoption," *American Economic Review*, Vol. 97, No. 3, pp.916-43

Adler, S. (2008) "In the Wrong Hands: Complementarities, Resource Allocation, and Cross-Country TFP Differences." mimeo University of California-Los Angeles

Baldwin, J., and Gu, W. (2006) "The Impact of Trade on Plant Scale, Production-Run Length and Diversification." in *Producer Dynamics: new evidence from microdata*, ed. Timothy Dunne, J. Bradford Jensen, and Mark Roberts. NBER forthcoming

Balistreri : Balistreri, E., (1997) "The performance of the Heckscher--Ohlin--Vanek model in predicting policy forces at the individual level," *Canadian Journal of Economics*, Vol 30, pp. 1 –17

Barro, R. and J. Lee (2000) "International Data on Educational Attainment: Updates and Implications" CID Working Paper No. 42, Harvard University

Beaulieu&Magee : Beaulieu, E., and Magee, C. (2004) "Four Simple Tests of Campaign Contributions and Trade Policy Preferences," *Economics and Politics*, Vol.16, No. 2, pp. 163-87

Becker, G and Murphy, K. (1992) "The Division of Labor, Coordination Costs, and Knowledge," *Quarterly Journal of Economics*, CVII, No. 4, pp. 1137-60

Bernard, A. and Jensen, J. B. (1999a) "Exceptional exporter performance: Cause, effect or both?" *Journal of International Economics* Vol. 47, No. 1, pp. 1-25

Bernard, A., Jensen, J.B., and Schott, P. (2006) "Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants." *Journal of International Economics*, 68(1): 219-37

Bernard, A., Redding, S., and Schott, P. (2006) "Multi-Product Firms and Trade Liberalization." NBER working paper w12782

Bernard, A., Redding, S., and Schott, P. (2008) "Multi-Product Firms and Product Switching." NBER working paper w12293

Blalock : Blalock, G. and Gertler, P. (2004) "Learning from exporting revisited in a less developed setting," *Journal of Development Economics*, Vol. 75, No. 2, pp. 397-416

Blanchard & Fisher : Blanchard, O. and Fisher, S. (1989) *Lectures on Macroeconomics*, MIT Press, Cambridge, Massachusetts

Bowen, H., E. Leamer and L. Sveikauskas (1987) "Multicountry, Multifactor Tests of the Factor Abundance Theory." *American Economic Review*, 77(5): 791-809

Burgess, S., Lane, J. and Stevens, D. (2000) "Job Flows, Worker Flows and Churning," *Journal of Labor Economics,* vol. 18, no.3, pp. 473-502

Clark, G. and R. Feenstra (2003) "Technology in the Great Divergence," in *Globalization in Historical Perspective*, eds. Michael D. Bordo, Alan M. Taylor, and Jeffrey G. Williamson. Univ. of Chicago and NBER. 277-314

Costinot, A. (2009) "An Elementary Theory of Comparative Advantage." *Econometrica*, forthcoming

Costinot, A., and J. Vogel (2009) "Matching and Inequality." mimeo Massachusetts Institute of Technology

Cuñat, A. and M. Melitz (2007) "Volatility, Labor Market Flexibility, and the Pattern of Comparative Advantage." NBER working paper #13062

Clerides, S., Lach, S., and Tybout, J. (1998) "Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Morocco," The Quarterly Journal of Economics, Vol. 113, No. 3, pp. 903-947

Cunat Melitz : Cunat, A. and Melitz, M. (2006) "Volatility, Labor Market Flexibility, and the Pattern of Comparative Advantage," NBER Working Paper #13062

Davidson, C., Martin, L., and Matusz, S. (1999) "Trade and Search Generated Unemployment," *Journal of International Economics*, vol. 48, pp. 271-99

Davidson, C. and Matusz, S. (2004) *International Trade and Labor Markets: theory, evidence and policy implications*. Kalamazoo, MI: W.E. Upjohn Institute

Davidson, C. and Matusz, S. (2005) "Trade and Turnover: Theory and Evidence," *Review of International Economics*, Vol. 13, No. 5, pp.861-80

Davidson, C., Matusz, S. and Shevchenko, A. (2008) "Globalization and Firm Level Adjustment with Imperfect Labor Markets." *Journal of International Economics*, 75(2): 296-309

Davis, S., Haltiwanger, J., and Schuh, S. (1996) *Job Creation and Destruction*, MIT Press, Cambridge, MA and London

Davis, D., and Harrigan, J. (2007) "Good Jobs, Bad Jobs, and Trade Liberalization." NBER working paper w13139

Davis, D and D. Weinstein (2001) "An Account of the Global Factor Content of Trade." *American Economic Review*, 2001, v91, 1423-1453.

