Journal of Development Economics
Vol. 67 (2002) 55–77

Foreign direct investment and the relative wage in a developing economy

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Received 1 October 1999; accepted 1 April 2001

Abstract

This paper examines the issue of the effect of foreign direct investment on the relative wage in the context of a developing economy. Recognizing that competing domestic entrepreneurs are potentially skilled workers, foreign investment in skilled-labor intensive sectors is shown to lower the relative wage. Moreover, a general lump sum subsidy to foreign and domestic firms is shown to lower aggregate welfare, whereas a discriminatory subsidy only to foreign firms may raise welfare.

JEL classification: F16; F21
Keywords: Foreign direct investment; Relative wage; Entrepreneurship

1. Introduction

In developed countries today, there is an extensive discussion regarding the contribution of freer international trade with low-wage developing countries toward the observed increase in the "relative wage"— the ratio of "skilled" to "unskilled" wage. As of now, whether trade in goods is a major determinant appears controversial. Writers such as Wood (1994), Bergstrand et al. (1994) and Leamer (1996) have argued in favor of the free-trade-relative-wage nexus. Others

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like Katz and Murphy (1992), Krugman and Lawrence (1993) and Bhagwati and Dehejia (1994) are of the opposite view. Although the relative wage movement is consistent with the factor endowment view of free trade, the contribution of free trade is thought to be quite small. Instead, unskilled labor saving technological progress is considered to be the main explaining factor.

There is also a distinct perception in developing countries like India that the relative wage has risen in recent years, although formal empirical evidence is hard to come by. This is well documented however in Latin American countries like Chile and Mexico; see Beyer et al. (1999) for Chile and Cragg and Epelbaum (1996) for Mexico. Given that many relatively unskilled labor abundant, developing countries have adopted trade liberalization programs, this is somewhat a puzzle in terms of the factor endowment hypothesis of trade. But it is explicable, again, in terms of unskilled labor technical progress, which has undeniably been a global phenomenon in recent decades.

This paper is only concerned with relative wage changes in the context of a developing economy, and, in particular, how globalization or openness, rather than technological progress, may affect it. However, its basic premises are that freer trade in goods and services are not the only form of openness. One must consider openness with regard to foreign direct investment (FDI) also. Indeed, many developing countries, along with trade liberalization programs, have lifted restrictions on FDI (which used to be widespread and severe). Furthermore, it is not true that there is a general rise in the relative wage across the developing countries. Unlike their Latin American counterparts, some East Asian countries, e.g. Malaysia, Philippines, Singapore and Taiwan, have recently experienced a fall in the skilled–unskilled wage differential. For example, Robbins (1994a,b) report wage differential compression over the periods 1973–early 1990s and 1978–1988 in Malaysia and Philippines, respectively; Wood (1994) notes a decline in wage inequality in Singapore between 1966 and 1990. During roughly the same time interval, the FDI penetration (as % of domestic capital formation) has also increased over time in these countries. For instance in Singapore, the average annual FDI penetration (as %) were 16.6, 17.4, 35.0 and 37.4 over 1976–1980, 1981–1985, 1986–1990 and 1991–1993, respectively; in Malaysia, these are respectively 11.9, 10.8, 11.7 and 24.6, which means that the FDI penetration ratio remained roughly unchanged till the end of 1980s before it surged in the early 90s (see Aryeetey and Nissanke, 1998).[1]

There is existing literature on FDI and relative wage. Specifically, the effects of FDI in the form of outsourcing of production activity from developed to develop-

[1] In absolute terms, FDI in Malaysia jumped nearly 20 times from 1980 to 1990; see ILO/EASMAT (1996). For a more detailed account of FDI changes in Malaysian, Singapore, Taiwan and Thailand, see Lim and Fong (1991).

ing countries on the relative wage in both developed and developing countries have been studied by Feenstra and Hanson (1995, 1996, 1997). Their models assume a production technology with a continuum of production stages that differ in their skilled–unskilled labor intensities. Depending on comparative advantage, some of these production processes are located in developed countries (North) and some in developing countries (South). The "South" is supposed to possess comparative advantage in relatively more basic, unskilled labor intensive stages of production, whereas the "North" has comparative advantage in more skilled-labor intensive, advanced stages of production. An outsourcing of basic stages of production from North to South (resulting, for example from an increase in the relative capital stock in the South) reduces the relative demand for employment of unskilled workers in the North and increases the relative wage. The Feenstra Hanson model also predicts that the relative wage rises in the South, since the average skilled-labor intensity in the relatively unskilled labor intensive basic stages of production rises; Feenstra and Hanson (1997) find empirical support toward this result for Mexico.[2]

Like Feenstra–Hanson works, the present paper also considers the impact of FDI on the relative wage in the developing (host) countries. But just the *opposite* conclusion is reached: FDI can actually decrease the relative wage. Two factors are highlighted that contribute to the negative impact of FDI in skilled-labor intensive sectors on the relative wage. First, the foreign firms are assumed to operate with a more efficient technology, which implies an intra-sector substitution of output from less efficient local firms to the more efficient foreign firms. By itself, this tends to reduce the relative demand for skilled workers and lower the relative wage. Second, a major thrust of the paper is to take into consideration entrepreneurial choice in the host country, which is recognized to be a very important factor of the development process of an economy in general; see Banerjee and Newman (1993) among others. It is assumed that the pool of potential entrepreneurs in a developing country is constituted by the skilled workers only (presumably, to organize workers effectively involves knowledge of technological details which only skilled workers can muster, and, there are high agency costs which deter unskilled workers from being entrepreneurs). Then it follows that, as foreign firms enter, domestic entrepreneurship is partially crowded out. The supply of skilled workers to be engaged in production is now greater, and, this would tend to depress the wage differential. The empirical implication is

[2] More recent work by Glass and Saggi (2001) also examines outsourcing to the South. But it does not focus on intra-country skilled-unskilled wage ratio. In their model relative wage is defined as the ratio of the average Northern wage to the average Southern wage. Moreover, unlike the Feenstra–Hanson model, it is dynamic in terms of endogeneizing the rate of innovation in the North, and it focuses on how the North's welfare may increase from increased outsourcing to the South.

that, as long as the skills required to work for multinational corporations are similar to those required to become a successful entrepreneur, the long run effect of FDI (after occupational choice of skilled workers is adjusted) on the relative wage would be negative.[3] The result also means that FDI in developing countries should not be resented on equity grounds.

Although distributional aspects are our focus, the implications toward aggregate welfare of the host country are also addressed. A general, nondiscriminatory (marginal) subsidy to foreign and domestic firms is shown to lower welfare, whereas a discriminatory (marginal) subsidy to foreign firms only can increase welfare. As will be discussed in Section 4, an interplay between market power, scale economies and competition accounts for these welfare effects.

In what follows, Section 2 will present the basic analytical framework. Unlike in Feenstra–Hanson models, FDI takes place in a final-good producing sector, and, foreign firms operate in a market which clears domestically. There are also local firms and the market is oligopolistic. Both the number of foreign firms and the number of domestic firms are given. The economy consists of this sector as well as another which is perfectly competitive and less skilled labor intensive in production. It is shown that more FDI activity in terms of an increase in the number of foreign firms has three effects on the relative wage. First, there is a direct effect: an increase in the total number of firms, per se, in the skilled labor intensive sector tends to widen the wage differential. Secondly, there is a technology gap effect, which would tend to lower the relative wage. Finally, there is a transfer effect via changes in foreign profits to be repatriated, which turns out to be ambiguous. The overall effect remains ambiguous too.

