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Martin Daniel Siyaranamual

Center for Economics and
Development Studies (CEDS)
Padjadjaran University

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Center for Economics and Development Studies,
Department of Economics, Padjadjaran University
Jalan Cimandiri no. 6, Bandung, Indonesia.
Phone/Fax: +62-22-4204510
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Constructing the Model of Environmental Migration

Martin Daniel Siyaranamual[*†]

Abstract

To address the surprising lack of research in the area of environmental migration, this paper reviews the existing literature and proposes two basic, two region, and general equilibrium models: a closed economy and a small open economy where migration occurs between regions. The models show that migration increases welfare in the rural region, characterized by a tragedy of the commons production function, but does not affect welfare in the region with a constant returns to scale production function. The paper also provides an economic definition of an environmental refugee in the respect of an environmental migrant.

[*] Junior researcher at Center for Economics and Development Studies (CEDS/LP3E), Padjadjaran University, Bandung, Indonesia.

[†] Correspondence: siyaranamual.martin@gmail.com

1. Introduction

The Stern's Report states that based on 'conservative estimates' 150-200 million people will be forced to migrate by 2050 as a result of environmental changes caused by climate change. This is a staggering figure considering that the Report also mentions, effectively in the same breath, the lack of research in the area of environmental migration.

The existing literature tends to be qualitative in nature or to focus on the issues of politics and conflict, or why environmental shock occurred environmental migration is viewed as a humanitarian problem where scientific modeling informs the severity of the humanitarian crisis, rather than an economic one.

While migration has been extensively analyzed econometrically, the analysis does not include environmental factors. Developed countries, however, will require confirmation of the estimates from the Stern Report, and will require a means of theoretical assessment of environmental policy changes, so much so that they may require coordination between migration policy and environmental policy.

A part of the issue of estimation concerns the definition of an 'environmental refugee' in respect of an 'environmental migrant'. Even though these terms have been thrown around in academic literature, humanitarian studies, and naturally in the media, nonetheless their definitions remain elusive (Homer-Dixon, 1999).

This structure of the paper is as follows. A review of the existing literature relevant to environmental migration is presented in section 2. Section 3 presents and discusses a series of issues raised by the literature review which are pertinent for economic modeling of environmental migration. Sections 4 and 5 each present a general equilibrium model of environmental migration in which some of the characteristics from section 3 have been applied. The discussion in section 6 covers general points, the issues important when modeling environment, and a discussion of the definition of environmental refugees in respect of environmental migrants.

2. Literature Review

This section presents an overview of literature relevant to environmental migration. It firstly reviews the findings from several papers on environmental migration and then looks at problematic of the definition of environmental refugees by presenting some qualitative articles. Lastly, this paper specifically presents the existing microeconomic model of environmental migration from Chichilnisky and di Matteo (1998) and the results of two relevant models on trans-boundary pollution.

The Stern Report states that "climate change is likely to increase migratory pressures on developed countries significantly", but also says that "the potential scale and effect are still very uncertain and require considerably more research." It is important to note the emphasis on migratory pressures on developed countries, referring here to South-North migration while, Hatton and Williamson (2002) predict that the most significant migration in the future will be South-South migration.

The Stern Report points out two reasons why climate change will force people to migrate. Firstly due to income gap: real wage differentials are considered the main driver of migration. Secondly, due to environmental disasters: climate change will cause conditions to deteriorate such that large numbers of people will be "compelled to leave their home when resources drop below a critical threshold." There are a number of aspects to notice about this claim. Firstly, the reference to a threshold below which people will migrate; secondly, the decrease in resources will occur as a result of disasters caused by climate change; and, thirdly, that it is not clear whether the disaster is the direct cause of migration or that it has an indirect effect, e.g., because it causes a drop in production that will increase wage differentials.

The Report says the exact number of people who will be displaced or forced to migrate will depend on the level of investment, planning and resources at a government's disposal to defend these areas or provide access to public services and food aid. This number is derived mostly from Myers and Kent (1995) who's saying that their estimates have not been tested rigorously. Myers' (1993b) definition of environmental refugees are people who can no

longer gain a secure livelihood in their former homelands because of drought, soil erosion, desertification, and other environmental problems. Nonetheless, He does not provide a definition of "secure livelihood" hence this definition leaves much unclear.

