APPENDIX **A**

Emigration Losses in a Model with Specialized Skills

There are two classes of inputs in our model: skilled and unskilled workers.[1] Unskilled workers (L) are perfectly substitutable for one another, but each skilled worker has a unique skill that differentiates him or her from peers. As a result, each skilled worker (indexed $i = 1$ to N) sells a level of skilled services, s^i, in monopolistically competitive skills markets to a competitive final goods industry. We do not explore how the number of specialists are determined before immigration but assume that there are fixed costs to becoming a specialist, thereby limiting their number.

The aggregate production function for competitively supplied final output is of the following form:[2]

$$Y = L^{1-\alpha}\sum_{i=1}^{N} s_i^{\alpha}, \tag{A-1}$$

where $0 < \alpha < 1$, and α is a measure of how easily one specialist can be substituted for another, with low values of α implying low degrees of substitutability.

1. In this appendix we adapt Romer's (1993) model of the welfare costs of trade restrictions on specialized intermediate capital inputs to explore the loss from the emigration of skilled specialists.

2. Introduced by Ethier (1982).

Differentiating (1) with respect to skill level i gives the inverse demand curve for that skill:

$$\text{(A-2)} \qquad \frac{\partial Y}{\partial s_i} = p(s_i) = \alpha L^{1-\alpha} s_i^{\alpha-1}.$$

Each skilled specialist chooses the price that maximizes profits given a constant cost, c, per unit of skill services provided. For simplicity, we think of c as being the monetary equivalent of the disutility of working, and thus it is not a source of income for any other actor in the economy. The optimal price and output for skill provider i are then given by

$$\text{(A-3)} \qquad p_i^* = \frac{c}{\alpha}$$

and

$$\text{(A-4)} \qquad s_i^* = \alpha^{\frac{2}{1-\alpha}} c^{\frac{-1}{1-\alpha}} L.$$

Since all skilled specialists face identical demands and costs, we can drop the i subscripts. And with each skill specialist supplying an identical skill level, s, we can rewrite the aggregate production function simply as

$$\text{(A-5)} \qquad Y = L^{1-\alpha} N s^{\alpha}.$$

We now conduct the standard experiment of removing a number of the skilled specialists, E, through emigration and observe what happens to the income of TRBs. Before the emigration takes place, TRBs receive that entire national output (Y_0) less the total revenue that is being paid to the soon-to-be emigrants. After the emigration, TRBs receive the entire national output (Y_1) that is produced with the now smaller skilled labor force. As usual, we measure the loss to TRBs as a fraction of the total skilled wage bill, which in this case is equal to the revenue of the entire set of skilled specialists ($N \times p \times s$):

$$\text{(A-6)} \qquad \frac{Loss}{Nps} = \frac{Y_0 - Eps - Y_1}{Nps} = \frac{L^{1-\alpha}s^{1-\alpha}}{p} - \frac{E}{N} - \frac{L^{1-\alpha}s^{1-\alpha}}{p}\left(\frac{N-E}{N}\right).$$

If we substitute using (3) and (4) and rearrange, we obtain a very simple expression for the loss to TRBs as a fraction of the preemigration total wage bill:

$$\frac{Loss}{Nps} = \left(\frac{1}{\alpha} - 1\right)\frac{E}{N}. \tag{A-7}$$

The first term on the right-hand side is equal to the proportionate markup applied by each of the profit-maximizing skill specialists. The second term is the emigration rate. Suppose, for example, that α is equal to 0.5, so that firms apply a 100 percent markup to their unit costs, *c*. In this case, the loss as a fraction of the (preemigration) wage bill is exactly equal to the emigration rate. That is, a 10 percent emigration rate leads to an income loss to TRBs equal to 10 percent of the (preemigration) wage bill. Although the model is highly simplified and the chosen markup is just illustrative, this calculation does hint that the losses sustained could be much greater than in a competitive skill market.

