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Migration and Population Growth's Impact on Natural Resources and Welfare: The Role of Manufacturing's Returns to Scale

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Abstract

I examine whether trade can improve the impact of population growth on natural resources (NR) and welfare over time. Under autarky, population growth results in NR and welfare collapse over time, irrespective of the value of the returns to scale in the manufacturing sector, ϕ. Under trade, NR and welfare are unchanged (increase) (collapse) over time for ϕ=(>)(<)1 – though the decrease in welfare under ϕ<1 is dampened relative to autarky. Thus, countries experiencing rapid population growth may benefit from opening up to trade.

JEL classification

F16, F18, Q27, Q56

Keywords

migration, population growth, Renewable Natural Resources (NR), impact on NR and welfare

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I. Introduction

Many developing countries obtain a significant share of their income from renewable natural resources (*NR*). These include arable land, forests, fisheries, water resources and grazing grounds. Imperfect property rights for *NR* results in excessive pressure and depletion of *NR*, at times dramatically so – e.g., massive deforestation in the Philippines (Bee, 1987) and in Sub-Saharan Africa (Cerutti, 2024). The problem has been exacerbated by rapid population growth, which has affected many developing countries and has led to the decline or collapse of some communities and to emigration from affected regions.[1]

This paper focuses on developing countries with a comparative advantage in a commodity that is based on open-access *NR*. It examines the impact of population growth and endogenous migration on *NR* and welfare. An interesting result is that their impact depends on the returns to scale in the manufacturing sector and on the difference in these returns between home and host countries.

The paper is organized as follows. Section II provides some population projection and migration figures. Section III presents the model. Section IV solves it and examines the impact of population growth. The results of Section IV are used in Section V which examines the impact of endogenous migration. Section VI concludes.

II. Population Growth and Migration

Population has increased across the developing world in recent decades, particularly in Sub-Saharan Africa (SSA) where 15 of the 20 countries with the highest growth rate in the decade

[1] The classic case of *NR* depletion is fisheries (Gordon 1954, Scott 1955). Some more recent studies have extended the analysis, using general equilibrium models to examine steady states and transition dynamics in economies with open-access *NR* (e.g., Brander and Taylor 1997, 1998; López and Schiff, 2013).

2012-2022 are located. Moreover, the top 23 countries with the highest population growth estimates for 2024 (CIA 2024) are located in SSA, with the rate ranking from 23.8 in the Republic of Congo to 46.5 per thousand in South Sudan. Based on UN (2019) central projections, population in 36 – or two thirds of all – SSA countries are expected to increase by at least 50 percent from 2050 to 2100, and to at least double in 10 of them. And of the twelve SSA countries with the highest share of agriculture, forestry and fishing in GDP, the CIA (2024) reports an estimated average population growth rate of 29.0 per thousand.

As for SSA's ten most populous countries, the projected growth rate is 88 percent for 2022-2050, 72 percent for 2050-2100, and 224 percent for 2022-2100. Thus, population growth will be a major issue for many developing countries, until 2100 for SSA and at least to 2050 for many non-SSA countries. The high population growth rates are expected to put considerable pressure on *NR* in SSA and in a number of countries in other developing areas.[2]

These projections also show enormous disparity across SSA countries. UN (2019) population growth projections for SSA are from 27 to 150 percent in 2022-2050, 5 to 143 percent in 2050-2100, and 33 to 508 percent in 2022-2100. This suggests that intra-SSA migration is likely to be important for the rest of the century.

According to the IOM (2024), most international migration from Africa occurred within the region, with around 21 million Africans living in another African country in 2000, much of it in a

[2] For 2020-2050, these include, among the larger countries, Bangladesh, India, Indonesia, Pakistan, the Philippines and Vietnam in South and Southeast Asia; Argentina, Brazil, Colombia, Mexico and Venezuela in Latin America; Iran, Iraq, Syria, Turkey and Yemen in Western Asia; and Uzbekistan and Kazakhstan in Central Asia. And of the world's 16 most populous low-income to upper middle-income countries, the only ones with negative population growth projections from 2020 to 2050 are China (-2.5 percent) and Russia (-7 percent).

neighboring country. And Mutava (2023) reports that the number was about 12.8 million in 2000, 14.6 million in 2010 and 20.9 in 2020, with an increase of 1.8 million from 2000 to 2010 and of 6.3 million from 2010 to 2020, or 3.5 times the former. Major Sub-Saharan African migration corridors include migration from Burkina Faso, Mali and Niger to the Ivory Coast, and from Zimbabwe, Lesotho and Malawi to South Africa.

