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A theory of real wage growth in LDCs

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A general equilibrium framework is presented to explain a variety of developmental experiences. The demand side is modelled by assuming a system of preferences that incorporate Engel's law in a stark way. The framework explains why poverty might be impervious to industrial progress in some countries. It also explains why countries which have been able to boost the exports of manufactured goods have been more successful in raising real wages in their economies than countries which have continued to export primary goods. The framework indicates how the initial conditions in terms of the level and distribution of wealth influence the growth of real wages in an economy.

1. Introduction

The purpose of this paper is to develop a general equilibrium model which permits the pattern of consumer demand to play a central role in the determination of real wages in a developing country. By explicitly modelling the demand side of a dual economy on the basis of Engel's laws, we are able to suggest answers to some intriguing questions. For example, why does poverty seem impervious to industrial progress in countries like India which have followed 'a closed economy' model? Why has the policy of promoting industrial exports, as followed by South Korea and Taiwan, been relatively more successful in this respect? Why did primary exporting countries like the U.S., Canada and Australia manage to increase their real wages while others like Ghana, Honduras and Tanzania did not?

The Dual Economy Model pioneered by Lewis (1954) and further developed by Fei and Ranis (1964) and Jorgenson (1969) among others, is the prevalent tool used to analyse the process of development in a labour

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abundant economy. The essence of this model is the process of labour reallocation between a low productivity activity (agriculture) and a high productivity activity (industry), which increases the incomes (profits) of those who are prone to save (i.e. the capitalists). This raises the aggregate savings rate which, in turn, accelerates the rate of growth.

But over the last four decades, saving rates in Asia as well as in Latin America have long surpassed the goal of 10–12% set by Lewis. [1] Even the growth rates of GDP are commendable across half the Third World by historical standards. Despite this, mass poverty persists in many LDCs. This is a puzzling problem that any new model should be equipped to analyse. It is for this reason that we construct a model here which abstracts altogether from the process of capital accumulation and savings. Our strategy is to attribute to technical change the status of the prime-mover in the process of development. Our interest then is in understanding what happens to real wages in an economy in which growth is spurred by technical change. We assume that technical change in LDCs is exogenous. It is crucial, however, for our purpose that we retain one important feature of the Lewis model, namely, the allocation of labour between industry and agriculture. However, a dispensable and controversial part of the Lewis model is the notion of surplus labour; we replace it here by a simple, neo-classical labour market.

In order to set out a theoretical framework that is capable of addressing the questions referred to above, we take as our starting cue the observation that development can proceed smoothly if the industrial output can be exported, as in South Korea, but is stuck 'spinning its wheels' if it is constrained by domestic demand, as in India. But how can domestic demand possibly be a constraint on the process of economic development? Clearly, Say's law cannot be violated in the long run. The following discussion illustrates how the composition of the demand can impinge on the development path.

Consider a simple economy with two sectors: grain (produced by land and labour) and textiles (produced by labour alone). These may be thought of, respectively, as the generic products of the agricultural and industrial sectors. Suppose the labour productivity in textiles production increases due to technical progress. Would this result in an increase in real wages? The wages would go up if labour is moved from grain to textiles. In an open economy such a reallocation of labour, with the attendant increase in real wages, is not hindered by the demand side. In a closed economy, such a reallocation is possible only if the elasticity of substitution between the two goods is suficiently high, i.e., if people would eat less and wear more clothes when the relative price of cloth falls. The nature of the preferences over industrial and

[1] To Lewis, the challenge of development was to raise the savings rate from 5–6% to 10–12% [Lewis (1954)]. According to World Bank Report 1988 [Tables 1 and 5], a number of countries whose GNP/capita is less than $500 have gross savings rates that exceed 12% of their incomes.

agricultural goods, therefore, must be an important determinant of the impact of industrial progress on real wages.

We feel that a preference structure that is appropriate for poor countries is one that is rooted in Engel's law, according to which there is an inverse relationship between a household's income and its share devoted to food. In fact, in order to create a simple theoretical model that would clearly bring out the causative processes driving various results we adopt a very stark and extreme form of Engel's law.[2] We assume a hierarchical preference structure (i.e. goods arranged in the order of need) for the population. Only after meeting a certain minimum level of food (grain) consumption (say $\bar{G}$) would an individual be inclined to spend on the industrial good, textiles (T).[3] The cornerstone of our model is the explicit incorporation of such a preference structure; the pattern of market demand is thus linked in a transparent fashion to the income distribution.[4] The market for industrial products is limited, then, to those agents in the population who command incomes, in terms of grain, that are in excess of $\bar{G}$.

If the population in our simple two-sector economy displayed such hierarchical preferences, what would be the consequences of industrial progress? Consider, first, the case in which the workers have incomes below $\bar{G}$ and the landlords have incomes above $\bar{G}$. Suppose initially the economy is in equilibrium. Now, an increase in productivity in the textile sector translates into a higher output of textiles and consequently a lower relative price for textiles. Workers, however, consume no textiles and, therefore, experience no change in their real incomes. In fact, the reduction in the price of textiles causes no substitution between the consumption of grain and that of textiles by anyone in the economy. It merely allows the landlords to absorb the entire increment in the textiles output, while drawing exactly the same land rent in terms of grain as before. Hierarchical preferences thus inhibit the gains of industrial progress from trickling down to the poor. It may be noted, however, that this would not be the case if the workers had incomes above $\bar{G}$. In other words, if the marginal product of labour in agriculture is above $\bar{G}$, the workers also would gain from industrial progress. The level of agricultural labour productivity at the time of introduction of modern industrial techniques in an economy is thus an important course-

[2]A detailed justification for this assumption will be provided in section 4.

[3]The choice of 'Textiles' as a representative industrial sector is meant to emphasize that the industry in our model is producing final goods for consumption rather than producer goods. If the industrial sector produces, say 'fertilizers', then an increase in its productivity should be regarded as an instance of agricultural productivity growth. The absence of linkage between industry and agriculture on the supply side limits the application of our theory, but is consistent with our focus on the demand side.

[4]This is also the cornerstone of an elegant paper by Murphy et al. (1989). They demonstrate that the distribution of wealth matters for the viability of modern industry. Baland and Ray (1991) is yet another significant contribution in this line of research, and is based on the efficiency wage hypothesis.

setter in development. This is a point that will be useful when we compare the developing countries of the past with those of today. The phenomenon just discussed would be valid even if the preferences were not strictly hierarchical but exhibited low substitutability between the two goods.

We can now see why the composition of demand need not inhibit the benefits of technical progress in industry from trickling down to the poor in an open economy. Consider the scenario where an LDC trades with a developed country, and that it imports some (but not all) of its textile requirements. Suppose, as before, that in the initial equilibrium workers' incomes are below $\bar{G}$ while those of landlords are above. If textile productivity increases in the LDC, the international relative price of textiles will fall, and the LDC will capture a larger share of the market. This will draw some labour off from the LDCs agricultural sector into its industrial sector, thereby increasing the workers' real wage. It is in this manner, we suggest, that trade breaks the constraint imposed by the composition of demand on the trickle-down effect.

