Property rights, renewable resources and economic development

Liaila S. Tajibaeva

Abstract: This paper analyzes the role of endogenous property rights in the development of an open resource-based economy. I incorporate renewable resources and endogenous decisions on property rights into a convex growth model with the formal and informal sectors. I find that along the transition path to steady state, property rights enforcement is not constant but improves with time as well as involves intermediate property rights specification (between open access and perfect property rights). International trade and labor market are driving these endogenous changes. Property rights improve with favorable terms of trade when the economy exports resource services and stronger property rights help maintain the resource stock by deterring illegal harvest. This pushes labor away from the informal harvest sector toward greater participation in the formal sector of the economy. In turn, more labor participation in the formal sector along with capital formation increase the country's output and consumption. Overall, with an open economy and well-functioning institutions, renewable resources have a positive impact on economic growth.

Key words: endogenous property rights, informal sector, non-extractive services, economic development, renewable natural resources, and terms of trade

Department of Economics, Ryerson University, 350 Victoria Street, Toronto, M5B 2K3, Canada;
Telephone: 416-979-5000 ext. 7724; Fax: 416-598-5916;
E-mail: ltajibaeva@economics.ryerson.ca

1 Introduction

The purpose of this research is to understand the development of an open, renewable natural resource-based economy. I do this by evaluating the role of terms of trade in endogenous development of property rights structure. Renewable natural resources generate income as the main export of developing economies. Producing resource goods and services requires maintaining resource stocks and enforcing ownership rights to prevent others from exploiting them. Costs are increasing in the level of enforcement. When ownership rights are not fully enforced, an informal sector in illegal harvest emerges. An informal sector diverts labor away from formal sectors, reducing total economic output. I find that an endogenous property rights structure does not stay constant but varies over time with changes in prices and markets. It improves with improving terms of trade and weakens when terms of trade are unfavorable. With a stronger property rights structure, the informal sector shrinks and may close down altogether. Introduction of the informal sector allows accounting for non-market activity that plays an important role in low-income economies. Recent findings and existing evidence support explicitly integrating informal home production into models of economic development (Parente *et al.* 2000).

When property rights are defined and enforced by government agencies, the state only imperfectly enforces property rights, which requires additional efforts by private property owners. Property owners incur significant costs to enforce private property rights effectively by, for example, employing guards and building fences (de Meza and Gould 1992). Since property rights are costly to enforce, there will likely be cases of imperfect property rights. "Whether an owner enforces his rights, or whether he allows others free access to exploit his pastures, woods, or lakes, depends on the private costs and benefits of exclusion (de Meza and Gould 1992)." Only when it is profitable to enforce property rights will that be done.

While economic analysis tends to focus on the extractive services of renewable natural resources (for example, fisheries or timber harvest) renewable natural resources are also a source of non-extractive services. Non-extractive services are derived without extraction from the natural resource stock and range from recreation to wildlife habitat. For example, ecotourism makes use of indigenous animal, plant, and fish species to generate non-extractive services. Trends show a high increase in ecotourism and all nature-related forms of tourism, with parks, nature reserves, and natural settings increasingly becoming popular tourist destinations (Hawkins and Lamoureux 2001). In 2007, the tourism industry accounted for 856 billion USD in receipts, with 908 million international tourist arrivals worldwide (World Tourism Organization 2007). For many countries, tourism is one of the main sources of export earnings (Copeland 1991).

I develop a theoretical framework necessary to analyze the growth of an open resource-based economy. My model has three main features. First, in addition to physical capital, I introduce dynamic renewable natural capital. Natural capital can produce both extractive or harvest products and non-extractive services. Second, I introduce endogenous decisions on property rights structure. Third, I introduce an informal sector that accounts for the non-market activity, and for that reason is not reported in gross domestic product accounts. Specifically, the economy has three sectors, two formal sectors in goods and services and one informal sector.

The first formal sector uses capital to produce goods that can be either consumed or invested. These goods are traded domestically and internationally. The second formal sector produces non-extractive services using natural resource stock. Tourism is a good example of a service sector, in which all services are sold to international tourists. This sector holds property rights to the resource stock. Every time period it makes decisions on the level of property rights enforcement to deter informal harvest of its natural resources. The cost of property rights enforcement increases in the amount of labor hired to enforce property rights. However, if enforcement decreases, the informal harvest sector expands. The informal sector extracts from the resource stock to produce its output. In each time period, individuals choose how to allocate their labor between informal harvest and wage employment. When property rights are enforced, informal harvest of the natural resource is illegal. While individuals can still choose to engage in illegal harvest, stricter enforcement leads to a higher probability of getting caught, and therefore to lower expected returns to harvesting. Informal harvest by each individual from natural resources is home-produced. It does not account for the negative effect it has on the future productivity of that stock and exerts negative externalities on all other current and future users of the resource.

I evaluate numerically the transition path and steady state of the model. I parameterize the model to replicate a developing economy with a renewable resource endowment and base parameter values on data from Tanzania. While wages and the capital rental rate are determined endogenously, this small open economy takes world prices of traded good and service as given. The economy always chooses to allocate some resources to enforce property rights and protect its natural resources. This holds even when the export price of services is low relative to the import price of other goods. In the initial stages of development, when the economy is relatively poor, property rights are weak. This results in a larger informal sector diverting labor from participating in the formal labor market. As exogenous terms of trade improve, the property rights structure improves as well. More labor is allocated away from the informal sector and towards the formal sector. As a result, the economy grows while informal harvest shrinks. If terms of trade become sufficiently favorable, property rights become fully enforced and the informal harvest sector becomes inactive.

To further understand the role of renewable natural resources in economic development, I compare the benchmark economy to an economy that does not have a natural resource endowment but is otherwise identical. The benchmark economy has two assets, physical and natural, one of which does not depreciate, while the alternative economy has one depreciating asset. Well-functioning institutions are the key factor contributing to management of natural assets and protecting them from non-market exploitation. Income generated by natural assets increases total output and consumption of the benchmark economy.

Bulte and Barbier (2005) provide an extended overview of current and past literature on trade and renewable resources. The authors summarize that property rights are usually assumed to be constant and fixed at one of the opposite regimes of either open access or perfect property rights. The authors point out that, in reality, harvest usually involves some intermediate property rights specification between these two extremes. This research addresses exactly the need to further knowledge of intermediate property rights structure. It innovates further by introducing and analyzing an endogenously determined transition path of property rights specification in the context of economic growth.

Copeland and Taylor (2009) consider an endogenous property rights regime by combining a renewable resource model with a model of moral hazard. The regulator's enforcement power, harvesting capacity, and incentive to extinguish the resource, determine success or failure of resource management. The authors find that "policy analysis based on the assumption of a fixed degree of property rights protection may lead to serious error." The authors focus on the steady state, leaving discussion of transition to future work. Brander and Taylor (1997) examine the consequences of opening a small economy that has open access renewable resources to international trade. Similar to Bulte and Barbier (2005), the authors note that the existing literature on renewable resources and trade is "modest in scope".

The paper also contributes in the evaluation of the roles of non-extractive services of resources and the presence of non-market activities associated with the use of resources in economic growth. Home production is a substantial component in how renewable resources are used in low-income economies. Becker's (1965) notion of household production has been incorporated in economic development literature but not in the context of renewable natural resources (see Parente *et al.* 2000 and Gollin *et al.* 2004 for two examples).

