



*Introducing Forest Access Cost Functions into a General
Equilibrium Model*

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Abstract

The purpose of this Research Memorandum is to propose an approach to incorporating forest access cost functions into global general equilibrium models such as GTAP. Towards this end, we develop a long run access cost function which can be calibrated to national data on total forest land, currently inaccessible forest land, forest land rents, and expected rates of return on investment. This is illustrated for an 11 region aggregation of the GTAP-AEZ data base. We find that this long run function generates far too high a rate of annual access, and so we introduce a short run component which introduces a quadratic term into the cost function. This can be chosen to target current rates of forest access as reported by the FAO. Finally, we discuss the treatment of this new type of investment in the general equilibrium model.

Keywords: Deforestation, inaccessible forests, cost function, investment.

JEL codes: Q23, Q24, Q27

Introduction

Careful modeling of land supply is a critical issue in agricultural policy analysis and in greenhouse gas mitigation assessments. However, economic models often embody crude representations of land supply. For example, in the GTAP model, aggregate land supply is assumed to be fixed. In their review of timber market models, Brent Sohngen and Roger Sedjo (2000) note that many models simply represent forest lands as non-responsive to prices by ignoring the movement of land from other sectors, as well as abstracting from the potential for accessing currently inaccessible forestlands. A great deal of the world's forests are currently inaccessible because of the lack of infrastructure or other restrictions. Indeed, in North America, 75% of forest lands are estimated to be currently inaccessible. In Australia and New Zealand, this figure is above 90%, by FAO estimates.¹ However, if prices for agricultural or forestry products rise, these forests could be accessed. So ignoring inaccessible forest tends to underestimate land supply reaction to price change.

The purpose of this note is to propose a way of introducing inaccessible forest into a global general equilibrium model such as GTAP. This paper is motivated by the experience of Golub et al. (2006) who found unrealistically high long run growth in forestry land rents in their long run projections of land supply and demand. An important potential source for this result is the absence of any treatment of inaccessible land in their model. We will try to overcome these limitations in this research memorandum.

Accessing a new forest presents the main features of an investment: money invested today leads to capital accumulation – in this case a larger stock of accessible land – which in turn permits production of a stream of future benefits. So introducing inaccessible land in GTAP means also introducing a new kind of investment. We don't observe the real cost of accessing new forests. Instead, we will hypothesize some key relationships which may be quantified in order to provide an acceptable access cost function for use in empirical modeling. This memorandum has three parts. Firstly, we determine how the inaccessible forest is accessed and what the first period access cost is. Secondly, it is necessary to choose a functional form for the access cost function so that we can predict future access costs. Thirdly, we must have a calibration strategy so that it can be implemented in a CGE model.

Choosing the level of investment in inaccessible land

We first distinguish between those regions in which inaccessible forest land is present, and those in which it is not. Here, we follow the lead of Brent Sohngen's Global Timber Supply Model in excluding the possibility of additional forest access in South Asia, High Income Asia and Western Europe (see Table 2). For those regions that do have inaccessible forests still available, we hypothesize that a part of the inaccessible forest is accessed during the first period in every region. This is a useful assumption for purposes of calibration, since it implies equality between the price of forest land and the marginal access cost, so we can infer the latter (unobserved) from the former (observed forestland price). For example, if a region experiences a lot of deforestation because of a low marginal cost of access, then the land rent must be small to reflect this fact. The link between forestland price and land rent is a simple economic rule. A forest landowner will access new land only if the access cost is less or equal to the expected benefits. And the expected benefits are summarized in the forestland price.

¹ There is some controversy regarding the FAO estimates, particularly for Australia. The FAO definition includes all lands with canopy cover of more than 10%. Thus much of the Australian outback, with relatively thin tree cover, that might not be considered forests by those on the ground, is considered forest by the FAO.

The owner will choose to access more land if the forestland price is higher than the access cost. The owner will not access new lands if the marginal access cost is higher than the forestland price. Hence the land accessed will be determined in equilibrium by the condition that the marginal access cost equals the forestland price.

