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Essays on Human Capital Mobility and Asset Pricing

by

Andrés Francisco Donangelo

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy

in

Business Administration

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA, BERKELEY

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Spring 2011

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Andrés Francisco Donangelo

Abstract

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Doctor of Philosophy in Business Administration

University of California, Berkeley

Professor Nicolae Gârleanu, Chair

This dissertation explores the intersection between labor and financial markets, in which labor mobility plays a fundamental role. Unlike physical assets such as buildings or machines, human capital can actually walk away from the firm as employees and managers switch employers. The interaction between labor mobility, firm risk and human capital has been remarkably under-researched until now. The main question of this broad project is how differences in the flexibility of workers to find employment across different industries—labor mobility—affects the owners of human and physical capital. The three parts of the dissertation look at this question from different angles.

The first part, *Labor Mobility and the Cross-Section of Expected Returns*, focuses on the effect of labor mobility on the degree of operating leverage of a firm and thus on asset returns. I construct a dynamic model where worker's employment decisions affect the productivity of capital and asset prices in predictable ways. The model shows that reliance on a workforce with flexibility to enter and exit an industry translates into a form of operating leverage that amplifies equity-holders' exposure to productivity shocks. Consequently, firms in an industry with mobile workers have higher systematic risk loadings and higher expected asset returns. I use data from the Bureau of Labor Statistics to construct a novel measure of labor supply mobility, in line with the model, based on the composition of occupations across industries over time. I document a positive and economically significant cross-sectional relation between measures of labor mobility, operating leverage, and expected asset returns. This relation is not explained by firm characteristics known in the literature to predict expected returns.

The second part, *Aggregate Asset-Pricing Implications of Human Capital Mobility in General Equilibrium*, extends the model in the first chapter to consider the general

equilibrium implications of labor mobility. The setup is based on a multi-industry dynamic economy with production. The extended model shows that mobility of labor affects not only cash-flows, but also aggregate risk, and the equity premium. This part considers two different types of human capital. Generalist human capital can move between industries, while specialized human capital and physical capital cannot. The greater relative mobility of human capital relative to physical capital affects how aggregate risk in the economy is split between these two components of total wealth. The model shows that aggregate consumption and wealth increase when human capital is more mobile. However, at the same time, aggregate risk and the equity risk premium also increase under human capital mobility.

I assume that the workforce in the economy is exogenously given in the first two chapters of this dissertation. This assumption is relaxed in the third chapter, *Investments in Human Capital and Expected Asset Returns*, where I endogenize the composition of occupations to discuss the interaction between human capital investments and labor mobility. This chapter focuses on the decision of workers to acquire different types of costly human capital with different degrees of associated labor mobility. This part introduces a two-sector general-equilibrium model with production and investments in human capital (i.e. education). Ex-ante identical workers face a trade-off between breadth and depth in the acquisition of industry-specific labor productivity. This chapter derives sufficient conditions for the existence of mobile workers. When these conditions are met, a fraction of workers chooses to acquire mobile but less productive generalist skills, even when labor risk can be fully hedged in financial markets.

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Chapter 1

Labor Mobility and the Cross-Section of Expected Returns

1.1 Introduction

Factor mobility—the ability to reallocate resources across the economy—maximizes aggregate output, mitigates asymmetric shocks, and thus increases total welfare. Although a positive-sum game at the aggregate level, factor mobility makes some players worse off, in particular those who lack control over it. I focus here on a type of factor mobility risky for the owners of a firm and relatively unexplored by the literature until now: labor mobility.

This chapter addresses the following question: are firms that employ workers with flexibility to move across industries more exposed to systematic risk than firms in which workers have low flexibility to switch industries? The answer to this question is important for a number of reasons. First, it helps us to understand where a firm's loading on systematic risk comes from by linking workers' decisions to asset-price dynamics. Second, it sheds light on why observable properties of the workforce employed in an industry should predict expected asset returns. Finally, it motivates empirical evidence that suggests that labor mobility represents an economically significant mechanism for asset pricing: zero-net investment portfolios that hold long positions in stocks of high-mobility firms and short positions in stocks of low-mobility firms earn an annual return spread of up to 8%, after controlling for firm characteristics known to predict expected stock returns.

I establish the link between workers' employment decisions and expected asset returns in a dynamic model of an industry where firms face a mobile labor supply.

Labor mobility is determined by the nature of labor skills required by a productive technology common to all firms in the industry. The more specific the labor skills required by occupations in the industry, the less mobile labor supply is. I first present a simple version of the model that conveys the main intuition of the labor-mobility mechanism. The simple model considers the special extreme cases of immobile and fully mobile labor. The level of labor employed in the industry is static in the immobile labor case, while it depends on the relative performance of the industry with respect to the economy in the fully mobile case. The model predicts that when economy-wide wages are sufficiently smooth relative to the industry’s productivity shocks, reliance on a mobile labor supply translates into a form of operating leverage and increases a firm’s exposure to systematic risk.

The basic idea of the labor mobility mechanism can be summarized as follows: Firms are continuously competing for workers in labor markets. Some industries, such as Health Care, are associated with segmented labor markets where workers have high levels of industry-specific labor specialization. Competition for workers in these “immobile” industries is limited to firms within the industry. Other industries, such as Retail Trade, rely on broader labor markets, where workers have more general skills. Workforces in these industries are mobile, since they are able to search for higher wages across broader sectors, and thus are less affected by industry-specific shocks. Firms in “mobile” industries compete for workers with firms in other industries as well, which leads to labor costs per worker that are less affected by the industry-specific performance and thus lever up the firm’s exposure to systematic risk.

Asset-pricing implications of labor mobility depend on the level of cyclicity and labor intensity of the industry. A firm in a mobile industry is more able to attract workers when its performance is relatively high with respect to that of the economy. Industries with output highly correlated to the business cycle tend to attract workers in good times and lose workers in bad times. The pro-cyclicity of labor supply amplifies the pro-cyclicity of productivity of capital, and attenuates the pro-cyclicity of wages in the industry. These effects are increasing in the labor intensity—the weight of labor on total output—of the industry.

I also consider intermediate levels of labor mobility. The richer setting is based on the interaction between two distinct labor markets: an industry-specific labor market of specialists in the industry and an economy-wide labor market of generalists. I model labor mobility as the ability of specialists and generalists to move across these two labor markets. I provide closed-form solutions for the value of the firm and instantaneous expected asset returns. I show that under the plausible assumptions,

expected asset returns are monotonically increasing in labor mobility.

Industry-specific labor mobility is not directly observable and represents a challenge for the study of factor mobility. To overcome this problem, I propose a new indirect measure of labor mobility based on the occupational composition across industries. The measure represents the level of across-industry concentration of occupations, based on data from the Bureau of Labor Statistics from 1988 to 2009. Workers in occupations concentrated in fewer industries are associated with industry-specialists with low labor mobility, while workers in occupations dispersed across the economy are associated with generalists with high mobility. The measure of inter-industry labor mobility captures the mean occupation dispersion of employed workers in a given industry, weighted by the number of workers assigned to each occupation.

I present empirical support for a positive relation between measures of labor mobility, operating leverage, and expected asset returns. Firm- and industry-level portfolios of stocks sorted on the measure of labor mobility earn monotonically increasing post-ranking stock returns, even after adjusting for firm characteristics such as size, book-to-market, and past returns. Returns of zero-investment portfolios long high-mobility and short low-mobility stocks earn significantly positive excess returns. The relationship between labor mobility and cross-sectional predictability of stock returns is confirmed in panel data regressions of firm-level returns on a lagged measure of labor mobility, in addition to firm-level controls. To disentangle financial leverage from labor mobility, I repeat portfolio sorts for unlevered stock returns as a proxy for asset returns and find similar results. As predicted by the model, the effect of labor mobility on stock returns is stronger for highly cyclical industries, as proxied by the correlation between the industry's revenues and GDP.

The model assumes an exogenously given pricing kernel and is therefore silent on the true source of aggregate risk for the economy. Although outside the scope of the model, a natural empirical question is whether traditional asset-pricing models are able to price portfolios of stocks sorted on the measure of labor mobility. The CAPM and Fama and French (1993) three-factor models are rejected in Gibbons, Ross, and Shanken (1989) (GRS) tests of alphas being jointly zero at the 1% level. The rejection of these models is economically significant: the top labor-mobility quintile portfolio formed either at the firm- or industry-level earn unexplained returns of up to 65 basis points per month, or 8% per year. Moreover, unexplained stock returns are in general increasing in labor mobility. I also find evidence that labor mobility is a priced risk. Panel data regressions, I find that a one standard deviation increase in labor mobility is associated with an increase of up to 1.9% in annual expected stock returns. None of

the standard models—CAPM and Fama-French three-factor models—can explain the dynamics of the labor-mobility spreads.

The rest of the chapter proceeds as follows. Section 2 discusses literature related to this work. Section 3 presents a simple model with perfect mobility or perfect immobility. Section 4 extends the simple model to the general mobility case. Section 5 presents the empirical tests, and Section 6 concludes.

1.2 Relation to existing literature

Related to this chapter is a broad asset-pricing literature that explores the relation between firms' characteristics and predictability in the cross-section of asset returns.¹ To this literature, this chapter adds labor mobility as a theoretically motivated and observable industry property that affects firm risk and expected stock returns.

My work also contributes to the literature that discusses the relation between labor-induced operating leverage and asset prices. Examples of this literature are Gourio (2007), Danthine and Donaldson (2002), Chen, Kacperczyk, and Ortiz-Molina (2010), and Parlour and Walden (2007). Gourio (2007) proposes a model where labor intensity is positively related to labor-induced operating leverage, a result consistent with the model proposed here. Labor intensity and labor mobility are two complementary mechanisms that affect a firm's operating leverage. In a cyclical industry, the effect of labor mobility on firm risk is increasing in labor intensity and, conversely, the effect of labor intensity on firm risk is increasing in labor mobility.

Danthine and Donaldson (2002) discuss a mechanism where a counter-cyclical capital-to-labor share leads to labor-induced operating leverage in a general equilibrium setting. In their model, wages are less volatile than profits, due to limited market participation of workers, and firms provide labor-risk insurance to workers through labor contracts. Stable wages act as an extra risk factor for shareholders, as markets are incomplete in their model. Motivating the assumption of labor contracts that transfer labor risk to equity holders and the assumption of limited market participation, Danthine and Donaldson (2002, pg. 42) say:

“The twin assumptions of competitive labour markets and Cobb-Douglas production function imply, counterfactually, that factor [capital and labor] income shares are constant over the short and medium terms.”

¹A small sample of this literature includes Basu (1983), Bhandari (1988), Fama and French (1992), Chan and Chen (1991), Dechow, Hutton, Meulbroek, and Sloan (2000), Griffin and Lemmon (2002), Hou and Robinson (2006), and Gourio (2007).

Although the statement is true in a single-industry economy, it does not hold under inter-industry labor mobility. Despite being presented here in a partial equilibrium setting, labor mobility causes the splitting of revenues between capital and labor to vary with time, even under the standard assumptions of Cobb-Douglas production functions and perfect competition. Labor mobility makes wages inelastic to asymmetric shocks in the economy, a result that does not require assumptions about insurance through labor contracts, market incompleteness, or limited participation.²

Chen et al. (2010) empirically investigate whether unionization levels affect the cost of capital across industries. They find that the cost of capital is higher for industries with high unionization levels, and therefore lower flexibility on the demand side of labor. My work focuses instead on the flexibility on the *supply* side of labor, i.e. the worker, and its effect on asset prices. It remains to investigate a possible interaction between labor mobility and frictions in the *demand* side of labor across industries, and its effect for the cross-section of returns.

Parlour and Walden (2007) explore a contracting mechanism with moral hazard to generate cross-sectional differences in risk sharing between workers and shareholders. Labor contracts enforce effort through ex-post performance-based compensation that affects how firm risk is split between workers and equity holders. In my model, labor contracts are affected by the level of mobility of the labor supply in an industry, which in turn affects the productivity of capital and expected stock returns.

This chapter builds upon the idea that mobile workers effectively carry some of the firm’s capital productivity when they leave an industry. A recent strand in the finance literature discusses a similar mechanism: the threat of managers that can carry organizational capital (OC) away from their employer. Examples of this literature are Lustig, Syverson, and Nieuwerburgh (2010) and Eisfeldt and Papanikolaou (2010). Lustig et al. (2010) discuss the impact of intra-industry inter-firm portability of OC for executives’ compensation and firm value. They show that high levels of portability reduce the effectiveness of labor contracts that insure executives against industry-specific labor risk. Eisfeldt and Papanikolaou (2010) link OC portability to the cross-section of returns. They motivate the connection to asset pricing through an extra risk factor related to technological shocks that affects the outside option of fully mobile managers, and not through an operating leverage mechanism as in the current chapter.

Related to the theoretical approach of this chapter are studies of the cross-section

²In a related paper, Berk and Walden (2010) discuss the role of labor mobility to explain endogenous non-participation in financial markets. The authors argue that labor relations “complete” the markets, through binding labor contracts between mobile and immobile agents.

of returns based on micro-level decisions through dynamic optimization. The main departure point from the literature is that, in my work, labor decisions made by workers affect firm risk, whereas the determinant of firm risk are decisions made by equity holders on investments in Berk, Green, and Naik (1999), Carlson, Fisher, and Giammarino (2004), and Zhang (2005), or on hiring policy, as in Bazdresch, Belo, and Lin (2009).

1.3 A simple model of labor mobility

This section develops a simple partial equilibrium model that illustrates the economic mechanism of labor mobility as a source of labor-induced operating leverage. Members of a mobile labor force can enter and exit the industry without significant losses in productivity, and my simple model focuses on the extreme cases in which labor supply is either immobile or perfectly mobile. The next section extends the base model to the general case with intermediate degrees of labor mobility. To keep the model tractable, and to focus on the effect of micro-level decisions on firm risk, I follow Berk et al. (1999) and take the pricing kernel as exogenous. The dynamics of the pricing kernel Λ are given by

$$\frac{d\Lambda_t}{\Lambda_t} = -r dt - \eta dZ_t^\lambda, \quad (1.1)$$

where $r > 0$ is the instantaneous risk free rate, Z^λ follows a standard Brownian motion, and $\eta > 0$ is the market price of risk in the economy.

A large number of firms and workers make up the industry, and there is perfect competition in the goods and labor markets. Firms are identical within an industry and are represented by an aggregate industry-firm with a standard constant-returns-to-scale Cobb-Douglas production technology. Perfect competition implies that wages equal the marginal product of labor. Operating profits and wages are given by

$$Y_t = (1 - \alpha)A_t L_t^\alpha, \quad (1.2)$$

$$W_t = \alpha A_t (L_t)^{\alpha-1}, \quad (1.3)$$

where Y denotes operating profits, W denotes wages inside the industry, L denotes labor employed, $0 < \alpha < 1$ denotes labor intensity, and A denotes total factor productivity (TFP). Physical capital is assumed to be fixed and normalized to unity. Labor is defined as the sum of the labor productivities of all workers employed in the firm.

TFP (A) growth follows a diffusion process with constant drift $\mu_A > 0$ and volatility $\sigma_A > 0$:

$$\frac{dA_t}{A_t} = \mu_A dt + \sigma_A dZ_t^A, \quad (1.4)$$

where dZ^A is the shock to TFP (A), and follows a standard Brownian motion with $E[dZ^A dZ^\lambda] = \rho dt$. I assume that $\rho > 0$, so that shocks to TFP growth are procyclical.

Note that labor L may vary over time. The level of labor employed in the industry is based on two state variables: TFP level (A) and wages (W) inside the industry. While the TFP levels are identical in the immobile and fully mobile industry, wages might not be. In the immobile industry, labor supply is fixed and wages are given by market clearing of workers inside the industry. Operating cash flows of the immobile industry (denoted by “I”) are given by

$$Y_t^I = (1 - \alpha)A_t (L^S)^\alpha, \quad (1.5)$$

where L^S is total labor employed in the immobile industry.³ From Ito’s lemma, the dynamics of operating cash flow growth in the immobile industry are given by

$$\frac{dY_t^I}{Y_t^I} = \mu_A dt + \sigma_A dZ_t^A. \quad (1.6)$$

Note that operating cash flows are solely exposed to the industry TFP growth shock dZ^A .

In the case with perfect mobility, workers can choose to work either inside or outside the industry, continuously seeking higher wages. Labor supply is assumed unlimited, and economy-wide wages are exogenously given and follow a geometric Brownian motion with dynamics given by:

$$\frac{dW_t^G}{W_t^G} = \mu_G dt + \sigma_G dZ_t^\lambda, \quad (1.7)$$

where $\mu_G > 0$ and $\sigma_G > 0$ are the drift and diffusion terms of the external-wage growth process.⁴ For simplicity, economy-wide wage growth is perfectly positively

³“S” stands for “specialists”, since in the immobile industry every specialist and no generalist is employed in the industry.

⁴Here “G” stands for “generalists”, since these can be interpreted as the wages earned by generalists workers with full mobility.

correlated to the systematic shock, so that wages are pro-cyclical.⁵ Labor markets are in equilibrium when wages in the industry equal wages outside the industry, $W = W^G$.⁶ Perturbations away from this equilibrium lead to frictionless inflows or outflows of workers that equalize wages. Labor employed in production is no longer fixed as in the immobile case, as firms adjust their labor demand so that the marginal product of labor equals external wages. Labor employed in the fully mobile industry (denoted by “M”) is given by:

$$L_t^M = \left(\frac{A_t \alpha}{W_t^G} \right)^{\frac{1}{1-\alpha}}. \quad (1.8)$$

Plugging (1.8) into (1.2) leads to the operating profits of the industry with a perfectly mobile workforce:

$$Y_t^M = (1 - \alpha) A_t^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{W_t^G} \right)^{\frac{\alpha}{1-\alpha}}. \quad (1.9)$$

The dynamics of Y^M are obtained by applying Ito’s Lemma to (1.9):

$$\frac{dY_t^M}{Y_t^M} = \mu_M dt + \frac{1}{1-\alpha} (\sigma_A dZ_t^A - \alpha \sigma_G dZ_t^\lambda), \quad (1.10)$$

where $\mu_M \equiv \frac{1}{1-\alpha} \left(\mu_A - \alpha \mu_G + \frac{\alpha}{1-\alpha} \left(\frac{\sigma_A^2}{2} + \frac{\sigma_G^2}{2} - \sigma_A \sigma_G \rho \right) \right)$.

The dynamics of labor employed in the industry induce differences in the exposures to industry-specific and aggregate shocks by the owners of capital. Equation (1.10) shows that on the one hand, shareholders in mobile industries are subject to a “levered” exposure to the TFP shock Z^A , where $\frac{\sigma_A}{1-\alpha} > 0$ is the loading in the TFP shock, levered by the industry’s labor intensity. On the other hand, labor costs linked to economy-wide wages represent a negative exposure $-\frac{\alpha \sigma_G}{1-\alpha} < 0$ to the aggregate shock Z^λ . When TFP shocks are more volatile than wage growth, the first effect dominates the second and output growth in the full mobile industry is more volatile than that of the immobile industry, for all levels of labor intensity. This result is formalized in the following proposition:

⁵Relaxing this assumption does not affect the qualitative results of the chapter. Moreover, the assumption is conservative: In an extended version of the model (not presented here), I find that the effect of labor mobility on expected returns is qualitatively *decreasing* in the correlation between economy-wide wage growth and the systematic shock.

⁶Here I am implicitly assuming that industry-specific shocks do not affect economy-wide wages. This is a reasonable assumption for a sufficiently small industry definition.

Proposition 1 (Labor mobility and cash flow volatility). *For all levels of labor intensity α :*

$$\sigma_A > \sigma_G \text{ is a sufficient condition for } \sigma_M > \sigma_I,$$

where $\sigma_I \equiv \sigma_A$ is the volatility of output growth under immobile labor and $\sigma_M \equiv \frac{\sqrt{\sigma_A^2 + \alpha^2 \sigma_G^2 - 2\rho\alpha\sigma_A\sigma_G}}{1-\alpha}$ is the volatility of output growth under perfect labor mobility.

The Proposition follows directly from Equations (1.6) and (1.10) and the definitions of σ_I and σ_M .

Under mild assumptions, full labor mobility also amplifies a firm's exposure to systematic risk and leads to higher expected asset returns. To show this result, I start by deriving the value of the firm. Unlevered asset value equals the value of the discounted stream of operating profits:

$$V = E_t \left[\int_t^\infty \frac{\Lambda_s}{\Lambda_t} Y_s ds \right]. \quad (1.11)$$

The solution to equation (1.11) is standard, since operating cash flows follow a geometric Brownian motion when labor is immobile or fully mobile.

Lemma 1 (Value of unlevered assets). *Conditional on existing, the solution to Equation 1.11 for the value of a firm in the immobile and fully mobile industries is given by:*

(i) *The value of the fully immobile firm is given by:*

$$V^I = \frac{Y^I}{E[R^I] - \mu_A}. \quad (1.12)$$

(ii) *The value of the fully mobile firm is given by:*

$$V^M = \frac{Y^M}{E[R^M] - \mu_M}. \quad (1.13)$$

where $E[R^I] \equiv r + \eta\sigma_A\rho$ and $E[R^M] \equiv r + \eta\frac{\rho\sigma_A - \alpha\sigma_G}{1-\alpha}$, are the instantaneous expected returns of the portfolio of stocks that continuously reinvests dividends, for the immobile and fully mobile industries, respectively.

Proof: See Section 4.1.1 of the appendix.

Unsurprisingly, the value of the firm in either industry is increasing in the TFP growth rate, and decreasing in the interest rate r and exposure to aggregate risk, $\sigma_A \rho$ in the immobile case and $\frac{\rho \sigma_A - \alpha \sigma_G}{1 - \alpha}$ in the fully mobile case.

Assumption 1 below ensures existence of a solution for the values of the firms in each of the two cases considered (Equation 1.11):

Assumption 1. (*Bounded values of benchmark industries*)

$$E[R^I] - \mu_A > 0 \quad \text{and} \quad (1.14a)$$

$$E[R^M] - \mu_M > 0. \quad (1.14b)$$

Lemma 1 shows that, under Assumption 1, the value of assets are perfectly correlated with operating cash flows in the extreme cases of labor immobility and full mobility. Consequently, Proposition 1 can be trivially extended to show that asset return volatility is greater in firms in the fully mobile industry. This result is formalized by the Corollary below:

Corollary 1 (Labor mobility and volatility of asset returns). *When Assumption 1 holds, asset returns in the mobile industry are more volatile than those in the immobile industry:*

$$\sigma_M > \sigma_I.$$

Proof: This follows directly from Proposition 1 and Lemma 1. A direct implication of Proposition 1 is that the asset return spread between a firm in the fully mobile and fully immobile industry is increasing in cyclicalty:

Corollary 2 (Labor mobility return spread and cyclicalty). *Asset return spreads between a firm in the fully mobile industry and a firm in an immobile industry are increasing in cyclicalty, ρ :*

$$\frac{\partial (E[R^M] - E[R^I])}{\partial \rho} = \eta \sigma_A \frac{\alpha}{1 - \alpha} > 0. \quad (1.15)$$

I now turn to the ranking of expected returns between a firm in the fully mobile and fully immobile industries. Corollary 1 states that the volatility of asset returns is higher in firms with fully mobile workforces. To extend the result for expected asset returns, I start by making an assumption on the systematic risk loadings of the TFP and wage growth. Let $\beta^A \equiv \rho \sigma_A$ be the slope of a regression of TFP growth on the systematic shock Z^λ , and $\beta^G \equiv \sigma_G$ be the slope of a regression of economy-wide wage growth on Z^λ :

Assumption 2 (Systematic risk loadings of the TFP shock and wages). *TFP growth is more exposed to systematic shocks than are economy-wide wages, $\beta^A > \beta^G$.*

Assumption 2 seems plausible for most industries, since aggregate productivity is cyclical and aggregate wages tend to be smoother than TFP growth.⁷ Wages in a fully mobile industry are perfectly correlated to economy-wide wages. A pro-cyclical cost per unit of labor productivity acts as a short position in systematic risk and effectively reduces expected asset returns. When Assumption (2) holds, the decrease in systematic risk due to less elastic wages is offset by the pro-cyclical levels of labor, which act as labor-induced operating leverage. The extra loading on systematic shocks is translated into higher expected asset returns in mobile industries. This result is formalized below:

Proposition 2 (Ranking of asset returns in immobile and mobile industries). *For all levels of labor intensity α , $\beta^A > \beta^G$ is a sufficient and necessary condition for $E[R^M] > E[R^I]$.*

The Proposition follows from Lemma 1, and from the definitions of $E[R^I]$ and $E[R^M]$.

A direct implication of Lemma 1 and Proposition 2 is that the labor mobility asset return spread between a firm in the fully mobile and a firm in an immobile industry is increasing in the labor intensity of the productive technology. This result is formalized in the corollary below:

Corollary 3 (Labor mobility return spread and labor intensity). *Assumption 2 implies that the asset return spread between a firm in the fully mobile industry and a firm in an immobile industry is increasing in labor mobility, α :*

$$\frac{\partial (E[R^M] - E[R^I])}{\partial \alpha} = \frac{\eta (\sigma_A \rho - \sigma_G)}{(1 - \alpha)^2} > 0. \quad (1.16)$$

1.4 General model of labor mobility

This section extends the simple model with perfect labor mobility/immobility to the case with intermediate levels of mobility. I show that, under the same assumptions used to derive Proposition 2, expected asset returns are monotonically increasing in a measure of labor mobility. Before establishing this result, I start by introducing labor mobility in the general setting.

⁷See for example Abraham and Haltiwanger (1995) and Gourio (2007).

In practice, the flexibility of a worker to seek employment across industries can be affected by a number of endowed characteristics or past decisions, such as education, age, geographical location, and bundle of acquired labor skills. In this chapter, I focus on the latter and consider two types of workers with different sets of skills: specialists and generalists. Specialists possess all labor skills demanded by the industry, but lack some skills demanded elsewhere. Generalists have the full set of skills demanded outside the industry, but not some of the skills demanded in the industry. Differences in the skill set of specialists and generalists lead to differences in their relative labor productivity inside and outside the industry. I define below the measure of labor mobility used in the general model, motivated by differences in the skill set of specialists and generalists. For simplicity, I assume that the labor productivity of both specialists working in the industry and generalists working outside the industry is normalized to one:⁸

Definition 1 (Measure of labor mobility (δ)). *Specialists that choose to exit and generalists that choose to enter the industry effectively reduce their labor productivity to*

$$0 < e^{-\frac{1}{\delta}} < 1, \quad (1.17)$$

where $\delta > 0$ is the measure of inter-industry labor mobility.

Figure 1.1 illustrates how differences in skills between the two types of workers make specialists relatively more productive inside the industry and generalists relatively more productive outside the industry. The simple model discussed in the previous section presents the special cases of $\delta \rightarrow 0$ (immobile industry) and $\delta \rightarrow \infty$ (fully mobile industry). When $\delta \rightarrow 0$, generalists cannot be employed in the industry and specialists cannot work elsewhere, so labor supply is immobile. When $\delta \rightarrow \infty$, specialists and generalists are effectively identical, so that labor supply is fully mobile.

⁸This can be interpreted as specialists and generalists having the same *level* of endowed labor skills.

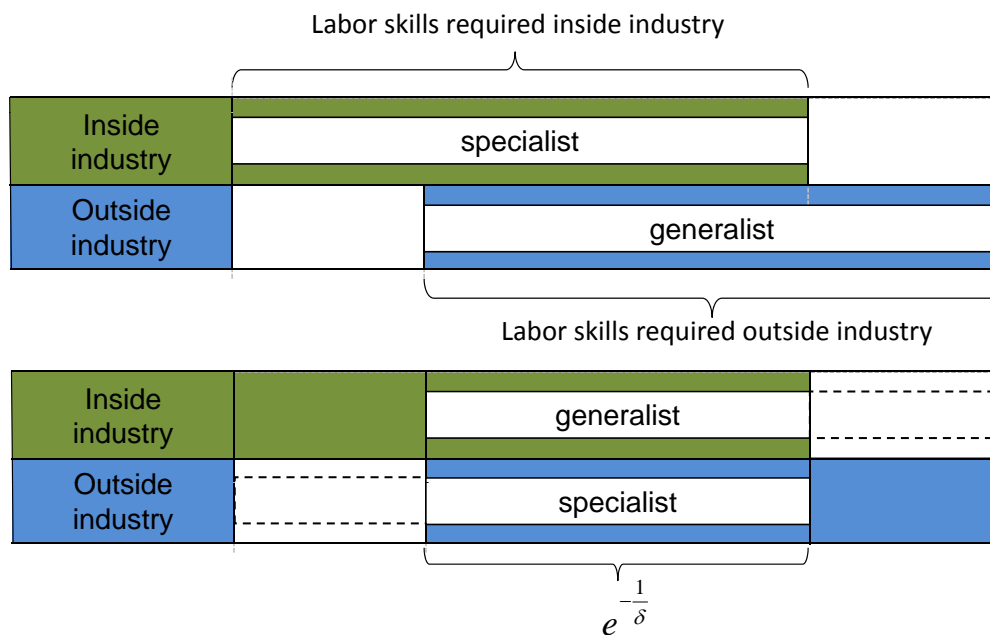


Figure 1.1: Labor productivity for specialists and generalists working inside and outside the industry.

Note that this modeling choice implies symmetry in the productivity losses for specialists and generalists that exit and enter the industry, respectively. Furthermore, losses in productivity for workers that move are fully reversible. Labor productivity is fully restored when a worker returns to the original location. Flows of workers across industry have only transitory effects for the firm as well. The *ability* of workers to move, on the other hand, has a persistent effect on the riskiness of the firm.

Flows of workers across an industry's border are driven by differences in wages inside and outside the industry, and affected by labor mobility. A specialist is willing to exit and a generalist is willing to enter the industry when the absolute difference between inside and outside wages is high enough to justify the losses in productivity. The discrete nature of the differences in productivity of workers inside and outside the industry creates three different regimes of labor supply mobility: *net outflow of specialists* (or simply *outflow*), *net inflow of generalists* (or simply *inflow*), and *stasis* regime. The *outflow* regime is characterized by states where economy-wide wages sufficiently higher than wages inside the industry, so that some specialists are willing

to exit the industry. Conversely, the *inflow* regime is characterized by states where wages inside the industry are relatively high, so that some generalists are willing to enter the industry. In states where wage differentials are not high enough to justify the decrease in productivity, there is no mobility and labor supply is constant and entirely composed by specialists (*stasis* regime).

It is convenient to define a state variable as a linear transformation of the natural log of the ratio of wages between specialists and generalists under no mobility. Let W^S be the wage earned by a specialist in the case with immobility of labor:

Definition 2 (Relative performance of the industry).

$$x \equiv \frac{\alpha}{1-\alpha} \ln \left(\frac{W^S}{W^G} \right) \quad (1.18)$$

The ratio $\frac{W^S}{W^G}$ can be interpreted as the relative productivity (or performance) of the industry relative to the –not explicitly modeled– economy-wide productivity or output. It is easy to show that x can also be represented as the logarithm of the ratio of cash flows of the fully mobile and fully immobile industries, $x \equiv \ln \left(\frac{Y^M}{Y^I} \right)$. Ito's Lemma gives the dynamics of x_t :

$$dx_t = \mu_x dt + \frac{\alpha}{1-\alpha} (\sigma_A dZ_t^A - \sigma_G dZ_t^G), \quad (1.19)$$

where $\mu_x \equiv \frac{\alpha}{(\alpha-1)^2} \left((\mu_G - \frac{\sigma_G^2}{2}) - (\mu_A - \frac{\sigma_A^2}{2}) \right)$.

The state variable x determines the location of the industry within the labor mobility regimes as follows. The boundary between the *outflow* and *stasis* regimes is determined by the state where the marginal *specialist* is indifferent between staying and leaving the industry. In this case, wages inside the industry are equalized to outside wages net of mobility frictions for *specialists*, $W_t^S = e^{-\frac{1}{\delta}} W_t^G$, or equivalently when $x = x_L(\delta) \equiv -\frac{1}{\delta} \left(\frac{\alpha}{1-\alpha} \right)$. The boundary between the *stasis* and *inflow* regimes is determined by the state where the marginal *generalist* is indifferent between staying and leaving the industry. In this case, when wages inside the industry are equalized to outside wages net of mobility frictions for *generalists*, $W_t^S = W_t^G e^{\frac{1}{\delta}}$, or equivalently when $x = x_H(\delta) \equiv \frac{1}{\delta} \left(\frac{\alpha}{1-\alpha} \right)$. To keep the notation simple, I hereafter refer to the boundaries simply as x_L and x_H , although it is important to keep in mind that they depend on the labor mobility measure δ . The table below summarizes the mobility regions in terms of the relative performance of the industry x , and the boundaries x_L and x_H :

Mobility regime	Relative wages between specialists and generalists
Net outflow of specialists	$x \leq x_L$
Stasis	$x_L < x < x_H$
Net inflow of generalists	$x \geq x_H$

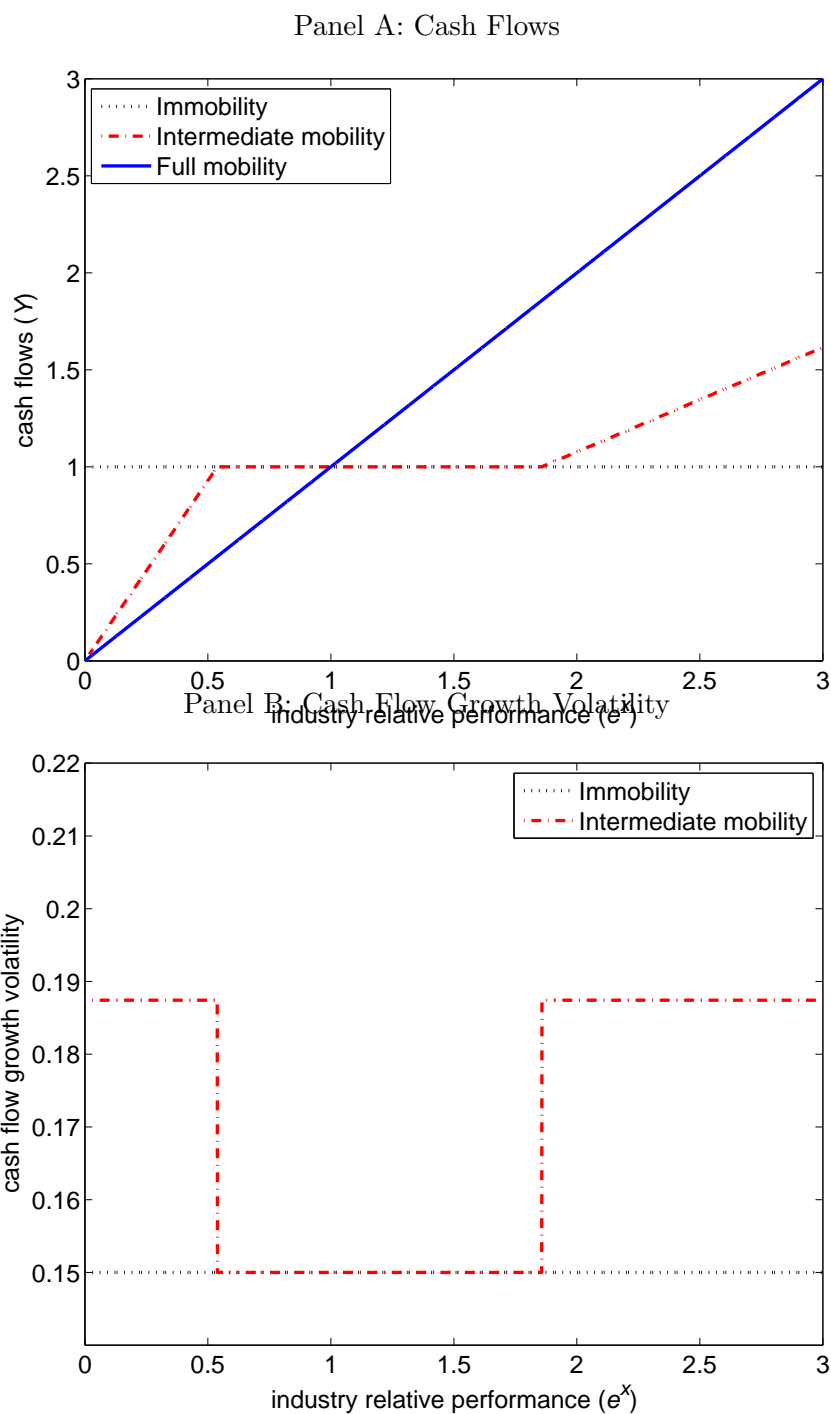
1.4.1 Cash flows

The dynamics of cash flows in each of the three regimes are related to the dynamics of cash flows of firms in the otherwise identical fully mobile and immobile industries. In the *outflow* and *inflow* labor regimes, a firm's cash flows are perfectly correlated to those of a firm in an otherwise identical fully mobile industry, since there are no associated irreversible frictions. In the *stasis* regime, cash flows are identical to those of a firm in an immobile industry. This correspondence between the regimes and the extreme mobility cases suggests that we can use the relative performance of the fully mobile and immobile industries as a state variable that defines the locus of the industry within the regimes.

