`Brain drain' without migration: Capital market integration and capital-skill complementarities

Kristian Behrens
CORE, Universite Catholique de Louvain

Yasuhiro Sato
Graduate School of Environmental Studies, Nagoya University

Abstract

We analyze the impacts of capital market integration on the skill composition of labor, using a framework in which heterogeneous agents decide to invest in the acquisition of skills and where production exhibits increasing returns in the available skill range (i.e., capital-skill complementarity).

We thank Hiroshi Aiura for useful comments and discussions. Of course, all remaining errors are ours. This research was partially supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT, Japan), Grant-in-Aid for 21st century COE Program, and by the Japan Society of the Promotion of Science, Grant-in-Aid for Scientific Research.
Citation: Behrens, Kristian and Yasuhiro Sato, (2006) "`Brain drain' without migration: Capital market integration and capital-skill complementarities." *Economics Bulletin,* Vol. 18, No. 1 pp. 1-9
Submitted: May 4, 2006. **Accepted:** May 22, 2006.
URL: http://economicsbulletin.vanderbilt.edu/2006/volume18/EB-06R10001A.pdf

1 Introduction

Following the deepening integration of international capital markets, a huge number of studies have analyzed its effects on competition for scarce capital and governments' fiscal behavior (e.g., Wilson, 1999; Zodrow, 2003; Wildasin and Wilson, 2004). Also, its impacts on industrial agglomeration and the pattern of trade have been examined (e.g., Krugman, 1980; Ottaviano and Forslid, 2003; Baldwin and Krugman, 2004; Ottaviano and van Ypersele, 2005). The purpose of the present paper is to investivates its effects on agents' incentives to acquire skills and, therefore, on the skill composition of the workforce, an aspect that has been neglected until now in the existing literature.[1]

Empirical evidence on skill composition presented by Barro and Lee (2001, Table 3) reveals that the gap between the skilled labor shares of developed and of developing countries has significantly increased in recent years. Most of the literature has attributed this evolution to the so-called 'brain drain', i.e., the international migration of skilled workers from developing to developed countries (see Docquier and Rapoport, 2004, for a recent overview). While this is doubtlessly an important part of the explanation, two points suggest that it may not be the whole story. First, even if the 'brain drain' has increased significantly since the 1970s, skilled labor mobility remains low when compared to the international flows of goods and capital. Second, standard theory predicts that skilled labor migration, by increasing supply and decreasing its returns in the host country, should reduce the incentives for further skill formation there (Borjas, 1999). When taken together, these two points suggest that skilled labor migration may not be the main explanation for the growing skill gap.

Our paper suggests that the increasing integration of capital markets and the presence of capital-skill complementarities may serve to explain this apparent puzzle. We show that the growing integration of capital markets, and hence, competition for capital in the presence of heterogeneous skilled workers, may provide an alternative explanation for the widening of the international skill gap. Focusing on the extreme case in which there is no international migration at all, we show that the well-documented capital-skill complementarities may lead to a *'brain drain' without migration.* The intuition underlying this result is as follows. When capital and skilled labor are complementary, capital will flow to skilled labor abundant countries. In doing so, it expands the range of available skills there, which raises the payoff to the unskilled of getting trained, because of increasing returns in the range of skills. This then entices additional unskilled workers to acquire skills, triggering further capital flows. Our main result establishes that capital market integration leads to a reallocation of capital from the 'small' to the 'large' country, which widens the international gap in skilled labor shares. Hence, even in the complete absence of migration, the small country loses skilled workers due to a deepening integration of the capital market.

The remainder of the paper is organized as follows. Section 2 presents the model. In

[1] Yet, see Sato and Thisse (2005) for an analysis of the impacts of capital market integration on skill mismatch

Section 2.1, we analyze the autarky case, and in Section 2.2 we turn to the case of capital market integration. Section 3 finally concludes.

2 The model

Consider an economy with a mass $N \equiv U + S$ of workers, where U and S denote the mass of the unskilled and of the skilled, respectively. Each agent (skilled and unskilled) is endowed with one unit of his labor type and with one unit of capital. All factors are supplied inelastically. Unskilled labor is perfectly homogeneous, whereas skilled labor consists of a continuum of horizontally differentiated types (think, e.g., of specialized tasks). We denote by f the distribution of skill types, with support on $[0, S]$. We assume, for simplicity, that skills are uniformly distributed: $f(j) = 1/S$ for all $j \in [0, S]$. The aggregate production function is assumed to be given by:

$$Y = \xi K^\alpha L_u^\beta \int_0^S [Sf(j)l_s(j)]^\gamma \, \mathrm{d}j = \xi K^\alpha L_u^\beta \int_0^S l_s(j)^\gamma \mathrm{d}j, \tag{1}$$