Section 3 presents a scenario in which entrepreneurial choice by domestic firms is endogenous. Skilled workers are potential entrepreneurs. They enter or leave (as sole proprietors) as profits exceed or fall short of the skilled wage. In equilibrium, profits are equal to the skilled wage. Now, an increase in the FDI activity has a crowding-out effect on domestic entrepreneurial activity. This tends to increase the supply of skilled workers for production activity and thereby tends to lower the relative wages. At the margin, it becomes decisive: an increase in the number of foreign firms is shown to *unambiguously* lower the relative wage. This is the principal conclusion of this paper.

Section 4 considers a longer run situation in which the entry and exit of foreign firms is also endogenous. The effects of entry deterring or conducive policies on the wage differential are explored. The same result holds: a subsidy to foreign firms lowers the wage differential. This section also examines the welfare effects of marginal subsidy policies.

Section 5 concludes the paper.

[3] I am thankful to a referee for casting the main conclusion of this paper in this precise way.

2. The basic framework

There are two sectors x and y. Sector y, perfectly competitive, is the numeraire sector. It uses unskilled labor only. Hence, the sectoral factor-intensity differential is captured in an extreme fashion. The technology satisfies constant returns, i.e., the labor coefficient is given and, for convenience, equated to one. There is also free entry and exit. Thus, effectively, the unskilled wage in terms of good y, say w_u, is given and normalized to one.

In sector x there are n_f foreign firms and n_d domestic firms, and the market structure is oligopolistic. There are indeed many instances of FDI occurring in noncompetitive industries particularly in developing economies. Both skilled and unskilled labor are used in production and there are constant returns. Each foreign firm has the marginal cost function $\bar{c}_x(w_s, w_u)$, where the subscripts denote "sector x", "skilled" and "unskilled", respectively. It satisfies all neoclassical properties $\bar{c}_x(0, w_u) = \bar{c}_x(w_s, 0) = 0$ and $\bar{c}_x(\cdot)$ is linearly homogenous and concave in w_s and w_u. Thus $\bar{c}_x(\cdot) = w_u\bar{c}_x(w_s/w_u, 1) \equiv c_x(w)$, where w denotes the relative wage; we have $c'(w) > 0 > c''(w)$. The skilled-labor and unskilled-labor coefficients are respectively $c'(w)$ and $c(w) - wc'(w)$.

The domestic firms face the marginal cost function $bc(w)$, where $b \geq 1$; $b-1$ measures the technology gap because of learning deficit (or IPR protection).

The economy is endowed with $\bar{L}_s$ skilled workers and $\bar{L}_u$ unskilled workers. The utility function of domestic residents is Cobb–Douglas, with γ being the share of expenditure on good x. Denoting the relative price of good x by p, the inverse demand function facing the industry is: $p = \gamma E/Q_x$, where E is the total expenditure and Q_x is the total output of good x. Firms are assumed to compete in the Cournot–Nash fashion.

Given the above inverse demand function, the first-order condition of profit maximization by a foreign firm is: $[p - c(p)]/p = q_{if}/Q_x$, where q_{if} is the output of the ith foreign firm. In symmetric equilibrium, $q_{if} = q_f$ and thus

$$\frac{p - c(w)}{p} = \frac{q_f}{Q_x}. \tag{1}$$

Similarly,

$$\frac{p - bc(w)}{p} = \frac{q_d}{Q_x}, \tag{2}$$

where q_d is the equilibrium output of a domestic firm. It is easily checked that the second-order conditions are met.

The next two equations spell the full-employment of skilled and unskilled workers:

$$c'(w)(n_f q_f + b n_d q_d) = \bar{L}_s - n_d \tag{3}$$

$$[c(w) - wc'(w)](n_f q_f + b n_d q_d) + L_y = \bar{L}_u. \tag{4}$$

Since the domestic entrepreneurs are skilled workers, $\bar{L}_s - n_d$ skilled workers are available for production of good x; L_y denotes unskilled workers employed in sector y.

Finally, the market-clearing condition is:

$$Q_x = \frac{\gamma E}{p}, \tag{5}$$

where $E = pQ_x + Q_y - [p - c(w)]n_f q_f$ is the aggregate expenditure or national income. The last term in it is the foreign profits, assumed to be repatriated in terms of the numeraire good. Eqs. (1)–(5) determine q_f, q_d, w, p and L_y. An increase in n_f would capture an increase in the FDI activity (in this sense, the model is similar to the FDI model of Markusen and Venables, 1999).

2.1. Solution

The system will be expressed in (w, Q_x) space. Towards this end, we first multiply Eqs. (1) and (2) by n_f and n_d, respectively, add and then obtain

$$p = \frac{n_f + bn_d}{n_f + n_d - 1} c(w) \tag{6}$$

$$\frac{p - c(w)}{p} = \frac{1 + (b-1)n_d}{n_f + bn_d} \tag{7}$$

$$\frac{p - bc(w)}{p} = \frac{b - (b-1)n_f}{n_f + bn_d}. \tag{8}$$

It will be presumed that

$$\frac{b}{b-1} \geq n_f \tag{R1}$$

so that, in equilibrium, the domestic firms do not incur losses. Moreover, we will 'realistically' presume $n_f \geq 2$ (as we will be concerned with an increase in n_f). Thus Eq. (R1) would be fulfilled only if $b < 2$. Hence, we assume

$$2 > b > 1. \tag{R2}$$

Next, we substitute Eqs. (7) and (8) into Eqs. (1) and (2) and obtain

$$q_f = \frac{1 + (b-1)n_d}{n_f + bn_d} Q_x; \quad q_d = \frac{b - (b-1)n_f}{n_f + bn_d} Q_x. \tag{9}$$

In turn, substituting these expressions into the full-employment equation of skilled workers,

$$\frac{n_f + b^2 n_d - (b-1)^2 n_f n_d}{n_f + bn_d} c'(w) Q_x + n_d = \bar{L}_s. \tag{10}$$

This is the first of the two relationships between w and Q_x. It generates a positive locus—shown as the SS curve in (Fig. 1). Essentially, it captures skilled labor market equilibrium. As w increases, cost minimization implies that firms employ a smaller skilled-labor coefficient in sector x; hence full employment of skilled labor accommodates more output in this sector. Thus w and Q_x are positively associated.

Notice that if $b=1$, i.e., there were no technological gap, Eq. (10) reduces to $c'(w)Q_x+n_d=\bar{L}_s$, which is invariant to a change in n_f. Otherwise, as n_f increases, the l.h.s. decreases. Thus, at any given value of Q_x, w must fall. It captures the fact that as more efficient foreign firms move in, output is substituted away from less efficient domestic firms. Hence, at any given level of industry output, the total demand for skilled workers falls and the relative wage tends to decline. This is one channel.

