On the Mechanics of Trade-Induced Structural Transformation

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Abstract

Gains from trade come from a certain amount of specialization among(?) trade partners. Specialization in the case of an agriculture-based developing country might be feared to imply a higher reliance than ever on low skill labor. Trade might thus be seen as a step away from the much awaited structural transformation of the economy, which can only come with increases in agricultural productivity. In this paper, we suggest that it needs not be the case. We show that trade openness can in fact trigger the structural transformation of such an agrarian society. It can induce a higher reliance on human capital accumulation and produce the necessary productivity gains for an economy to pick up. Our dynamic general equilibrium model provides a clear illustration of the mechanics behind structural transformation. (F16, J21,J22, O11,O24)

Key words. Trade openness, skill-supply, agricultural extension services, general equilibrium.

1 Introduction

Many developing countries depend heavily on agricultural commodities for export earnings, particularly those from Sub-Saharan Africa (UNCTAD 2003). From the view-point of traditional trade theory, gains from trade come from specialization in goods for which a country has a comparative advantage. This should spell optimism, not pessimism, among development's planners. Yet for agriculture-based developing countries, public discussions of specialization point to the negative impact the dependence on agricultural exports has on their development process (UNCTAD 2003). Excessive price fluctuations associated with primary agricultural products have been exposed as impediments to gains from specialization for these countries. For example, UNCTAD estimates that in 1999-2002 coffee producers would have earned US$ 19 billion more, sugar producers US$ 1.4 billion more and cotton producers US$ 1 billion more, had world's prices stayed at the average 1998 level.

Notwithstanding the above, the main issue facing agriculture-based countries, as a group, has been to decide what to negotiate for in multilateral trade talks. Should trade negotiations with manufacturing-based countries focus on the design of mechanisms to reduce excessive price fluctuations of agricultural commodities– thereby preserving specialization as a feature of North-South trade–? Or, should they focus instead on increased diversification of their exports base to include manufacturing products? For the second of these two options–which often requires temporary protection–, the case in point is that diversification is viewed as essential to the process of economic development of agriculture-based countries. This however comes with the proviso that temporary protection necessary to launch the new industries can become permanent (Matsuyama, 1990), due to government failure (Krueger, 1996). What is more, whatever a country diversifies into, there is the likelihood of other countries doing the same (UNCTAD 2003). This rush toward diversification may result in depressed world prices, thereby lowering gains from trade. Hence the specialization-diversification dilemma facing agriculture-based developing countries. It is important that this dilemma be resolved so as to clarify the issues these countries should focus on in multilateral trade negotiations. Can specialization be a driving force of economic development in an agriculture-based country? In other words, in absence of excessive price fluctuations, can reliance on agricultural commodities as a source of export earnings enhance the development process of such a country?

These questions are crucial to consider because today's developing countries farmers, more than their predecessors of the beginning of the twentieth century are under increased pressure to make judicious choices regarding crop selection, inputs use, quality control, pre- and post-harvest technologies. Responding to such pressure in a way that leads to on-farm productivity growth requires the provision of support services needed to guide their decisions (The World Bank 1997). Hence the importance of agricultural extension.[1]

As a services provision sector, agricultural extension relies intensively on skilled labor–agronomists and agricultural technicians– for the design and transfer of organizational methods, management systems, production and marketing technologies. The development of the extension services sector is therefore of prime importance for agriculture-based developing countries. Yet, in these countries, shortage of skill supply seriously limit the availability of quality extension service to farmers, which in turn limits on-farm productivity growth. To the extent that structural transformation involves sustained growth in the relative proportion of skilled labor, can trade-induced specialization in agriculture enhance the development process of agrarian economies?

In this paper, we formalize this idea using a three-sector intertemporal general equilibrium model. For the small agriculture-based economy we consider, trade openness has three direct effects. First, it lowers the relative price of the import-competing good, and pools both physical capital and skilled labor out of the import-competing sector. The skilled labor thus released may be absorbed by the extension service sector, while the released physical capital moves into the farming sector, as a complementary input to agricultural extension services. Second, it unleashes a process of

[1] Agricultural extension encompasses a range of services aimed at expanding farmers' exposure to effective organization and management skills, and to new technologies. It focuses on helping farmers master techniques and socioeconomic knowledge necessary to the improvement of the productivity of their farms.

capital-augmenting technical change that reduces the importance of unskilled labor relative to physical capital in farming. This causes farmers to substitute capital for unskilled labor as the demand for agricultural extension services rises. Third, trade-induced specialization causes the return to skill investment to rise, thus leading to an increase in the supply of skilled labor in the long-run. Section 2 presents a selective review of the literature on trade openness and factor accumulation. Section 3 presents the model, which is then solved in sector 4. Concluding remarks in section 5 close the paper.