Bates (2002) attempts to clarify the previously vague definition of environmental refugees and environmental migrants, noting the academic literature has been sloppy in this area. A working definition is people "who migrate from their usual residence due to change in their ambient non-human environment." The paper suggests three categories of environmental shock: disasters, expropriations, and deteriorations.

Suhrke (1995) had also previously pitched into the debate on the existence of environmental migration, motivating in part Bates' response. It is also difficult to extract a clear economic interpretation of Suhrke's description of environmental migration since it alludes to a number of factors in environmental migration: environmental degradation was a factor in outmigration (emigration) although it may be a proxy for another variable; demographic growth; various forms of degradation, change in relative wages in different regions, industrial sectors, or demographic groups; and, the type of interaction between the environment and population. This highlights the difficulty understanding how environment and migration are related, and how to model the relationship.

Suhrke continues on to point out further qualitative factors relating migration to environment, such as: a dynamic tragedy of the common[1]; the better opportunities in other regions; classic pull-push model[2] or the uncertainty on reversibility of migration.

Other interesting arguments on environmental migration are coming from the paper of Homer-Dixon (1999). In this paper He argues that environmental migration implies that the clear and dominant cause of migration is environmental disturbance which is seldom

[1] Environmental degradation affects patterns of resource use such that as resources are extracted, yields decline, forcing farmers to exploit the land more intensively interpretation.

[2] Some environmentally-related migrations were indistinguishable from economically motivated migrations.

the case since environmental factors only produce their effects in complex interaction with other aspects. Moreover, he also points out that environmental scarcity rarely manifests itself in a sharp and hurtful way that people are suddenly compelled to leave.

The decision to migrate cannot be linearly modeled as a set of push and pull factors. He prefers to loosely define the reason for migration as the perceived difference in quality of life in the sending and receiving regions: once the difference reaches a certain size, an inhabitant migrates. Environmental scarcity causes environmental migration, but in such as way that there are complex interrelationships. Three reasons for this scarcity are: demand induced scarcity caused by rapid population growth (direct and major cause); supply induced scarcity, e.g., cropland degradation and depletion (secondary); and, structural scarcity, e.g., land distribution.

The motivation for Chichilnisky and di Matteo (1998) is the world phenomena whereby the international market allows overconsumption in the North and overproduction in the South due to differing property rights regimes. The paper is also motivated by Myer's (1993) result that migration is closely linked to environmental degradation.

The paper poses questions about how migration affects the exploitation of natural resources, how policies to check environmental degradation interact with migration flows, and how trade policies affect migration flows and the exploitation of natural resources. To this end, the paper presents a general equilibrium model for analyzing some aspects of environment, trade and migration. Migration is linked to wage differentials and property rights regime of the environmental resource.

Chichilnisky and di Matteo model gives the following results: if migration occurs due to wage differentials between countries (which the model assumes) then migration occurs when technologies are different; migration from the South decreases exploitation of the resource in the South, and increases welfare in the South, although it can decrease welfare in the North depending on exogenous parameters. Migration can lead to higher prices of the resource in the North, and better terms of trade in the South, reduces the wage differential in favor of the South, and reduces resource extraction while a tax on the resource in the

South surprisingly increases the rate of extraction. These results do not hold if the labor elasticity of substitution is greater than one. Some results are key results derive from a previous paper by Chichilnisky (1995) which shows that when two countries have identical technology and preferences, a sufficient reason for them to engage in trade is the difference in property rights of the natural resource—the South has an apparent competitive advantage in the resource intensive good, thus the South exports the resource intensive good and imports capital intensive good.

While Chichilnisky's model make an important contribution to microeconomic models of environmental migration, some criticisms are: it assumes free movement of labor which is empirically untrue, particularly as most developed countries have quotas on immigration; wage differentials are the only reason for migration while Hatton and Williamson (2002) provide numerous other factors; it does not consider that a receiving government can optimize immigration policy such as quotas in each period; the model makes certain strong assumptions such as the utility function has an elasticity of substitution between the consumption capital intensive good and leisure less than one, and the restriction on direct investment or induced technical change when local resource prices diverge as a result of migration.

The model of Chichilnisky & di Matteo (1998) has the same logical structure as the Heckscher-Ohlin model that highlights the connection between labor migration and exploitation of natural resources; however technologies differ between countries. Moreover this paper also assumes that resource is extracted using labor as the only input and according to a strictly concave production function. The South is assumed to have common property rights. This results in the amount of the resource supplied being an increasing function of the prices of the resource. The exact form of the supply curves depends on the property rights.