The model developed in this paper follows the recent strand of literature which analyses the relationship between income distribution and growth in the context of a dual economy [Bourguignon (1990), Baland and Ray (1992) and Rakshit (1982)]. The mechanisms common to this literature are: (i) the movement of labour across the two sectors is the main source of the change in income distribution, and (ii) the income distribution, in turn, affects the equilibrium outcome through a demand composition that varies across income classes. Rakshit (982) reformulates the surplus labour dual economy model with a demand side which has workers spending all their income on food and landlords spending it all on industrial products. Some of the comparative static experiments he conducts are similar to ours. For example, he examines the effect of agricultural productivity growth on the equilibrium outcome. Bourguignon (1990) examines the effects of growth on the shape of the Lorenz curve and relates the nature of growth (i.e. egalitarian or inegalitarian) to the price and income elasticities of the demand functions of different classes. The Baland and Ray (1992) paper is closer in spirit to our's; the primacy of food in the preference structure plays an important role in their analysis of the growth pattern. They focus, however, on unemployment in a model based on (nutritional) efficiency wages. Our model has the weakness of being less general than these models; its strength is its simplicity, which makes quite transparent the process of development in a dual economy and the role played by the demand side.

In section 2 of this paper, we construct a formal two-sector general equilibrium model with only land and labour as factors and work out the welfare implications of changes in industrial productivity, agricultural productivity and wealth distribution across the population. The analysis in this section is carried out for a closed economy, simulating an import-substituting

industrialization, which is, typically, driven by domestic demand. In section 3 we examine an open economy, simulating, first, a primary exporting economy, and, then, a manufactured good exporting economy. In section 4, we discuss the validity of the assumption of hierarchical preferences in the light of the relevant empirical literature. It might seem strange that we have chosen to place this section at the end of the paper rather than at the beginning. We have done so because we would like the reader to be able to judge whether the modifications to our assumption of hierarchical preferences indicated by the empirical literature would affect the results in a fundamental way. We summarise the results in section 5 and argue that the incorporation of hierarchical preferences in a two-sector model renders it into a convenient tool to think about the process of development.

2. A two-sector closed economy model

We begin our analysis with a simple model of a closed economy with two sectors. The two sectors are agriculture and industry. There are only two factors of production: land and labour. In the next section we examine an open economy.

We assume all agents to have identical preferences defined over two goods: grain (G) and textiles (T). We take these as the generic products which belong to the broader classes of essentials (food) and industrial products. As noted in the Introduction, the preference structure we assume reflects a hierarchy in needs. At low income levels, an agent's income elasticity for grain is taken to be unity, while those for other goods are zero. This remains so up until the agent can consume an amount $\bar{G}$ of grain, at which point the income elasticity for grain falls to zero and that for textiles becomes high. All further increases in incomes are spent on textiles. Thus preferences are assumed to be hierarchical, with saturation being possible with respect to grain but not with respect to textiles.

Consider a closed economy of N_0 agents, each endowed with one unit of labour. A number N_L of the agents own land, and the rest $N_W(=N_0-N_L)$ are landless workers. The total amount of land in the economy we denote by L_0. For simplicity, we assume that the distribution of land within the landlord class is perfectly egalitarian, i.e. each landlord owns an amount L/N_L of land.

Our characterization of the production technologies is as follows. Let N_i and L_i denote the amounts of labour and land used in sector i. (We denote the grain and textiles sectors by subscripts g and t, respectively.) We assume that the output, G, of the food sector is related to the inputs labour (N_g) and land (L_g) by the production function

$$G = B_g F(N_g, L_g), \tag{1}$$

where B_g denotes a total factor productivity parameter, increases in which signify Hicks-neutral technical progress. We assume that $F(N_g, L_g)$ is a function that is increasing, strictly quasiconcave and linearly homogeneous in its arguments. We also assume that the marginal product of each factor approaches infinity and zero, respectively, as the amount of input used approaches zero and infinity.

Textile production uses only labour. The textile output, T, is linearly related to the amount of labour used, N_t:

$$T = B_t N_t, \tag{2}$$

where B_t is the total factor productivity in textiles.

We now consider the determination of general equilibrium in this economy. We take grain to be the numeraire and denote the relative price of textiles by P_t. The returns to the factors labour and land are denoted by w and v, respectively. Since agents have no preference for leisure in our model, all agents supply one unit of labour, irrespective of their asset positions. For given factor prices, the incomes Y_W and Y_L of workers and landlords are given, respectively, by

$$Y_W = w, \tag{3a}$$

$$Y_L = w + vL_0/N_L. \tag{3b}$$

Let G^d and T^d denote the demands for grain and textiles by an agent of class i, $i \in \{W, L\}$. Given the hierarchical nature of the preferences, we may write

$$G_i^d = \min\{\bar{G}, Y_i\}, \tag{4a}$$

$$T_i^d = (Y_i - G_i^d)/P_t. \tag{4b}$$

The aggregate demands G^d, T^d, for grain and textiles, respectively, can thus be written

$$N_W G_W^d + N_L G_L^d, \tag{5a}$$

$$N_W T_W^d + N_L T_L^d. \tag{5b}$$

We now turn to the supply side. We assume that all factor and output markets are competitive. The price of textiles can immediately be written in terms of the wage rate:

$$P_t = w/B_t. \tag{6}$$

The general equilibrium is determined, therefore, if we can compute the factor prices. To this end, we exploit the marginal conditions for labour and land in grain production. We can rewrite (1), using the linear homogeneity and the strict quasiconcavity of $F(\cdot,\cdot)$, as

$$G = B_g L_g f(N_g/L_g) \tag{7}$$

where $f(\cdot) \equiv F(1,\cdot)$, with $f' > 0$ and $f'' < 0$. (Single and double primes denote first and second derivatives, respectively.) Also, f' approaches zero (infinity) as its argument approaches infinity (zero).

The marginal conditions with respect to labour and land are:

$$N_g\colon\ B_g f'(N_g/L_g) = w, \tag{8a}$$

$$H_g\colon B_g[f(N_g/L_g) - (N_g/L_g) f'(N_g/L_g)] = v. \tag{8b}$$

Inverting (8a) we get

$$N_g/L_g = f'^{-1}(w/B_g) \equiv n(w/B_g), \quad \text{with} \quad n' < 0. \tag{9}$$

Substituting for (N_g/L_g) into (8b), we get the land rental rate in terms of w:

$$v = V(w, B_g) \equiv B_g[f(n(w/B_g)) - n(w/B_g)(w/B_g)]. \tag{10}$$

The demand for labour in textile production is simply given by T^d/B_t. Thus the market clearing conditions for labour and land, respectively, are given by

$$N_g + T^d/B_t = N_0, \tag{11a}$$

$$L_g = L_0. \tag{11b}$$

Substituting L_0 for L_g in (9), we can write (11a) as

$$L_0 n(w/B_g) + T^d/B_t = N_0. \tag{12}$$

From (10) substituting $V(w, B_g)$ for v into (3b), and using (2) in (4b) we see that T^d can be expressed in terms of a single price, namely, the wage rate.

The market for textiles clears by construction. (The labour demand in textiles was constructed on the presumption that the quantity of textiles produced by that labour equals the quantity demanded.) The market clearing condition for grain can be dropped by Walras' law. Thus the general equilibrium of this closed economy is entirely determined by the solution to the labour market clearing condition (12).