2 Selective Literature Review

Sustained growth in per capita income involves a structural transformation of the economy, an important feature of which is the change in the skill composition of the labor force. For initially skill-scarce countries, static trade models predict that trade liberalization will cause a fall in the return to skill. This prediction raises the question of whether, in the long-run, and for an initially skill-scarce country, trade openness will cause this scarcity to persist. Efforts to address this question have essentially pitted two strands of the theoretical literature on trade openness and skill-supply dynamics. Contributions in the first strand include works by Findlay and Kierzkowski (1983), Matsuyama (1992), and Stokey (1996). These authors argue that trade openness for an initially skill-scarce country will cause the scarcity of skills to persist in the long run. By contrast, the second strand of this literature, including contributions by Cartiglia (1997), Eichers (1999), and Ranjan (2001) overturn this prediction.

A common point in the second strand of this theoretical literature is the emphasis on the link between the costs of skill accumulation (including payments of education fees) and the skilled labor wage. Since it takes skilled individuals to impart skills, a rise in the skilled labor wage has an adverse effect on skill-investment in the presence of credit constraints, because it raises education costs. These authors argue that trade openness for an initially skill-scarce country can correct this adverse credit-constraint effect, by inducing a fall in the skilled labor wage. This fall, in turn, by causing education costs to fall, leads to an increase in the proportion of individuals who invest in education. The result, they argue, is an increase in the supply of skilled labor in the long-run. However, since trade also induces a contraction of the import-competing sector, which is intensive in skilled-labor use, this prediction implies that the long-run increase in the supply of skilled labor will fail to benefit the export sector, which, by contrast, is intensive in unskilled labor. Indeed, trade-openness in these models seems to lead to growth in the education sector at the expense of the rest of the economy (namely the import-competing sector and the export sector): teachers are hired just to train future teachers. In our model, the increase in the supply of skilled labor benefits the export sector in two ways. First, it leads to greater use of extension services in farming. Second, the increase in the supply of extension services brought about by the increase in the skilled labor supply triggers a process of agricultural transformation whereby physical capital substitutes for unskilled labor in farming. Furthermore, models in that category appear to be at odd with existing empirical evidence regarding the link between trade openness and the skill-premium, because they imply a decrease is the skill-premium (understood as the ratio of the skilled labor wage over the unskilled labor wage). Yet for many trade-liberalizing developing countries (including Brazil), available evidence reveals rising skilled labor supplies accompanied by non-declining (instead of declining) skill-premia (Robbins 1996; Arbache, Dickerson and Green, 2004).[2] Unlike this literature, we obtain a positive association between trade openness and skill supply that is consistent with this empirical evidence. Our model retains some features of the second group of trade and factor accumulation models, except for four main features. First, unlike Cartiglia (1997), Eichers (1999) and Ranjan (2001), our non-traded sector produces an input for the export (not the import-substituting) sector. Second, education costs are unrelated to the domestic skilled labor wage. In fact, in our model, education only has an opportunity cost, which is composed in part by the forgone unskilled labor wage from investing in education. Third, capital and unskilled labor are perfect substitutes in farming (the export sector), which creates a basis for a process agricultural trans-

[2]Other related contributions include Acemoglu (2002, 2003), and Desjounqueres, Machin and Van Reenen (1999).

formation . Fourth, the availability of agricultural extension services increases the importance of physical capital relative to unskilled labor in farm production. These four features highlight our main contribution to this literature.

3 Model

Assume a small three-sector economy in which economic activities extend over an infinite number of periods. It operates in discrete time t. There are two final goods: a commercial crop (good a) which we take as the numeraire, and an import-competing good (good m). Both final goods are tradable. In addition, there is an intermediate good (good x), which is used as an input into the production of the good a. This intermediate good is non-tradable. We interpret the nontrabable good sector as the extension services sector, which provides technology-based solutions for relaxing on-farm yield constraints. The output of this sector is simply referred to as agricultural extension services.

At the beginning of every period, a new generation of two period-lived heterogenous agents is born. In every period, a generation of old agents coexists with a generation of young agents. There is no population growth, and each generation has total population size normalized at unity. In their first period, all agents must decide whether to invest in skill accumulation or to supply unskilled labor to firms from that period on. In their second and last period, agents supply labor to firms in exchange for a wage, ω_i, depending on their skill status i $(i = s, u)$. An old agent with skill status $i = s$ (respectively $i = u$) will be called a skilled (respectively an unskilled) agent.

Young agents are each endowed with a level of physical capital, k, which they rent out to firms in the beginning of the first period, at a market price r. They differ in their respective endowments of physical capital, and are distributed across physical capital levels according to a cumulative function, Ψ, with strictly positive p.d.f., ψ, over the bounded support, $\left[\underline{k}, \bar{k}\right]$, $0 \leq \underline{k} < \bar{k} < \infty$. This difference in physical capital endowment is the only source of inequality in this environment.

Let e be a binary variable which takes the value $e = 1$ if a young individual decides to invest in skill accumulation, and $e = 0$ if he elects to supply unskilled labor to firms. A young agent who plays the strategy $e = 0$, supplements his capital income with an unskilled labor income in the first period, and will remain an unskilled worker throughout his entire lifetime. In contrast, an agent who plays the strategy $e = 1$ will forgo income from unskilled labor in the first period, in order to receive a skill-enhancing education, and so becomes a skilled worker in his second and last period of life. All education costs are due to opportunity costs.