There is no developed labor market in the extraction sector of the economy, labeled the subsistence sector; hence there is no market wage, rather an opportunity cost of labor which equals the common property marginal product (CMP) times its price.

As a result, the quantity of the resource supplied, increases as the price of environmental resource increases. It is assumed that the supply function of the resource is linear for simplicity with a parameter that explains supply is the resource is more sensitive to its price, representing the tragedy of the commons.

Proposition 1 says that as the relative price of the resource decreases or the relative price of the consumption good increases, the worker in the subsistence sector of the economy has to work more to secure a minimum level of subsistence, under the assumption that the utility function has an elasticity of substitution between leisure and capital intensive good less than one. Thus supply of environmental resource good is an increasing function of its price. This result is used in a number of later propositions.

The paper argues that labor migrates because both real wages and price of the resource cannot equalize across countries simultaneously, although either real wages or resource price can, by coincidence equalize. The result differs from the Heckscher-Ohlin model because technologies are different. The paper compares the terms of trade when real wages equalize to the terms of trade when resource prices equalize, and concludes that the two conditions cannot occur simultaneously, based on assumptions about the values of certain endogenous variables.

Nonetheless, Chichilnisky and di Matteo do not quantify the relationship between the real wage differential and the number of workers migrating because it is a complex phenomenon. In order to accommodate migration into the model, the model is reinterpreted as a two phase model.

One of the most important results from the paper is that migration increases welfare in the South while no conclusion is possible on the welfare changes in the North without more information about the exogenous variables. To obtain the result in the South, the paper argues, that since the consumption of capital intensive good is given in each country, an increase in welfare is synonymous with an increase in demand for resource intensive good.

The result relies on the assumption that the resource intensive sector in the South is much more resource intensive than in the North. If this were also the case in the North, migration from the South would bring about a decrease in the terms of trade, and resource extraction would increase.

Chichilnisky joins with a number of other papers concluding that partial equilibrium analysis of taxation can be misleading because the introduction of a unit tax on the use of the resource in the South, whose proceeds are used to increase demand for capital intensive good, reduces the terms of trade, the price of the resource, and increased extraction of the resource in the South.

Hoel and Shapiro (2001) model trans-boundary pollution, perfectly mobile households and governments that re-optimize environmental policy. While other papers have emphasized that optimal environmental policy in an international setting needs to be co-operative, Hoel and Shapiro paper shows that the Nash equilibrium is the efficient solution of the policy game between governments when households are perfectly mobile. Policy coordination may still be required if there are multiple Nash equilibria.

Hoel and Shapiro use a framework where pollution taxes are collected in the local public sector, which treats newcomers and natives equally, so that newcomers can attain the same level of consumption and utility as old residents. The last two conditions imply that welfare is equalized between jurisdictions.

The solution is obtained through a general theorem that states that the vector of policy choices between regions that maximize utility in all regions subject to feasibility constraints must also be a Nash equilibrium of the game described above. The interpretation is that because perfect social mobility equalizes utility between regions, no matter what policies are chosen at a regional level, all regions share a common interest in maximizing common utility level. Alternatively, under perfect mobility, migration is like a rope, holding the regions together, if one region suffers, all regions suffer.

Haavio (2003) models trans-boundary pollution, household mobility and governments that constantly re-optimize environmental policy non-cooperatively, based on models such as that of Hoel and Shapiro (2001). He introduces migration costs that represent imperfect household mobility. He finds that the introduction of imperfect household mobility and constant policy re-optimization by governments leads to a dynamic tragedy of the commons, where the externality increases as household mobility increases. There is, however, a discontinuity between perfect and almost perfect household mobility.

He emphasizes that the presence of shifting costs of migration implies that decisions to relocate are forward-looking: people do not migrate because they think they will be immediately better off but because they expect a better future. Similar to Hatton and Williamson, he points out that rational governments re-optimize policy if permitted, and also that migration is a costly and gradual process. As migration costs approach zero, the economy becomes distorted as under global pollution. However, if migration costs are zero, the efficiency result in the literature is re-established.

The cost of migration is modeled as an increasing function of the net migration to and from the source and destination countries. That is, the costs increase the more people that are currently migrating to that destination country, and the costs increase the more people are migration from the source country.

