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A WOODEN BARREL THEORY OF
INTERNATIONAL TRADE**

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ABSTRACT

Endowment Versus Finance: A Wooden Barrel Theory of International Trade*

This paper develops a theory of international trade in which financial development and factor endowment jointly determine comparative advantage. We apply the financial contract model of Holmstrom and Tirole to the Heckscher-Ohlin-Samuelson (HOS) framework. A key result is what we call the law of a wooden barrel: if the external finance constraint is binding, then augmenting capital stock would have no effect on output and returns. On the other hand, if the external finance constraint is not binding, the standard HOS predictions are resuscitated.

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A wooden barrel may be formed with staffs of uneven length; How much water it can hold depends on its shortest staff— A Chinese proverb.

1 Introduction

Finland is relatively more abundant in forestry resources than Denmark. The classical Heckscher-Ohlin-Vanek (HOV) model of international trade would predict that Finland is more likely than Denmark to produce and export in resource intensive industries, such as wood products and furniture. Yet, as pointed out by Carlin and Mayer (2003), during recent decades, “the relative growth of these industries accelerated markedly in Denmark relative to Finland.” The growth of four industries with the highest dependence on external finance in their study, instruments, electrical machinery, plastics and non-electrical machinery, increased during the 1980s and 1990s in Finland, but declined in Denmark. What may explain this apparent deviation from the HOV model? According to Carlin and Mayer, it is related to the fact that Finland is financially better developed. A formal regression analysis reveals that “measures of the financial structure of the two countries appear to be more relevant to the comparative performance of their industries than are the underlying resource endowments.”

The Carlin and Mayer paper is part of a growing empirical literature, pioneered by Rajan and Zingales (1998) and followed by Beck and Levine (2002) and Fisman and Love (2004), among others, that demonstrates that, across many countries, those industries that rely relatively more on external capital are likely to grow faster relative to other industries in countries with a more developed financial system. In other words, cross-industry patterns of production and growth appear to be related to the nature of financial system, especially in terms of availability of capital external to firms. Perhaps it is not surprising that the effect of financial development should also show up in the trade data. Using a data set on 56 countries and 36

industries, Beck (2002) reports evidence that countries with higher levels of financial development have higher export shares and trade balances in industries that use more external finance.

These studies do not imply that factor endowment is irrelevant in explaining cross-country patterns of production and trade. Indeed, one sees in recent years a resurgence in papers reporting empirical support for the factor endowment based theory of international trade modified by allowing for technology differences across countries, including the influential works by Trefler (1993, 1995), Harrigan (1997), Davis and Weinstein (2001, 2003), and Romalis (2004).

These two sets of empirical papers suggest that both financial development and factor endowment are important in explaining patterns of production and trade. To our knowledge, there is no unifying theoretical model to this date that allows both elements simultaneously. In this paper, we aim to construct such a theory. Specifically, we apply the financial contract model of Holmstrom and Tirole (1998) to the Heckscher-Ohlin-Samuelson (HOS) framework, deriving firms' equilibrium internal-external capital structure, and then providing a general equilibrium theory of trade in which financial development plays a prominent role.

To preview some of the key results, our theory predicts a wooden barrel law of trade. When a country's financial system is underdeveloped (relative to the level of its capital endowment) so that capital owners are reluctant or not able to provide all the external capital that the entrepreneurs desire at the equilibrium interest rate, then the external finance constraint becomes binding – the shortest staff on the wooden barrel. The Rybczynski theorem no longer holds. An improvement in the financial system, however, would increase the output of the sector more dependent on external finance, and decrease the output of the other sector. Such an economy may be viewed as institution-binding: a failure in the capital market makes some capital unemployed. Increasing the supply of external finance by improving the financial institution would have a real effect on the economy. On the other hand,

enlarging the size of capital endowment, e.g., through infusion of foreign cash grants, would have no effect on the economy.

When a country has a sufficiently developed financial system (relative to the size of its capital endowment), however, then all the standard results from the HOS model, such as the Rybczynski theorem, holds as in textbooks. In this case, capital endowment rather than external capital capacity is the binding constraint – the shortest staff on the wooden barrel. Such an economy may be labeled as endowment-binding: Enlarging the size of factor endowments would have a real effect on the economy, while improving the financial institution would have no effect. At different development stages, the economy could be mainly institution-binding or endowment-binding. Identifying which constraint is binding is a crucial question for public policy.

Like the standard trade theory, our theory predicts a conflict of interest between labor and capital. In addition, our theory predicts a conflict of interest between different owners of capital. When the external finance constraint is binding, a part of the capital endowment may be unemployed. On the one hand, financial development increases the relative output of the capital intensive industry, and therefore reduces its relative price. This decreases the return on capital and increases the wage rate. On the other hand, financial development relaxes the external finance constraint, and therefore reduces unemployment of capital. Both owners of unemployed capital and labor benefit from financial development, while owners of currently employed capital are worse off. In this sense, financial development depends on the relative strength of political forces among labor, unemployed (or potential) capital owners, and existing capital owners. Rajan and Zingales (2003) provided empirical support for a political economy theory of financial development. Our model, to the best of our knowledge, is the first one that provides a theoretical foundation for such a story.

Our model bears some resemblance to the three factors, two goods HOS model,

but they are not the same thing. In the HOS model, product prices and factor prices together clear the product and factor markets. The financial system introduced in our model imposes an additional constraint which could result in the underemployment of capital in equilibrium.

Our theory may have important policy implications for economic development. When a financial system is deficient, for example, because of poor corporate governance, massive transfers of capital from abroad through the World Bank or the IMF, or cash grants from rich country governments, are unlikely to induce more productive investment. Policy priority should be on improving the financial institution and corporate governance rather than enlarging capital endowment. On the other hand, when the financial system is sufficiently developed, relaxing the constraint on the capital endowment would be useful, as predicted by the HOS model.

For concreteness, consider Chile and Mexico, which had comparable per capita incomes in 1980. Both countries over the next two decades saw large scale capital inflows. Chile, however, appears to end up with a higher per capita income and better economic outcomes generally today, having avoided two financial crises along the way. The reasons behind the different performances are complex and myriad. We argue that the difference in the respective financial systems is one important factor. Chile has both a more developed stock market – measured by the ratio of stock market capitalization to GDP, and a more developed banking sector – measured by the ratio of domestic credit to private sector to GDP, than Mexico.¹ Using the logic in our model, relaxing the constraint of capital stock such as through an inflow of international capital is more likely to generate productive investment in a country like Chile than in a country like Mexico.

This paper is related to the recent literature on international trade and organization of the firm. See McLaren (2000), Grossman and Helpman (2002, 2005), Levchenko (2003), and Costinot (2005) for applications of a transaction cost approach, and

¹The inference is based on Table 2, Rajan and Zingales (1998).

Antras (2003), Antras and Helpman (2004), and Nunn (2005) of a property rights approach. The existing literature applies the Grossman-Hart-Moore view of incomplete contracts in the study of organization of the firm, and focuses on the determinants of trade pattern by contract environment.² In contrast, we apply the insights of Holmstrom and Tirole on moral hazard to study firms' dependence on external finance. As a result, our paper provides a way to understand how financial development and factor endowment jointly determine the trade pattern.

Our paper is also related to a small theoretical literature that models the role of financial system in determining production and trade patterns. Kletzer and Bardhan (1987), Baldwin (1989), Beck (2002), and Matsuyama (2005) show that countries with a relatively well-developed financial system have a comparative advantage in industries that rely more on financial system, while Do and Levchenko (2004) show that financial systems in countries with larger financially intensive sectors are more developed. These papers as well as our model provide a theoretical foundation for the Rajan-Zingales (1998) effect that has been robustly documented in a growing body of empirical studies. Our theory differs from these papers in three ways. First, none of the existing papers discusses the role of the financial system in an otherwise classic HOS-style trade model, whereas our model retains as much of the standard features as possible. Consequently, our model is the first in the literature that nests the HOS model as a special case. Second, unlike the existing papers, our paper considers the role of cross-country differences in financial system and in factor endowment simultaneously. Third, our model discusses the effect of the change in product prices on factor prices, which are building blocks for a future political economy analysis of financial development.

The rest of paper is organized as follows. Section 2 describes the setup of the model and discusses the microfoundation for firms' dependence on external finance. Section 3 analyzes the model with a set of key results including the wooden barrel

²Marin and Verdier (2002, 2003) combine a principal-agent problem with a monopolistic competition model to study endogenous power dynamics inside the firm.

theory. Section 4 summarizes the result. Finally, an Appendix contains formal proofs of various propositions made in the text.

2 The Model

In an otherwise standard two goods, two factors, and two countries HOS framework, we introduce firms' demand for liquidity. There is a large literature of multiperiod agency models in corporate finance in which long-term contract problems are solved to implement firms' second-best liquidity demand (see Diamond 1991, Berglof and von Thadden 1994, Hart and Moore 1998, and Holmstrom and Tirole 1998). We modify the setup in Holmstrom and Tirole (1998) from a one good, one factor model to a two goods, two factors model.