We now make use of the market-clearing condition (Eq. (5)) and the full-employment condition for unskilled workers (Eq. (4)). Substituting the latter into the former and eliminating L_y, and, by using Eqs. (3), (6) and (9), the other relationship between w and Q_x is arrived at (see Appendix A):

$$\left\{\frac{1-\gamma}{\gamma}\frac{n_f+bn_d}{n_f+n_d-1}+\frac{n_f[1+(b-1)n_d]^2}{(n_f+n_d-1)(n_f+bn_d)}\right\}Q_x = \frac{\bar{L}_u-[c(w)/c'(w)-w](\bar{L}_s-n_d)}{c(w)}. \tag{11}$$

The l.h.s. is increasing in Q_x and the r.h.s. is a decreasing function of w. Thus Eq. (11) gives rise to a negative locus between w and Q_x. It is shown by the UU curve

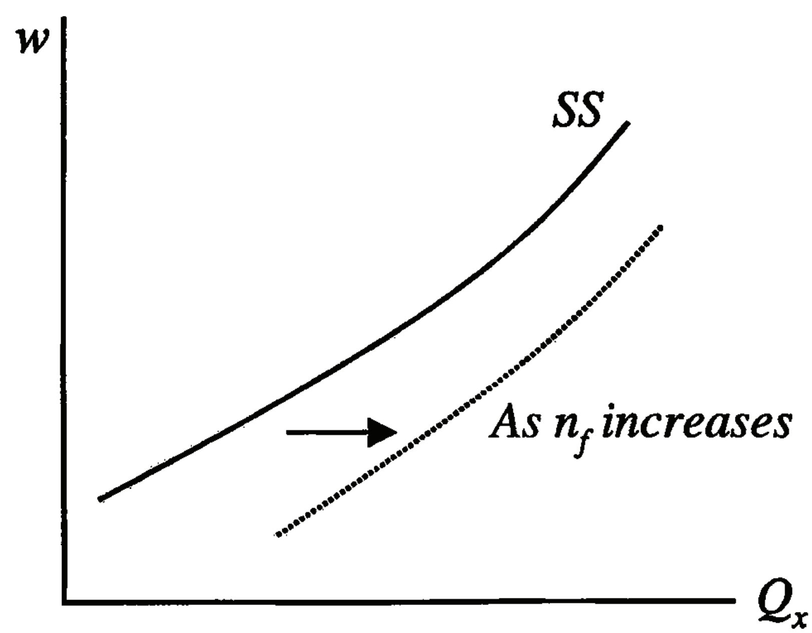

Fig. 1. The SS curve.

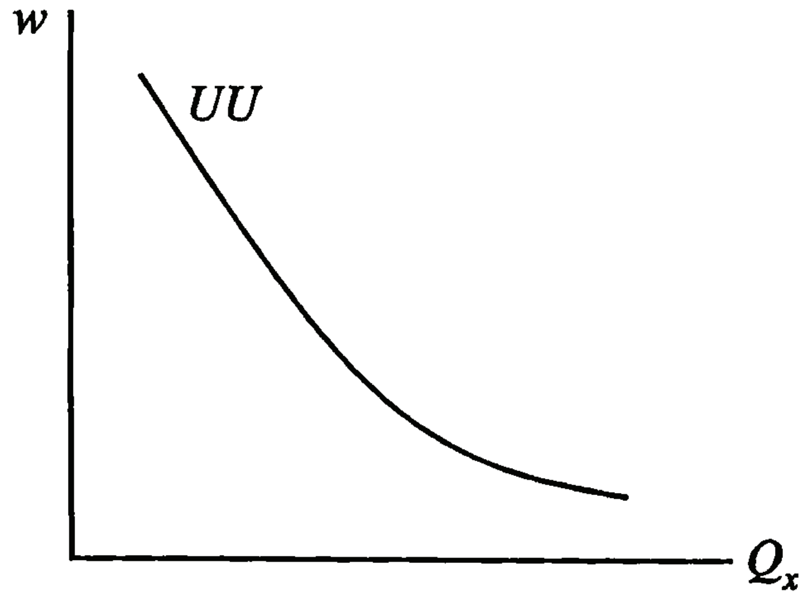

Fig. 2. The *UU* curve.

in Fig. 2, and it essentially captures full employment of unskilled labor. Higher w implies a higher (input) coefficient of unskilled workers in sector x; hence, full employment of unskilled labor accommodates less output in this sector.

From the coefficient of Q_x, we see that a change in n_f affects the UU schedule in two ways:

$$\frac{d}{dn_f}\left(\frac{n_f + bn_d}{n_f + n_d - 1}\right) = -\frac{1 + (b-1)n_d}{(n_f + n_d - 1)^2} < 0, \tag{12}$$

and

$$\frac{d}{dn_f}\left[\frac{n_f}{(n_f + n_d - 1)(n_f + bn_d)}\right] = -\frac{n_f^2 - bn_d(n_d - 1)}{(n_f + n_d - 1)^2(n_f + bn_d)^2} \gtrless 0 \tag{13}$$

as n_d is sufficiently large or not.

The first effect tends to shift the UU curve out and means that, at any given value Q_x, w tends to rise. This is the direct and the most obvious effect: an increase in the number of firms operating in the skilled labor intensive sector tends to push up the wage differential.

The second is a transfer (leakage) effect—through changes in foreign profit earnings to be repatriated, $\Pi_f = n_f q_f[p - c(w)]$.[4] Since these are repatriated in

[4] Technically, if we ignore foreign profits, the second term of the coefficient of Q_x in Eq. (11) would vanish and this effect would be zero.

terms of good y, the unskilled labor intensive good, an increase in Π_f lowers the relative supply of this good for domestic consumption- -at the original relative price. Although national income falls, the relative demand for this good is unaffected. Hence, in equilibrium, the relative price of the unskilled labor intensive good rises, i.e., that of good x falls. This lowers the relative demand for skilled labor and depresses the relative wage. The question then is how an increase in n_f would affect Π_f. Note that the latter is a product of (a) the number of foreign firms, (b) the individual output by a foreign firm and (c) the mark-up. As n_f increases, Π_f tends to increase on account of (a). Individual firm output declines, which would lower Π_f by (b). An increase in n_f would also mean more competition and a smaller mark up; hence the effect on Π_f through (c) is also negative. Therefore, the overall effect is ambiguous. The magnitude of n_d is crucial. The higher n_d is, the lesser the magnitudes of the individual output effect and the mark-up effect are, and hence more likely it is that Π_f would increase, the expression (13) would be positive and the relative wage would fall.

In summary then, there are three effects of foreign entry- -the direct effect, the technology gap effect and the transfer effect– and the net effect is ambiguous. In the special situation where there are no domestic firms in sector x, there is no technology gap effect and hence the SS curve remains invariant. However, the direct positive effect on w is present anyway, which tends to shift the UU curve out. Moreover, the negative effect on Π_f through (b) and (c) would be stronger than the positive effect through (a); Π_f would decline, and the UU curve would also shift out via the transfer effect. Thus $dw/dn_f > 0$ unambiguously. However, in another special case where there is no technology gap, although the SS curve does not shift, the UU curve may shift out or depend on the magnitude of n_d relative to n_f; accordingly, w may increase or decrease.

These implications would serve as our benchmark.