The problem presented in the paper of Haavio (2003) is a differential game. In the socially optimal steady state, marginal utility of consumption equals the social marginal utility of environmental amenities. The non-cooperative game solution is suboptimal. The pollution stock has the strategic value of reducing immigration, which lowers its cost as perceived by an individual country. If a country implements socially optimal environmental policies, foreigners gradually migrate to that country and take their share of the cake. On the other hand, consuming now, rather than later, makes the country less attractive for foreigners. Migration costs establish instantaneous private access on the benefit side. Reduced migration costs accentuate the role of future access, and reinforce the strategic value of the pollution stock in deterring immigration. For example, in a two region, two

period model, where households are immobile in the first period, in the second period, households are perfectly mobile. This leads to the households consuming too much in the first period, before moving to equalized utility in the second period.

Haavio points out empirical evidence supporting these results where migration encourages people to disregard their environment such as mining communities, military bases, nomadic, and refugees.

3. Key Issues to Consider in the Model

This section is a summary of the points raised in the literature review which a model on environmental migration should consider.

Research has pointed out the largest migrations will occur within countries rather than between countries. Hatton and Williamson point out that South-South migration has been largely ignored, but will become relatively more significant. Chichilinsky's model, by having resource intensive sectors in southern developing countries, different technologies between regions, input prices local to each region, but global prices for produced goods, focuses however on international or cross border migration.

One reason why South-North migration is less likely to occur is because governments in developed countries receiving South-North migration are able to 'optimize' policy, i.e., place quotas or costs on migration. This leads to an important question raised by Hatton and Williamson that is beyond the scope of the models: how do sovereign regions that endogenously re-optimize immigration policy affect migration and the extraction of an environmental resource?

This paper develops a framework, a simplification of Chichilnisky (1995) and Chichilnisky & di Matteo (1998) model, from which the following questions can be answered:

1. How do environmental refugees differ from environmental migrants? Is the distinction provided by Myers between "pulled by opportunity for a better economic life" and those "pushed by environmental destitution" a useful one?
2. How does environmental shock cause migration?

Some additional points which are considered in the models are:

1. How to model migration when it is caused by factors other than real wage differentials?
2. The literature differentiates between migration that is caused by environmental shock and gradual environmental degradation.
3. Hatton and Williamson (2002) suggest that a "hump-shaped" relationship between wealth and amount of migration due to costs of migration.

4. Model of Closed Economy

There are two regions, urban (R_u) and rural (R_r). The population resides either in the urban region or in the rural. The total population, N_0 is normalized to one, hence N represents the proportion of people living in the rural region and $1 - N$ represents the proportion of people living in the urban region.

There are two goods, X and Y, whose prices are given by P_X and P_Y, respectively. Good X is produced in the rural region while good Y in the urban region.

The rural region's production is characterized by a 'tragedy of the commons' production function, $X = f(E/N)$, such that the total production of the rural region is given by $Nf(E/N)$. The production function $f(\cdot)$ is assumed to be twice differentiable and strictly concave, $f'(0) = +\infty$. E is a constant representing a fixed amount of common resource such as farming land.

The production function in the rural region exhibits constant returns to scale and is specified as $Y = g(1 - N)$. The rate of return of production in the rural region is normalized to 1 so that production in the rural region is given by $Y = 1 - N$.

Each inhabitant has inelastic labor supply function for the provision of one unit of labor in return for $X = f(E/N)$ in the rural region or a Y good in the urban area.

The economy is closed such that prices P_X and P_Y vary according to supply and demand. Goods are freely traded between rural region and urban region.

There are no firms as such – each inhabitant receives what he or she produces and can trade (part of) it for the other good. Inhabitants of rural and urban regions have the same Cobb-Douglas utility functions: $U(X,Y) = X^{\alpha}Y^{1-\alpha}$.

4.1. Optimal Allocation

A benevolent social planner would optimize the allocation of N and $1-N$ to each region in the economy to maximize overall social welfare, in this case, for a representative individual with a Cobb-Douglas utility function:

$$\max_{N} U(X,Y) = X^{\alpha}Y^{1-\alpha}$$

where

$$X = Nf(E/N)$$

$$Y = 1 - N$$

The optimal N^* is solved by the following equation

$$\frac{N^*}{1-N^*} = (1+\epsilon)\frac{\alpha}{1-\alpha}$$

where ϵ is the elasticity of $f(E/N)$ with respect to N.