where K stands for the total capital input; L_u stands for the total input of unskilled labor; $l_s(j)$ stands for the skilled labor input per worker of type j; α, β, and γ are positive constants satisfying $0 < \alpha, \beta, \gamma < 1$ and $\gamma \equiv 1 - \alpha - \beta$; and $\xi > 0$ denotes the economy's total factor productivity (henceforth, TFP). It is readily verified that this production function exhibits constant returns to scale in input quantities but *increasing returns to scale in the range of varieties of skilled labor* (e.g., Ethier, 1982). It can also be verified that, for a given mass of skilled labor S, efficiency requires the firm to use all skill types in the same quantity. Hence, $l_s(j) = l_s$ for all j.

In what follows, we assume that the final good is produced under perfect competition and sold in a perfectly competitive world market. We choose it as the numéraire and normalize its price to one. Let w_u, w_s and r stand for the skilled and unskilled wages, and the rental rate of capital, respectively. Given symmetry in skilled labor inputs, the first-order conditions for profit maximization, combined with the labor market clearing conditions $L_u = U$ and $l_s = 1$ (because all labor types are supplied inelastically) yields

$$w_u = \beta\xi K^\alpha U^{\beta-1} S, \qquad w_s = \gamma\xi K^\alpha U^\beta, \qquad r = \alpha\xi K^{\alpha-1} U^\beta S. \tag{2}$$

Conditions (2) highlight the external effect of a larger range of skilled labor types: unskilled wages increase in S, because a larger skill range raises unskilled productivity. The presence of such Marshallian externalities has been repeatedly highlighted in the theoretical and empirical literature.[2] Note also that skilled labor and capital are complementary. In what

[2] Horizontal skill heterogeneity is known to lead to increasing returns with respect to the labor pool, which is considered as being one of the most important features of skills (e.g., Hamilton *et al.*, 2000). See also Duranton and Puga (2004) and Rosenthal and Strange (2004), for an application to the urban context.

follows, we assume that $\alpha < 1/2$, i.e., the capital-skill complementarity is not too strong.[3]

Agents decide on whether or not to invest in the acquisition of skills, i.e., the distribution of total population N between skilled S and unskilled U is endogenously determined. To keep things simple, we assume that an unskilled worker v can become skilled by incurring once a fixed training cost $c(v) \in [0,1]$. This training cost differs across agents, who are heterogeneous in terms of their ability to get trained. We further assume that training costs are uniformly distributed on the interval $[0,1]$. Denote by c the cut-off level of training costs, i.e, workers with training costs $c(v) < c$ (resp., $c(v) \geq c$) become skilled (resp., remain unskilled). Hence, the number of workers who become skilled and who remained unskilled are given by $S = cN$ and $U = (1-c)N$, respectively.

The equilibrium value of c, denoted by c^*, will of course be determined by arbitrage between skilled and unskilled labor:

$$w_u(c^*; K, N) + c^* = w_s(c^*; K, N). \tag{3}$$

Inserting the expressions $S = cN$ and $U = (1-c)N$ into (2), we obtain the factor prices w_s, w_u, and r as a function of the *rate of skill formation* c and the capital input K:

$$w_u = \xi\beta K^\alpha (1-c)^{\beta-1} c N^\beta, \quad w_s = \xi(1-\alpha-\beta) K^\alpha (1-c)^\beta N^\beta, \quad r = \xi\alpha K^{\alpha-1}(1-c)^\beta c N^{\beta+1}. \tag{4}$$

Solving condition (4) for the capital demand yields

$$K = \left[\frac{\xi\alpha(1-c)^\beta c N^{1+\beta}}{r}\right]^{1/(1-\alpha)} \tag{5}$$

which, when substituted back into the labor demands (4) finally allows us to obtain:

$$w_u = \beta\left[\left(\frac{\alpha}{r}\right)^\alpha \xi(1-c)^{\alpha+\beta-1} c N^{\alpha+\beta}\right]^{1/(1-\alpha)}$$
$$w_s = (1-\alpha-\beta)\left[\left(\frac{\alpha}{r}\right)^\alpha \xi(1-c)^\beta c^\alpha N^{\alpha+\beta}\right]^{1/(1-\alpha)}$$

Substituting these wages w_s and w_u into (3) and rearranging it, we get:

$$\left[(1-\alpha-\beta) - (1-\alpha)c\right]\left[\xi\left(\frac{\alpha}{r}\right)^\alpha (1-c)^{\alpha+\beta-1} c^{2\alpha-1} N^{\alpha+\beta}\right]^{1/(1-\alpha)} = 1. \tag{6}$$

The equilibrium rate of skill formation c^* then solves (6).

