# Technology Differences and Capital Flows*

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**Abstract**

The one-to-one mapping between cross-country differences in capital returns and the direction of international capital flows is broken in a multi-sector world where international factor price differences are driven by technology differences. A technology-backward or low-return-to-capital country will face capital inflows or outflows after financial integration depending on whether no-tradable demand is boosted or not.

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# 1 Introduction

One of the traditional paradigms in international economics stays that cross-country differences in per capita income and wages are determined by international differences in factor endowments. In particular, poor or underdeveloped countries are abundant in labor. Therefore, the return to capital is lower in these countries, and openness to capital flows must generate a flow of capital from rich to poor countries.

This paradigm has been challenged in two dimensions. First, cross-country differences in factor abundance seen unable to explain international differences in per capita income. In other words, differences in factor endowment must be many times greater than they actually are in order to explain observed differences in per capita income across countries (Prescott, 1998; Parente and Prescott, 2002). Also, capital does not tend to flow from rich to poor countries, as cross-country differences in capital returns should mandate. This is not to say that capital does not flow to poor countries, but the vast majority of capital flows occur across developed countries (with the exception of China in the last years).[1] This "puzzle" lead Lucas (1990) to search for an answer on why capital does not flow from rich to poor countries.

Both challenges have given rise to a similar answer: international productivity differences. Cross-country technology differences are able to account for differences in factor returns and per capita income that differences in factor endowments cannot account for. Trefler (1993) and Hall and Jones (1999) present direct evidence on this. Also, with international productivity differences, a country with low wages or low income per capita may also be a low-return-to-capital country, meaning that capital market integration may not lead to capital inflows in labor-abundant countries.[2]

International productivity differences break the link between relative factor endowments and factor prices,

[1] See Razin, Rubinstein and Sadka (2003).

[2] The term international productivity differences can be interpreted in several ways. It can reflect international differences in technologies, externalities (Lucas, 1990), institutional factors, or the presence of immobile factors of production. An alternative explanation is provided by Tornell and Velasco (1992), who argue that if property rights are not well defined, a lower but private technology for asset accumulation can dominate the high public technology, generating capital flows out of the country with low protection for property rights.

meaning that labor-abundant countries may have lower return to capital than capital-abundant countries if the former are technology-backward. However, technology differences do not break the one-to-one mapping between cross-country differences in capital return and capital flows. Capital market integration make a high-return-to-capital country a net importer of capital regardless of whether cross-country differences in the return to capital are due to differences in factor endowments or technologies. The converse is also true.

This paper challenges the view that countries with a low return to capital must become net exporters of capital after capital market integration. I do so by developing a simple multi-sector model with two tradable goods and a non-tradable product. Factor endowments are such that both tradable goods are produced, and international factor price differences follow from technology differences. Capital market integration leads to an unambiguous rise in the return to capital in the technology-backward country, a fall in the return to the internationally immobile factor – labor – and pressures toward specialization in the labor-intensive tradable sector. The size and direction of capital flows will depend on whether the non-tradable sector expands or contracts after integration. If capital market integration leads to an expansion of the non-tradable demand and production, labor market equilibrium conditions are reached with capital outflows. However, if non-tradable demand and production fall, and the fall is big enough, the new equilibrium is reached with capital inflows. This result is relevant for it suggests that explanations for the lack of capital flows toward poor countries may not be found in differences in capital returns but rather on the effects of liberalization on non-tradable demand.

The rest of the paper is structured as follows. Next section presents a very simple one-sector framework to show the link between cross-country differences in factor returns and capital flows. Section 3 extends the analysis to a multi-sector framework. First, I show that the implications of the one-sector model hold in a framework with many tradable products. The second part shows that the inclusion of a non-tradable sector changes significantly the results, giving rise to a non-monotonic relationship between capital returns and capital flows. Section 4 concludes.