4.2. Competitive Equilibrium

Inhabitants maximize their utility constrained by the production function for the region in which the inhabitant resides.

The urban inhabitant maximizes utility based on the budget constraint that she receives one unit of good Y via the production function $g(\cdot)$:

$$\max_{XY} U_{R_u}(X,Y) = X_{R_u}^{\alpha} Y_{R_u}^{1-\alpha}$$

subject to

$$P_X X + P_Y Y \leq P_Y g(1) = P_Y$$

The results of optimization above are demand functions per individual in the urban region.

$$Y_{R_u}^{D} = 1 - \alpha$$

$$X_{R_u}^{D} = \alpha \frac{P_Y}{P_X}$$

Similarly, the rural inhabitant maximizes her utility under the budget constraint. She uses the production technology $f(\cdot)$, characterized by tragedy of the commons production function, which depends on the number of other inhabitants of the rural region:

$$\max_{XY} U_{R_r}(X,Y) = X_{R_r}^{\alpha} Y_{R_r}^{1-\alpha}$$

subject to

$$P_X X + P_Y Y \leq P_X f\left(\frac{E}{N}\right)$$

which brings to the individuals' demand functions:

$$Y_{R_r}^{D} = (1-\alpha)\frac{P_X}{P_Y} f\left(\frac{E}{N}\right)$$

$$X_{R_r}^{D} = \alpha f\left(\frac{E}{N}\right)$$

Markets clear such that total demand from the two regions equals total supply:

$$Y_{R_u}^{D} + Y_{R_r}^{D} = Y_R^S \Longrightarrow (1-\alpha)(1-N) + \left[(1-\alpha)\frac{P_X}{P_Y} f\left(\frac{E}{N}\right)\right] N = (1-N)$$

$$X_{R_u}^{D} + X_{R_r}^{D} = X_R^S \Longrightarrow \left(\alpha \frac{P_Y}{P_X}\right)(1-N) + \left(\alpha f\left(\frac{E}{N}\right)\right) N = N f\left(\frac{E}{N}\right)$$

Due to Walras' law both equations provide the solution to the equilibrium:

$$\frac{P_Y}{P_X} = \frac{(1-\alpha)}{\alpha}\frac{Nf\left(\frac{E}{N}\right)}{(1-N)}$$

The model follows a repeating two-stage model as suggested by Chichilnisky (1995). In the first period prices stabilize given constant N. In the second stage inhabitants migrate according to the difference in utility. That is, inhabitants of the rural migrate to the urban if $U_{R_u} < U_{R_r}$, and from the urban to the rural if $U_{R_u} > U_{R_r}$ as suggested in Hatton and Williamson (2002), and used in Hoel and Shapiro (2003), and Haavio (2005). This treatment diverges from Chichilnisky's model (1995) where differences in real wage are the sole determinant of the migration decision. The approach where utility is compared is more general in that the utility function can be extended to model other factors involved in the decision to migrate such as those suggested by Hatton and Williamson (2002) and Haavio (2005). However, in this model as it is without other factors entering into utility, utility translates into real wage.

Migration is assumed to be costless at this point. As in Chichilnisky's model (1995), the speed and magnitude of migration is not calculated, following the assertion that it is a complex process that does not occur instantaneously. It is assumed that prices adjust faster than migration occurs. Inhabitants do not consider the external effect of their decision to migrate has on production in the rural.

Given N is constant in the first period, prices stabilize as presented above. In the second phase, the inhabitants migrate to equalize utility. The model is in equilibrium (prices and migration) when: $U_{R_u} = U_{R_r}$or it is equivalent to the condition below:

$$X_{R_u}^{\alpha} Y_{R_u}^{1-\alpha} = X_{R_r}^{\alpha} Y_{R_r}^{1-\alpha} \Longrightarrow \frac{P_Y}{P_X} = f\left(\frac{E}{N}\right)$$

where from the previous condition $\frac{P_Y}{P_X} = \frac{(1-\alpha)}{\alpha}\frac{Nf\left(\frac{E}{N}\right)}{(1-N)}$, therefore:

$$f\left(\frac{E}{N}\right) = \frac{(1-\alpha)}{\alpha}\frac{Nf\left(\frac{E}{N}\right)}{(1-N)}$$

$$\frac{N}{(1-N)} = \frac{\alpha}{(1-\alpha)}$$

Migration occurs from rural to urban when good X-good Y relative marginal utility, $\frac{\alpha}{(1-\alpha)}$, is less than rural-urban relative population, $\frac{N}{(1-N)}$. Prices and migration are in equilibrium when these two conditions are equal.