Proposition 1. There exists a unique general equilibrium for the economy. This equilibrium is globally stable.

Proof. See Appendix A.

Given the existence, uniqueness and global stability of the competitive equilibrium, we are now ready to examine the comparative statics of this equilibrium. Of immediate interest is the effect of an increase in the total factor productivity in textiles, B_t, on poverty. The situation relevant to a LDC is one in which workers are consuming only grain (i.e., earning a wage below $\bar{G}$) and landlords are satiated with grain and are also consuming textiles. We may note that we can solve the model sequentially.[5] In this instance, the grain market clearing condition is $G = w(N_0 - N_L) + \bar{G}N_L$, where $G = B_g F(N_g, L_0)$ and $w = B_g f'(N_g/L_0)$. The solution to the above condition directly determines the only endogenous variable occurring in it, namely, N_g. The textile price and output are then given by $P_t = w/B_t$ and $T = B_t(N_0 - N_g)$, respectively.

Proposition 2. If, in the general equilibrium, the landlords are sated with grain but the workers are not, an increase in textile productivity leaves workers indifferent and makes landlords strictly better off.

Proof. See Appendix A.

An increase in textile productivity lowers the price of textiles (in terms of grain) and clearly makes better off those who consume textiles. The only way workers, who are not consuming textiles, can benefit from a productivity increase in textiles is through a reallocation of labour which increases its marginal product. This process, however, is blocked when preferences are hierarchical. One way to understand this is as follows. Suppose the new equilibrium results in some labour being transferred from agriculture to industry. As a result, the marginal product of labour (i.e. the wage) will increase which, in turn, will create greater demand for grain. But the supply of grain must have decreased as a result of the labour transfer. This suggests that the grain market cannot be in equilibrium with a different labour allocation than in the original equilibrium.

In reality, while the preferences of agents in LDCs are obviously not strictly hierarchical, the degree of substitutability between food and industrial goods is sufficiently low so that the increase in real wage resulting from an increase in the industrial productivity would tend to be only marginal.

The above proposition brings out an important drawback of an inward oriented strategy of development in which both sectors produce almost exclusively for the domestic markets. Typically, poverty remains impervious to industrial progress as an increase in the industrial output is not accompanied by a decrease in the amount of labour employed in agriculture. Many valid reasons for this are discussed in the literature. For example, the

[5]We are indebted to Jean Marie Baland for pointing out that we may give a recursive interpretation to the determination of the equilibrium, in keeping with the intuitive explanations we give throughout the paper.

factor-price distortion caused by import substitution which typically characterizes inward oriented regimes tends to impart a labour saving bias to technical progress in industry. Proposition 2 demonstrates, however, that *even if* the technical progress were Hicks-neutral, the typical demand pattern in a poor country is such that it would block the process of 'trickle down'.[6] We have assumed above that the population is constant. If the population were growing, industrial progress could even be accompanied by a reduction in the real wage.

There is substantial empirical evidence which suggests that the inward oriented strategies adopted by Asian and Latin American countries have not had a significant positive impact on real wages. In some cases, real wages have declined. Fields (1980) offers evidence to the effect that in the Philippines (1956–1971) as well as in India (1960–1968) real wages declined. In both these economies the absolute amount of labour employed in agriculture also increased during the relevant period [see Dandekar (1986) for evidence on India, and Fields (1980, p. 224) for evidence on the Philippines.] And yet, the manufacturing output grew at over 6% per annum in the Philippines and at over 3% per annum in India during this time. In both these countries, the income levels of the poorest classes were low enough and the strategies of development sufficiently inward oriented to fit the assumptions underlying our theory.[7] Mexico (1956–1977) [Serron (1980)] and Brazil (1948–1962) [Hewlett (1980)] are some other examples of countries where an inward oriented strategy resulted in disappointing poverty performance.[8]

We now turn to the effects of an increase in agricultural total factor productivity, B_g.

Proposition 3. An increase in the total factor productivity in agriculture,

[6]Our model is not equipped to analyse the impact of a biased technical change as it has no capital in it. But, conceptually it is easy to see that a labour-saving technical change in Textiles would in fact reduce real wages. If the strong assumption of zero substitutability between goods in consumption biases our result in Proposition 2 in one direction, our assumption of neutral technical change does just the opposite.

[7]It could be argued that it is inappropriate to apply Proposition 2 to India since the recent empirical analysis [Ahluwalia (1985)] suggests that the total factor productivity in Indian industry has been declining rather than increasing. It should be pointed out, however, that labour productivity in Indian industry has shown a consistent increase [Bruton (1989, p. 1626)] and that is what matters for our theory to work. Due to the absence of capital in our model, the only way we have of representing technical progress is through a change in the total factor productivity parameter. But the labour allocation process which is at the core of the result in Proposition 2, is based on the difference in labour productivities across the sectors.

[8]An inward oriented strategy often creates market power in the hands of domestic producers. Unionized industrial workers succeed in raising their wages above their opportunity wages by claiming a part of these market rents. Often real wages presented by empirical studies of developing countries are these industrial wages which are irrelevant to asses the impact of a certain policy regime on poverty. We would like to emphasize, therefore, that by 'poverty performance' we mean the real wages of agricultural workers.

(*a*) *increases the equilibrium wage rate,*
(*b*) *decreases the land rental to wage ratio if any textiles are produced in equilibrium,*
(*c*) *makes the landlords better off if, in equilibrium, workers are still not sated with grain.*

Proof See Appendix A.

According to part (a) of the above proposition, an increase in grain total factor productivity always improves workers' welfare, irrespective of whether or not they are sated with grain. Part (b) informs us that while the rental rate on land may increase in terms of grain, it decreases relative to the wage rate and, hence, relative to the price of textiles. Despite this, part (c) implies, landlords are necessarily better off if the workers are not yet sated with grain, i.e., if landlords provide the sole demand for textiles.

Intuition for Proposition 3 is as follows. Suppose, following the increase in agricultural productivity, the allocation of labour stays the same. Then the marginal products of labour and land would both increase in the same proportion. But landlords are sated with grain, so the increase in demand for grain will rise less than proportionately to the increase in agricultural productivity. Therefore, some labour would be reallocated to textiles. Since the land-to-labour ratio rises in agriculture, the marginal product of labour will increase even more. The marginal product of land, however, will not rise as much (and might even decline) following the exodus of labour. This explains parts (a) and (b) of the above proposition. Since the increase in textile output produced with the labour absorbed from agriculture is consumed entirely by landlords, the landlords are better off. This result demonstrates that as long as workers are not yet sated with grain, an increase in agricultural productivity brings about a *strict* Pareto improvement in the well-being of all agents in the economy.