## 2 One Sector Model

Consider a small open economy that produces one good labeled $x$ with a constant-returns-to-scale technology and two internationally-immobile factors of production: labor $L$ and capital $K$. The product price − determined in international markets − is $p_x$. The equilibrium is characterized by the following two conditions:

$$p_x = a_{Lx} w + a_{Kx} r \tag{1}$$

$$\frac{a_{Kx}}{a_{Lx}} = \frac{\overline{K}}{\overline{L}} = \overline{k} \tag{2}$$

where $a_{Lx}$ is the inverse of average productivity of labor (similar for capital), that depends on the wage-rental rate ratio $w/r$. Finally, $\overline{L}$ and $\overline{K}$ represent the endowment of labor and capital respectively. Condition (1) states that product price must equal marginal and average costs. Equation (2) mandates equalization of relative factor endowments and relative factor usage in industry $x$. Combining (1) and (2) we can solve for the equilibrium factor prices $w$ and $r$ as functions of factor endowments consistent with zero-profits and factor market clearing conditions.

The graphical solution is shown in figure 1, that depicts a unit value isoquant $(1/p_x)$ for two countries that share the same technology. Points $v$ and $v^*$ represent endowment points of two countries ($*$ refers to a foreign country) that differ only in their factor endowments. In particular, the labor-abundant domestic country has lower wages and a higher return on capital. This result is obtained analytically by combining equations (1) and (2) with the definition of the elasticity of substitution between labor and capital $\sigma$, to obtain[3]

$$\frac{r^*}{r} = 1 - \frac{\theta_L}{\sigma}\left(\frac{\overline{k^*}}{\overline{k}} - 1\right) \tag{3}$$

where $r$ is the (capital market) autarky rate of return on domestic capital and $\theta_L$ is the share of labor in total output in the domestic economy. According to (3), a labor abundant country ($\overline{k} < \overline{k^*}$) has a higher return to capital ($r > r^*$).

*[Insert Figure 1]*

[3] $\sigma = \widehat{\overline{k}}/(\widehat{w} - \widehat{r})$ where $\widehat{\overline{k}} =$d$\overline{k}/\overline{k}$.

Capital market integration equalizes the return to capital in all countries. Assuming an international return of $r^*$, this means that labor abundant countries, $-$with $r > r^*-$ will face capital inflows until the return to capital is equalized to the international level. Moreover, capital market integration leads to international wage equalization, even when labor markets remain segmented.

Allowing for international technology differences $-$besides differences in factor endowments$-$ breaks the link between cross-country differences in factor abundance and factor returns. Pre-integration differences in the return to capital are given by

$$\frac{r^*}{r} = -\frac{\theta_L}{\sigma}\left(\frac{\overline{k^*}}{\overline{k}} - 1\right) + \frac{\delta}{1+\delta} \tag{4}$$

where $\delta/(1+\delta)$ is the Hicks-neutral total factor productivity difference between domestic and foreign producers.[4] The greater the technology advantage of foreign producers, the greater the difference in the return to capital. Similarly for wages. It is evident from (4) that a capital-scarce country can have a low return to capital if technology is sufficiently backward. This solution is depicted in figure 2, where the domestic return to capital and the wage rate in the capital-scarce country are lower than $r^*$.

*[Insert Figure 2]*

In this case, international capital return equalization pushes the domestic (technology-backward) country toward a more labor-intensive production technique, and the full employment condition implies that capital outflows must take place. Notice that international technology differences do not break the one-to-one mapping between rental rate differences and capital flows, but rather the mapping between cross-country differences in factor endowments and relative rental rates.

[4] Assuming that $a_{Li} = (1+\delta_L)a^*_{Li}l(\omega)$ and $a_{Ki} = (1+\delta_K)a^*_{Ki}k(\omega)$ where $l(\omega)$ and $k(\omega)$ denote the adjustment in average productivity due to differences in relative factor prices $\omega$, the TFP gap between domestic and foreign producers is given by $\theta_L\delta_L/(1+\delta_L) + \theta_K\delta_K/(1+\delta_K)$. For $\delta_L = \delta_K$, this expresion becomes $\delta/(1+\delta)$.