Let $y_\tau(e, k)$ denote the period τ income for an agent who makes the decision e

when he is endowed with k units of capital:

$$y_\tau(e,k) = \begin{cases} rk + (1-e)\,\omega_u & \text{for } \tau = t \\ e\omega_s + (1-e)\,\omega_u & \text{for } \tau = t+1 \end{cases}$$

where τ indexes the agent's life periods.

Let p_j denote the relative price of good j $(j = m, x)$. In each period, a typical individual divides his income between consumption of good a (denoted as C_a) and of good m (denoted as C_m). The utility function representing agents' preferences is given by

$$\sum_{\tau=t}^{t+1} \beta^{\tau-t} \ln c_\tau, \qquad 0 < \beta \leq 1, \tag{1}$$

where β denotes a time-discounting factor, and $c_\tau = (C_{a\tau})^\mu (C_{m\tau})^{1-\mu}$, $0 < \mu < 1$. Agents choose their occupational strategy (e) by anticipating the consequences this choice will have on their life-time utility which in turn depends on how much they consume in every period. By backward induction, forward-looking agents first determine their optimal life-time utility given their occupational choice decision, then they choose the occupational strategy that yields the highest life-time utility.

Given an agent's occupational strategy (e) and his endowment of physical capital (k), his periodic budget constraint are given by $C_{a\tau} + C_{m\tau} \leq y_\tau(e,k)$. Given the above specification of the utility function, in each period demand is Cobb-Douglas:

$$C_{a\tau} = \mu y_\tau(e,k), \qquad \tau = t, t+1 \tag{2}$$

$$C_{m\tau} = (1-\mu)\frac{y_\tau(e,k)}{p_m}, \qquad \tau = t, t+1 \tag{3}$$

and $\mu \in (0,1)$, where p_m denotes the relative price of good m–the import-competing final good. The above demand schedules will prove useful for characterizing skilled and unskilled labor supplies.

3.1 Agents' Occupational Choices

At any date t, the supply of skilled labor is given by the total proportion, η_{st}, of skilled individuals. This figure equals the total proportion of agents who chose to invest in skill when young. Since all young agents are forward-looking, in choosing their occupation, they balance the discounted future benefits against present education costs.

Let $V(e,k,M_t)$ denotes the indirect life-time utility of a young agent who makes the investment decision, e, in the first period, when he is endowed with a level of physical capital, k, and the state of the world is given by the vector $M_t = (r_t, \omega_u, \omega_{st+1}, \omega_{ut+1}, p_m)$. From (1), substituting in (2) and (3), yields

$$\begin{aligned} V(e,k,M_t) &= \ln\left[r_t k + (1-e)\,\omega_{ut}\right] + \beta \ln\left[e\omega_{st+1} + (1-e)\,\omega_{ut+1}\right] \\ &\quad - (1+\beta)(1-\mu)\ln p_m + R, \end{aligned} \tag{4}$$

where R denotes a residual term. Thus, a young agent will choose to invest in skill-enhancing education if and only if his endowment, k, of physical capital satisfies

$$V(1,k,M_t) > V(0,k,M_t),$$

and will choose to take employment as an unskilled worker, instead, if and only if it satisfies

$$V(1, k, M_t) < V(0, k, M_t).$$

Let $\vartheta(k, \theta_t, \pi_{t+1}) = V(1, k, M_t) - V(0, k, M_t)$ denote the net value gain an agent derives from investing in skill in the first period, when he is endowed with a level of physical capital k, and faces an opportunity cost of education, $\theta_t = \omega_{ut}/r_t$ and a next period skill-premium given by $\pi_{t+1} = \omega_{st+1}/\omega_{ut+1}$. Using Eq. (4), it can be established that

$$\vartheta(k, \theta_t, \pi_{t+1}) = \ln\left[\frac{k}{k + \theta_t}\right] + \beta \ln \pi_{t+1}. \tag{5}$$

Clearly, the net value gain from investing in skill rises with the agent's physical capital endowment, k, or with the future level of the skill-premium, π_{t+1}, ceteris paribus. In contrast, this net value gain from skill investment decreases with a rise in the opportunity cost of this investment.

Since ϑ is increasing in k, young agents who benefit from investing in skill are necessarily those endowed with a level of physical capital higher than the threshold, k_t^*, which is solution to the equation $\vartheta(k, \theta_t, \pi_{t+1}) = 0$. Using Eq.(5), we therefore obtain k_t^* as follows:

$$k_t^* = \frac{\theta_t}{(\pi_{t+1})^\beta - 1}.$$

To simplify the analysis, assume without loss of generality that $\beta = 1$. Furthermore, as π_{t+1} tends to $+\infty$, $\theta_t / (\pi_{t+1} - 1) \to \theta_t / \pi_{t+1} = 1/R_t$, where

$$R_t = \frac{\pi_{t+1}}{\theta_t} \tag{6}$$

denotes a measure of the return to education. Hence the threshold endowment of physical capital can be reduced to

$$k_t^* = \frac{1}{R_t}, \qquad \text{all } t. \tag{7}$$

Eq. (7) states that the threshold endowment of physical capital is approximately the inverse of the return to education.