Note that, by construction, operating cash flows of the fully mobile industry can be solely represented as $Y^M = Y^I e^x$. From the definitions of the lower and upper boundaries, x_L and x_H , we can determine cash flow levels:

$$Y = \begin{cases} Y^I e^{x+x_H}, & \text{if } x \leq x_L \text{ (outflow of labor),} \\ Y^I, & \text{if } x_L < x < x_H \text{ (stasis),} \\ Y^I e^{x+x_L}, & \text{if } x \geq x_H \text{ (inflow of labor).} \end{cases} \quad (1.20)$$

Panel A in Figure 1.2 illustrates the relation between cash flows and the industry's performance relative to the economy. When the industry's performance is relatively low (small x), cash flows are greater than those of the fully mobile industry, but smaller than those of an otherwise identical immobile industry. When relative performance is about average, labor mobility does not affect industry's cash flows. When performance is relatively high (large x), cash flows in the industry are greater than those of the immobile industry, although smaller than that of the fully mobile industry. When there is a net inflow of labor, labor mobility increases labor supply and boosts production, but not as much as in the case with perfect mobility.



Parameters values used in plots: $Y^I = 1$, $\eta = 0.4$, $r = 2.5\%$, $\alpha = 0.65$, $L^I = 1$, $\mu_A = 3\%$, $\sigma_A = 15\%$, $\rho = 0.8$, $\mu_G = 2\%$, and $\sigma_G = 3\%$. Intermediate mobility case $\delta = 3$.

Figure 1.2: Model solution: cash flows, cash flow volatility, and industry relative performance.

From Equation (1.20), cash flow volatility in each region is given by:

$$\sigma = \begin{cases} \sigma_M, & \text{if } x \leq x_L \quad (\text{outflow of labor}), \\ \sigma_I, & \text{if } x_L < x < x_H \quad (\text{stasis}), \\ \sigma_M, & \text{if } x \geq x_H \quad (\text{inflow of labor}), \end{cases} \quad (1.21)$$

where σ_M and σ_I are the volatility of cash flow growth of the fully mobile and immobile industries respectively, previously defined in Proposition 1. When the volatility of the TFP growth is greater than the volatility of economy-wide wage growth ($\sigma_A > \sigma_G$), cash flow growth in a fully mobile industry is more volatile than that of an immobile industry ($\sigma_M > \sigma_I$), as presented in Proposition 1. Proposition 3 below extends Proposition 1 for the general mobility case:

Proposition 3 (The volatility of cash flow growth is weakly increasing in labor mobility). *For all levels of labor intensity α , $\sigma_A > \sigma_G$ is a sufficient condition for $\frac{d\sigma_Y}{d\delta} \geq 0$.*

Proof: The Proposition follows directly from Equation (1.21) and Proposition 1.

Panel B in Figure 1.2 illustrates Proposition 3. Cash flow growth volatility equals that of a firm in an immobile industry in the stasis region, and that of a fully mobile industry in the outflow and inflow of labor regions. As labor mobility increases, the stasis region shrinks, leading to a weakly increasing volatility of cash flow growth for all values of x .

1.4.2 Asset returns

In this section, I show that the positive relation between labor mobility and expected asset returns also holds in the general model. The main intuition for the result is analogous to the case presented in the simple model: the increase in cash flow volatility due to labor mobility adds systematic risk to the firm when economy-wide wages are less exposed to systematic risk than is TFP (A) growth.

I start again by deriving the value of the firm, given by Equation 1.11. Note that the main departing point from the simple model is that now cash flows do not follow geometric Brownian motion. Under mild regularity conditions, we can represent Equation (1.11) as the solution to the ordinary differential equation presented by Lemma 2 below:

Lemma 2 (Homogeneity of value of the unlevered firm). *If the function $f(x)$ exists and is twice continuously differentiable, then:*

(i) Equation (1.11) can be expressed as $V = Y^1 f(x)$.

(ii) $f(x)$ solves the following ordinary differential equation (ODE):

$$0 = 1 + \max [e^{x+x_L} - 1, 0] - \max [1 - e^{x+x_H}, 0] + c_1 f(x) + c_2 f'(x) + c_3 f''(x), \quad (1.22)$$

where the constants $c_1 - c_3$ are given in the appendix.

Proof: See Section 4.1.2 of the appendix.

Lemma 2 greatly simplifies the problem by reducing a Partial Differential Equation (PDE) into an ODE with known closed form solution. Proposition 4 presents the solution of the value of the firm:

Proposition 4 (Value of the unlevered firm). *The solution to equation (1.11) is given by:*

$$V = \begin{cases} V^M e^{x_H} + V^1 B_1 (p_{b,L}(x) - p_{b,H}(x)), & \text{if } x \leq x_L \quad (\text{outflow of labor}), \\ V^1 (1 + B_3 p_{a,L}(x) - B_1 p_{b,H}(x)), & \text{if } x_L < x < x_H \quad (\text{stasis}), \\ V^M e^{x_L} + V^1 B_3 (p_{a,L}(x) - p_{a,H}(x)), & \text{if } x \geq x_H \quad (\text{inflow of labor}), \end{cases} \quad (1.23)$$

where V^M and V^1 are the values of otherwise identical firms in the fully mobile and immobile industries (presented in Equations (1.13) and (1.12)), $p_{b,L}(x)$ and $p_{b,H}(x)$ are the prices of claims that pay \$1 when x reaches x_L and x_H from below, and $p_{a,L}(x)$ and $p_{a,H}(x)$ are the prices of claims that pay \$1 when the barrier is hit from above. B_1 and B_3 are positive constants given in the appendix.

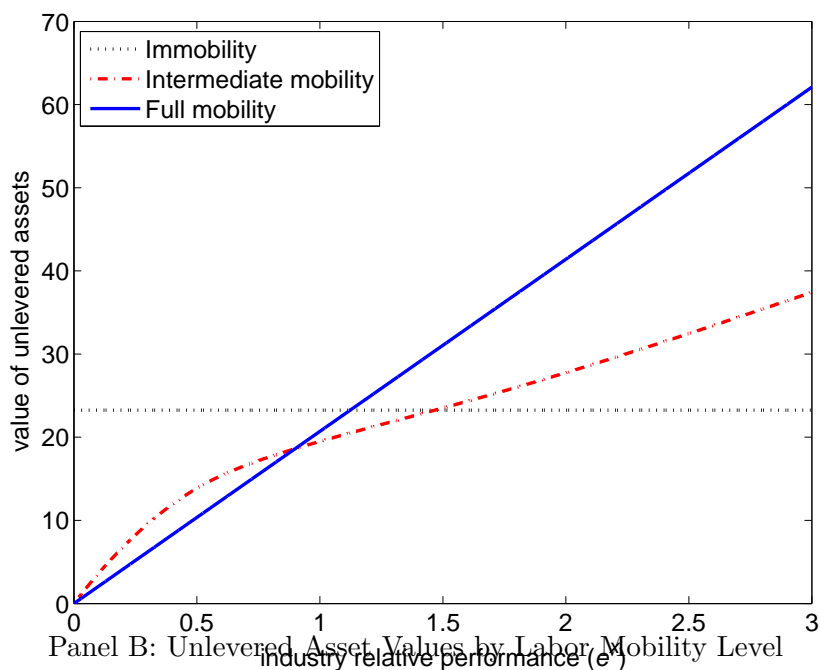
Proof: See Section 4.1.3 of the appendix.

Proposition 4 shows that the value of the firm can be replicated with securities that mimic the asset value of otherwise identical firms in fully mobile and immobile industries, in addition to option-like securities related to each of the four barrier derivatives.

Panel A in Figure 1.3 illustrates Proposition 4. The figure shows the relation between relative performance of the industry x (keeping the TFP (A) level fixed) and the value of firms in industries with different levels of labor supply mobility (δ). In the immobile case, the value of the firm is not affected by x for a fixed value of A . In the fully mobile case, the value of the firm is linearly affected by e^x , and the slope is determined by the labor intensity in the industry. Even for very low strictly positive levels of δ , the value of the firm becomes highly sensitive to x when the

industry underperforms relative to the economy. When the industry overperforms, the sensitivity of the value of the firm to x increases with δ , but not as much as in the fully mobile case. Panel B in Figure 1.3 shows the value of the firm for different values of labor mobility and relative performance of the industry. Labor mobility decreases the value of the firm, except when the industry is over performing relative to the economy. The figure seems to confirm the intuition that labor mobility is increases risk by making labor supply time-varying, although it allows higher level of production when the industry is out performing the economy, and therefore attracting workers from outside.

Panel A: Unlevered Asset Values by Relative Performance Level



Parameters values used in plots: $Y^I = 1$, $\eta = 0.4$, $r = 2.5\%$, $\alpha = 0.65$, $L^I = 1$, $\mu_A = 3\%$, $\sigma_A = 15\%$, $\rho = 0.8$, $\mu_G = 2\%$, and $\sigma_G = 3\%$. Panel A: low mobility $\delta = 1$, and high mobility $\delta = 3$. Panel B: Low performance $e^x = 0.25$, intermediate performance $e^x = 1$, and high performance $X = 4$.

Figure 1.3: Model solution: unlevered asset values and earnings-over-price ratios for different levels of industry relative performance and labor mobility.

Expected unlevered asset returns are defined as the instantaneous drift of the gain process growth:

$$E[R] \equiv E \left[\frac{dV + Ydt}{V} \right]. \quad (1.24)$$

As is the case for the value of the firm, the functional form for the expected returns depends on the current labor mobility region of the industry, as shown in the Lemma below:

Lemma 3 (Instantaneous expected returns). *Instantaneous expected returns are given by:*

$$E[R] = r + \eta(\beta^I + \beta_t^M), \quad (1.25)$$

where $\beta^I \equiv \sigma_A \rho$, $\beta_t^M \equiv \frac{\alpha}{1-\alpha} (\sigma_A \rho - \sigma_G) \xi(x_t; \delta)$, and ξ is a positive function of x given in the appendix.

Proof: See Section 4.1.4 of the appendix.

Equation (1.25) shows that the exposure to systematic risk, can be decomposed into two components, β^I and β_t^M . β^I is the exposure to systematic risk of an immobile firm, due to the properties of its total factor productivity. β_t^M is the additional exposure to systematic risk due to labor mobility.

β_t^M provides the main intuition of the effect of labor mobility on asset prices. It is helpful to consider its two main components: ξ and $\frac{\alpha}{1-\alpha} (\sigma_A \rho - \sigma_G)$. ξ captures the level of labor mobility and is affected by the industry's relative performance x and by δ . $\frac{\alpha}{1-\alpha} \sigma_A \rho$ is the exposure to systematic risk that arises from the pro-cyclical changes in labor employed, and countercyclical wages induced by pro-cyclical TFP shocks. The term $-\frac{\alpha}{1-\alpha} \sigma_G$ is the opposing effect of economy-wide wage shocks on labor levels and wages that effectively *reduces* a firm's exposure to systematic risk. When $\frac{\alpha}{1-\alpha} (\sigma_A \rho - \sigma_G) > 0$, flows of workers towards the industry are pro-cyclical. Proposition 5 below shows that in this case, $\frac{\partial \xi(x; \delta)}{\partial \delta} > 0$, so that labor mobility is positively related to expected returns in the general model:

Proposition 5 (Instantaneous expected returns and labor mobility). *Instantaneous expected returns are increasing in the measure of labor mobility (δ) if the values of the benchmark industries are well-defined (Assumption 1) and the volatility of external*

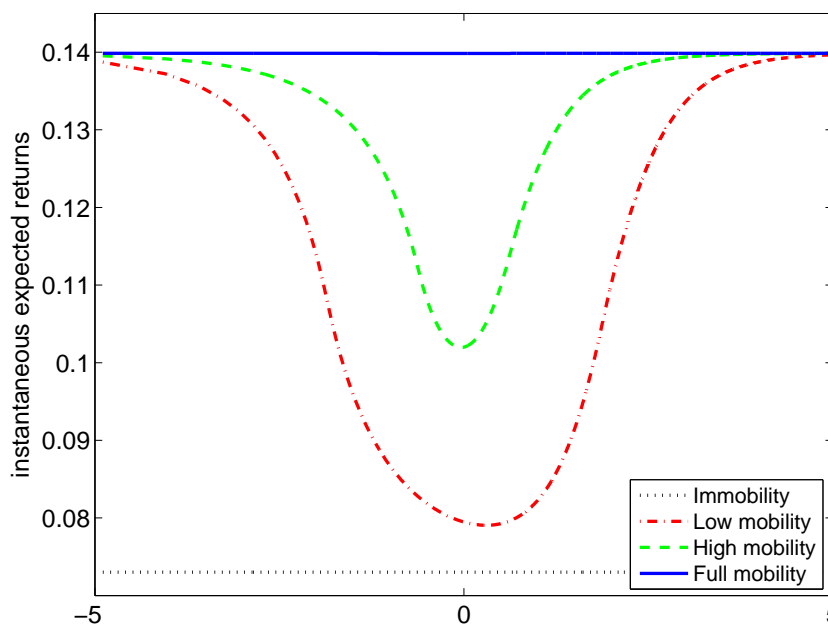
wages is relatively low (Assumption 2).

$$\frac{\partial E[R]}{\partial \delta} > 0. \tag{1.26}$$

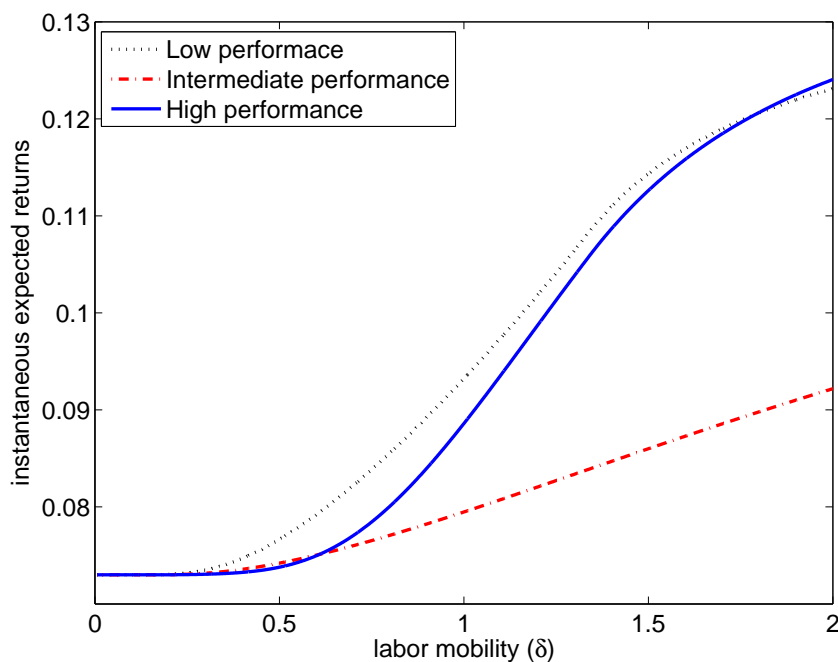
Proof: See Section 4.1.5 of the appendix.

Panel A in Figure 1.4 illustrates the relation between relative performance of the industry x and instantaneous expected asset returns. When Assumptions 1 and 2 hold, expected returns of firms in fully mobile industries are higher than those in immobile industries. Under the intermediate mobility case, expected returns are lower in the stasis region and higher in the inflow and outflow of labor regions. When x is very low or very high, the continuous flow of workers make the dynamics, and therefore expected asset returns, of the industry converge to those of the fully mobile industry. For any level of relative performance x , expected returns are increasing in labor mobility. Panel B in Figure 1.4 illustrates Proposition 5 using a different perspective. For fixed values of x , expected returns are weakly increasing in δ .

Panel A: Instantaneous Expected Returns by Labor Mobility Level



Panel B: Instantaneous Expected Returns by Industry Relative Performance Level



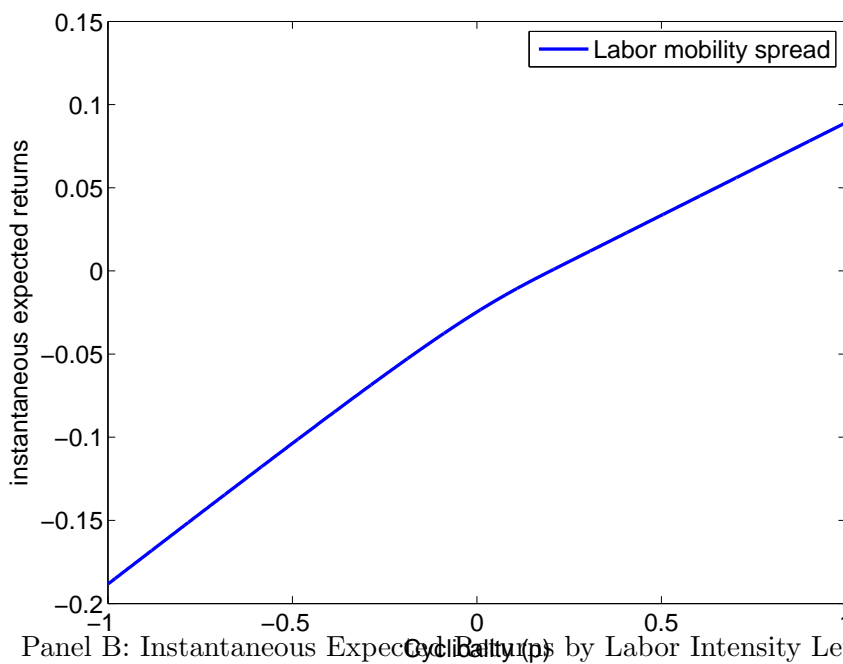
Parameters values used in plots: $Y^I = 1$, $\eta = 0.4$, $r = 2.5\%$, $\alpha = 0.65$, $L^I = 1$, $\mu_A = 3\%$, $\sigma_A = 15\%$, $\rho = 0.8$, $\mu_G = 2\%$, and $\sigma_G = 3\%$. Panel A: low mobility $\delta = 1$, and high mobility $\delta = 3$. Panel B: Low performance $e^x = 0.25$, intermediate performance $e^x = 1$, and high performance $X = 4$.

Figure 1.4: Model solution: Instantaneous expected returns for different levels of labor mobility and industry relative performance.

Panel A in Figure 1.5 illustrates the interaction between cyclicality and labor mobility. The figure shows that labor mobility spreads are increasing in the cyclicality (ρ) of the industry. In particular, for sufficiently low values of ρ where Assumption 2 is violated, the labor mobility spread becomes negative.

Panel B in Figure 1.5 illustrates that the effect of labor mobility on instantaneous expected returns is increasing in labor intensity. This is an intuitive result, since labor intensity is a measure of the sensitivity of capital productivity to labor levels employed in production.

Panel A: Labor Mobility Spread by Industry Cyclical Level



Parameters values used in plots: $Y^I = 1$, $\eta = 0.4$, $r = 2.5\%$, $\alpha = 0.65$, $L^I = 1$, $X = 1$, $\mu_A = 3\%$, $\sigma_A = 15\%$, $\rho = 0.8$, $\mu_G = 2\%$, and $\sigma_G = 3\%$. Panel B: Low labor intensity $\alpha = 0.55$, medium labor intensity $\alpha = 0.65$, and high labor intensity $\alpha = 0.75$.

Figure 1.5: Model solution: Cyclical, labor intensity, and labor mobility.

1.4.3 Labor mobility and composition of occupations

A direct test of the model would require a ranking of industries based on δ , the mobility of workers to enter and exit the industry. Unfortunately, the labor productivity loss associated with mobility, and therefore δ , are unobservable. In this section, I show that the composition of occupations across industries captures the cross-sectional variation in δ . This result motivates the use of an alternative measure based on observable occupation data as a proxy for labor mobility in the empirical tests. I fully discuss this alternative measure in Section 1.5.1. I start by making the following assumption on the distribution of generalists and specialists in the economy (which is not explicitly modeled in this chapter).

Assumption 3 (Distribution of generalists and specialists in the economy).

1. *Generalists are not significantly concentrated in any particular industry.*
2. *Specialists are not significantly concentrated in any particular industry other than their home industry.*

Let the fraction of specialists that remain inside the industry be denoted by γ and let the inter-industry concentration of an occupation be defined as the sum of the squared fractions of workers assigned to the occupation in each industry.⁹ The inter-industry concentration of specialists and generalists is γ^2 and 0, respectively. Now let the fraction of workers in the industry that are specialists be denoted by ω . The inter-industry *concentration* of the average worker in the industry is given by $\Gamma \equiv \gamma^2\omega$. A measure of inter-industry *mobility* is simply the inverse of the measure of the concentration measure by industry.¹⁰ Lemma 4 below shows that, under Assumption 3, $(E[\Gamma])^{-1}$, is in fact monotonically increasing in δ :

Lemma 4 (Expected occupational concentration of the mean worker and labor mobility). *Under Assumption 3 and for finite δ , a ranking of industries sorted on $(E[\Gamma])^{-1}$ coincides with a ranking of industries sorted on δ .*

Proof: See Section 4.1.6 of the appendix.

⁹Notice that this measure is analogous to a Herfindahl index of inter-industry concentration of occupations.

¹⁰Please refer to Section 1.5.1 for the economic motivation and complete description of the construction of the empirical measure of labor mobility.

1.4.4 Summary of empirical implications

I summarize some of the empirical implications of the labor mobility model as follows.¹¹

1. Expected asset returns are monotonically increasing in the measure δ of labor mobility presented in Definition 1 (Proposition 5).
2. The “labor mobility spread” is increasing in the level ρ of industry cyclicalities (Corollary 2 of Lemma 1).
3. A measure of labor mobility based on the composition of occupations, introduced in Section 1.4.3 and fully discussed in Section 1.5.1, leads to the same ranking of industries as the measure δ of labor mobility (Lemma 4).

The following section explores the latter to empirically investigate the first two implications of the model.

1.5 Empirical evidence

The model suggests a positive relationship between labor mobility and expected asset returns (Proposition 5). I empirically investigate this link by using two standard methodologies of portfolio sorts and panel data regressions. I start by introducing a new measure of labor supply mobility based on the composition of occupations across industries and motivated by Lemma 4.

1.5.1 Data

Measuring labor mobility

I obtain industry level occupation data from 1988 to 2009 from The Bureau of Labor Statistics (BLS). The dataset provides annual breakdowns of the number of workers assigned to a large number of standardized occupations across several industries. Please refer to Section 4.1.7 of the appendix for a description of this dataset and the sample of occupations and industries used in this work.

¹¹The following empirical implications implicitly assume that the value of the firm is well defined (Assumption 1), that the covariance of economy-wide wages and systematic shocks is lower than that of the industry’s total factor productivity growth (Assumption 2), and that specialists outside their home industry and generalists are sufficiently dispersed in the economy (Assumption 3).

The Herfindahl index, commonly used as an indicator of the amount of competition of firms within an industry, inspires the inter-industry occupation-level concentration measure proposed in this chapter. I construct my measure of labor mobility in two-stages: first at the occupation level and then aggregated at the industry level. I start by classifying occupations in terms of inter-industry mobility based on the dispersion of workers assigned to each occupation across industries. Let $\text{emp}_{i,j,t}$ be the number of workers employed by industry i and assigned to occupation j at time t . The measure of concentration of workers assigned to occupation j at time t is given by:

$$\text{con}_{j,t} = \sum_i \gamma_{i,j,t}^2, \quad (1.27)$$

where $\gamma_{i,j,t} \equiv \frac{\text{emp}_{i,j,t}}{\sum_i \text{emp}_{i,j,t}}$ represents the fraction of all workers assigned to occupation j that are employed in industry i at time t . For example, of the 69,500 workers assigned to the “Airline pilots, copilots, and flight engineers,” 60,900 are found in the industry “Scheduled Air Transportation,” so that in this particular case $\gamma_{i,j,t} = \frac{60,900}{69,500} \approx 0.88$. The intuition behind this measure is that workers assigned to occupations concentrated in a few industries have arguably less flexibility to switch industries than workers assigned to occupations found across several industries. Following the example, the occupation “Airline pilots, copilots, and flight engineers” is found in only 10 industries in 2009 and is highly concentrated ($\text{con}_{j=\text{pilots},t=09} \approx 0.77$), which suggests low inter-industry mobility of its workers. The occupation “Network and computer systems administrators” is found in 236 industries in 2009 and is highly dispersed ($\text{con}_{j=\text{sys admin},t=09} \approx 0.04$), which suggests high inter-industry mobility.

In the second stage, I aggregate the occupation-level mobility measure by industry over time, weighting by the wage bill associated to each occupation. The industry classification changes in 2002 while the occupation classification changes in 1999 in the BLS dataset. For this reason, the measure is estimated for each industry for the periods of 1988-1998, 1999-2001, and 2002-2009. The measure of labor mobility of industry i at period p is given by:

$$\text{mob}_{i,p} = \sum_t \frac{1}{T_p} \left(\left(\sum_j (\text{con}_{j,t} \times \omega_{i,j,t}) \right)^{-1} \right), \quad (1.28)$$

where T_p is the number of year in period p , $\omega_{i,j,t} \equiv \left(\frac{\text{emp}_{i,j,t} \times \text{wage}_{i,j,t}}{\sum_j \text{emp}_{i,j,t} \text{wage}_{i,j,t}} \right)$ is the fraction of wages paid to workers in industry i that are assigned to occupation j at time t .

The measure in equation (1.28) is standardized in order to simplify the inter-

pretation of the results.¹² The proposed measure is negatively related the degree of segmentation of the labor market associated to a given industry, and is specific to the supply-side of labor, as opposed to the demand-side of labor, which is the focus of the current work. Another desirable property of the measure is that it is immune to ex-post shocks to the productivity or the demand of the industry. For instance, a measure based on realized flows of workers across industries might be affected by a latent source of firm risk that also affects asset returns.

Table 1.1 presents a list of the bottom 25 and top 25 industries ranked by labor mobility in the year 2009, out of a total of 282 four-digit NAICS industries. A casual inspection of Table 1.1 reveals that many industries with low mobility have firms that are in general not publicly listed in an exchange,¹³ while most of the high mobility industries are. Another observational fact is that many manufacturing industries are represented in the top 25 list, but not in the bottom 25, while the opposite is true for service industries.

¹²The cross-sectional mean and standard deviation of the labor mobility measure are zero and one at any given year, respectively.

¹³For example “Elementary and secondary schools,” “Drinking places, alcoholic beverages,” and “Offices of dentists.”

Table 1.1: Top Immobile and Top Mobile Industries

The table presents the bottom 25 (Panel A) and top 25 (Panel B) four-digit NAICS industries sorted on the measure of labor mobility, as of 2009. The measure of labor mobility is constructed as the average of the measure of occupational industry-dispersion across industries and across time, weighted by the number of employees in each occupation.

Panel A: Bottom 25 Industries by Labor Mobility			Panel B: Top 25 Industries by Labor Mobility		
NAICS	Name	mobility	NAICS	Name	mobility
812200	Death care services	-1.54	423500	Metal and mineral merchant wholesalers	2.39
812100	Personal care services	-1.52	424800	Household appliances and miscellaneous machines	2.26
482100	Rail Transportation	-1.52	423200	Furniture and furnishing merchant wholesalers	2.08
621200	Offices of dentists	-1.47	332800	Coating, engraving, and heat treating metals	2.06
611100	Elementary and secondary schools	-1.46	424600	Chemical merchant wholesalers	1.99
722100	Full-service restaurants	-1.43	424100	Paper and paper product merchant wholesalers	1.94
561500	Travel arrangement and reservation services	-1.39	424300	Motor vehicles	1.91
541100	Legal services	-1.37	425100	Electronic markets and agents and brokers	1.84
481100	Scheduled air transportation	-1.35	332600	Tobacco products	1.84
624400	Child day care services	-1.35	311100	Animal food manufacturing	1.76
722400	Drinking places, alcoholic beverages	-1.32	332500	Hardware manufacturing	1.75
238200	Building equipment contractors	-1.29	423800	Machinery and supply merchant wholesalers	1.73
481200	Nonscheduled air transportation	-1.29	335100	Electric lighting equipment manufacturing	1.72
238100	Building foundation and exterior contractors	-1.29	325500	Paint, coating, and adhesive manufacturing	1.70
115100	Support activities for crop production	-1.29	334300	Audio and video equipment manufacturing	1.69
722200	Limited-service eating places	-1.19	423300	Lumber and construction supply merchant wholesal	1.65
238300	Building finishing contractors	-1.16	423600	Railroad rolling stock	1.62
485400	School and employee bus transportation	-1.12	325600	Soap, cleaning compound, and toiletry mfg.	1.62
523100	Securities and commodity contracts brokerage	-1.11	327100	Clay product and refractory manufacturing	1.61
524200	Insurance agencies, brokerages, and related	-1.06	424400	Grocery and related product wholesalers	1.60
561600	Coal and petroleum gases	-1.05	332200	Cutlery and handtool manufacturing	1.59
721100	Traveler accommodation	-1.04	322200	Converted paper product manufacturing	1.58
522100	Footwear	-1.03	311500	Dairy product manufacturing	1.50
813100	Religious organizations	-1.02	493100	Warehousing and storage	1.46
722300	Special food services	-1.01	332700	Machine shops and threaded product mfg.	1.45

Asset returns and portfolio formation

I consider two main types of asset returns: equity returns and unlevered equity returns. While equity returns provide results easier to compare to those in the literature, unlevered asset returns relate more directly to the model's predictions of the labor-mobility effect on firm risk. The well-known negative relation between firm risk and optimal leverage ratios implies that part of a possible effect of labor mobility on equity risk might be offset by lower leverage ratios. Unlevered stock returns are constructed according to:

$$r_{i,y,m}^u = r_{y,m}^f + (r_{i,y,m} - r_{y,m}^f)(1 - \text{lev}_{i,y-1}) \quad (1.29)$$

where $r_{i,y,m}$ denotes the monthly stock return of firm i over month m of year y , $r_{y,m}^f$ denotes the one-month Treasury bill rate at month m of year y , and $\text{lev}_{i,y-1}$ denotes the leverage ratio measure, defined as book value of debt over the sum of book value of debt plus the market value of equity at the end of year $y - 1$.

Each measure of returns is presented as stock returns in excess of the one-month Treasury rate or stock returns adjusted for firm characteristics known to be ex-ante predictors of stock returns in the cross-section. I follow the methodology in Daniel, Grinblatt, Titman, and Wermers (1997) and construct 125 benchmark portfolios, sequentially triple-sorted on the previous year's size, book-to-market, and past stock performance (momentum rank). The procedure uses NYSE-based breakpoints in the triple sorting and constructs value-weighted portfolios to avoid overweighting very small stocks. I then subtract the returns of the benchmark portfolios from each constituent firm's stock returns. An adjusted return of zero for a given stock indicates that the return is fully explained by the firms' size, book-to-market, and past performance.

Furthermore, I present asset returns at both the firm and industry levels, since labor mobility is an industry-specific characteristic. There are several common methods for forming industry portfolios sorted on labor mobility. I construct equally weighted mobility sorts portfolios by first creating industry portfolios of value-weighted stocks, and then equally weighting these industry portfolios into mobility-sorted portfolios; I construct value-weighted mobility portfolios by value-weighting the industry portfolios by the sum of the lagged market values of the firms in the industry.

Section 4.1.8 of the appendix provides a detailed explanation of the financial and accounting data used, as well as additional constructed variables.

1.5.2 Characteristics of industries sorted on labor mobility

Panel A in Table 1.2 reports mean characteristics of labor mobility quintiles for the full sample of industries over the period considered. Noteworthy is the fact that the measure of operating leverage increases significantly over the labor mobility quintiles. This fact seems to support the model. Mean leverage ratios are significantly lower for high labor mobility quintiles. The measures of size and assets tend to decrease over the labor mobility quintiles. CAPM betas are slightly increasing across labor mobility quintiles. The mean book-to-market ratio is smaller for high labor mobility quintiles. Measure of education and unionization seem to be larger for quintiles with high labor mobility.

Panels B and C in Table 1.2 report mean firm-level characteristics of labor mobility quintiles for industries with high and low cyclicalities, respectively. Pairwise comparisons across mobility quintiles shows that the mean firms in the subsample of industries with high and low cyclicalities are fairly similar. Within each of the two sub-samples, CAPM betas are almost flat, although they are slightly increasing across labor mobility quintiles. Although carrying greater systematic risk through slightly larger market betas, the sub-sample of cyclical firms have higher mean book-to-market ratios.

Table 1.2: Summary Statistics

The table reports time-series averages of firm-level characteristics of industries sorted by labor mobility. The table shows statistics for all industries in the sample (Panel A), for the subsample of industries with correlation between quarterly revenues and GDP above median (Panel B), and below median (Panel C). “Mob.” is the measure of labor mobility, and constructed as the average of the measure of occupational industry-dispersion across industries and across time, weighted by the number of employees in each occupation. “ln(Size)” is defined as logarithm of the market value of equity plus book value of total debt. “ln(Assets)” is defined as logarithm of the total book value of assets. “ln(B/M)” is the logarithm of the ratio of book value, defined as shareholders’ equity divided by market value of equity. “Beta” is CAPM, constructed following the methodology described in Fama and French (1992). “O.Lev.” is the average operating leverage, defined as the slope of a time-series regression of a firm’s cash flow growth on sales growth. “Lab.Int.” is labor intensity, defined as the ratio of the number of employees divided by PPE. “Prof.” is profitability, defined as the ratio of earnings to total assets. “Lever.” is leverage ratio, defined as the ratio of book value of debt adjusted for cash holdings, as reported in Compustat, divided by the assets. “Edu.” is the mean education level, measured as the average required education per occupation across industries, weighted by the number of employees in each occupation. “Union” is the average percentage of employees covered by union memberships, based on data from unionstats.com. The sample covers the period 1989–2009.