The rest of the paper has the following structure. The next section develops the model. Section 3 defines and characterizes equilibrium. Section 4 parameterizes the model, solves for, and analyses the transition path and the steady state. Section 5 concludes.

2 The model

This section integrates renewable natural resources, endogenous property rights decisions, home production, and trade in a convex model of economic growth. The economy has an infinite horizon over discrete time periods. It consists of households, three production sectors, and three factors of production. The factors of production are labor, capital stock, and a renewable natural resource stock. Natural resources produce both extractive goods and non-extractive services. The three production sectors consist of two formal and one informal sectors. The first formal sector produces goods that can be used for consumption and investment. The second formal sector produces non-extractive resource services. This sector holds property rights over the resource. The informal sector consists of a home-produced harvest of renewable natural resources. The country trades in both formal sectors and has balanced trade. I next go over each of these components in detail.

2.1 Households' preferences and endowments

There are I infinitely lived households. All households are identical in their preferences and initial factor endowments. Define $c_t \in \Re_+$ as consumption at time $t \in [0, 1, 2, ..., \infty)$ by a representative household. A representative household has logarithmic utility function:

$$\sum_{t=0}^{\infty} \beta^t \ln (c_t), \tag{1}$$

where $\beta \in (0, 1)$ is household's discount factor. Overall consumption, c_t, consists of a composite good $x_t \in \Re_+$ and a harvest good $h_t \in \Re_+$. A household cares only about the level of overall consumption and does not care about its composition[1]:

$$c_t = x_t + h_t. \tag{2}$$

The composite good can be invested, i_t, or consumed, x_t, while the harvest good, h_t, is perishable and cannot be stored from one period to another. The composite good is supplied by domestic and foreign producers.

In each period, a household has an endowment of time denoted by $\bar{l}$. All of the time endowment is spent on labor (there is no leisure in this model). In period t, a household decides how to allocate its endowment of time between spending l_t hours working for a wage w_t in a formal sector, and spending the remaining $\bar{l} - l_t$ hours in home production harvesting the biological resource for its own consumption. In addition to the labor endowment, each household owns initial capital, k_0. The household accumulates capital through investment,

$$k_{t+1} - k_t = i_t - \delta k_t, \tag{3}$$

where $\delta \in (0, 1]$ is capital depreciation rate. A household rents out its capital, k_t, at the rental rate r_t.

The representative household's budget constraint is

$$\sum_{t=0}^{\infty} p_{1t} (x_t + i_t) \leq \sum_{t=0}^{\infty} (w_t l_t + r_t k_t + \epsilon_1 \pi_{1t}) + \epsilon_2 \pi_2, \tag{4}$$

where p_{1t} is the period t world price of composite good, π_{1t} is the period t profit in the composite good sector, π_2 is the present value of the stream of profits in the service sector, and ϵ_1 and ϵ_2 are the household's shares of respective profits. The harvest good, h_t, does not enter the budget equation. The harvest of biological resource is home-produced and is consumed directly by a household, without entering the market.

2.2 Biological resource and informal extractive sector

The economy is endowed with an initial stock of a renewable biological resource, B_0. Additions to the resource stock are made through natural biological growth minus harvest. In the absence of harvest, resource dynamics are given by $B_{t+1} - B_t = G(B_t)$, where $G(B_t)$ describes natural growth of the resource that accounts for the natural birth and mortality rates. Let $G(B_t) = sB_t \left(1 - \frac{B_t}{\bar{B}}\right)$, where s is the intrinsic growth rate of the biological resource and $\bar{B}$ is the environmental carrying capacity or the maximum biological resource stock that can be sustained by the environment.[2] In the absence of harvest, the biological resource stock, B_t, converges to its maximum carrying capacity, $\bar{B}$.

The non-extractive service sector has property rights over the natural resource stock. This sector produces its services without extracting from the resource stock. It makes harvest of the natural resource by households illegal. However, the quality of institutions is poor and owners have full responsibility to enforce their property rights. In each time period, the owners decide on the level of enforcement of their ownership rights. Denote enforcement of ownership rights by $z_t \in [0, 1]$. When z_t is equal to zero, there is no enforcement of property rights and the natural resource is open access. When z_t is equal to one, property rights are perfectly enforced and there is no informal harvest. When z_t is anywhere between zero and one, property rights are enforced at some intermediate level. The higher the enforcement level the harder it is to engage in illegal harvest.

In each period, the service sector chooses an enforcement level z_t, which a household takes as given and then decides whether to engage in illegal harvest or not. If a household chooses to harvest, it next decides how much time to spend harvesting given the ownership enforcement level. Each household is endowed with a harvest technology, $H\left(\bar{l}-l_t, B_t; z_t\right)$, which, given property rights, z_t, transforms labor, $\bar{l}-l_t$, and aggregate biological resource stock, B_t, into harvest. Harvest technology takes the following form, $H\left(\bar{l}-l_t, B_t; z_t\right) = (1-z_t)\left(\bar{l}-l_t\right)^{1-\theta} B_t^{\theta}$, where harvest is measured in the same units as the resource stock, B_t. The biological resource share in the harvest technology is denoted by $\theta \in (0,1)$. The harvest function is decreasing in the level of property rights enforcement.

The informal harvest sector has an endogenous choice of closing down. Low opportunity cost of lost wages and weak property rights provide a strong incentive for informal sector to stay active. However, if the opposite is true, and the opportunity cost of lost wages is high or property rights are strong, the informal sector shrinks in size to the point of dissipating. Harvest is a home-produced good consumed directly by a household and is equal to h_t.[3] Consumption of the resource good by a household in time period t is equal to:

$$h_t = (1-z_t)\left(\bar{l}-l_t\right)^{1-\theta} B_t^{\theta}. \tag{5}$$

The harvest decision by each individual household does not account for the negative effect that it has on the future productivity of the resource stock. Total harvest in period t is the sum of harvest by all individual households, I, and is equal to Ih_t. With harvest, the biological resource equation of motion is given by:

$$B_{t+1} - B_t = sB_t\left(1 - \frac{B_t}{\bar{B}}\right) - (1-z_t)\, I\left(\bar{l}-l_t\right)^{1-\theta} B_t^{\theta}. \tag{6}$$

2.3 Formal goods sector

There are many domestic, perfectly competitive firms in the formal goods sector. Each firm has access to technology $F_1(K_t)$ in capital $K_t \in \Re_+$: $F_1(K_t) = A_1 K_t^{\alpha}$, where A_1 is total factor productivity and $\alpha \in (0,1)$ is capital share. The firm maximizes its revenues from the composite good sales minus its capital factor costs:

$$\pi_{1t} = \max_{K_t \geq 0} p_{1t} A_1 K_t^{\alpha} - r_t K_t. \tag{7}$$

The composite good is traded domestically and internationally.

2.4 Formal services sector

The service sector has access to technology $F_2(B_t) = A_2 B_t^{\gamma}$ in renewable natural resource $B_t \in \left[0, \bar{B}\right]$, where A_2 is total factor productivity and $\gamma \in (0,1)$ is the resource share. The service sector does not extract natural resource to produce its service. For example, tourism or ecotourism use rich biological stocks to provide their services, such as safaris, bird watching, and whale watching. All services are exported.

The service sector has ownership rights over the renewable natural resource. In each time period, it decides on the level of enforcement, z_t. Ownership enforcement is a labor technology $F_3(L_t) = \sigma L_t$, where $L_t \in \Re_+$ and $\sigma L_t \in [0,1]$.