[3] This is a sufficient condition for an equilibrium to exist under capital market integration.

2.1 Autarky

Let us start with the autarky equilibrium. In that case, the country's available capital stock is solely determined by its endowments, i.e., $K = N$. From condition (4), the rental rate of capital then becomes:

$$r = \xi\alpha(1-c)^{\beta}cN^{\alpha+\beta}. \tag{7}$$

Substituting (7) into (6), and rearranging, we get

$$\Gamma(c) \equiv \frac{c(1-c)^{1-\beta}}{(1-\alpha-\beta)-(1-\alpha)c} = \xi N^{\alpha+\beta}. \tag{8}$$

One can readily verify that

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}c} > 0 \qquad \text{when} \qquad c < \overline{c} \equiv \frac{1-\alpha-\beta}{1-\alpha},$$

and that equation (8) has a unique solution $c^* \in (0, \overline{c})$. It is further be readily verified from conditions (7) and (8) that $c^*(\cdot)$ and $r^*(\cdot)$ satisfy

$$\xi N^{\alpha+\beta} > \widetilde{\xi}\widetilde{N}^{\alpha+\beta} \quad \Rightarrow \quad c^*\left(\xi N^{\alpha+\beta}\right) > c^*\left(\widetilde{\xi}\widetilde{N}^{\alpha+\beta}\right) \quad \text{and} \quad r^*\left(\xi N^{\alpha+\beta}\right) > r^*\left(\widetilde{\xi}\widetilde{N}^{\alpha+\beta}\right).$$

Since $\xi N^{\alpha+\beta}$ can roughly be interpreted as the country's size in terms of labor 'efficiency units', we see that in autarky *larger countries (as measured in 'efficiency units') have a higher rate of skill formation and a higher rental rate of capital.* This last effect stems from the fact that the productivity of capital is higher in the larger country, due to the capital-skill complementarity, which raises its equilibrium returns.

Proposition 1 (autarky) *In autarky, larger countries have a higher equilibrium rate of skill formation and a higher rental rate of capital.*

2.2 Capital market integration

Assume that there are two countries with total masses of workers N_1 and N_2, and TFP ξ_1 and ξ_2, respectively. All other parameters are common to the two countries. Without loss of generality, we assume that country 1 is is larger than country 2 as measured in efficiency units, i.e., $\xi_1 N_1^{\alpha+\beta} \geq \xi_2 N_2^{\alpha+\beta}$. This assumption encompasses the following two scenarios:

(i) First, the case in which $\xi_1 = \xi_2 = \xi$ can be interpreted as both countries having access to the same technology, which may be seen as a characteristic feature of the developed world. We refer to this case as 'North-North' scenario, and our size assumption implies that $N_1 > N_2$.

(ii) Second, the case in which $\xi_1 > \xi_2$ can be interpreted as country 1 having access to a better technology than country 2. If we further assume that $N_1 < N_2$, but that $\xi_1 N_1^{\alpha+\beta} > \xi_2 N_2^{\alpha+\beta}$, this setting seems realistic when interpreting country 1 as the developed world ('North') and country 2 as the developing world ('South'). North has an overall larger labor supply, as measured in efficiency units, although South has a larger total population. We refer to this case as the 'North-South' scenario.

To focus solely on the impacts of capital market integration, we make the simplifying assumption that both skilled and unskilled workers are immobile, i.e., there is no international migration. In this respect, we move away from classical 'brain drain' aspects in which skilled workers are internationally mobile (Docquier and Rapoport, 2004).

Assume that capital markets are integrated, so that capital may flow freely between the two countries. Arbitrage then implies that there is a common equilibrium rental rate r.[4] Equating the demand for capital in both countries, obtained from condition (5), to the world capital supply $K_1 + K_2 = N_1 + N_2$ yields the following market clearing condition:

$$N = N_1 + N_2 = \left[\frac{\xi_1 \alpha (1-c_1)^\beta c_1 N_1^{1+\beta}}{r}\right]^{1/(1-\alpha)} + \left[\frac{\xi_2 \alpha (1-c_2)^\beta c_2 N_2^{1+\beta}}{r}\right]^{1/(1-\alpha)},$$

which, after some simple algebraic manipulations, allows us to express the rental rate of capital as follows:

$$r = \left[\Lambda_1(c_1)\frac{N_1}{N} + \Lambda_2(c_2)\frac{N_2}{N}\right]^{1-\alpha} \qquad \text{with} \qquad \Lambda_i(c_i) \equiv \left[\xi_i \alpha (1-c_i)^\beta c_i N_i^{\alpha+\beta}\right]^{1/(1-\alpha)} \tag{9}$$