Quintile	Mob.	ln(Size)	ln(Assets)	ln(B/M)	Beta	O.Lev.	Lab.Int.	Prof.	Lever.	Edu.	Union
Panel A: Characteristics of Mobility Sorted Quintile Portfolios											
Low	-1.13	12.87	6.24	-0.58	1.23	1.03	52.06	0.13	0.23	-0.01	17.0
2	-0.33	12.86	6.16	-0.57	1.31	1.30	64.65	0.13	0.20	0.00	14.5
3	0.29	12.84	5.84	-0.77	1.35	1.30	50.06	0.09	0.14	0.38	17.4
4	0.86	12.66	5.76	-0.70	1.33	1.41	48.39	0.12	0.16	0.20	19.5
High	1.48	12.46	5.66	-0.58	1.33	1.48	52.28	0.12	0.15	0.45	20.2
Panel B: Characteristics of Mobility Sorted Quintile Portfolios (High Cyclical Firms)											
Low	-1.21	13.12	6.49	-0.55	1.22	1.06	42.41	0.14	0.22	-0.35	16.97
2	-0.30	12.72	6.09	-0.48	1.34	1.39	97.07	0.13	0.20	-0.11	14.53
3	0.30	12.85	6.13	-0.55	1.33	1.36	52.69	0.13	0.19	0.19	17.44
4	0.84	12.75	6.02	-0.57	1.32	1.40	48.77	0.12	0.20	-0.02	19.49
High	1.45	12.31	5.56	-0.53	1.35	1.53	59.53	0.12	0.16	0.46	20.19
Panel C: Characteristics of Mobility Sorted Quintile Portfolios (Low Cyclical Firms)											
Low	-1.05	12.58	5.94	-0.60	1.24	1.00	56.45	0.12	0.24	0.38	16.97
2	-0.37	13.01	6.23	-0.67	1.27	1.18	48.42	0.13	0.20	0.09	14.53
3	0.28	12.84	5.52	-1.04	1.38	1.21	48.42	0.03	0.09	0.61	17.44
4	0.88	12.56	5.45	-0.84	1.34	1.43	47.93	0.12	0.12	0.46	19.49
High	1.51	12.58	5.73	-0.61	1.30	1.43	47.20	0.12	0.15	0.41	20.19

Table 1.3 further investigates the relation between the measure of labor mobility and average industry characteristics with regressions. The table shows estimates of panel data regressions with year fixed effects to estimate the degree of univariate and multivariate correlation with the characteristics; also shown are the corresponding

standard errors clustered by industry. The equation tested is:

$$\text{mob}_{i,t} = \lambda_{0,t} + \sum_k \lambda_{k,t} C_{k,i,t} + \tau_t + \epsilon_{i,t}, \quad (1.30)$$

where $C_{k,i,t}$ is the mean industry characteristic k of industry i at year t , τ_t is the year- t dummy, and $k = 0$ denotes the intercept.

Table 1.3: Panel Data Regressions of Labor Mobility on Industry Average Characteristics

The table reports estimates of panel data regressions with year-fixed effects of the measure of labor mobility on industry average characteristics and corresponding standard errors. Variables are defined in Table 1.2. Panel A shows results of 9 univariate regressions (by columns) and Panel B shows results of 10 multivariate regressions (by rows). Standard errors are clustered by industry. Significance levels are denoted by (* = 10% level), (** = 5% level) and (***) = 1% level). The sample covers the period 1989–2009.

ln(Size)	log(B/M)	Beta	O.Lev.	Lab.Int.	Prof.	Lev.	Edu.	Union
Panel A: Simple Regressions								
-0.02 (0.02)	0.11*** (0.03)	0.07 (0.09)	16.86*** (1.81)	-1.17*** (0.14)	0.01 (0.18)	-0.38*** (0.11)	-0.11*** 0.02	5.88*** 1.27
Panel B: Multiple Regressions								
-0.09*** (0.02)	-0.07 (0.04)	0.14 (0.10)	0.15*** (0.02)	-1.20*** (0.15)	-0.03 (0.23)	-0.99*** (0.14)	-0.13*** (0.03)	4.71*** (1.28)
-0.09*** (0.02)	-0.07 (0.04)		0.17*** (0.02)	-1.17*** (0.15)	-0.07 (0.22)	-0.85*** (0.14)	-0.13*** (0.02)	4.76*** (1.26)
-0.01 0.02	0.10*** 0.03							
-0.01 (0.02)	0.08** (0.03)	0.05 (0.10)						
0.00 (0.02)	0.22*** (0.04)	0.05 (0.10)				-0.93*** (0.13)		
			0.17*** (0.02)			-0.42*** (0.11)		
			0.18*** (0.02)			-0.62*** (0.12)		6.36*** (1.27)
			0.17*** (0.02)	-1.10*** (0.14)		-0.76*** (0.12)		4.39*** (1.28)
							-0.09*** (0.02)	4.95*** (1.27)
				-0.99*** (0.12)			-0.09*** (0.02)	3.01** (1.29)

Panel A shows results from univariate regressions of the measure of labor mobility on each of the mean industry characteristics presented in Table 1.2, while Panel B shows results from multivariate regressions. All regression specifications support

the finding in Table 1.2 that labor mobility seems to be positively associated with the measure of operating leverage. The table also shows that labor mobility seems negatively related to both industry sales and labor intensity, or conversely, positively associated to capital intensity. This finding suggests that there might be a positive relation between the measure of labor mobility and the degree of durability of the industry, as in Gomes, Kogan, and Yogo (2009). Indirect evidence that supports the operating leverage mechanism of labor mobility and not the portfolio allocation mechanism of durability is provided in Table 1.3. This table shows a significant negative cross-section relation between labor mobility and financial ratios. This finding is consistent with the positive relation between labor mobility and firm risk, predicted by the model. Since labor mobility affects both stock returns and the volatility of cash flow growth, it should also affect optimal capital structure decisions. In particular, when the owners of a firm face a trade-off between operating leverage and financial leverage, firms in mobile industries should have lower financial leverage levels than their counterparts with immobile labor supplies.¹⁴

Table 1.4 shows the relation between operating leverage, labor mobility and other average firm characteristics. Labor mobility seems to be positively related to operating leverage, and this relation does not seem to be explained by other characteristics. Operating leverage seems to be positively related to size, book-to-market, beta, and unionization level of the labor force, and negatively related to profitability. The positive relation between the percentage of workers covered by union memberships and operating leverage seems to support the findings in Chen et al. (2010).

1.5.3 Portfolio Sorts

Single sorts on labor mobility

This section investigates whether realized returns of portfolios of stocks sorted on the measure of labor mobility are increasing in labor mobility. All results are presented for equally and value-weighted portfolios, constructed both at the firm and industry levels.

Panel A of Table 1.5 presents average post-ranking excess monthly stock returns and monthly stock returns adjusted for size, book-to-market, and past returns, of quintiles of mobility-sorted stocks. The first four columns indicate an increasing pattern in excess equity returns, both at the firm and industry levels, and for both

¹⁴See for example Gahlon and Gentry (1982) for a discussion of the trade-off between these two forms of leverage.

Table 1.4: Panel Data Regressions of Operating Leverage on Labor Mobility and Industry Average Characteristics

The table reports estimates of panel data regressions with year-fixed effects of the measure of operating leverage on industry average characteristics and corresponding standard errors. Variables are defined in Table 1.2. Panel A shows results of 9 univariate regressions (by columns) and Panel B shows results of 10 multivariate regressions (by rows). Standard errors are clustered by industry. Significance levels are denoted by (* = 10% level), (** = 5% level) and (***) = 1% level). The sample covers the period 1989–2009.

ln(Size)	log(B/M)	Beta	Mob.	Lab.Int.	Prof.	Lev.	Edu.	Union
Panel A: Simple Regressions								
0.00	0.12***	0.57***	12.11***	-0.21***	-0.72***	0.06	-0.03***	2.91***
(0.02)	(0.03)	(0.09)	(1.28)	(0.07)	(0.20)	(0.10)	0.01	0.91
Panel B: Multiple Regressions								
0.03*	0.09**	0.72***	0.12***	0.03	-0.47**	-0.23*	-0.03	2.74***
(0.02)	(0.04)	(0.10)	(0.02)	(0.07)	(0.24)	(0.13)	(0.02)	(0.96)
0.01	0.09**		0.14***	0.02	-0.76***	-0.10	-0.02	1.49
(0.02)	(0.04)		(0.02)	(0.07)	(0.23)	(0.13)	(0.02)	(0.98)
0.01	0.11***		0.12***					
0.02	0.03		0.01					
0.04**	0.12***	0.63***	0.10***					
(0.02)	(0.03)	(0.09)	0.01					
0.04***	0.15***	0.63***	0.10***			-0.21*		
(0.02)	(0.03)	(0.09)	(0.01)			(0.12)		
			0.12***			0.11		
			(0.01)			(0.10)		
			0.14***			0.06		1.93**
			(0.02)			(0.12)		(0.94)
			0.14***	0.01		0.06		1.93**
			(0.02)	(0.07)		(0.12)		(0.96)
			0.14***				-0.01	1.90**
			(0.02)				(0.02)	(0.91)
			0.14***	0.00			-0.01	1.87**
			(0.02)	(0.07)			(0.02)	(0.95)

equally weighted and value-weighted returns. The H-L portfolio is rebalanced yearly, with a long position in stocks in the highest mobility quintile and a short position in stocks in the lowest mobility quintile. The H-L portfolio earns economically significant

excess returns of between 0.20% and 0.75% per month. *t*-tests using Newey-West standard errors with four lags confirm that the spreads are significantly different from zero. The last four columns of Panel A present the same pattern for adjusted equity returns. Spreads are significantly different from zero, suggesting that the relation of labor mobility and stock returns is not explained by size, book-to-market, nor past returns.

Cross-Section of Returns of Stocks of Firms Sorted on Labor Mobility
(continued from previous page)

Portfolio/ Test	Excess Returns				Adjusted Returns			
	Firm		Industry		Firm		Industry	
	Equal	Value	Equal	Value	Equal	Value	Equal	Value
Panel C: Portfolio Unlevered Returns								
L	0.44	0.54	0.42	0.45	-0.05	0.24	0.09	0.14
2	0.26	0.51	0.41	0.41	-0.23	0.18	0.11	0.13
3	0.67	0.78	0.66	0.59	0.12	0.42	0.30	0.26
4	0.67	0.92	0.72	0.81	0.17	0.62	0.40	0.45
H	0.63	1.03	0.89	1.15	0.07	0.68	0.54	0.83
H-L	0.22	0.54***	0.51**	0.77***	0.14	0.48***	0.46**	0.70***
	(0.19)	(0.22)	(0.22)	(0.28)	(0.15)	(0.17)	(0.20)	(0.24)
Panel D: Monotonicity Tests								
Bonferroni (H_0 : monotonicity)								
reject?	N	N	N	N	N	N	N	N
p -value	0.842	1.000	1.000	1.000	0.544	1.000	1.000	1.000
Wolak (H_0 : monotonicity)								
reject?	N	N	N	N	N	N	N	N
p -value	0.771	0.980	0.970	0.962	0.516	0.983	0.970	0.938
Patton-Timmerman (H_0 : no monotonicity)								
reject?	N	Y	Y	Y	N	Y	Y	Y
p -value	0.303	0.016	0.009	0.057	0.485	0.024	0.001	0.038

Panel B of Table 1.5 presents evidence for the monotonicity of the returns patterns of the mobility-sorted portfolios presented in panel A. The first two tests, the Bonferroni bounds test and the Wolak test, are based on the null hypothesis that the pattern is monotonic. The Bonferroni test is based on the probability of observing a t -statistic as small as the minimal t -statistic under the null hypothesis, given the total number of tests. The Wolak test compares the difference between unconstrained estimates of the pairwise differences in returns between portfolios and estimates constrained to be monotonic, using bootstrapped errors. Neither test rejects the hypothesis that the pattern of returns across quintiles is monotonic. The last test is the Patton and Tim-

mermann (2010) monotonicity test, based on the null hypothesis of a non-monotonic pattern of expected returns. The test is a one-sided test of the maximum difference across the quintile returns. The test rejects the null hypothesis of non-monotonicity in all cases, except for equally weighted portfolios formed at the firm level.¹⁵

Panel C of Table 1.5 presents a similar analysis for unlevered returns, which are more directly comparable to the prediction of the model. When returns are adjusted for financial leverage ratios, the level of unlevered returns decrease across labor mobility quintiles. Spreads of the H-L portfolios are positive and statistically different from zero in all portfolio constructions. Panel D shows that neither the Bonferroni bounds tests nor the Wolak tests are able to reject the hypothesis that the return pattern across quintiles is monotonic. The Patton-Timmermann test provides further confirmation of monotonicity, by rejecting the null hypothesis that the patterns are not monotonic across all types of portfolios, except for those equally weighted formed at the firm level.

Double-sorts on labor mobility and cyclical

This section investigates whether the positive relation between labor mobility and expected returns is more significant for highly cyclical industries. The model predicts that the effect of labor mobility on asset returns is increasing in the correlation between a firm’s Total Factor Productivity growth and the aggregate shock Z^A (Corollary 2), and in the empirical analysis, I use a proxy for this relationship in the form of a measure correlation between revenues in an industry and GDP, using data from the U.S. Bureau of Economic Analysis. The procedure is as follows: I first construct series of quarterly revenue growth values for each firm listed on Compustat, from 1988 to 2009. I then aggregate firms at the industry level by averaging revenue growth and weighting by lagged revenues, leading to a time-series of industry-level revenue growth. This two-step procedure assures that the revenue growth series for the industry consistently only considers firms that are in the industry at each point in time. The industry-level proxy for cyclical is the correlation between revenue growth at the industry level and quarterly GDP growth, using the full sample period.

I form 10 portfolios, first by grouping firms/industries into quintiles, and then by grouping firms/industries of each quintile into “most cyclical” (MC) and “least cyclical” (LC) halves. The model predicts that the effect of labor mobility on firm risk and asset returns should be increasing in the degree of cyclical. Panels A and

¹⁵I would like to thank Andrew Patton and Allan Timmermann for making available the Matlab code adapted in the monotonicity tests described above.

B of Table 1.6 provide empirical support for this prediction. The spread of the H-L portfolios for the most cyclical half is positive and significant for all different portfolio constructions, but in general not for the least cyclical half. The spread between the portfolios H-L for the MC and the LC group is positive, and in some cases statistically significant. Panels C and D of Table 1.6 present the results of the procedure above for unlevered returns. The labor-mobility spreads of the MC groups are again larger than those of the LC groups. The spread between the portfolios H-L of the MC and LC groups are also positive, although not statistically different from zero in all cases, except for equally weighted portfolios formed at the firm level.

Table 1.6 show that the effect of labor mobility on asset returns is also positive and sometimes significant for the sub-sample of least cyclical firms as well. This result is consistent with the fact that the sample of firms considered in this work, as well as in most finance literature, is more cyclical than the average employer in the USA. For instance, the sample does not consider small businesses and the public sector that taken together employ over 65% of all the workforce in the USA. Employment in the public sector and in small businesses have been less cyclical than that of the aggregate economy in the time period considered.¹⁶

¹⁶Sources: Bureau of Labor Statistics report “Employment in the public sector: two recessions impact on jobs”, BLS, 2004 and Small Business Administration report “Employment dynamics: small and large firms over the business cycle”, Monthly Labor Review, 2007.

Table 1.5: Cross-Section of Returns of Stocks of Firms Sorted on Labor Mobility

The table reports post-ranking mean realized excess monthly stock returns over one-month Treasury bill rates, and adjusted monthly returns of portfolios of firms/industries sorted on labor mobility. Panel A shows results for returns, and Panel B reports monotonicity test results of the return patterns presented in Panel A. These tests are described in Patton and Timmermann (2010). Panel C shows results for unlevered equity excess returns, estimated as excess stock returns times one minus lagged leverage ratio (measured using book value of debt and market value of equity). Panel D reports monotonicity test results of the return patterns presented in Panel C. “Adjusted Returns” are adjusted for size, book-to-market, and momentum, according to the methodology in Daniel et al. (1997). “Firm” and “Industry” indicate portfolios formed at the firm and industry levels, respectively. “Equal” and “Value” indicate portfolios formed using equally weighted and value-weighted returns, respectively. H-L is the zero investment portfolio long the portfolio of industries with high labor mobility (H) and short the portfolio of industries with low labor mobility (L). Newey-West standard errors are estimated with four lags. Significance levels are denoted by (* = 10% level), (** = 5% level) and (***) = 1% level). The sample covers the period 1989–2009.

Portfolio/ Test	Excess Returns				Adjusted Returns			
	Firm		Industry		Firm		Industry	
	Equal	Value	Equal	Value	Equal	Value	Equal	Value
Panel A: Portfolio Equity Returns								
L	0.68	0.71	0.58	0.60	0.01	0.32	0.18	0.21
2	0.41	0.66	0.54	0.53	-0.25	0.23	0.16	0.18
3	0.83	0.89	0.85	0.67	0.13	0.48	0.37	0.30
4	0.81	1.03	0.84	0.93	0.17	0.65	0.44	0.47
H	0.78	1.15	1.03	1.27	0.05	0.74	0.61	0.89
H-L	0.20	0.51**	0.52**	0.75***	0.10	0.47***	0.46**	0.70***
	(0.21)	(0.24)	(0.24)	(0.31)	(0.17)	(0.20)	(0.22)	(0.27)
Panel B: Monotonicity Tests								
Bonferroni (H_0 : monotonicity)								
reject?	N	N	N	N	N	N	N	N
p -value	0.616	1.000	1.000	1.000	0.356	1.000	1.000	1.000
Wolak (H_0 : monotonicity)								
reject?	N	N	N	N	N	N	N	N
p -value	0.699	0.978	0.933	0.928	0.365	0.947	0.960	0.965
Patton-Timmerman (H_0 : no monotonicity)								
reject?	N	Y	Y	Y	N	Y	Y	Y
p -value	0.524	0.014	0.065	0.088	0.685	0.051	0.016	0.040

Table 1.6: Cyclicity, Labor Mobility, and the Cross-Section of Returns

The table reports post-ranking mean realized excess monthly stock returns over one-month Treasury bill rates, and adjusted monthly returns of portfolios of firms/industries double sorted on labor mobility (rows) and cyclicity (columns). Panel A shows results for equity returns, and Panel B reports monotonicity test results of the return patterns presented in Panel A. Panel D reports monotonicity test results of the return patterns presented in Panel C. MC-LC is the difference between returns of portfolios of firms/industries of least and most cyclical half of each labor mobility quintile. Newey-West standard errors are estimated with four lags. Significance levels are denoted by (* = 10% level), (** = 5% level) and (***) = 1% level). The sample covers the period 1989–2009.

Portfolio	Firm						Industry					
	Equally weighted			Value-weighted			Equally weighted			Value-weighted		
	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC
Panel A: Excess Stock Returns of Portfolios Double Sorted by Mobility and Cyclicity												
L	0.75	0.59	-0.16	0.82	0.64	-0.18	0.77	0.56	-0.21	0.81	0.52	-0.29
2	0.30	0.47	0.17	0.66	0.62	-0.04	0.42	0.59	0.17	0.57	0.54	-0.03
3	0.73	0.84	0.11	0.70	1.11	0.41	0.80	0.80	0	0.82	0.79	-0.03
4	0.89	0.70	-0.19	0.98	0.96	-0.02	1.07	0.68	-0.39	1.03	0.74	-0.29
H	0.67	0.85	0.18	1.13	1.14	0.01	0.84	1.11	0.27	1.21	1.34	0.13
H-L	-0.03	0.40**	0.42**	0.40*	0.53**	0.13	0.26	0.61**	-0.02	0.59	0.85**	0.25
	(0.28)	(0.22)	(0.25)	(0.28)	(0.26)	(0.28)	(0.37)	(0.28)	(0.36)	(0.53)	(0.37)	(0.57)
Panel B: Adjusted Equity Returns of Portfolios Double Sorted by Mobility and Cyclicity												
L	0.03	-0.03	-0.06	0.39	0.26	-0.13	0.30	0.15	-0.15	0.34	0.12	-0.22
2	-0.36	-0.17	0.19	0.22	0.23	0.01	0.08	0.23	0.15	0.22	0.20	-0.02
3	0.04	0.15	0.11	0.34	0.62	0.28	0.33	0.31	-0.02	0.34	0.29	-0.05
4	0.31	0.02	-0.29	0.58	0.59	0.01	0.60	0.34	-0.26	0.63	0.30	-0.33
H	-0.04	0.10	0.14	0.75	0.68	-0.07	0.55	0.63	0.08	0.83	0.91	0.08
H-L	-0.06	0.24	0.29	0.41**	0.49**	0.08	0.26	0.53**	-0.17	0.52	0.84***	0.32
	(0.22)	(0.19)	(0.23)	(0.23)	(0.22)	(0.25)	(0.31)	(0.25)	(0.32)	(0.43)	(0.34)	(0.50)

Cyclicality, Labor Mobility, and the Cross-Section of Returns
(continued from previous page)

Portfolio	Firm						Industry					
	Equally weighted			Value-weighted			Equally weighted			Value-weighted		
	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC	Least Cyclical	Most Cyclical	MC-LC
Panel C: Excess Unlevered Returns of Portfolios Double Sorted by Mobility and Cyclicity												
L	0.48	0.37	-0.11	0.62	0.49	-0.13	0.57	0.41	-0.16	0.58	0.38	-0.20
2	0.20	0.30	0.1	0.51	0.49	-0.02	0.26	0.45	0.19	0.41	0.45	0.04
3	0.61	0.63	0.02	0.63	0.93	0.3	0.66	0.63	-0.03	0.72	0.68	-0.04
4	0.77	0.57	-0.20	0.91	0.84	-0.07	0.97	0.55	-0.42	0.96	0.62	-0.34
H	0.53	0.69	0.16	1.01	1.03	0.02	0.75	0.98	0.23	1.12	1.22	0.1
H-L	0.05	0.37**	0.32*	0.46**	0.56***	0.10	0.28	0.61***	0.04	0.69*	0.87***	0.19
	(0.23)	(0.20)	(0.21)	(0.25)	(0.22)	(0.24)	(0.31)	(0.25)	(0.29)	(0.46)	(0.33)	(0.49)
Panel D: Adjusted Unlevered Returns of Portfolios Double Sorted by Mobility and Cyclicity												
L	-0.02	-0.10	-0.08	0.29	0.20	-0.09	0.16	0.08	-0.08	0.19	0.08	-0.11
2	-0.27	-0.17	0.10	0.19	0.20	0.01	0.00	0.19	0.19	0.14	0.17	0.03
3	0.05	0.11	0.06	0.30	0.54	0.24	0.26	0.24	-0.02	0.28	0.24	-0.04
4	0.28	0.03	-0.25	0.54	0.56	0.02	0.57	0.29	-0.28	0.59	0.34	-0.31
H	-0.03	0.14	0.17	0.68	0.66	-0.02	0.49	0.58	0.09	0.81	0.85	0.04
H-L	-0.01	0.26*	0.28*	0.43**	0.50***	0.08	0.30	0.52***	-0.01	0.62*	0.81***	0.19
	(0.20)	(0.16)	(0.19)	(0.21)	(0.19)	(0.22)	(0.29)	(0.22)	(0.25)	(0.38)	(0.29)	(0.43)

1.5.4 Panel data regressions of stocks returns on labor mobility

I run month-fixed-effect panel data regressions of post-ranking firm- and industry-level returns on the measure of labor mobility, along with average firm characteristics known to explain expected returns: size, book-to-market ratios, one-year-lagged stock returns, leverage ratios, and CAPM market beta. Results are reported in Table 1.7. Standard errors are clustered by industry (Panel A) and firm (Panel B). Across all specifications, the average slope of returns on the measure of labor mobility is positive and significantly different from zero, and is relatively unaffected by firms' characteristics. These results seem to confirm the results of the portfolio sorts, presented in Section 1.5.3. The slopes range from 10 to 16 basis points per month, and can be interpreted as the risk premium associated with a one-standard-deviation increase in labor mobility. In annual terms, the slopes range from 1.2% to 1.9% per year per unit of standard deviation.

1.5.5 Labor mobility and standard asset pricing models

This section investigates whether the spreads in average returns across labor-mobility quintiles can be explained by traditional asset-pricing models. I conduct standard two-stage time-series asset pricing tests using the CAPM and Fama and French (1993) three-factor model. In a first stage, I run time-series regressions of excess portfolio returns on the excess market returns (CAPM), the combination of excess market returns and SMB and HML factors (Fama-French model). I then use the covariance matrix of residuals in a test of whether the intercepts of the time-series regressions are jointly different from zero, as in Gibbons et al. (1989).

Panels A and B of Table 1.8 report results of asset pricing tests using portfolios of stocks of firms sorted on the measure of labor mobility. A simple inspection of the table reveals that neither the CAPM nor Fama-French three-factor model is able to price portfolios of high mobility stocks, in particular for value-weighted portfolios. A possible explanation of this finding is that labor mobility is a priced risk, orthogonal to the traditional risk factors used in the literature. In the model I develop in this chapter, I consider the pricing kernel to be exogenously given. In this sense, the model is silent on this failure of the CAPM and Fama-French three-factor models. It remains an open question the reason of the failure of the traditional asset-pricing models in pricing mobility-sorted stocks.

Table 1.8 shows that both the CAPM and the Fama-French three-factor models are rejected using standard GRS tests, except for the CAPM when value-weighted portfolios are used. The rejection of these traditional asset-pricing models is particularly remarkable given the relatively short sample period considered in the tests and the use of only five portfolios. The relation between CAPM betas and labor mobility is mixed. For equally weighted portfolios, CAPM betas increase, and they decrease for value-weighted portfolios.

Panels C and D of Table 1.8 show results of analogous tests, using portfolios of stocks of industries sorted on the measure of labor mobility. In this case, the models also fail to price value-weighted portfolios of industries with high labor mobility. Both the CAPM and the Fama-French three-factor models are rejected when pricing equally weighted portfolios, although the GRS test is unable to reject these models when value-weighted portfolios are used.

The model is silent on why traditional asset-pricing models seem to fail to price the “labor-mobility premium”. A hypothesis is that mobile workers transfer non-insurable systematic risk to their employers, and that traditional asset-pricing models fail to capture this risk because we do not observe the human capital portion of aggregate

wealth. An extension of the model into a general equilibrium setting should shed light on the failure of traditional asset-pricing models in pricing labor mobility sorted stocks.

1.6 Conclusion

I develop a production-based model of an industry where labor mobility, i.e. the ex-ante flexibility of workers to move across industries, subjects the owners of fixed capital to labor supply fluctuations. For cyclical firms, labor mobility translates into a form of labor-induced operating leverage and leads to higher exposure to systematic risk. The model provides theoretical motivation for the role of labor mobility as an industry property that predicts cross-sectional differences in expected asset returns.

Labor mobility is determined in the model by the level of specificity of labor skills required by the productive technology employed in the industry. I construct a new simple empirical measure for labor mobility motivated by the model. The measure is based on the level of inter-industry dispersion of workers in a given occupation as a proxy for labor mobility.

I show novel supporting empirical evidence for the main predictions of the model. First, I find that the measure of labor mobility is positively related to a measure of operating leverage. I also find that the return spread between assets of industries with high mobility and those of industries with low labor mobility is significant, even after controlling for characteristics known by the literature to explain the cross-section of returns. This finding is confirmed by fixed time effects panel data regressions. I also find that the effect of labor mobility is larger for highly cyclical firms, a result consistent with the model.

This work suggests that labor mobility is an observable industry characteristic with new and promising implications for asset pricing. A natural extension of this work is to consider the aggregate implications of labor mobility. Aggregate labor mobility might help reconcile the apparent discrepancy between the low volatility of consumption and the high volatility of aggregate financial indexes. In particular, labor mobility should make human capital—the discounted value of the future stream of the sum of wages in the economy—less risky than the portion of aggregate wealth traded in financial markets. Under this hypothesis, changes in the relative importance of mobile workers in the economy should help forecast changes in the relative riskiness of non-financial and financial wealth and thus expected stock returns.

Table 1.7: Panel Data Regressions of Monthly Returns on Labor Mobility and Firm Characteristics

The table shows estimates and standard errors of panel data regressions with month-fixed effects of stock returns (in basis points) on labor mobility and average firm-level characteristics, described in Table 1.2. Panel A reports results of tests based on industry-level portfolios. Panel B reports results from tests based on individual stocks. R-squared is the average adjusted r -squared across monthly regressions. Standard errors are clustered by industry (Panel A) and firm (Panel B). Significance levels are denoted by (* = 10% level), (** = 5% level) and (***) = 1% level). The sample covers the period 1989–2009.

Panel A: Industry Level							
	I	II	III	IV	V	VI	VII
Mob.	16.4*** (0.4)		15.6*** (0.5)	15.4*** (0.5)	14.8*** (0.5)		13.9** (0.6)
ln(Size)		-15.3** (0.6)	-10.1* (0.6)	-8.6 (0.7)		-16.1*** (0.6)	-11.0* (0.6)
ln(B/M)		30.3** (1.4)	34.5** (1.4)	35.3** (1.4)		27.9** (1.4)	32.7** (1.4)
Past Ret.			1.3 (3.8)	0.8 (3.8)			-0.2 (3.8)
Beta				12.7 (3.7)			
Services?	N	N	N	N	Y	Y	Y
Time Eff.	Y	Y	Y	Y	Y	Y	Y
R-squared	0.4043	0.4045	0.4044	0.4040	0.4049	0.4046	0.4050
Panel B: Firm Level							
	I	II	III	IV	V	VI	VII
Mob.	13.4*** (0.2)		11.0*** (0.2)	10.7*** (0.2)	12.8*** (0.2)		10.4*** (0.2)
ln(Size)		-16.1*** (0.1)	-15.9*** (0.1)	-14.9*** (0.1)		-16.0*** (0.1)	-15.9*** (0.1)
ln(B/M)		10.1*** (0.3)	3.6 (0.3)	4.3 (0.3)		10.2*** (0.3)	3.6 (0.3)
Past Ret.			-38.0*** (0.6)	-38.5*** (0.6)			-38.1*** (0.6)
Beta				13.6* (0.7)			
Services?	N	N	N	N	Y	Y	Y
Time Eff.	Y	Y	Y	Y	Y	Y	Y
R-squared	0.1264	0.1265	0.1270	0.1265	0.1272	0.1269	0.1265

Table 1.8: Time-Series Asset Pricing Tests

This table reports asset pricing tests of the CAPM and Fama and French (1993) model using five portfolios of stocks sorted on labor mobility at the firm level. The tables reports the intercept (monthly alpha) of time-series regressions of excess portfolio returns at the industry- and firm-level on the excess market returns (Panels (A) and (C), respectively), and excess market returns at the industry- and firm-level, and SMB and HML factors (Panels (B) and (D), respectively). GRS stands for the F-statistic for the Gibbons et al. (1989) test of whether the intercepts of the time-series regressions are jointly different from zero, as in Gibbons et al. (1989). Newey-West standard errors are estimated with four lags. Significance levels are denoted by (* = 10% level), (** = 5% level) and (*** = 1% level). The sample covers the period 1989–2009.

Panel A: CAPM Tests (sorts at industry level)										
	Equally weighted Portfolios					Value-weighted Portfolios				
	L	2	3	4	H	L	2	3	4	H
Alpha (%)	0.00 (0.17)	-0.20 (0.17)	0.14 (0.21)	0.09 (0.18)	0.16 (0.21)	0.07 (0.17)	0.07 (0.15)	0.41** (0.19)	0.37** (0.18)	0.62*** (0.19)
MKT Beta	0.71 (0.06)	0.94 (0.05)	1.00 (0.04)	0.87 (0.05)	0.88 (0.06)	0.76 (0.05)	0.97 (0.06)	0.68 (0.06)	0.74 (0.06)	0.69 (0.07)
GRS	1.48					3.66				
<i>p</i> -val (%)	19.6					0.3				
Panel B: Fama-French Three Factor Model Tests (sorts at industry level)										
	Equally weighted Portfolios					Value-weighted Portfolios				
	L	2	3	4	H	L	2	3	4	H
Alpha (%)	-0.17 (0.13)	-0.32** (0.13)	0.07 (0.13)	-0.06 (0.12)	-0.02 (0.14)	-0.04 (0.14)	0.19 (0.15)	0.48*** (0.17)	0.33** (0.17)	0.60*** (0.18)
MKT Beta	0.73 (0.04)	0.89 (0.04)	0.89 (0.03)	0.83 (0.03)	0.87 (0.04)	0.82 (0.04)	0.91 (0.05)	0.70 (0.06)	0.76 (0.04)	0.72 (0.05)
SMB Beta	0.37 (0.08)	0.55 (0.06)	0.74 (0.04)	0.57 (0.05)	0.54 (0.13)	-0.04 (0.06)	0.00 (0.06)	-0.28 (0.08)	-0.01 (0.05)	-0.07 (0.09)
HML Beta	0.37 (0.06)	0.21 (0.08)	0.06 (0.04)	0.27 (0.05)	0.36 (0.08)	0.26 (0.05)	-0.29 (0.07)	-0.13 (0.11)	0.08 (0.10)	0.05 (0.13)
GRS	2.07					4.69				
<i>p</i> -val (%)	6.9					0				

Time-Series Asset Pricing Tests
(continued from previous page)

Panel C: CAPM Tests (sorts at firm level)										
	Equally weighted Portfolios					Value-weighted Portfolios				
	L	2	3	4	H	L	2	3	4	H
Alpha (%)	0.11 (0.20)	-0.38* (0.19)	0.06 (0.25)	0.24 (0.24)	0.06 (0.21)	0.22 (0.15)	-0.02 (0.17)	0.15 (0.20)	0.46*** (0.17)	0.63*** (0.19)
MKT Beta	0.70 (0.07)	1.08 (0.08)	1.03 (0.05)	0.99 (0.05)	0.89 (0.04)	0.75 (0.04)	0.99 (0.07)	0.91 (0.08)	0.83 (0.06)	0.72 (0.07)
GRS	1.76					3.95				
<i>p</i> -val (%)	12.2					0.10				
Panel D: Fama-French Three Factor Model Tests (sorts at firm level)										
	Equally weighted Portfolios					Value-weighted Portfolios				
	L	2	3	4	H	L	2	3	4	H
Alpha (%)	-0.08 (0.14)	-0.37** (0.16)	-0.03 (0.22)	0.18 (0.18)	-0.05 (0.15)	0.15 (0.13)	0.11 (0.17)	0.31* (0.18)	0.46*** (0.17)	0.65*** (0.19)
MKT Beta	0.71 (0.05)	0.94 (0.07)	0.97 (0.05)	0.86 (0.05)	0.83 (0.03)	0.80 (0.03)	0.92 (0.05)	0.86 (0.06)	0.86 (0.05)	0.70 (0.05)
SMB Beta	0.39 (0.07)	0.67 (0.06)	0.55 (0.14)	0.80 (0.08)	0.56 (0.11)	-0.11 (0.06)	0.01 (0.07)	-0.13 (0.06)	-0.13 (0.07)	0.04 (0.08)
HML Beta	0.40 (0.06)	-0.12 (0.09)	0.14 (0.10)	0.00 (0.06)	0.18 (0.07)	0.18 (0.05)	-0.31 (0.08)	-0.37 (0.09)	0.03 (0.11)	-0.06 (0.12)
GRS	1.73					4.87				
<i>p</i> -val (%)	12.7					0.02				

Chapter 2

Aggregate Asset-Pricing Implications of Human Capital Mobility in General Equilibrium

2.1 Introduction

Human capital is the most important input for the production of goods and services in the economy and the main source of aggregate wealth.¹² However, unlike physical capital, such as buildings or machines, human capital can literally walk away from the firm as managers and other employees switch employers. Observable flows of workers are significant and vary over time and across industries.³ This fact suggests that labor mobility is a promising macro variable for asset pricing and for the analysis of human capital. This chapter extends the micro-founded labor mobility mechanism in the first chapter to shed light on the role of *aggregate* labor mobility as a macro-variable that predicts expected stock returns in the time-series.

We analyze the mechanism through which labor mobility affects equity risk and expected returns in a multi-industry dynamic general equilibrium economy. We endo-

¹This chapter is based on my article with the same title, joint with Miguel Palacios and Esther Eilling.

²See for example Jorgenson and Fraumeni (1989), Baxter and Jerman (1987), Lustig and Nieuwerburgh (2008), Lustig, Van Nieuwerburgh, and Verdelhan (2009).