# 3 Multi-Sector Model

## 3.1 Two Tradable Goods

Consider a small open economy with two tradable industries $x$ and $y$. Both goods are produced with CRS Leontief technologies. The fixed-proportions assumption has only second-order effects in the results because the action in the model is driven by cross-industry mobility of factors. As in section 2, both labor and capital are internationally-immobile in the pre-integration scenario. For simplicity, assume that $x$ is capital intensive, so that technology-given factor proportions satisfy $k_x > k_y$ with $k = K/L$.

It is natural to assume that factor endowments $\overline{k}$ are such that both tradable products are produced ($k_x > \overline{k} > k_y$). Otherwise the one-sector model is relevant, and the Leontief assumption has to be dropped to allow for factor market clearing. The equilibrium conditions are the following

$$p_x = a_{Lx}w + a_{Kx}r, \tag{5}$$

$$p_y = a_{Ly}w + a_{Ky}r, \tag{6}$$

$$\overline{L} = L_x + L_y, \tag{7}$$

$$\overline{K} = k_x L_x + k_x L_y. \tag{8}$$

Notice that the first two equations uniquely determined the wage and rental rates consistent with zero profits in both sectors. Similarly, equations (7) and (8) uniquely determine the distribution of labor and capital across sectors such that market clearing holds.

Technology parameters are such that $a_{Lx}/a^*_{Lx} = a_{Kx}/a^*_{Kx} = (1+\delta_x) \geq 1$, meaning that there are Hicks-neutral technology differences between the domestic and foreign producers of $x$.[5] Similarly for $y$. Assuming $\delta_x = \delta_y = \delta$, the pre-integration wages and rental rates are given by[6]

[5] All result in the paper hold if factor-saving technology differences are considered.

[6] Assuming $\delta_x = \delta_y = \delta$ implies international relative factor price equalization. All the results of the model hold with sector-specific technology differences. This assumption is however imposed to assure that technology backward countries have lower return to both capital and labor.

$$w_0 = \frac{p_y a^*_{Kx} - p_x a^*_{Ky}}{(1+\delta)\, A} \tag{9}$$

$$r_0 = \frac{p_x a^*_{Ly} - p_y a^*_{Lx}}{(1+\delta)\, A} \tag{10}$$

where $A = a^*_{Ly} a^*_{Kx} - a^*_{Ky} a^*_{Lx} > 0$. Expressions (9) and (10) imply that $w^*/w_0 = r^*/r_0 = (1+\delta)$.

As in the one-sector model, capital market integration leads to a rise in the domestic return to capital to $r^*$, rendering the capital-intensive sector $x$ uncompetitive. The post-integration wage rate $w_1 = (p_y - a^*_{Kx}(1+\delta)\, r^*) / a^*_{Lx}(1+\delta)$ is unambiguously lower than $w_0$. Specialization in $y$ means that factor market clearing is reached with capital outflows so that $\widehat{\overline{K}} = \triangle\overline{K}/\overline{K} = k_y/\overline{k} - 1 < 0$, reinforcing the result of the one-sector model.

### 3.2 Adding a Non-Tradable Sector

Consider that besides sectors $x$ and $y$ there is a non-tradable sector $n$ that produces with a Leontief CRS technology. Assume also that $k_x > k_y > k_n$. Equations (5) and (6) determine the pre-integration factor prices as long as the conditions for positive production of both tradable goods hold. To assure diversification of tradable production we require an explicit analysis of non-tradable equilibrium.

Assuming a simple log-linear utility function of the representative consumer so that non-tradable consumption represents a constant share $\alpha$ of income, the non-tradable market clearing condition can be written as

$$\alpha \left[ w\overline{L} + r\overline{K} \right] = p_n c_n = wL_n + rK_n \tag{11}$$

that implies

$$\alpha \left[ w + r\overline{k} \right] = (w + rk_n)\, \lambda_n \tag{12}$$

where $\lambda_n$ is the ratio of non-tradable employment to total employment. Equation (11) states that in equilibrium total expenditure in non-tradable goods has to be equal to the value non-tradable production. Therefore a pre-integration equilibrium with positive production of $x$ and $y$ exists as long as the value of