2.1 Basic Setup

Focusing now on a single country, we suppose that the production process takes two periods and the firm has a stochastic technology. The first period production function of industry i is $y_i^1 = G_i(L_i, K_i^1)$, $i = 1, 2$, where y_i^1 is the output produced using labor L_i and date 1 investment K_i^1 , if the project succeeds. The production functions are assumed to be homogeneous of degree one in (L_i, K_i^1) . The initial labor-capital ratio, L_i/K_i^1 , is assumed to be fixed and denoted as a_i^1 . Thus, $y_i^1 = G_i(L_i, K_i^1) = G_i(a_i^1, 1)K_i^1$. Let p_i be the price of good i and w be the wage rate. If the project succeeds, the capital revenue is

$$p_i y_i^1 - w L_i = [p_i G_i(a_i^1, 1) - w a_i^1] K_i^1 = R_i K_i^1 \quad (1)$$

where $R_i = p_i G_i(a_i^1, 1) - w a_i^1$ represents the return to a unit of initial investment.

At the beginning of date 1, a financial contract is signed between the firm and investors and an initial investment K_i^1 is injected to the firm. Correspondingly, $a_i^1 K_i^1$ of labor are hired. The gain to capital is $R_i K_i^1$ if the project succeeds and zero if it

fails. The labor is paid at w in the second period. At the beginning of date 2, an additional and uncertain amount $\rho_i K_i^1 > 0$ of financing is needed to cover operating expenditures and other needs. The liquidity shock ρ_i is distributed according to the cumulative distribution function $F_i(\rho)$ with a density function $f_i(\rho)$. No labor is needed for liquidity shock. If $\rho_i K_i^1$ is paid, the project continues and the output of $G_i(a_i^1, 1)K_i^1$ will be produced at the end of date 2. If $\rho_i K_i^1$ is not paid, the project terminates and produces nothing. The failed projects are liquidated and factors of these projects are reallocated at the beginning of the second period.³ Consumption takes place at the end of the second period.

Investment is subject to moral hazard problem in the firm. The entrepreneur (firm) privately chooses an effort levels of either “work” or “shirk.” If the entrepreneur works, the probability of success is λ_i^H (high); if the entrepreneur shirks, the probability of success is λ_i^L (low), where $\lambda_i^H - \lambda_i^L = \Delta\lambda_i > 0$. If the entrepreneur shirks, the benefit to him is $B_i K_i^1 > 0$, which is proportional to the level of the investment K_i^1 . The entrepreneur makes a decision on effort levels after the continuation decision is made in the second period.

At date 2, the first period investment K_i^1 is sunk. The net present value of the investment is maximized by continuing the project whenever the expected return from continuation, $\lambda_i^H R_i$, exceeds the cost ρ_i , that is, $\lambda_i^H R_i - \rho_i \geq 0$. Let

$$\rho_i^1 = \lambda_i^H R_i \tag{2}$$

and refer it as the *first-best cutoff* and denote r as the interest rate. Following Holmstrom and Tirole (1998), we assume that the project’s net present value is positive if the entrepreneur works but not if he shirks. That is,

³We combine three periods in the setup of Holmstrom and Tirole (1998) into two periods for simplicity.

$$\begin{aligned}
& \int \max[\lambda_i^H R_i - \rho_i, 0] f_i(\rho) - (1+r) \\
> 0 > \int \max[\lambda_i^L R_i + B - \rho_i, 0] f_i(\rho) - (1+r)
\end{aligned} \tag{3}$$

Therefore, we only need to consider the contract implementing the effort of “work.”

2.2 Dependence on External Finance

The empirical literature reports that the level of dependence on external finance across different industries varies dramatically. Rajan and Zingales (1998) define external finance as the amount of desired investment that cannot be financed through internal cash flows generated by the same business. They measure a firm’s dependence on external finance by capital expenditures minus cash flow from operations divided by capital expenditures.⁴

Let the initial investment in the firm, $K_i^1 = K_i^N + K_i^{X1}$, where K_i^N is firm’s endowment of cash and K_i^{X1} is the funds that the firm raises from outside investors at date 1. The firm has no endowment of cash at date 2 so the amount of internal capital is measured by K_i^N . The amount of external capital, K_i^X , is measured by K_i^{X1} plus the funds for additional liquidity shock $\rho_i K_i^1$ at date 2.

Let $C_i = \{K_i^1, \mu_i(\rho_i), R_i^B(\rho_i)\}$ be the contract where $\mu_i(\rho_i)$ is a state-contingent continuation policy (1 = *continue*, 0 = *stop*), and $R_i^B(\rho_i)$ is the amount the entrepreneur is paid per unit of initial investment if the project succeeds. Investors are left with $R_i - R_i^B(\rho_i)$. If the project fails or is terminated, both sides are assumed to receive zero. Following Holmstrom and Tirole (1998), an optimal contract can be found by choosing $\{K_i^1, \mu_i(\rho_i), R_i^B(\rho_i)\}$ to solve the following moral hazard problem.

⁴Rajan and Zingales report that Drugs and Pharmaceuticals is the industry that uses the most external finance, having the external dependence ratio of 1.49. The external dependence ratio in Electric Machinery is 0.77. Apparel, with the external dependence ratio of 0.03, has little external funding needs.

$$\max U_i = K_i^1 \int \lambda_i^H R_i^B(\rho_i) \mu_i(\rho_i) f_i(\rho_i) d\rho_i - (1+r) K_i^N \quad (4)$$

subject to

$$K_i^1 \int \{\lambda_i^H [R_i - R_i^B(\rho_i)] - \rho_i\} \mu_i(\rho_i) f_i(\rho_i) d\rho_i \geq (1+r) K_i^{X1} \quad (5)$$

and

$$R_i^B(\rho_i) \lambda_i^H \geq R_i^B(\rho_i) \lambda_i^L + B_i \quad (6)$$

The expression (4) is the firm's net return. (5) is the participating constraint of investors, while (6) is the entrepreneur's incentive compatibility constraint. Solving the above problem, the optimal continuation policy $\mu_i(\hat{\rho}_i)$ is a cutoff rule that $\mu_i(\hat{\rho}_i) = 1$ if $\rho_i \leq \hat{\rho}_i$ and $\mu_i(\hat{\rho}_i) = 0$ if $\rho_i > \hat{\rho}_i$. Let $\rho_i^0 = \lambda_i^H [R_i - R_i^B(\rho_i)]$ and rewrite the expression (5) as $K_i^N \geq K_i^1/n_i(\hat{\rho}_i)$, where

$$n_i(\hat{\rho}_i) = \frac{1+r}{(1+r) - \int_0^{\hat{\rho}_i} (\rho_i^0 - \rho_i) f_i(\rho_i) d\rho_i} \quad (7)$$

represents the *equity multiplier*, which is quasi-concave in $\hat{\rho}_i$ and maximized at $\hat{\rho}_i = \rho_i^0$. If $\frac{1}{n_i(\hat{\rho}_i)} \leq 0$, the investors' expected marginal return on their investment at date 1 would be larger than the opportunity cost. The firm would be free to invest arbitrarily large amounts at date 1, making the moral hazard problem unconstrained.

Following Holmstrom and Tirole (1998), we assume

$$\int_0^{\hat{\rho}_i} (\rho_i^0 - \rho_i) f_i(\rho_i) d\rho_i < 1+r \quad (8)$$

to eliminate this case. The condition (8) is necessary and sufficient for the participating constraint (5) to be binding, which gives the firm's initial investment

$$K_i^1 = K_i^1(\hat{\rho}_i) = n_i(\hat{\rho}_i) K_i^N \quad (9)$$

Substituting binding constraint (5) into (4), the firm's objective function can be written as $U_i(\hat{\rho}_i) = m_i(\hat{\rho}_i)K_i^1$, where

$$m_i(\hat{\rho}_i) = \int_0^{\hat{\rho}_i} (\rho_i^1 - \rho_i) f_i(\rho_i) d\rho_i - (1+r) \quad (10)$$

is the *marginal net social return* on investment. $m_i(\hat{\rho}_i)$ is quasi-concave and maximized at $\hat{\rho}_i = \rho_i^1$. Condition (3) ensures that $m_i(\rho_i^1) > 0$. Note that $\hat{\rho}_i = \rho_i^1$ is feasible for the moral hazard problem. Thus, at the optimal contract $\hat{\rho}_i = \rho_i^*$, we must have $U_i(\rho_i^*) = m_i(\rho_i^*)K_i^1(\rho_i^*) \geq m_i(\rho_i^1)K_i(\rho_i^1) > 0$. Given $m_i(\rho_i^*) > 0$, the firm will choose $R_i^B(\rho_i)$ as small as possible to maximize $K_i^1(\rho_i^*)$. Thus, the incentive compatibility constraint (6) must be binding, which gives

$$R_i^B = \frac{B_i}{\Delta\lambda_i} \text{ and } \rho_i^0 = \lambda_i^H [R_i - \frac{B_i}{\Delta\lambda_i}] \quad (11)$$