The firm maximizes its revenue from the service sales minus its labor cost:

$$\pi_2 = \max_{\{z_t, L_t, B_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \rho^t \left(p_{2t} A_2 B_t^{\gamma} - w_t L_t\right) \tag{8a}$$

subject to

$$B_{t+1} - B_t = sB_t\left(1 - \frac{B_t}{\bar{B}}\right) - (1 - z_t)\, I\tilde{h}_t \text{ for all } t \tag{8b}$$

$$z_t = \sigma L_t \text{ for all } t \tag{8c}$$

$$L_t \geq 0 \text{ for all } t$$

$$B_{t+1} \in \left[0, \bar{B}\right] \text{ for all } t$$

$$B_0 > 0 \text{ given,}$$

where $\rho \in (0,1)$ is the service firm's discount factor, p_{2t} is the world price of tourism, and $\tilde{h}_t = \left(\bar{l} - l_t\right)^{1-\theta} B_t^{\theta}$ is the household's harvest decision that the service sector takes as given. Equation (8a) is the firm's objective function of the sum of discounted profits. Equation (8b) is the natural resource dynamics. Equation (8c) is the property rights enforcement function, and the rest are non-negativity conditions.

These four components, namely, households, informal extractive sector, formal goods sector, and formal non-extractive services sector, comprise a small open economy.

3 Competitive equilibrium

I now define and characterize competitive equilibrium for the above economy.

Definition 1 *Given an initial capital stock, Ik_0, an initial biological resource stock, B_0, households' labor endowment, $I\bar{l}$, and world prices for goods and services $\{p_{1t}, p_{2t}\}_{t=0}^{\infty}$, allocation*

$\{c_t, x_t, i_t, h_t, l_t, k_{t+1}, z_t, L_t, K_t, B_{t+1}\}_{t=0}^{\infty}$ and a price system $\{w_t, r_t\}_{t=0}^{\infty}$ constitute an equilibrium if:

1. Given household's endowment vector $\left(\bar{l}, k_0\right)$ and allocation z_t by the services firm, allocation $\{c_t, x_t, i_t, h_t, l_t, k_{t+1}\}_{t=0}^{\infty}$ maximizes representative household's objective function (equation 1) subject to constraints (equations 2, 3, 4, and 5) and non-negativity conditions $0 \leq l_t \leq \bar{l}$, and $c_t, x_t, h_t, k_{t+1} \geq 0$.

2. Allocation $\{K_t\}_{t=0}^{\infty}$ maximizes goods firm's profits (equation 7).

3. Given biological resource stock endowment B_0 and allocation Ih_t by households, allocation $\{z_t, L_t, B_{t+1}\}_{t=0}^{\infty}$ solves services firm's profit maximization problem (equations 8).

4. Markets clear

$$I\left(x_t + i_t\right) = A_1 K_t^{\alpha} + q_t \text{ for all } t, \tag{9a}$$

$$Il_t = L_t \text{ for all } t, \tag{9b}$$

$$Ik_t = K_t \text{ for all } t, \tag{9c}$$

$$(1 - z_t)\, I\left(\bar{l} - l_t\right)^{1-\theta} B_t^{\theta} \leq B_t \text{ for all } t, \tag{9d}$$

$$p_{2t} A_2 B_t^{\gamma} = p_{1t} q_t \text{ for all } t. \tag{9e}$$

Market clearing condition (9a) states that total domestic production plus imports, denoted by q_t, of the composite good equal its consumption and investment by all households. Condition (9b) states that the amount of labor supplied by all households equals the amount of labor employed by the firms. Condition (9c) states that the amount of capital supplied by all households equals the amount of capital rented by the firms. Condition (9d) states that harvest by all households cannot exceed the existing biological resource stock. Condition (9e) is the balance of trade equation.

Representative household's problem can be simplified by substituting for c_t from equation (2) and for h_t from equation (5) into the objective function (equation 1); and by substituting for i_t from equation (3) into the budget constraint (equation 4). With these substitutions the household's problem can be stated as follows:

$$\max_{\{x_t, l_t, k_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \ln\left(x_t + (1-z_t)\left(\bar{l} - l_t\right)^{1-\theta} B_t^{\theta}\right) \tag{10a}$$

subject to

$$\sum_{t=0}^{\infty} p_{1t}\left(x_t + k_{t+1} - (1-\delta)k_t\right) \leq \sum_{t=0}^{\infty}\left(w_t l_t + r_t k_t + \epsilon_1 \pi_{1t}\right) + \epsilon_2 \pi_2 \tag{10b}$$

$$x_t, k_{t+1} \geq 0$$

$$0 \leq l_t \leq \bar{l}$$

$$k_0 > 0 \text{ given,}$$

where equation (10a) is the household's objective function and equation (10b) is its budget constraint. The Lagrangian for the household's constrained utility maximization problem is

$$\begin{aligned}\mathcal{L}\left(\{x_t, l_t, k_{t+1}\}_{t=0}^{\infty}, \lambda\right) &= \sum_{t=0}^{\infty} \beta^t \ln\left(x_t + (1-z_t)\left(\bar{l} - l_t\right)^{1-\theta} B_t^{\theta}\right) + \\ &\quad \lambda\left\{\sum_{t=0}^{\infty}\left(w_t l_t + r_t k_t + \epsilon_1 \pi_{1t} - p_{1t}\left(x_t + k_{t+1} - (1-\delta)k_t\right)\right) + \epsilon_2 \pi_2\right\}.\end{aligned}$$

First order conditions and transversality equation for the capital stock are:

$$\frac{\partial \mathcal{L}}{\partial x_t} = \frac{\beta^t}{x_t^* + (1-z_t)\left(\bar{l} - l_t^*\right)^{1-\theta} B_t^{\theta}} - \lambda^* p_{1t} = 0 \tag{11a}$$

$$\frac{\partial \mathcal{L}}{\partial l_t} = -\frac{\beta^t (1-z_t)(1-\theta)\left(\bar{l} - l_t^*\right)^{-\theta} B_t^{\theta}}{x_t^* + (1-z_t)\left(\bar{l} - l_t^*\right)^{1-\theta} B_t^{\theta}} + \lambda^* w_t = 0 \tag{11b}$$

$$\frac{\partial \mathcal{L}}{\partial k_{t+1}} = \lambda^*\left(-p_{1t} + r_{t+1} + p_{1t+1}(1-\delta)\right) = 0 \tag{11c}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \sum_{t=0}^{\infty}\left(\begin{array}{c} w_t l_t^* + r_t k_t^* + \epsilon_1 \pi_{1t} - \\ p_{1t}\left(x_t^* + k_{t+1}^* - (1-\delta)k_t^*\right)\end{array}\right) + \epsilon_2 \pi_2 = 0 \tag{11d}$$

$$\lim_{t\to\infty} \frac{\beta^t}{x_t^* + (1-z_t)\left(\bar{l} - l_t^*\right)^{1-\theta} B_t^{\theta}}\left(\frac{r_{t+1}}{p_{1t+1}} + 1 - \delta\right) k_t^* \to 0, \tag{11e}$$

where (*) denotes household's constrained utility maximizing allocation. Equation (11c) states the intertemporal price condition:

$$\frac{r_{t+1}}{p_{1t+1}} + 1 - \delta = \frac{p_{1t}}{p_{1t+1}}. \tag{12}$$

Taking the ratio of equation (11a) in period $t+1$ over period t and substituting for price ratio from equation (12) we get:

$$\frac{\left(\frac{r_{t+1}}{p_{1t+1}} + 1 - \delta\right)\left(x_t^* + (1 - z_t)\left(\bar{l} - l_t^*\right)^{1-\theta} B_t^\theta\right)}{x_{t+1}^* + (1 - z_{t+1})\left(\bar{l} - l_{t+1}^*\right)^{1-\theta} B_{t+1}^\theta} = \frac{1}{\beta}. \tag{13}$$

Taking the ratio of equation (11b) to equation (11a) we get:

$$(1 - z_t)(1 - \theta)\left(\frac{B_t}{\left(\bar{l} - l_t^*\right)}\right)^\theta = \frac{w_t^*}{p_{1t}}. \tag{14}$$

Equations (11d) through (14) constitute the representative household's competitive equilibrium conditions.