$\lambda_n(\in (0,1))$ that satisfies (12) at factor prices described in (9) and (10) is such that

$$\frac{k_y - \overline{k}}{k_y - k_n} < \alpha\gamma = \lambda_n < \frac{k_x - \overline{k}}{k_x - k_n} < 1 \tag{13}$$

with

$$\gamma = \frac{pa^*_{Ly}\left(\overline{k} - k_y\right) + a^*_{Lx}\left(k_x - \overline{k}\right)}{pa^*_{Ly}\left(k_n - k_y\right) + a^*_{Lx}\left(k_x - k_n\right)} > 1$$

and $p = p_x/p_y$. Condition (13) assures that the factor availability for tradable production, after deducting factor usage in sector $n$ consistent with non-tradable market equilibrium, belongs to $(k_y, k_x)$. Factor prices obtained in (9) and (10) pin down a price for the non-tradable good and therefore an optimal level of consumption −and factor usage− consistent with (12). Factor usage in industry $n$ has to be such that the remaining factor endowments can be split between both tradable products according to equations (7) and (8), where $\overline{L}$ has to be replaced by $\overline{L} - L_n$ and $\overline{K}$ by $\overline{K} - K_n$. A necessary condition for this is that $k_x > \overline{k} > k_n$. For the sake of the argument, I assume that domestic country's factor endowment $\overline{k}$ is such that in the pre-integration equilibrium both $x$ and $y$ are produced.

Figure 3 depicts the equilibrium, where I have plotted unit value isoquants for the three sectors. The trace $\overline{vv_1}$ measures factor usage in non-tradable production (at $p_n$ consistent with $w_0$ and $r_0$). $v_1$ − that measures factor availability for tradable production− must belong to the cone $k_y k_x$ to assure positive production of $x$ and $y$. I have depicted $\overline{k} < k_y$ for expositional simplification, but it is possible that tradable diversification takes place if $k_x > \overline{k} > k_y$.

*[Insert Figure 3]*

What are the effects of international capital market integration? As before, the domestic return to capital converges to $r^* > r_0$, rendering capital-intensive industry $x$ uncompetitive. Therefore, the post-integration wage rate − obtained using the zero-profit condition for sector $y$− is given by

$$w_1 = \frac{a^*_{Ly}\left(p_y a^*_{Kx} - p_x a^*_{Ky}\right) + \delta a^*_{Ky}\left(p_y a^*_{Lx} - p_x a^*_{Ly}\right)}{(1+\delta)\, A a^*_{Ly}} < w_0. \tag{14}$$

Notice that for $\delta = 0$, $w_1 = w_0 = w^*$ and $r_1 = r_0 = r^*$, revealing that without international technology differences there is international factor price equalization before integration, and therefore capital market opening does not generate capital flows, regardless of differences in factor endowments (Mundell, 1957). The convergence of capital returns to the international level and the corresponding adjustment in domestic wages generates an unambiguous fall in the price of the non-tradable good. This is because the change in relative factor prices is determined by factor shares in the labor-intensive tradable industry, that is more capital-intensive than the non-tradable sector. The effect on non-tradable demand and production will depend on the impact of relative price changes on nominal income. If $\overline{k} > k_y$ nominal income rises, while if $\overline{k} < k_y$ nominal income falls. The final impact on non-tradable production will depend on whether the change in $p_n$ is higher or lower than the change in nominal income.

At post-integration wage $w_1$ and rental rate $r^*$, non-tradable factor usage $\lambda_{n1}$ satisfies[7]

$$\lambda_{n1} = \alpha\pi > \alpha\gamma = \lambda_{n0} \tag{15}$$

revealing that non-tradable consumption, production, and factor usage rise following capital market integration. The intuition is the following. If $\overline{k} > k_y$ non-tradable supply rises because of the fall in factor costs while non-tradable demand increases following the rise in nominal income. If $\overline{k} < k_y$, non-tradable supply rises but non-tradable demand decreases because nominal income falls. However, the shift in supply is greater than the shift in demand because $\overline{k} > k_n$, so the percentage fall in production costs is greater than the fall in income and demand.