Using (7), (9), and (10), the firm's net return becomes

$$U_i(\hat{\rho}_i) = m_i(\hat{\rho}_i)n_i(\hat{\rho}_i)K_i^N = \frac{(1+r) [\rho_i^1 - h(\hat{\rho}_i)]}{h(\hat{\rho}_i) - \rho_i^0} K_i^N \quad (12)$$

where

$$h(\hat{\rho}_i) = \frac{(1+r) + \int_0^{\hat{\rho}_i} \rho_i f_i(\rho_i) d\rho_i}{F_i(\hat{\rho}_i)} \quad (13)$$

Because $m_i(\hat{\rho}_i)$ and $n_i(\hat{\rho}_i)$ are both concave, we must have $\rho_i^0 < \rho_i^* < \rho_i^1$. $h(\hat{\rho}_i)$ represents the virtual cost of the unit investment, which is the opportunity cost of initial investment at date 1, $(1+r)$, plus the expected financing for the liquidity shock at date 2, $\int_0^{\hat{\rho}_i} \rho_i f_i(\rho_i) d\rho_i$, under the condition that the project continues. Maximizing $U_i(\hat{\rho}_i)$ is equivalent to minimizing $h(\hat{\rho}_i)$. The first order condition then gives

$$\int_0^{\rho_i^*} F_i(\rho_i) d\rho_i = 1+r \quad (14)$$

which implies that $h(\rho_i^*) = \rho_i^*$. The firm's net return with optimal contract can now

be written as $U_i(\rho_i^*) = R_i^N K_i^N$, where

$$R_i^N = \frac{(1+r) [\rho_i^1 - \rho_i^*]}{\rho_i^* - \rho_i^0} \quad (15)$$

represents the firm's *marginal net return on internal capital*.

Equation (14) shows that optimal cutoff of the liquidity shock, ρ_i^* , increases as r increases. As the interest rate r becomes higher, the opportunity cost of the investment is higher. To attract investors into the project, the firm needs to promise higher probability that the project continues under the liquidity shock, which implies higher optimal cutoff rate ρ_i^* . We summarize this result as the following Lemma, which will become useful for analysis in later sections.

Lemma 1 *The optimal cutoff of the liquidity shock, ρ_i^* , increases as the interest rate r increases.*

We now are ready to derive the firm's dependence on external finance. Let there be a continuum of firms in industry i with unit mass. Each firm is endowed with K_i^N units of internal capital. Liquidity shocks ρ_i for each firm are independent. Thus, $F_i(\rho_i)$ denotes both the ex ante probability of a firm facing a liquidity shock below ρ_i and the realized fraction of firms with liquidity shock below ρ_i . The total capital usage is the sum of initial investment $K_i^1(\rho_i^*)$ and expected liquidity shocks being paid. Denoting the total capital usage as K_i , we have

$$\begin{aligned} K_i &= \left[(1+r) + \int_0^{\rho_i^*} \rho_i f_i(\rho_i) d\rho_i \right] K_i^1(\rho_i^*) \\ &= \left[(1+r) + \int_0^{\rho_i^*} \rho_i f_i(\rho_i) d\rho_i \right] n_i(\rho_i^*) K_i^N \\ &= s_i(\rho_i^*) K_i^N \end{aligned} \quad (16)$$

where

$$s_i(\rho_i^*) = \frac{(1+r) \left(1 + \int_0^{\rho_i^*} \rho_i f_i(\rho_i) d\rho_i \right)}{(1+r) - \int_0^{\rho_i^*} (\rho_i^0 - \rho_i) f_i(\rho_i) d\rho_i} \quad (17)$$

The labor-capital ratio in the entire production process becomes

$$\begin{aligned} a_i(\rho_i^*) &= \frac{L_i}{K_i} = \frac{1}{1+r + \int_0^{\rho_i^*} \rho_i f_i(\rho_i) d\rho_i} \left(\frac{L_i}{K_i^1(\rho_i^*)} \right) \\ &= \frac{a_i^1}{1+r + \int_0^{\rho_i^*} \rho_i f_i(\rho_i) d\rho_i} \end{aligned} \quad (18)$$

The external dependence index, which is measured by external capital to total capital ratio, is equal to

$$\phi_i = \frac{K_i - K_i^N}{K_i} = \frac{s_i(\rho_i^*) - 1}{s_i(\rho_i^*)} \quad (19)$$

The firm's expected output (realized industry output) is

$$y_i = F_i(\rho_i^*) \lambda_i^H G_i(a_i^1, 1) K_i^1(\rho_i^*) = F_i(\rho_i^*) \lambda_i^H G_i(a_i^1, 1) n_i(\rho_i^*) K_i^N \quad (20)$$

We will assume that $f_i(\rho_i)$ is a uniform distribution in $[0, \bar{\rho}_i]$. The expression (14) gives the solution of ρ_i^* as

$$\rho_i^* = [2(1+r)\bar{\rho}_i]^{\frac{1}{2}} \quad (21)$$

Using equations (18) and (21), the labor intensity (labor-capital ratio) in the entire production process is

$$a_i(\rho_i^*) = a_i(r) = \frac{a_i^1}{2(1+r)} \quad (22)$$

The initial labor-capital ratio, a_i^1 , is assumed to be fixed. As Lemma 1 shows, more capital will be injected as the interest rate r increases. Thus, the labor intensity $a_i(\rho_i^*)$ decreases as interest rate increases. However, if we had allowed a_i^1 to be a function of (w, r) , $a_i^1(w, r)$ would have increased as r increased, since the firm would have liked to use more labor if the capital had become more expensive, and the overall labor intensity $a_i(\rho_i^*)$ may or may not have decreased as the interest rate

had increased.

3 The Analysis: The Law of Wooden Barrel

We will first derive equilibrium conditions in both factor and product markets and then follow the standard procedure in the theory of international trade to analyze the model. An external finance constraint—the sum of external capital usages across all industries does not exceed the external capital capacity in the country—is added to labor and capital constraints. Note that in determining equilibrium outputs (y_1^*, y_2^*) , these three constraints cannot be all binding. This is where *the law of wooden barrel* comes from: only two binding constraints out of three—the shortest staves of the wooden barrel—determine the equilibrium outputs.

3.1 Equilibrium Conditions

The first set of equilibrium conditions for the two-by-two economy is that firm's marginal net return on internal capital should equal its opportunity cost. Let there be K_i^N of entrepreneurs in sector i and each of them is endowed with one unit of capital. We assume that capital owners need to pay a unit cost of f at the beginning of the first period to become the entrepreneur. f may represent the cost of training or the fee of certification. Using equation (15), the conditions are stated as

$$\begin{aligned} R_1^N(p_1, w, r) &= \frac{(1+r)[\rho_1^1 - \rho_1^*]}{\rho_1^* - \rho_1^0} = (1+r)f \\ R_2^N(p_2, w, r) &= \frac{(1+r)[\rho_2^1 - \rho_2^*]}{\rho_2^* - \rho_2^0} = (1+r)f \end{aligned} \quad (23)$$

which are called *internal capital net return curves*.

The second set of equilibrium conditions is factor endowment constraints. Using

equations (16) and (20), we have

$$K_i = b_i(r)y_i \quad (24)$$

where

$$b_i(r) = \frac{s_i(\rho_i^*)}{F_i(\rho_i^*)\lambda_i^H G_i(a_i^1, 1)n_i(\rho_i^*)} = \frac{[2(1+r)]^{\frac{1}{2}}}{G_i(a_i^1, 1)} \left(\frac{\rho_i^{\frac{1}{2}}}{\lambda_i^H} \right) \quad (25)$$

is the capital usage per unit of good i in the entire production process. Note that $b_i(r)$ is only a function of r in our model. The capital usage per unit of good i at date 1, $\frac{1}{G_i(a_i^1, 1)}$, is adjusted by the probability of success and the liquidity shock at date 2, which is represented by the multiplier $\beta_i = \frac{\rho_i^{\frac{1}{2}}}{\lambda_i^H}$. Let L and K be the country's labor and capital endowments, respectively. The factor endowment constraints are written as

$$a_1(r)b_1(r)y_1 + a_2(r)b_2(r)y_2 \leq L \quad (26)$$

$$b_1(r)y_1 + b_2(r)y_2 \leq K \quad (27)$$

The sector 1 is labor intensive if $a_1(r) > a_2(r)$, which is equivalent to $a_1^1 > a_2^1$ in our model. We denote $\tilde{a}_i = \frac{a_i^1}{\beta_i} = \frac{\lambda_i^H a_i^1}{\rho_i^{\frac{1}{2}}}$ and call it *effective labor intensity*, which will be used in later sections.