Given the market clearing condition (9c), the composite firm's profit maximization problem establishes the capital rental rate as follows:

$$\frac{r_t^*}{p_{1t}} = \alpha A_1 \left(I k_t^*\right)^{\alpha - 1}. \tag{15}$$

The service firm solves its constrained profit maximization problem (8). After substituting property rights enforcement equation (8c) into the resource difference equation (8b), the Lagrangian for the service firm can be written as:

$$\begin{aligned} \mathcal{M}\left(\{L_t, B_{t+1}, \mu_t\}_{t=0}^\infty\right) &= \sum_{t=0}^\infty \rho^t \left(p_{2t} A_2 B_t^\gamma - w_t L_t\right) + \\ &\quad \sum_{t=0}^\infty \mu_t \left(B_t + s B_t \left(1 - \frac{B_t}{\bar{B}}\right) - (1 - \sigma L_t)\, I \tilde{h}_t - B_{t+1}\right). \end{aligned}$$

First order conditions and transversality equation for the natural resource stock are:

$$\frac{\partial \mathcal{M}}{\partial L_t} = -\rho^t w_t + \mu_t^* \sigma I \tilde{h}_t = 0 \tag{16a}$$

$$\frac{\partial \mathcal{M}}{\partial B_{t+1}} = \rho^{t+1} p_{2t+1} \gamma A_2 B_{t+1}^{*\gamma - 1} - \mu_t^* + \mu_{t+1}^* \left(1 + s - \frac{2s}{\bar{B}} B_{t+1}^*\right) = 0 \tag{16b}$$

$$\frac{\partial \mathcal{M}}{\partial \mu_t} = B_t^* + s B_t^* \left(1 - \frac{B_t^*}{\bar{B}}\right) - (1 - \sigma L_t^*)\, I \tilde{h}_t - B_{t+1}^* = 0 \tag{16c}$$

$$\lim_{t \to \infty} \rho^t \mu_t^* B_t^* \to 0, \tag{16d}$$

where (*) denotes service firm's profit maximizing allocation. Substituting for μ_t^* and μ_{t+1}^* from equation (16a) in equation (16b) we get:

$$\frac{w_t \tilde{h}_{t+1}}{\rho w_{t+1} \tilde{h}_t} = 1 + s - \frac{2s}{\bar{B}} B_{t+1}^* + \frac{p_{2t+1}}{w_{t+1}} \sigma I \tilde{h}_{t+1} \gamma A_2 B_{t+1}^{*\,\gamma-1}. \tag{17}$$

Equations (16c), (16d), and (17) constitute service firm's profit maximization conditions.

Denote by ξ_t terms of trade in period t, which is the ratio of the export price of services, p_{2t}, to the import price of goods, p_{1t}. Combine the equations that characterize representative household's utility maximization problem, both sectors' profit maximization problems, and market clearing conditions to derive characteristic equations of a competitive equilibrium.

$$\frac{\left(\alpha A_1 \left(I k_{t+1}\right)^{\alpha-1} + 1 - \delta\right) \left(x_t + \left(1 - \sigma I l_t\right) \left(\bar{l} - l_t\right)^{1-\theta} B_t^\theta\right)}{x_{t+1} + \left(1 - \sigma I l_{t+1}\right) \left(\bar{l} - l_{t+1}\right)^{1-\theta} B_{t+1}^\theta} = \frac{1}{\beta} \tag{18a}$$

$$\frac{1}{\rho} \left(\alpha A_1 \left(I k_{t+1}\right)^{\alpha-1} + 1 - \delta\right) \left(\frac{1 - \sigma I l_t}{1 - \sigma I l_{t+1}}\right) \left(\frac{\bar{l} - l_{t+1}}{\bar{l} - l_t}\right) = \tag{18b}$$

$$1 + s - \frac{2s}{\bar{B}} B_{t+1} + \xi_{t+1} \frac{\sigma I \gamma A_2}{1 - \theta} \left(\frac{\bar{l} - l_{t+1}}{1 - \sigma I l_{t+1}}\right) B_{t+1}^{\gamma-1}$$

$$I \left(x_t + k_{t+1} - (1 - \delta) k_t\right) = A_1 \left(I k_t\right)^\alpha + q_t \tag{18c}$$

$$B_{t+1} - B_t = s B_t \left(1 - \frac{B_t}{\bar{B}}\right) - I \left(1 - \sigma I l_t\right) \left(\bar{l} - l_t\right)^{1-\theta} B_t^\theta \tag{18d}$$

$$I \left(1 - \sigma I l_t\right) \left(\bar{l} - l_t\right)^{1-\theta} B_t^\theta \leq B_t \tag{18e}$$

$$\xi_t A_2 B_t^\gamma = q_t \tag{18f}$$

Equation (18a) is the Euler Equation. Equation (18b) requires equilibrium marginal product of labor to be equal in both service and harvest good sectors. Equation (18c) is the composite good sector feasibility condition stating that consumption and investment is equal to production and import of the composite good. Equation (18d) is the biological resource equation of motion. Equation (18e) is the biological resource feasibility condition stating that total harvest cannot exceed the resource stock. Equation (18f) is the balance of trade condition. Equations (18) characterize competitive equilibrium from definition 1. I now solve numerically for and analyze the transition path and steady state[4].

4 Numerical experiments

In this section, I determine transition paths of all variables and prices to the steady state by solving the system of equations (18) and using numerical experiments. Parameters replicate a developing economy with a renewable natural resource endowment and are based on data from Tanzania.[5] Like most low-income countries, Tanzania is primarily an agrarian country where agriculture is predominantly smallholder and subsistence in nature (World Bank [25]). Tanzania is rich in biodiversity and has set aside a quarter of its land area as nationally protected wildlife sanctuaries (World Bank [24]). These wildlife resources and spectacular landscape and scenery attract tourists. International tourism makes up one third of the country's total exports (World Bank [24]). 87.4% of all international visitors to the country come for leisure and holidays, earning Tanzania in 2007 1 billion USD in international tourism receipts[6] (National Bureau of Statistics of Tanzania 2006, World Bank 2008). Because in Tanzania tourism sector is considered to have great economic growth potential, the country aims to raise its contribution to gross domestic product to more than 25% (World Bank 2002). However, with 36% of population in Tanzania living below national poverty line, it is not surprising that wildlife in protected areas and around them are poached and hunted by local communities (World Bank 2008). Wildlife threatened by illegal hunting is one of the most pressing environmental issues in Tanzania (CIA 2004). These factors make Tanzania a relevant and timely case study.