Migration from Burkina Faso to the Ivory Coast has increased over time and that from Mali to the Ivory Coast has done so after 2012. Migration from Zimbabwe to South Africa has also increased, with legal migration rising from half a million in 2000 to more than 1.2 million in 2008. It has also become more permanent over time. Similarly, migration from Malawi to South Africa has increased for both regular and irregular migration.

III. Model

A general equilibrium model of a small open economy is developed that captures the essence of the problem while being as simple as possible.

1. Production

Assume a two-sector small economy, with a *NR*-based commodity sector, Q, and a manufacturing sector, M, and two factors of production, labor and *NR*. Access to *NR* is open.

Population growth is assumed to be exogenous.[3] Each individual is endowed with one unit of labor. Denote *NR* by N, returns to scale in sector M by ϕ, population (or labor) by L, and employment in sector Q by L_Q and in sector M by L_M, with $L_Q + L_M = L$.

[3] Diamond (2011, Ch. 10) examines some of the causes of Africa's rapid population growth that are exogenous to *NR*, including improved hygiene, preventive medicine, greater vaccination, use of antibiotics, controls for malaria and other endemic diseases, and more. Studies with endogenous population include Brander and Taylor (1997, 1998).

In their analysis of *NR*, Brander and Taylor (1997, 1998) and López and Schiff (2013) have assumed a constant-returns-to-scale production function in the manufacturing sector, M. I assume here instead that $M = L_M^{\phi} = (L - L_Q)^{\phi}$, with $\phi \gtreqless 1$.

The equation for *NR*, which is derived in Appendix 1, is $N = \alpha - \beta L_Q$, where α is the environment's carrying capacity – or the maximum sustainable *NR*, given the environment – and employment L_Q in the commodity sector has a negative impact on *NR*, with $\partial N/\partial L_Q = -\beta$. *NR* enter the production of the commodity, Q, as conventionally done in the literature (Gordon 1954; Schaefer 1957; Copeland and Taylor 1994; and others), namely $Q = L_Q N$. Thus:

$$N = \alpha - \beta L_Q \geq 0, Q = L_Q N = L_Q(\alpha - \beta L_Q); M = L_M^{\phi}, \phi \gtreqless 1, L_M = L - L_Q > 1, \qquad (1)$$

where $L_M > 1$ ensures that M increases with ϕ.

Assume also that once *NR* are totally depleted, they cannot grow back, i.e., $N = 0 \Rightarrow \dot{N} = 0$.[4] Manufacturing is chosen as the numéraire.

2. Preferences

Individuals have Cobb-Douglas preferences over $m = M/L$ and $q = Q/L$. Denoting the share of income spent on q by γ, preferences are given by:

$$U = q^{\gamma} m^{1-\gamma}, 0 < \gamma < 1. \qquad (2)$$

[4] For instance, once all the fish in a lake have been caught, their stock remains nil. Note also that the Easter Island forest was destroyed centuries ago and never grew back (Brander and Taylor 1998).

IV. Solution

Assume the manufacturing price is the numéraire. The commodity's relative supply price, p_s, is given by the ratio of the commodity's average cost (given open access to the *NR*) and the manufacturing's marginal cost, or by the ratio of $\frac{w}{AP_{L_Q}}$ and $\frac{w}{MP_{L_M}}$, i.e., the ratio of $\frac{w}{\alpha-\beta L_Q}$ and $\frac{w}{\phi {L_M}^{\phi-1}} = \frac{w}{\phi(L-L_Q)^{\phi-1}}$. With p_s equal to the world price, p_w, we have $p_w = \frac{\phi(L-L_Q)^{\phi-1}}{\alpha-\beta L_Q}$. Given that p_w is exogenous for the small open economy, we can derive the impact of L on L_Q. The solution, which is derived in Appendix 2, is:

$$\frac{\mathrm{d}L_Q}{\mathrm{d}L} = \frac{(1-\phi)(\alpha-\beta L_Q)}{(1-\phi)(\alpha-\beta L_Q) + \beta(L-L_Q)}. \tag{3}$$

Individual income $y = y_s = y_d$, i.e., $y = p_w q_s + m_s = p_w q_d + m_d$.[5] From (2), $p_w q_d = \gamma y$ and $m_d = (1-\gamma)y$. Thus, $q_d = \left(\frac{\gamma}{p_w}\right) y$, and

$$U = \left(\frac{\gamma}{p_w}\right)^{\gamma} (1-\gamma)^{1-\gamma} y;\ y = \left[p_w L_Q\left(\alpha - \beta L_Q\right) + (L - L_Q)^{\phi}\right]/L. \tag{4}$$

<u>*Impact of Population Growth*</u>

We now examine the impact of population growth, in the absence of migration, on *NR* and welfare in an individual country under constant, decreasing and increasing returns to scale.