Since $\Psi(k_t^*) = \Psi(1/R_t)$, the total number, n_t, of young agents who will become skilled individuals in their second period of life is given by

$$n_t = 1 - \Psi(1/R_t), \tag{8}$$

all $t = 0, 1, ...$ Given the properties of the function, Ψ, it follows from Eq. (7) that any exogenous factor that raises the return to education, R_t, tends to cause an increase in the proportion, n_t, of young agents who choose to forgo unskilled-labor income in order to invest in skill-enhancing education:

$$\frac{\partial n_t}{\partial R_t} > 0.$$

However, in a general equilibrium, the return to education, R_t, will also adjust to changes in n_t, and we must take this into consideration when analyzing the effects of trade openness in this initially skill-scarce, agriculture-based economy.

Recall that given our normalization of the population size of this economy, in period t, the total supply of skilled labor is given by the proportion of agents who chose to invest in skill-accumulation in period $t-1$. In contrast, the total supply of unskilled labor in period t, is composed of two different generations of agents: old agents who did not invest in skill-accumulation in period $t-1$ (in total number $1-n_{t-1}$), and young agents who elect to work from period t on (in total number $1-n_t$). Therefore, letting η_{it} denote the total supply of labor of quality i ($i = s, u$) in period t, it follows that

$$\eta_{st} = n_{t-1} \tag{9}$$

$$\eta_{ut} = 2 - n_t - n_{t-1}, \tag{10}$$

$t = 0, 1, ...$

Structural transformation in this economy therefore is captured by the law of motion for η_{it} as determined by the law of motion of n_t. To characterize this law of motion, we explicitly model the supply side of the economy.

3.2 Production and Factor Prices

In this subsection, we describe the production technologies for all goods produced in this economy. For convenience we temporarily drop the time subscript, except when absolutely necessary.

A. Production of the import-competing good

Production of the import-competing good requires physical (K_m) and skilled labor (S_m). Output in this sector is described by a constant-return-to-scale technology:

$$Y_m = (K_m)^{\alpha} (S_m)^{1-\alpha}, \qquad \alpha \in (0,1)$$

Profit-maximization by perfectly competitive firms leads to the following factor demand schedules:

$$\omega_{sm} = (1-\alpha) p_m \left(\frac{K_m}{S_m}\right)^{\alpha} \tag{11}$$

$$r_m = \alpha p_m \left(\frac{K_m}{S_m}\right)^{\alpha-1}. \tag{12}$$

B. The research and extension services sector

This sector produces extension services, using skilled labor only.[3] Workers in this sector are agronomists and/or agricultural technicians. They technically assist

[3] In our model, agricultural extension services are assumed to be privately provided. In areas dominated by commercial farming, private sector involvement in the provision of extension services seems to be a natural mechanism for addressing farmers' services needs in ever-changing agro-ecological environments (World Bank, 1997). With the increased commercialization of agriculture in many developing countries, it seems therefore appropriate to assume a private provision of extension services. In practice, many developing countries, often with the help of The World Bank, have created competitive private-sector network of extension consultants to deliver inputs and technology to private farmers (Schultz et al., 1996). Umali-Deininger (1996) also documents the involvement private consulting firms in the provision of extension services in countries such as Argentina, Brazil, Colombia, Mexico, Uruguay, Korea, and Taiwan.

farmers in raising on-farm productivity. The representative firm's output, Y_x, thus is given by:

$$Y_x = (S_x)^{1-\alpha}. \tag{13}$$

Profit maximization in this non-tradable sector leads to:

$$\omega_{sx} = (1-\alpha)\, p_x\, (S_x)^{-\alpha}, \tag{14}$$

where p_x denotes the relative price of extension services. Assuming skills are perfectly transferable across sectors, resource constraint in the skilled labor market is given by: $S_m + S_x \leq \eta_s$.

C. The farming sector

Extension service has been an important input for agricultural development in most developing countries (Evenson and Mwabu, 1998; Hoddinott et al. 2004), along with capital, land and labor. To keep the focus on the importance of extension services, we abstract away from land as an input into farming. Farming essentially requires the use of agricultural extension services (X), physical capital, K_a, and unskilled labor, U. For the functional form of the production technology in farming, we draw from Jeremy Greenwood and Ananth Seshadri (2002) and from Per Krusell et al. (2000). In particular, physical capital and unskilled labor are perfect substitutes and have unit elasticity of substitution with agricultural extension services (input X):

$$Y_a = X^{1-\alpha} \left[\phi\left(\bar{X}\right) K_a + U\right]^{\alpha}, \tag{15}$$

where $\bar{X}$ denotes the total supply of extension services, and $\phi\left(\bar{X}\right)$ denotes the positive effect the availability of agricultural extension services has on the productivity of the physical capital input. For simplicity, we set

$$\phi\left(\bar{X}\right) = \bar{X}^{\varepsilon}, \qquad 0 < \varepsilon < 1 \tag{16}$$

Eq.(15) implies that input X is complementary to the composite input $\phi\left(\bar{X}\right) K_a + U$. In equilibrium, demand equals supply: $X = \bar{X}$.