The parameter values used in numerical experiments are given in table 1. I calibrate household's discount factor, β, to 0.917, so that the real interest rate implied by the model is asymptotically equal to the average annual real interest rate of 9% observed in Tanzania from 1993 to 2005. For simplicity, the discount factor in the services sector, ρ, is assumed to be equal to β. I calibrate the capital share, α, to 0.32, to match the residual of the share of compensation of employees in gross domestic product adjusted for employment and workforce participation (for adjustment methodology see Gollin (2002)). The labor share in home production, $1-\theta$, is set at 0.89 as derived in Gollin *et al.* (2004) and is also consistent with labor share of 0.9 in Serengeti, Tanzania, wildlife harvest technology (Barrett and Arcese 1998). Depreciation rate, δ, equals to 0.5 and is based on existing literature (e.g., Bergoeing *et al.* 2001, Cooley and Prescott 1995). I base the estimate of the intrinsic growth rate of the renewable resource, s, on biological studies of the ungulate populations in the Serengeti-Mara ecosystem[7]. I perform sensitivity analysis to the different levels of the intrinsic growth rate. For the purposes of numerical experiments, I assume production share of the biological resource in services, γ, to be 0.6. Household's labor endowment, $\bar{l}$, is normalized to 1. For a detailed description of how parameters were calibrated refer to xxx (2007).

Terms of trade, ξ_t, which is the ratio of the real export price to the real import price, for Tanzania are shown in figure 1. I follow Kehoe and Ruhl (2008) to construct terms of trade data using original data on exports and imports for Tanzania.[8] Since terms of trade for Tanzania do not show large variation through time and are available only for fourteen years, in the benchmark economy I use constant terms of trade, which are equal to the data average of 0.85. To evaluate the effect of the magnitude of terms of trade on the rest of the economy I conduct sensitivity analysis by varying terms of trade across different experiments. Next, to evaluate the effect of time variability, I lift the assumption of constant terms of trade and let them change with time. I determine the transition path of all variables and prices for three different terms of trade time series. In the first series, terms of trade improve with time. In the second series, terms of trade decline with time, and in the third series, terms of trade are randomly drawn from a normal distribution. The transition path is solved in Matlab by programming shooting algorithm. The algorithm solves all characteristic equations simultaneously for all time periods until the economy reaches the steady state. The transition paths are solved for various combinations of initial physical and natural assets. With higher initial assets transition to steady state simply becomes smoother with time.

I begin with the benchmark case where terms of trade are constant and equal to 0.85. Along the transition path to the unique steady state renewable natural resources are always protected by property rights. However, property rights enforcement is not constant over time. The results for this case are shown in figure 2. At the beginning, when the resource stock is low, property rights are set high to deter illegal harvest and ensure that the stock is replenished. However, once the stock is replenished property rights slacken and remain low during initial development of the economy. With time property rights improve and remain strong reaching the steady state level of 0.93 (0 means open access and 1 means perfect enforcement of property rights). The first column of results in table 2 shows steady state values for this case. At this level of property rights enforcement the natural resource stock is intact at 98% of its carrying capacity. About 90% of total labor force is employed in the formal sector earning wages while the informal sector shrinks to a small part of the economy.

Better enforcement of property rights has a positive effect on economic output and consumption. Property rights enforcement mainly responds to changes in earnings from export of the resource services. For example, with less favorable terms of trade earnings from export of the resource services decline. This decline in export earnings weakens an incentive to enforce property rights. The second column of results in table 2 shows the steady state values when, everything else equal, terms of trade decline from 0.85 benchmark to 0.2. Enforcement of property rights is 35% lower compared to the benchmark case with more favorable price ratio. As a direct response to this decline in property rights enforcement the informal harvest expands ten times in size and the renewable resource declines by a half from 98% of its carrying capacity to 49%. Larger informal sector drains labor away from the formal labor market. This reduction in employment has a negative effect on total output. Reduction in total output and trade volume lead to a 30% reduction in consumption.

Figure 3 shows the transition path of property rights and the size of the informal sector for six different levels of terms of trade (0.4, 0.6, 0.7, 0.8, 0.85, and 0.874). Terms of trade and property rights move in the same direction. Improving the ratio of the export price to the import price enhances the incentive to protect the natural resource. More labor is allocated to enforce property rights and the natural resource stock increases. As a result earnings from exports increase and the economy enjoys higher consumption and larger output. When terms of trade are equal to 0.874 property rights improve with time and after sixty years of development become perfectly enforced. The informal sector declines and, once property rights become perfectly enforced, closes down completely. These results are consistent with historical experience of many countries. During the initial stages of economic development countries experience poor quality of institutions and large informal sector of production. With time, quality of institutions usually improves and the formal markets largely replace the informal sector.

To evaluate the effect of time variability I let terms of trade change with time. I begin with the case of monotonically improving terms of trade, which asymptotically approach the unique steady state value from below. The terms of trade series and the results for this case are shown in figure 4. During the initial economic development property rights remain low. This happens for two reasons. First, terms of trade are still low. Since the export price of resource services is low relative to the import price of other goods the economy abstains from spending too much on property rights protection of the natural resources. Second, the capital stock and output are still low, which translate into low consumption. Attempting to increase consumption, people turn to the informal home production, which now that the resource stock is replenished yields higher harvest. With time, terms of trade improve, which creates a stronger incentive to protect resources from the informal harvest.[9]

When terms of trade are random they are drawn from a normal distribution with variance decreasing over time and mean set to the unique steady state value. Terms of trade series for this case are shown in figure 5a. In the short run, property rights follow year to year variability of terms of trade. Improving terms of trade are followed by stricter enforcement of property rights and less favorable terms of trade are followed by weaker enforcement of property rights. In the long run, based on data terms of trade do not exhibit any upward or downward trend. As a result, after the initial decline in property rights their trend remains constant as well. Property rights trend is shown as a dotted line in figure 5a. Results for the rest of the economy are shown in figure 5b. When the natural resource stock is low property rights are set high to deter harvest. Similarly, when the natural resource stock is high property rights are set low and harvest increases.

Improvement in the intrinsic growth rate of the natural resource, s, has the opposite effect of improvement in terms of trade. The third column of results in table 2 shows the steady state values when, everything else equal, intrinsic growth rate of the resource increases from 0.4 benchmark to 0.9. As the resource stock becomes better at naturally replenishing itself less labor is devoted to protecting it through property rights enforcement. As a result there is a stronger incentive to engage in illegal harvest. Exports and imports along with formal output decrease. However, total consumption does not decline and instead slightly increases through substitution of the goods purchased at the market by the goods supplied by informal harvest.

Overall, renewable natural resources can be beneficial to an economy provided the existence of well functioning institutions. However, when institutions or property rights are weak the informal harvest increases, drawing labor away from the formal markets, slowing them down and reducing output.

5 Conclusion

In this paper, I analyze the effects of terms of trade and property rights on the development of a small resource-based economy. In my model, endogenous property rights are not constant but change with time. Along the transition path to steady state property rights improve with favorable terms of trade and the economy exports resource services. Stronger property rights help maintain the renewable natural resource stock by deterring illegal harvest. As the informal harvest shrinks, more labor is reallocated from non-market activity to working in the formal economy. More labor along with capital formation increase the country's output, trade volume, and consumption. In this environment of an open economy and well-functioning institutions, renewable natural resources have a positive impact on economic growth.