1. <u>Constant returns to scale: $\phi = 1$</u>

In this case, $M_s = {L_M}^{\phi} = L_M$ and $MP_{L_M} = \phi(L - L_Q)^{\phi-1} = 1$ is independent of L and so is U. Thus, $p_w = \frac{\phi(L-L_Q)^{\phi-1}}{\alpha-\beta L_Q} = \frac{1}{\alpha-\beta L_Q}$. From equation (4), we have $y = 1$. Hence:

[5] Thus, $p_w(q_s - q_d) = m_d - m_s$, i.e., trade is balanced.

$$U = \left(\frac{\gamma}{p_w}\right)^{\gamma} (1-\gamma)^{1-\gamma}.^{6} \qquad (5)$$

Note that U is independent of L_Q, L_M or L in this case. Similarly, from (3), we have $\frac{\mathrm{d}L_Q}{\mathrm{d}L} = 0$, i.e., L_Q is independent of L. Since $p_w = \frac{1}{\alpha - \beta L_Q}$, it follows that L_Q is a function of p_w and not of L. This result implies that $\frac{\partial L_Q}{\partial L} = \frac{\partial N}{\partial L} = \frac{\partial Q_s}{\partial L} = 0$, and $\frac{\partial M_s}{\partial L} = \frac{\partial L_M}{\partial L} = 1$. The reason is that since $MP_{L_M} = 1$ and p_w is exogenous, $AP_{L_Q} = \alpha - \beta L_Q = 1/p_w$ is given. Thus, any population increase is fully absorbed by the manufacturing sector and does not affect L_Q, NR or Q_s. In other words, population growth does not result in *NR* or welfare collapse.

2. Decreasing returns to scale: $\phi < 1$

In this case, numerator and denominator of (3) are positive, implying that $\frac{\mathrm{d}L_Q}{\mathrm{d}L} > 0$ and $\frac{\mathrm{d}N}{\mathrm{d}L} = -\beta \frac{\mathrm{d}L_Q}{\mathrm{d}L} < 0$. Thus, *NR* and welfare decline over time and collapse in the long run. As L and L_Q increase, *NR* eventually reach zero, with $Q_s = 0$. Then, $VAP_{L_Q} = 0$ and since $NR = 0$ implies that $\dot{N} = 0$, labor L_Q moves to sector M, with $L_M = L$, and $Y = M_s = L^{\phi}$. Thus, $M_d = (1-\gamma)L^{\phi}$ and $p_w Q_d = \gamma L^{\phi}$, with $Q_d = (\gamma/p_w)L^{\phi}$.[7] Individual values are as follows:

$$y = m_s = L^{\phi-1}, m_d = (1-\gamma)L^{\phi-1}, q_d = \left(\frac{\gamma}{p_w}\right)L^{\phi-1}, U = \left(\frac{\gamma}{p_w}\right)^{\gamma}(1-\gamma)^{1-\gamma}L^{\phi-1}. \qquad (6)$$

Since $\phi < 1$, it follows that all variables in (6) decline with population L, i.e., welfare and *NR* decline with L.

[6] Equation (4) implies that welfare declines with the country's terms of trade, which is due to the distortion in the commodity sector where allocation of L_Q depends on AP_{L_Q} rather than on MP_{L_Q}.

[7] Since $M_s = L^{\phi}$, while $M_d = (1-\gamma)L^{\phi}$, γL^{ϕ} is exported, and $p_w Q_d = \gamma L^{\phi}$ is imported. Evidence for trade pattern reversal is provided in Schiff (2024).