Since good X is non-tradable, domestic market-clearing implies that

$$X = Y_x. \tag{17}$$

Under perfect competition, profit-maximization leads to the following factor demand schedules:

$$p_x = (1-\alpha)\left[\frac{\phi(X)K_a + U}{X}\right]^{\alpha} \tag{18}$$

$$\omega_u = \alpha\left[\frac{\phi(X)K_a + U}{X}\right]^{\alpha-1}, \tag{19}$$

$$r_a = \alpha\phi(X)\left[\frac{\phi(X)K_a + U}{X}\right]^{\alpha-1}. \tag{20}$$

Resource constraint in the physical capital market is given by:

$$K_a + K_m \leq K,$$

where

$$K = \int_0^1 k dk$$

denotes the aggregate stock of physical capital.

Since $\phi' > 0$, Eqs. (19) and (20) imply that growth in the stock of agricultural extension services will increase the marginal productivity of both physical capital and unskilled labor, but the magnitude of this increase is higher for physical capital than for unskilled labor, thus setting up a process of capital-augmenting technical change in agriculture.

4 Equilibrium Effects

In this section, we examine the effects of trade openness on the structure of the labor force, and their implication for the development of the extension services sector. In what follows we define an equilibrium in the context of an open small economy.

Definition 1. (Intertemporal Equilibrium) An intertemporal general equilibrium for this initially skill-scarce, agricultural-based, open economy is a sequence of factor prices, $\{p^*_{xt}, r^*_{at}, r^*_{mt}, \omega^*_{ut}, \omega^*_{sxt}, \omega^*_{smt}\}^{\infty}_{t=0}$, a sequence of threshold physical capital endowments, $\{k^*_t\}^{\infty}_{t=0}$, a sequence, $\{n^*_t\}^{\infty}_{t=0}$, of numbers of school-goers, a sequence of intersectoral allocation of production factors, $\{K^*_{at}, K^*_{mt}, S^*_{xt}, S^*_{mt}, U^*_t, X^*_t\}^{\infty}_{t=0}$, a sequence of returns to education $\{R^*_t\}^{\infty}_{t=0}$, and a sequence of relative supply of skilled labor and unskilled labor $\{\eta^*_{st}, \eta^*_{ut}\}^{\infty}_{t=0}$, such that for all t and given $\left(p_m, p^*_{xt}, \eta^*_{st}, \eta^*_{ut}, \eta^*_{st+1}, \eta^*_{ut+1}, \omega^*_{sxt}, \omega^*_{smt}, \omega^*_{ut}, K\right)$,

(i) $X^*_t = (S^*_{xt})^{1-\alpha}$, S^*_{xt} satisfies (14), S^*_{mt} satisfies (11), K^*_{at} satisfies (20), K^*_{mt}

satisfies (12), and U_t^* satisfies (19);

(ii) $\omega_{sxt}^* = \omega_{smt}^* = \omega_{st}^*$ and $r_{at}^* = r_{mt}^* = r_t^*$;

(iii) given (K_{at}^*, U_t^*, X_t^*), p_{xt}^* satisfies Eq.(18);

(iv) given $\left(p_m, p_{xt}, \eta_{st}^*, \eta_{ut}^*, \eta_{st+1}^*, \eta_{ut+1}^*, K\right)$, R_t^* satisfies Eq. (6), for all $t = 0, 1, ...$;

(v) given k_t^*, n_t^* satisfies

$$n_t = 1 - \Psi\left(k_t^*\right). \tag{21}$$

(vi) given $\left(p_m, \eta_{st}^*, \eta_{ut}^*, \eta_{st+1}^*, \eta_{ut+1}^*, K\right)$, k_t^* satisfies Eq. (7), for all $t = 0, 1, ...$;

(vii) η_{st}^* and η_{ut}^*, satisfy

$$\begin{aligned} \eta_{st}^* &= n_{t-1}^* \\ \eta_{ut}^* &= 2 - n_t^* - n_{t-1}^* \end{aligned}$$

for all $t = 0, 1, ...$;

(viii) all markets clear.

In a model like ours, the picture of the general equilibrium effects of trade openness can be quite blurry. To clarify this picture, we restrict attention to long-term effects by emphasizing the economy's behavior along the steady state.

Definition 2. (Steady State Equilibrium) A steady state equilibrium is a general equilibrium, which in addition satisfies $n_t^* = n_{t-1}^* = n^*$, all t, where n^* denotes the steady-state proportion of individuals who invest in skill.

Combining the definition of a steady state equilibrium, with conditions (iv) and (vi) of a general equilibrium, it follows that

$$n^* = 1 - \Psi\left(k_t^*\right) \tag{22}$$

which implies that $k_t^* = k^*$ along the steady state. This in turn, implies that the return to education, R_t^*, is constant along the steady state: $R_t^* = R^*$.