The third set of equilibrium conditions is the external finance constraint, which requires that the sum of external capital usages across all industries cannot exceed the external capital capacity in the country. Let the country's external capital capacity be K^X . The external finance constraint is stated as

$$\phi_1(p_1, w, r)b_1(r)y_1 + \phi_2(p_1, w, r)b_2(r)y_2 \leq K^X \quad (28)$$

Higher external capital capacity to GDP ratio represents a more developed financial system. In empirical literature, stock market capitalization, domestic credit to private sector, and stock market capitalization plus domestic credit have all been

used to measure K^X . Countries at similar levels of economic development differ dramatically in their levels of financial development. La Porta et al. (1997, 1998) show that the country's financial development is determined by the legal protection of investors. Common-law countries generally have both the strongest investor protection and the most developed capital market, whereas the French-civil-law countries possess the weakest investor protection and the least developed capital market. Rajan and Zingales (2003) argue that the strength of political forces in favor of financial development is a major variable factor, and incumbents in sectors of finance and industry may oppose financial development since it breeds competition. How the country's K^X is determined is a matter beyond the scope of this paper. We will treat K^X as an exogenous variable and analyze the effect of its increase on equilibrium outputs and prices.

The fourth equilibrium condition requires that the product market clears. We assume that the representative consumer's preference is homothetic. Thus, the ratio of the quantities consumed, $D(\frac{p_1}{p_2})$, depends only upon the relative commodity price ratio. Let relative supply equal relative demand. The condition that the product market clears is stated as

$$\frac{y_1}{y_2} = D\left(\frac{p_1}{p_2}\right) \quad (29)$$

3.2 Determination of Factor Prices

Following the standard procedure in the theory of international trade (Feenstra 2004), we first solve for equilibrium factor prices (w, r) under given product prices (p_1, p_2) . Substituting equations (2), (11) and (21) into (23), *internal capital net return curves* can be written as

$$\lambda_1^H a_1^1 w + [2(1+r)\bar{\rho}_1]^{\frac{1}{2}} = \lambda_1^H \left[p_1 G_1(a_1^1, 1) - \left(\frac{f}{1+f}\right) R_1^B \right] \quad (30)$$

$$\lambda_2^H a_2^1 w + [2(1+r)\bar{\rho}_2]^{\frac{1}{2}} = \lambda_2^H \left[p_2 G_2(a_2^1, 1) - \left(\frac{f}{1+f}\right) R_2^B \right] \quad (31)$$

It is easy to show that *internal capital net return curves* are convex towards origin and downward sloping in (w, r) space. The slopes of *internal capital net return curves* are

$$\frac{dr}{dw} = -\frac{[2(1+r)]^{\frac{1}{2}} \lambda_i^H a_i^1}{\bar{p}_i^{\frac{1}{2}}} = -[2(1+r)]^{\frac{1}{2}} \tilde{a}_i \text{ for } i = 1, 2 \quad (32)$$

where $\tilde{a}_i = (\lambda_i^H a_i^1) / \bar{p}_i^{\frac{1}{2}}$, is the *effective labor intensity* defined in Section 3.1. Assume that $\tilde{a}_1 > \tilde{a}_2$, so sector 1 is effectively labor intensive than sector 2. As indicated in Figure 1, the *internal capital net return curve* of sector 1 is steeper than that of sector 2. The result similar to Stolper-Samuelson theorem holds here. The initial factor price equilibrium is given by point A . An increase in the price of good 1 will shift out the *internal capital net return curve* of sector 1, as illustrated, and move the equilibrium to point B . It is clear that the wage has gone up, from w_0 to w_1 , and the interest rate has declined, from r_0 to r_1 .

Proposition 2 *An increase in the price of a good will increase the return to the factor used intensively (effectively) in that good, and reduce the return to the other factor.*

3.3 Comparative Statics

The labor constraint (26), the capital constraint (27), and the external finance constraint (28) will jointly determine the equilibrium outputs (y_1^*, y_2^*) . They are denoted by the LL , KK , and XX lines in Figure 2, respectively. Industry 1 is labor intensive so that the LL line is steeper than the KK line. If the labor-intensive industry is less dependent on external finance than the capital-intensive industry, i.e., $\phi_1 < \phi_2$, the XX line will be flatter than the KK line. Otherwise the XX line will be steeper than the KK line. The intersection between the LL and KK lines is denoted as point E in Figure 2. If the XX line crosses the point E , the external finance constraint is *exactly binding* in which the country's external capital capacity

exactly meets the demand for external finance from all industries when factors are fully employed. If the XX line is outside the point E , the external finance constraint is *non-binding*. The country's financial system in this case is defined as *developed relative to the level of factor endowments*: the country's external capital capacity exceeds the demand for external finance from all industries when factors are fully employed. If the XX line is inside the point E , the external finance constraint is *binding* and the country's financial system is *underdeveloped relative to the level of factor endowments*: the country's external capital capacity cannot meet the demand for external finance at the equilibrium interest rate. The case of an *exactly binding* is a knife-edge. For comparative statics, we consider cases when the external finance constraint is *binding* or *non-binding*.

The level of external finance is described by a technology coefficient, ϕ_i , and a capacity parameter, K^X . We will assume for simplicity that financial development increases external finance capacity K^X , but has no effect on technology ϕ_i .

We first study the case of the *non-binding* external finance constraint, which we denote as Case 1 and depict in Figure 2. The equilibrium output E is determined by the intersection of the LL and the KK lines, while the XX line is outside point E . Consider first an improvement in the financial system such that the XX line shifts out to the $X'X'$, while the LL and KK lines do not change. It can be immediately seen that such an improvement has no effect on the equilibrium output E . The financial system is able to provide up to K^X of external capital. The equilibrium amount of external capital, however, is determined by the demand for external capital at interest rate r , which is equal to $\phi_1 b_1 y_1^* + \phi_2 b_2 y_2^*$ and less than the external capital capacity. The country's financial system is not a constraint. Factor endowments determine the economic outcome. If the capital endowment is augmented, say, by an infusion of an international cash grant, the financial system is capable of turning the cash grant into effective investment and raise the country's output.

The comparative statics in this case is actually reduced to the classic Rybczynski theorem. Rewrite the binding factor constraints (26) and (27) as

$$\begin{aligned} a_{1L}y_1 + a_{2L}y_2 &= L \\ a_{1K}y_1 + a_{2K}y_2 &= K \end{aligned} \tag{33}$$

where $a_{iL} = a_i(r)b_i(p_i, w, r)$ and $a_{iK} = b_i(p_i, w, r)$. Totally differentiating these equations and using the ‘‘Jones’ algebra,’’ we obtain

$$\begin{aligned} \lambda_{1L}\hat{y}_1 + \lambda_{2L}\hat{y}_2 &= \hat{L} - [\lambda_{1L}\hat{a}_{1L} + \lambda_{2L}\hat{a}_{2L}] \\ \lambda_{1K}\hat{y}_1 + \lambda_{2K}\hat{y}_2 &= \hat{K} - [\lambda_{1K}\hat{a}_{1K} + \lambda_{2K}\hat{a}_{2K}] \end{aligned} \tag{34}$$

We define $dy_1/y_1 = \hat{y}_1$, and likewise for all other variables. In addition, we define the *fraction of labor used in industry i* , $\lambda_{iL} = y_i a_{iL}/L$, where $\lambda_{1L} + \lambda_{2L} = 1$. We define λ_{iK} in analogous manner. \hat{L} and \hat{K} represent the *direct effect* of changes in endowments at given product prices, while the second terms in the right hand side of equations (34) represent the *feedback effect* of induced product price changes on the factor usage per unit of production. As shown in the Appendix, we obtain the classical *magnification effect* that $\hat{y}_1^T > \hat{L} > \hat{K} > \hat{y}_2^T$, when we consider the *direct effect*. As depicted in Figure 2, the initial equilibrium output is given by point E . An increase in the labor endowment shifts LL out to $L'L'$ and moves the equilibrium to point E' . It is clear that the output of good 1 goes up, whereas the output of good 2 declines.

As y_1 is increased while y_2 is reduced, equation (29) indicates that p_1 decreases relative to p_2 in the equilibrium. By Proposition 1, r increases while w decreases. As discussed at the end of the last section, more capital would be injected to the project and $a_i(r)$ decreases as r increases. Note that the *feedback effect* is somewhat different

from the classical HOS model. Labor usage per unit of production decreases, while capital usage per unit of production increases. Thus, the *feedback effect* shifts the $L'L'$ line out further to $L''L''$ and shifts the KK line in to $K''K''$, which moves the equilibrium from E' further down to E'' . The *feedback effect* strengthens rather than dampens the *magnification effect*, increasing y_1 and reducing y_2 further. As we discussed at the end of the last section, if a_i^1 were allowed to change, we could have the classical *feedback effect* which would dampen the *magnification effect*. However, as long as the stability condition holds, the *magnification effect* is more than compensated for the dampening effect of price changes, so that the Rybczynski theorem always holds. An increase in K can be similarly analyzed. We now summarize our results by the following proposition.