3. Endogenous occupational choice by skilled workers

In the last section, the number of domestic entrepreneurs was assumed given– which is appropriate only from a short-run perspective. Over a longer run, occupational choice would be endogenous. In the development literature, this phenomenon has been studied by Kanbur (1979) and Grossman (1984) among others. It is presumed that a 'worker' has two choices: be a production worker, or be an entrepreneur and employ production workers. Risk-aversion is typically assumed. In equilibrium, the wage rate must equal the expected utility from profit income. We consider a scenario which is different from the above in two ways. First, there is risk-neutrality. Second, as discussed earlier in the Introduction, only skilled workers are potential entrepreneurs in sector x. Thus, our two-sector economy has the structure that unskilled workers are mobile between the two sectors, while skilled workers are mobile between the two occupations.[5] In equilibrium, a domestic firm's profits equal w, and n_d is endogenous. The central result to be derived in this section is that the relative wage unambiguously declines with FDI.

We characterize the economy, beginning with an expression of a domestic firm's profits, π_d. Using Eqs. (6) and (9),

$$\pi_d = [p - bc(w)]q_d = \frac{[b-(b-1)n_f]^2}{(n_f+n_d-1)(n_f+bn_d)}c(w)Q_x.$$

Thus $\pi_d = w$ yields:

$$Q_x = \frac{w}{c(w)}\frac{(n_f+n_d-1)(n_f+bn_d)}{[b-(b-1)n_f]^2}. \tag{14}$$

An increase in w relative to the unit cost would, ceteris paribus, tend to lower a domestic firm's profits and must therefore be associated with higher output to ensure zero excess profits. Hence, Eq. (14) shows that, at given n_f and n_d, w and Q_x are positively associated.

If we substitute the last equation into Eq. (10) and use $\theta_s = wc'(w)/c(w)$, we get

$$h(w,n_d;n_f) \equiv \frac{\theta_s(w)(n_f+n_d-1)\left[n_f+b^2n_d-(b-1)^2n_fn_d\right]}{[b-(b-1)n_f]^2} + n_d - \bar{L}_s = 0. \tag{15}$$

This is the analog of Eq. (10). Notice that, in the presence of entry and exit of domestic firms and occupational choice facing skilled workers, the 'effective' skilled-labor coefficient is the share of skilled workers in total cost, θ_s. It is because, on one hand, an increase in w induces firms to lower the skilled-labor coefficient, which, in turn, tends to reduce the industry demand for skilled workers; on the other hand, as discussed earlier, an increase in w, relative to the unit cost, is associated with an expansion of industry output (so as to ensure zero abnormal profits for domestic firms), which tends to increase the industry demand for skilled workers. The net impact is the product of these two effects, which is equal to the share of skilled labor.

[5] In this sense, our analysis has some similarly with Das (2001), wherein the implications of international trade in goods towards the relative wage is considered taking into consideration two functions of skilled workers, namely, working in the production process directly and supervising the work of unskilled workers.

Next, the aggregate domestic profit income equals $(\bar{L}_s - n_d)w$. Thus, national income is equal to $w\bar{L}_s + \bar{L}_u$, and the market clearing condition is expressed as $\gamma(w\bar{L}_s + \bar{L}_u) = pQ_x$. Substituting into it the expression of p in Eq. (6)

$$\gamma\left(w\bar{L}_s + \bar{L}_u\right) = \frac{n_f + bn_d}{n_f + n_d - 1} c(w) Q_x.$$

In turn, if we substitute Eq. (14) into it and eliminate $c(w)Q_x$, we have

$$g(w, n_d; n_f) \equiv \frac{w}{\gamma\left(w\bar{L}_s + \bar{L}_u\right)} - \left[\frac{b - (b-1)n_f}{n_f + bn_d}\right]^2 = 0. \tag{16}$$

This equation, equivalent to the full employment condition of unskilled labor, is the analog of Eq. (11).

In principle, Eqs. (15) and (16) determine two variables, w and n_d and "solve" the model economy. It is straightforward to see that Eq. (16) spells a negative relationship between w and n_d. The type of relationship between the two variables implied by Eq. (15) depends on how θ_s changes with respect to w, i.e., on the elasticity of factor substitution (denoted as σ). Specifically, $\theta_s'(w) \lesseqgtr 0$ as $\sigma \gtreqless 1$. Given that Eq. (15) may define a positive or negative relationship between w and n_d, a general analysis of this model is more complex than that in the preceding section.

However, the central features of this model economy are most clearly and simply brought out in the special case where $\sigma > 1$ (such that $\theta_s'(w) < 0$) and $b = 1$. In this case, Eqs. (15) and (16) reduce to

$$\theta_s(w)(n-1)n + n - n_f - \bar{L}_s = 0 \tag{17}$$

$$\frac{w}{\gamma\left(w\bar{L}_s + \bar{L}_u\right)} - \frac{1}{n^2} = 0, \tag{18}$$

where $n = n_d + n_f$. Consistent with our earlier discussion, these equations define respectively a positively and a negatively sloped schedule between w and n, denoted respectively by the SS′ curve and UU′ curve in Fig. 3.

The impacts of foreign entry in the form of an increase in n_f are now straightforward to obtain. The SS′ curve shifts out while the UU′ remains unchanged. We see that w falls and n rises. These changes imply that, in Eq. (17), $\theta_s(w)(n-1)n$ rises and hence $n_d = n - n_f$ falls. Intuitively, foreign entry tends to lower profits, drive out some of the skilled workers from being entrepreneurs, and thereby increase the supply of skilled workers for production and tend to lower the relative wage; it is a crowding out effect. (The negative relationship between FDI and domestic entrepreneurship is noted in Hirschman (1969) and Pazos (1967).)

Against the backdrop of the three effects of FDI on the relative wage discussed in the previous section—which left the net impact ambiguous—this is an additional effect (through a decline in the number of domestic firms) and it tilts the

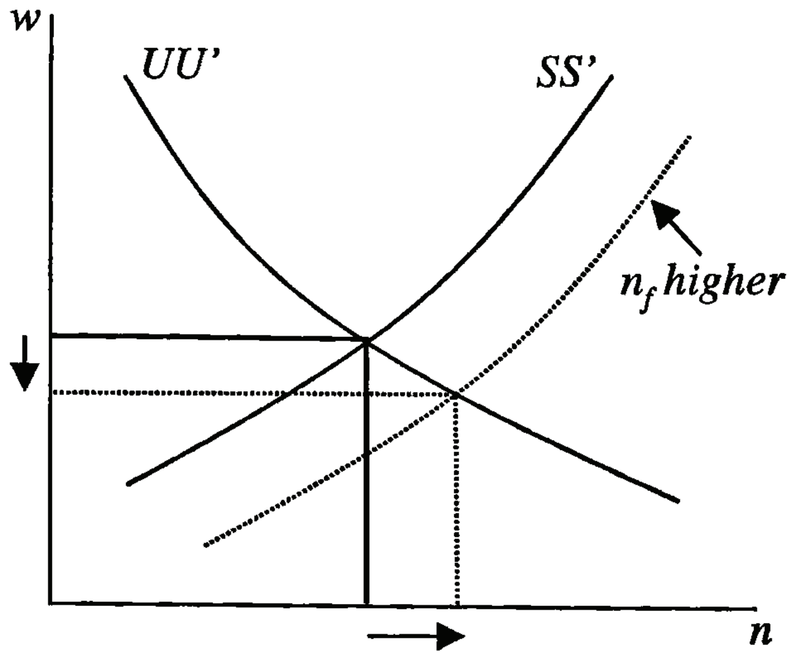

Fig. 3. The effect of FDI on the relative wage.

balance decisively toward a decline in the relative wage. This is the central thesis of the paper.