Skill formation is governed as before by the condition $w_{ui} + c_i = w_{si}$ which, using expressions (6) and (9), can be rewritten as follows:

$$r = \alpha \left[\xi_1 (1-c_1)^{\alpha+\beta-1} c_1^{2\alpha-1} N_1^{\alpha+\beta}\right]^{1/\alpha} \left[(1-\alpha-\beta) - (1-\alpha)c_1\right]^{1/(1-\alpha)} \tag{10}$$

$$r = \alpha \left[\xi_2 (1-c_2)^{\alpha+\beta-1} c_2^{2\alpha-1} N_2^{\alpha+\beta}\right]^{1/\alpha} \left[(1-\alpha-\beta) - (1-\alpha)c_2\right]^{1/(1-\alpha)} \tag{11}$$

Conditions (10) and (11) can be solved for the rates of skill formation c_1 and c_2 as a function of r, which then allows us to solve for r^* using (9). Let r_1^a and r_2^a stand for the autarky rental rates of capital. In the Appendix, we prove the following result:

Proposition 2 (integration) *When $\alpha < 1/2$, there exists a unique equilibrium such that $r_2^a < r^* < r_1^a$. Furthermore, $c_1^* > c_1^a$ and $c_2^* < c_2^a$, i.e., the two countries diverge in terms of their skilled labor shares.*

[4]Stricly speaking, this only holds for an interior equilibrium involving a positive share of capital in both countries. Given our production function, this will always be the case since the marginal productivity of capital is infinite at zero.

Proposition 2 shows that capital mobility leads to capital export from the small to the large country, thereby raising the skilled labor share in the latter and reducing it in the former. Thus, capital market integration in the presence of capital-skill complementarities has the same effect on skilled shares than the 'brain drain', even when skilled labor is internationally immobile.

3 Conclusions

We analyzed the impacts of capital market integration on skill formation in the presence of horizontally heterogeneous skills and capital-skill complementarities. In autarky, the large country has a higher skilled labor share than the small country which, due to capital-skill complementarities, leads to a higher autarky rental rate of capital in the large country. Therefore, when capital markets become internationally integrated, capital moves from the small to the large country. This reallocation modifies the payoffs to the acquisition of skills, thereby increasing the skilled labor share in the large country and decreasing that same share in the small country. Hence, capital mobility may be an important explanation of the growing skill gap since it gives rise to a 'brain drain' without migration.

References

[1] Baldwin, R. E. and P. Krugman (2004) Agglomeration, integration and tax harmonization. *European Economic Review* 48, 1-23.

[2] Barro, R. J. and J.-W. Lee (2001) International data on educational attainment: updates and implications, *Oxford Economic Papers* 3, 541-563.

[3] Borjas, G.J. (1999) The economic analysis of immigration. In Ashenfelter, O. and D. Card (eds.), *Handbook of Labor Economics vol.3*, Elsevier: North-Holland, pp.1697-1761.

[4] Docquier, F. and H. Rapoport (2004) Skilled migration: the perspective of developing countries. Policy Research Working Paper Series #3382, The World Bank.

[5] Duranton, G. and D. Puga (2004) Micro-foundations of urban agglomeration economies. In Henderson, J.V. and J.-F. Thisse (eds.), *Handbook of Regional and Urban Economics, vol.4*, Elsevier: North-Holland, pp. 2063-2117.

[6] Ethier, W.J. (1982) National and international returns to scale in the modern theory of international trade, *American Economic Review* 72, 389-405.

[7] Hamilton, J., J.-F. Thisse and Y. Zenou (2000) Wage competition with heterogeneous workers and firms, *Journal of Labor Economics* 18, 453-472.

[8] Krugman, P.R. (1980) Scale economies, product differentiation and the pattern of trade, *American Economic Review* 70, 950-959.

[9] Ottaviano, G.I.P. and R. Forslid (2003) An analytically solvable core-periphery model, *Journal of Economic Geography* 3, 229-240.

[10] Ottaviano, G. I. P. and T. van Ypersele (2005) Market size and tax competition. *Journal of International Economics* 67, 25-46.

[11] Rosenthal, S. and W. C. Strange (2004) Evidence on the nature and sources of agglomeration economies. In Henderson, J.V. and J.-F. Thisse (eds.), *Handbook of Regional and Urban Economics, vol. 4*, Elsevier: North-Holland, pp. 2119-2171.

[12] Sato, Y. and J.-F. Thisse (2005) Competing for capital when labor is heterogeneous, *CORE Discussion Papers* 2005/61.