The forestland price is determined as the net present value (NPV) of the flow of benefits from the forestland. The forest landowner benefits are defined in GTAP as the land rent². With static expectations (per usual in a recursive dynamic model) the NPV of future benefits can be expressed as follows:

$$P_t^{ForestLand} = Landrent_t \cdot \frac{1 + ROR_t}{ROR_t} \quad (1)$$

with $P^{ForestLand}$ the price of one hectare of forestland, $LandRent$ the land rent for one hectare and ROR the net expected rate of return in the region where the access is occurring.

If we consider that the newly accessed land will bring benefits the period after its access, like an investment, the access cost will not equal the forestland price but the present value of the next period forestland price:

$$AccessCost_t = NPV(P_{t+1}^{ForestLand})$$

$$AccessCost_t = \frac{P_{t+1}^{ForestLand}}{1 + ROR_t}$$

with static expectations: $AccessCost_t = \frac{P_t^{ForestLand}}{1 + ROR_t}$

substituting in for $P^{ForestLand}$ we get:

$$AccessCost_t = \frac{Landrent_t}{ROR_t} \quad (2)$$

At each period, the possibilities are: either the access cost is bigger than the land rent divided by the expected rate of return and no new forest is accessed, or the access cost is smaller and new forest is accessed until access cost equals the NPV of land rents.

² In his model, Brent Sohngen also includes the value of the forest cover. However, in our framework, we do not have an estimate of this value and therefore abstract from this determinant of access benefits. This means that our estimates of marginal access cost will be considerably lower than those in his model.

Table 1 reports the land rents, rate of return and implied marginal cost of accessing new land that we have compiled for the eight regions in our GTAP aggregation that are experiencing new access in the initial period. The land rents reported here are calculated by combining GTAP forestry sector output values and Brent Sohngen's data³ on country-specific land rents and sectoral output values. We apply the world average share of land rents in product sale, 38 %, from Sohngen's data to the GTAP forestry sector output. After dividing this estimate of total forest land rents by the accessible forest area we get the average land rents per hectare for each region. The net expected rate of return comes from the version 5 GTAP-Dyn database for 1997. We calculate the access cost using equation (2), which involves simply dividing land rents by the rate of return.

Region	Land rent (\$/ha)	Net rate of return	Access cost (\$/ha)
North America	38	0.121	314
China	60	0.084	715
Rest of the world	24	0.122	198
Australia & New Zealand	43	0.109	391
ASEAN	41	0.140	293
Latin America	8	0.136	59
Economies in transition	14	0.060	238
Middle East and North Africa	77	0.069	1120

Table 1: Access cost at the first period

We also need data on accessible and inaccessible forest areas. These have been obtained from Brent Sohngen's website and from calculations using the 16-region Global Timber Supply Model (Sohngen et al., 1999). We opt to follow Sohngen's model in determining the regions without inaccessible forest, because we are interested in an economic definition of inaccessible forest (e.g., there could be inaccessible forests in Germany, but no amount of increase in commercial land rents will bring it into production.) For the other regions, we use the country-level data from Sohngen's website, as derived from the FAO. Table 2 presents these areas calculated at an 11-region level.

Region	Accessible forest	Inaccessible forest	Share of accessible forest
North America	154,309	451,968	25%
China	81,904	49,775	62%
South Asia	52,147	-	100%
Rest of the world	169,898	121,501	58%
Australia & New Zealand	10,810	153,943	7%
High income Asia	30,312	-	100%
ASEAN	50,335	94,941	35%
Latin America	300,507	577,251	34%
Western European Union Europe	131,061	-	100%
Economies in transition	190,134	723,170	21%
Middle East and North Africa	15,263	1,854	89%

Table 2: Area of accessible and inaccessible forest (1000 ha)

³ From the website: <http://www-agecon.ag.ohio-state.edu/people/sohngen.1/forests/GTM/index.htm>