The post-integration equilibrium is unambiguously reached with capital outflows. This is evident by noticing that relative factor availability for production of $y$ after non-tradable factor usage is $\left(\overline{k} - k_n\lambda_{n1}\right) / (1 - \lambda_{n1}) > k_y$. But labor market equilibrium requires $\left(\overline{k}\left(1 + \widehat{\overline{K}}\right) - k_n\lambda_{n1}\right) / (1 - \lambda_{n1}) = k_y$, meaning that $\widehat{\overline{K}} < 0$. The rise in non-tradable factor usage means that relative factor availability for production of $y$ is always more capital abundant than relative factor requirements in $y$. In terms of figure 3, the increase in non-tradable production implies that the factor availability for tradable production is $v_2$. The post-integration equilibrium is hence characterized by capital outflows of $\overline{v_2 y_2}$. Capital outflows are accompanied by a depreciation of the real exchange rate. Are there conditions under which the new equilibrium is reached with capital

[7] $\pi = \dfrac{pa^*_{Ly}\left(\overline{k} - k_y\right) + a^*_{Lx}\left(k_x - \overline{k}\right) + \delta\left(k_y - \overline{k}\right)\left(a^*_{Lx} - pa^*_{Ly}\right)}{pa^*_{Ly}\left(k_n - k_y\right) + a^*_{Lx}\left(k_x - k_n\right) + \delta\left(k_y - k_n\right)\left(a^*_{Lx} - pa^*_{Ly}\right)} > \gamma$

inflows? Intuitively, capital inflows will take place after capital market integration if the latter is associated with a big-enough fall in non-tradable demand.

### 3.2.1 Sticky Non-tradable Prices

If non-tradable production is demand determined, the change in non-tradable production and factor usage is determined by the change in nominal income that follows from capital market integration. Assuming that the pre-integration level of $p_{n0}$ clears the non-tradable market, the post integration level of non-tradable production is given by[8]

$$c_n = \alpha \frac{\left(w_1 \overline{L} + r^* \overline{K}\right)}{p_{n0}}$$

that implies

$$\lambda_{n1} = \alpha \frac{\left(w_1 + r^* \overline{k}\right)}{\left(w_0 + r_0 k_n\right)}. \tag{16}$$

Plugging (9), (10) and (14) into (16) yields $\lambda_{n1} = \alpha\tau$, where $\tau \lesseqgtr \gamma$ depends on whether $\overline{k} \lesseqgtr k_y$.[9] A post-integration fall in non-tradable production takes place as long as the country is labor abundant compared to the factor requirements of industry $y$ $\left(\overline{k} < k_y\right)$ At the initial level of $p_n$ the fall in nominal income generates a fall in non-tradable production. Nevertheless, capital inflows will take place if

$$\alpha\tau < \frac{k_y - \overline{k}}{k_y - k_n} \tag{17}$$

that is more likely to hold in technology-backward countries $(\partial\tau/\partial\delta < 0)$ and labor-abundant countries $(\partial\tau/\partial\overline{k} > 0$ and $\partial\left[\left(k_y - \overline{k}\right)/\left(k_y - k_n\right)\right]/\partial\overline{k} < 0)$. The intuition is straightforward. A technology backward country faces greater increase in the return to capital following integration, and hence the equilibrium fall in wages and income is greater. Also, the more labor-abundant a country is the greater the fall income associated with a fall in the wage-rental rate ratio. In terms of figure 3, the post-integration factor endowment for production of $y$ is $v_3$, meaning that capital inflows of $\overline{v_3 y_3}$ must take place to assure labor market clearing.

[8] I assume that nominal wages are flexible. This assures that tradable production takes place. Othewise, the zero-profit condition in $y$ would not hold.

[9] $\tau = \frac{a^*_{Lx}(k_x - \overline{k}) + pa^*_{Ly}(\overline{k} - k_y) + \delta(k_y - \overline{k})(a^*_{Lx} - pa^*_{Ly})}{a^*_{Lx}(k_x - k_n) + pa^*_{Ly}(k_n - k_y)}$.