³Kambourov and Manovskii (2008) show that realized worker mobility in the US has increased significantly since the late 1960s, even across broad industry classifications. Annual mobility across one-digit industries has increased from 7 percent in 1968 to 12 percent in 1997. Donangelo (2010) shows that industries differ significantly in the extent to which they rely in general versus industry-specific labor skills.

genize aggregate labor mobility through heterogeneous types of human capital available in labor markets. In particular, individuals endowed with a “general” type of human capital have flexibility to move across industries, while individuals endowed with “specialized” human capital types have less flexibility. We show that, in this setting, aggregate labor mobility affects both conditional betas and the market risk premium.⁴

Our model can be interpreted as a generalization of the “Two-Trees” model of Cochrane, Longstaff, and Santa-Clara (2008). Whereas Cochrane et al. (2008) specify the dividend processes exogenously, our production-based model provides a mechanism through which labor mobility impacts the dividend processes of the two industries. Furthermore, our work builds upon a growing literature that explores the theoretical relationship between labor and stock returns (for instance, Danthine and Donaldson (1992), Danthine and Donaldson (2002), Boldrin, Christiano, and Fisher (2001), and Berk and Walden (2010))⁵ and that studies channels through which labor can affect stock returns. For instance, Merz and Yashiv (2007) focus on firms’ hiring decisions and Chen et al. (2010) consider labor unions. Donangelo (2010) constructs an empirical measure of labor mobility based on the occupational profile of workers across industries. This measure is positively related to expected stock returns in the cross-section, which is in line with our model.

We show that aggregate labor mobility, i.e. the importance of generalist workers in the economy, increases the equity risk premium. Higher levels of aggregate labor mobility improve the allocation of resources in the economy and thereby increase consumption. In general, aggregate labor mobility makes the representative agent wealthier. However, at the same time, higher labor mobility also increases aggregate risk. The mechanism is as follows. First, the benefits from aggregate labor mobility are largest when productivity is different across industries. When one industry is much more productive than the other, workers switch to the more productive industry, thereby increasing production. As a result, shocks to the economy are magnified due to labor mobility.⁶ For instance, when generalist workers leave an industry after a negative shock, the productivity of capital in the industry is decreased even more. Thus, differences in productivity across industries become larger and the benefits

⁴The conditional Capital Asset Pricing Model holds exactly with log utility and approximately with higher levels of relative risk aversion, as in Santos and Veronesi (2006).

⁵In addition, various papers show empirical evidence of the impact of human capital on stock returns, such as Shiller (1995), Jagannathan and Wang (1996), Campbell (1996), Lustig and Nieuwerburgh (2008), and Eiling (2009).

⁶Note that in our model, all shocks are systematic.

from labor mobility are reduced. In other words, aggregate labor mobility creates a new source of risk; the risk of losing the benefits from aggregate labor mobility as the relative productivity between industries changes. In sum, when generalist mobile labor is a more important production factor, the representative agent becomes wealthier but also faces higher risk; the equity premium increases.

In our model, the risk-return profile of the generalist human capital type is close to that of the equity market portfolio, while the profile of specialist human capital is similar to that of equity in the worker's industry. Therefore, stock markets are more effective for diversifying industry-specific labor risk for specialists than for more mobile generalists. All else equal, we should expect to see that mobile workers diversify less in the stock market while specialized workers choose to hold a large number of different stocks to diversify their risk.

Our specification of aggregate labor mobility is motivated by the traditional literature on human capital that distinguishes between general and specific labor skills. This literature points out how different types of labor skills, or human capital, affect labor mobility.⁷ Workers who possess specialized industry-specific skills are, in some sense, "locked" inside their industries of specialization.⁸ In contrast, workers endowed with more general skills that are useful across industries have more inter-industry labor mobility.

We solve a special case of the economy with only two industries. Firms in each industry have identical constant-returns-to-scale production technologies that employ both industry-specific and general human capital as production factors, in addition to physical capital.⁹ There is perfect competition of firms and perfect labor markets within each industry. In particular, all workers can freely move across firms inside their industry. This simplification allows us to explore the labor mobility mechanism, while keeping the solution tractable. In this simple case, there are three types of workers, each endowed with a single type of human capital that determines their mobility: specialists who can only work in one of the two industries and generalists

⁷See for example Becker (1964) and Castania and Helfat (2001). Helwege (1992) and Neal (1995) are examples of empirical studies that suggest that sector-specific skills reduce labor mobility and thus increase labor risk.

⁸We illustrate this with an example: if an investment banker were randomly chosen and asked to seek employment in another industry, she would probably receive lower compensation in her new job than in the financial industry. This loss in compensation is due to the industry-specific skills that are unusable in other industries. Since specialized workers, such as the investment banker in our example, are reluctant to take a lower paying job when they abandon their industries, they have low "mobility".

⁹Note that a Cobb-Douglas production technology with constant returns to scale implies decreasing returns to each of the factors.

who possess skills to work in both industries.

The rest of the chapter proceeds as follows. Section 2 discusses literature related to this work. Section 3 presents the economy and equilibrium and section 4 solves the model for the special case of two industries. Section 5 discusses the main results and section 6 concludes. The appendix contains proofs and further details on the derivation of our model.

2.2 Related literature

This chapter is related to a growing literature that studies the dynamics of the interaction between labor and financial markets. This literature started with Danthine and Donaldson (1992), where labor market frictions expose workers to labor income shock oscillations and generate realistic cyclical variability in the share of wages to output.¹⁰ This seminal work, and virtually all the literature that follows it, relies on restrictions on the space spanned by available securities or restrictions on the access to financial markets of some of the agents to generate realistic results. Our main departure point and contribution is to replace such frictions by the assumption that workers have different degrees of mobility to transit across industries. This assumption generates interesting and novel results, even in a neo-classical framework with complete markets and full stock market participation.

Danthine and Donaldson (2002) is the first paper to discuss the dynamic asset pricing implications of labor induced amplification of shocks to capital. This work shows that the ratio of labor income to revenues over the business cycle acts as operating leverage that amplifies shocks to capital owners in bad times. The effect of their mechanism is similar to that of labor mobility in our model. Danthine, Donaldson, and Siconolfi (2006) measure changes in labor operating leverage in the economy and conclude that it is of first order of importance for asset pricing, more so than aggregate shocks. Using their model, they show that time varying distributional risk is equivalent to habit formation.

A strand of the literature recognizes the economic importance of factor mobility for asset pricing. Boldrin et al. (2001) was the first asset pricing model to point out that limited inter-sectorial mobility of labor and capital is an important element that, in conjunction with habit formation, helps to explain the equity premium and risk-free rate puzzles. Most of this literature relies on significant labor adjustments costs faced by firms in order to generate implications for expected stock returns. We

¹⁰See also Boldrin and Horvath (1995).

depart from this literature by focusing on mobility constraints for the supply side of labor instead of for the demand side of labor.

Our work is closest in spirit to Berk and Walden (2010) and Donangelo (2010). Berk and Walden (2010) show that limited market participation naturally emerges from incomplete markets. In their model, agents with different degrees of mobility enter into binding long-term labor contracts. They find that flexible workers become the owners of equity and insure inflexible workers through these contracts. Under complete markets, we find that mobile workers have fewer incentives to diversify their risk in stock markets given that their human capital is closer to the fully diversified equity market portfolio.

Donangelo (2010) studies a similar relation between labor supply mobility and expected stock returns. In a partial equilibrium framework, the paper shows that the mobility of the firm's workforce increases the volatility of its profits, equity volatility and expected returns. While this chapter focuses on the asset pricing implications of aggregate labor mobility, the relation between industry-specific labor mobility and industry equity returns can also be seen in the context of our model.

The setup of our model is based on Palacios (2009). That paper generates a counter-cyclical consumption to labor income ratio based on a Real Business Cycle model. The mechanism helps to explain the lower risk of aggregate wealth and human capital relative to equity. We extend Palacios (2009) to a multi-sector economy, allowing a fraction of the labor force to be mobile across industries.

2.3 A general equilibrium model with different degrees of labor mobility

We derive a dynamic general equilibrium model with multiple industries in which agents possess different types of human capital, represented by labor skills. The agents' bundles of labor skills determine their labor mobility. We first discuss the general model setup with I industries and N types of human capital. In the following section we derive the solution of the model for the special case where $I = 2$ and $N = 3$. This keeps the solution to the model tractable, while showing the main mechanisms through which labor mobility and human capital affect risk and expected returns.

2.3.1 General model setup

Economic environment

The setting of the model is a competitive production economy with I different industries. Time is continuous and the time horizon is infinite. Agents are endowed with a bundle of N types of human capital skills that are used as input for different industries. We assume that agents can trade claims that span all possible outcomes of the economy. Hence, markets are complete.¹¹ The economy has three markets: 1) a labor market for each type of human capital, 2) the market for goods produced in the economy, and 3) the financial market, where financial claims are traded. We are interested in pricing three types of claims: claims to different types of human capital, equity in different industries and the equity market portfolio, and an instantaneous risk free bond.

Agents

Each agent is endowed with an initial allocation of claims $X_{j,0}$. The vector $X_{j,ehc}$ contains the elements of X_j that are claims to actual production: equity and human capital. Both these claims have a net supply of one. $X_{j,fin}$ contains the elements of X_j that are financial claims which are in zero net supply, such as a risk free bond and other contingent claims. Together, $X_{j,ehc}$ and $X_{j,fin}$ contain all the elements of X_j . Each agent j is also endowed with a bundle of human capital skills S_j , where S is a vector of length N . The n^{th} element of vector S_j corresponds to the units of human capital agent j holds of skill n . A skill can be interpreted as an occupation, a certain type of education, the ability to perform a certain task, or all of these things combined. Without loss of generality, we normalize skills in the economy so that:

$$\sum_{k=1}^N \int_j S_k dj = 1. \quad (2.1)$$

Production

There are I different industries in the economy. Each industry has a continuum of firms which produce one specific type of good. Production of each kind of good

¹¹In this setup, human capital is considered a tradable asset. Several existing papers also treat human capital as a tradable asset (e.g. Jagannathan and Wang (1996) and Lustig and Nieuwerburgh (2008)), while other papers consider human capital to be nontradable (e.g. Mayers (1972)). In reality, human capital is arguably in between fully tradable and fully nontradable. The assumption of tradability and hence complete markets ensures the existence of a unique pricing kernel.

is accomplished by combining industry-specific physical capital and different types of human capital skills. We assume physical capital is immobile, so that the aggregate physical capital available to each industry cannot be changed. A possible interpretation is that industries are bundles of capital and occupations producing a certain good. The difference between industries lies in the different combination of production inputs required to produce goods. Production in industry i will be given by:

$$Y_i = Z_i \prod_{x=0}^N F_x^{\alpha_{x,i}}. \quad (2.2)$$

This functional form corresponds to the Cobb-Douglas production function, where Z_i is total factor productivity, F_x is the input of production factor x , and $\alpha_{x,i}$ is the intensity of factor x in the production function of industry i . Note that input $x = 0$ corresponds to industry-specific physical capital. To achieve constant returns of scale that allow us to aggregate firms into industry-representative firms, we add the condition $\sum_{x=0}^I \alpha_{x,i} = 1$.

Labor mobility

A production factor's mobility depends on it being used in different industries with the same intensity $\alpha_{x,i}$. If an agent's human capital consists mainly of skill x , and this skill is used as an input in many different industries, the agent's labor mobility is relatively high. On the other hand, if skill x is used only in one industry, the agent's human capital is relatively immobile. In our setting, labor mobility can be measured similar to Donangelo (2010), as the Gini coefficient calculated over the $\alpha_{x,i}$ across all I industries. This provides a measure of mobility of human capital skill x . A Gini coefficient of 1 would imply that a given factor (human capital skill) is used equally in all industries, implying high levels of mobility for that factor. A Gini coefficient of 0 would imply that a given labor skill is only used in one industry; in this case there is no mobility. In our model, labor markets within industries are perfect, and therefore there is full mobility within each industry. Consequently, wages are set at the marginal product of labor in the industry.

Our definition of mobility stresses the use that different factors of production might have in different industries, rather than the possibility of physically moving the factor to meet some production need. We choose this specification because the largest fraction of production in the economy is human capital. Within any geographical

market with multiple industries, the largest issue for an agent's labor mobility will be whether she has the skills to participate in a given industry, rather than whether she can actually switch the location of where she goes to work. We recognize that geographical and legal frictions reduce mobility, but those are beyond the scope of this chapter. Also, several labor economics papers show that occupation and industry tenure reduce labor mobility (see e.g. Jovanovic (1979), McLaughlin and Bils (2001), and Kambourov and Manovskii (2008)). In our model, an agent's labor mobility is constant over time and determined entirely by her initial endowments of human capital skills. Making the agent's labor mobility a function of her industry tenure would require an overlapping generations model, which is also beyond the scope of this chapter.

Preferences

Agents consume a bundle of goods, ranking the utility according to the following relation:

$$U(C_1, C_2, \dots, C_I) = \frac{1}{1 - \gamma} \left(\sum_{i=1}^I \theta_i C_i^\rho \right)^{\frac{1-\gamma}{\rho}}. \quad (2.3)$$

Recall I is the number of industries in the economy. C_i is the agent's consumption of good i . This specification assumes a Constant Elasticity of Substitution (CES) between different goods, with Constant Relative Risk Aversion (CRRA) preferences for aggregate bundles. The CES specification can also be viewed as the production function of a single consumption good using multiple intermediate goods as inputs. ρ determines the substitutability across goods: a positive ρ implies that the goods are substitutes, while a negative ρ implies the goods are complements. When $\rho \rightarrow 0$, the CES aggregator converges to the Cobb-Douglas case. An agent's lifelong utility is calculated as the standard discounted sum of each period's utility:

$$LU = E_t \left[\int_t^\infty \frac{e^{-\beta\tau}}{1 - \gamma} \left(\sum_{i=1}^I \theta_i C_{i,\tau}^\rho \right)^{\frac{1-\gamma}{\rho}} d\tau \right], \quad (2.4)$$

where β is the subjective discount rate. The assumption that all agents have identical preferences ensures the existence of an aggregate agent.

Uncertainty

Denote by $(\Omega, \mathfrak{F}, \mathbb{P})$ a fixed complete probability state, and the stochastic process $(B_t)_{t \geq 0}$, a standard I-dimensional Brownian motion with respect to the filtration (\mathcal{F}_t) . The Brownian motion drives shocks to productivity in each industry (Z_i) such that the dynamics of productivity are as follows:

$$dZ_{i,t} = \eta_i Z_{i,t} dt + \sigma_i Z_{i,t} dB_i, \text{ for } i \in \{1, \dots, I\}. \quad (2.5)$$

We denote the instantaneous correlation between any two shocks by $\varphi_{i,j}$.

Firm's maximization problem

The firm's objective is to maximize the present value of dividends for shareholders. Capital is fixed in our model, which implies that there are no investments and no depreciation. Perfect competition implies that firms take the price for their output P_i and the stochastic discount factor M as given. The only decision left for a firm is the amount demanded of each type of human capital at any given period. This decision is denoted by the N -vector L_i . All revenues net of labor expenses are given back to shareholders as dividends D_i . For all firms in industry i , the optimization problem is as follows:

$$\max_{\{L_i\}_t^\infty} E_t \left[\int_t^\infty M_\tau D_{i,\tau} d\tau \right] \quad (2.6)$$

$$\text{s.t.} \quad D_{i,t} = P_{i,t} Y_{i,t} - W_t' \cdot L_{i,t}, \quad \forall t \in [0, \infty), \quad (2.7)$$

where W_t is the N -dimensional vector of wages per unit of human capital.

Agent's maximization problem

Agent j 's problem consists of maximizing her lifelong utility, taking prices and wages as given, subject to her budget constraint. The present value of her consumption is limited by the present value of her human and financial wealth. We assume the agent does not have any utility over leisure, and therefore optimally chooses to

offer labor inelastically.¹² The agent's problem can be expressed as:

$$\max_{\{C_t\}_t^\infty} E_t \left[\int_t^\infty \frac{e^{-\beta\tau}}{1-\gamma} \left(\sum_{i=1}^I \theta_i C_{i,\tau}^\rho \right)^{\frac{1-\gamma}{\rho}} d\tau \right] \quad (2.8)$$

$$\text{s.t. } C'_t \cdot P_t = W'_t \cdot S_{j,t} + X'_{j,t} \cdot D_t, \quad \forall t \in [0, \infty). \quad (2.9)$$

2.3.2 Definition of equilibrium

Goods, labor, and financial markets must clear in equilibrium. The definition that follows is standard:

Definition 1. *In this economy, an equilibrium is defined as a stochastic path for the tuple:*

$$\{\{Z_{i,t}\}_1^I, \{L_{i,t}\}_1^N, \{P_{i,t}\}_1^I, \{W_{i,t}\}_1^N, \{Y_{i,t}\}_1^I, \{D_{i,t}\}_1^I, \{X_{j,t}\}_j, M_t\}_t^\infty$$

such that, for every t :

1. Given $\{Z_{i,t}, P_{i,t}, \{W_{i,t}\}_1^N, M_t\}$, each firm chooses $L_{i,t}$ to maximize the present value of dividends (Equation (2.6)).
2. Given the processes for $\{\{P_{i,t}\}_1^I, \{W_{i,t}\}_1^N, D_t, M_t\}$, the agent chooses $\{C_{i,t}\}_1^I$ to maximize his expected lifelong utility, subject to the transversality condition (Equation (2.8)).
3. Goods markets clear: $C_{i,t} = Y_{i,t}$.
4. Labor markets clear: $L_{j,t} = S_j$.
5. Financial markets clear. This implies for aggregate equity and human capital shares $\int_j X_{ehc,t} = 1$ and for financial shares $\int_j X_{fin,t} = 0$.

2.4 Special case: Two industries and three types of human capital

Here we study a special case where the economy consists of two industries A and B and each agent is endowed with one of three types of human capital. In particular,

¹²This implies full employment in the economy.

each industry requires a unique industry-specific type of human capital skill as well as a general human capital skill.

2.4.1 Characterization of the two-sector economy

Preferences

In a two-good economy the representative agent's utility simplifies to:

$$U(C_A, C_B) = \frac{\left((\theta_A C_A^\rho + \theta_B C_B^\rho)^{\frac{1}{\rho}} \right)^{1-\gamma}}{1-\gamma}. \quad (2.10)$$

The term $(\theta_A C_A^\rho + \theta_B C_B^\rho)^{\frac{1}{\rho}}$ can be interpreted as the agent's instant utility from the consumption of a basket containing C_A and C_B of final goods A and B, respectively. $(\theta_A C_A^\rho + \theta_B C_B^\rho)^{\frac{1}{\rho}}$ can also be interpreted as the amount produced of a final good C from amounts C_A and C_B of intermediate goods A and B, respectively. Under the latter interpretation, the agent solely derives utility from consuming the final good C. Both interpretations lead to the exact same results.

Human capital skills of each type of agent

We assume that there are three types of agents, each endowed with a different labor skill. We label each type of agent as $\{A, G, B\}$. The stock of labor skills of each type of agent is:

$$S_A = \{1, 0, 0\} \quad (2.11a)$$

$$S_G = \{0, 1, 0\} \quad (2.11b)$$

$$S_B = \{0, 0, 1\}. \quad (2.11c)$$

Hence, agents endowed with S_A only have the skills to work in industry A, while agents endowed with specific skills S_B can only work in industry B. Agents with general skills S_G can work in both industries. We denote as ξ_A , ξ_G , and ξ_B , as the proportions of each type of agent in the total population, which are exogenously determined.

Production in industries A and B

Production in both industries simplifies to:

$$Y_A = Z_A K_A^{1-\alpha_A} (L_A^{1-\psi_A} L_{G,A}^{\psi_A})^{\alpha_A} \quad (2.12a)$$

$$Y_B = Z_B K_B^{1-\alpha_B} (L_B^{1-\psi_B} L_{G,B}^{\psi_B})^{\alpha_B}. \quad (2.12b)$$

The intensity of physical capital K_i in the production function of industry i is given by $(1 - \alpha_i)$. The intensity of general human capital input is given by $\psi_i \alpha_i$, and the intensity of industry-specific human capital input is given by $(1 - \psi_i) \alpha_i$. In the general model with I industries, the Gini coefficient over the intensity of a certain type of human capital in the production process across all industries is a indication of its mobility. Similarly, in the case of two industries, the mobility of the generalist human capital depends on the difference between $\psi_A \alpha_A$ and $\psi_B \alpha_B$. If these two intensities are equal, the generalist human capital is fully mobile. The greater the difference, the lower the mobility. In the extreme, this type of human capital is only used in one industry, making it fully immobile specialist human capital.

2.4.2 Prices, wages and dividends in equilibrium

In this section we first derive equilibrium good prices and wages. We then use the dynamics of consumption and the stochastic discount factor to find the prices of claims to each type of human capital, equity prices in each industry, and the risk-free rate. We also price the equity market portfolio, which is a claim to the sum of the dividends in the two industries.

Prices of goods and wages in equilibrium

We set the weighted production of goods A and B, $Y \equiv (\theta_A Y_A^\rho + \theta_B Y_B^\rho)^{\frac{1}{\rho}}$, as the numeraire in the economy. Non satiation and absence of investments implies that revenues equal consumption expenses:

$$Y_A P_A + Y_B P_B = (\theta_A Y_A^\rho + \theta_B Y_B^\rho)^{\frac{1}{\rho}}. \quad (2.13)$$

where P_A and P_B are the prices of goods A and B respectively. Taking partial derivatives with respect to Y_A and Y_B on both sides, leads to the market clearing

conditions:

$$P_A = \theta_A Y^{1-\rho} Y_A^{\rho-1} \quad (2.14a)$$

$$P_B = \theta_B Y^{1-\rho} Y_B^{\rho-1}. \quad (2.14b)$$

Prices and wages are a function of variables known instantaneously. To save on notation, we omit the subscript t unless strictly necessary for clarity. Taking wages for each type of human capital and the price at which the firm can sell its products as given, the firm's first order condition implies the following demands for labor, $i \in \{A, B\}$:

$$L_{G,i} = \frac{Y_i P_i \psi_i \alpha_i}{w_G} \quad (2.15)$$

$$L_i = \frac{Y_i P_i (1 - \psi_i) \alpha_i}{w_i}, \quad (2.16)$$

where L_i is the demand for human capital specific to industry i , w_i is the wage rate for human capital specific to industry i , and w_G is the wage rate for general human capital. Hence, the vector of wage rates per unit of labor takes the form $W = \{w_A, w_G, w_B\}$. Note that because labor markets clear and specific human capital is only employed in one industry, we have $\xi_A = L_A$ and $\xi_B = L_B$. This implies that expression (2.16) pins down wages for industry-specific human capital, which are proportional to the dividends in the industry. The following lemma summarizes the demand for general human capital in the two industries.

Lemma 1. *Let $\Phi = \{K_A, K_B, \alpha_A, \alpha_B, \psi_A, \psi_B, \xi_G, \rho, \theta_A, \theta_B\}$. Then the equilibrium amount of generalist labor employed by industry A is $L_{G,A} \equiv L_{G,A}(\Phi, Z_A, Z_B)$. $L_{G,A}(\Phi, Z_A, Z_B)$ satisfies the following equation:*

$$1 = \frac{\theta_A \psi_A \alpha_A}{\theta_B \psi_B \alpha_B} \left[\frac{Z_A K_A^{1-\alpha_A} L_A^{(1-\psi_A)\alpha_A}}{Z_B K_B^{1-\alpha_B} L_B^{(1-\psi_B)\alpha_B}} \right]^\rho \frac{L_{G,A}^{\psi_A \alpha_A \rho - 1}}{(\xi_G - L_{G,A})^{\psi_B \alpha_B \rho - 1}}. \quad (2.17)$$

Proof: See Appendix.

Note that while an explicit solution for $L_{G,i}$ is not available, finding the solution numerically is trivial. Since every worker with general skills will earn the same wage, irrespectively of their industry of employment, market clearing implies that the wage

of the general type of human capital is given by:¹³

$$w_G = \frac{Y^{1-\rho}}{\xi_G} (Y_A^\rho \theta_A \psi_A \alpha_A + Y_B^\rho \theta_B \psi_B \alpha_B). \quad (2.18)$$

The next step in solving the model is finding the prices of claims to equity, each type of human capital, and the risk-free rate. First, we derive the dynamics of the stochastic discount factor.

2.4.3 Dynamics of consumption and the stochastic discount factor

At this point, it is convenient to change variables to simplify the solution of the model. We define $Z_T \equiv Z_A + Z_B$ and $s \equiv \frac{Z_A}{Z_A + Z_B}$. Z_T is a measure of total productivity in the economy, while s is a relative measure of productivity between the two technologies. An increase in s implies that industry A has become relatively more productive than industry B . Using these variables is helpful because they lend to interpretation of “aggregate shocks” (shocks to Z_T) and “industry shocks” (shocks to s). As shown below, all the asset pricing relationships depend on aggregate productivity and on the relative changes of productivity between industries. The function describing the amount of general labor in industry A can then be expressed as $L_{G,A} \equiv L(\Psi, s)$.

The dynamics of the state variables Z_T and s are:

$$\frac{dZ_{T,t}}{Z_{T,t}} = (s_t \eta_A + (1 - s_t) \eta_B) dt + s_t \sigma_A dB_A + (1 - s_t) \sigma_B dB_B \quad (2.19)$$

$$\begin{aligned} \frac{ds_t}{s_t} &= (1 - s_t) [(\eta_A - \eta_B) - s_t \sigma_A^2 + (1 - s_t) \sigma_B^2 + (2s_t - 1) \sigma_A \sigma_B \varphi_{A,B}] dt \\ &+ (1 - s_t) [\sigma_A dB_A - \sigma_B dB_B], \end{aligned} \quad (2.20)$$

where $\varphi_{A,B}$ is the correlation between the two Brownian motions B_A and B_B . The dynamics of the productivity shares in the two industries s_t are similar to the dynamics of dividend shares of the two assets in the model of Cochrane et al. (2008). The drift of ds_t equals zero if $s_t = 0, 1$ or ϖ , where

$$\varpi = \frac{(\eta_A - \eta_B) + \sigma_B^2 - \varphi_{A,B} \sigma_A \sigma_B}{\sigma_A^2 \sigma_B^2 - 2\varphi_{A,B} \sigma_A \sigma_B}. \quad (2.21)$$

¹³The expression below is obtained by setting $L_{G,A} + L_{G,A} = \xi_G$ and solving for w_g .

If $0 < \varpi < 1$, the drift is positive for $s_t \in (0, \varpi]$ and negative for $s_t \in (\varpi, 1)$. The diffusion of ds_t is the largest when $s_t = 0.5$, so the productivity share process is most volatile if productivity is the same in the two industries. This share process s_t will be nonstationary, as ultimately one of the two Brownian motions will dominate. This less desirable feature is common for this type of share process (see also Cochrane et al. (2008)).

We first derive the dynamics of consumption. Denote the equilibrium value of a consumption bundle by $CO(Z_t, s_t)$ as:

$$CO(Z_{T,t}, s_t) = (\theta_A C_A^\rho + \theta_B C_B^\rho)^{\frac{1}{\rho}}. \quad (2.22)$$

The utility the aggregate agent derives from the equilibrium mix of goods produced in the economy can be rewritten as:

$$U = \frac{CO(Z_{T,t}, s_t)^{1-\gamma}}{1-\gamma}. \quad (2.23)$$

We start by showing that the optimal bundle of the representative agent is a function only of Z_T and s . The following lemma formalizes the result:

Lemma 2. *Given Φ , $Z_{T,t}$ and s_t ,*

The equilibrium consumption bundle consumed by agents in the economy is:

$$CO(Z_{T,t}, s_t) = Z_{T,t} co(s_t). \quad (2.24)$$

The first derivative and second derivative of $co(s_t)$ are given by:

$$co'(s_t) = co(s_t)F(s_t) \quad (2.25)$$

$$co''(s_t) = co(s_t)(G(s_t) + F(s_t)^2), \quad (2.26)$$

where

$$F(s_t) = \frac{f(s_t) - 1}{(1 - s_t)} \quad (2.27)$$

$$G(s_t) = \frac{1}{s_t^2(1 - s_t)^2} [-f(s_t) [(1 - 2s_t) - g(s_t)(1 - f(s_t))] - s_t^2], \quad (2.28)$$

and

$$f(s_t) = \frac{P_A Y_A}{P_A Y_A + P_B Y_B}. \quad (2.29)$$

$$g(s_t) = \left[\left(\frac{1}{\rho} - \alpha_A \psi_A \right) + \frac{Y_A^\rho P_A \psi_A \alpha_A \xi_G}{Y^{1-\rho} (Y_A^\rho \theta_A \psi_A \alpha_A + Y_B^\rho \theta_B \psi_B \alpha_B)} (\alpha_A \phi_A - \alpha_B \phi_B) \right]^{-1}. \quad (2.30)$$

Proof: See Appendix.

The production share ratio can be interpreted as the ratio of total dividends paid out in the two industries, consisting of dividends paid to equity holders and dividends paid to workers (i.e. wages). This allows us to link our consumption dynamics to those in the two-asset model of Cochrane et al. (2008). Similar to our model, their consumption volatility depends on the relative dividend share of the two assets. However, Cochrane et al. (2008) model the dividend processes exogenously, while our production-based model endogenizes dividend dynamics. In particular, we show a mechanism through which labor mobility affects dividends.

By Itô's Lemma, the dynamics of consumption $CO(Z_t, s_t)$ are as follows:

$$\frac{dCO_t}{CO_t} = \mu_C dt + \sigma_{C,A} dB_A + \sigma_{C,B} dB_B, \quad (2.31)$$

where

$$\begin{aligned} \mu_C &= s_t \eta_A + (1 - s_t) \eta_B + s_t (f(s_t) - 1) (\eta_A - \eta_B) \\ &\quad + \frac{1}{2} [-f(s_t) [(1 - 2s_t) - g(s_t)(1 - f(s_t))] - s_t^2] (\sigma_A^2 + \sigma_B^2 - 2\sigma_A \sigma_B \varphi_{A,B}) \end{aligned} \quad (2.32)$$

$$\sigma_{C,A} = \sigma_A f(s_t) \quad (2.33)$$

$$\sigma_{C,B} = \sigma_B (1 - f(s_t)). \quad (2.34)$$

Note that conveniently, the dynamics of consumption do not depend on total productivity Z_T , but they only depend on the relative productivity share s_t . When relative productivity share s_t goes to zero or one, consumption dynamics are the same as in the single industry benchmark case: mean consumption growth equals the mean productivity growth η_i of the productive industry i and consumption volatility equals its diffusion σ_i . When both industries are productive, mean consumption growth also depends on the mean of the difference in productivity growth of the two industries, $(\eta_A - \eta_B)$, and its variance, $\text{Var} \left(\frac{dZ_A}{Z_A} - \frac{dZ_B}{Z_B} \right)$. Consumption volatility depends on

both σ_A and σ_B , weighted by $f(s_t)$, which in turn is affected by labor mobility.

Having determined the utility from the basket of goods and its dynamics, we can find the dynamics of marginal utility and the stochastic discount factor. Marginal utility, measured in terms of the optimal basket of goods, will be given by:

$$CO(Z_{T,t}, s_t)^{-\gamma} = Z_{T,t}^{-\gamma} co(s_t)^{-\gamma}. \quad (2.35)$$

Thus, the stochastic discount factor equals:

$$M(t, Z_{T,t}, s_t) = e^{-\beta t} Z_{T,t}^{-\gamma} co(s_t)^{-\gamma}, \quad (2.36)$$

where β is the subjective time discount rate. Since we know the dynamics of Z_T and s , we can derive the dynamics of the stochastic discount factor:

$$\frac{dM_t}{M_t} = \mu_M dt + \sigma_{M,A} dB_A + \sigma_{M,B} dB_B, \quad (2.37)$$

where

$$\mu_M = -\beta - \gamma\mu_C + \gamma(1 + \gamma)\frac{\Omega_C^2}{2} \quad (2.38)$$

$$\Omega_C^2 = \sigma_{C,A}^2 + \sigma_{C,B}^2 + 2\varphi_{A,B}\sigma_{C,A}\sigma_{C,B} \quad (2.39)$$

$$\sigma_{M,A} = -\gamma\sigma_{C,A} \quad (2.40)$$

$$\sigma_{M,B} = -\gamma\sigma_{C,B} \quad (2.41)$$

Market completeness implies that the instantaneous risk-free rate equals the negative of the drift of the stochastic discount factor: $r_{f,t} = -\mu_{M,t}$. The expression for $r_{f,t}$ is the same as in the standard case with only one sector in the economy. The risk free rate is determined by the standard subjective discount rate, expected consumption growth and a precautionary savings term, which depends on the variance of consumption growth. However, while in the standard case r_f is constant over time, in our two-sector economy it varies over time; μ_C and Ω_C both depend on the relative share of productivity in each industry, s_t .

In equilibrium, the risk premium on a claim equals the negative of the covariance between the SDF and the returns on the claim: $-\sigma_M\sigma_{Cl}$. In our model, labor mobility affects both σ_M and σ_{Cl} . The results section of the chapter discusses how labor mobility affects σ_{Cl} , here we first focus on σ_M . As consumption volatility is affected labor mobility through $f(s_t)$, so is the diffusion of the stochastic discount factor

(SDF):

$$\sigma_{M,A} = -\gamma\sigma_A f(s_t) \quad (2.42a)$$

$$\sigma_{M,B} = -\gamma\sigma_B(1 - f(s_t)), \quad (2.42b)$$

This expression shows that volatility of the SDF (and hence the market price of risk) varies over time. In the special case where the economy is characterized by identical production functions, the production share $f(s_t)$ simplifies to:

$$f(s_t) = 1 - \frac{1}{1 + \left(\frac{s_t}{1-s_t}\right)^{\frac{2\Psi-1}{1-\Psi}}}, \quad (2.43)$$

where $\Psi = \alpha_A\psi_A = \alpha_B\psi_B$. This case explicates the intuition for the effect of labor mobility on the time variation in the market price of risk, which is the main point of departure from an endowment economy. Higher values of Ψ increase the importance of mobile workers have in the economy. As the productivity share s_t varies stochastically over time, generalist workers move between industries A and B, thereby affecting dividends. This suggests that a measure of the dispersion of generalist workers across the economy may help forecast future market risk premia.

2.4.4 Value of equity and human capital

The next step in the analysis is to derive the value of claims in this economy. There are multiple ways to solve the problem. The easiest is to use the result that in a complete market the discounted process, including dividends, for any claim in the economy is a martingale. The economy can be characterized by Z_T and s , so the solution to the value of any claim only depends on Z_T and s . Furthermore, given the structure of the economy and our use of CRRA utility, we can guess that the value of claim Cl is of the form $Cl(Z_T, s) = Z_T cl(s)$. Remember that we are interested in valuing three types of claims: equity in industries A and B and the equity market portfolio, general and industry-specific human capital and an instantaneous risk free bond. In the previous section we derived $r_{f,t}$. In this section we value equity and human capital. The following proposition characterizes the solution to value claims in this economy, allowing us to estimate expected returns, volatilities and betas.

Proposition 1. *If the function $cl(Z_{T,t}, s_t)$ exists and is twice continuously differentiable, then the equilibrium arbitrage-free price of a claim in this economy is:*

1. $Cl(Z_{T,t}, s_t) = Z_{T,t}cl(s_t)$

2. $cl(s_t)$ solves the following ODE:

$$0 = d_{Cl}(s) + cl(s)A_1(s) + cl'(s)A_2(s) + cl''(s)A_3(s), \quad (2.44)$$

where

$$\begin{aligned} A_1(s) = & -\beta + (1 - \gamma) \left(s\eta_A + (1 - s)\eta_B - \gamma \frac{\sigma_B^2}{2} \right) \\ & + (1 - \gamma)\gamma \left(\frac{\Omega_s^2}{2s(1 - s)} - s \left(\frac{\sigma_A^2 - \sigma_B^2}{2} \right) \right) \\ & + (1 + \gamma)\gamma \frac{\Omega_s^2}{2} F(s_t)^2 \\ & - \gamma s(1 - s) \left(\eta_A - \eta_B \gamma \left(\frac{\sigma_A^2}{2} - \frac{\sigma_B^2}{2} - \left(\frac{1}{2} - s \right) \frac{\Omega_s^2}{s^2(1 - s)^2} \right) \right) \\ & \frac{co'(s)}{co(s)} - \gamma \frac{\Omega_s^2}{2} G(s_t) \end{aligned} \quad (2.45a)$$

$$\begin{aligned} A_2(s) = & s(1 - s) [(\eta_A - \eta_B) \\ & - \gamma \left(\frac{\sigma_A^2 - \sigma_B^2}{2} - \frac{\Omega_s^2}{s^2(1 - s)^2} \left(\frac{1}{2} - s \right) + \frac{\Omega_s^2}{s(1 - s)} F(s_t) \right)] \end{aligned} \quad (2.45b)$$

$$A_3(s) = \frac{\Omega_s^2}{2}, \quad (2.45c)$$

with $cl(0) = \frac{d_{Cl}(0)}{r_f(0) + \gamma\sigma_B^2 - \eta_B}$ and $cl(1) = \frac{d_{Cl}(1)}{r_f(1) + \gamma\sigma_A^2 - \eta_A}$ as boundary conditions.