To carry out the analysis, I develop a theoretical framework for an open resource-based economy. In addition to capital stock, I introduce a dynamic renewable natural resource stock that produces both extractive goods and non-extractive services. The strength of the model is its ability to incorporate realistic features such as endogenous decisions on property rights enforcement and informal home production. Informal home production allows accounting for non-market activity. In addition, the model makes informal sector's option of becoming inactive endogenous. For these reasons, the model developed here is promising to further our knowledge of trade, property rights, and renewable resources.

One possible extension of this research is to address technological growth in addition to the already present resource growth. Another possible extension is adding a market for resource harvest. Currently, households harvest for their own consumption. Creating a market, either legal or illegal, will increase the incentive to engage in harvest. This could have an impact on property rights and labor allocation decisions across the sectors. Expanding the model in these directions would yield further insights into the role of renewable natural resources in economic development.

Notes

1. Given the nature of consumption in low-income countries, it is likely that home-produced and market-produced goods are close substitutes. For example, Parente *et al.* (2000) find that in a developing economy elasticity of substitution between home and market goods is equal to 2.5.

2. The logistic growth function has been widely used in modeling biological populations. In general, logistic growth starts at a zero, rises, peaks, falls, and reaches zero at a finite environmental carrying capacity (Conrad and Clark 1987).

3. For clarity of presentation, this stylized model has one type of households. One can extend the model to include two types: resource owners and illegal harvesters. Then a small proportion of households will hold ownership rights to the resource and earn profits π_2, while the remaining majority of households will engage in illegal harvest. This will complicate the model and make computation of transition path messy without changing essential results. Since the simplified model achieves all the necessary results I skip this extension.

4. There exists a unique steady state provided that $\frac{1}{\rho\beta} < 1+s$. Unless one of the discount factors, β or ρ, or the intrinsic growth rate, s , are very low, this condition is satisfied for all parameter values.

5. The data sources are summarized in Appendix A.

6. For comparison, international tourism receipts are equivalent to 6% of the country's gross domestic product, which, in 2007, was equal to 16 billion USD (World Bank 2008).

7. The Serengeti-Mara ecosystem, in bordering Tanzania and Kenya, hosts the world's largest ungulate herds (Sinclair 1979).

8. Exports and imports data for Tanzania are available from World Development Indicators (2008) starting 1990. I follow Kehoe and Ruhl (2008) to construct terms of trade data using equation (Exports of goods and services in current US$ / Exports of goods and services in constant 2000 US$) / (Imports of goods and services in current US$ / Imports of goods and services in constant 2000 US$).

9. I also evaluate the case with decreasing terms of trade, which asymptotically approach the unique steady state value from above. In this case, property rights decline monotonically at a decreasing rate gradually becoming constant at the steady state level.

A Data Appendix

Series	Source
Real interest rate (%), Tanzania	WDI
Indirect taxes, net, current prices,Tanzania (millions)	U.N. NAS
Consumption of fixed capital, current prices, Tanzania (millions)	U.N. NAS
Compensation of employees, current prices, Tanzania (millions)	U.N. NAS
Operating surplus, current prices, Tanzania (millions)	U.N. NAS
GDP, current prices, Tanzania (millions)	U.N. NAS
Implicit Price Deflator, Tanzania (1990=100)	U.N. NAS
Economically active persons, 5-80+, Tanzania	NBST
Employed persons with paid work, 5-80+, Tanzania	NBST
GDP (constant 2000 US$), Tanzania	WDI
GDP deflator (1992=100), Tanzania	WDI
GDP per capita (constant 2000 US$), Tanzania	WDI
GDP per capita, PPP (constant 2000 international $), Tanzania	WDI
Exports of goods and services, Tanzania (constant 2000 US$)	WDI
Imports of goods and services, Tanzania (constant 2000 US$)	WDI
Exports of goods and services, Tanzania (current US$)	WDI
Imports of goods and services, Tanzania (current US$)	WDI
Population, total, Tanzania	WDI
Population ages 15-64 (% of total), Tanzania	WDI
Real GDP per worker, Tanzania	PWT 6.2

Notes

WDI stands for World Development Indicators (2008).

U.N. NAS stands for U.N. National Accounts Statistics: Main Aggregates and Detailed Tables (1994) and (2006).

NBST stands for National Bureau of Statistics of Tanzania, National Profile Statistical Tables (2007).

PWT 6.2 stands for Penn World Tables (2006).

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Table 1: Parameter values

Parameter description	Value
Discount factor (β)	0.917
Capital depreciation rate (δ)	0.05
Resource stock production share in harvest (θ)	0.11
Capital stock production share (α)	0.32
Resource stock production share in services (γ)	0.6
Discount factor in services (ρ)	0.917
Resource intrinsic growth rate (s)	0.4
Total factor productivity in goods sector (A_1)	1
Total factor productivity in services sector (A_2)	1
Scaling effect in property rights enforcement technology (σ)	1

Table 2: Steady State

Variable description	High terms of trade	Low terms of trade	High intrinsic growth
Property rights[1] (z_{ss})	0.93	0.69	0.60
Consumption of a composite good (x_{ss})	2.15	1.44	2.02
Consumption of a harvest good (h_{ss})	0.01	0.10	0.17
Total consumption (c_{ss})	2.16	1.54	2.19
Employment[2] (l_{ss})	0.93	0.69	0.60
Capital stock (k_{ss})	3.35	3.35	3.35
Resource stock[3] (B_{ss})	0.98	0.49	0.75
Investment (i_{ss})	0.17	0.17	0.17
Import of a composite good (q_{ss})	0.84	0.13	0.72
Formal output of goods (y_{1ss})	1.47	1.47	1.47
Formal output of services (y_{2ss})	0.99	0.65	0.85
Informal output of harvest (h_{ss})	0.01	0.10	0.17
Total formal output (Y_{ss})	2.46	2.12	2.32
Total output ($Y_{ss} + h_{ss}$)	2.47	2.22	2.49

[1] $z \in [0, 1]$, where 0 is open access and 1 is perfect enforcement.

[2] $l \in [0, 1]$, where 1 is full employment.

[3] $B \in [0, 1]$, where 0 is depletion and 1 is carrying capacity.

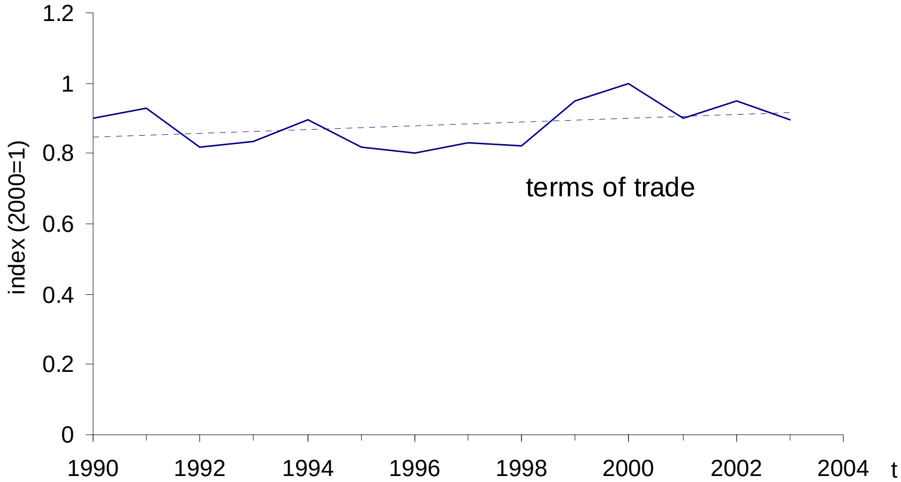


Figure 1: Terms of trade data for Tanzania.