Choice of functional form of the long run access cost function

We assume that the marginal access cost changes with the share of accessible forest. In particular, the access cost function is convex in accessed forest. Therefore, as the share of total forest that has been accessed increases, the cost of accessing an additional hectare rises. This makes sense, since we expect that the more readily accessible lands will be accessed first. In addition, we assume that access costs become infinite as we approach complete access (the last hectare of inaccessible land can't be economically accessed). Several functional forms can mimic these effects. We choose the following one:

$$AccessCost(h) = -\alpha \cdot \ln\left(\frac{\bar{h} - h}{\bar{h}}\right) + \beta \quad (3)$$

with α and β two positive parameters, \bar{h} the total forest area, and h the accessed forest area, so $\bar{h} - h$ is the remaining inaccessible forest land. Thus the term in brackets (.) is bounded between zero and one, so that $\ln(.)$ is bounded between $-\infty$ and 0. The parameter alpha governs the elasticity of access costs with respect to cumulatively accessed forest land, $\sigma(h)$:

$$\sigma(h) = \frac{\alpha}{AC(h)} \cdot \frac{1}{\bar{h}/h - 1} \quad (4)$$

where:

$$\frac{d\sigma}{dh} = \frac{\alpha \cdot \bar{h}}{AC(h) \cdot (\bar{h} - h)^2} \cdot \left(1 - \frac{\alpha \cdot h}{AC(h) \cdot \bar{h}}\right) > 0 \quad (5)$$

In other words, the elasticity of access costs becomes larger as more hectares are accessed. Note also that β is the implied level of access costs for the first hectare of land being accessed (i.e., access costs evaluated at $h = 0$).

Calibration of the cost function

The calibration problem consists of choosing α and β to match information on current access costs (land prices) as well as the elasticity of access costs with respect to accessed land. The parameter α is a slope parameter that can be calculated from the elasticity σ . We begin by calibrating to the elasticity of access costs with respect to accessible land, then we choose the intercept parameter β to reproduce the observed level of access costs (land prices) from Table 1. Our problem is that we do not currently have good information on the access cost elasticity. Therefore, we adopt a simple approach that avoids introducing spurious variation across countries. Specifically, we postulate that each region will have the same access cost elasticity, were it to be evaluated at the same current share of accessible land. For this we simply choose an elasticity of 0.05 (very low) at 5% of accessible share – roughly the share currently exhibited in Australia/New Zealand. The variation in these elasticities across regions now depends solely on the currently observed accessible share (and the functional form). This gives rise to the access cost elasticities reported in Table 3. Note that the Middle East and North Africa, with a very high current share of access (89% from Table 2), has the highest access cost elasticity, while Australia/New Zealand have the lowest.

Region	σ	α	β
North America	0,26	234	245
China	0,83	270	452
Rest of the world	0,75	83	126
Australia & New Zealand	0,07	365	366
ASEAN	0,37	192	212
Latin America	0,37	38	42
Economies in transition	0,21	188	194
Middle East and North Africa	2,55	121	850

Table 3: First period elasticities and parameters of the access cost function

Figure 1 plots these access schedules for the 8 regions with accessible forest lands. (This figure is best read in the electronic version of the paper.) Note that the access cost functions begin at the current level of access, and show the cost of increasing the amount of access forests. Latin America, which has the lowest forest land rents and hence lowest marginal access cost presently (Table 1), is the bottom line in this figure. The highest forest land rents and access costs belong to MENA and China, followed by Australia/New Zealand, ASEAN and North America. Note that Latin America not only has low land rents, but its access cost curve also remains flat for a long time. Thus it can expand its accessed forests dramatically without significantly raising land rents. On the other hand, small increases in forest access in China, and particularly MENA, will lead to much higher land rents, as they are estimated to be currently at a rather steep point on their access cost function.