The effect of productivity increases in agriculture on the consumption levels of the two classes can be seen schematically from fig. 1. When agricultural productivity is very low, both factors are concentrated in the food sector since food is at the top of the hierarchy in preferences. As B_g increases, the food consumption of both classes increases, but at different rates – more rapidly for landlords than that of workers because the former earn a rental income in addition to labour income. The landlords reach saturation with respect to food only when the total factor productivity in grain production reaches a sufficiently high level ($\tilde{B}_g$ in fig. 1). Any further increase in B_g will see the landlords spend their additional income on textiles. Only at this stage will we see the emergence of industry and a decline in the amount of labour used in agriculture. This simple observation – that agricultural productivity must be sufficiently high before a demand for

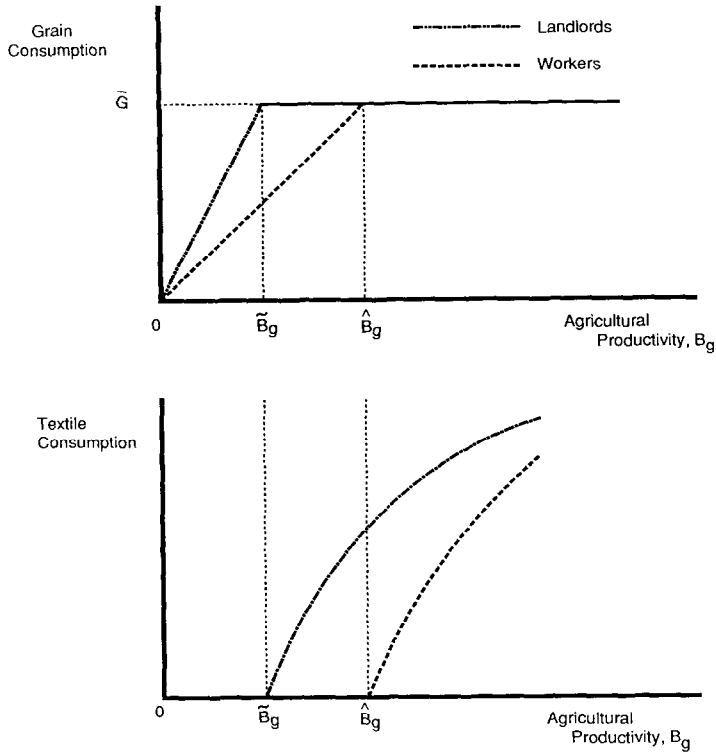

Fig. 1. Illustrates how the grain and textiles consumptions of landlords and workers change when agricultural productivity increases.

industrial goods manifests – underlines the importance of agriculture in the process of industrialization.[9] This is implicit in Lewis' assertion that Britain had an industrial revolution before France because its labour productivity in agriculure was higher by about 30 percent [Lewis (1978, p. 161)].

We now examine the effects of land reform in the context of our model. By land reform, we mean that the total amount of land is parcelled out to a larger number of agents, with all landlords owning identical amounts of land, i.e., a land reform amounts to an increase in N_L.

Proposition 4. If the landlords are sated with grain in the general equilibrium but the workers are not, a land reform that increases the proportion of agents owning land reduces the wage rate.

[9]Note that our view that agriculture is central to the process of development follows Lewis (1978), Mellor (1978) and Murphy et al. (1989).

Proof. See Appendix A.

The above proposition pertains to those agents who own no land even after the land reform. Paradoxically, their well-being unambiguously declines in the new equilibrium relative to the old. This is purely a general equilibrium effect arising from a change in the composition of demand. Land reform transfers land from existing landlords to some workers who previously owned no land. Since the workers were not sated with grain, the workers-turned-landlords will manifest a greater demand for grain with their land rental income. The old landlords, whose land holdings have been cut down, are now forced to demand less textiles. The increase in demand for grain accompanied by a decrease in demand for textiles would draw more labour into agriculture. This lowers the marginal product of labour.

The above result, however, should be qualified. If we allow for industrial products of different labour intensities, land reform can, under reasonable conditions, increase the demand for labour. This, in fact, is the more likely scenario in present day LDCs.

In the land reform exercise performed above, the act of making the land distribution more egalitarian increases food demand, and consequently reduces industrial employment and the wage rate. But this, by itself, should not be construed as an argument against land reform. It is an argument to tie 'land reform' to a strategy of growth led by industrial exports. It is also interesting that if the land-to-labour ratio in the economy is such that a perfectly egalitarian land distribution could push the entire population above $\bar{G}$ (as may be true of, say, Argentina or Brazil), then land reform has much to recommend itself. Not only the poorest will be better off but once every person is a consumer of textiles, any subsequent improvement in industrial productivity makes the whole country better off. In other words, in sufficiently land-abundant countries land reform could end, once and for all, the spectacle of de-linked growth in which the poor cannot participate. We have also discussed elsewhere [Eswaran and Kotwal (1986)] some countervailing factors like a more labour intensive cultivation following land reform which can make a landless worker better off.[10]

3. The effect of trade on poverty

We have seen in the previous section that industrial progress can have negligible effect on poverty in a closed economy. What prevents the benefits of industrial progress from filtering down to the workers is the composition of demand, which, in turn, is determined by the hierarchical nature of agents'

[10]For lack of space, we do not conduct a comparative static exercise with respect to population increase which would yield intuitively obvious results.

preferences. It is natural to ask whether opening up the LDC to trade with developed countries would relieve the demand constraint and thus better the lot of those in poverty, via general equilibrium effects on the wage rate, even though they may not be consuming industrial goods. To this end, we now expand the model of the previous section to allow the LDC to trade with a developed country. This would enable us to compare, in terms of the effects on poverty, the strategies of import substitution and export led growth.

We shall denote the LDC by X and the developed country by Y. We assume that production functions in the two countries have identical forms, but the total factor productivities are different – presumably larger for both goods in the developed country. All parameters, quantities and prices pertaining to the two countries will be superscripted by x or y. For example, B_g^y will denote the total factor productivity in the agricultural sector of the developed country, etc. The factor endowments in the two countries are, of course, not necessarily the same. People in both countries are assumed to have identical preferences.

In what follows below, it is analytically convenient to consider the case in which neither country completely specializes. In particular, this means that even after the opening up of free trade, the LDC still produces some textiles even though most of the domestic needs may be imported.

As before, we shall take grain to be the numeraire. If P_t denotes the international price of textiles, the wage rates in the two countries are given by

$$w^x = B_t^x P_t, \quad w^y = B_t^y P_t. \tag{13}$$

It is here convenient to focus on the market clearing condition for textiles (instead of that for labour). We take it that all agents in the developed country are sated with grain, but only the landlords in the LDC are. Then at price P_t, the aggregate demand for textiles is given by

$$N_L^x(w^x - \bar{G})/P_t + L_0^x V(w^x, B_g^x)/P_t + N_0^Y(w^y - \bar{G})/P_t + L_0^y V(w^y, B_g^y)/P_t, \tag{14}$$

where $V(\cdot,\cdot)$ is defined by (10). The labour employed in the agricultural sectors of countries x and y are given by (9) as

$$L_0^x n(w^x/B_g^x) \quad \text{and} \quad L_0^y n(w^y/B_g^y) \tag{15}$$

respectively, where w^x and w^y are given it terms of P_t by (13). The total supply of textiles at price P_t is thus given by

$$B_t^x[N_0^x - L_0^x n(w^x/B_g^x)] + B_t^y[N_0^y - L_0^y n(w^y/B_g^y)]. \tag{16}$$