Proposition 3 *If the financial system is sufficiently developed, the equilibrium output is determined by the factor endowment constraints. Further financial development has no effect on the equilibrium outcome. An increase in a factor endowment will increase the output of the industry that uses it intensively, and decrease the output of the other industry.*

We now turn to cases of *binding* external finance constraint. We assume that the capital-intensive industry is more dependent on external finance, i.e., $\phi_2 > \phi_1$. This is denoted as Case 2 and depicted in Figure 3. The XX line is inside point E and flatter than the KK line. It must be the case that the LL and XX lines are binding, while the KK line is not binding. Equilibrium outputs (y_1^*, y_2^*) are determined by the labor constraint (26) and the external finance constraint (28), as indicated by point A . The actual capital usage is $K^* = b_1 y_1^* + b_2 y_2^* < K$. The unemployment of capital is denoted as K^U , which is equal to $K - K^*$, and measured by AE .

K is the total amount of capital that could be used in production if the financial system were sufficiently developed. If the financial system is underdeveloped, however, some of capital may be unemployed: even though firms may wish to have more

external capital, capital owners (households with savings) are reluctant to invest all their capital in the firms due to moral-hazard induced failure of capital market.

To use more capital, firms would like to produce more capital-intensive goods relative to labor-intensive goods, which would require more external capital. However, the binding external finance constraint prevents any capital usage beyond K^* . An increase in capital endowment would only raise K^U and have no effect on the equilibrium outcome.

Rewrite the binding labor constraint (26) and financial development constraint (28) as

$$\begin{aligned} a_{1L}y_1 + a_{2L}y_2 &= L \\ a_{1X}y_1 + a_{2X}y_2 &= K^X \end{aligned} \quad (35)$$

where $a_{iX} = \phi_i(p_i, w, r)b_i(p_i, w, r)$ is the external capital usage per unit of production. Totally differentiating these conditions and using ‘‘Jones’ algebra,’’ we obtain

$$\begin{aligned} \lambda_{1L}\hat{y}_1 + \lambda_{2L}\hat{y}_2 &= \hat{L} - [\lambda_{1L}\hat{a}_{1L} + \lambda_{2L}\hat{a}_{2L}] \\ \lambda_{1X}\hat{y}_1 + \lambda_{2X}\hat{y}_2 &= \widehat{K^X} - [\lambda_{1X}\hat{a}_{1X} + \lambda_{2X}\hat{a}_{2X}] \end{aligned} \quad (36)$$

Define the *fraction of external capital used in industry i* , $\lambda_{iX} = y_i a_{iX} / K^X$, where $\lambda_{1X} + \lambda_{2X} = 1$. Similar to Case 1, we obtain the *magnification effect* that $\hat{y}_2 > \widehat{K^X} > \hat{L} > \hat{y}_1$ when the *direct effect* is considered. The *direct effect* of financial development on equilibrium outputs is also depicted in Figure 3. A financial development shifts the XX line out to the $X'X'$ line, as illustrated, moving the equilibrium from point A to point A' . It is clear that the output of industry 2, the industry more dependent on external finance, goes up, and the output of industry 1 declines.

We then consider the *feedback effect*. The increase in y_2 and the decrease in y_1

raise equilibrium price p_1 relative to p_2 , which reduces r by Proposition 1. As we argued before, the decrease in r raises labor usage per unit of production, while reducing external capital usage per unit of production. Thus, the *feedback effect* shifts in LL to $L''L''$ and shifts out $X'X'$ further to $X''X''$, which moves the equilibrium from A' further up to A'' . Again, the *feedback effect* strengthens rather than dampens the *magnification effect*, increasing y_2 and reducing y_1 further.

Case 3—that the labor intensive industry is more dependent on external finance—seems counter intuitive,⁵ while all our analysis above goes through as well. Further financial development increases the output of industry 1, the industry more dependent on external finance, while reducing the output of industry 2. The analysis and the proof of this case is relegated to the Appendix. We summarize our results for cases of *binding* external finance constraint as the following proposition.

Proposition 4 *Suppose the financial system is underdeveloped, then the equilibrium outputs are determined by the external finance constraint and the binding factor endowment constraint. There can be unemployment of some factor in equilibrium. An increase in the endowment of the non-binding factor has no effect on the economy. A further financial development will increase the output of the industry more dependent on external finance, and decrease the output of the other industry.*

It is worth noting that our comparative statics bears some resemblance to a three factors, two goods HOS model, but they are not the same thing. More factors than goods in the standard HOS model makes the Rybczynski theorem no longer hold. However, it does not create a non-binding constraint and unemployment of factors. In the three factors, two goods HOS model, six endogenous variables (one relative product price, three factor prices, and two outputs) need to be determined by the general equilibrium system. A product market clearing condition like (29),

⁵There is some empirical evidence to support Case 3. As Rajan and Zingales (1998) documented, Textile, a traditional labor-intensive industry, has an external dependence ratio of 0.40, which is much higher than the external dependence ratio of a traditional capital-intensive industry Iron and Steel, 0.09.

two zero profit conditions, and three full employment conditions like (33) would exactly solve for six endogenous variables. Product prices and factor prices together are able to clear product and factor markets in the standard general equilibrium analysis. It is the institutional constraint introduced in our model that imposes an additional constraint to the general equilibrium analysis, which results in problems of non-binding constraint and unemployment of factors. Intuitively, it is failure of capital market due to poor financial institution, rather than more factors than goods, that causes unemployment of resources.

3.4 Conflict of Interests in Financial Development

Not all factors benefit from financial development. In Figure 3 a further financial development represented by the increase in K^X raises y_2 and reduces y_1 and moves the equilibrium from point A to point A'' . It is immediately seen that the unemployment of capital K^U is reduced from AE to $A''H$. A better financial system allows more capital endowment to be employed. The increase in y_2 and the decrease in y_1 raise equilibrium price p_1 relative to p_2 , which raises w and reduces r by Proposition 1. Therefore, financial development makes unemployed capital better off, all labor better off, but the currently employed capital worse off. A more developed financial system facilitates entry, and thus benefits the unemployed capital; however it makes the capital market more competitive, and thus leads to lower return for incumbent capital owners.

Proposition 5 *In a country with an underdeveloped financial system, further financial development makes owners of unemployed capital better off, all labor better off, but owners of incumbent capital worse off.*

As Rajan and Zingales (2003) mentioned, “financial development is so beneficial that it seems strange that anyone would oppose it.” Nevertheless, their empirical investigation supports an interest group theory of financial development where

incumbents oppose financial development because it breeds competition. Our analysis above provides a possible theoretical foundation for a political economy theory of financial development. In our model, labor and unemployed capital owners support, while incumbent capital owners oppose financial development. The country’s financial development will be determined by the strength of political forces among these different interest groups.

3.5 International Trade

The financial system, in addition to factor endowments, determines patterns of trade. Consider two countries with binding external finance constraints, identical technologies, identical liquidity shocks and managers’ behavior, identical and homothetic tastes, and identical factor endowments. They engage in free trade in goods (but not factors). We will assume away the possibility of factor intensity reversals. We assume that the home country has a more developed financial system than the foreign country so that $K^X > K^{X*}$.⁶

Let us begin with the autarky equilibria. From Proposition 3, home must produce relatively more of the financially dependent good. Let p^a be the autarky relative price of that good at home. The foreign autarky relative price must be higher than that at home. That is, $p^{a*} > p^a$. Let p be the relative price in a free trade equilibrium. Similar to the arguments of the textbook HOS model, we must have $p^a < p < p^{a*}$. Thus, home exports the good produced by the more financially dependent industry, and imports the good produced by the less financially dependent industry. Provided that all countries have their endowments and external capital capacity within their “cone of diversification,” factor prices in each country are uniquely determined by product prices, using equations (30) and (31). That is, factor prices are equalized across countries. The country as a whole gains from free trade, since the representative consumer reaches higher utility than in autarky. At

⁶The superscript * is used to denote variables in the foreign country.

home, the factor used intensively in the industry more dependent on external finance will gain from opening of the trade, while the other factor loses. The reverse is true in the foreign country.

Proposition 6 *Suppose the external finance constraints in both countries are binding. The country with a more developed financial system exports the good that is relatively more dependent on external finance in the production process.*

Following the standard HOS model, we do not consider capital movement across countries. In the case discussed above, capital prices are equalized in the two countries so that employed capital will not move across countries. Unemployed capital will not move either, since the capital usage in each country has already reached its limit bound by external capital capacity. However, if we consider a case that the home country has a developed financial system, while the foreign country has an underdeveloped financial system, the situation will be different. Assuming that external capital capacity at home is sufficiently large, all unemployed capital in the foreign country will flow into the home country. The effect of such capital movement is just like the effect of the increase in capital endowment at home.

4 Conclusion

By introducing firms' demand for external finance into the HOS model, we conduct a general equilibrium analysis of financial development and study the joint effects of factor endowments and financial institution on the economy. Whether the factor endowment or the institution plays a more important role in the economy follows *the law of wooden barrel*: binding constraints determine the equilibrium outcome.