3. Increasing returns to scale: $\phi > 1$

In this case, the numerator in equation (3) is negative and, as shown in Appendix 3, its denominator must be positive for a stable interior equilibrium (at a given population level), so that $\frac{\mathrm{d}L_Q}{\mathrm{d}L} < 0$. The reason is that an increase in L_M raises its marginal product. Hence, L_Q's average product must increase as well. This implies that L_Q must decrease (and *NR* must increase) as L increases. Thus, $\frac{\mathrm{d}L_M}{\mathrm{d}L} > 1$. At some point, $L_Q = Q_s = 0$, so $L_M = L$ and $\frac{\mathrm{d}L_M}{\mathrm{d}L} = 1$ (and $NR = \alpha$). The functions for y, m_d, q_d and U are identical to those in equation (6). The difference is that $\phi > 1$, which implies that income, consumption of the two goods and welfare increase over time as L increases.

V. International Migration

Consider two countries, C1 and C2, which export the commodity to the rest of the world. Assume emigration from C1 to C2 entails zero costs and individuals maximize their wellbeing U in the absence of altruism.[8]

I examine the impact of migration under three alternative assumptions regarding the difference between C1 and C2, namely a difference in population size, in population growth, and in the manufacturing sector's returns to scale.

1. Difference in Population Size

Denote population in country C_i by L_i, with $L_1 > L_2$.

[8] Incorporating immigration costs does not affect the sign of migration's impact (and migration may be nil when the migration cost is sufficiently high). Note also that regional migration within Africa is more important than migration to non-African countries, and that much regional migration is to a neighboring country, resulting in low migration costs.

i) Assume $\phi < 1$. Then, $U_1 < U_2$, and migration is from C1 to C2, which reduces L_1 and raises L_2, thus raising U_1 and reducing U_2. Since the two countries are otherwise identical, it follows that migration equates U_1 and U_2 by equating L_1 and L_2, i.e., migration equals $(L_1 - L_2)/2$ so that $L_1^* = L_2^*$ and $U_1^* = U_2^*$, where asterisks denote post-migration equilibrium values. Also, $L_1 > L_2$ initially implies $NR_1 < NR_2$ for $\phi < 1$.

In other words, migration is from the low-*NR* country to the high-*NR* one, which raises them in C1 and reduces them in C2, with $NR_1^* = NR_2^*$. Thus, migration results in the total convergence of *NR* and welfare in the two countries. An identical population growth reduces welfare in both countries. However, given their total convergence, it does not generate additional migration.

ii) Under $\phi = 1$, and as is shown in Section IV, population – as well as identical population growth – has no impact on welfare or *NR*, i.e., $U_1 = U_2$ and $NR_1 = NR_2$. Thus, no migration takes place.

iii) Under $\phi > 1$, $U_1 > U_2$, and migration is from C2 to C1, which raises U_1 and reduces U_2. Thus, migration raises the welfare gap. Since $L_1 > L_2$, migration raises the population gap, $L_2 - L_1$. Moreover, since L_Q declines with population L when $\phi > 1$, $L_1 > L_2$ implies $NR_1 > NR_2$, and migration raises NR_1 and reduces NR_2, thus raising the *NR* gap, $NR_1 - NR_2$.[9] Under identical population growth, the welfare gap $U_1 - U_2$ keeps rising, so that migration increases over time and C1's population emigrates to C2.

[9] Since $\phi > 1$, L_Q declines in C1 as its population increases, and so does Q_s (at least after a point if L_Q is initially very large and $MP_{L_Q} < 0$) while Q_d increases, and the difference is imported. Evidence for trade pattern reversal is provided in Schiff (2024).

2. <u>Difference in Manufacturing Returns to Scale</u>

Assume C2 is more developed than C1, with $\phi_1 < \phi_2$. Then, given identical initial population, $L_1 = L_2$, we have $U_2 > U_1$, and migration is from C1 to C2. Moreover, initial $L_{M2} > L_{M1}$ and $L_{Q2} < L_{Q1}$, so that $NR_2 > NR_1$. We examine three cases.

i) Assume $\phi_1 < \phi_2 < 1$. Migration from C1 to C2 raises U_1 and NR_1, and reduces U_2 and NR_2, resulting in $U_1^* = U_2^*$. Thus, C2's initial productivity advantage relative to C1 is canceled by the increase in population in C2 relative to C1. Also, migration is from the low-*NR* to the high-*NR* country, reducing the *NR* gap.