Proposition 1 *When prices are in equilibrium, inhabitants migrate until rural-urban relative population are equal to relative marginal utility of goods produced, regardless of the value of the fixed amount of the common resources.*

The result looks unusual because the allocation is affected by neither the amount of the common environmental resource, nor the elasticity of $f\left(\frac{E}{N}\right)$ with respect to N. So any shock on E does not result in migration from rural to urban. The reason is that if production of Xdecreases following a decrease in E, it is accompanied by a corresponding increase in price of good X, P_X relative to P_Y. The paradox occurs due to the Cobb-Douglas utility function and constant returns to scale technology in the urban region.

The resulting allocation of N is suboptimal because inhabitants in the rural do not consider the externality they cause for other rural region inhabitants. The severity of the tragedy is 'limited' because the population size is fixed. If new inhabitants arrive, that is, N_0 is now increased to N_0', per capita social welfare decreases because per capita production of X decreases because the $N'f\left(\frac{E}{N'}\right) < Nf\left(\frac{E}{N}\right)$ due to concavity while per capita production of Y remains constant.

Social welfare decreases in both the optimal and competitive equilibrium cases as E decreases. Migration from the rural to the urban will increase per capita social welfare while $N < N^*$, and decrease it thereafter.

5. Model of Small Open Economy

The first model is modified to consider a small open economy where global prices are determined on the world markets and the two regions are price takers. Otherwise, conditions are the same.

5.1. Optimal Allocation

Goods X and Y can be bought on the world market at prices P_X and P_Y, respectively. An optimal solution is given by maximizing total budget of the two regions by allocating $N_0 = 1$ between the two regions.

$$\max_N P_X N f\left(\frac{E}{N}\right) + P_Y(1 - N)$$

subject to $\quad 0 \leq N \leq 1$

The optimal value for N is given by:

$$\frac{P_Y}{P_X} = f\left(\frac{E}{N}\right) - \frac{\partial f(\cdot)}{\partial N} \cdot \frac{E}{N}$$

An interpretation of above equation is the ratio of marginal production of both goods with respect to N equals the ratio of their prices. Note that the marginal production of good Y with respect to N is 1.

5.2. Competitive Equilibrium

I assume trade balances, but the formalities of expressing a small open economy here are unnecessary, because we need just to assume that each individual buys as much of what he can afford constrained by what he has produced.

An inhabitant of the urban region, for example, still has demand functions $Y_{R_u}^D$ and $X_{R_u}^D$, as specified previously, regardless of whether he buys goods X and Y from the rural or on world markets.

Importantly, the consumer takes P_X and P_Y as given, and demand equals supply. Since prices are given in this model, only one period is necessary. In this period, inhabitants migrate from the rural region to the urban region while $U_{R_u} > U_{R_r}$, or from urban region to rural region while $U_{R_u} < U_{R_r}$, as in the previous model. This leads to an expression of the conditions under which migration does not occur, which is the same as in the closed economy model:

$$\frac{P_Y}{P_X} = f\left(\frac{E}{N}\right)$$

The interpretation is that inhabits migrate until the real wages, $P_X f\left(\frac{E}{N}\right)$in the rural region, and P_Y in the urban region are equal. In this model, unlike in the closed economy model, inhabitants take into account productivity compared to the inhabitants in the other region, because prices no longer adapt to a reduction in supply. This allows the following:

Proposition 2 *In a small open economy, a negative shock on the environmental resource, or a negative shock on the relative price of goods, causes migration to the urban region, if migration was previously in equilibrium.*

In the competitive equilibrium inhabitants do not take into account the externality their presence in the rural region causes to others and thus the equilibrium is sub-optimal. This is seen by comparing the equilibrium condition of the optimal solution, to that of the competitive equilibrium. Similar to the first model, the extent of a tragedy of the commons is limited because population is constant and inhabitants are able to move from the rural to the urban to increase their utility once utility drops to below that of inhabitants in the urban.

Social welfare decreases in both the optimal and competitive equilibrium cases as common environmental resource decreases. Migration from the rural region to the urban region will increase per capita social welfare while $N < N^*$, and decrease it thereafter.