Our model provides a possible theoretical foundation for a political economy story of financial development. As the underdeveloped financial system prevents full employment of capital, some capital is wasted. On the one hand, financial development increases the relative output of the more financially dependent good,

which reduces its relative price, and therefore reduces the return to capital and increases the wage rate. On the other hand, financial development relaxes the binding external finance constraint, and therefore reduces unemployment of capital. Both owners of unemployed capital and labor benefit from financial development, while owners of incumbent capital are worse off. Therefore, labor and owners of unemployed capital support financial development, while owners of incumbent capital oppose it.

Financial development measured by the increase in external capital capacity is treated as exogenous in this paper. Relaxing this assumption and making financial development endogenous will be an interesting topic and is left for future studies.

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5 Appendix

Proof of Proposition 1

Totally differentiating equations (30) and (31), we obtain

$$\begin{aligned}\theta_{1w}\widehat{w} + \theta_{1r}\widehat{r} &= h_1\widehat{p}_1 \\ \theta_{2w}\widehat{w} + \theta_{2r}\widehat{r} &= h_2\widehat{p}_2\end{aligned}\tag{37}$$

where $\widehat{w} = dw/w$ denotes the percentage change in wage rate and likewise for other variables, while $\theta_{iw} = (\lambda_i^H a_i^1 w) / p_i$, $\theta_{ir} = \left(\frac{1}{p_i^{\frac{1}{2}} r}\right) / \left[(2(1+r))^{\frac{1}{2}} p_i\right]$ and $h_i = \lambda_i^H G_i(a_i^1, 1)$. We can solve for the change in factor prices from equations (37) as

$$\widehat{w} = \frac{\theta_{2r} h_1 \widehat{p}_1 - \theta_{1r} h_2 \widehat{p}_2}{|\theta|} \text{ and}\tag{38}$$

$$\widehat{r} = \frac{\theta_{1w} h_2 \widehat{p}_2 - \theta_{2w} h_1 \widehat{p}_1}{|\theta|}\tag{39}$$

where $|\theta| = \theta_{1w}\theta_{2r} - \theta_{1r}\theta_{2w}$. It can be easily shown that $|\theta| > 0$ if sector 1 is effectively labor intensive than sector 2. Consider an increase in the price of good 1 which is represented by $\widehat{p}_1 > 0$ and $\widehat{p}_2 = 0$. It is immediately seen from (39) that $\widehat{w} > 0$ and $\widehat{r} < 0$. The effect of the increase in the price of good 2 can be similarly done. The *magnification effect* studied by Jones (1965) does not hold in general. \widehat{p}_i is not a weighted average of \widehat{w} and \widehat{r} so we are not sure if \widehat{p}_i lies in between \widehat{w} and \widehat{r} . Thus, only under certain conditions will factor prices change in percentage terms by more than changes in product prices.

Proof of Proposition 2

Note that $a_{iL} = a_i b_i$ and $a_{iK} = b_i$. Using (22) and (25), we have

$$\widehat{a}_{iL} = -\frac{r}{2(1+r)}\widehat{r} \text{ and } \widehat{a}_{iK} = \frac{r}{2(1+r)}\widehat{r}\tag{40}$$

These solutions for $\hat{a}_{ij}(j = L, K)$ can then be substituted into equations (34) to obtain

$$\lambda_{1L}\hat{y}_1 + \lambda_{2L}\hat{y}_2 = \hat{L} + \frac{r}{2(1+r)}\hat{r} \quad (41)$$

$$\lambda_{1K}\hat{y}_1 + \lambda_{2K}\hat{y}_2 = \hat{K} - \frac{r}{2(1+r)}\hat{r} \quad (42)$$

Let $|\lambda 1|$ denote the determinant of the 2×2 matrix on the left hand side of the above system. Using the fact that $\lambda_{1j} + \lambda_{2j} = 1$, we have

$$|\lambda 1| = \lambda_{1L} - \lambda_{1K} = \lambda_{2K} - \lambda_{2L} > 0 \quad (43)$$

The last inequality uses the assumption that industry 1 is labor intensive, which implies that $a_{1L}/a_{1K} > L/K > a_{2L}/a_{2K}$. Consider the *direct effect* first and let $\hat{r} = 0$. Solving for the system of (41) and (42), we obtain the classical *magnification effect* that $\hat{y}_1^T > \hat{L} > \hat{K} > \hat{y}_2^T$ when $\hat{L} - \hat{K} > 0$. If $\hat{K} - \hat{L} > 0$, then we have $\hat{y}_2 > \hat{K} > \hat{L} > \hat{y}_1$.

We then consider the *feedback effect*. We first derive the *stability condition*. Market clear condition (29) serves to define the elasticity of substitution between goods on the demand side, σ_D .

$$\hat{y}_1 - \hat{y}_2 = -\sigma_D(\hat{p}_1 - \hat{p}_2) \quad (44)$$

Subtracting (42) from (41) yields

$$\hat{y}_1 - \hat{y}_2 = \frac{(\hat{L} - \hat{K})}{|\lambda 1|} + \frac{r}{|\lambda 1|(1+r)}\hat{r} \quad (45)$$

Let good 2 be the numeraire good. Using (39), (44) and (45), we have $A_1\hat{r} =$

$(\widehat{L} - \widehat{K}) / |\lambda_1|$ where

$$A_1 = \frac{|\lambda_1| |\theta| \sigma_D (1+r) - r \theta_{2w} h_1}{|\lambda_1| (1+r) \theta_{2w} h_1} \quad (46)$$

The *stability condition* requires that $A_1 > 0$. That is, an increase in capital endowment reduces the interest rate.

Now substituting (44) into (39), we have

$$\widehat{r} = \frac{\theta_{2w} h_1}{|\theta| \sigma_D} (\widehat{y}_1 - \widehat{y}_2) \quad (47)$$

Then substituting the above expression into equations (42), we obtain

$$\begin{aligned} (\lambda_{1L} - \eta) \widehat{y}_1 + (\lambda_{2L} + \eta) \widehat{y}_2 &= \widehat{L} \\ (\lambda_{1K} + \eta) \widehat{y}_1 + (\lambda_{2K} - \eta) \widehat{y}_2 &= \widehat{K} \end{aligned} \quad (48)$$

where $\eta = [r \theta_{2w} h_1] / [2(1+r) |\theta| \sigma_D]$. Let $|\Lambda_1|$ denote the determinant of the two-by-two matrix on the left hand side of (48). The condition that $A_1 > 0$ implies that $|\Lambda_1| > 0$.

Solving for \widehat{y}_1 and \widehat{y}_2 gives

$$\begin{aligned} \widehat{y}_1 &= \widehat{L} + \frac{(\lambda_{2L} + \eta) (\widehat{L} - \widehat{K})}{|\Lambda_1|} > \widehat{L} \text{ and} \\ \widehat{y}_2 &= \widehat{K} - \frac{(\lambda_{1K} + \eta) (\widehat{L} - \widehat{K})}{|\Lambda_1|} < \widehat{K} \end{aligned}$$

when $\widehat{L} - \widehat{K} > 0$.

Proof of Proposition 3: Case 2

Using expressions (17), (19) and (25), external capital usage per unit of production

can be written as

$$a_{iX} = \frac{1}{\lambda_i^H G_i(a_i^1, 1)} \left[\frac{r [2(1+r)\bar{\rho}_i]^{\frac{1}{2}} + \rho_i^0}{1+r} \right] \quad (49)$$

Using equations (23), we obtain that $\rho_i^1 + f\rho_i^0 = (1+f)\rho_i^*$. Then substituting definitions of (2) and (11) into this expression, we get $\rho_i^0 = \rho_i^* - \lambda_i^H B_i / [(1+f)\Delta\lambda_i]$.