The international price, P_t^*, of textiles in the free trade equilibrium is that which equates (14) and (16). Using (13), this condition may be written

$$N_L^x(B_t^x P_t^* - \bar{G})/P_t^* + L_0^x V(B_t^x P_t^*, B_g^x)/P_t^* + N_0^y(B_t^y P_t^* - \bar{G})/P_t^*$$

$$+ L_0^y V(B_t^y P_t^*, B_g^y)/P_t^* - B_t^x[N_0^x - L_0^x n(B_t^x P_t^*/B_g^x)]$$

$$- B_t^y[N_0^y - L_0^y n(B_t^y P_t^*/B_g^y)] = 0. \tag{17}$$

The land market clearing condition is implicitly assumed to hold when we set the total land use in agriculture equal to land endowment (L_0^x or L_0^y). The labour market clearing condition is implictly invoked in writing down (16), since the labour employed in a country's textile sector is assumed to be the labour endowment less the employment in agriculture. The market clearing condition for grain can be dropped by Walras' law. Thus the solution to (17) completely characterizes the free trade equilibrium. We consider the equilibrium for exogenous parameter values that yield

$$L_0^x n(B_t^x P_t^*/B_g^*) < N_0^x \quad \text{and} \quad L_0^y n(B_t^y P_t^*/B_g^y) < N_0^y,$$

i.e., neither country specializes completely in agriculture.

The following proposition records the effects of industrial productivity increases on the wages obtained in LDCs:

Proposition 5. (*a*) *An increase in the industrial productivity of the developed country reduces the equilibrium wage in the LDC.*

(*b*) *An increase in the industrial productivity of the LDC increases the equilibrium wage in the LDC.*

Proof. See Appendix B.

Part (a) of Proposition 5 is based on the following logic. An increase in the industrial productivity of the developed country lowers the international price of textiles. The developed country acquires a larger proportion of the textile market at the expense of the LDC. The corresponding de-industrialization of the LDC results in an exodus of labour from industry to agriculture, thereby lowering the marginal product of labour in agriculture. Since workers, by assumption, are not sated with grain, they do not benefit from the lower price of textiles. Thus industrial progress in the developed country unambiguously makes LDC workers worse off. This has typically been the case in those countries (such as the Latin American countries) which have financed the imports of industrial goods from developed countries by exporting primary goods (here represented by food). In the 19th century, when Britain was experiencing rapid industrial progress, Ireland

(during 1815–1849) and India (during 1877–1900) imported manufactured goods from Britain in exchange for food. The real wage was increasing in Britain during this period but not in Ireland or in India.[11,12]

It is natural to ask at this point why the outcome was so favourable in the primary exporting countries that Lewis (1978) describes as the Temperate Settlement Region (e.g. Canada, U.S., Australia). In fact, Canada's development is described by 'The Staple Theory of Growth' [Watkins (1963)]. There are two possible answers in the context of our model. First, land was hardly a fixed factor in the land abundant countries of the Temperate Settlement Region. Second, due to a higher land/labour ratio and more equitable land ownership pattern in the Temperate Region, the real wage was higher than in the poorer regions [Lewis (1978)]; the workers were consumers of industrial goods. As a result, a decline in the price of industrial goods was directly beneficial to the workers. Moreover, whether primary exports benefit the poor or not depends very much on the skewness of the land distribution. Land rents increase as a result of a primary export boom, and an egalitarian land distribution would ensure that the benefits would be spread across the bulk of the rural population. This can more than compensate for the decrease in wage income following a decline in industry.

Part (b) of Proposition 5 informs us, that, in sharp contrast to the result obtained in the closed economy model, an increase in LDC textile productivity makes LDC workers strictly better off – even if they do not consume textiles. The decrease in the international price of textiles brought about by increased LDC textile productivity results in a greater share of the market being served by the LDC. Labour is thus drawn off LDC agriculture, thereby increasing LDC wages. (Since the process works in reverse in the developed country, the wage rate of workers there decreases when the LDCs industrial productivity increases.) International trade thus is a boon to the poor in a country whose industrial productivity is growing faster than its trading partners.[13] This may shed some light on why South Korea and Taiwan

[11]See Thomas (1985) for Ireland and Lewis (1978) for India.

[12]Bardhan (1982) presents a rigorous general formulation of Lewis' open economy model. A comparable result in Bardhan's paper is that an improvement in productivity in the non-food exportable producing sector (e.g. textiles) in the rich country keeps the inter-country real wage inequality unchanged. Although Bardhan assumes a general demand function in his model, he uses the price of food as the price index for workers in the poor country and the price of luxuries as the price index for workers in the rich country. This implies that workers in the poor country spend all their income on food while those in the rich country spend it on luxuries. Thus, the preference structure he assumes is similar to the one we assume. Yet the result is different mainly because food is not traded in his model.

[13]A possible objection to the above framework is that most LDCs are not big enough players in any market that industrial progress within them could influence international prices, and a two-country framework is, therefore, inappropriate. But notice that by assuming a two-country world we are biasing the case against ourselves. If a LDC is a price taker so that the price of textiles does not fall as a result of an increase in its industrial productivity, there would be even a greater reallocation of labour from agriculture to industry than there would be otherwise.

managed to successfully alleviate poverty. Their strategy of increasing industrial exports continuously to Western markets was based on a sustained effort to increase productivity in their industrial sectors.

The lesson that emerges from the above is that it is not free-trade per se but the ability to increase industrial productivity while engaging in international trade which alleviates poverty.[14] Trade works as a catalyst in a process driven by industrial productivity growth. Without it, the benefits of industrial progress do not trickle down to the poor.

One point in the above discussion needs clarification. Proposition 5 identifies the success in increasing real wage with the success in boosting industrial productivity and not industrial exports. In other words, it is possible to have a primary exporting country in which the real wages are rising along with industrial productivity. As a consequence, however, the industrial imports would fall until at some point the country would become an industrial exporter. This has been the process at work in Taiwan, South Korea and other Asian countries now emerging as successful industrial exporters.

We do not present here the results of the comparative static exercise in which B_g increases, since the effect on domestic wages is the same as for a closed economy. Thus, a primary export boom caused by an increase in the agricultural productivity of the LDC would have the opposite effect on the LDC real wage than would a primary export boom induced by an increase in the industrial productivity of the developed country. The country experiences briefly discussed above correspond to the latter case.

4. How sensible is the assumption of hierarchical preferences?

In the previous sections we have demonstrated how the assumption of hierarchical preferences can yield sharp results. Now that the reader has seen the logic driving these results, we are in a better position to examine the available empirical literature in order to make a case justifying the adoption of what seems like an unreasonably strong assumption. In particular, we will argue that the results are not sensitive to those aspects of reality which do not conform to the hierarchical preference system. In other words, what is instrumental in driving the results is not rejected by the empirical evidence.

There are two characteristics of the hierarchical preference system which drive our results. First, the poor consume hardly any industrial goods (or,

[14]A well-known argument favouring the development of an industrial sector over that of a primary exporting sector is that the former would create greater links with the rest of the economy. See Gillis et al. (1987, p. 428). There is yet another reason why a comparative advantage in an industrial good as opposed for a primary good is beneficial: it increases returns to a factor that is elastic rather than merely increasing rents to a fixed factor [Eswaran and Kotwal (1991)].