An important corollary of this result is that the presence of sticky nominal non-tradable prices does not generate unemployment. Factors released by the fall in non-tradable production −combined with capital inflows− are employed in the tradable sector. Indeed, the size and sign of capital inflows are pinned down by the full-employment condition. Moreover, no depreciation of the real exchange rate takes place following capital inflows.

# 4 Conclusion

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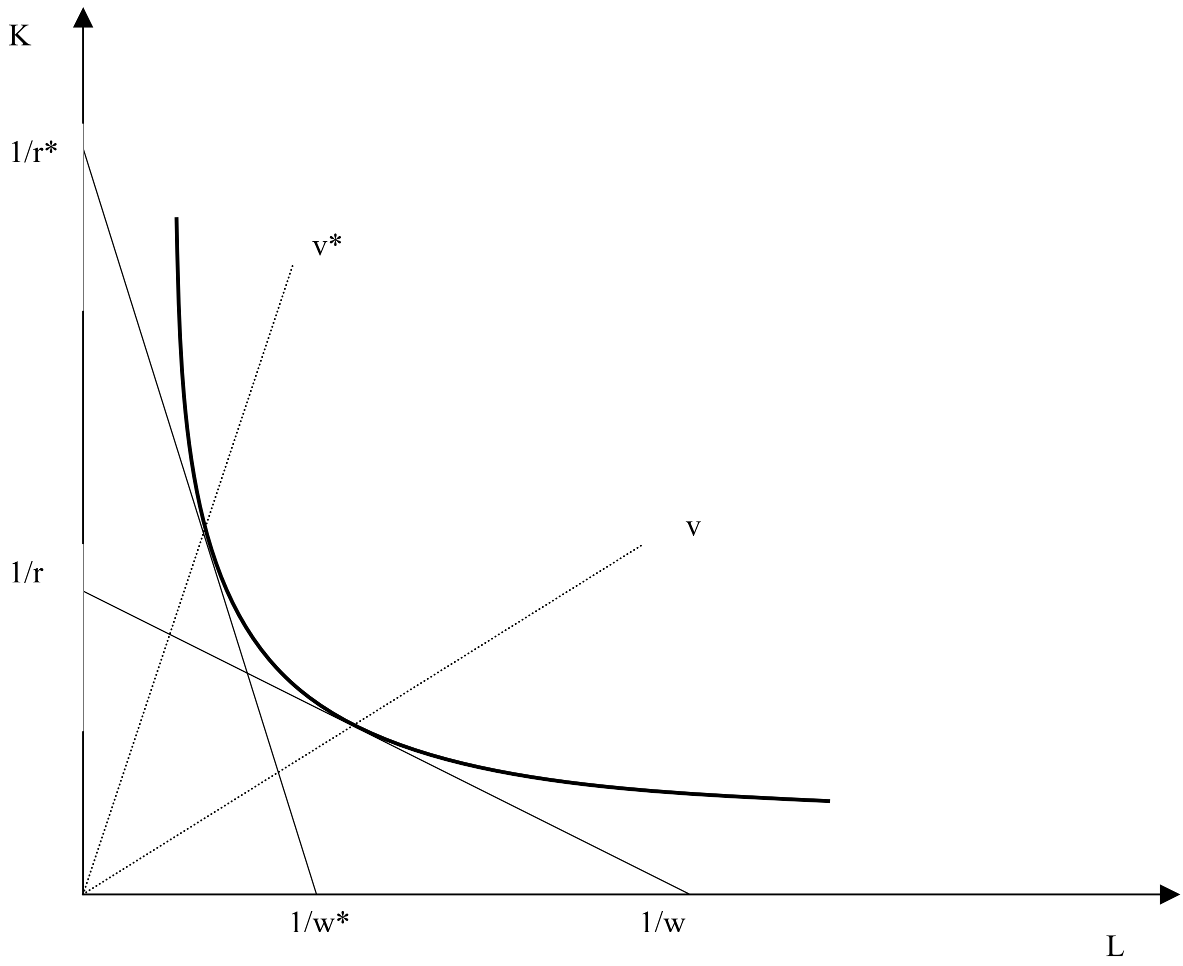
## Figure 1