In more detailed terms, the magnitudes of the individual effects considered in the last section change as follows. In Eq. (12), it is seen that the direct positive effect of FDI on w is less in magnitude when n_d is smaller; this is intuitive. Moreover, as discussed in the previous section, the smaller the magnitude of n_d, the more likely is it that the transfer effect of an increase in n_f on w is positive. Finally, since $b = 1$, there is no technology gap effect. But if b were greater than one, it is seen from Eq. (10) that the technology gap effect may increase or decrease as n_d falls.[6,7] Hence, the overall strength of these effects may be greater or less, compared to when n_d is exogenous. It is thus interesting that the crowding out effect, even though only partial, is pivotal at the margin.

We now turn to the general case. As mentioned earlier, the negative effect of FDI on the relative wage is not dependent on the magnitude of σ or b (neither do we need to assume that σ is constant). It holds as long as the equilibrium defined

[6] In Eq. (10),

$$\frac{\mathrm{d}\left\{\dfrac{n_f + b^2 n_d - (b-1)^2 n_f n_d}{n_f + b n_d}\right\}}{\mathrm{d}n_f} = -\frac{b^2(b-1)n_d}{(n_f + b n_d)^2},$$

which may be an increasing or a decreasing function of n_d.

[7] It is straightforward but tedious to derive that $\mathrm{d}n_d/\mathrm{d}n_f < 0$, $\mathrm{d}n/\mathrm{d}n_f < 0$ (and $\mathrm{d}w/\mathrm{d}n_f < 0$) when $b > 1$ and $\sigma \geq 1$.

by Eqs. (15) and (16) is stable. An outline of its proof is given below, while the details are worked out in Appendix B.

Consider the following simple Walrasian adjustment process in the market for unskilled labor, assuming that other markets clear instantaneously. At time t, let the auctioneer announce its relative price $1/w$. Let the aggregate demand for unskilled labor be denoted L_{uD}. At given $1/w$, L_{uD} is given by the simultaneous solution of Eqs. (15) and (16) for n and L_{uD} when L_{uD} substitutes $\bar{L}_u$ in Eq. (16). An implicit function L_{uD} $(1/w)$ is obtained. Let the adjustment process be: increase or decrease $1/w$ accordingly as $L_{uD}(1/w) \gtrless \bar{L}_u$. It then follows that an equilibrium is (locally) stable if and only if $L'_{uD}(1/w) < 0$, or, $\mathrm{d}L_{uD}/\mathrm{d}w > 0$. In terms of comparative statics of market clearing of unskilled labor, $L_{uD} = \bar{L}_u$. Therefore, the stability condition is equivalent to $\mathrm{d}w/\mathrm{d}\bar{L}_u > 0$ (as an application of Samuelson's well-known correspondence principle). While we have considered the adjustment process in the market for unskilled labor only, other plausible adjustment processes should also yield the same stability condition.

We now totally differentiate Eqs. (15) and (16) implicitly with respect to $\bar{L}_u$ and obtain

$$\frac{\mathrm{d}w}{\mathrm{d}\bar{L}_u} = \frac{w}{\gamma\left(w\bar{L}_s + \bar{L}_u\right)^2}\frac{\partial h/\partial n_d}{\Delta}, \quad \Delta \equiv \frac{\partial g}{\partial w}\frac{\partial h}{\partial n_d} - \frac{\partial h}{\partial w}\frac{\partial g}{\partial n_d}. \tag{19}$$

It is straightforward to obtain from Eq. (15) that $\partial h/\partial n_d > 0$ (its expression is given in Appendix B). Hence, $\mathrm{d}w/\mathrm{d}\bar{L}_u > 0$ if and only if $\Delta > 0$, which is the stability condition. Now differentiating Eqs. (15) and (16) implicitly with respect to n_f, one obtains:

$$\Delta\frac{\mathrm{d}w}{\mathrm{d}n_f} = \begin{vmatrix} \dfrac{\partial h}{\partial n_f} & \dfrac{\partial h}{\partial n_d} \\ \dfrac{\partial g}{\partial n_f} & \dfrac{\partial g}{\partial n_d} \end{vmatrix}. \tag{20}$$

Appendix B proves that the right-hand side determinant is negative—and hence $\mathrm{d}w/\mathrm{d}n_f < 0$—as long as $b \geq 1$.

4. Entry and exit of foreign firms

Thus far, the number of foreign firms has been presumed exogenous, or a direct control variable by the host country's government. We now analyze the case where foreign entry is not directly regulated. There is entry and exit of these firms as profits exceed or fall short of the opportunity cost of foreign entrepreneurs. The latter, denoted by $\bar{r}$, will be assumed given. In equilibrium then, the profits earned by foreign firms are equal to $\bar{r}$, and n_f is endogeneous. Indirectly however, a host country can control the number of foreign firms through tax/subsidy policies.

In what follows, we examine the effects of such policies toward foreign firms only and a nondiscriminatory policy toward both types of firms. Let t_{f} and t_{d} denote a lump-sum (entry) tax on foreign and domestic firms, respectively. For simplicity, let there be no technology gap and thus $b=1$.

Note first that the domestic entry–exit condition is modified as $\pi_{\mathrm{d}} = w + t_{\mathrm{d}}$. Accordingly, we have a modified expression of Q_x compared to that in Eq. (14), and hence the skilled-labor full-employment condition (along with $b=1$) is expressed as

$$\theta_{\mathrm{s}}(w)(n_{\mathrm{f}}+n_{\mathrm{d}}-1)(n_{\mathrm{f}}+n_{\mathrm{d}})\left(1+\frac{t_{\mathrm{d}}}{w}\right)+n_{\mathrm{d}}=\bar{L}_{\mathrm{s}}. \tag{15''}$$

The disposable income is now $w\bar{L}_{\mathrm{s}}+\bar{L}_{\mathrm{u}}+n_{\mathrm{f}}\ t_{\mathrm{f}}+n_{\mathrm{d}}t_{\mathrm{d}}$. Hence, the market-clearing condition is changed to

$$\frac{w+t_{\mathrm{d}}}{\gamma\left(w\bar{L}_{\mathrm{s}}+\bar{L}_{\mathrm{u}}+n_{\mathrm{f}}t_{\mathrm{f}}+n_{\mathrm{d}}t_{\mathrm{d}}\right)}=\frac{1}{(n_{\mathrm{f}}+n_{\mathrm{d}})^{2}}. \tag{16''}$$

Moreover, an additional "zero-profit" condition for foreign firms, $\pi_{\mathrm{f}} = \bar{r} + t_f$, holds. Since $b=1$, $\pi_{\mathrm{f}} = \pi_{\mathrm{d}} = w + t_{\mathrm{d}}$ also. Thus

$$\bar{r}+t_{\mathrm{f}}=w+t_{\mathrm{d}}. \tag{21}$$

Eq. (21) alone determines the relative wage. Given w, Eqs. (15″) and (16″) simultaneously determine n_{f} and n_{d}.