[13] Wildasin, D. E. and J. D. Wilson (2004), Capital tax competition: bane or boon?, *Journal of Public Economics* 88, 1065-1091.

[14] Wilson, J. D. (1999) Theories of tax competition, *National Tax Journal* 52, 269-304.

[15] Zodrow, R. G. (2003) Tax competition and tax coordination in the European Union, *International Tax and Public Finance* 10, 651-671.

Appendix: Proof of Proposition 2

Proof. Let $c_i \equiv c_i(r)$ stand for the solution to (10) and (11). Clearly

$$\lim_{r\to 0} c_i = \frac{1-\alpha-\beta}{1-\alpha} > 0 \qquad \text{and} \qquad \lim_{r\to+\infty} c_i = 0.$$

Differentiating the skill formation condition (10) or (11) yields:

$$\frac{\mathrm{d}c_i}{\mathrm{d}r} = \frac{r}{\alpha}\left[\frac{1-\alpha-\beta}{1-c_i} + \frac{2\alpha-1}{c_i} - \frac{(1-\alpha)^2}{(1-\alpha-\beta)-(1-\alpha)c_i}\right].$$

It can be readily verified that

$$\frac{1-\alpha-\beta}{1-c_i} - \frac{(1-\alpha)^2}{(1-\alpha-\beta)-(1-\alpha)c_i} < 0.$$

which, together with $\alpha < 1/2$, establishes that $\mathrm{d}c_i/\mathrm{d}r < 0$.

Substituting $c_i = c_i(r)$ into (9), we obtain an equation that can be solved for the equilibrium rental rate r^*. It is readily verified that

$$\frac{\mathrm{d}\Lambda_1}{\mathrm{d}r} = \frac{\mathrm{d}\Lambda_1}{\mathrm{d}c_1}\frac{\mathrm{d}c_1}{\mathrm{d}r} < 0 \qquad \text{and} \qquad \frac{\mathrm{d}\Lambda_2}{\mathrm{d}r} = \frac{\mathrm{d}\Lambda_2}{\mathrm{d}c_2}\frac{\mathrm{d}c_2}{\mathrm{d}r} < 0.$$

Since $\Lambda_1(0) > 0$, $\Lambda_2(0) > 0$, and $\lim_{r\to\infty}\Lambda_1 = \lim_{r\to\infty}\Lambda_2 = 0$, the existence of a unique value r^* is guaranteed. Note further that, since (7) implies that $r_2^a < r_1^a$, only three cases may arise: (i) $r^* < r_2^a < r_1^a$; or (ii) $r_2^a < r_1^a < r^*$; or (iii) $r_2^a < r^* < r_1^a$. We now show that cases (i) and (ii) are impossible. Thus, since an equilibrium exists when $\alpha < 1/2$, case (iii) must hold.

Assume that (i) holds. Since the skill formation conditions (10) and (11) hold under both autarky and capital market integration, it is clear that $c_1^* > c_1^a$ and $c_2^* > c_2^a$ (recall that $\mathrm{d}c_i/\mathrm{d}r < 0$). Hence

$$\begin{aligned} r^* = \left[\Lambda_1(c_1^*)\frac{N_1}{N} + \Lambda_2(c_2^*)\frac{N_2}{N}\right]^{1-\alpha} &> \left[\Lambda_1(c_1^a)\frac{N_1}{N} + \Lambda_2(c_2^a)\frac{N_2}{N}\right]^{1-\alpha} \\ &= \left[(r_1^a)^{1/(1-\alpha)}\frac{N_1}{N} + (r_2^a)^{1/(1-\alpha)}\frac{N_2}{N}\right]^{1-\alpha} > r_2^a, \end{aligned}$$

Assume next that (ii) holds. From the skill formation conditions, $c_1^a > c_1^*$ and $c_2^a > c_2^*$ must hold in this case. We hence have

$$r^* = \left[\Lambda_1(c_1^*)\frac{N_1}{N} + \Lambda_2(c_2^*)\frac{N_2}{N}\right]^{1-\alpha} < \left[(r_1^a)^{1/(1-\alpha)}\frac{N_1}{N} + (r_2^a)^{1/(1-\alpha)}\frac{N_2}{N}\right]^{1-\alpha} < r_1^a,$$

which proves that this case cannot arise either. Existence of an equilibrium then makes sure that case (iii) must hold.

Finally, since $\mathrm{d}c_i/\mathrm{d}r < 0$, $r_1^a > r^*$ implies that $c_1^* > c_1^a$ and $r^* > r_2^a$ implies that $c_2^a > c_2^*$, which proves our result. ■