4.1 The Determinants of The Steady State Return to Education

In this subsection, we characterize the equilibrium return to education as defined in Eq.(6) along the economy's steady state. Under the assumption of intersectoral capital mobility, capital market clearing implies that the rental rate of capital will be equalized across sectors: $r_a = r_m = r$. Since there is also intersectoral mobility of skilled labor, skilled-labor market clearing implies that $\omega_{sx} = \omega_{sm} = \omega_s$.

Lemma 1. The demand for skilled labor in the non-tradable sector is given by

$$S_x = \bar{A}\left(p_m\right)^{-\delta}, \tag{23}$$

where $\delta = 1/\alpha\left(1-\alpha\right)\left(1-\varepsilon\right)$ and

$$\bar{A} = \left(1-\alpha\right)^{(1-\alpha)\delta}. \tag{24}$$

Proof. See appendix ■

Since $\delta > 0$, Lemma 1 implies that, a rise (a decline) in the relative price of the import-competing good causes the demand for skilled labor in the intermediate-good sector to decline (rise):

$$\frac{dS_x}{dp_m} < 0.$$

This is quite intuitive as both the import-competing sector and the extension services sector have a competing claim on the supply of skilled labor. Our next step is to characterize the steady-state return to education, E^*.

First, from the definition of the opportunity cost, substituting in (19) and (20), yields the steady-state opportunity cost of education as follows:

$$\theta^* = \frac{1}{\phi(X)}$$

Combining Eq.(16) with the extension services production function using market-clearing conditions and substituting in Eq. (23) yields:

$$\theta^* = \left(\bar{A}\right)^{-(1-\alpha)\varepsilon} (p_m)^{\bar{\delta}}, \tag{25}$$

where $\bar{\delta} = \delta\varepsilon(1-\alpha)$. Then, observe that for a small economy with initially a comparative advantage in the production of the agricultural good, trade openness (i.e., a decline in p_m) lowers the opportunity cost of education:

$$\frac{\partial\theta^*}{\partial p_m} > 0.$$

This is because trade openness triggers a process of technological progress that raises the importance of physical capital relative to unskilled labor in farming. Observe from (25) that growth in the economy-wide stock of physical capital has no effect on the opportunity cost of education. This result is a direct consequence of the assumption that physical capital and unskilled labor are perfect substitutes in farming.

We next turn to the characterization of the skill-premium. Recall that the skill-premium in wage is defined as the ratio of the skilled-labor wage over the unskilled-labor wage. As such, it measures the relative earnings of skilled workers. We can therefore characterize the steady-state skill-premium through the following lemma:

Lemma 2. The steady-state skill-premium is given by

$$\pi^* = \frac{\lambda}{n^*} \left[(p_m)^{-\bar{\delta}} K + (1 - n^*) \nu \right], \tag{26}$$

where

$$\lambda = \frac{(1-\alpha)}{\alpha} \bar{A}^{(1-\alpha)\varepsilon},$$

$$\nu = 2/\bar{A}^{(1-\alpha)\varepsilon}.$$

Proof. See appendix ■

For a small economy with initially a comparative advantage in the production of the agricultural good, the partial equilibrium effects of trade openness (i.e., a decline in p_m) on the skill-premium are unambiguously positive:

$$\frac{\partial \pi^*}{\partial p_m} < 0,$$

since $\bar{\delta} > 0$. In contrast, an exogenous increase in the supply of skilled labor, n^*, tends to reduce this skill-premium:

$$\frac{\partial \pi^*}{\partial n^*} < 0.$$

Furthermore, since

$$\frac{\partial \pi^*}{\partial K} > 0,$$

growth in the stock of physical capital will increase the skill-premium. This result follows from the assumption of perfect substitutability between physical capital and unskilled labor. Growth in the economy-wide stock of physical capital, by decreasing the cost of physical capital, induces the substitution of physical capital for unskilled labor in farming, thus causing the wage for unskilled labor to decline. Because growth in the demand for physical capital in farming raises the marginal productivity of agricultural extension services, demand for extension services will rise as a result of capital inflow in farming, thus leading to an increase in the skilled labor wage, as supply adjusts to demand. Hence the increase in the skill-premium.

From the definition of the return to education, Lemma 1 and Lemma 2 imply that the steady-state return to education is given by

$$E^* = \left[(p_m)^{-\bar{\delta}} K + (1 - n^*) \nu \right] (p_m)^{-\bar{\delta}} (n^*)^{-1} \bar{\lambda}, \tag{27}$$

where $\bar{\lambda} = \lambda \bar{A}^{(1-\alpha)\varepsilon}$. The partial equilibrium effects of trade openness on the return to education are straightforward. As can be seen from Eq.(27), the steady-state return to education tends to rise with trade openness (i.e., a decline in p_m):

$$\frac{\partial E^*}{\partial p_m} < 0,$$

and with a rise in the economy's stock of physical capital, K :

$$\frac{\partial E^*}{\partial K} > 0.$$

This implies that growth in the economy-wide stock of physical capital will increase the return to education, because it increases the skill-premium, without causing a decline in the opportunity cost of education. However, the return to education tends to decrease with an exogenous increase in the supply of skilled labor:

$$\frac{\partial E^*}{\partial n^*} < 0.$$

Therefore since n^* will adjust to changes in p_m, it follows that the general equilibrium effects of trade openness on the return to education are the sum of two different effects: a direct effect (i.e., $\partial E^*/\partial p_m$) and an indirect effect ($[\partial E^*/\partial n^*]\,\partial n^*/\partial p_m$).