From Eq. (21), it immediately follows that a discriminatory subsidy to foreign entry (a fall in t_{f} from zero) lowers the relative wage ($\mathrm{d}w/\mathrm{d}t_{\mathrm{f}}=1$). Hence, the negative effect of FDI on the real wage holds in terms of FDI inducing subsidy policy.[8]

A general nondiscriminatory tax is described by $t_{\mathrm{f}} = t_{\mathrm{d}} \equiv t$. Note from Eq. (21) that any change in a general nondiscrimatory tax or subsidy leaves the relative wage unaffected.

4.1. Welfare effects

Although the link between FDI policies and distribution is the central concern of this paper, we briefly examine now the effects of these policy changes on aggregate welfare. In the presence of occupational choice, the implications are somewhat nonstandard.

In the economy under consideration, the market structure being noncompetitive in sector x, price exceeds marginal cost; this has an obvious bearing toward welfare effects of policy changes. Less obvious is that there are scale economies in

[8] Also, it is interesting in passing that the formal analysis of this model is simpler compared to when n_{f} is exogenous.

the entrepreneurial activity: it is implicit that an entrepreneur manages an enterprise with same efficiency irrespective of the size of operation or output (as also in Kanbur, 1979; Grossman, 1984). Thus, compared to market equilibrium, the same industry output can be generated with just one firm—domestic or foreign— since the technology is constant-returns. Therefore, the first-best outcome in this economy requires consumer price being equal to marginal cost and the optimum number of firms in sector x being equal to one—the absolute minimum.[9] Whether it should be a domestic firm or foreign firm depends on the magnitude of $\bar{r}$ relative to the marginal value product of skilled labor when the available number skilled workers for production is $\bar{L}_s - 1$.

It then follows that unless the full range of policy option is available, there is a tradeoff between market power and the number of firms akin to the issue of optimum number of firms in the industrial organization literature, e.g., von Weizsacker (1980), Perry (1984), Mankiw and Whinston (1986) and Suzumura and Kiyono (1987). Thus the impact of tax/subsidy policies on n and p is central: an increase in n would tend to *lower* and an increase in p would tend to also lower aggregate welfare. But these are not independent. A policy change would have two effects: a *relative-wage effect* and a *market-size effect*. The former is that an increase in the relative wage tends to raise the marginal cost and price and hence reduce welfare. The latter has direct and indirect components. An increase in n lowers welfare for the reasons discussed earlier; this is the direct component. Indirectly, it tends to lower the price of good x and enhance welfare; this effect is however outweighed by the direct impact and the net market-size effect on welfare is negative.

We can assess the welfare effects of a marginal t_f and t. Let us continue to assume that $b = 1$. Using $\mathrm{d}w/\mathrm{d}t_f = 1$ and $\mathrm{d}w/\mathrm{d}t = 0$, it is straightforward to obtain from Eq. (16″) that $\mathrm{d}n/\mathrm{d}t_f$ and $\mathrm{d}n/\mathrm{d}t$ are both negative, as one would expect. Moreover, with $b = 1$, Eq. (6) reduces to

$$p = \frac{n}{n-1} c(w). \tag{6'}$$

Consider first the effect of a marginal increase in t_f. It turns out that $\mathrm{d}U/\mathrm{d}t_f \gtrless 0$, where U denotes welfare. Intuitively, since the relative wage rises,

[9] This is verified by setting up the planner's problem as: maximize $U(C_x, C_y) = U[(n_f + n_d) L_{ux} f_x(k_x),\ L_{uy} - \bar{r} n_f]$ subject to $(n_f + n_d) L_{ux} k_x + n_d \leq \bar{L}_s$ and $(n_f + n_d) L_{ux} + L_{uy} \leq \bar{L}_u$, where $U(\cdot)$ is the utility function, L_{ux} is unskilled labor employed by a firm in sector x, k_x is the ratio of skilled labor employment to unskilled labor employment and $f_x(\cdot)$ is the output to unskilled labor ratio. The constraints pertain to all employment conditions, taking into account that domestic entrepreneurs are skilled workers. It is straightforward to obtain that optimality requires $(U_x / U_y)[f_x(k_x) - (k_x f_x'(k_x)] = 1$, where U_x / U_y is the ratio of marginal utilities; that is, the value of the marginal product of unskilled workers at the consumer price be the same between the two sectors. This is equivalent to price being equal to the marginal cost. Moreover, the 'indirect welfare' is monotonically decreasing with respect to n_f and n_d, implying that the optimal number of firms is one.

price rises and this lowers welfare. On the other hand, the number of firms decreases, which tends to improve welfare (through increased production efficiency). The net effect is ambiguous. It is possible therefore that a subsidy to foreign firms is welfare-improving.[10] An overall implication towards FDI policy is that a foreign entry-inducing subsidy can moderate income inequality and enhance aggregate welfare at the same time.

Finally, consider a nondiscriminatory tax/subsidy policy. It is interesting to note that such a policy would unambiguously *lower* welfare. It is because there is only a market-size effect, no relative-wage effect; since n decreases, welfare improves.[11]

5. Concluding remarks

The trade-development literature abounds with studies on efficiency effects of FDI. However, discussions and analyses on distributional effects of FDI are generally lacking.[12] This paper has presented simple analytics of this issue, assuming that FDI flows into relatively skilled labor intensive sectors of a developing economy.

[10] A sufficient condition for this to happen is that $(2-\gamma)\,\theta_s \geq 1$. Formally, we differentiate Eq. (16″) with respect to t_f, use $\mathrm{d}w/\mathrm{d}t_f = 1$ and obtain

$$\frac{\mathrm{d}n}{\mathrm{d}t_f} = \frac{\gamma(\bar{L}_s + n_f) - n^2}{2nw} = \frac{\gamma n[1 + \theta_s(n-1)] - n^2}{2nw} < 0.$$

Using the expression, and $\mathrm{d}w/\mathrm{d}t_f = 1$ again, differentiation of Eq. (6′) gives

$$\frac{\mathrm{d}p}{\mathrm{d}t_f} = -\frac{c(w)}{w(n-1)}\left[\frac{\gamma(\bar{L}_s + n_f) - n^2}{2n(n-1)} - \theta_s n\right]$$

Let welfare be expressed in its indirect form: $U = V(p, w\bar{L}_s + \bar{L}_u + n_f t_f)$. Normalizing the marginal utility from income to one, being that the consumption of good x equals Q_x in equilibrium and that $\mathrm{d}w/\mathrm{d}t_f = 1$ (once again), we have $\mathrm{d}U/\mathrm{d}t_f = -Q_x \mathrm{d}p/\mathrm{d}t_f + \bar{L}_s + n_f$. Substituting the expression for $\mathrm{d}p/\mathrm{d}t_f$ into it and on simplication (see Appendix C),

$$\frac{\mathrm{d}U}{\mathrm{d}t_f} = \frac{n}{2(n-1)}\{n[1-(2-\gamma)\theta_s] - (2-\gamma)(1-\theta_s)\} \gtrless 0.$$

[11] Formally, we have $\mathrm{d}n/\mathrm{d}t = -(n-\gamma)/(2w)$. Hence

$$\frac{\mathrm{d}U}{\mathrm{d}t} = -Q_x\frac{\mathrm{d}p}{\mathrm{d}t} + n_f + n_d = \frac{c(w)Q_x}{(n-1)^2}\frac{\mathrm{d}n}{\mathrm{d}t} + n = \frac{wn}{n-1}\frac{\mathrm{d}n}{\mathrm{d}t} + n = n - \frac{wn}{n-1}\frac{n-\gamma}{2w}$$
$$= \frac{n[n-(2-\gamma)]}{n-1} > 0.$$

[12] Indeed, the 1998 report of the WTO study group on foreign direct investment calls for further study on FDI and distribution.