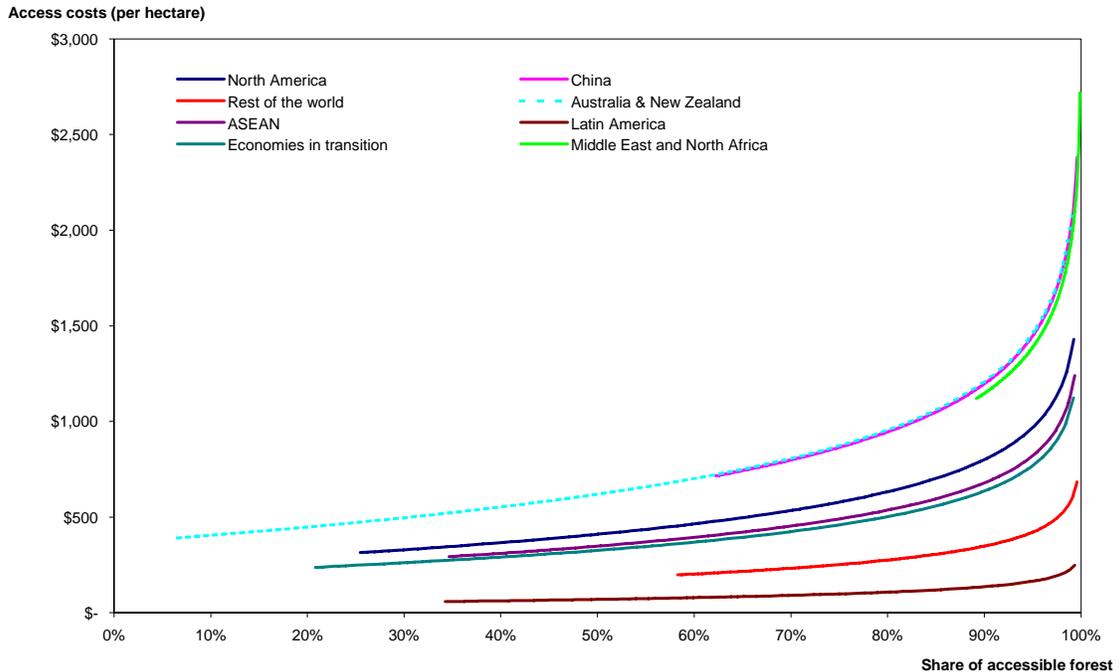


Figure 1: Representation of the access cost function with the calculated parameters

Before proceeding, it is worthwhile to evaluate the performance of these access cost functions. Consider the effect of a 10 % increase in land rents in Latin America. The first period land rent is 7.9\$/ha, and the associated land price is 58.5 \$/ha, which is much smaller than in other regions. Our framework’s explanation is the presence of lots of inaccessible land that can be brought into production (e.g., from the Amazon forest). If the land rent increases by 10 %, with the same net rate of return, the NPV of land rent shall pass from 58.5 \$/ha to 64.4 \$/ha (see Figure 2). The new point of equilibrium between the access costs and the NPV of land rent implies 76.5 million hectare of newly accessed forest, which is 9 % of Latin American forest. Contrast this with the FAO’s estimated average annual change (2000-2005) in South America in forest area of -4.2 million hectare.⁴ This is an order of magnitude smaller than the model’s prediction based on a 10% hike in land rents.