4.2 Trade Openness and Skill-Accumulation

In this subsection, we focus on the long-term effects of trade openness on the supply of skilled labor for a small economy with initially a comparative advantage in the production of the agricultural good. Since the analysis is carried in the steady state, we first establish the existence and uniqueness of the steady state equilibrium.

From condition (22), substituting in Eq.(27) yields the following condition for the existence of a steady-state equilibrium:

$$n = f(n, p_m, K) \tag{28}$$

where

$$f(n, p_m, K) = 1 - \Psi\left[\frac{\bar{\lambda}^{-1}(p_m)^{\bar{\delta}}\, n}{\left[(p_m)^{-\delta} K + (1-n)\,\nu\right]}\right].$$

Observe that Eq.(28) is a well-defined fixed-point problem, owing to the properties of the function f.

A number of observations can be made from condition (28). First, since the domain of the function Ψ is bounded below by $\underline{k} \geq 0$, then $\Psi(0) = 0$, so that $f(0, p_m, K) = 1$. This implies that there does not exist a steady-state equilibrium with no skilled labor. In other words, any steady state equilibrium of this economy satisfies $n^* > 0$.

Second, to the extent that the lowest individual endowment of physical capital satisfies

$$\underline{k} < \frac{\bar{\lambda}^{-1}(p_m)^{2\bar{\delta}}}{K}, \tag{29}$$

clearly, $f(1, p_m, K) < 1$, implying that an equilibrium with no unskilled labor does not exist either. In other words, any equilibrium of this economy satisfies $0 < n^* < 1$.

Third, since the function Ψ is strictly increasing, clearly, by construction, f is strictly decreasing as a function of n and p_m, respectively. In contrast, f is strictly increasing as a function of the economy-wide stock of physical capital, K. Hence the Brower fixed-point theorem may be applied to establish the existence of a steady state equilibrium:

Proposition 1 Suppose $\underline{k}$ satisfies condition (29). Then, there exists a unique $n^* \in (0,1)$, such that $n^* = f(n^*, p_m, K)$, and

$$(i) \quad \frac{\partial n^*}{\partial p_m} < 0$$

$$(ii) \quad \frac{\partial n^*}{\partial K} > 0.$$

Properties (i) and (ii) of proposition 1 follow from a direct application of the Implicit function theorem. Property (i) states that in the long run, trade openness raises the supply of skilled labor in an initially skill-scarce agriculture-based country. This is because trade openness in such an economy, triggers a process of technical progress that increases the importance of physical capital use relative to unskilled labor use in farming. When this happens, the return to education rises, thus raising the number, n^*, of individuals who benefit from investing in skill-enhancing education. Crucial for this result is the assumption that physical capital and unskilled labor are perfect substitutes as farming inputs, while both are complementary to the extension services input.

Property (ii) states that an inflow of physical capital in the economy will increase the supply of skilled labor in the long run. There are two underlying reasons for this result. First, because of the substitutability between physical capital and unskilled labor in agriculture, an increase in the supply of physical capital causes a proportional decrease in the marginal productivity of each of the two inputs, thus leaving unchanged the opportunity cost of skill-investment. Second, because physical capital and agricultural extension services are complementary, a higher supply of physical capital increases the productivity of extension services, thus leading to an increase in the market demand for these services. Since extension services sector is intensive in skilled labor, in the long run, the rise in the demand for these services will increase the demand for skills, thus increasing the skill premium. Property (ii) is also consistent with the physical capital and skilled labor complementarity hypothesis prevalent in the literature on factor returns and accumulation (e.g., Krusell et al. 2000, Greenwood and Seshadri 2002).

5 Concluding Remarks

This paper examines the forces underlying the structural transformation of a small economy with initially a comparative advantage in the production of agricultural commodities. To explore the nature of these forces, we use a three-sector intertemporal general equilibrium model, with two final goods and one intermediate, non-tradable good. Our model identifies three main ingredient for a successful process of structural transformation. The first is the substitutability between physical capital and unskilled labor as inputs into farming. The second is a capital-augmenting process of technical change in farming induced by greater availability of agricultural extension services. Third is trade openness, which, in the long-run, lead to an increase in the relative supply of skilled labor. Structural transformation of an agriculture-based economy therefore involves the development of a skill-intensive extension services sector that induces the transformation of the farming sector, by reducing the importance of unskilled labor in farming. Without this reduction in the relative importance of unskilled labor in farming, trade openness will fail to act as an engine of structural transformation, because it will induce a decline in the return to skill investment. This in turn, will cause skill-scarcity to persist, thus impeding the development of the agricultural extension services sector, responsible for raising on-farm productivity (Evenson and Mwabu, 1998; Hoddinott et al. 2004). If trade-induced specialization in agriculture is to act as an engine of economic development, our study therefore finds that it must trigger a process of technical change that reduces the importance of unskilled labor relative to physical capital in farming. This would enable the development of a skill-intensive extension services sector, as the supply of skilled labor rises.