The direct effect of foreign entry in skilled-labor intensive sectors on the wage differential is, for obvious reasons, positive. However, many other things can in general happen. There is technology transfer, if nothing else, through demonstration effects. This should encourage domestic entrepreneurship, sustain the increase in demand for skilled labor and contribute to the rise in the relative wage. These are relatively short-run effects. In the long run, technology transfer may or may not eliminate the technology gap. If this gap remains, then an increase in FDI would entail substitution of production from less efficient domestic firms to more efficient foreign firms, which would tend to lower the relative wage. Further, more FDI activity would lead to some crowding out of domestic entrepreneurship. Given that skilled workers are the potential entrepreneurs in the skilled-labor intensive sector, this would increase the supply of skilled labor for "employment" and would push down the relative wage. The analysis of this paper builds around some of these notions. In particular, it emphasizes occupational choice by skilled workers. Thus, it may be considered as an extension of Grossman (1984), who studied the effect of FDI on domestic entrepreneurship and welfare and in which entrepreneurs are potentially "workers", without any distinction being made between skilled and unskilled ones.

The central result of this paper is that FDI would cause the relative wage to fall —which is the opposite of the finding of Feenstra and Hanson (1997). The critical differences with the Feenstra–Hanson model are (a) the endogeneity of the occupational choice of skilled workers, the implications of which are described above, and (b) the technology gap. In the presence of such a gap, foreign entry leads to a substitution of output away from less efficient domestic firms toward more efficient foreign firms. Ceteris paribus, this implies some savings in terms of factor use; the sector being relatively skilled labor intensive, there is less relative demand for skilled workers, which tends to lower the relative wage. Note also that the presence of free trade is a critical assumption of the Feenstra–Hanson model since it implies that the relatively unskilled labor abundant South would specialize in relatively unskilled labor intensive stages of production, and, thus capital movement to the South from the North takes place in the relatively skilled labor intensive stages of production at the margin, pushing the relative wage up. Without trade, South would be incompletely specialized and foreign investment would not necessarily occur in the relatively skilled labor-intensive stages of production; hence the relative wage would have increased or decreased. In our model, there is no trade, but nothing hinges on this assumption. If, for example, there were trade, the nature of oligopoly competition in the domestic market between domestic and foreign firms would have remained the same as depicted in our model, so long as markets are segmented and marginal costs are constant (as in reciprocal dumping models).

How does the main result of our analysis square with existing empirical evidence? Unlike the effect of trade in goods on the relative wage, the effect of FDI on the relative wage in the host country remains largely unexplored empirically—let alone any evidence (supporting or refuting) on the mechanisms analyzed here; the important work of Feenstra and Hanson (1997) for the Mexican economy is of course an exception. Needless to say, any formal empirical exercise is beyond the scope of this paper. Bu it is worth noting that the observed decline in relative wages in some East Asian economies has been accompanied by increases in FDI (as discussed in the Introduction), although the underlying factors highlighted in the literature are quite different from what is pursued in this paper. However, the task of simultaneously estimating the separate effects of trade liberalization and liberalization of FDI remains.

In order for the hypothesis of occupational mobility—of the kind described in the paper—to hold, it is critical that (a) local entrepreneurship mostly require technical skills which can also be used in working for multinational firms and (b) the time horizon be sufficiently long for occupational choices to adjust. East Asian countries have opened their doors to FDI for two decades by now. Hence, it is reasonable to suppose that condition (b) is fulfilled. In general, condition (a) is likely to be met for certain types of skills like managerial ability. Also, in case of goods or services that do not require substantial start-up cost, product-specific skilled labor is likely to be mobile between the two occupations highlighted in the model; computer software skills are prime examples of this kind. In any event, microlevel studies on occupational mobility do not seem to be available to date in order to ascertain whether condition (a) may be a good approximation. The analysis of the paper also shows that the greater the technology gap, the higher is the magnitude of the negative impact of FDI on the relative wage. There is some evidence to the effect that the technology gap in high-tech industries such as electronics between developed countries and East Asian countries like Hong Kong, Singapore, South Korea and Taiwan have been negligible or eliminated (Heeks and Slamen-McCann, 1996). Overall then, given the existing documentary and empirical work, it is difficult to assess, as of now, how strong the reduced-form effect of FDI is or how strong the mechanisms behind the paper's main hypothesis are toward the relative wage movement in developing economics.[13] It is hoped that the Feenstra--Hanson papers and the analysis of this paper provide a motivation for further and more definitive empirical analysis of the important link between FDI and relative wage.

Although the paper focuses on the distributional effect of FDI in the presence of occupational choice for skilled workers, welfare effects of FDI in such a context are interesting on their own. A general lump-sum subsidy to foreign and domestic firms is shown to leave the relative wage unchanged and *reduce* aggregate welfare, whereas as subsidy only to foreign firms may improve it.

[13] I am thankful to a referee for insisting me to include this discussion on the empirical perspective of the model.

There are many related issues which are left out but need to be investigated in order to obtain a more comprehensive understanding. For example, the technology learning phase by domestic entrepreneurs associated with the flow of FDI is not addressed at all. Our analysis pertains to the post-learning phase in the industry. Also, the entrepreneurial activity, per se, is modelled in a minimal way. Although it is consistent with the practice in the existing literature, various aspects of the theory of entrepreneurial incentive and limitations recognized in the modern theory of internal organization of firms should be taken into consideration and they should also have a bearing toward income distribution. Moreover, there are various imperfections and rigidities in a developing economy such as in the labor market, and, in particular, in the capital market that would affect the interaction between foreign and domestic entrepreneurs, and through occupational choice decisions, the relative wage.

Acknowledgements

Many thanks are due to the two referees of this journal for their numerous suggestions for improvement. It has also benefited from seminar participants at the Jawaharlal Nehru University, especially from Anjan Mukherji and Kunal Sengupta.

Appendix A

Eq. (11) in the text is derived here. First, using Eqs. (6) and (9), repatriated profits are expressed as

$$[p-c(w)]n_{\mathrm{f}}q_{\mathrm{f}}=\frac{n_{\mathrm{f}}[1+(b-1)n_{\mathrm{d}}]^{2}}{(n_{\mathrm{f}}+n_{\mathrm{d}}-1)(n_{\mathrm{f}}+bn_{\mathrm{d}})}c(w)Q_{x}. \tag{A1}$$

Next, we eliminate $n_{\mathrm{f}}\ q_{\mathrm{f}}+\ bn_{\mathrm{d}}q_{\mathrm{d}}$ from Eqs. (3) and (4) and obtain

$$L_{y}=\bar{L}_{\mathrm{u}}-\left[\frac{c(w)}{c'(w)}-w\right](\bar{L}_{\mathrm{s}}-n_{\mathrm{d}}). \tag{A2}$$

Thus,

$$E=pQ_{x}+L_{y}-[p-c(w)]n_{\mathrm{f}}q_{\mathrm{f}}=pQ_{x}+\bar{L}_{\mathrm{u}}-\left[\frac{c(w)}{c'(w)}-w\right](\bar{L}_{\mathrm{s}}-n_{\mathrm{d}})$$
$$-\frac{n_{\mathrm{f}}[1+(b-1)n_{\mathrm{d}}]^{2}}{(n_{\mathrm{f}}+n_{\mathrm{d}}-1)(n_{\mathrm{f}}+bn_{\mathrm{d}})}c(w)Q_{x}.$$

Substituting this into Eq. (5),

$$\frac{(1-\gamma)Q_x}{\gamma} = \frac{\bar{L}_u - \left[\frac{c(w)}{c'(w)} - w\right](\bar{L}_s - n_d) - \frac{n_f[1+(b-1)n_d]^2}{(n_f+n_d-1)(n_f+bn_d)}c(w)Q_x}{p}$$

Making use of Eq. (6) and rearranging the above equation yield Eq. (11).