Table 1

PSF data, rural India 1973-1974.

Per capita total expenditure (Rs)	PSF (%)	Cumulated % of persons
10.57	82.5	0.36
14.04	82.9	0.75
16.81	83.6	1.95
19.67	83.5	4.15
22.45	83.0	7.39
26.03	83.5	13.40
30.98	83.2	25.54
38.38	82.5	45.08
48.56	80.4	65.61
68.56	70.9	84.50
85.31	71.3	93.58
119.42	63.0	98.36
169.85	52.5	99.38
284.69	45.2	99.94

only the rich consume industrial goods). This is what makes their real wage insensitive to changes in the price of textiles in our model for a given allocation of labour. Second, all the price changes manifest as income effects rather than substitution effects; the elasticity of substitution between food and industrial goods is zero. This is what prevents any reallocation of labour from food to textiles in response to a drop in the price of textiles.

Let us first examine the assumption that only the rich and not the poor consume industrial goods. This assumption, in a milder form, has been implicit in the development literature for a long time. The notion that the consumption basket for the poor consists of 'wage goods' and that food constitutes its major part was commonplace in the writings of the classical writers from Adam Smith to Arthur Lewis. Even in the recent literature [e.g. Bardhan (1982)], we observe that the food price is used as a price index for workers in poor countries.

Engel (1895) was the first to study this empirical issue systematically. Based on a data set collected in 1857 in Belgium, Engel stated his first law that for households of the same composition, there is an inverse relationship between income (or expenditure) and the proportion of budget spent on food (PSF). Recently, there has been a great deal of interest in testing Engel's law on data gathered in the present day poor countries. Partly, this has been due to the suggestions made by Srinivasan (1983), Rao (1981) and Lipton (1983) among others that the food share (PSF) can be used to define the poor.

It is instructive to examine table 1 [Source: Rao (1981)]. The food share (PSF) is fairly flat at about 82% for the bottom 65.61% of the people representing a five fold rise in per capita expenditure over the lowest level in

the table. After that the food share descends rather steeply. Thomas (1986) lists similar tables for several LDC's displaing similar characteristics. In our model we are assuming that PSF is constant at 100% up until $\bar{G}$ and then declines.

Clearly, food is not the only basic need and even the very poor must spend some resources on fuel, housing, health care, transportation and clothing. For the Indian data cited above, these non-food items must account for 19% of the budget for the bottom 66% of the population. The important question is what part of this non-food portion of the budget is spent on the products of modern industry. The textile sector in our model represents modern industry in which significant productivity improvements have been possible through technological transfer. There is little technical progress in the delivery of health care or the cottage industries which supply the expenditure items like fuel, tobacco and liquor. Even clothing and footwear used by the poor in countries like India are often products of cottage industry rather than modern industry. Mellor (1978) analyzed the data from All India Consumer Expenditure Survey (1964–1965) and concluded that the bottom two deciles of the popultion spent a negligible amount on textiles and footwear and 0.8% on consumer durables. By contrast, the corresponding numbers for the upper half of the top decile are 7.5% and 2.85% respectively. Deaton and Case (1988) found that in 1980–1981 the bottom decile in Sri Lanka spent 24% of their budget on non-food items. Out of this 24%, the budget shares for various items were as follows: 3.8% for tobacco, 7.8% for fuel, 3.6% for housing, 2.1% for household goods, 2.7% for clothing, 1.6% for health and 0.7% for recreation. There is no information available on what part of the expenditure on housing, household goods and clothing is on the products of modern industry. But our guess would be that it is a very small part. Modern construction materials for housing, and many of the modern household goods such as kitchen gadgets are not as relevant to the poor as the local materials and cottage industry products like pots and pans. Thus, our first premise that it is the rich who constitute most of the demand for industrial goods seems to be on a sound footing.

It may be noted that hierarchical preferences also imply that the income elasticity of food is zero for the rich. There is no empirical basis to support such a premise. Mellor (1978) found that the income elasticity for food was 1.04 for the bottom two deciles and 0.12 for the upper half of the top decile. Our results, however, would be unaffected if the rich had a positive income elasticity for food. Let us first consider Proposition 2. If the price of textiles went down, the landlords (the rich) would experience an increase in their real incomes. As a result, if their demand for food increases, there would be, in fact, a reallocation of labour from industry to agriculture reducing the real wage. Industrial progress would make workers worse off, thus strengthening the result. By the same logic, the result in Proposition 5 would be

strengthened. As long as the income elasticity of the rich for textiles is much higher than that for food, Propositions 3 and 4 would also go through.

The assumption that plays the key role in our model is that of low substitutability between food and industrial goods. Our first problem with the available empirical literature in this regard is that the problem is not directly addressed in a way that is useful to us. Ray (1979) analyses a time series of household expenditure survey for India (1952–1969) using AIDS (Almost Ideal Demand System). Two limitations of this work, for our purposes, are: the price elasticities are uncompensated and thus do not measure the pure substitution effect, and they are computed at mean incomes rather than at different income levels. What is crucial for our model is that the substitution effect is negligible for the poor. Our results are not weakened if substitutability exists for the rich. In a society with a skewed income distribution, the price elasticities computed at mean incomes do not tell us much about the substitution possibilities for the poor. We note, however, an inference of Ray (1979):

> 'The absence of cross price effects provides limited evidence in support of the structuralist contention that in low income countries there is little opportunity for substitution between broad groups of commodities'.

In subsequent work Ray (1982) points out, however, that although the substitution effects are low, they are not zero. Low substitution effects would mean that if the price of textiles went down the real wages would go up but only marginally. In practical terms, the results and the logic underlying them would remain intact.

5. Summary of results

The theoretical framework we have constructed in this paper allows us to understand a variety of developmental experiences across many countries. It offers an explanation for why poverty in an inward oriented economy is impervious to industrial progress that is different from the well-known explanations (e.g., an increase in capital intensity or the deadweight loss resulting from an overregulated economy). Our explanation is based on a feature of extreme poverty, namely, hierarchical preferences between food and industrial goods. These preferences stem almost from a biological imperative and are thus relatively independent of cultures. On this same basis we can appreciate the critical role of productivity growth in agriculture in the process of development. Also, it suggests that it is not free-trade per se but the development of comparative advantage in industrial goods that is likely to benefit the poor. Although all these results have been derived under stark hierarchical preferences, it is clear that the logic underlying these results would be intact as long as the substitutability between goods is low and as

long as the income elasticities varied greatly across income classes. Engel's law thus plays a significant role in determining the fate of the poor under any strategy.[15]

In general, we would expect the composition of aggregate demand to depend on the distribution of income. Hierarchical preferences highlight this dependence and are the polar opposite, in this respect, of the conventional assumption of homothetic preferences. Under the latter type of preferences, it matters little whether an increase in income generated by an exogenous change (say, technical progress) accrues to one individual or is distributed across all individuals equally; the relative size of each sector remains the same. The relative size of each sector (in terms of employment) is an important determinant of real wages, because on the production side of the economy there is an asymmetry across sectors: agriculture is much more subject to diminishing returns than is industry. With hierarchical preferences, the initial wealth distribution significantly affects real wages.