6. Discussion

6.1. General Discussions

In both competitive equilibriums, inhabitants of the rural region do not take into account the externality they cause on other inhabitants' production, thus making the allocation of N sub-optimal. Governments may consider taxes or other policy to motivate inhabitants to move between regions, although implementation of a poll tax would be unpopular.

In the small open economy model, movement of inhabitants from rural region to urban region improves the welfare of the rural if the $N < N^*$ but has no effect on welfare in the urban because, by assumption, $\frac{\partial g(\cdot)}{\partial N} = 1$. In this case, the regions are only linked through migration-prices do not change to represent scarcity supply of good X or Y as they do in the closed economy model.

Fluctuations in the relative world prices of P_X and P_Y will also cause migration in the small open economy model. Similarly, shocks on common environmental resource will also cause migration. This is different from the closed economy where migration does not depend on common environmental resource. Additionally, due to the Cobb-Douglas utility function and the constant returns to scale production function in the urban region, the competitive equilibrium leads to a value for N which does not depend on other variables.

Lastly, the models provide an alternative to Chichilnisky's more complex model. Both models have 'tragedy of the commons' production functions in the subsistence sector of the economy. The two models presented in this essay introduce the potential for migration to occur due to factors other than real wage differentials because inhabitants compare utility, not just real wages to decide whether to migrate or not.

Nonetheless, because of the simplification of the models presented here, there are three criticisms, raised by Hatton and Williamson (2002), which this paper does not answer. The three criticisms are: Firstly, most of the theories of migration do not take into

account immigration controls. Secondly, most research has examined the labor market performance of migrants, but has not verified the underlying model of migration by which the performance is interpreted. Thirdly, traditional assumptions lead to the Stolper-Samuelson condition whereby the emigration rate is strictly decreasing with economic development in the source country.

6.2. Problematic of Modeling the Environmental Resource

The discussion about the effects of environment and migration highlights some of the difficulties of economic modeling with respect to environmental resources and amenities.

There are many authors who assert that environmental scarcity leads to migration. All agree that people interact with the environment in extremely complex ways. If these interactions are understood, they can be modeled, although they may not provide a tractable model. Clearly the way these interactions are modeled will lead to different conclusions. This leads to the question how environment enters into a model.

Typically the environmental resource is modeled in one of two ways. Firstly, as an input factor to production, e.g. water or land, in production $X = f(Z, L, E)$ such as in Chichilnisky's model or the two models presented in this paper. The production function is increasing in E. Alternatively; it is a variable in the utility function that is affected by the amount of emissions from production as in the models of trans-boundary pollution, e.g., it refers to utility from air quality. So the utility function is denoted by $U(X, \varepsilon)$, but damaged by pollution from production. $\varepsilon = E^* - d(Z)$, where E^* is the perfect state of the environment and $d(\cdot)$ is the damage caused by emissions, Z. In the latter case, governments and consumers take environmental amenities into account when maximizing policy and utility, respectively.

With the intent to emphasize the complex nature of interaction with the environment and the difficulty in modeling it, the following are considerations for economic modeling of environmental migration:

Firstly, if environment enters into utility, but is not related to production through it being an input factor, or it being damaged by emissions from production, then environment is a static exogenous variable in a decision rule to migrate.

Secondly, according to Suhrke (1994), the environment has a multiplicative effect on the migration. This could be modeled either in utility such as $U(X,E) = XE$ or in the production function $U(L,E) = LE$ where L is labor, or in both utility and production functions. However, this contradicts the assumption that environment is modeled as a separable function of utility, e.g., $U(X,Y,E) = \xi(X,Y) + \varphi(E,X)$. Separability of E in the utility function is in certain circumstances a useful property.

Thirdly, it is well known that wealthier people are more interested in environmental quality. This suggests a utility function such as $U(X,E) = \xi(X) + \varphi(E,X)$, where the derivatives of $\varphi(E,X)$ with respect to its independent variables are $\frac{\partial\varphi(\cdot)}{\partial E} > 0$, $\frac{\partial\varphi(\cdot)}{\partial X} > 0$, and $\frac{\partial^2\varphi(\cdot)}{\partial X\partial E} > 0$.

Fourthly, a paradoxical situation arises if an inhabitant's utility function models overcrowding as $U = U\left(X,Y,\frac{E}{N}\right)$, where U is increasing in $\frac{E}{N}$. This would mean that living alone would give the greatest utility. A threshold or "hump-shaped" relationship is more defensible.