Appendix B

It is proven here that the determinant in the right-hand side of Eq. (20) is negative when $b \geq 1$. Differentiating Eq. (16),

$$\frac{\partial g}{\partial n_f} = 2b\frac{[b-(b-1)n_f][1+(b-1)n_d]}{(n_f+bn_d)^3} > 0;$$

$$\frac{\partial g}{\partial n_d} = 2b\frac{[b-(b-1)n_f]^2}{(n_f+bn_d)^3} > 0.$$

Substituting these into Eq. (20), the determinant is negative if and only if

$$\begin{vmatrix} \frac{\partial h}{\partial n_f} & \frac{\partial h}{\partial n_d} \\ 1+\frac{(b-1)(n_f+n_d-1)}{b-(b-1)n_f} & 1 \end{vmatrix} = \frac{\partial h}{\partial n_f} - \frac{\partial h}{\partial n_d} - \frac{\partial h}{\partial n_d}\frac{(b-1)(n_f+n_d-1)}{b-(b-1)n_f} \equiv B < 0. \tag{A3}$$

We have

$$\frac{\partial h}{\partial n_f} = \theta_s(\cdot)\frac{n_f+b^2n_d-(b-1)^2n_fn_d+(n_f+n_d-1)\left[1-(b-1)^2n_d\right]}{\left[b-(b-1)n_f\right]^2} + \theta_s(\cdot)\frac{2(b-1)(n_f+n_d-1)\left[n_f+b^2n_d-(b-1)^2n_fn_d\right]}{\left[b-(b-1)n_f\right]^3}$$

$$\frac{\partial h}{\partial n_d} = 1 + \theta_s(\cdot)\frac{n_f + b^2 n_d - (b-1)^2 n_f n_d + (n_f + n_d - 1)\left[b^2 - (b-1)^2 n_f\right]}{[b-(b-1)n_f]^2}.$$

Substituting these into Eq. (A3),

$$B = -1 + \theta_s(\cdot)\frac{(n_f + n_d - 1)\left[1 - b^2 + (b-1)^2(n_f - n_d)\right]}{[b-(b-1)n_f]^2}$$

$$+ \theta_s(\cdot)\frac{2(b-1)(n_f + n_d - 1)\left[n_f + b^2 n_d - (b-1)^2 n_f n_d\right]}{[b-(b-1)n_f]^3} - \frac{(b-1)(n_f + n_d - 1)}{b-(b-1)n_f}$$

$$\times\left\{1 + \theta_s(\cdot)\frac{n_f + b^2 n_d - (b-1)^2 n_f n_d + (n_f + n_d - 1)\left[b^2 - (b-1)^2 n_f\right]}{[b-(b-1)n_f]^2}\right\}$$

$$= -1 - \theta_s(\cdot)\frac{(b-1)(n_f + n_d - 1)[1 + b - (b-1)n_f + (b-1)n_d]}{[b-(b-1)n_f]^2}$$

$$- \frac{(b-1)(n_f + n_d - 1)}{b-(b-1)n_f} + \theta_s(\cdot)(b-1)$$

$$\times\frac{(n_f + n_d - 1)\left[n_f + b^2 n_d - (b-1)^2 n_f n_d\right] - (n_f + n_d - 1)^2\left[b^2 - (b-1)^2 n_f\right]}{[b-(b-1)n_f]^3}$$

$$= -1 - \theta_s(\cdot)\frac{(b-1)(n_f + n_d - 1)[1 + b - (b-1)n_f + (b-1)n_d]}{[b-(b-1)n_f]^2}$$

$$- \frac{(b-1)(n_f + n_d - 1)}{b-(b-1)n_f} + \frac{\theta_s(\cdot)(b-1)(n_f + n_d - 1)}{b-(b-1)n_f}$$

$$= -1 - \theta_s(\cdot)\frac{(b-1)(n_f + n_d - 1)[1 + b - (b-1)n_f + (b-1)n_d]}{[b-(b-1)n_f]^2}$$

$$-[1 - \theta_s(\cdot)]\frac{(b-1)(n_f + n_d - 1)}{b-(b-1)n_f} < 0.$$

This proves that $\mathrm{d}w/\mathrm{d}n_f < 0$ when $b \geq 1$.

Appendix C

It is proven here that $\mathrm{d}U/\mathrm{d}t_f$ equals the expression given in footnote 10. We have $\mathrm{d}U/\mathrm{d}t = -Q_x \mathrm{d}p/\mathrm{d}t_f + \bar{L}_s + n_f$. Substituting into it the expression of

$\mathrm{d}p/\mathrm{d}t_\mathrm{f}$ in the same footnote,

$$\frac{\mathrm{d}U}{\mathrm{d}t_\mathrm{f}}=\frac{c(w)Q_x}{w(n-1)}\left[\frac{\gamma(\bar{L}_\mathrm{s}+n_\mathrm{f})-n^2}{2n(n-1)}-\theta_\mathrm{s}(\cdot)n\right]+\bar{L}_\mathrm{s}+n_\mathrm{f}$$

$$=n\left[\frac{\gamma(\bar{L}_\mathrm{s}+n_\mathrm{f})-n^2}{2n(n-1)}-\theta_\mathrm{s}(\cdot)n\right]+\bar{L}_\mathrm{s}+n_\mathrm{f},\text{using Eq. (14)}$$

$$=\frac{\gamma n_\mathrm{f}-n_\mathrm{f}^2+n_\mathrm{d}^2-\bar{L}_\mathrm{s}(2n_\mathrm{f}+2n_\mathrm{d}-\gamma)}{2(n-1)}+\bar{L}_\mathrm{s}+n_\mathrm{f},\text{using Eq. (15'')}$$

$$=n_\mathrm{f}+\frac{\gamma n_\mathrm{f}-n_\mathrm{f}^2+n_\mathrm{d}^2-\bar{L}_\mathrm{s}(2-\gamma)}{2(n-1)}$$

$$=\frac{n^2-(2-\gamma)(\bar{L}_\mathrm{s}+n_\mathrm{f})}{2(n-1)}$$

$$=\frac{n^2-(2-\gamma)\theta_\mathrm{s}(\cdot)n(n-1)-(2-\gamma)n}{2(n-1)},\text{using Eq. (15'') again}$$

$$=\frac{n}{2(n-1)}\{n[1-(2-\gamma)\theta_\mathrm{s}(\cdot)]-(2-\gamma)[1-\theta_\mathrm{s}(\theta)]\}.$$

which is the same as the expression given in footnote 10.

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