Assuming an identical population growth, and denoting the time derivative of L_i by $\dot{L_i}$, we have $\frac{\dot{L_1}}{L_1} = \frac{\dot{L_2}}{L_2}$. Since $L_1 < L_2$ after migration, it follows that $\dot{L_1} < \dot{L_2}$, which further raises the gap, $L_2 - L_1$, which raises the migration flow that equates welfare levels between C1 and C2.

ii) Assume $\phi_1 < 1 < \phi_2$. As migration reduces L_1 and raises L_2, welfare as well as *NR* rise in both countries, and the sign of the change in the welfare gap, $U_2 - U_1$, is ambiguous. On the other hand, assuming an identical population growth, welfare and *NR* decline in C1 and increase in C2, resulting in a larger welfare gap and a greater migration level. Eventually, C1's population migrates to C2.

iii) Assume $1 < \phi_1 < \phi_2$. Then, migration reduces U_1 and NR_1 and raises U_2 and NR_2. Thus, the welfare gap, $U_2 - U_1$, increases, which leads to more migration (though the increase is dampened in the case of remittances from C2 to C1). The greater migration results in a further increase in the welfare gap, and a further increase in migration, and so on, with the long-run outcome being that the population of the less developed C1 emigrates to the more developed C2.

3. Difference in Population Growth

In this case, we have $\phi_1 = \phi_2 = \phi$. Assume $\frac{\dot{L_1}}{L_1} > \frac{\dot{L_2}}{L_2} > 0$. Though $L_1 = L_2$ initially in this case, the higher population growth in C1 results in $L_1 > L_2$. Thus, the results only differ from those in Sub-section 1 above in terms of dynamics.

i) For $\phi < 1$, welfare and *NR* decline faster in C1 than in C2, and migration leads to equality in population levels, *NR* and welfare. However, as population keeps growing and faster in C1 than in C2, the welfare gap rises, so that migration flows required to equate C1 and C2's population and welfare rise over time.

ii) For $\phi = 1$, population growth has no impact on welfare, i.e., welfare $U_1 = U_2$, and no migration takes place. Commodity output is identical in both countries, while manufacturing is larger in C1, the country with the largest population.

iii) For $\phi > 1$, $U_2 > U_1$ (and $NR_2 > NR_1$), so migration is from C1 to C2. This reduces U_1 and raises U_2, raising the welfare gap, $U_1 - U_2$, between the more and less developed countries over time.[10] Thus, migration increases over time and results in C1's population migrating to C2. Note that migration is from the low-*NR* to the high-*NR* country.

VI. Conclusion

The paper's objective was to examine the impact of population growth and migration on *NR* and welfare, using a simple general equilibrium model of a commodity sector based on an open-access *NR* and a manufacturing sector with constant, increasing or decreasing returns to scale ϕ, i.e., with

[10] This also raises the difference in the decline in commodity output and in the increase in manufacturing output.

$\phi = (>)(<)1$. The model was solved and the impact of population growth on an individual country was obtained. These results formed the basis for the analysis of migration between two countries, based on differences in population, in population growth and in the returns to scale.

The main findings are:

i) Population growth has no (a positive) (negative) impact on *NR* and welfare under constant (increasing) (decreasing) returns to scale ϕ, i.e., under $\phi = (>)(<) 1$.

ii) Migration is typically from low-*NR* countries to high-*NR* ones;

iii) No migration takes place under constant returns to scale ($\phi = 1$), irrespective of population size or growth rate, or in their difference between countries C1 and C2;

iv) Migration results in convergence of C1 and C2's welfare and *NR* under $\phi < 1$ and in their divergence under $\phi > 1$;

v) In the latter case, migration starts a process which result in a move of the population from the low-*NR* and low-welfare country to the high one; and

vi) Migration always results in an increase in welfare and *NR* in one country and a decrease in them in the other country, except for $\phi_1 < 1 < \phi_2$, in which case migration raises welfare and *NR* in both countries.

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Appendix 1. Natural Resource Equation

Following Schaefer’s (1957) seminal article and many *NR* studies thereafter (e.g., López and Schiff 2013), *NR* growth is specified as $\dot{N} \equiv dN/dt = \rho N\left(1-\frac{N}{K}\right)-\mu Q, N>0$, where $\rho>0$ is the *NR*'s natural growth rate when it is unexploited), K is the environment's carrying capacity – or the maximum sustainable *NR*, given the environment – and $\mu > 0$ is the rate of *NR* depletion per unit of commodity output Q.