Proof: See Appendix.

The boundary conditions are given by the value of a claim in a one-industry economy. When $s = 0$, industry B dominates the economy, and thus aggregate volatility and growth is given by the growth rate and volatility of industry B's productivity growth. When $s = 1$, industry A dominates the economy, and its volatility and growth rate equal the economy's volatility and growth rate.

As long as we can express dividends as $D_{Cl} = Z_T d_{Cl}$, this ODE does not depend on Z_T , but only on the state variable s . d_{Cl} is interpreted as the dividends of a claim, normalized by aggregate productivity. In order to price claims in our economy, we need to calculate the normalized dividend of each claim and solve this ODE for $cl(s)$. Therefore, the final step is to find these normalized dividends. The second proposition characterizes the dividend process for each of the claims we are interested in.

Proposition 2. Let $\pi(s) = \frac{\theta_A}{\theta_B} \left(\frac{Y_A}{Y_B} \right)^\rho$. The dividend paid to owners of shares of equity in each industry, owners of claims to the wages of specialized human capital in each industry, and owners of claims to the wages of generalized human capital, normalized by Z_T , is given by:

1. Equity of industry A

$$d_A = (1 - \alpha_A) \frac{co(s)}{1 + \frac{1}{\pi(s)}} \quad (2.46)$$

2. Equity of industry B

$$d_B = (1 - \alpha_B) \frac{co(s)}{1 + \pi(s)} \quad (2.47)$$

3. Specialized human capital of industry A

$$w_A L_A = (1 - \psi_{g,A}) \alpha_A \frac{co(s)}{1 + \frac{1}{\pi(s)}} \quad (2.48)$$

4. Specialized human capital of industry B

$$w_B L_B = (1 - \psi_{g,B}) \alpha_B \frac{co(s)}{1 + \pi(s)} \quad (2.49)$$

5. Generalist human capital:

$$w_G L_G = \alpha_A \psi_{g,A} \frac{co(s)}{1 + \frac{1}{\pi(s)}} + \alpha_B \psi_{g,B} \frac{co(s)}{1 + \pi(s)} \quad (2.50)$$

6. The equity market portfolio is a claim on the sum of the dividends in the two industries. The normalized dividends for the equity market portfolio follow as the sum of d_A and d_B .

7. The aggregate wealth portfolio is a claim on the sum of the dividends of each industry and aggregate wages paid to all types of workers.

Proof: See appendix.

The expressions for the dividends paid to each claim in the economy highlight the sources of risk for the owner of each asset. All claimants are exposed in the same

way to aggregate productivity shocks. However, each claim has a different exposure to industry shocks, as the dividends for each claim depend differently on s . Whether such exposure results in higher or lower expected returns depends on the parameters of the model. We study those in the next section.

2.5 Analysis of results

Our numerical results convey the intuition behind the model and show how labor mobility affects human capital and expected stock returns. In this section we first explain our parameter choice and then we present the results.

2.5.1 Parameter choice

Since Mehra and Prescott (1985) we know that a parsimonious CRRA-utility framework does not match all the asset pricing moments while providing smooth consumption and a low risk-free rate. Rather than making the model less parsimonious by adding frictions or changing agents' preferences, we focus on the mechanism through which labor mobility affects risk for workers and shareholders. The goal of our numerical analysis is not to match the equity premium and the risk-free rate, but to show the relative movement of risk premia in the economy.

For the utility function, we assume the agent places equal weight on each of the two goods ($\theta_A = \theta_B = .5$) and that the goods are perfect substitutes (elasticity of substitution $\rho = 1$). This parameter choice stresses the impact of labor mobility in the presence of decreasing returns to labor, while shutting down the effect of less than perfect substitution. We use a subjective discount rate $\beta = .1\%$ with the objective of obtaining a small risk-free rate. As for the coefficient of risk aversion, we use a conservative value of $\gamma = 2$. We could increase this parameter to achieve higher risk premia, but at the cost of also increasing the risk-free rate. Whereas the magnitude of the moments changes as γ changes, the direction of the results does not change.

We have more flexibility when choosing the parameters of the production functions. We assume symmetric labor intensities across industries $\alpha_A = \alpha_B = .64$, implying that workers receive 64% of production in the economy.¹⁴ We normalize capital in each industry to one and use two settings for ψ . In the first one, we solve for $\psi = 0$, corresponding to the benchmark “no labor mobility” case. For the second setting of ψ we use .5. This setting implies that half of the wages in the economy are

¹⁴See for example Palacios (2007) for empirical estimates of labor intensity in the economy.

paid to generalist workers. In the benchmark case, we assume independent and identically distributed technology shocks across industries, with expected growth rate η of 2%, and volatility σ of 10%. A growth rate of 2% implies a long-term consumption growth rate of 2%, while a volatility of 10% allows us to achieve unlevered volatilities of 10% for equity. This choice implies a high volatility for consumption as well, a known drawback of the neo-classical framework. The appendix discusses the numerical solution method used.

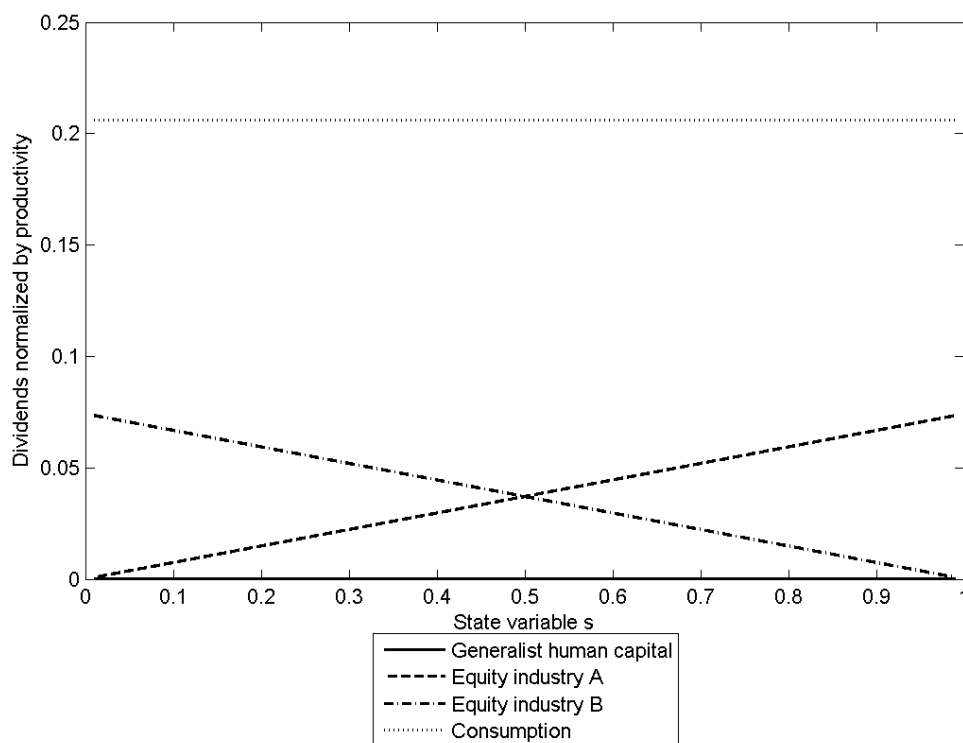
2.5.2 Results

We begin exploring the dynamics of the economy. After analyzing dividends and the values of the different claims, we examine their return volatilities, risk premia and conditional betas. Finally, we show how labor mobility affects returns by changing the importance of generalist labor in the economy.

Dividends and asset prices

Figure 2.1 shows the value of a consumption bundle as well as the instantaneous payoff (i.e., the dividend) for equity and general mobile human capital, all scaled by total productivity Z_T , for an economy with no labor mobility. Dividends to human capital specialized in each of the two industries are not reported in figure 2.1 since they are simply scaled dividends to equity of the respective industries. The figure shows that total consumption remains constant as the relative productivity of each industry changes. Any gains in productivity due to one industry becoming more productive is captured by total productivity and as a result consumption per unit of total productivity remains constant. Dividend payments per unit of total productivity grow linearly from zero—when the industry is so unproductive that its dividends are swamped by those produced by the other—to a maximum value, corresponding to the dividend per unit of productivity for that industry. Generalist human capital has a constant dividend of zero, since no such workers exist in the economy.

Figure 2.2 shows the impact that labor mobility has on the dividends paid by different claims. Panel A at the top of the figure contrasts consumption with and without mobility. With labor mobility, consumption per unit of total productivity increases when one industry becomes relatively more productive than the other. The reason is that after one industry becomes relatively more productive its marginal product of labor increases, which opens the opportunity for capital being better used when some workers switch from the relatively unproductive industry. The result is a

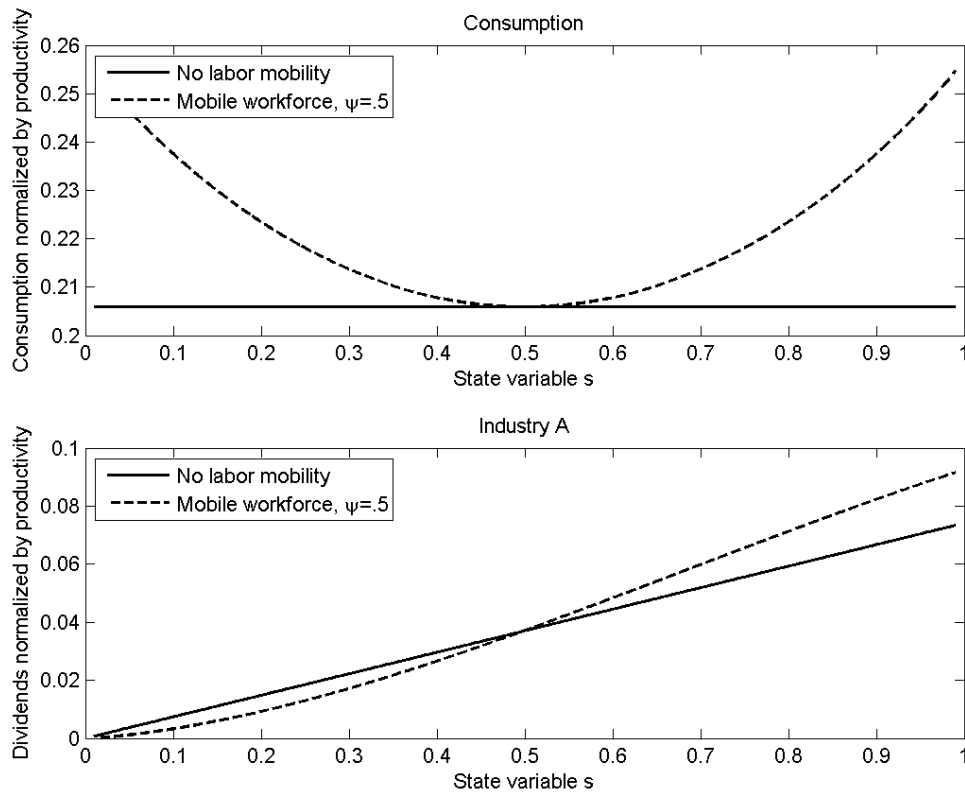


Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.1: Dividends for different claims as a function of relative productivity (without labor mobility)

more efficient economy. Panel B at the bottom of the figure shows that the economy-wide gains are not evenly distributed among the different stakeholders. In particular, the dividend paid by equity can be smaller or larger in the presence of labor mobility depending on whether the industry is relatively productive or not. Labor mobility amplifies the impact of becoming relatively more productive, so that in the presence of labor mobility the relatively productive industry gets two extra dividends: one from being relatively more productive, and the other from being able to use a larger workforce. When the industry is relatively *unproductive* labor mobility acts as an extra punishment. Not only is it able to pay a smaller dividend, its workers leave, further reducing its productive capacity.

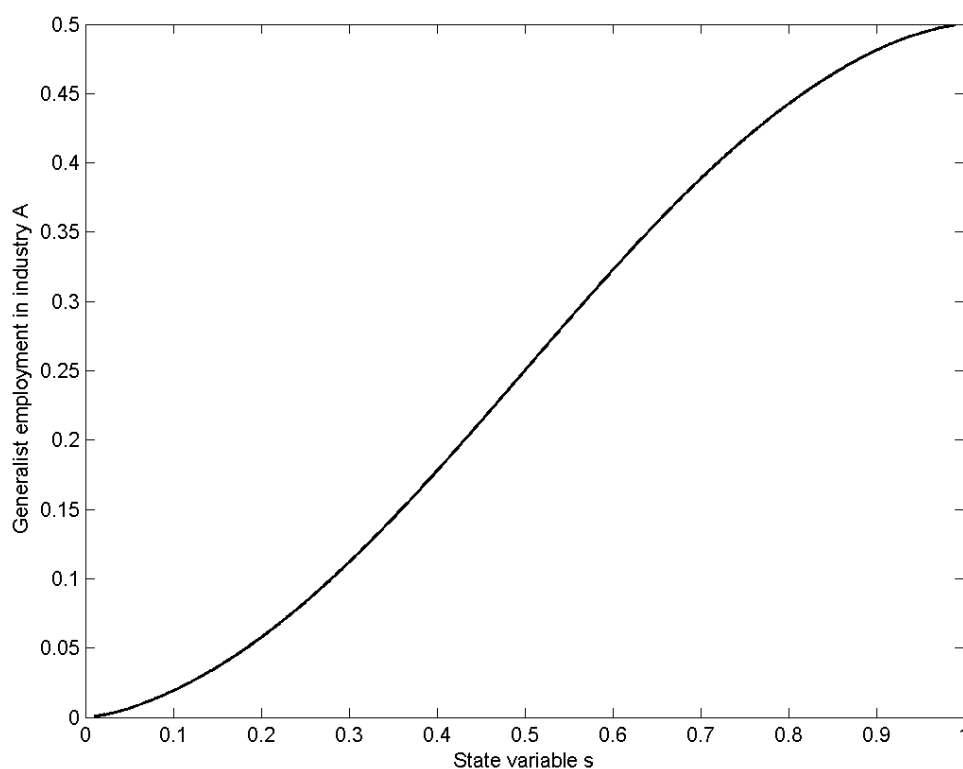
To better understand what drives the increase in consumption as s gets farther



Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.2: Dividends for consumption and industry A (with and without labor mobility)

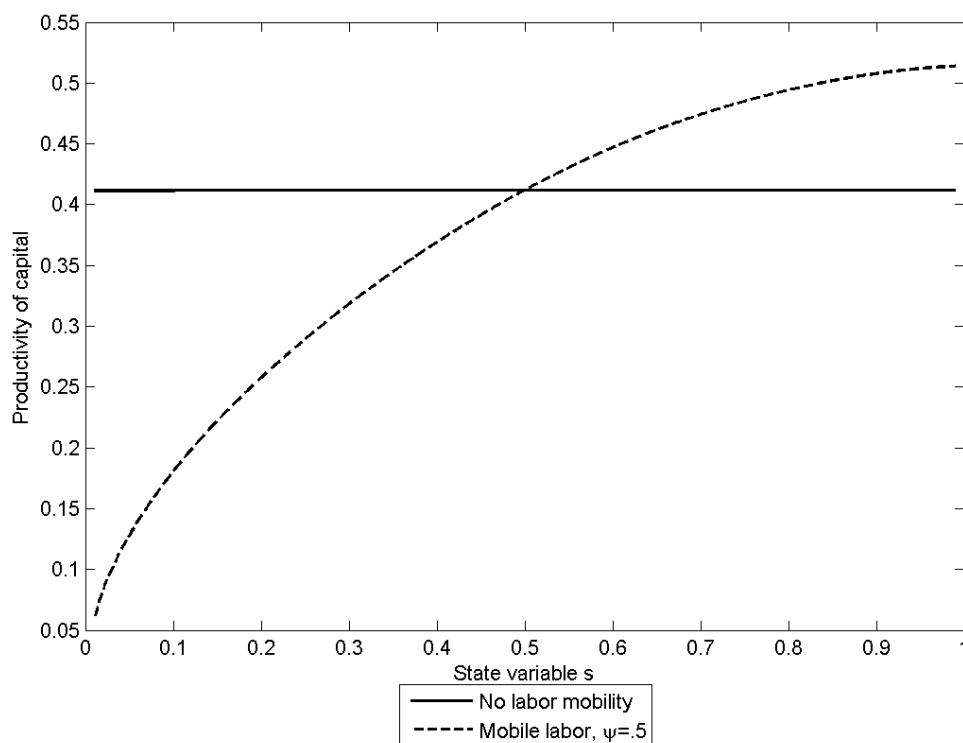
from .5, figure 2.3 shows the fraction of mobile employees who work in industry A for different values of the relative productivity of industry A. As industry A becomes relatively more productive, the fraction of mobile employees who work in it increases. This movement amplifies the increase in capital's productivity, as we can see in figure 2.4. Figure 2.4 plots the ratio between production and $Z_A K_A$ (or $Z_B K_B$ in the case of industry B), which is a normalization of capital's productivity. As the figure shows, a relative increase in Z_A does not change the ratio between production and $Z_A K_A$ when the labor force is immobile. In contrast, with a mobile labor force, a relative increase in Z_A triggers an additional increase in capital's productivity. The extra increase comes from the new workers that enter the industry and this is the mechanism through which labor mobility affects asset prices.



Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.3: General labor employed in industry A as a function of relative productivity

Given that consumption is valley-shaped (as seen in figure 2.1), marginal utility is relatively high when s gets close to .5. Therefore, claims with high payoffs in states when s is close to .5 act as hedges and command smaller risk premia, while claims with payoffs in states where one industry is much more productive than the other (s close to 0 or 1) will be relatively riskier and have higher risk premia. Inspection of figure 2.1 reveals that neither equity nor human capital act as perfect hedges. Equity (and industry-specific human capital) pays most in times of low marginal utility (when the industry associated with equity is relatively productive) but its dividend decreases for all other states. On the other hand, generalist human capital pays well regardless of which industry is relatively productive, making it a better but not perfect hedge, since its maximum payoff coincides with the point in which marginal utility is lowest



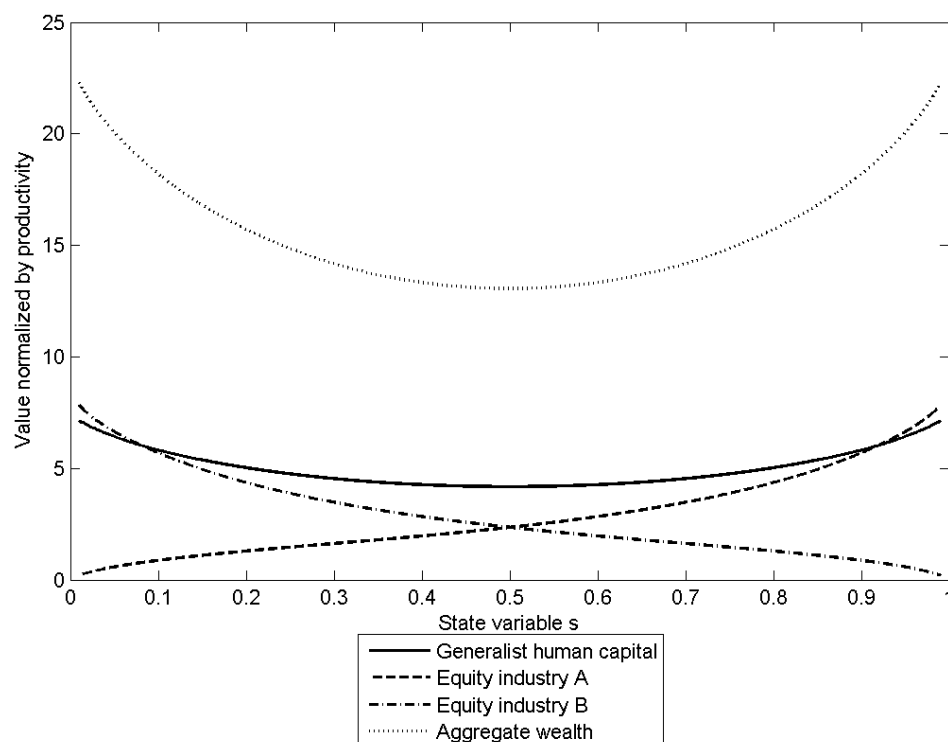
Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.4: Productivity per unit of physical capital scaled by total productivity

(close to $s = 0$ or $s = 1$). We can therefore expect a complex relationship between relative productivity, equity risk, and human capital risk.

Figure 2.5 shows the value of generalist human capital, equity in industries A and B, and aggregate wealth. Unsurprisingly, equity is very valuable when the industry associated with it is relatively productive, while generalist human capital is valuable regardless of the state of the economy. As would also be expected, the relationship between relative productivity and the value of mobile human capital is non-monotonic. Starting from $s = 0$, the value of mobile human capital falls and then rises as the value of its dividend falls and rises after $s = .5$. The value of aggregate wealth exhibits the same behavior as a function of s . Given our choice of parameters, the economy is symmetric and aggregate wealth is a constant multiple of generalist human capital.

As a result, aggregate wealth changes non-monotonically as the relative productivity of each industry changes.



Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.5: Value of equity, generalist human capital and aggregate wealth as a function of relative productivity

The most striking difference between each claim's value is that generalist human capital provides a hedge against movements in relative productivity, while the value of equity (and immobile human capital) in each industry collapses as that industry becomes relatively unproductive. In the special case when both industries have identical characteristics, a mobile worker is perfectly hedged against economic fluctuations and does not need to diversify labor risk in financial markets.

Volatilities, risk premia and betas

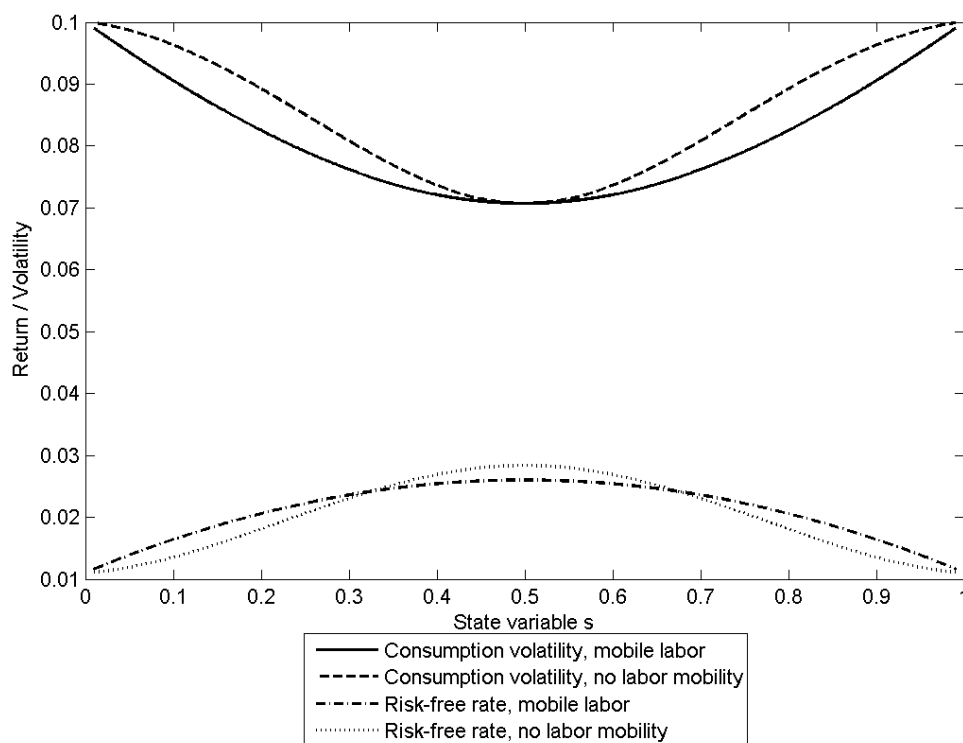
Now that we have found the value for each claim in the economy, we can characterize their risk and return characteristics. Without loss of generality, we focus on three claims: a claim to dividends from industry A, which we refer simply as “equity” from now on, a claim to the aggregate wages paid to mobile workers, which we call generalist human capital, and a claim to the sum of dividends in the two industries, which is the equity market portfolio. Note that in our model, specialist wages are scaled dividends of equity in the industry. Therefore, the risk premium on specialist human capital is the same as the risk premium on equity in the industry.

In our model the consumption CAPM holds. However, except for the special cases when $\gamma = 1$, the conditional CAPM with respect to the total wealth portfolio does not hold. Nevertheless, small values of relative risk-aversion ($\gamma = 2$) produce very high correlations between consumption and aggregate wealth, implying that the conditional CAPM holds approximately, as in Santos and Veronesi (2006). Therefore, in addition to analyzing volatilities and risk premia, we also consider conditional betas.¹⁵ However, we emphasize that our main conclusions are based on risk premia and volatilities, which are the quantities that follow from our model directly and do not depend on whether the conditional CAPM holds or not. We use the conditional betas to better understand the behavior of risk premia.

We begin by analyzing the behavior of consumption volatility and the risk-free rate. Figure 2.6 shows that consumption volatility is minimized when $s = .5$. In other words, when productivity is equal in both industries, consumption is well diversified and is least risky. This decreases the precautionary savings motive, and consequently we see that the instantaneous risk free rate is maximized at $s = .5$. The parameter values lead to a reasonable risk-free rate (the largest value is about 3%) and equity volatility, but unsurprisingly, too high levels of consumption volatility.

Figure 2.6 also shows the effect of labor mobility on consumption volatility and the risk-free rate. When one industry is much more productive than the other ($s = \{0.1\}$), or when both industries are equally productive ($s = .5$), labor mobility has no effect. Elsewhere labor mobility *increases* consumption’s volatility, and as a consequence *reduces* the risk-free rate. Labor mobility increases consumption’s volatility because workers switching from one industry to another amplify the positive (negative) industry shocks by making capital even more (less) productive.

¹⁵Note that in a symmetric economy (i.e. all parameters are identical for industries A and B), the equity market portfolio is a constant fraction of the aggregate wealth portfolio. Consequently, in a symmetric economy the beta measured with respect to the market or with consumption is the same.



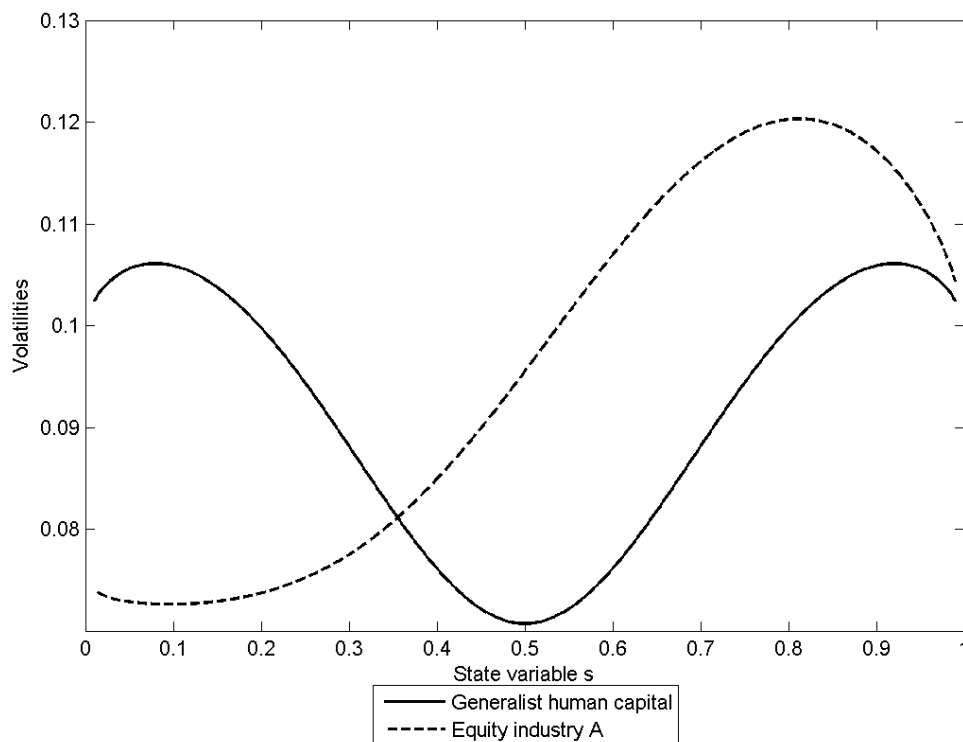
Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.6: Consumption volatility and the risk-free rate

To explore the impact that labor mobility has on asset prices, we first present the volatility, risk premium and beta for different claims in the presence of labor mobility. Figures 2.7, 2.8, and 2.9 present the volatility, risk premium, and beta for each claim.¹⁶ First, figure 2.7 shows that the volatility of the returns on general human capital reaches a minimum at $s = .5$; here the generalist worker is best diversified. Equity volatility depends on the relative productivity of the industry (s), the sensitivity of the value of the claim to changes in s , and the volatility of s itself (see equation (4.2.15) in the appendix). We can see that as industry A becomes relatively more productive, its equity return volatility increases initially. However, at some point, around $s = .75$, the volatility reaches a maximum and then decreases.

¹⁶The conditional beta should not be confused with the subjective discount rate, with symbol β .

This fall in volatility as s_t increases follows from the volatility of s_t going to zero as s_t approaches one. The pattern for equity in industry B follows by symmetry.

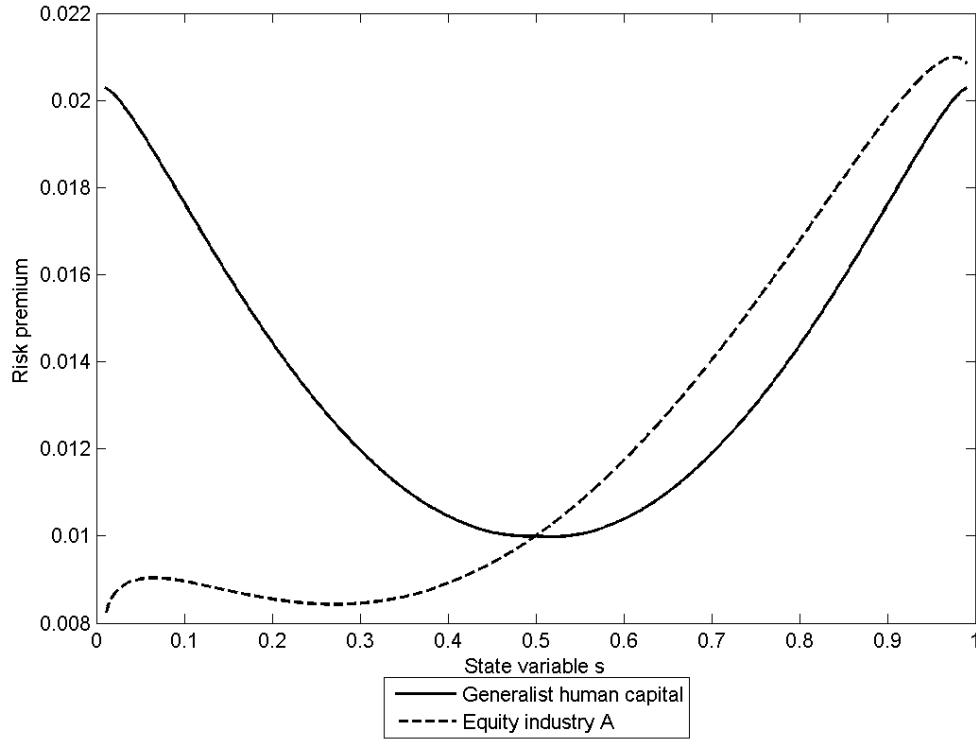


Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.7: Volatility of equity and generalist human capital

Figure 2.8 shows that the overall patterns in the risk premia closely follow the patterns in volatilities. The risk premium for generalist human capital is lowest when $s = .5$ and increases as either one of the two industries becomes relatively more productive. On the other hand, the risk premium for equity in industry A increases as the industry becomes relatively more productive. In this case, industry A becomes a larger part of the economy and its equity is more highly correlated with aggregate consumption, thereby increasing its risk premium. When s is close to .9, the risk premium decreases slightly, which is due to the decrease in equity return volatility.

The sensitivity of equity to productivity shocks stems from the magnifying effect

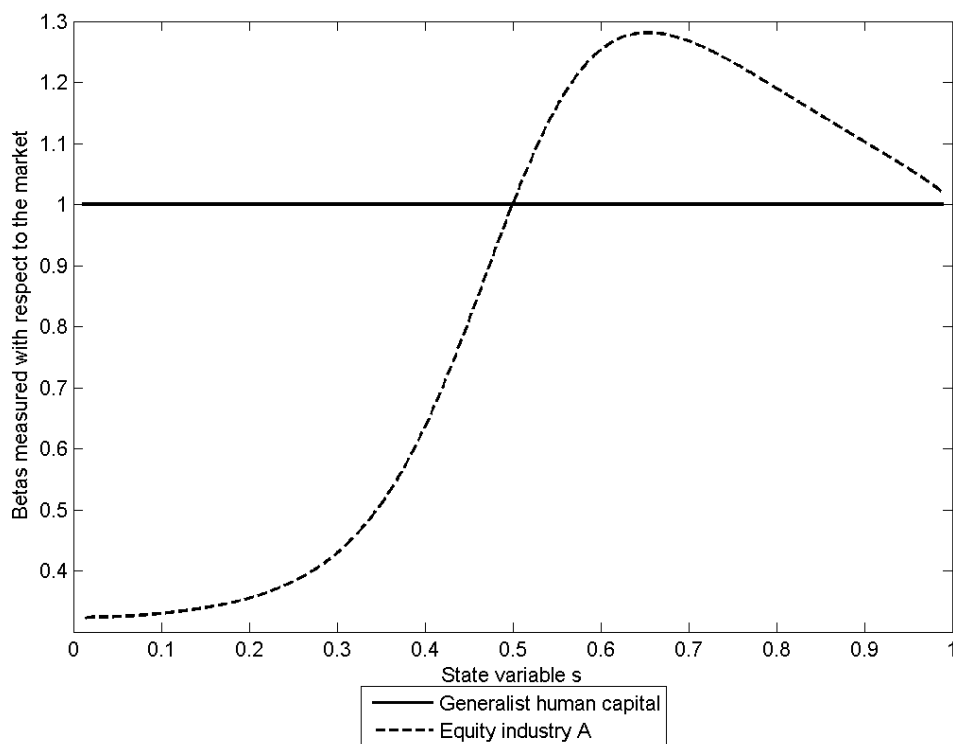


Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.8: Risk premium of equity and generalist human capital

that labor movement has on capital's productivity. The flip side of this observation is that generalist human capital is less exposed to shocks to relative productivities, i.e. shocks to s . Comparing the risk premium of specialist human capital (which is the same as that of industry equity) to that of generalist human capital, leads the following observation. When one industry is relatively more productive than the other, the risk premium of generalist human capital is smaller than the risk premium of specialized workers in that industry. However, when an industry is relatively unproductive, specialist human capital's exposure to relative productivity shocks is smaller than that of generalist human capital, and as a result, generalist human capital's risk premium is higher than that of the specialist in the industry in that particular region of s .