The main planks of our framework – Engel's law and diminishing returns in agriculture are well-accepted notions in the literature. But by explicitly incorporating them in a dual economy model we have constructed a framework that allows us to think systematically about how various developmental policies have affected real wages across different countries over time.

Appendix A

Proof of Proposition 1

The general equilibrium, we have seen, is completely determined by the labour market clearing condition (12) of the text. Since the demand for labour from the textile sector depends on which classes, if any, have incomes above $\bar{G}$, condition (12) may be rewritten explicitly as

$$L_0 n(w/B_g) = N_0 \quad \text{if} \quad w + L_0 V(w, B_g)/N_L < \bar{G}, \tag{A.1a}$$

$$L_0 n(w/B_g) + \frac{1}{w}(w + L_0 V(w, B_g)/N_L - \bar{G})N_L = N_0$$
$$\text{if} \quad w < \bar{G} < w + L_0 V(w, B_g)/N_L, \tag{A.1b}$$

$$L_0 n(w/B_g) + \frac{1}{w}[(w - \bar{G})N_0 + L_0 V(w, B_g)] = N_0 \quad \text{if} \quad w > \bar{G}, \tag{A.1c}$$

[15]Thomas (1986) shows that the functional relationship between the food share and income is non-monotonic. This result, though in violation of Engel's law, poses no problem for the working of our model.

where $V(w, B_g)$ is given by (10) of the text. It is easy to verify, by partially differentiating (10) with respect to w and using the first-order condition (8a) of the text, that

$$\partial V(w, B_g)/\partial w = -n(w/B_g) < 0. \tag{A.2}$$

The labour demand functions, represented by the left-hand sides of (A.1a)–(A.1c), are clearly continuous. They are also downward sloping. To see this, consider the left-hand side of (A.1b), for example. Differentiating this with respect to w we obtain

$$(L_0/B_g)n'(w/B_g) + \bar{G}N_L/w^2 - L_0V(w, B_g)/w^2 + L_0V_1(w, B_g)/w. \tag{A.3}$$

The total grain demand is given by

$$\bar{G}N_L + w(N_0 - N_L),$$

which must be equal to

$$wN_g + L_0V(w, B_g)$$

since the product is exhausted by the factor payments. Thus

$$\bar{G}N_L = wN_g + L_0V(w, B_g) - w(N_0 - N_L).$$

Substituting the above expression for $\bar{G}N_L$ in (A.3), we obtain

$$(L_0/B_g)n'(w/B_g) + N_g/w - (N_0 - N_L)/w - L_0n(w/B_g)/w,$$

where we used (A.2). This further reduces, on using (9) of the text, to

$$(L_0/B_g)n'(w/B_g) - (N_0 - N_L)/w < 0 \quad \text{since} \quad n'(w/B_g) < 0.$$

Similarly the left-hand sides of (A.1a) and (A.1c) can be shown to be monotonically decreasing in w.

Since the agricultural production function has been assumed to be such that the inputs have infinite (zero) marginal products at zero (infinite) employment of the inputs, it follows that

$$\lim_{w \to 0} n(w/B_g) = \infty \quad \text{and} \quad \lim_{w \to \infty} n(w/B_g) = 0.$$

Thus the demand for labour in (A.1a)–(A.1c) approaches infinity as $w \to 0$ declines monotonically as w increases and, since $V(w, B_g)$ is declining in w, approaches zero as $w \to \infty$. Therefore, the labour market clearing condition necessarily has a solution for all $N_0 > 0$. Furthermore, the fact that the

labour demand function is downward sloping implies that the solution is unique and that this equilibrium is globally stable.

Proof of Proposition 2

The appropriate labour market clearing condition here is (A.1b). Differentiating this condition totally with respect to B_t, we obtain

$$X_1(w^*, B_t, B_g, N_L)\frac{dw^*}{dB_t} = -X_2(w, B_t, B_g, N_L), \tag{A.4}$$

where X_i denotes the partial derivative with respect to the ith argument of the excess demand function:

$$X(w, B_t, B_g, N_L) \equiv L_0 n(w/B_g) + \frac{1}{w}(w + L_0 V(w, B_g)/N_L - \bar{G})N_L - N_0. \tag{A.5}$$

We have seen above, in the proof of Proposition 1 that

$$X_1(w, B_t, B_g, N_L) < 0 \quad \text{for} \quad \text{all } w > 0. \tag{A.6}$$

Also, since $X_2(w, B_t, B_g, N_L) = 0$, it follows from (A.4) that

$$\frac{dw^*}{dB_t} = 0. \tag{A.7}$$

Thus workers are unaffected by an increase in B_t.

A landlord's consumption of textiles is given by

$$\frac{B_t}{w}(w + L_0 V(w, B_g)/N_L - \bar{G}).$$

It follows, using (A.7), that an increase in B_t makes the landlords strictly better off.

Proof of Proposition 3

(a) Totally differentiating the appropriate labour market clearing con condition, namely (A.1b), with respect to B_g, we obtain

$$X_1(w, B_t, B_g, N_L)\frac{dw^*}{dB_g} = -X_3(w, B_t, B_g, N_L), \tag{A.8}$$

where

$$X_3(w, B_t, B_g, N_L) = -w\frac{L_0}{B_g^2}n'(w, B_g) + L_0 V_2(w, B_g)/w > 0,$$

since $n'(w/B_g)<0$ and $V_2(w, B_g)>0$, as can be verified from (10) of the text. It follows from (A.6) and (A.8) that

$$\frac{dw^*}{dB_g}>0. \tag{A.9}$$

(b) Taking the ratio of the first-order conditions (8a) and (8b) of the text, we obtain

$$\frac{v}{w}=[f(n)-nf'(n)]/f'(n)\equiv\phi(n),$$

where, from the strict concavity of $f(n)$, it follows that $\phi'(n)>0$.

Inverting this, we obtain

$$n=\phi^{-1}(v/w)\equiv\Psi(u), \quad \Psi'>0, \tag{A.10}$$

where $u\equiv v/w$ is the land rental-to-wage ratio.

The market clearing condition (A.1b) can now be written

$$L_0\Psi(u^*)+N_L(w^*-\bar{G})/w^*+L_0u^*=N_0. \tag{A.11}$$

Totally differentiating (A.11) with respect to B_g, we obtain

$$L_0(\Psi'+1)\frac{du^*}{dB_g}=-\bar{G}N_L/(w^*)^2<0,$$

so that

$$\frac{du^*}{dB_g}<0, \tag{A.12}$$

i.e., the land rental-to-wage ratio declines when B_g increases.

(c) The amount of labour employed in textiles in equilibrium is given by $N_0-L_0\Psi(u^*)$. The derivative of this with respect to B_g is given by $-L_0\Psi'du^*/dB_g>0$, i.e., when B_g increases, more labour is employed in textiles and the textile output increases. Landlords are thus unambiguously better off.