Fifth, in the two models presented, if the environmental resource, E in the rural region were introduced into the utility function, it could only be a variable in the utility of an inhabitant of the rural region – there being no environmental resource in the urban region in the two models. This means that urban and rural inhabitants are different in some way, that when they migrate their preferences are changed, and that utilities are no longer comparable in the same dimensions.

Lastly, if a variable E were introduced in the urban utility function, then a comparison between E_{R_u} and E_{R_r} would represent the comparison of many underlying characteristics of the environment. One variable representing environment is an enormous simplification.

This could be solved by separating the E into a set of variables. Otherwise, it is unlikely that it captures the complex interactions between inhabitant and environment which all literature on the subject of migration emphasizes.

The point of the section is to highlight that modeling of environmental quality and environmental resources is fraught with complexities. Simplifying assumptions may give results that are contrary to reality because the natural processes are misunderstood, while the assumptions are made for tractability reasons. Thus, to answer the observations that human interaction with the environment is a complex process, an econometric study into the factors of environmental migration is warranted.

6.3. Does the Concept of Environmental Refugees Differ from the Concept of Environmental Migration?

The qualitative literature on environment and migration discusses extensively the possible distinction between environmental refugees and migrants, but is inconclusive. Refugees are 'pushed', while migrants are both 'pushed and pulled'; migrants face a decision, it would seem.

A change on environment, whether gradual degradation or a shock, modeled as $E - s$, an ex-post reduction of E causes a reduction in production per worker in the Rural region. In the first model, prices adjusted to reflect the increased scarcity of good X. While overall social welfare decreases, migration does not occur if the model was previously in equilibrium. In the second model, the decrease in production in the rural region, lowers the real wage in that region, thus motivating a migration to the urban region, if wages and prices were previously in equilibrium.

From this scenario, it is not possible to differentiate, between a migrant and a refugee because the decision, even following a shock on E is a comparison between utility levels. A shock on E decreases real wages in the rural, which causes migration to the urban region.

However, if migration costs are introduced into the model, it is possible to see a distinction between environmental migrants and environmental refugees. In this scenario, an inhabitant in the rural region compares his utility in the rural and in the urban. The cost of the migration, c is introduced into the budget constraint of the urban region inhabitant. This can be represented formally as:

$$\max_{XY} U_{R_u}(X, Y)$$

subject to

$$P_X X + P_Y Y < P_Y - c$$

while for the rural region inhabitant, there is no differences with the previous one:

$$\max_{XY} U_{R_r}(X, Y)$$

subject to

$$P_X X + P_Y Y < P_X f\left(\frac{E}{N}\right)$$

Obviously, the constraint in the optimization program for the rural region inhabitant is bigger than the constraint for the urban region inhabitant.

As inhabitants have homogenous utility functions (but different constraints), the equation reduces to $P_X f\left(\frac{E}{N}\right) > P_Y - c$. As a result of a shock on E, the income of an inhabitant of the rural, $P_X f\left(\frac{E}{N}\right)$ decreases to be less than the costs of migration, $P_X f\left(\frac{E}{N}\right) < c$.

The result is that a rational worker, although possibly aware of decreasing income due to reduced environmental resource is forced to remain in the rural region when income does not cover the cost of migration and there is no access to credit through a banking system. A rural inhabitant, who in one period may have been a potential migrant to the urban, will become an environmental refugee if the wage drops below the cost of migration because of an environmental shock. The reduction in income can also arise due to fluctuations in relative world prices.

The cost of migration can be interpreted to include a number of factors such as risk under risk aversion. Migration may also involve a significant time span without income. Thus, it is possible to make the distinction between migrants and refugees based on those who can afford to migrate after a shock on E and those who cannot. If, however, migration is costless, i.e., $c = 0$, it is difficult to argue for any economic distinction based on these models between an environmental migrant and an environmental refugee, because ex-post environmental shock, if environment is not modeled in the utility function, the worker in the rural cannot achieve the same level of utility so migrates due to the ex-post wage differential.

This result is useful for governments and non-governmental organizations to classify people affected by environmental change. Such organizations can use such a distinction to determine recipients of aid such as micro-credit loans. However, providing credit to rural region inhabitants to cover the cost of migration to the urban region may be in conflict with environmental efficiency objectives.

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