Figure 2.9 shows the conditional betas of equity and generalist human capital. In this symmetric economy, generalist human capital is a constant share of aggregate wealth and therefore has a conditional beta of one. When $s = .5$, both industries have the same productivity. Given that we also assume that all other parameters are the same for both industries, they must both have a beta of one. As industry A becomes relatively more important (i.e. $s > .5$), its systematic risk increases and therefore its beta goes up. Since the two industry betas must aggregate to one in this symmetric economy, the beta of industry B decreases.



Results with the following parameters: $\psi_A = \psi_B = .5$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.9: Beta of equity and generalist human capital

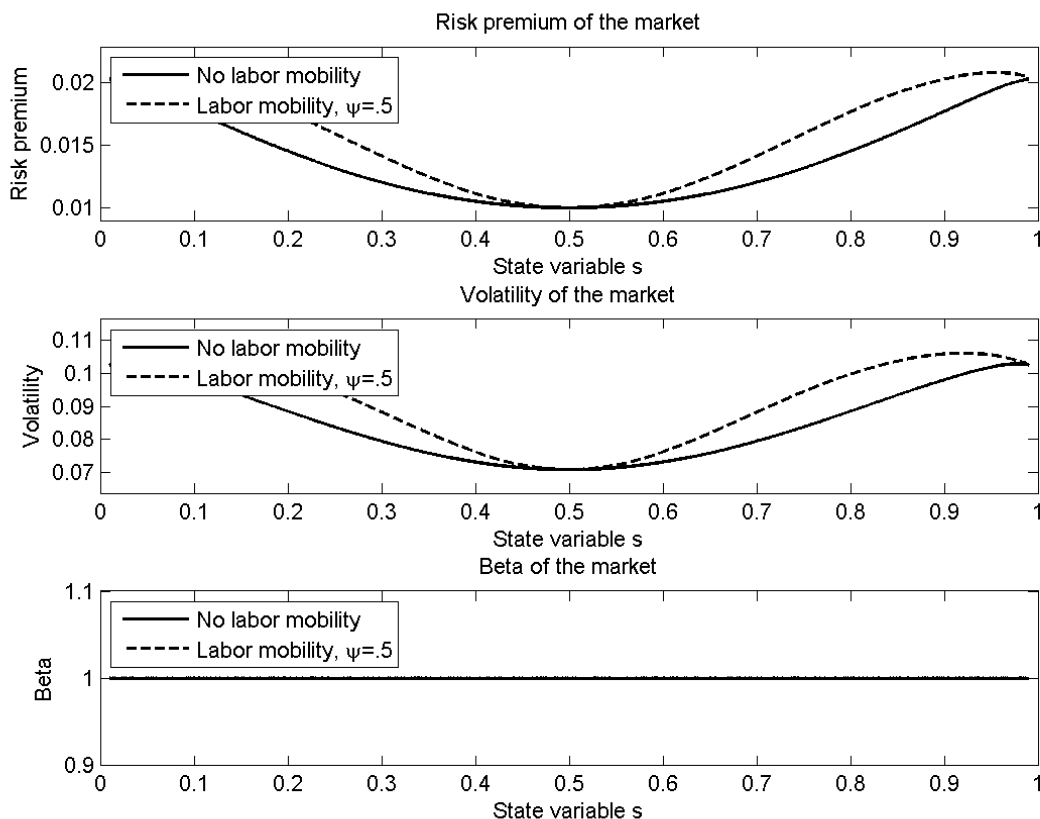
The relationship between labor mobility, volatility, risk and expected excess returns

Now that we understand how volatilities, risk premia and betas depend on the relative productivity share s , we take a closer look at the role of labor mobility. Labor mobility depends on the relative importance of generalist human capital in the production processes of the two industries, measured by intensity ψ_i . We vary the level of ψ from 0 (no labor mobility) to .5 (generalist human capital represents 50% of the wages paid in the economy).

We start by analyzing the impact of labor mobility on aggregate risk. Figure 2.10 shows the risk-premium, volatility, and beta of the market with and without labor mobility. Panel A in the top of the figure shows that the risk-premium of the market is not affected by labor mobility when one industry dominates the other ($s = 0, 1$) or when both industries are equally productive ($s = .5$). Elsewhere, labor mobility increases the market's risk premium. This result follows from studying the impact that labor mobility has on the market price of risk and on the market's volatility. The market price of risk ($\gamma\sigma_c$) changes as the volatility of consumption changes. As we saw in figure 2.6, labor mobility increases consumption's volatility when one industry is relatively more productive than the other. Thus, the market price of risk is higher in those same instances. As for the market's volatility, panel B in the middle of figure 2.10 shows the effect that labor mobility has on it. Labor mobility does not have an impact on the market's volatility in either of the cases described above ($s = \{0, .5, 1\}$), but increases it elsewhere. This result is also driven by the effect that labor mobility has on consumption's volatility. In the symmetric economy that we study here, the dividends paid by the market are proportional to consumption, and thus their volatility increases when consumption's volatility increases.

Next, figure 2.11 plots the risk premium, volatility and beta for equity for different levels of labor mobility. Panel A in the top of the figure shows that labor mobility does not have an unambiguous impact on industry A's risk premium. Labor mobility increases the riskiness of industry A when it is relatively more productive than industry B. On the other hand, labor mobility *decreases* industry A's riskiness when it is relatively less productive.

To further understand the effect of labor mobility on the risk premium on equity in industry A, it is useful to consider its effect on volatility and the conditional beta. Panel B in the middle of figure 2.11 contrasts the volatility of industry A with and without labor mobility. One can see that labor mobility has an asymmetric effect on volatility. Volatility with labor mobility is always larger, but the effect is much larger

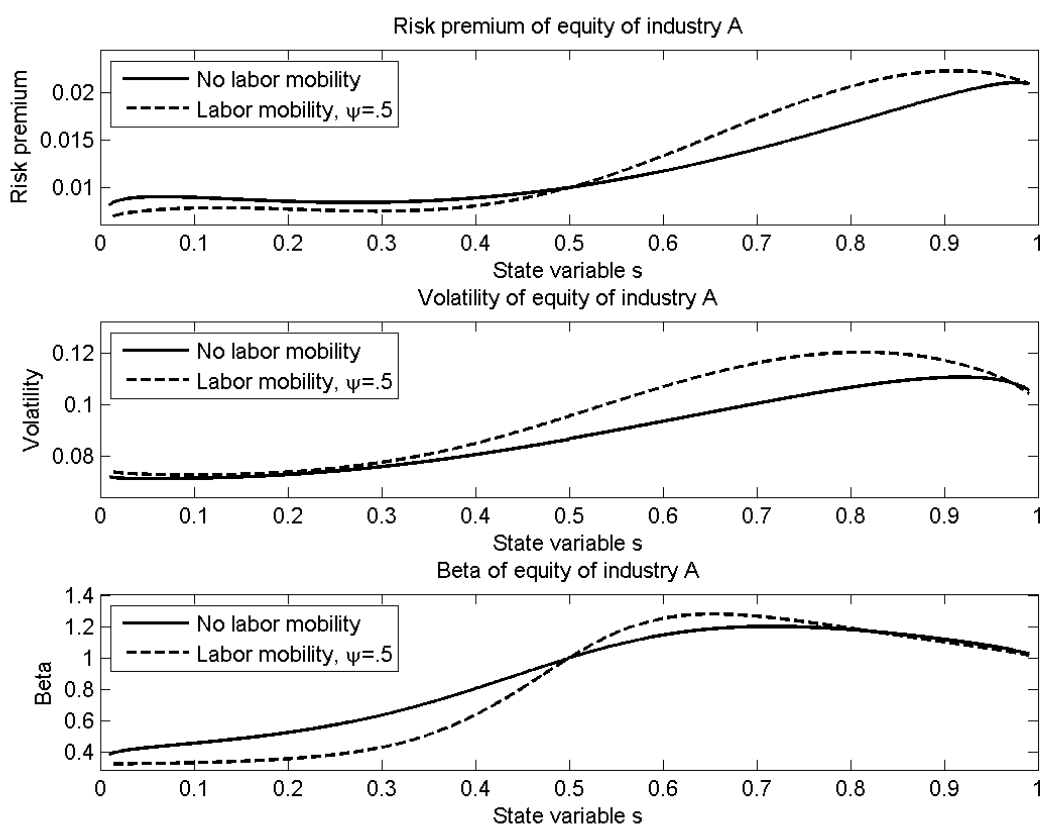


Assumes $\psi_A = \psi_B$. Results with the following parameters: $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.10: Impact of labor mobility on the market

when industry A is relatively more productive ($S > .5$). This would suggest that industry A's equity premium would be unconditionally larger with labor mobility. The reason why this is not the case can be found studying the conditional beta. Panel C in the lower part of figure 2.11 shows that industry A's conditional beta is somewhat larger when industry A is relatively more productive, but much lower when it is relatively less productive.

The previous result suggests that the effect of labor mobility on the risk premium is due to an “operating leverage” effect, related to volatility, and a “systematic effect”, related to equity's correlation with the market. Volatility is driving industry A's higher risk premium when it is more productive, whereas a smaller correlation



Results with the following parameters: $\psi_B = .8$, $K_A = K_B = 1$, $\alpha_A = \alpha_B = 0.64$, $\eta_A = \eta_B = 0.02$, $\sigma_A = \sigma_B = 0.1$, $\varphi_{A,B} = 0$, $\gamma = 2$, $\rho = 1$, $\beta = .001$.

Figure 2.11: Impact of labor mobility on industry A

with the market is driving a lower risk premium when industry A is relatively less productive. Donangelo (2010) builds a model that relates labor mobility through “operating leverage”. The results presented here also link the effect of labor mobility with changes in the systematic risk of industry A. In conclusion, labor mobility affects the risk-premium simultaneously through its volatility and its correlation with the market.

Discussion

Our results highlight the effect of labor mobility on equity and human capital risk and returns. When the importance of generalist labor in the economy increases, we

observe two distinct effects. First, both the market portfolio and generalist human capital become riskier and earn higher risk premia. Second, industry-specific human capital and equity also become riskier and earn higher risk premia, but only when the industry is relatively more productive. Furthermore, labor mobility affects the cross-section of equity returns. When an industry relies more on mobile labor, its equity becomes riskier and carries higher expected excess returns. This section discusses some of the implications of our findings.

First, the result that the market and generalist human capital become riskier as generalist labor becomes more important in the economy might seem paradoxical, as it would suggest that labor mobility made the representative agent worse off. Some reflection reveals that this is not the case. When labor mobility increases, the representative agent is better off, as the production frontier of the economy expands. An increase in mobility makes him wealthier. However, the benefits of mobility are sensitive to the relative productivity of the industries in the economy. The benefits are largest when one industry is relatively more productive than the other, and smallest when neither industry is much more productive than the other. Thus, labor mobility creates a new source of risk: the risk of losing the benefits of labor mobility as the relative productivity between industries change. After an increase in labor mobility the representative agent is wealthier, but faces more risk; the equity premium goes up.

Next, our results show that the equity risk premium –both for each industry and the market– varies over time as the productivity share s_t changes. Generalist workers move between industries of employment in response to changes in relative productivities, thereby affecting dividends. This suggests that we can relate equity risk premia to the importance of generalist workers in the economy and to the dispersion of these workers across industries.

Lastly, this model can be extended to the study the portfolio decisions of agents with different types of human capital. Generalists are mainly exposed to market risk, while specialists are more exposed to their own industry risk. In the special case when the industries are identical –the main focus of our numerical analysis– the incentives to diversify away labor risk in financial markets is maximum for specialists.

2.6 Conclusion

This chapter extends the first chapter into a general equilibrium model by incorporating labor mobility in a multi-industry dynamic economy with production. This

chapter shows that aggregate labor mobility impacts risk and expected returns on equity and human capital. Even when shocks in different industries are uncorrelated, aggregate labor mobility induces systematic variations in firms' profits, affecting their risk and expected returns. Each industry uses industry-specific labor as well as general labor as inputs for production, in addition to physical capital. Individuals are endowed with different types of human capital skills. Those with industry-specific labor skills are fully immobile and can only work in one of the industries, whereas those with general skills are mobile as they can work in different industries.

We show that aggregate labor mobility affects the time-series of human capital and equity returns. Aggregate labor mobility affects the time series variation in the stochastic discount factor. These findings suggest that a measure of labor aggregate mobility is a promising new macroeconomic variable for asset pricing. Finally, in our model, the risk and return profile of generalist human capital is closer to that of the market portfolio, while that of specialist human capital is closer to equity in the industry. Mobile human capital is intrinsically more diversified, suggesting that stock markets are relatively less attractive for diversification purposes to generalists than to specialists.

Chapter 3

Investments in Human Capital and Expected Asset Returns

3.1 Introduction

I assume that the workforce in the economy is exogenously given in the first two chapters of this dissertation. This assumption is relaxed in this chapter, where I endogenize the composition of occupations to discuss the interaction between human capital investments and labor mobility.

Limited time and money leads individuals to face a trade-off between the breadth and the depth in their education. Specialists and generalists are two types of workers that illustrate this trade-off: Specialists are workers that choose to acquire “deeper” and “narrower” bundle of skills, while generalists are workers that choose to acquire “shallower” and “broader” bundle of skills. In general, for a given amount of investment in human capital (HC), specialists are more productive than generalists since they continuously employ a greater fraction of their acquired skills in their jobs.¹ Given the lower unconditional labor productivity of generalists, a natural question is under what conditions will workers optimally choose to become generalists? This chapter addresses this question and provides sufficient conditions for the existence of labor mobility in an economy.

I endogenize labor mobility in a two-period, two-sector general-equilibrium model with production and investments in HC.² Individuals choose not only the level, but also the type of their labor productivity. Different HC types differ in their degree of

¹See Grossman and Shapiro (1982) and Acemoglu and Shimer (2000). In addition, *ceteris paribus*, employers seem to prefer to employ specialists (Cerdan and Decreuse (2011)).

²These investments can be interpreted as formal education and on-the-job training.

mobility and risk-return profiles.³ An illustrative example of the link between low labor mobility and high labor risk is the significant income loss faced by individuals in highly specialized occupations in investment banking during the liquidity crisis of 2008-2009.⁴

In equilibrium, some individuals might use their investments in HC to hedge against labor risk by becoming generalists, even when there are no participation constraints in a complete financial market setting. The model incorporates the common view in the literature that generalists are more mobile but also less productive per unit of acquired skills than individuals with specialized skills. I show that the mobile HC type can be interpreted as a combination of specialized HC and options to swap HC types, with associated costs given by a lower level of labor productivity of generalists. The value of these “mobility” options determines the existence of generalists in the economy.

I show that the main asset pricing implications of labor mobility discussed in the first two chapters hold as long as a strictly positive fraction of workers chooses to become generalists. This is generally the case when the value of the mobility option is positive, or equivalently when the following conditions are satisfied: the amplitude of asymmetric shocks in the economy is sufficiently large, goods produced by the sectors are either sufficiently strong complements or substitutes, and frictions to mobility are sufficiently small.

The rest of the chapter proceeds as follows. Section 2 discusses literature related to this work. Section 3 presents the model. Section 4 presents the main results, and Section 5 concludes.

3.2 Relation to existing literature

This chapter is related to the economics literature of education decisions and labor supply. This literature studies the impact of the acquisition of firm- and sector-specific skills on labor income and labor risk at the individual level.⁵ The specification for labor mobility as an options problem was pioneered by Grossman and Shapiro (1982),

³In Helwege (1992) and Neal (1995), sector-specific skills are associated to reduced labor mobility and an increase in labor risk. Christiansen, Joensen, and Nielsen (2007) and Saks and Shore (2003) document the trade-off between labor income risk and expected labor income in educational choices.

⁴Philippon and Reshef (2007) suggest that the pre-crisis high wages in the financial sector were caused by increases in demand for labor skills over the last decades and consequently to an increase in labor risk.

⁵See for instance Grossman and Shapiro (1982), Kim (1989) and Wasmer (2006)

that presents a theory of factor mobility and model the trade-off between breadth and depth in the acquisition of HC. The main departure point from this work is to consider the interaction between labor decisions and firm risk, as well as combining education and portfolio allocation decisions.

This chapter also belongs to the literature strand on GE asset pricing models with production.⁶ GE models are a natural framework for the analysis of HC as they connect the pricing kernel directly to macroeconomic variables that determine wages and consumption.⁷ Danthine and Donaldson (2002) explores labor induced operating leverage to explain aggregate expected equity returns over time. My work extends their mechanism to the cross-section. Differences in labor mobility across industries capture information about the cross-sectional distribution of operating leverage, lost in aggregate time-series analyses.

Parlour and Walden (2007) explores a contracting mechanism with moral hazard to generate cross-sectional differences in risk sharing between workers and shareholders. Labor contracts enforce effort through ex-post performance based compensation that partially exposes workers to labor risk. The main driver for asset pricing implications in Parlour and Walden (2007) is labor risk hedging in labor markets. In my work, the main driver is on the real side, through the impact of labor supply flows on productivity of capital.

The financial economics literature provides ample evidence of the sensitivity of the results of a model to different specifications for unobservable HC properties. Mayers (1973) was the first work to explicitly consider HC into an asset pricing model. Mayers (1973) proxies HC by labor income and finds theoretical support for incorporating it into the CAPM, a claim empirically refuted by Fama and Schwert (1977). Campbell (1996) sets HC returns equal to financial market returns, at the expense of consumption moments inconsistent with the data. Jagannathan and Wang (1996) uses labor income growth as a proxy for HC returns in tests for a conditional CAPM. This chapter takes a step further and uses a GE framework to model the value and returns to HC. In this setting, HC returns are endogenous and depend on fundamental factors such as convexity of education costs, productivity shocks and segmentation of labor markets, as well as physical capital, productivity shocks and institutional factors such as the breadth of the financial markets.

Finally, this chapter is also related to the incipient strand of the asset-pricing literature that explores labor risk accounted for labor specialization. Garleanu, Kogan,

⁶Examples of this literature are Jermann (1997), Boldrin et al. (2001) and Danthine and Donaldson (2002)

⁷For a discussion of this class of models see Cochrane (2006)

and Panageas (2009) presents an overlapping-generations model where technology innovation represents a risk for older workers that cannot easily update their labor skills. Firms at the forefront of innovation (growth firms) are out-of-reach for workers specialized in old technologies and thus provide a hedge against displacement risk. In my work, firms that rely on high-mobility labor supplies are positively exposed to aggregate human capital risk and represent bad hedges against aggregate labor risk. Innovation and labor mobility share similarities as intrinsic properties of an industry that affect the exposure of firms to human capital risk.

I depart from existing literature by focusing on adjustment costs on the supply side rather than on the demand side of labor (see for example Chen et al. (2010) and Bazdresch et al. (2009)). Another departure point is to allow workers, as opposed to firms, to directly invest in HC.

3.3 Model

The model is based on a two-date, two-sector general-equilibrium setup. Dates are denoted by $t = 0$ and $t = 1$ and sectors are denoted a and b . The time line of the model is shown in figure 3.1.

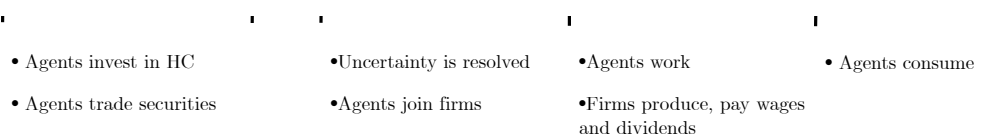


Figure 3.1: of the model

3.3.1 Firms

Each sector has a large number of competitive firms that take prices and wages as given. Technology used by firms within the same sector is identical, but technologies used in different sectors are possibly different. In particular, each produces a different intermediate good, denoted good a and good b . Productive technologies of firms in sectors a and b follow constant-returns-to-scale Cobb-Douglas production functions. Perfect competition and the use of identical productive technologies within the sector allow us to aggregate all firms in a given sector into a single sector-representative

firm. The production function of the sector-representative firms is given by:

$$Y_j = P_j L_j^{\alpha_j} K_j^{1-\alpha_j}, \quad (3.1)$$

where P_j is the total factor productivity (TFP), L_j the total labor and K_j is total capital employed by sector j . Owners of capital get to keep all cash-flows after wages are paid. Operating profits are given by:

$$\Pi_j = p_j P_j L_j^{\alpha_j} K_j^{1-\alpha_j} - L_j w_j, \quad (3.2)$$

where p_j is the price of the good produced by firms in sector j , w_j is the cost of labor in sector j .

TFP levels are stochastic and represent the only sources of uncertainty in the economy. TFPs levels in each of the two sectors, P_a and P_b , follow identical and independent binary distributions shown in figure 3.2, where $\bar{P} > 0$ and $\delta \geq 1$. Each of the four states-of-the-world $\omega \in \Omega$ is defined by the pair $\{P_a(\omega), P_b(\omega)\}$ and has an associated probability of $\frac{1}{4}$, as shown in Figure 3.2.



Figure 3.2: Distribution of sectors a and b TFP

Agents transform goods a and b into a final consumption good with a price normalized to one⁸. The aggregate production of the final consumption good is given by the constant elasticity of substitution (CES) aggregator:

$$Y = (\alpha(Y_a)^\rho + (1 - \alpha)(Y_b)^\rho)^{\frac{1}{\rho}}, \quad (3.3)$$

where Y_a is the aggregate production of intermediate good a , Y_b is the aggregate production of intermediate good b , α is the weight on good a on the final consumption good and $\frac{1}{1-\rho}$, is the elasticity of substitution between goods a and b , where $\rho < 1$. Firms maximize instantaneous profits over the amount of labor to be hired. Firm's

⁸This assumption implies that the consumption good the numeraire good in the economy.

maximization problem is given by:

$$\max_{L_j} \Pi_j. \quad (3.4)$$

The solution of (3.4) leads to the optimal hiring policy:

$$L_j^* = \left(\frac{w_j}{p_j \alpha_j P_j K_j^{1-\alpha_j}} \right)^{\frac{1}{1-\alpha_j}} \quad (3.5)$$

3.3.2 Agents

Agents are identical and indexed by $i \in I$, where I is a set of unitary mass. Agents have identical endowments at $t=0$ given by one share of stock of each sector and w_0 units of the consumption good. For simplicity, the sum of all initial endowments is normalized to one.

Agents derive utility over the consumption of a final consumption good at $t=1$:

$$U(c_i) = \frac{c_i^{1-\gamma}}{1-\gamma} \quad (3.6)$$

where c_i is agent i 's consumption and $\gamma > 0$. Agents do not derive utility from leisure and the disutility from working is zero. There is no consumption at $t=0$.

Labor supply available across sectors is defined by investments in human capital and employment decisions by individuals. Agents are born without labor skills and may acquire it from an education provider (EP). EP offers to sell unlimited amounts of one of three types of labor skills: one that can only be employed in sector a , one that can only be employed in sector b , and one that can be employed in either sector. Agents cannot acquire more than one type of labor skill. Agent's i decision to acquire an amount e of education of type k is denoted by e_i^k , where the choice of variable "e" refers to "education". Education decisions separate workers into three possible groups, as defined below:

Definition 1. A "specialist in a " is an agent who chooses to acquire labor skills specific to sector a , e_i^a . A "specialist in b " is an agent who chooses to acquire labor skills specific to sector b , e_i^b . A "generalist" is an agent who chooses to acquire general labor skills that can be used in either sector, e_i^g .

By dispersing their labor skills in a single sector, generalists are relatively less productive than specialists. For each unit of education, generalists have a labor

productivity $(1 - f_j)$ when working in sector j , where $f_j \geq 0$ is sector j 's specific "mobility friction".⁹ f_j can be interpreted as the fraction of labor skills that are specific to the sector and therefore not contained in the generalist's education.

EP offers to sell an amount e of education at a price $g(e)$. The price schedule $g : \mathbb{R}_+ \rightarrow \mathbb{R}_+$ is identical for the three education types and satisfies the following conditions:

$$g \in C^1 \tag{3.7a}$$

$$g(0) = 0 \tag{3.7b}$$

$$g'(e) > 0 \quad \forall e > 0 \tag{3.7c}$$

$$g''(e) \geq 0 \quad \forall x > 0 \tag{3.7d}$$

$$\lim_{e \rightarrow 0} (g'(e)) = 0 \tag{3.7e}$$

Conditions 3.7a - 3.7d state that the cost function is smooth and convex (or alternatively that the benefits of education are concave). The last condition ensures that all agents will optimally hold strictly positive amounts of labor skills.¹⁰

Labor is indivisible at the individual level, so an agent can only work in a single sector in a given state. Moreover, workers sign employment contracts after uncertainty is resolved. I will denote agent i 's employment decision by the variable $\nu_i(\omega) \in \{0, 1\}$. $\nu_i(\omega) = 1$ indicates that the agent works in sector a and $\nu_i(\omega) = 0$ indicates that the agent works in sector b . Agents that specialize their labor productivity in sectors a and b have employment decisions $\nu_i(\omega) = 1$ and $\nu_i(\omega) = 0 \quad \forall \omega \in \Omega$ respectively. This is trivially true since specialists cannot work in a sector other than that of their chosen specialization.

Agents can trade zero net-supply state contingent claims in a complete market. Agent i 's portfolio allocation decision is summarized by the vector $\phi_i \equiv (\phi_{i,1}, \phi_{i,2}, \phi_{i,3}, \phi_{i,4})$ of portfolio shares in each of the four Arrow-Debreu (A-D) securities, in addition to her initial unitary shares in stocks.

Agents take A-D security prices (\mathbf{p}), wages (\mathbf{w}) and dividends in each sector and state (\mathbf{d}) as given. Agent i 's decisions are summarized by the consumption (\mathbf{c}_i), education (\mathbf{e}_i), career ($\boldsymbol{\nu}_i$), and portfolio allocation ($\boldsymbol{\phi}_i$), all defined previously.

The optimization process in reverse chronological order for clarity: At $t=1$, the state of nature ω is known. To save on notation I will omit ω whenever possible in

⁹Labor productivity can be interpreted as a set of knowledge and/or skills acquired by a worker that determine labor efficiency and allows her to earn labor income.

¹⁰Card (1999) discusses the nature of education costs.

what follows. Agent i ' only decision is over consumption. Non-satiation implies that the agent will spend all available wealth in consumption:

$$c_i^* = d_a + d_b + \phi_i \mathbf{I}_4(\omega) + l_i \quad (3.8)$$

where d_a and d_b are dividends received from stocks a and b respectively, $\mathbf{I}_4(\omega)$ is the ω^{th} column of the 4×4 identity matrix and $l_i \in \{l_i^s, l_i^g\}$ is labor income of agent i and

$$l_i^s \equiv e_i^s (\nu_i (w_a - w_b) + w_b)$$

is labor income received by specialists in sector s , w_a and w_b are wages in industries a and b respectively, and

$$l_i^g \equiv e_i^g \underbrace{(1 - \nu_i (f_a - f_b) - f_b)}_{\text{mobility friction}} (\nu_i (w_a - w_b) + w_b)$$

is labor income received by generalists. f_j is the labor mobility friction, and captures sector-specific labor frictions related to the level of specific skills required by the industry that the specialist but not the generalist has.

Since the final consumption good is the numeraire, c_i^* can also be interpreted as agent i 's wealth at $t=1$.

At $t=0$, agent i maximizes expected utility over education, career and portfolio weights, taking into account her optimal wealth c_i^* at $t=1$:

$$\max_{e_i, \nu_i, \phi_i} \mathbb{E} [U(c_i^*)] \quad (3.9)$$

subject to the budget constraint:

$$\underbrace{g(e_i) + \phi_i \mathbf{P}'}_{\text{investments}} \leq \underbrace{w_0 + s_a + s_b}_{\text{initial endowment}} \quad (3.10)$$

where \mathbf{p} is the vector of security prices and s_a and s_b are the market values of stocks a and b respectively.

3.3.3 Market clearing

Aggregate consumption of the final consumption good equals aggregate production:

$$\int_I c_i(\omega) di = Y(\omega) \quad (3.11)$$

where Y is the production of the final consumption good given in equation (3.3). The market for intermediate goods clears when prices of the goods a and b are given by:

$$p_a = \alpha Y_a^{\rho-1} Y^{1-\rho} \quad \text{and} \quad p_b = (1 - \alpha) Y_b^{\rho-1} Y^{1-\rho} \quad (3.12)$$

See Acemoglu (2001) for details. Labor supply equals labor demand in each sector and is equal to the sum of labor productivity of all specialists and net labor productivity (after mobility friction losses) of generalists that choose to work in that sector:

$$L_a = \int_I e_i^a + \nu_i e_i^g (1 - f_a) di \quad \text{and} \quad L_b = \int_I e_i^b + (1 - \nu_i) e_i^g (1 - f_b) di \quad (3.13)$$

The assumption that agents do not have disutility for working implies that, for a strictly positive wage, they will work as much as they can to maximize consumption. Perfect competition among firms in a sector implies that equation (3.13) holds when wages are equal to marginal product of labor in that sector:

$$w_j^* = \frac{d\Pi_j}{dL_j} = p_j \alpha_j P_j L_j^{\alpha_j-1} K_j^{1-\alpha_j} \quad (3.14)$$

All remaining revenues after the payment of wages is distributed to the shareholders as dividends:

$$\begin{aligned} d_j^* &= \frac{p_j P_j L_j^{\alpha_j} K_j^{1-\alpha_j} - L_j w_j^*}{K_j} \\ &= p_j (1 - \alpha_j) P_j L_j^{\alpha_j} K_j^{-\alpha_j} \end{aligned} \quad (3.15)$$

Aggregate holdings of each A-D security equal the zero net supply of these securities:

$$\int_I \phi_{k,i} di = 0 \quad \text{for } k = 1, \dots, 4 \quad (3.16)$$

I denote the set of all consumption decisions by $\Omega^c \equiv \{c_i(\omega)\}_{i \in I}$, the set of all education decisions by $\Omega^e \equiv \{e_i(\omega)\}_{i \in I}$, the set of all investment decisions by $\Omega^\phi \equiv \{\phi_i(\omega)\}_{i \in I}$ and the set of all career decisions by $\Omega^\nu \equiv \{\nu_i(\omega)\}_{i \in I}$. I define the

competitive equilibrium below:

Definition 2. A “competitive equilibrium” is defined as the tuple of all consumption, investment, education and career decisions, as well as prices and payoffs, $\tau \equiv (\Omega^{c*}, \Omega^{\phi*}, \Omega^{e*}, \Omega^{\nu*}, \mathbf{p}, \mathbf{d})$ satisfying:

1. All firms satisfy their maximization problems
2. All agents satisfy their maximization problems
3. Goods markets clear
4. Labor markets clear
5. Stock markets clear

3.3.4 Stochastic discount factor

Complete markets and homogeneity of agents allows us to solve the problem for a representative agent with CRRA utility U over aggregate consumption $C = \int_I c_i di$.¹¹ The SDF \mathbf{m} is defined by the representative agent’s marginal utility and is given by:

$$m(\omega) = \frac{C(\omega)^{-\gamma}}{\mathbb{E}[C^{-\gamma}]} \quad (3.17)$$

where the risk free rate is normalized to 1. See appendix for details.

3.3.5 Separating strategies

Even though agents are ex-ante identical, different decisions make them ex-post heterogeneous. Here I identify the set of all possible distinct decisions that agents undertake in equilibrium. Optimal investments in HC are determined by the level where the marginal cost equals the marginal benefit in terms of future labor income. A specialist’s optimal labor productivity investment is given by:

$$e_i^{sa} = (g')^{-1} (\mathbb{E}[mw_a]) \quad \text{and} \quad e_i^{sb} = (g')^{-1} (\mathbb{E}[mw_b]) \quad (3.18)$$

¹¹Rubinstein (1974) shows conditions for aggregation in an exchange economy or economies with production where agents take production per state as given. In this paper, firms have convex production sets and in equilibrium distribute defined wages and dividends per state, so that production represents an “indirect exchange” and aggregation applies.

for specialists in a and b respectively. Generalist of type \hat{g} 's optimal labor productivity is given by:

$$e_i^g(\boldsymbol{\nu}_i) = (g')^{-1} (\mathbb{E}[m(\nu_i w_a(1 - f_a) + (1 - \nu_i)w_b(1 - f_b))]) \quad (3.19)$$

where here I explicit that the investment in labor productivity depends on the set of employment decisions, $\boldsymbol{\nu}_i$. Please refer to the appendix for details.

Lemma 1. (*Employment decision as a sufficient statistic of the agent's strategy*): *In equilibrium, the employment decision $\boldsymbol{\nu}_i$ fully characterizes all decisions made by an individual.*

See appendix for details.

Lemma 1 allow us to restrict the analysis to differences in employment strategies when determining all universe of possible separating strategies. In particular, all other decisions, such as portfolio allocation and consumption are determined by employment decision $\boldsymbol{\nu}_i$.

In order to further reduce the universe of separating strategies, I eliminate unfeasible strategies. A generalist strategy provides a mobility option to the agent, but mobility frictions makes it costly. Because of the option premium, an agent will only choose a generalist strategy if she plans to join each of the two sectors in at least one state. Otherwise the agent will always work on the same sector and be better off choosing a specialist strategy, thus avoiding mobility fees. All generalists work on the same sector when shocks are the most asymmetric, since the mobility option payoff is maximum in these states.

Lemma 2. (*Limited number of separating strategies*). *In equilibrium, there are at most four different sets of employment decisions and therefore four different separating strategies denoted "specialist in a ", "specialist in b ", "generalists type a " and "generalists type b ".*

proof: Appendix. Lemma 2 shows that a generalist is better off by choosing employment in the same sector in every state where shocks are symmetric across sectors and mobility is less valuable. Generalists of types a and b are defined as generalists that plan to work in sectors a and b in such states, respectively.

3.4 Results

This section presents the main implications of the model. The focus is on how investments in different types of HC at the worker level aggregate and affect the composition of occupations and consequently the relative riskiness across sectors in the economy.

The results presented here are sensitive to the nature of the goods produced by the two sectors. In particular, the choice of the elasticity of substitution between the goods affects the direction of the flows of workers. When goods are assumed to be substitutes, labor flows towards sectors with higher productivity levels. When goods are assumed complements, the flow is reversed since lower productivity make goods scarce, and price increases end up raising revenues and wages. In order to simplify the discussion of results, I restrict the consumption goods to be substitutes.

Assumption 1. (*Substitute goods*). *The elasticity of substitution between goods a and b is greater than 1, or equivalently $\rho > 0$.*

When goods are substitutes (Assumption 1), Lemma 3 states that mobile workers are attracted to sectors with high productivity. The intuition is that when $\rho > 0$, the quantity effect of a change in TFP exceeds the price effect, effectively increasing wages in the sector.¹² This intuition is formalize in the Lemma below:

Lemma 3. *When $\rho > 0$, the number of workers in a sector is increasing in the TFP level.*

See appendix for details.

3.4.1 Implications for workers

Let $\boldsymbol{\eta} \equiv \{\eta_{sa}, \eta_{sb}, \eta_{ga}, \eta_{gb}\}$ be the partition of the unitary mass of agents that choose to become *specialist in a* , *specialist in b* , *generalist type a* , and *generalist type b* respectively.

Lemma 4. (*Existence of specialists*). *A strictly positive fraction of agents chooses to become specialist in a ($\eta_{sa} > 0$) and a strictly positive fraction of agents chooses to become specialist in b ($\eta_{sb} > 0$) in equilibrium. Wages in both sectors satisfy the*

¹²In the case where goods are complements ($\rho < 0$), an increase in total factor productivity leads to a negative price impact that leads to a reduction in wages. In this case, mobile workers are attracted to sectors with *low* productivity.

following condition in an equilibrium where the marginal agent is indifferent between becoming specialist in a or specialist in b:

$$\mathbb{E}[mw_a] = \mathbb{E}[mw_b] \quad (3.20)$$

See appendix for details. Lemma 4 rules out outcomes where, at any given state, any sector's labor supply is made up of generalists only. This would imply that a generalist working in a sector in its worst state would be better off by choosing a specialist strategy and increasing her compensation by avoiding mobility costs. Since both types of specialists will always exist, and since in equilibrium the marginal is indifferent between either strategy, the value of one unit of labor productivity should be equalized across sectors.