Using this result and the expression (21), we can rewrite (49) as

$$a_{iX} = \frac{1}{\lambda_i^H G_i(a_i^1, 1)} \left[[2(1+r)\bar{\rho}_i]^{\frac{1}{2}} - \frac{\lambda_i^H B_i}{(1+f)(1+r)\Delta\lambda_i} \right] \quad (50)$$

Note that equation (50) implies that the term inside the bracket of the right hand side of (50) is positive. Totally differentiating the above, we have

$$\widehat{a}_{iX} = \left[\frac{\left(\frac{\bar{\rho}_i}{2}\right)^{\frac{1}{2}} r(1+r)^{-\frac{1}{2}} + \frac{r\lambda_i^H B_i}{(1+f)(1+r)^2 \Delta\lambda_i}}{[2(1+r)\bar{\rho}_i]^{\frac{1}{2}} - \frac{\lambda_i^H B_i}{(1+f)(1+r)\Delta\lambda_i}} \right] \widehat{r} \quad (51)$$

Let γ_i denote the expression inside the bracket of the right hand side of equation (51), $\gamma_i > 0$ since the denominator of the expression is positive. The expressions for \widehat{a}_{iX} and \widehat{a}_{iL} can then be substituted into equations (36) to obtain

$$\begin{aligned} \lambda_{1L}\widehat{y}_1 + \lambda_{2L}\widehat{y}_2 &= \widehat{L} + \frac{r}{2(1+r)}\widehat{r} \\ \lambda_{1X}\widehat{y}_1 + \lambda_{2X}\widehat{y}_2 &= \widehat{K^X} - \mu\widehat{r} \end{aligned} \quad (52)$$

where

$$\mu = [\lambda_{1X}\gamma_1 + \lambda_{2X}\gamma_2] > 0 \quad (53)$$

Let $|\lambda_2|$ denote the determinant of the 2×2 matrix on the left hand side of the system (52). Note that

$$\frac{a_{1L}}{a_{1K}} > \frac{a_{2L}}{a_{2K}} \Rightarrow \frac{a_{1L}}{a_{1K}} > \frac{\phi_1 a_{2L}}{\phi_2 a_{2K}} \Leftrightarrow \frac{a_{1L}}{a_{1X}} > \frac{a_{2L}}{a_{2X}} \quad (54)$$

since $\phi_1 < \phi_2$. Then similar to the argument for $|\lambda 1|$, we have $|\lambda 2| > 0$. First, let \widehat{w} and \widehat{r} be zero and consider the *direct effect*. Solving for the system of equations (52), we obtain the *magnification effect* that $\widehat{y}_2 > \widehat{K^X} > \widehat{L} > \widehat{y}_1$ when $\widehat{K^X} - \widehat{L} > 0$. If $\widehat{L} - \widehat{K^X} > 0$, then we have $\widehat{y}_1 > \widehat{L} > \widehat{K^X} > \widehat{y}_2$.

We then consider the *feedback effect*. Substituting the expression (47) into equations (52), we obtain

$$\begin{aligned} (\lambda_{1L} - \eta) \widehat{y}_1 + (\lambda_{2L} + \eta) \widehat{y}_2 &= \widehat{L} \\ (\lambda_{1X} + \xi) \widehat{y}_1 + (\lambda_{2X} - \xi) \widehat{y}_2 &= \widehat{K^X} \end{aligned} \quad (55)$$

where $\xi = (\mu\theta_{2w}h_1) / (|\theta|\sigma_D)$. Similar to the argument above, we have $A_2\widehat{r} = (\widehat{L} - \widehat{K^X}) / |\lambda 2|$ in this case where

$$A_2 = \frac{2(1+r)|\lambda 2||\theta|\sigma_D - \theta_{2w}h_1[r + 2(1+r)\mu]}{2|\lambda 2|(1+r)\theta_{2w}h_1} \quad (56)$$

The *stability condition* requires that $A_2 > 0$. Let $|\lambda 2|$ denote the determinant of the two-by-two matrix on the left hand side of (55). The condition that $A_2 > 0$ implies $|\lambda 2|$ to be positive. Solving for \widehat{y}_1 and \widehat{y}_2 gives $\widehat{y}_2 > \widehat{K^X} > \widehat{L} > \widehat{y}_1$ if $\widehat{K^X} - \widehat{L} > 0$.

Analysis and Proof of Proposition 3: Case 3

As shown in Figure 4, the XX line is steeper than the KK line now since $\phi_1 > \phi_2$ and is inside the point E . The equilibrium output is determined by the intersection of the KK line and the XX line at point B . The *direct effect* of further financial development shifts XX out to $X'X'$, as illustrated, and moves the equilibrium to point B' . The output of industry 1, the industry more dependent on external finance, goes up, and the output of industry 2 declines.

The *feedback effect* in this case differs from the previous two cases. The increase in y_1 and the decrease in y_2 reduce the relative price p_1 , which increases r by

Proposition 1. The increase in r raises both external capital usage and the capital usage per unit of production. Thus, the *feedback effect* shifts in both XX and KK lines. The shifting in of the KK line increases y_1 and reduces y_2 , which strengthens the *magnification effect*. The shifting in of the XX line, however, reduces y_1 and increases y_2 , which dampens the *magnification effect*. Overall, y_1 will increase relative to y_2 , although the composition of outputs may not change by as much, relatively, as the change in K^X . In this case, labor endowment L is not fully employed. Actual labor usage is $L^* = a_1 b_1 y_1^* + a_2 b_2 y_2^* < L$. The unemployment of labor is equal to $L - L^*$. Assume that anyone in the labor force has equal probability of finding a job, which is measured by L^*/L . Thus, the expected wage of labor is given by wL^*/L in this case. Now we turn to the mathematical proof.

Rewrite the binding capital constraint (26) and external finance constraint (28) as

$$\begin{aligned} a_{1X}y_1 + a_{2X}y_2 &= K^X \\ a_{1K}y_1 + a_{2K}y_2 &= K \end{aligned} \tag{57}$$

Totally differentiating these conditions and using (42) and (52), we obtain

$$\lambda_{1X}\hat{y}_1 + \lambda_{2X}\hat{y}_2 = \widehat{K^X} - \mu\hat{r} \tag{58}$$

$$\lambda_{1K}\hat{y}_1 + \lambda_{2K}\hat{y}_2 = \widehat{K} - \frac{r}{2(1+r)}\hat{r} \tag{59}$$

Let $|\lambda 3|$ denote the determinant of the 2×2 matrix on the left hand side of the above system. Note that $a_{1X}/a_{1K} > a_{2X}/a_{2K}$ since $\phi_1 > \phi_2$, which implies that $|\lambda 3| > 0$. Solving for the system of equations (58) and (59) when $\hat{r} = 0$ to obtain the *direct effect*, we have the *magnification effect* that $\hat{y}_1 > \widehat{K^X} > \widehat{K} > \hat{y}_2$ if $\widehat{K^X} - \widehat{K} > 0$.

We then consider the *feedback effect*. Subtracting (59) from (58) and using the result that $|\lambda 3| = \lambda_{1X} - \lambda_{1K} = \lambda_{2K} - \lambda_{2X}$, we obtain

$$|\lambda 3| (\hat{y}_1 - \hat{y}_2) = \left(\widehat{K^X} - \widehat{K} \right) + \left(-\mu + \frac{r}{2(1+r)} \right) \hat{r} \quad (60)$$

Using (39), (44), and (60), we have $A_3 \hat{r} = \left(\widehat{K^X} - \widehat{K} \right) / |\lambda 3|$ where

$$A_3 = \frac{2(1+r) |\lambda 3| |\theta| \sigma_D - \theta_{2w} h_1 [r - 2(1+r) \mu]}{2 |\lambda 3| (1+r) \theta_{2w} h_1} \quad (61)$$

The *stability condition* requires that $A_3 > 0$. The equation (60) can be written as

$$|\lambda 3| (\hat{y}_1 - \hat{y}_2) = \left(\widehat{K^X} - \widehat{K} \right) + (-\xi + \eta) (\hat{y}_1^T - \hat{y}_2^T)$$

Let $|\Lambda 3| = |\lambda 3| + \xi - \eta$. The condition that $A_3 > 0$ implies $|\Lambda 3| > 0$. Thus, we have $\hat{y}_1 - \hat{y}_2 > 0$ if $\widehat{K^X} - \widehat{K} > 0$.