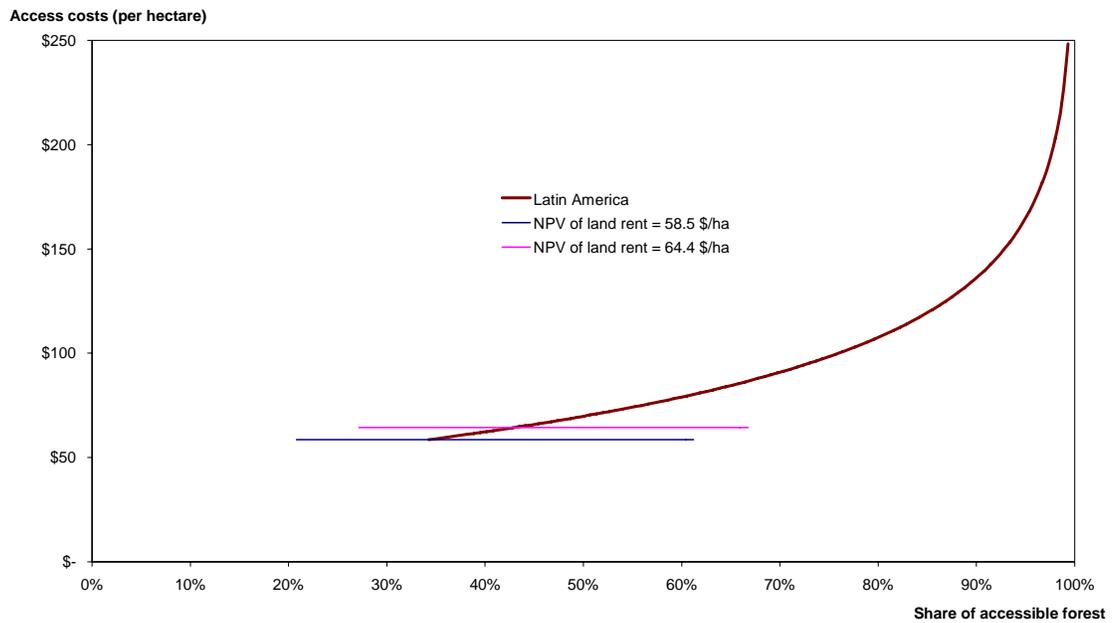


Figure 2: Effect of a 10 % increase in land rent on long run forest access

⁴ FAO. 2005. "Global Forest Resources Assessment 2005", FAO Forestry Paper 147.

We can compute the total investment in forest access as follows:

$$I_{AC} = \int_{h_0}^{h_1} AC(h)dh$$

$$I_{AC} = \left[\alpha \cdot (\bar{h} - h) \cdot \left(\ln \left(1 - \frac{h}{\bar{h}} \right) - 1 \right) + \beta \cdot h \right]_{h_0}^{h_1} \quad (6)$$

From equation (6), we estimate the cost of access to be \$4.7 billion, whereas the forestry product sale of Latin America is only \$6.3 billion. Thus, it seems that our access cost function leads to too high a rate of access. This comes about due to the lack of short run constraints. Even if a large part of the forest is cheap to access, it can't be accessed in a single period. Some area must be accessed before we can reach the rest. Besides, the investment in inaccessible forest requires labor and capital, which can't be easily move from one sector to another. Yet these constraints on short run access are not embodied in our functional form. This suggests the need to modify this "long run" access cost function.

Treating (3) as the long run access cost function, modify it to reflect the type of short run considerations raised in the previous paragraph; specifically, we append a term that is quadratic in the annual rate of access, i.e. the change in h per annum, as in equation (7). As a further step in the calibration procedure, we can adjust this quadratic term to give the same rate of access in the first decade that is observed in the FAO data. This gives rise to the following equation:

$$ShortRunAccessCost(h_{t+1}) = -\alpha \cdot \ln \left(\frac{\bar{h} - h_{t+1}}{\bar{h}} \right) + \beta + \gamma \cdot \left(\frac{h_{t+1} - h_t}{h_t} \right)^2 \quad (7)$$

Assuming that the 4.2 million hectare deforestation in Latin America occurs for a small increase in land rent -- say 3% -- we would set γ equal to \$450/ha². This figure can be adjusted in light of the predicted rate of increase in land rents in the general equilibrium model for the period in question.

Calibration of investment in accessed forests

Having calibrated the national access cost function, we now turn to the general equilibrium issue of providing the necessary resources to accomplish this investment activity. Because in general equilibrium, these costs must be accounted for. Ideally, forest access would already be included in the investment vector and the associated inputs could be extracted and treated separately for these purposes. However, in practice this activity will often not be included in gross national investment. And when it is, we do not know which inputs are used in this activity. Therefore, we propose a simpler approach. Specifically, we assume that the costs consist of variable labor and capital expenditures. In this way, the social accounting matrix can be expanded to include another investment activity (forest access), and labor and capital can be added as costs for this activity. This serves to augment income of (e.g., in GTAP) the regional household. As with normal investment, this activity is financed with savings, in general equilibrium, and the additional savings are exactly covered by the additional labor and capital income. In this way, we maintain Walras' Law.

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