An equilibrium is given by the solution of the maximization problem of the representative agent:

$$\max_{\eta} \mathbb{E}[U(Y)] \quad (3.21)$$

subject to the budget constraint:

$$\sum_{k \in \Omega^k} g(e^k) \eta_k = 1 \quad (3.22)$$

so that aggregate investment in HC equals aggregate endowment and where Ω^k is the set of all separating strategies. Furthermore, the marginal agent is indifferent between any of these strategies.

When mobility frictions are too high, or when wage sensitivity to shocks is too weak, the generalist strategy becomes dominated by the specialist strategy. As we do observe mobility of workers across industries in the real world, I restrict the parameter space of the model to the interesting case where labor mobility does exist. I consider a solution to equation (3.21) that satisfies the following equality:

$$\underbrace{X(g')^{-1}(X)}_{\text{value of general hc}} - \underbrace{g((g')^{-1}(X))}_{\text{cost of general hc}} = \underbrace{Y(g')^{-1}(Y)}_{\text{value of specialized hc}} - \underbrace{g((g')^{-1}(Y))}_{\text{value of specialized hc}} \quad (3.23)$$

where $G \equiv \mathbb{E}[m \max[w_a(1 - f_a), w_b(1 - f_b)]]$ and $S \equiv \mathbb{E}[mw_a] = \mathbb{E}[mw_b]$ See appendix for details. Equation (3.23) is satisfied when a positive mass of generalists exists in equilibrium. A generalist strategy is viable when its net present value is at least as great as the net present present value of the specialist investment in human capital.

G represents the present value of a unit of generalist labor productivity, as well as its marginal cost. Note that G is analogous to an option to choose the greatest net wage at $t=1$. The option value is increasing in asymmetric shocks that create a wedge in wages across states. In an equilibrium where the marginal agent is indifferent between becoming a *specialist* or a *generalist*, condition (3.23) binds.

The following example illustrates the feasible region for the existence of mobile workers. With log-utility, $\alpha_a = \alpha_b = \frac{1}{\rho}$, and $f_a = f_b = f$, a positive mass of generalists will exist when the following condition is satisfied:

$$f \leq \frac{1}{2} (1 - \delta^{-2\rho})$$

where $\delta \geq 1$ and $\rho > 0$. In this example, the feasible region for mobile workers is increasing in both the elasticity of substitution and the amplitude of shocks, as shown in figures 3.3(a) and 3.3(b) respectively.

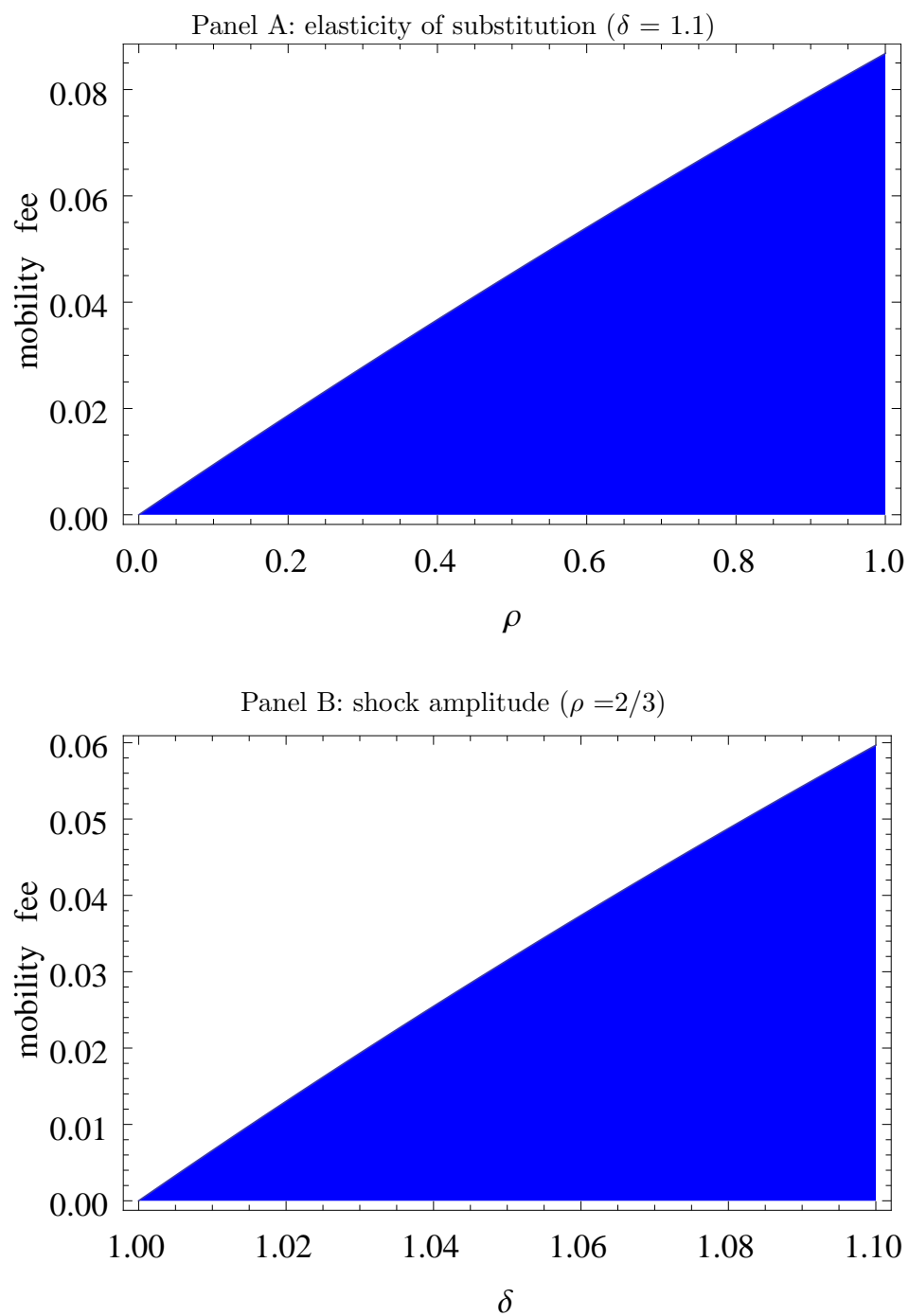


Figure 3.3: Feasible region for mobility

An occupation-based measure of labor mobility

The labor mobility friction parameters f_a and f_b drive differences in labor mobility across industries in the model. These frictions decrease the labor productivity of mobile workers employed in the industry. Real world examples of such frictions are the amount of institutional information that investment bankers should acquire and retain, professional certification required by health care professionals and search costs in geographically dispersed industries. It would be impractical to construct direct measures of all possible mobility frictions across every industry. To overcome this problem, I propose a measure of labor mobility derived from the model and based on observed occupation composition across industries. I show below the equivalence between this proposed new measure and the industry's exogenous mobility friction:

Lemma 5. (*Frictions to labor mobility and the composition of occupations in a sector*). *Conditional on the existence of generalists in the economy, i.e. when equation (3.23) holds, the expected ratio of generalists to specialists in sector k , $\mathbb{E} \left[\frac{\eta_{gk}}{\eta_{sk}} \right]$, is monotonically decreasing in the labor mobility friction in the sector, f_k .*

Under plausible assumptions, Lemma 5 justifies the use of the endogenous expected ratio of *generalists* to *specialists* in an industry as a proxy for labor mobility frictions.

3.4.2 Implications for firms

I here analyze the properties of the equilibrium. Solving the model numerically amounts to computing a solution to equation (3.21). The comparative statics presented here are robust for a broad range of parameter values within the parameter space where equation (3.23) holds and mobile workers exist. Outside this parameter space, i.e. for high friction values, one or two generalist types cease to exist and the results discussed might not hold.

Table 3.1 shows parameter values used in the following graphical illustrations. The two types of goods are assumed perfect substitutes. Under this assumption the economy simplifies to the case of only one good at a cost of high amplitude of shocks, δ , needed to ensure the existence of a positive mass of mobile workers. I find qualitatively similar results for the case of complement goods.

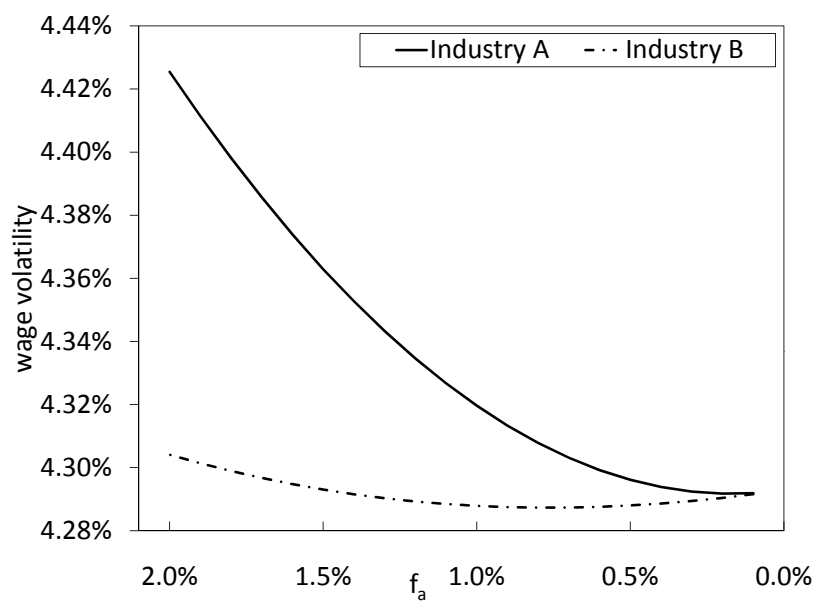
Table 3.1: Parameter values used in numerical illustrations

Name	Parameter	Value
CES	$\frac{1}{1-\rho}$	∞
Risk aversion	γ	3/2
Initial endowment	w_0	1
Convexity of HC investments	$\frac{dg(x)}{xdx}$	2
Labor intensity	α_a, α_b	2/3
Physical capital	K_a, K_b	1/2
Base TFP	A	4
Shock amplitude	δ	1.2

Result 3.4.1. *Volatility of cash-flows available to equity holders in sector k , $\mathbb{E}[(d_k - \mathbb{E}[d_k])^2]$ is decreasing, and volatility of cash-flows available to workers in sector k , $\mathbb{E}[(w_k - \mathbb{E}[w_k])^2]$, is increasing in the sector's labor mobility friction, f_k .*

When physical capital is less mobile than human capital, labor mobility amplifies risk sharing between shareholders and workers. Labor mobility broadens labor markets and reduces workers' exposure to their employers' risk. Firms in high labor-mobility industries pay more stable wages and have more volatile residual cash-flows. Figure 3.4(a) shows the increase in wage volatility as labor mobility increases. Figure 3.4(b) shows profits volatility as an increasing function of labor mobility.

Panel A: wage volatility



Panel B: profits volatility

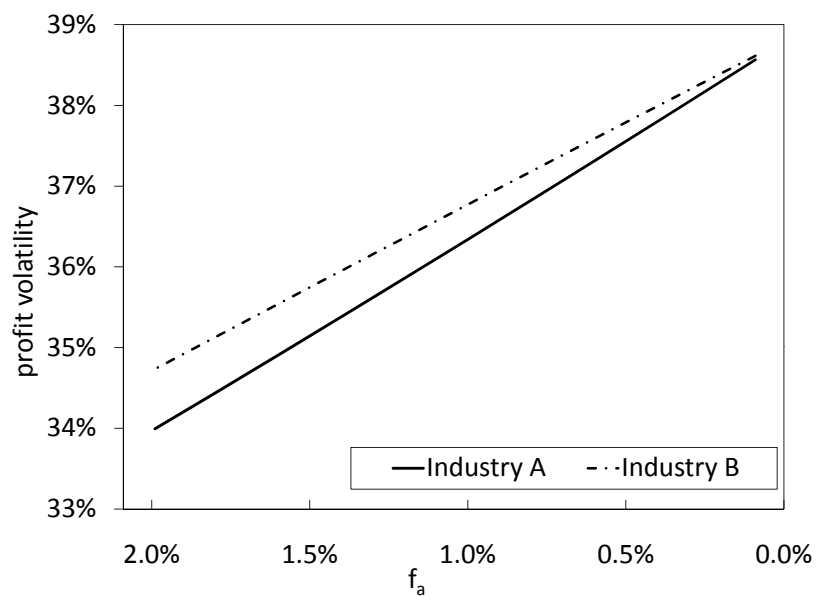


Figure 3.4: Lever effect of labor mobility

Result 3.4.2. *Expected stock returns in a sector k are decreasing in the sector's labor mobility friction, f_k .*

Firms become more exposed to systematic risk as labor compensation become insensitive to business performance. As firms in mobile industries paying more stable labor compensation as they compete for labor in a broader market. Firms in low mobility industries are more insulated against aggregate risk since wages are more in sync with the industry performance. An implication of the impact of labor market segmentation on risk sharing is that labor income should be less correlated to profits in industries with high labor mobility than in industries with low labor mobility. Figure 3.5(a) illustrates the decrease in risk sharing between shareholders and workers as labor mobility increases. A greater exposure to systematic risk should be reflected in higher expected stock returns for firms in industries with high labor mobility, as shown in figure 3.5(b).

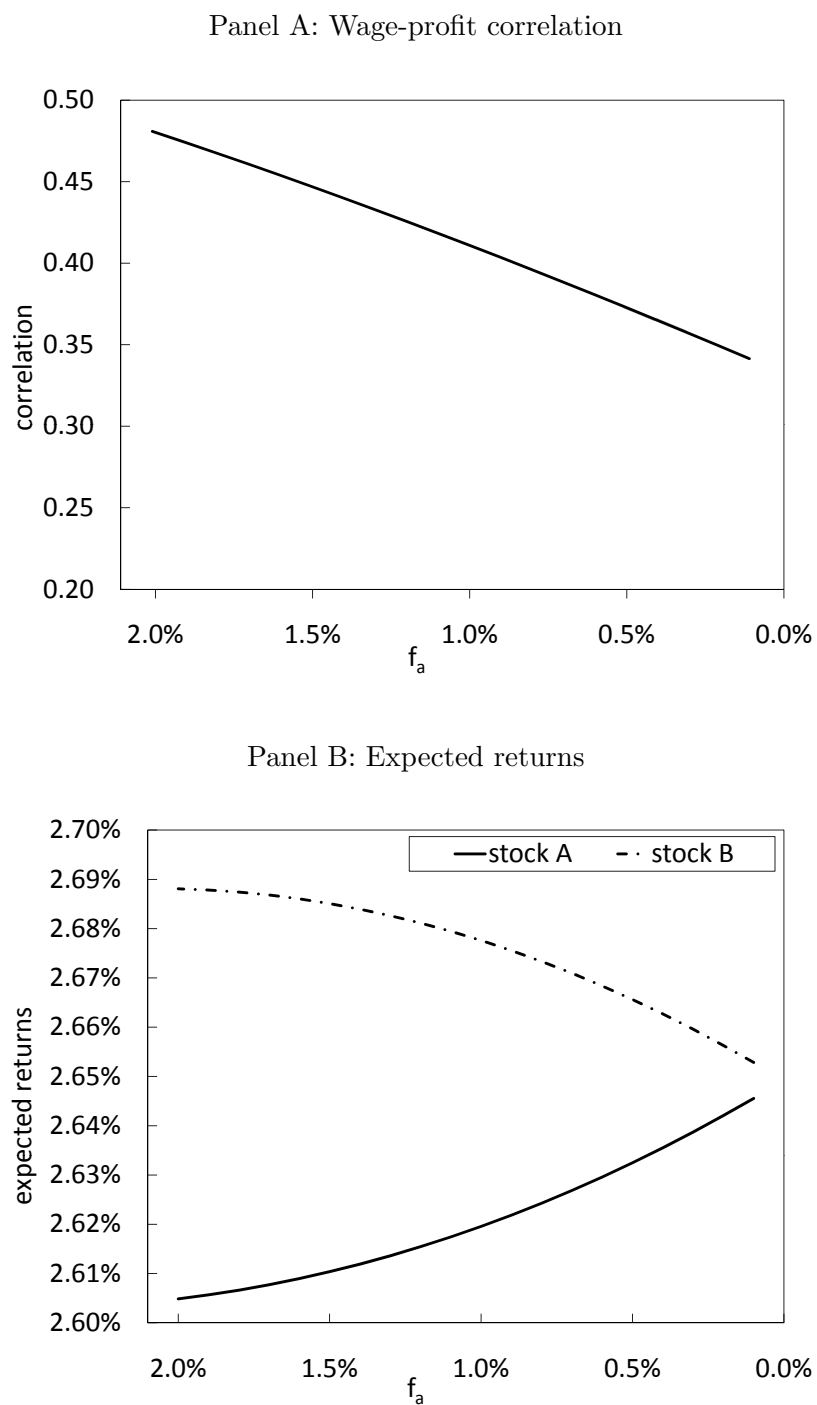


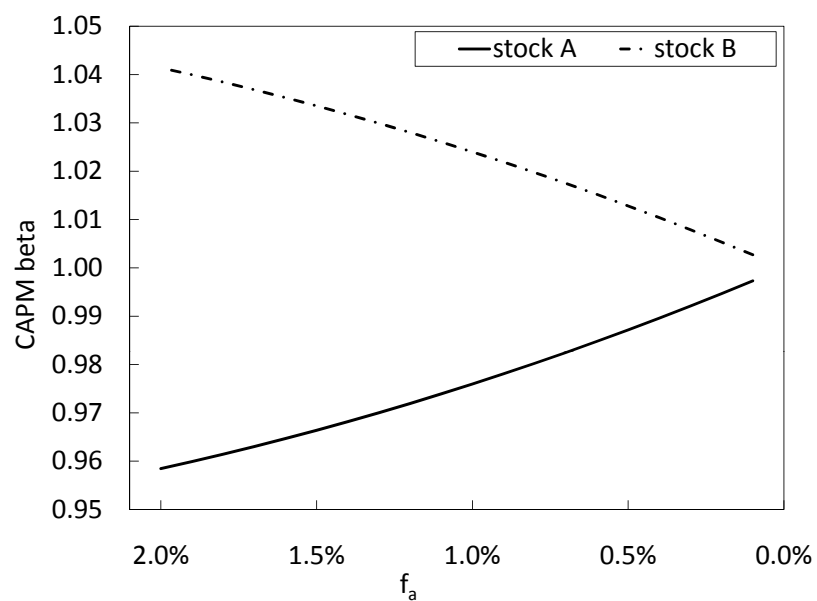
Figure 3.5: Shareholder-worker risk sharing and expected returns

Result 3.4.3. *CAPM market betas and unexplained returns in sector k are decreasing in the industry's labor mobility friction, f_k .*

Traditional linear asset pricing models should partially capture higher expected stock returns of high mobility industries. Betas in these industries are higher because cash-flows oscillate more closely with aggregate cash-flows in the economy. Labor mobility amplifies profits during good times for the industry, since access to a broader labor supply allows firms to hire abundant labor at relatively stable wages when needed. During bad times, the opposite is true. Firms in high mobility industries do not have flexibility to decrease wages as workers can simply leave the industry. In order to maintain labor utilization at an optimal level, high-mobility firms end up lowering production more than firms in low mobility industries, resulting in lower profits. Figure 3.6(a) shows the positive relation between CAPM market betas and labor mobility.

Figure 3.6(b) shows that pricing errors are positively associated to labor mobility. The CAPM fails to capture risk orthogonal to the financial market portfolio. Firms are exposed to fluctuations in human capital in addition to physical capital values. In the example shown, firms that rely on a mobile workforce are also more exposed to aggregate human capital risk. Firms in low mobility industries are mostly exposed to human capital of workers with specialized skills, intrinsically more in line with the value of physical capital.

Panel A: CAPM betas



Panel B: Unexplained stock returns

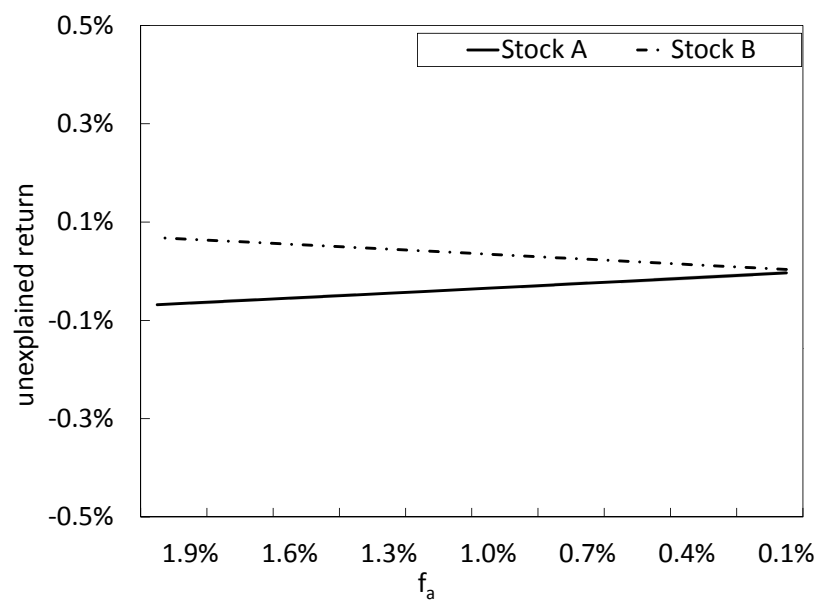


Figure 3.6: Shareholder-worker risk sharing and expected returns

3.5 Conclusion

I develop a two-sector general equilibrium economy with production, consumption and investments in education. Labor mobility is endogenized through education and employment decisions at the individual level and generates labor supply uncertainty. In equilibrium, agents separate in low-risk, low-return generalist strategies and high-risk, high-return specialist strategies. In particular, labor mobility frictions reduce the attractiveness of a sector to generalists, equity risk and expected returns. This framework is able to capture some aspects of the interaction between aggregate education decisions, labor supply, capital and labor productivities and expected equity returns across sectors.

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Chapter 4

Appendix

4.1 First chapter

4.1.1 Proof of Lemma 1

Proof. Assume that there exists a traded asset that pays a continuous stream of dividends identical to the operating profits of the industry. The discounted value of a portfolio of a traded asset that continually reinvests its dividends in the asset is a martingale:

$$0 = \Lambda Y + \frac{\mathbb{E}[d(\Lambda V(Y, t))]}{dt} \quad (4.1.1)$$

Applying Ito's Lemma to equation (4.1.1) and simplifying leads to equation (4.1.2):

$$0 = Y + rV(Y) + (\mu - \eta\sigma\rho)YV'(Y) + \frac{\sigma^2}{2}Y^2V''(Y), \quad (4.1.2)$$

where μ and σ are the drift and volatility of the firm's operating profits, respectively. (4.1.2) has a known solution given by $V = \frac{Y}{r + \eta\sigma\rho - \mu}$. For the industry with immobile labor, the particular solution becomes:

$$V^1 = \frac{Y^1}{r + \eta\sigma_1\rho - \mu_1} \quad (4.1.3)$$

where $\sigma_I \equiv \sigma_A$ and $\mu_I \equiv \mu_A$. For the industry with perfectly mobile labor, the particular solution becomes:

$$V^M = \frac{Y^M}{r + \eta(\sigma_{M1}\rho + \sigma_{M2}) - \mu_M} \quad (4.1.4)$$

where $\mu_M \equiv \frac{1}{1-\alpha} \left(\mu_A - \alpha\mu_G + \frac{\alpha}{1-\alpha} \left(\frac{\sigma_A^2}{2} + \frac{\sigma_G^2}{2} - \sigma_A\sigma_G\rho \right) \right)$, $\sigma_{M1} \equiv \frac{1}{1-\alpha}\sigma_A$, and $\sigma_{M2} \equiv -\frac{\alpha}{1-\alpha}\sigma_G$. \square

4.1.2 Proof of Lemma 2

Proof. Since Y^I and Y^M are sufficient statistics for operating cash flows, (equation (1.20)), they should also be sufficient statistics for the value of the firm, so that $V = V(Y^I, Y^M)$. If the function $V(Y^I, Y^M)$ exists and is twice continuously differentiable, then the value of the firm (Equation (1.11)) satisfies the following partial differential equation (PDE):

$$\begin{aligned} 0 = & Y^I + \max[Y^M e^{x_L} - Y^I, 0] - \max[Y^I - Y^M e^{x_H}, 0] \\ & - Vr + V_I Y^I (\mu_I - \sigma_I \eta \rho) + V_M Y^M (\mu_M - (\sigma_{M1}\rho + \sigma_{M2})\eta) \\ & + V_{II} (Y^I)^2 \frac{\sigma_I^2}{2} + V_{MM} (Y^M)^2 \left(\frac{\sigma_{M1}^2}{2} + \frac{\sigma_{M2}^2}{2} + \sigma_{M1}\sigma_{M2}\rho \right) + V_{IM} Y^I Y^M (\sigma_I \sigma_{M1} + \sigma_I \sigma_{M2} \rho), \end{aligned} \quad (4.1.5)$$

subject to:

(i) transversality conditions:

$$\lim_{Y^I \rightarrow 0} V(Y^I, Y^M) = V^I \quad \text{and} \quad (4.1.6a)$$

$$\lim_{Y^M \rightarrow 0} V(Y^I, Y^M) = V^M, \quad (4.1.6b)$$

(ii) value-matching conditions:

$$V_1(Y^I, Y^I e^{x_L}) = V_2(Y^I, Y^I e^{x_L}) \quad \text{and} \quad (4.1.7a)$$

$$V_2(Y^I, Y^I e^{x_H}) = V_3(Y^I, Y^I e^{x_H}), \quad (4.1.7b)$$

where V_1 , V_2 , and V_3 are the respective values of the firm in mobility regions 1, 2, and 3 respectively, and

(iii) smooth-pasting conditions:

$$\left. \frac{\partial V_1(Y^I, Y^M)}{\partial Y^M} \right|_{Y^M=Y^I e^{x_L}} = \left. \frac{\partial V_2(Y^I, Y^M)}{\partial Y^M} \right|_{Y^M=Y^I e^{x_L}} \quad \text{and} \quad (4.1.8a)$$

$$\left. \frac{\partial V_2(Y^I, Y^M)}{\partial Y^M} \right|_{Y^M=Y^I e^{x_H}} = \left. \frac{\partial V_3(Y^I, Y^M)}{\partial Y^M} \right|_{Y^M=Y^I e^{x_H}}. \quad (4.1.8b)$$

Assume that there exists a traded asset that pays a continuous stream of dividends identical to the operating profits of the industry. The discounted value of a portfolio of a traded asset that continually reinvests its dividends in the asset is a martingale (see Shreve (2004), pg. 234):

$$0 = \Lambda_t Y(Y_t^I, Y_t^M) + \frac{\mathbb{E}_t [d(\Lambda_t V(Y_t^I, Y_t^M))]}{dt} \quad (4.1.9)$$

Applying Ito's Lemma to equation (4.1.9) and simplifying leads to equation (4.1.5).

Homogeneity of cash flows implies that the solution to Equation (4.1.5) should also be homogeneous of degree one in Y^I and Y^M . Equation (4.1.5) can thus be simplified to an ordinary differential equation, as stated in Lemma 2: From Equation (1.20), we can express the industry operating cash flows as:

$$\begin{aligned} Y &= Y^I + \max[Y^M e^{x_L} - Y^I, 0] - \max[Y^I - Y^M e^{x_H}, 0] \\ &= Y^I (1 + \max[e^{x+x_L} - 1, 0] - \max[1 - e^{x+x_H}, 0]) \end{aligned} \quad (4.1.10)$$

From equation (4.1.10), we can see that operating cash flows Y is homogeneous of degree one in (Y^I, Y^M) . This implies that the value of the firm is also homogeneous of degree one in (Y^I, Y^M) . We can thus express the value of the firm as $V = Y^I f(x)$, so that:

$$V_t = 0 \quad (4.1.11a)$$

$$V_I = f(x) - x f'(x) \quad (4.1.11b)$$

$$V_M = e^{-x} f'(x) \quad (4.1.11c)$$

$$V_{II} = \frac{1}{Y^I} (f''(x) - f'(x)) \quad (4.1.11d)$$

$$V_{MM} = \frac{e^{-x}}{Y^M} (f''(x) - f'(x)) \quad (4.1.11e)$$

$$V_{IM} = \frac{1}{Y^M} (f'(x) - f''(x)) \quad (4.1.11f)$$

Plugging (4.1.11) back to (4.1.5) and dividing by Y^I gives the ODE:

$$0 = 1 + \max [e^{x+x_L} - 1, 0] - \max [1 - e^{x+x_H}, 0] + c_1 f(x) + c_2 f'(x) + c_3 f''(x)$$

where:

$$\begin{aligned} c_1 &\equiv \mu_A - r - \eta\sigma_A\rho \\ c_2 &\equiv \mu_x + \frac{\alpha}{1-\alpha} (\sigma_G (\eta - \sigma_A\rho) - \sigma_A (\eta\rho - \sigma_A)) \\ c_3 &\equiv \left(\frac{\alpha}{1-\alpha}\right)^2 (\sigma_A^2 + \sigma_G^2 - 2\sigma_A\sigma_G\rho) \end{aligned}$$

□

4.1.3 Proof of Proposition 4

Lemma (2) greatly simplifies the solution to equation (4.1.5) and allows us to obtain a closed-form solution for the value of the firm, as shown below:

Proof. At region 1, equation (1.22) becomes:

$$0 = e^{x+x_H} + f_1(x)c_1 + f_1'(x)c_2 + f_1''(x)c_3, \quad (4.1.12)$$

with solution:

$$f_1(x) = (e^{(x+x_H)b_2} - e^{(x+x_L)b_2}) \frac{B_1}{c_1} - e^{x+x_H} B_2, \quad (4.1.13)$$

where

$$\begin{aligned} b_1 &\equiv \frac{-c_2 - \sqrt{c_2^2 - 4c_1c_3}}{2c_3}, \\ b_2 &\equiv \frac{-c_2 + \sqrt{c_2^2 - 4c_1c_3}}{2c_3}, \end{aligned}$$

and

$$B_1 \equiv \frac{c_1 + (c_2 + c_3)b_1}{(c_1 + c_2 + c_3)(b_1 - b_2)}, \quad \text{and}$$

$$B_2 \equiv \frac{1}{c_1 + c_2 + c_3}.$$

At region 2, equation (1.22) becomes:

$$0 = 1 + f_2(x)c_1 + f_2'(x)c_2 + f_2''(x)c_3, \quad (4.1.14)$$

with solution:

$$f_2(x) = e^{(x+x_L)b_2} \frac{B_1}{c_1} - e^{(x+x_H)b_1} \frac{B_3}{c_1} - B_4, \quad (4.1.15)$$

where:

$$B_3 \equiv \frac{c_1 + (c_2 + c_3)b_2}{(c_1 + c_2 + c_3)(b_1 - b_2)}, \quad \text{and}$$

$$B_4 \equiv \frac{1}{c_1}.$$

At region 3, equation (1.22) becomes:

$$0 = e^{x+x_L} + f_3(x)c_1 + f_3'(x)c_2 + f_3''(x)c_3, \quad (4.1.16)$$

with solution:

$$f_3(x) = (e^{(x+x_L)b_1} - e^{(x+x_H)b_1}) \frac{B_3}{c_1} - e^{x+x_L} B_2. \quad (4.1.17)$$

Solving the above system of equations leads to:

$$f(x) = \begin{cases} (e^{(x+x_H)b_2 - (x+x_L)b_2}) \frac{B_1}{c_1} - e^{x+x_H} B_2, & \text{if } x \leq x_L, \\ e^{(x+x_H)b_1} \frac{B_3}{c_1} - e^{(x+x_L)b_2} \frac{B_1}{c_1} - B_4, & \text{if } x_L < x < x_H, \\ (e^{(x+x_H)b_1} - e^{(x+x_L)b_1}) \frac{B_3}{c_1} - e^{x+x_L} B_2, & \text{if } x \geq x_H. \end{cases} \quad (4.1.18)$$

and

$$V(I, x; \delta) = \begin{cases} Y^I \left((e^{(x+x_H)b_2} - e^{(x+x_L)b_2}) \frac{B_1}{c_1} - e^{x+x_H} B_2 \right), & \text{if } x \leq x_L, \\ Y^I \left(e^{(x+x_H)b_1} \frac{B_3}{c_1} - e^{(x+x_L(\delta))b_2} \frac{B_1}{c_1} - B_4 \right), & \text{if } x_L < x < x_H, \\ Y^I \left((e^{(x+x_H(\delta))b_1} - e^{(x+x_L(\delta))b_1}) \frac{B_3}{c_1} - e^{x+x_L} B_2 \right), & \text{if } x \geq x_H. \end{cases} \quad (4.1.19)$$

The result follows from the definitions of V^I , V^M , and from the following definitions of $p_{b,L}$, $p_{b,H}$, $p_{a,L}$, and $p_{a,H}$:

$$p_{b,L}(x) \equiv \left(\frac{X_L}{X} \right)^{-b_2}, \quad p_{b,H}(x) \equiv \left(\frac{X_H}{X} \right)^{-b_2}, \quad p_{a,L}(x) \equiv \left(\frac{X}{X_L} \right)^{b_1}, \quad \text{and} \quad p_{a,H}(x) \equiv \left(\frac{X}{X_H} \right)^{b_1},$$

where $X \equiv e^x$, $X_L \equiv e^{x_L}$, and $X_H \equiv e^{x_H}$. \square

4.1.4 Proof of Lemma 3

Proof. Instantaneous expected returns are given by:

$$E[R] = \begin{cases} E \left[\frac{dV + Y^M e^{x_H} dt}{V} \middle| x \leq x_L \right], & \text{if } x \leq x_L, \\ E \left[\frac{dV + Y^I dt}{V} \middle| x_L < x < x_H \right], & \text{if } x_L < x < x_H, \\ E \left[\frac{dV + Y^M e^{x_L} dt}{V} \middle| x \geq x_H \right], & \text{if } x \geq x_H. \end{cases} \quad (4.1.20)$$

Plugging in Equations 4.1.19 and 1.20 into Equation 4.1.20, and after some algebra manipulation, we get

$$E[R] = r + \eta \left(\sigma_A \rho + \frac{\alpha}{1 - \alpha} (\sigma_A \rho - \sigma_G) \xi(x; \delta) \right), \quad (4.1.21)$$

where

$$\xi(x; \delta) = \begin{cases} b_2 + \frac{Y}{V} \left(\frac{1-b_2}{E(R^M) - \mu_M} \right), & \text{if } x \leq x_L, \\ \frac{Y}{V} \left(p_{a,L} \left(\frac{(b_2-1)b_1}{E(R^M) - \mu_M} - \frac{b_1 b_2}{E(R^I) - \mu_I} \right) - p_{b,H} \left(\frac{(b_1-1)b_2}{E(R^M) - \mu_M} - \frac{b_1 b_2}{E(R^I) - \mu_I} \right) \right) \frac{1}{(b_2-b_1)}, & \text{if } x_L < x < x_H, \\ b_1 + \frac{Y}{V} \left(\frac{1-b_1}{E(R^M) - \mu_M} \right), & \text{if } x \geq x_H. \end{cases} \quad (4.1.22)$$

The equation above makes explicit the relation between conditional expected asset returns of the general case and the unconditional asset returns of the benchmark mobility cases. \square

4.1.5 Proof of Proposition 5

Proof. A simple inspection of Equation (1.25) shows that $\frac{\partial E[R]}{\partial \delta} > 0$ is equivalent to $\frac{\partial \xi(x; \delta)}{\partial \delta} > 0$.