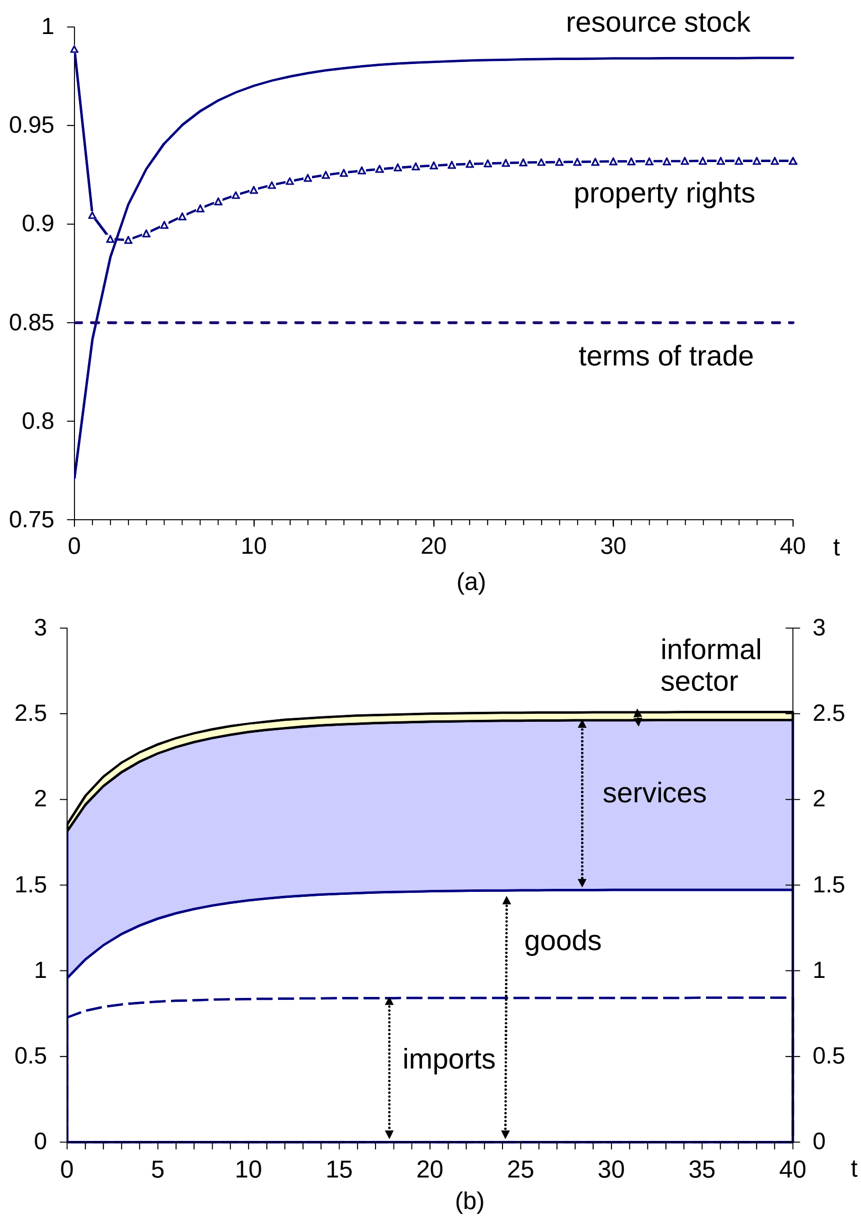


Figure 2: Transition path to steady state: (a) property rights, z_t; and renewable natural resource stock, B_t; (b) imports, q_t; output of goods, y_t^1; output of services, y_t^2; informal output, h_t; total formal output, $Y_t = y_t^1 + y_t^2$; and total output, $Y_t + h_t$. Property rights $z_t \in [0, 1]$, where 0 signifies open access and 1 perfect enforcement of property rights.

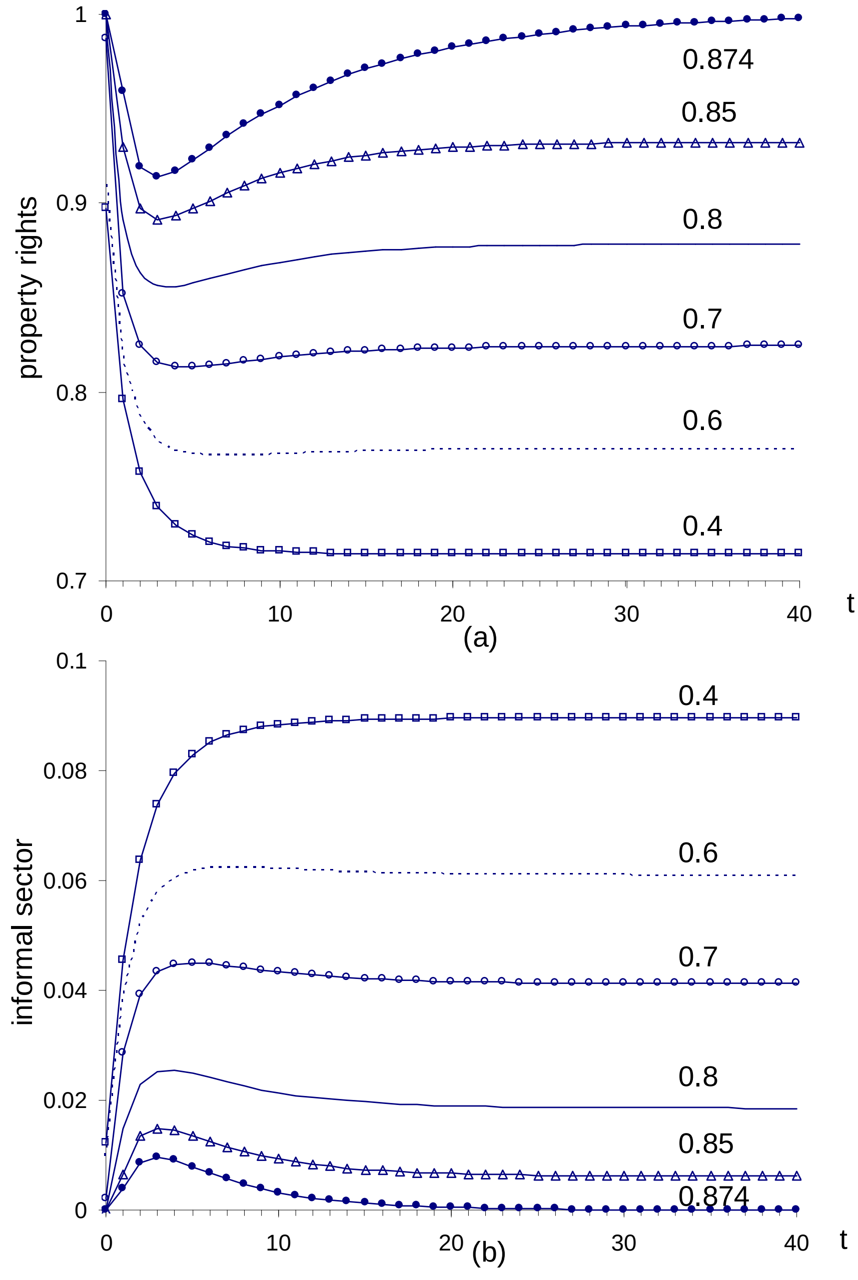
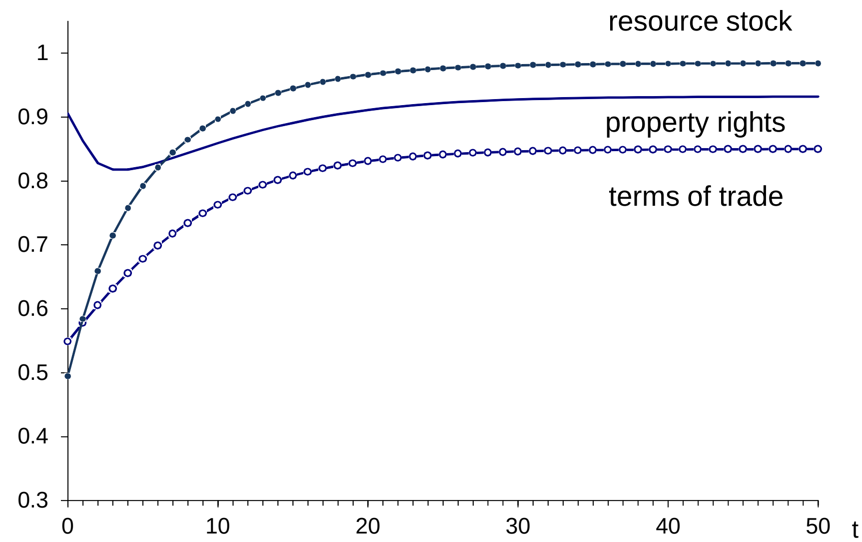
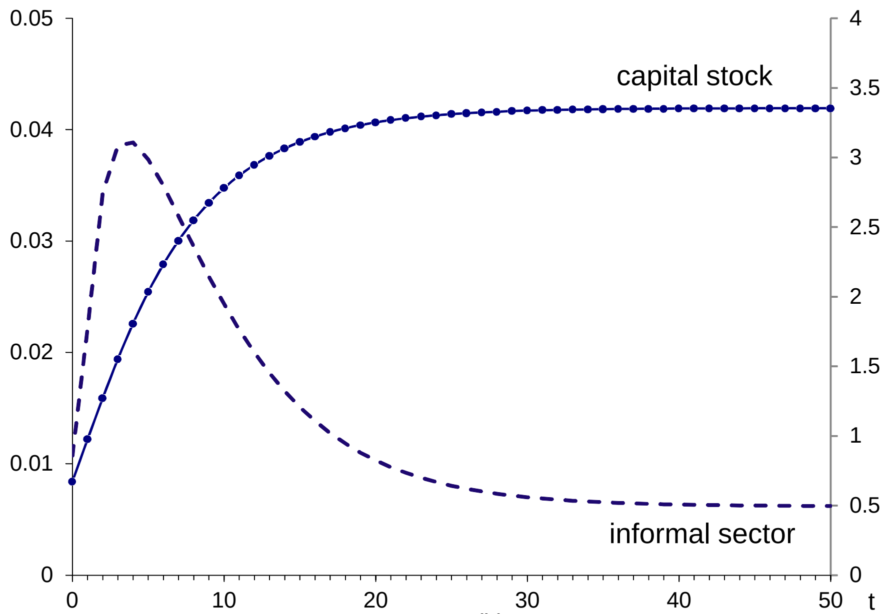