Doms, M., Dunne, T., and Troske, K. (1997) "Wages, Workers and Technology," *The Quarterly Journal of Economics*, Vol. 112, No. 1, pp. 253-290

Dunne, T., Foster, L., Haltiwanger, J., and Troske, K. (2004) "Wage and Productivity Dispersion in U.S. Manufacturing: The Role of Computer Investment." *Journal of Labor Economics*, 22(2): 397-429

Eckel, C. and Neary, P. (2008) "Multi-Product Firms and Flexible Manufacturing in the Global Economy." working paper University of Oxford

Felbermayr, G., Prat, J., and Schmerer, J.H. (2008) "Globalization and Labor Market Outcomes: Wage Bargaining, Search Frictions, and Firm Heterogeneity." IZA Discussion Paper No. 3363

Fernandes, A. (2007) "Trade policy, trade volumes and plant-level productivity in Colombian manufacturing industries," *Journal of International Economics*, Vol. 71, No. 1, pp.52-71

Hart, O. and J. Moore (1990), "Property Rights and the Nature of the Firm." *Journal of Political Economy*, 98(6): 1119-1158.

Head, K., and Ries, J (1999) "Rationalization Effects of Tariff Reductions" *Journal of International Economics*, 47(2): 295-320

Irwin, D. (1996) "Industry or class cleavages over trade policy? Evidence from the British General Election of 1923," In: Feenstra, R., Grossman, G., Irwin, D. (Eds.), *The Political Economy of Trade Policy: Papers in Honor of Jagdish Bhagwati*, MIT Press, Cambridge, pp. 53-- 76.

Itskhoki, O., and Helpman, E. (2007) "Labor Market Rigidities, Trade and Unemployment." NBER working paper w13365

Kremer, M. and Maskin, E. (1996) "Wage Inequality and Segregation by Skill," NBER working paper w5718

Legros, P., and Newman, A. (2002) "Monotone Matching in Perfect and Imperfect Worlds." *Review of Economic Studies*, 69(4): 925-42

___ and ___ (2007) "Beauty is a Beast, Frog is a Prince: Assortative Matching in a Nontransferable World." *Econometrica*, 75(4): 1073 - 1102

Leontief, W (1953) "Domestic Production and Foreign Trade: The American Capital Proposition Re-Examined." *Proceedings of the American Philosophical Society*, 97(4): 332-49

Li, H. (2001) "The Relative Importance Of Effort, Organization, And Technological Change In Chinese Factories." *Contemporary Economic Policy*, 19(1): 99-108

Lucas, R. (1978) "On the Size Distribution of Business Firms." *The Bell Journal of Economics*, 9(2): 508-523

Magee, C., (1980) "Three simple tests of the Stolper--Samuelson theorem," In: Oppenheimer, P. (Ed.), *Issues in International Economics*, Oriel Press, London, pp. 138--153.

Magee, C. Davidson, C. and Matusz, S. (2005) "Trade, Turnover and Tithing," *Journal of International Economics*, Vol. 66, pp.157-176

Manasse, P. and Turrini, A. (2001) "Trade, wages and 'superstars'," *Journal of International Economics*, vol. 54, pp.97-117

Matusz, S. (1986) "Implicit Contracts, Unemployment, and International Trade." *The Economic Journal*, 96(2): 307-22

Matusz, S. (1996) "International Trade, the Division of Labor, and Unemployment." *International Economic Review*, 37(1): 71-84

Melitz (2003) : Melitz, M. (2003) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, vol. 71, no.6, pp.1965-1725

Nocke, V., and Yeaple, S. (2006) "Globalization and Endogenous Firm Scope." NBER working paper w12322

Ohnsorge, F. and Trefler, D. (2007) "Sorting it Out: International Trade and Protection with Heterogeneous Workers," *Journal of Political Economy*, vol. 115, no. 5, pp.868-892

Pavcnik, N. (2002) "Trade liberalization, exit, and productivity improvements: Evidence from Chilean plants" *Review of Economics Studies*, Vol. 69, pp. 245-76

Rosen, S. (1981) "The Economics of Superstars." *The American Economic Review*, 71(5): 845-858

Trefler, D. and S. Zhu (2005) "The Structure of Factor Content Predictions." NBER Working Paper #11221

Trefler, D. and S. Zhu (2006) "The Structure of Factor Content Predictions." mimeo Michigan State University

Trefler, D. and S. Zhu (2000) "Beyond the Algebra of Explanation: HOV for the Age of Technology." *American Economic Review Papers and Proceedings*, 90(2)): 145-149

Trefler, D (1995) "The Case of the Missing Trade and Other Mysteries." *The American Economic Review*, 85: 1029-1046

Trefler, D (1993) "International Factor Price Differences: Leontief was Right!" *Journal of Political Economy*, 101: 961-987

Yang, X. and Borland, J. (1991) "A Microeconomic Mechanism for Economic Growth," *Journal of Political Economy*, Vol. 99, No. 3, pp. 460-82

Yeaple, S. (2005) "Firm Heterogeneity, International Trade and Wages," *Journal of International Economics*, Vol. 65, No. 1, pp 1-20