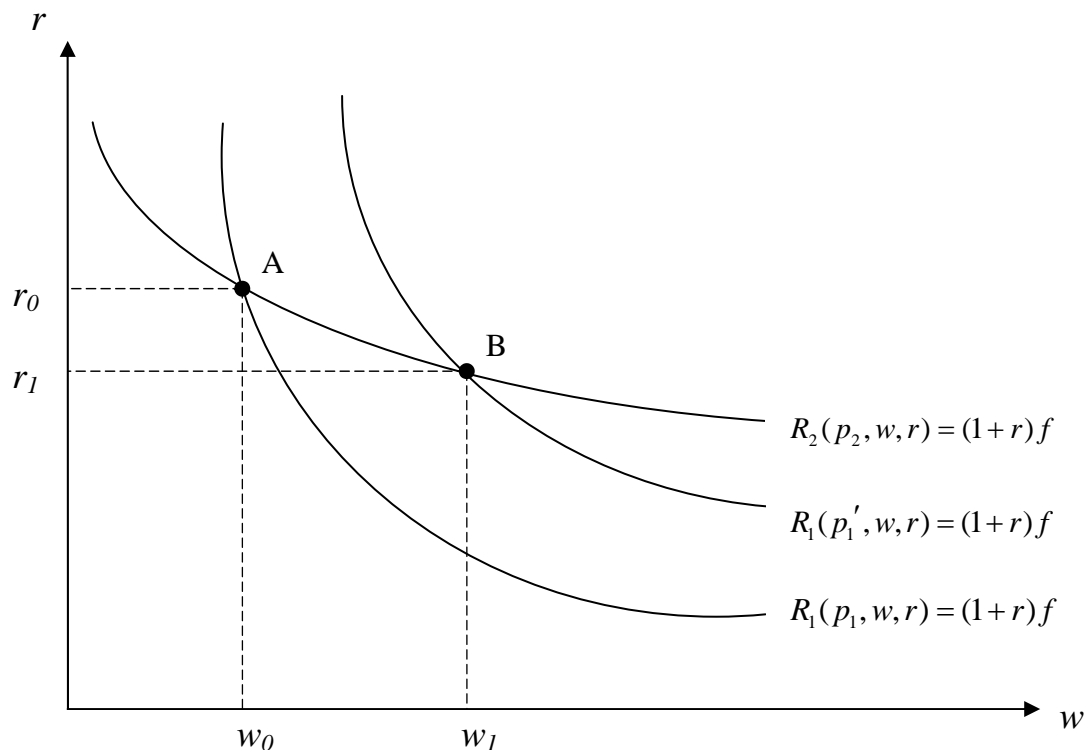


Figure 1

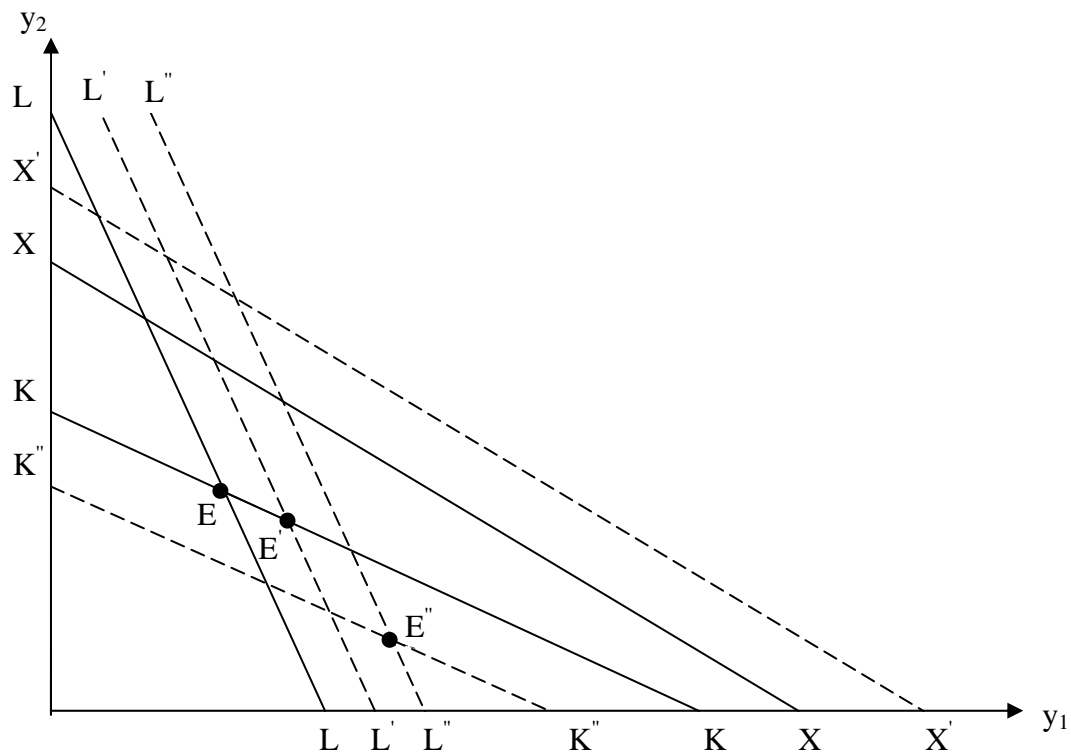


Figure 2

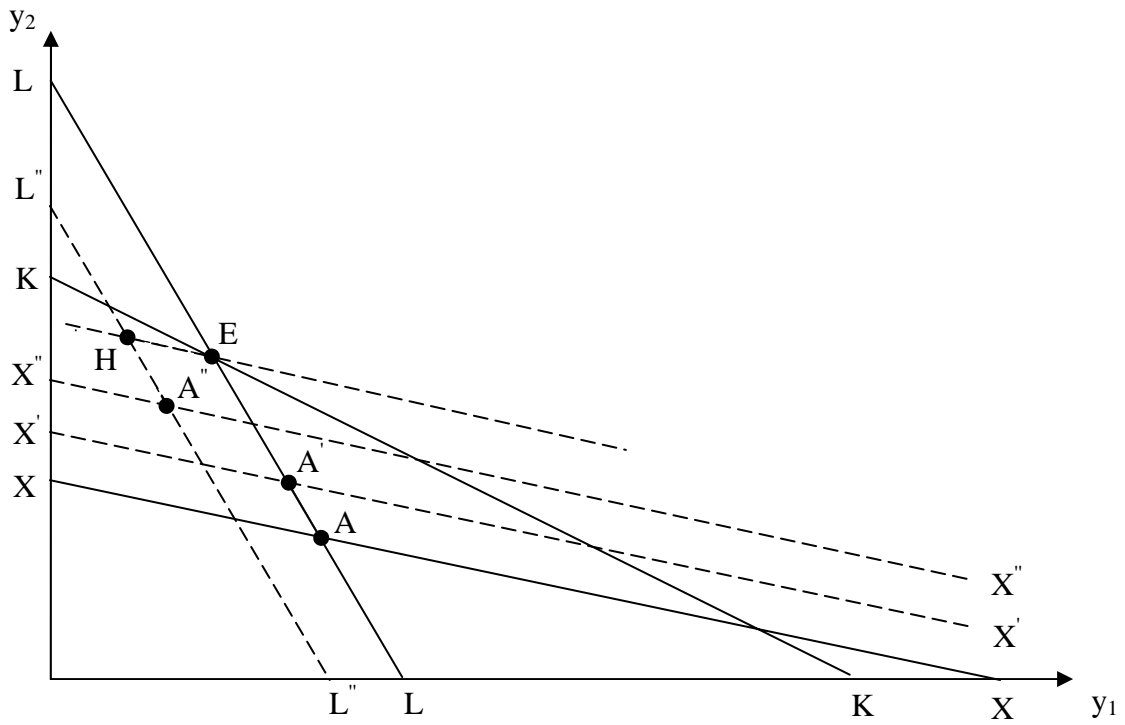


Figure 3

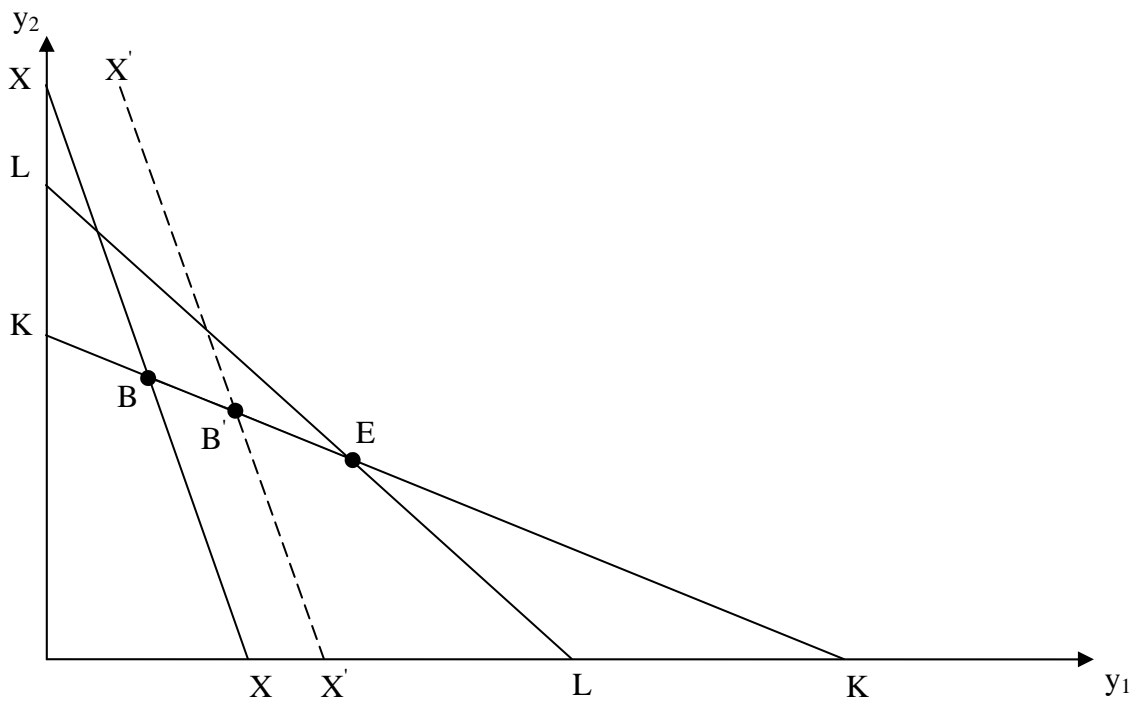


Figure 4