Figure 3: Transition path to steady state for different values of terms of trade($\xi = 0.4$, 0.6, 0.7, 0.8, 0.85, and 0.874): (a) property rights, z_t; and (b) informal harvest, h_t.



(a)



(b)

Figure 4: Transition path to steady state: (a) property rights, z_t; and terms of trade, ξ_t; (b) informal output, h_t; renewable natural resource stock, B_t; capital stock, k_t.

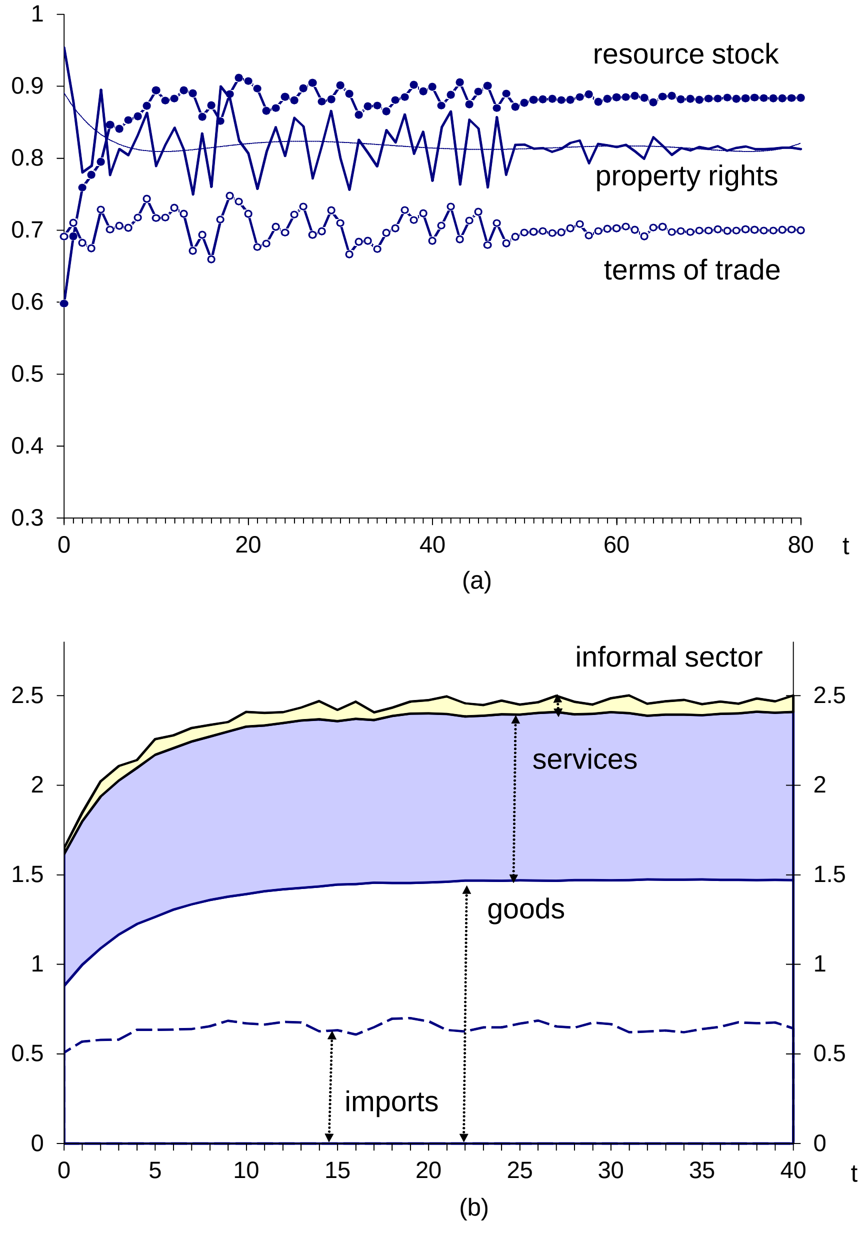


Figure 5: Transition path to steady state: (a) property rights, z_t; renewable resource stock, B_t; and terms of trade ξ_t; (b) imports, q_t; output of goods, y_t^1; output of services, y_t^2; informal output, h_t; total formal output, $Y_t = y_t^1 + y_t^2$; and total output, $Y_t + h_t$.