Previous studies imply that this increase in the relative proportion of skilled individuals fails to benefit the export sector, which they model as unskilled-labor intensive (e.g. Cartiglia 1997). Our model reverses this prediction by modelling farming and extension services (intensive in skills) as two complementary activities. This ensures that the export sector (i.e., the farming sector) is directly benefited by the trade-induced increase in the supply of skilled labor, in a way that strengthens its international competitiveness.

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Appendix 1: Proofs of Lemma

Proof of Lemma 1. First, using Eqs. (12) and (20), the following can be obtained as an implication of the equal rental rates condition:

$$p_m \left[\frac{\phi(X) K_a + U}{X} \right]^{1-\alpha} = \phi(X) \left(\frac{K_m}{S_m} \right)^{1-\alpha}. \tag{30}$$

Second, using Eqs. (11) and (14), the following can be obtained as an implication of the equal skilled-labor wage condition:

$$p_x = p_m \left(\frac{S_x K_m}{S_m} \right)^{\alpha}. \tag{31}$$

Third, combining Eqs. (31)and (18), rearranging terms yields

$$\frac{\phi(X) K_a + U}{X} = \gamma (p_m)^{1/\alpha} \left(\frac{K_m}{S_m} \right) S_x, \tag{32}$$

with

$$\gamma = \left(\frac{1}{1-\alpha} \right)^{1/\alpha}. \tag{33}$$

Finally, from Eq.(30), substituting in Eqs. (32), (13) and (16), using market-clearing conditions and rearranging terms yields the result.

Proof of Lemma 2. From $\pi_t = \omega_{st}/\omega_{ut}$, substituting in Eqs.(11) and (19) yields the steady-state skill-premium as follows:

$$\pi^* = \left(\frac{1-\alpha}{\alpha} \right) p_m \left[\frac{\phi(X^*) K_a^* + U^*}{X^*} \right]^{1-\alpha} \left(\frac{K_m^*}{S_m^*} \right)^{\alpha}.$$

Substituting in Eq.(30) and rearranging terms yields

$$\pi^* = \frac{1-\alpha}{\alpha}\phi(X^*)\left(\frac{K_m^*}{S_m^*}\right). \tag{34}$$

Next, consider Eq.(32) above. Since $K_a^* = K - K_m^*$ as an implication of the physical capital's resource constraint, substituting this expression in Eq.(32), rearranging terms yields

$$\frac{\phi(X^*)K_a^* + U^*}{X^*} = \left[\gamma(p_m)^{1/\alpha}\frac{X^* S_x}{\phi(X^*)} + S_m^*\right]\left(\frac{K_m^*}{S_m^*}\right)$$

which implies that

$$\frac{K_m^*}{S_m^*} = \frac{\phi(X^*)K_a^* + U^*}{X^*}\left[\gamma(p_m)^{1/\alpha}\frac{X^* S_x}{\phi(X^*)} + S_m^*\right]^{-1}. \tag{35}$$

Now, from Eq.(34), substituting in Eq.(35) rearranging terms yields

$$\pi^* = \frac{1-\alpha}{\alpha}\left[\frac{[\phi(X^*)K + U^*]}{\gamma(p_m)^{1/\alpha}[\phi(X^*)]^{-1}X^* S_x + S_m^*}\right].$$

Substituting in Eqs.(16), and (23), using market-clearing conditions and rearranging terms yields

$$\pi^* = \frac{1-\alpha}{\alpha}\left[\frac{(p_m)^{\delta-\bar{\delta}}\bar{A}^{(1-\alpha)\varepsilon}K + 2(p_m)^{\delta}(1-n^*)}{\left(\gamma\bar{A}^{(1-\alpha)(1-\varepsilon)} - 1\right)\bar{A} + (p_m)^{\delta}n^*}\right],$$

where $\bar{A} = (1-\alpha)^{(1-\alpha)\delta}$ and $\bar{\delta} = \delta\varepsilon(1-\alpha)$. Using Eqs.(24) and (33), it can be shown that

$$\left(\gamma\bar{A}^{(1-\alpha)(1-\varepsilon)} - 1\right)\bar{A} = \left(\frac{\alpha}{1-\alpha}\right)(1-\alpha)^{\delta(1-\alpha)}.$$

Therefore, for appropriately chosen $\alpha \in (0,1)$ and $\varepsilon \in (0,1)$, it can be argued that

$$\left(\gamma \bar{A}^{(1-\alpha)(1-\varepsilon)} - 1\right) \bar{A} \rightarrow 0$$

so that

$$\pi^{*} = \frac{\lambda}{n^{*}} \left[(p_m)^{-\bar{\delta}} K + (1 - n^{*}) \nu \right],$$

where

$$\begin{aligned} \lambda &= \frac{1-\alpha}{\alpha} \bar{A}^{(1-\alpha)\varepsilon} \\ \nu &= 2\bar{A}^{-(1-\alpha)\varepsilon}. \end{aligned}$$

This completes the proof.