NR enter the production of the commodity, Q, as conventionally done in the literature (Gordon 1954; Schaefer 1957; Copeland and Taylor 1994; and many others), namely $Q = L_Q N$.

Thus, $\dot{N} = \rho N \left(1 - \frac{N}{K}\right) - \mu L_Q N, N > 0$, with $\dot{N} = 0$ for $N = \left(1 - \frac{\mu L_Q}{\rho}\right) K$.

Denoting K by α and $\frac{\mu K}{\rho}$ by β, we have:

$$N = \alpha - \beta L_Q \geq 0, Q = L_Q N = L_Q(\alpha - \beta L_Q); M = L_M^{\phi}, \phi \gtreqless 1, L_M = L - L_Q > 1, \qquad (1)$$

where α is the environment's carrying capacity (or maximum sustainable *NR* level), L's negative externality is $MP_L - AP_L = (\alpha - 2\beta L_Q) - (\alpha - \beta L_Q) = -\beta L_Q$ – which is also equal to the impact of L_Q on N, and $L_M > 1$ ensures M increases with ϕ.

Appendix 2. Impact of Population L on Commodity Employment L_Q

The supply price, p_s, equals the world price p_w, i.e., $p_w = \frac{\phi(L-L_Q)^{\phi-1}}{\alpha-\beta L_Q}$. As p_w is exogenous for the small open economy, we have $\mathrm{d}p_w = \left(\frac{\partial p_w}{\partial L_Q}\right) \mathrm{d}L_Q + \left(\frac{\partial p_w}{\partial L}\right) \mathrm{d}L = 0$, or $\frac{\mathrm{d}L_Q}{\mathrm{d}L} = -\frac{\partial p_w / \partial L}{\partial p_w / \partial L_Q}$.

Since $\frac{\partial p_w}{\partial L_Q} = \frac{\phi(L-L_Q)^{\phi-2}[(1-\phi)(\alpha-\beta L_Q) + \beta(L-L_Q)]}{(\alpha-\beta L_Q)^2}$, and $\frac{\partial p_w}{\partial L} = \frac{\phi(\phi-1)(L-L_Q)^{\phi-2}}{\alpha-\beta L_Q}$, it follows that:

$$\frac{\mathrm{d}L_Q}{\mathrm{d}L} = \frac{(1-\phi)(\alpha-\beta L_Q)}{(1-\phi)(\alpha-\beta L_Q) + \beta(\mathbb{L}-L_Q)}. \qquad \text{(A3)}$$

Appendix 3: Stability of Short-Term Equilibrium for $\phi > 1$

The condition for equilibrium stability when $\phi > 1$ is $(1-\phi)(\alpha - \beta L_Q) + \beta(L - L_Q) > 0$.

<u>Proof</u>: Population at time t is L_t and the labor market equilibrium condition is $p_w AP_{L_Q} = MP_{L_M}$, or $p_w(\alpha - \beta L_Q) - \phi {L_M}^{\phi-1} = 0$, $L_Q + L_M = L_t$. Say manufacturing employment, L_{M0}, is above its equilibrium level, i.e., $L_{M0} > L_M$. As $L_{Q0} + L_{M0} = L_t$, we have $L_{Q0} < L_Q$. The equilibrium (L_Q, L_M) is stable if, at (L_{Q0}, L_{M0}), $p_w(\alpha - \beta L_{Q0}) - \phi {L_{M0}}^{\phi-1} > 0$, in which case labor moves from the manufacturing to the commodity sector and its allocation moves to equilibrium values (L_Q, L_M). [11]

Thus, for any value of L_t, the equilibrium is stable if $\frac{\partial[p_w(\alpha-\beta L_Q)-\phi {L_M}^{\phi-1}]}{\partial L_M} = \beta p_w + \phi(1-\phi){L_M}^{\phi-2} > 0$. Since $p_w = \frac{\phi {L_M}^{\phi-1}}{\alpha-\beta L_Q}$, we have $\phi {L_M}^{\phi-2}\left[\frac{\beta L_M}{\alpha-\beta L_Q} + (1-\phi)\right] > 0$. Thus, the stability condition is $\beta(L - L_Q) + (1-\phi)(\alpha - \beta L_Q) > 0$. QED.

[11] The same logic applies for $L_{M0} < L_M$, in which case stability implies that $p_w(\alpha - \beta L_{Q0}) - \phi {L_{M0}}^{\phi-1} < 0$.