From Assumptions 1 and 2 we have that:

$$\begin{aligned} E(R^I) - \mu_A &= -c_1 > 0 \\ E(R^M) - \mu_M &= -(c_1 + c_2 + c_3) > 0 \\ \rho\sigma_A - \sigma_G &> 0 \end{aligned}$$

Lemma 6. *The inequalities below follow directly from the fact that $\sigma_A > 0$, $\mu_A \geq 0$, $\sigma_G > 0$, $\mu_G \geq 0$, $\rho \geq 0$, $0 < \alpha < 1$, and from Assumptions 1 and 2:*

$$c_3 > 0, \quad (4.1.23a)$$

$$b_1 < 0, \quad (4.1.23b)$$

$$b_2 > 1, \quad (4.1.23c)$$

$$B_1 < 0, \quad (4.1.23d)$$

$$B_3 < 0, \quad (4.1.23e)$$

$$C_1 \equiv E(R^I) - \mu_A + b_2 ((E(R^M) - \mu_M) - (E(R^I) - \mu_I)) > 0, \quad (4.1.23f)$$

$$C_2 \equiv E(R^I) - \mu_A + b_1 ((E(R^M) - \mu_M) - (E(R^I) - \mu_I)) > 0, \quad (4.1.23g)$$

$$(E(R^M) - \mu_M) > C_2 \quad (4.1.23h)$$

I proceed to show that the latter holds in each of the three mobility regimes:

Outflow of labor regime. In this region $x \leq x_L$:

$$\frac{\partial \xi(x; \delta)}{\partial \delta} = \frac{\alpha (e^{x_H})^{1+b_2} e^x \overbrace{\left(1 + b_2 + (e^{x_H})^{2b_2} (b_2 - 1)\right)}^{(>0, \text{Lemma 5})} Y^{b_2} \overbrace{(1 - b_2)B_1}^{(>0, \text{Lemma 5})} \overbrace{(E(R^M) - \mu_M)}^{(>0, \text{Assumption 2})}}{(1 - \alpha)\delta^2 \left((e^{x_H})^{1+b_2} e^x + \left((e^{x_H})^{2b_2} - 1 \right) Y^{b_2} B_1 (E(R^M) - \mu_M) \right)^2} > 0 \quad (4.1.24)$$

Stasis regime. In this region $x_L < x < x_H$:

$$\frac{\partial \xi(x; \delta)}{\partial \delta} = a(b_2 - b_1) \times \frac{\overbrace{C_2 e^{x_H(b_1+2b_2)+xb_1}}^{(>0, \text{ Lemma 5})} (\mathbb{E}(R^M) - \mu_M) b_1^2 + \overbrace{C_1 e^{b_2(x+x_H)} ((\mathbb{E}(R^M) - \mu_M) b_2^2 - C_2 e^{b_1(x+x_H)}(b_1 + b_2))}^{(>0, \text{ Lemma 5})}}{(C_1 e^{xb_2} - e^{x_H b_2} (C_2 e^{b_1(x+x_H)} + (\mathbb{E}(R^M) - \mu_M) (b_1 - b_2)))^2} \delta^2 >$$

(4.1.25)

Inflow of labor regime. In this region $x \geq x_H$:

$$\frac{\partial \xi(x; \delta)}{\partial \delta} = \frac{\alpha (e^{x_H})^{1+b_1} e^x \overbrace{\left((e^{x_H})^{2b_1} - 1 + b_1 + (e^{x_H})^{2b_1} b_1 \right)}^{(<0, \text{ Lemma 5})} Y^{b_1} \overbrace{(1 - b_1) B_3}^{(<0, \text{ Lemma 5})} (\mathbb{E}(R^M) - \mu_M)}{(1 - \alpha) \delta^2 \left((e^{x_H})^{b_1} e^x + e^{x_H} \left((e^{x_H})^{2b_1} - 1 \right) Y^{b_1} B_3 (\mathbb{E}(R^M) - \mu_M) \right)^2} > 0$$

(4.1.26)

□

4.1.6 Proof of Lemma 4

Proof. The logarithm of the ratio of cash flows of the fully mobile and fully immobile industries x is not observable in the data, so assume that the priors for the mean and variance of x be $\mathbb{E}[x] = 0$ and $\text{Var}[x] = \sigma^2$, for any given industry. The unconditional expectation of Γ for a given industry is:

$$\mathbb{E}[\Gamma] = \int_{-\infty}^{\frac{x_L}{\sigma}} e^{2\frac{z\sigma}{\alpha}} \phi(z) dz + \int_{\frac{x_L}{\sigma}}^{\frac{x_H}{\sigma}} \phi(z) dz + \int_{\frac{x_H}{\sigma}}^{\infty} e^{-\frac{z\sigma}{\alpha}} \phi(z) dz, \quad (4.1.27)$$

where ϕ is the standard normal probability density function. The empirical measure of labor mobility is based on $(\mathbb{E}[\Gamma])^{-1}$. Under Assumption 3 and for finite δ , the following strict inequality holds:

$$\frac{\partial(\mathbb{E}[\Gamma]^{-1})}{\partial \delta} = \frac{1}{(\mathbb{E}[\Gamma])^2} \frac{\alpha e^{-\frac{2x_H}{\alpha}} \left(e^{\frac{x_H}{\alpha}} - 1 \right) \left(1 + 2e^{\frac{x_H}{\alpha}} \right) \phi\left(\frac{x_H}{\sigma}\right)}{(1 - \alpha) \sigma \delta^2} > 0 \quad (4.1.28)$$

The expression above shows that $(\mathbb{E}[\Gamma])^{-1}$ is in fact monotonically increasing in δ . □

4.1.7 Occupations data

The Bureau of Labor Statistics (BLS), through its Occupational Employment Program conducts a survey that tracks employment across occupations and industries from 1988 to 1995 and from 1997 to 2009. The survey covers approximately 200,000 non-farm establishments every six months, not including self-employed workers, from all states in the United States. Before 1996, BLS collected data through three-year survey cycles, so that each industry was updated every three years. After 1997 the frequency increased to annual cycles. In the earlier sample period, I use the same industry data for three years until it is updated by the survey to ensure a full set of industries when constructing the occupation concentration measure.

Before 1999, the survey used the Occupational Employment Statistics (OES) taxonomy system with 770 occupations. After 1999, the survey switched to the Standard Occupational Classification (SOC) system with 821 to 965 occupations. Industries are classified using three-digit Standard Industrial Classification (SIC) codes until 2001 and four-digit North American Industry Classification System (NAICS) codes after that. I reclassify OES codes to SOC codes using the crosswalk provided by the National Crosswalk Service Center. This reclassification allows the merger of occupation data and data on education levels by occupation from O*NET. Education level is the average required education per occupation across industries, weighted by the number of employees in each occupation.

I exclude from the sample industries denoted as “Not Elsewhere Classified” or “Miscellaneous” (SIC xx9 and NAICS xxx9), since firms in these industries might not hold enough similarities to justify free internal mobility of workers as in the model.

4.1.8 Financial and accounting data

Monthly common stock data is from the Center for Research in Security Prices (CRSP shrcd =10 or 11). Accounting information is from Standard and Poor’s Compustat annual industrial files. I include only stocks listed on NYSE, AMEX, and NASDAQ, with available data in the CRSP-COMPUSTAT merged files. I follow the literature and exclude firms with primary standard industrial classifications between 4900 and 4999 (regulated) and between 6000 and 6999 (financials). I exclude firm-year observations with missing monthly returns in the year and/or with missing measures of size, book-to-market, and leverage from the previous year. I exclude industry-year observations with less than 10 firms with valid stock data. Firm-level accounting

variables and size measures are Winsorized at the 0.5% level in each sample year to reduce the influence of possible outliers. For the same reason, I exclude from the sample the lowest 10th size percentile of the sample of firms to avoid anomalies driven by micro-cap firms, as discussed by Fama and French (2008).¹

Size is defined as the market value of equity (Compustat fields `prc` times `shrout`). Book value is defined as shareholders' equity (Compustat `SEQ`) divided by the market value of equity. I require the measures of book-to-market and size to be available at least seven months prior to the test year. Leverage ratios are calculated as the book value of debt adjusted for cash holdings, as reported in Compustat, divided by the assets (book-valued leverage ratio), or divided by the sum of market value of equity and book value of debt (market-valued leverage ratio). Tangibility ratios are defined as Property, Plant, and Equipment (PPE) divided by total assets. Profitability is defined as the ratio of earnings to total assets. Labor intensity is proxied by the ratio of the number of employees divided by PPE. Altman's *Z*-score proxies for the likelihood of bankruptcy of a firm in the following two years and is estimated as in Leary and Roberts (2010).²

Market betas are constructed following Fama and French (1992). Monthly market returns are defined by the value-weighted return on all NYSE, AMEX, and NASDAQ stocks minus the one-month Treasury bill rate. I first estimate pre-ranking betas on 60 monthly returns for individual stocks. I form 100 portfolios of stocks each year, double sorted on 10 lagged size groups and 10 lagged pre-ranking market beta groups. Size groups are defined by NYSE-based breakpoints to prevent overweighting very small stocks. I then estimate betas for each of the portfolios using the full sample period and assign the respective beta to each stock in the portfolio in each year. Market betas are estimated as the sum of the slope coefficients of regressions of excess returns on contemporaneous and lagged market excess returns.

I construct a measure of operating leverage at the firm-level based on the sensitivity of operating cash-flows to changes in sales. Operating leverage for firm i is defined as the slope of sales growth ($\lambda_{i,1}$) of the following time-series regression:

$$\text{cfg}_{i,t} = \lambda_{i,0} + \lambda_{i,1}\text{saleg}_{i,t} + \epsilon_{i,t}, \quad (4.1.29)$$

where $\text{cfg}_{i,t}$ is the change in log operating cash flows (COMPUSTAT items `dp` + `item`

¹The results discussed in this chapter are robust to keeping all micro-caps and to excluding the lowest 10th and 20th size percentiles of firms in the sample.

²The *Z*-score is defined as the sum of 3.3 times earnings before interest and taxes, plus sales, plus 1.4 times retained earnings, plus 1.2 times working capital divided by total assets.

ib) and $\text{sale}_{i,t}$ is the change in log sales (item sale). The measure is estimated only for firms with at least five years of data on sales and cash-flow growth.

4.2 Second chapter

4.2.1 Proof of Lemma 1

To find the general labor demanded in industries A and B, we proceed as follows. The consumer's budget constraint, taking prices and wages as given, implies:³

$$\frac{\theta_A}{\theta_B} \left(\frac{C_A}{C_B} \right)^\rho = \frac{P_A C_A}{P_B C_B}. \quad (4.2.1)$$

In equilibrium, goods markets clear ($C_i = Y_i$), leading to:

$$\frac{\theta_A}{\theta_B} \left(\frac{Y_A}{Y_B} \right)^\rho = \frac{P_A Y_A}{P_B Y_B}. \quad (4.2.2)$$

Combining expression (2.15) for each industry, and expression(4.2.2), we obtain the following relationship between the general labor demanded in each industry and production in each industry:

$$1 = \frac{\theta_A \psi_A \alpha_A}{\theta_B \psi_B \alpha_B} \left[\frac{Z_A K_A^{1-\alpha_A} L_A^{(1-\psi_A)\alpha_A}}{Z_B K_B^{1-\alpha_B} L_B^{(1-\psi_B)\alpha_B}} \right]^\rho \frac{L_{G,A}^{\psi_A \alpha_A \rho - 1}}{L_{G,B}^{\psi_B \alpha_B \rho - 1}}. \quad (4.2.3)$$

Finally, the labor market clearing condition for general human capital implies $L_{G,A} + L_{G,B} = \xi_G$. Hence:

$$1 = \frac{\theta_A \psi_A \alpha_A}{\theta_B \psi_B \alpha_B} \left[\frac{Z_A K_A^{1-\alpha_A} L_A^{(1-\psi_A)\alpha_A}}{Z_B K_B^{1-\alpha_B} L_B^{(1-\psi_B)\alpha_B}} \right]^\rho \frac{L_{G,A}^{\psi_A \alpha_A \rho - 1}}{(\xi_G - L_{G,A})^{\psi_B \alpha_B \rho - 1}}. \quad (4.2.4)$$

³This follows from the agent's first order conditions when choosing between goods. Aggregate consumption must be financed through the wages and dividends that agents receive. The Lagrangian for the representative agent is: $1 - \gamma (\theta_A C_A^\rho + \theta_B C_B^\rho)^{\frac{1-\gamma}{\rho}} + \lambda (Bud - P_A C_A - P_B C_B)$ where $Bud = W' \cdot S_j + X_j \cdot D$ and λ is the Lagrange multiplier.

4.2.2 Proof of Lemma 2

First, using the definition of s , equation (2.17) can be expressed as:

$$1 = \frac{\theta_A \psi_{g,A} \alpha_A}{\theta_B \psi_{g,B} \alpha_B} \left[\frac{s K_A^{1-\alpha_A} L_A^{(1-\psi_{g,A})\alpha_A}}{(1-s) K_B^{1-\alpha_B} L_B^{(1-\psi_{g,B})\alpha_B}} \right]^\rho \frac{L_{g,A}^{\psi_{g,A} \alpha_A \rho - 1}}{(\xi_g - L_{g,A})^{\psi_{g,B} \alpha_B \rho - 1}}. \quad (4.2.5)$$

Consequently, the general labor demanded in each industry, which follows from this expression, only depends state variable s and the model parameters Φ .

Next, we derive the consumption of a basket of goods from the two industries, denoted by $CO(Z_t, s_t)$. Because goods markets clear we have $C_i = Y_i$.

$$CO(Z_T, s) = [\theta_A Y_A^\rho + \theta_B Y_B^\rho]^{1/\rho} \quad (4.2.6)$$

$$\begin{aligned} &= \left[\theta_A \left(Z_A K_A^{1-\alpha_A} L_A^{(1-\psi_A)\alpha_A} L_{G,A}(s)^{\psi_A \alpha_A} \right)^\rho \right. \\ &\quad \left. + \theta_B \left(Z_B K_B^{1-\alpha_B} L_B^{(1-\psi_B)\alpha_B} (\xi_G - L_{G,A}(s))^{\psi_B \alpha_B} \right)^\rho \right]^{1/\rho} \\ &= Z_T \cdot \left[\theta_A \left(s K_A^{1-\alpha_A} L_A^{(1-\psi_{g,A})\alpha_A} L(s)^{\psi_{g,A} \alpha_A} \right)^\rho \right. \end{aligned} \quad (4.2.7)$$

$$\begin{aligned} &\quad \left. + \theta_B \left((1-s) K_B^{1-\alpha_B} L_B^{(1-\psi_B)\alpha_B} (\xi_G - L_{G,A}(s))^{\psi_B \alpha_B} \right)^\rho \right]^{1/\rho} \\ &= Z_T \cdot co(s). \end{aligned} \quad (4.2.8)$$

Note that even though we have not derived explicitly the function $co(\Phi, s)$, equations (4.2.5) and (4.2.6) determine it.

We can find the expression for $L'_{G,A}(s)$ by multiplying both sides of expression (4.2.5) by w_B and taking the first derivative of both sides. This leads to the following expression for $L'_{G,A}(s)$:

$$L'_{G,A}(s) = \frac{\rho L_{G,A}(s) (\xi_G - L_{G,A}(s))}{(1-s)s (\xi_G (1 - \rho \alpha_A \psi_A) + \rho L_{G,A}(s) (\alpha_A \psi_A - \alpha_B \psi_B))}. \quad (4.2.9)$$

The first and second derivatives of $co(s)$ follow:

$$co'(s) = co(s) F(s) \quad (4.2.10)$$

$$co''(s) = co(s) [G(s) + F(s)^2], \quad (4.2.11)$$

where

$$F(s) = \frac{1}{s(1-s) \left(1 + \frac{\psi_A \alpha_A (\xi_G - L_{G,A}(s))}{\alpha_B \psi_B L_{G,A}(s)}\right)} - \frac{1}{1-s} \quad (4.2.12)$$

$$G(s) = \frac{1}{s(1-s)} \left(\frac{-1}{\left(1 + \frac{\psi_A \alpha_A (\xi_G - L_{G,A}(s))}{\alpha_B \psi_B L_{G,A}(s)}\right)} \left(\frac{1-2s}{s(1-s)} - \frac{\rho \xi_G}{(1-s)s(\xi_G(1-\rho\alpha_A\psi_A) + \rho L_{G,A}(s)(\alpha_A\psi_A - \alpha_B\psi_B))} \right) - \frac{s}{(1-s)} \right) \left(\frac{1}{\left(\frac{\alpha_B \psi_B L_{G,A}(s)}{\psi_A \alpha_A (\xi_G - L_{G,A}(s))} + 1\right)} \right). \quad (4.2.13)$$

Functions $F(s)$ and $G(s)$ can be rewritten as in Lemma 2.

4.2.3 Proof of Proposition 1

We can write the dynamics of a claim $Cl(Z_T, s) = Z_T cl(s)$ as follows:

$$\frac{dCl_t}{Cl_t} = \mu_{Cl} dt + \sigma_{Cl,A} dB_A + \sigma_{Cl,B} dB_B, \quad (4.2.14)$$

where

$$\mu_{Cl} = s\eta_A + (1-s)\eta_B + s(1-s)(\eta_A - \eta_B) \frac{cl'(s)}{cl(s)} + \frac{\Omega_s^2}{2} \frac{cl''(s)}{cl(s)} \quad (4.2.15)$$

$$\sigma_{Cl,A} = s\sigma_A \left(1 + (1-s) \frac{cl'(s)}{cl(s)}\right) \quad (4.2.16)$$

$$\sigma_{Cl,B} = (1-s)\sigma_B \left(1 - s \frac{cl'(s)}{cl(s)}\right). \quad (4.2.17)$$

Denote the diffusion of a claim as $\sigma_{Cl} = \{\sigma_{Cl,A}, \sigma_{Cl,B}\}$.

Using Itô's Lemma, we can derive the dynamics of the discounted value of a claim, i.e.

$M(t, Z_T, s)Cl(Z_T, s)$. We are mainly interested in the drift of this process, which

equals:

$$\mu_{Cl} - r_f - \gamma (\sigma_{Cl}\sigma_C + \varphi_{A,B} (\sigma_{Cl,A}\sigma_{C,B} + \sigma_{Cl,B}\sigma_{C,A})). \quad (4.2.18)$$

In a complete market, this drift equals zero. An alternative expression for the drift of the discounted process of the value of a claim comes from the definition of the value of a claim:

$$Cl_t = E_t \int_t^\infty D_{Cl,\tau} M_\tau d\tau, \quad (4.2.19)$$

where $D_{Cl,t}$ is the dividend of the claim (i.e. for equity this is the dividend paid out by the firm, and for human capital is the total amount of wages paid). Applying Itô to this integral leads to a drift of $\beta - \frac{D_{Cl}}{Z_T cl(s)}$. Next, we equate this to the first expression of the drift (4.2.18), which also equals zero. Substitution of all the terms lead to the ODE in the proposition.

4.2.4 Proof of Proposition 2

The goods market-clearing condition implies that the value of the basket of goods produced equals the value of production:

$$P_A Y_A + P_B Y_B = Z_T \cdot co(\Psi, s). \quad (4.2.20)$$

Using equation (4.2.2), the relationship between the value of production in each industry can be written as:

$$P_B Y_B \pi(\Psi, s) = P_A Y_A. \quad (4.2.21)$$

Solving for the value of production of industry B we find:

$$P_B Y_B (1 + \pi(\Psi, s)) = Z_T \cdot co(\Psi, s). \quad (4.2.22)$$

The dividend paid to owners of shares in industry B is $(1 - \alpha_B)P_B Y_B$. This comes from the FOC of the manager's decision of how much labor to hire given the wage rate. Therefore, the dividend of equity in industry B equals

$$D_B = Z_T (1 - \alpha_B) \frac{co(\Psi, s)}{1 + \pi(\Psi, s)}. \quad (4.2.23)$$

Conveniently, the value of the dividend normalized by Z_T , d_B , is only a function of s . Similar reasoning produces expressions for the dividends of all the other claims in the economy.

4.2.5 Numerical solution method

We solve the ODE for each claim using the boundary conditions and an initial guess for the derivative of the function when $s = 0$ and $s = 1$. The coefficient multiplying the derivative ($A_2(s)$) of the function changes sign in the interval $(0,1)$, which makes the solution unstable using standard numerical techniques. To solve the problem, we find the value of s in the interval for which $A_2(s) = 0$. Denote this point as s^* . We proceed to guess the derivative of $cl(s)$ when $s = 0$ (the value of $cl(0)$ is given by the boundary conditions) and find $cl(s_-^*)$ and $cl'(s_-^*)$. (s_- denotes the solution approaching from the left). We repeat starting from $s = 1$ and moving backwards on s and find $cl(s_+^*)$ and $cl'(s_+^*)$. We iterate our guesses until $cl(s_-^*) = cl(s_+^*)$ and $cl'(s_-^*) = cl'(s_+^*)$. Once we have solved for the ODE, we can calculate all the relevant variables in the model.

4.3 Third chapter

4.3.1 Representative agent and pricing kernel

Agent have utility solely over aggregate consumption of the final good at $t=1$. The consumption good is bought through wages, dividends or through payoffs of A-D securities traded at $t=1$. At $t=0$ the agent maximizes expected utility over employment and investment decisions: $\max_{\nu_i, \phi_i, e_i} E[U(c(\nu_i, \phi_i, e_i))]$. The weight of security 4, ϕ_4 , can be re-expressed as:

$$\phi_4 = 1 - \phi_1 - \phi_2 - \phi_3$$

Moreover, A-D securities are in zero net supply so that their aggregate weight is zero. Using simplified notation, the f.o.c.s. for the representative agent are given by:

$$\frac{d\mathbb{E}[U(C)]}{d\phi_1} = \mathbb{E}[U'(C)(r_s - r_4)] = 0 \quad \text{fors } \in \{1, 2, 3\}$$

Where $r_1 \dots r_4$ are the returns of the A-D securities. Any linear combination of $U'(C)$ correctly prices excess returns, but the risk free rate remains undefined. I normalize

the interest rate to zero, such that $\mathbb{E}[m] = 1$, so that $m = U'(C)/\mathbb{E}[U'(C)]$ uniquely prices cash-flows in the economy. After substituting for the CRRA functional form of U , the pricing kernel in terms of the final good consumption is given by:

$$m(s) = \frac{C(s)^{-\gamma}}{\mathbb{E}[C^{-\gamma}]}$$

4.3.2 Investments in human capital

The agent maximizes expected utility over education, employment and portfolio allocation decisions. The Lagrangian equation is given by:

$$\mathcal{L} = \mathbb{E}[mc_i] + \Lambda(w_0 + s_a + s_b - g(e_i) - \phi_i \mathbf{p}')$$

Specialists

f.o.c.s with respect to the investment in human capital e and Λ for specialists in industry s are given by:

$$\begin{aligned} \frac{d\mathcal{L}}{de^s} &= \mathbb{E}[mw_s] = \Lambda g'(e^s) \\ \frac{d\mathcal{L}}{d\Lambda} &= (w_0 + s_a + s_b - g(e^s) - \phi \mathbf{p}') = 0 \end{aligned}$$

so that $\Lambda = 1$. Moreover, $g'(x)$ is bijective on $x \geq 0$, so it is invertible. Therefore:

$$e^a = (g')^{-1}(\mathbb{E}[mw_a]) \quad \text{and} \quad e^b = (g')^{-1}(\mathbb{E}[mw_b])$$

Since, $g''(x) \geq 0 \forall x > 0$, the S.O.C.s ($-g''(e_a^*) < 0$, $-g''(e_b^*) < 0$) imply that the solution is in fact a maximum.

Generalists

The f.o.c. with respect to the investment in human capital for generalists is:

$$\frac{d\mathcal{L}}{de_a} = \mathbb{E}[m(\nu_i w_a(1 - f_a) + (1 - \nu_i)w_b(1 - f_b))] = g'(e^g)$$

Using the same logic as before, we get:

$$e^g(\nu_i) = (g')^{-1}(\mathbb{E}[m(\nu_i w_a(1 - f_a) + (1 - \nu_i)w_b(1 - f_b))])$$

The s.o.c. confirms that the solution represents a maximum.

4.3.3 Proof of Lemma 1

Proof. Assume that wages are strictly positive. I first consider the case for specialists in a and b , where the employment decisions are respectively set as $\nu_i(s) = 1$ and $\nu_i(s) = 0$, $\forall s \in s$. The acquisition of strictly positive amounts labor productivity always leads to strictly positive present value of labor income:

$$\mathbb{E}[me^a w_a] > 0 \text{ and } \mathbb{E}[me^b w_b] > 0$$

Since it is not possible to short sell labor productivity, and since $g(0) = 0$, $g'(x) > 0$ and $\lim_{x \rightarrow 0}(g'(x)) = 0$, the net present value of investing in HC is positive for some strictly positive amounts labor productivity. Each type of specialist will therefore acquire strictly positive amounts of HC, $e^a > 0$ and $e^b > 0$. Moreover, since $g'(x)$ is bijective over $x \geq 0$, e^a and e^b are unique for a given each type of specialist.

A similar logic shows that generalists will also acquire positive levels of labor productivity. A generalist is defined by its employment decisions ν_i . Positive wages imply that:

$$\mathbb{E}[m(\nu_i w_a(1 - f_a) + (1 - \nu_i)w_b(1 - f_b))] > 0$$

And because of the assumptions on cost of labor productivity, we have that $e^g > 0$. Identical preferences, endowments, investments in human capital and complete markets imply that all agents of the same type will have the same consumption in every state. The portfolio allocation decision of agent i is determined by the following system of equations:

$$c_t(s) = \phi \mathbf{I}_4(s) + l_t(s) \quad \forall s \in s$$

Where the first term is the payoff from investments in the financial market and l_t is labor income defined before. Complete markets imply that the solution the above system has a solution. Moreover, since the number of securities equals the number of states, the solution is unique.

□

4.3.4 Proof of Lemma 2

Proof. From lemma 1, we have that an employment decision fully characterizes a separating strategy. I will show that out of the eight possible employment decisions (2 industries \times 4 states), at most four will coexist in equilibrium. Specialists in a and b define two of the possible employment decisions. It remains to show that generalists will choose at most 2 different employment strategies. I first claim that all generalists will work in the same sector in at least two states. These will be the states with asymmetric shocks across industries. Without loss of generality let states 1 and 2 be such that:

$$\begin{aligned} w_a(1)(1 - f_a) - w_b(1)(1 - f_b) &> w_a(s)(1 - f_a) - w_b(s)(1 - f_b) \quad \forall s \neq 1 \in s \\ w_b(2)(1 - f_b) - w_a(2)(1 - f_a) &> w_b(s)(1 - f_b) - w_a(s)(1 - f_a) \quad \forall s \neq 2 \in s \end{aligned}$$

If a generalist chooses not to work in industry a in state 1, then he will also choose not to work in industry a in any other state, so he will be better off as a *specialist in b* to avoid incurring mobility costs. The same argument can be made about a generalist choosing not to work in industry b in state 2, being better off as a *specialist in a*.

Since employment in states 1 and 2 are identical for all generalists, employment decision on states 3 and 4 will determine the *generalist* types. These states are characterized by symmetric shocks across industries. The economy is identical in these two states, except for differences in aggregate productivity and potentially for the distribution of generalists over industries. This can be seen in the ratio of wages between industry a and b in states 3 and 4 that is given by:

$$\frac{w_a(3)}{w_b(3)} = \left(\frac{L_a(3)^{\alpha_a \rho - 1}}{L_b(3)^{\alpha_b \rho - 1}} \right) K_1 \quad \frac{w_a(4)}{w_b(4)} = \left(\frac{L_a(4)^{\alpha_a \rho - 1}}{L_b(4)^{\alpha_b \rho - 1}} \right) K_1$$

where K_1 is a constant of the parameters of the model. At $t=1$, labor supply in each industry can only be affected by the mobility of generalists since the supply of specialists was defined at $t=0$. I will consider two cases. First, if there are generalists in both industries in states 3 and 4. In this case, the ratio of labor supply across industries will be constant across states. To see this, if two industries have generalist labor in a given state s , generalists should be indifferent between these sectors $w_a e^g(1 - f_a) = w_b e^g(1 - f_b)$, so that:

$$\frac{w_a(s)}{w_b(s)} = \frac{1 - f_b}{1 - f_a} \quad \text{and} \quad \frac{L_a(3)}{L_b(3)} = \frac{L_a(4)}{L_b(4)}$$

Second, suppose that there are no generalists in one of the industries (wlog, industry b) in one of the states (wlog, state 3) but there are in the other (state 4). In this case we have that $w_a(3)e^g(1-f_a) > w_b(3)e^g(1-f_b)$ and $w_a(4)e^g(1-f_a) \leq w_b(4)e^g(1-f_b)$ so that:

$$\frac{w_a(3)}{w_b(3)} > \frac{1-f_b}{1-f_a} \quad \frac{w_a(4)}{w_b(4)} \leq \frac{1-f_b}{1-f_a}$$

which implies that

$$L_a(3) > L_b(3)K_2 \quad \text{and} \quad L_a(4) \leq L_b(4)K_2$$

where K_2 is another constant of the parameters of the model. Since wages are decreasing in labor supply, this is a contradiction. So if there are no generalists in one of the industries in one of the two symmetric states, then there will be no generalists in the other symmetric state. Employment in either state 3 or 4 fully describe the generalists strategy. There are therefore at most four different employment strategies, defined by the two types of generalists and the two types of specialists. \square

4.3.5 Proof of Lemma 3

Proof. First I will show that *specialists* will always exist in each sector. From the wages of each sector in equilibrium, we have:

$$\begin{aligned} \lim_{L_a \rightarrow 0} w_a^* &= \infty & \text{and} & \quad \lim_{L_a \rightarrow 0} w_b^* &= 0 \\ \lim_{L_b \rightarrow 0} w_b^* &= 0 & \text{and} & \quad \lim_{L_b \rightarrow 0} w_a^* &= \infty \end{aligned}$$

Everything else constant, when the labor supply of a given sector goes to zero, the relative price of the sector's product tends to infinity, so the purchasing power of wages in both sectors goes to zero. Without loss of generality let state 1 be such that $w_a(1) - w_b(1) > w_a(s) - w_b(s) \forall s \neq 1 \in s$ and state 2 be such that $w_b(2) - w_a(2) > w_b(s) - w_a(s) \forall s \neq 2 \in s$. If an agent optimally chooses to work in sector a in state 2, then he will also choose to work in the sector in all other states, so he will become a *specialist in a*. An agent that chooses to work in sector b in state 1 will become *specialist in b*.

The existence of *specialists* in each sector imply that in an equilibrium where the marginal agent is indifferent between becoming an *specialist* in sector a or b . Human capital investment's net present value should be equalized across specialists in a and

b. Let $h^s(e) = g'(e)e - g(e)$.

$$h^s(e^a) = h^s(e^b)$$

Since $h'^s(x) = g''(e)e > 0$ for $e > 0$ the equation above implies that $e^a = e^b$ and therefore that $\mathbb{E}[mw_a] = \mathbb{E}[mw_b]$.

□

4.3.6 Assumption 1

A generalist has the option to choose the highest paying industry, net of mobility frictions. The expected labor income is $\mathbb{E}[m \max(w_a(1 - f_a), w_b(1 - f_b))]$. An agent will be choose to become a generalist of type a when the option value of mobility minus the premium paid in terms of mobility frictions equals or exceeds the net present value of becoming a specialist. The condition then follows by applying the net present value of investment in HC introduced in the proof of lemma 3 is $h^g(e) = \mathbb{E}[m \max(w_a(1 - f_a), w_b(1 - f_b))]e - g(e)$ to the generalist and comparing it to the one for a specialist.

4.3.7 Assumption 2

Generalists exists in the economy as long as condition 3.23 is satisfied. An increase in the labor mobility friction decreases the aggregate number of generalists, but the decrease is more significant among generalists that work in the affected industry in states with symmetric shocks (states and 2). The expected ratio of generalists to specialists in a sector increases with the number of generalists and decreases with the number of specialists that work in the sector in each state. A simple inspection of the value of a generalist education of type \hat{g} , $\mathbb{E}[m(\hat{\nu}_i w_a(1 - f_a) + (1 - \hat{\nu}_i)w_b(1 - f_b))]$, illustrates that the greater the friction in an industry, the lower the benefit for all generalists, but greater for the ones that are planning to work in that industry in 3 states and less severe for the ones that are planning to work for in only one state. Moreover, wages in the industry are decreasing in total labor as seen in equation 3.14, therefore, everything else constant, a decrease in expected generalists in a sector stimulates more specialists to join the sector. An increase in the industry's mobility friction therefore decreases the expected ratio of generalists to specialists in the industry.

4.3.8 Proof of Lemma 3

Proof. Without loss of generality, I consider a firm in industry a in a given state s . Differentiating equation 3.3 with respect to TFP shocks P_a and simplifying, we get:

$$\frac{dY}{dP_a} = \rho(Y_a^\rho + Y_b^\rho) \left(Y_a^{\rho-1}(P_a^{\rho-1}L_a^{\alpha_a\rho} + P_a^\rho\alpha_aL_a^{\alpha_a\rho-1}\frac{dL_a}{dP_a})C_1 - Y_b^{\rho-1}(P_b^\rho\alpha_bL_b^{\alpha_b\rho-1}\frac{dL_b}{dP_a})C_2 \right)$$

where C_1 and C_2 are positive constants. At $t=1$, any change in labor supply is due to mobile workers. Substituting $\frac{dL_b}{dP_a} = -\frac{dL_a}{dP_a}\frac{1-f_b}{1-f_a}$ in the equation above, we have:

$$\frac{dY}{dP_a} = \rho\frac{dL_a}{dP_a}(Y_a^\rho + Y_b^\rho) \left(Y_a^{\rho-1}(P_a^{\rho-1}L_a^{\alpha_a\rho} + P_a^\rho\alpha_aL_a^{\alpha_a\rho-1})C_1 + Y_b^{\rho-1}(P_b^\rho\alpha_bL_b^{\alpha_b\rho-1}\frac{(1-f_b)}{(1-f_a)})C_2 \right)$$

When $\rho > 0$, $\text{sign}(\frac{dL_a}{dP_a}) = \text{sign}(\frac{dY}{dP_a})$, so that positive TFP shocks lead to decreases in labor supply in the sector. □

4.3.9 Result 3.4.1

Without loss of generality, I consider a firm in sector a . I define dispersion of output as $\text{dispersion}_{HL,LH} = \frac{\text{output}_{HL}}{\text{output}_{LH}} \geq 1$. I need to show:

$$\frac{d \text{dispersion}_{HL,LH}}{df_a} = (L_{HL}^a L_{LH}^a)^{\alpha_a} \left(\frac{1}{L_{HL}^a} \frac{dL_{HL}^a}{df_a} - \frac{1}{L_{LH}^a} \frac{dL_{LH}^a}{df_a} \right) C_1 \leq 0,$$

where $C_1 \geq 0$ is a constant of the parameters of the model.

From lemma 2, when $\rho > 0$, all generalists work in sector a in state HL and sector b in state LH. An increase in mobility frictions decreases the mass of mobile workers productivity, $\frac{dL^g}{df_a} \leq 0$, and increases the mass of either type of specialist's productivity, $\frac{dL_{LH}^a}{df_a} \geq 0$ and $\frac{dL_{HL}^b}{df_a} \geq 0$. Also, the supply of labor productivity at state HL is given by $L_{HL}^{sa} + L_{HL}^{sb} + L_{HL}^g(1-f_a) = C_2$, for some $C_2 > 0$, leading to $\frac{dL_{HL}^a}{df_a} = \frac{dL_{HL}^{sa}}{df_a} + \frac{dL_{HL}^g}{df_a} - L_{HL}^g = -\frac{dL_{HL}^{sb}}{df_a} \leq 0$ and the result follows.