Proof of Proposition 4

Totally differentiating (A.1b) with respect to N_L we obtain

$$X_1(w^*, B_t, B_g, N_L)\frac{dw^*}{dN_L}=-X_4(w, B_t, B_g, N_L). \tag{A.13}$$

From (A.5), we obtain

$$X_4(w^*, B_t, B_g, N_L) = \frac{1}{w^*}(w^* - \bar{G}) < 0. \tag{A.14}$$

since, by assumption, $w^* < \bar{G}$.

From (A.6), (A.13) and (A.14) it follows that

$$\frac{dw^*}{dN_L} < 0. \tag{A.15}$$

Appendix B: Proof of Proposition 5

Let the excess demand for textiles when the international textile price is P_t be denoted by $Z(P_t, B_t^x, B_t^y)$. This function is given by the left-hand side of eq. (17) of the text, with P^* replaced by P_t.

(a) Totally differentiating the equilibrium condition (17) with respect to B_t^y, we obtain

$$Z_1(P_t^*, B_t^x, B_t^y)\frac{dP_t^*}{dB_t^y} = -Z_3(P_t^*, B_t^x, B_t^y), \tag{B.1}$$

where

$$\begin{aligned} Z_1(P_t^*, B_y^x, B_t^y) = {} & \frac{N_L^x \bar{G}}{(P_t^*)^2} + \frac{N_0^y \bar{G}}{(P_t^*)^2} \\ & + [L_0^x B_t^x V_1(B_t^x P_t^*, B_g^x)] + L_0^y B_t^y V_1(B_t^y P_t^*, B_g^y)]/P_t^* \\ & - [L_0^x V(B_t^x P_t^*, B_g^x) + L_0^y V(B_t^y P_t^*, B_g^y)]/(P_t^*)^2 \\ & + L_0^x (B_t^x)^2 n'(B_t^x P_t^*/B_g^x)/B_g^x + L_0^y (B_t^y)^2 n'(B_t^y P_t^*/B_g^y)/B_g^y, \end{aligned} \tag{B.2}$$

and

$$\begin{aligned} Z_3(P_t^*, B_t^x, B_t^y) = {} & N_0^y - L_0^y V_1(B_t^y P_t^*, B_g^y) \\ & - [N_0^y - L_0^y n(B_t^y P_t^*/B_g^y)] + (B_t^y L_0^y P_t^*/B_g^y) n'(B_t^y P_t^*/B_g^y). \end{aligned} \tag{B.3}$$

Rearranging (17) and dividing through by P_t^*, we obtain

$$\begin{aligned} (N_L^x \bar{G} + N_0^y \bar{G})/(P_t^*)^2 = {} & (N_L^x B_t^x + N_0^y B_t^y)/P_t^* + [L_0^x V(B_t^x P_t^*, B_g^x)] \\ & + L_0^y V(B_t^y P_t^*, B_g^y)]/(P_t^*)^2 \end{aligned}$$

$$- B_t^x[N_0^x - L_0^x n(B_t^x P_t^*/B_g^x)]/P_t^*$$
$$- B_t^y[N_0^y - L_0^y n(B_t^y P_t^*/B_g^y)]/P_t^*.$$

Substituting the right-hand side of the above expression for

$$(N_L^x \bar{G} + N_0^y \bar{G})/(P_t^*)^2 = (N_L^x B_t^x + N_0^y B_t^y)/P_t^*$$
$$+ [L_0^x V(B_t^x P_t^*, B_g^x) + L_0^y V(B_t^y P_t^*, B_g^y)]/(P_t^*)^2$$
$$- B_t^x[N_0^x - L_0^x n(B_t^x P_t^*/B_g^x)]/P_t^*$$
$$- B_t^y[N_0^y - L_0^y n(B_t^y P_t^*/B_g^y)]/P_t^*.$$

Substituting the right-hand side of the above expression for $(N_L^x \bar{G} + N_0^y \bar{G})/(P_t^*)^2$ in (B.2) we obtain

$$Z_1(P_t^*, B_t^x, B_t^y) = -(N_0^x - N_L^x)B_t^x/P_t^* + [L_0^x B_t^x V(B_t^x P_t^*, B_g^x)$$
$$+ L_0^y B_t^y V_1(B_t^y P_t^*, B_g^y)]/P_t^* + [L_0^x B_t^x n(B_t^x P_t^*/B_g^x)$$
$$+ L_0^y B_t^y n(B_t^y P_t^*/B_g^y)]/P_t^* + L_0^x (B_t^x)^2 n'(B_t^x P_t^*/B_g^x)/B_g^x$$
$$+ L_0^y (B_t^y)^2 n'(B_t^y P_t^*/B_g^y)/B_g^y.$$

Noting that

$$V_1(B_t^x P_t^*, B_g^x) = -n(B_t^x P_t^*/B_g^x), \tag{B.4a}$$
$$V_2(B_t^y P_t^*, B_g^y) = -n(B_t^y P_t^*/B_g^y), \tag{B.4b}$$

we may rewrite the above as

$$Z_1(P_t^*, B_t^x, B_t^y) = -(N_0^x - N_L^x)B_t^x/P_t^* + L_0^x (B_t^x)^2 n'(B_t^x P_t^*/B_g^x)/B_g^x$$
$$+ L_0^y (B_t^y)^2 n'(B_t^y P_t^*/B_g^y)B_g^y$$
$$< 0, \tag{B.5}$$

since $0 < N_L^x < N_0^x$ and $n' < 0$.

Using (B.4b) in (B.3) we obtain

$$Z_3(P_t^*, B_t^x, B_t^y) = (B_t^y L_0^y P_t^*/B_g^y) n'(B_t^y P_t^*/B_g^y)$$
$$< 0. \tag{B.6}$$

From (B.1), (B.5) and (B.6), we obtain $dP_t^*/dB_t^y < 0$, so that

$$\frac{dw^x}{dB_t^y} = B_t^x \frac{dP_t^*}{dB_t^y} < 0, \tag{B.7}$$

i.e., workers in the LDC are worse off when B_t^y increases.

(b) Totally differentiating (17) with respect to B_t^x, we obtain

$$Z_1(P_t^*, B_t^x, B_t^y)\frac{dP_t^*}{dB_t^x} = -Z_2(P_t^*, B_t^x, B_t^y), \tag{B.8}$$

where $Z_2(P_t^*, B_t^x, B_t^y)$, by following steps identical to those that lead to (B.6), is obtained as

$$Z_2(P_t^*, B_t^x, B_t^y) = -(N_0^x - N_L^x) - (B_t^x L_0^x B_g^x)n'(B_t^x P_t^*/B_g^x). \tag{B.9}$$

From (B.8) we have

$$\frac{dP_t^*}{dB_t^x} = -\frac{Z_2(P_t^*, B_t^x, B_t^y)}{Z_1(P_t^*, B_t^x, B_t^y)}.$$

Substituting from (B.5) and (B.9) into the above expression, it is easily verified that

$$-P_t^*/B_t^x < \frac{dP_t^*}{dB_t^x} < 0. \tag{B.10}$$

Since $w^x = B_t^x P_t^*$, it follows that

$$\frac{dw^x}{dB_t^x} = P_t^* + B_t^x \frac{dP_t^*}{dB_t^x} > 0, \tag{B.11}$$

using (B.10). So LDC workers are strictly better off.

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