APPENDIX **B**

Effects of the Brain Drain on Institutions of Higher Education

The institutional consequences of international human capital flows can be illustrated by their effects on institutions of higher education, the source of future human capital. To assess these effects, we posited a closed economy with a faculty-to-student ratio (akin to a capital-to-output ratio) of x:y where $t = 0$. The attrition rate in the faculty is f(x), and a certain part of the student output, $F(y)$, becomes new faculty. In time period $t = 1$, the new stock of faculty, x^*, can be expressed as

$$x - f(x) + F(y) = x^*.$$

Assuming a constant faculty-to-student ratio, if

$f(x) > F(y)$, $y^* < y$,
$f(x) < F(y)$, $y^* > y$, and
$f(x) = F(y)$, $y^* = y$.

Note that y is a variable with both a quantity and quality dimension. Long-term growth for a developing country requires $y^* > y$ both in quantity and quality. If this is the case, then $F(y)$ cannot be a random draw from the pool of y; the average quality of $F(y)$ must be greater than the median quality of y.

In an open economy with out-migration of human capital, $f(x)$ would initially increase, and $F(y)$ would decline. The attrition rate, $f(x)$, would increase both because the opportunity cost of teaching would increase (since wage convergence is greater in tradables than in nontradables) and because international migration implies that the mobile factor may be able to secure greater rents. On the other hand, $F(y)$ would decline, inasmuch as a computer science graduate from an elite educational institution is much less likely to consider teaching as a career; his or her nonteaching salary is being set globally, but teaching salary is still being set locally. If $y^* > y$, but only on the quantity dimension, either the ratio x:y must decline or the quality of the pool from which $F(y)$ is drawn must decline. In either case, y^* is likely to decline in quality. A society needs good teachers to produce even moderate quality in large numbers whether or not they are engaged in research.

APPENDIX C

Open Economy Effects

As noted in chapter 4, the most widely used framework for investigating how changes in factor endowments affect an open economy is the Heckscher-Ohlin model. In a small open economy facing given terms of trade and internationally equalized factor prices, and using the same technologies as its trading partners, the emigration of skilled workers will reallocate resources away from skill-intensive sectors. But in contrast to our closed-economy benchmark model, this one assumes no change in the skilled wage or any other factor price. Hence the model predicts that emigration shrinks a skill-intensive sector such as software but does not harm the welfare of TRBs as factor incomes are unchanged. The mechanism at work is that described in the famous Rybczynski theorem: output is reallocated away from the skill-intensive sector until the demand for skill is reduced to match the shrunken supply.

Few governments around the world would be sanguine about the shrinkage of skilled-labor pools even if they were convinced that current factor prices are not affected. Part of the reason may be that policymakers believe high-tech sectors such as software—especially at the more innovative end of the industry spectrum—generate ample opportunities for learning-by-doing and knowledge spillovers.[1] Thus our shift to an open economy setting moves attention away from current income losses

1. For arguments along these lines, see Lucas (1993).

incurred by those remaining behind (TRBs) to shifts in the allocation of remaining resources to industries with lower growth potentials.

Daniel Trefler's work with a variety of trade models challenging the myth of an immigration surplus may shed some light on the question of whether an emigration surplus exists in an open economy.[2] Trefler's results show that an emigration surplus loss is present in a specific factors trade model, whether skilled workers are the mobile factor or one of the specific factors. He also shows that Heckscher-Ohlin results change when technologies differ across countries. Interestingly, it does matter whether the technological (or productivity) differences are inherent in workers (hence any technological backwardness will travel with them) or in countries (which means an emigrating worker can leave the backwardness behind). When technology differences are inherent in workers, says Trefler, the standard Heckscher-Ohlin results are not affected as factor price equalization occurs for productivity-adjusted factor prices. This is not true when technology differences are specific to countries, as emigration leads to favorable movements in the terms of trade and an increase in the welfare of TRBs.

A recent assessment of how balanced flows of factors affect an economy with a superior CRS technology has come to the following conclusion: to the extent that the resulting increased size of the economy leads to a worsening of its terms of trade, the balanced inflow of productive factors leads to lower welfare.[3] The United States, it seems, has been made *worse off* because of its openness to foreign capital and workers. On the sending side, a balanced outflow of factors will lead to an improvement in welfare, provided it is large enough for its terms of trade to change. A welfare loss to the sending country could reemerge if the factor outflows (for example, all skilled workers) are unbalanced, or if there are adverse fiscal effects.

2. Trefler (1997).

3. Davis and Weinstein (2002); their work focuses mainly on the United States. See also Trefler (1997).