## Figure 2

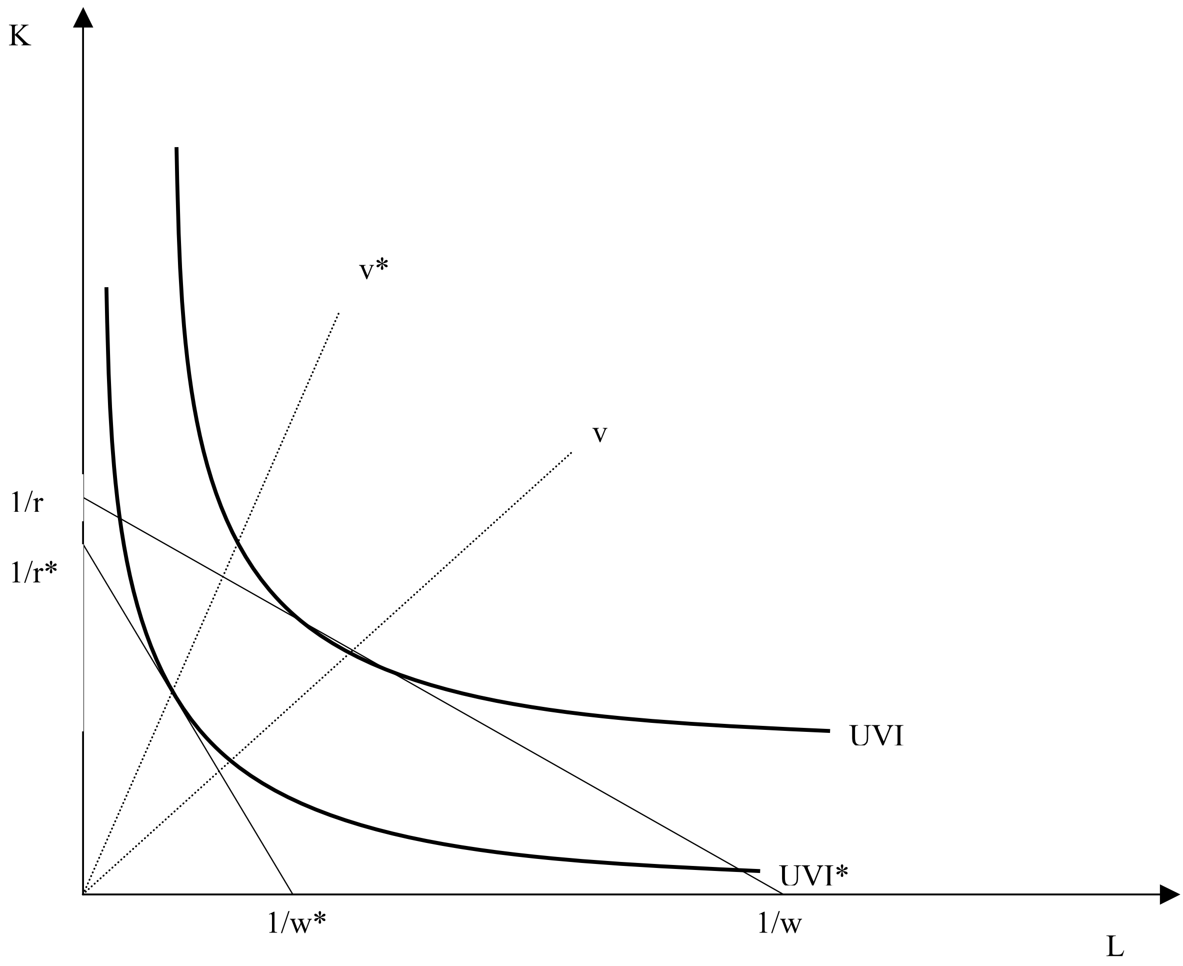


**Figure 3**