The Long Run Forest Conservation and the Paper Recycling: Evidence from East Asian Countries

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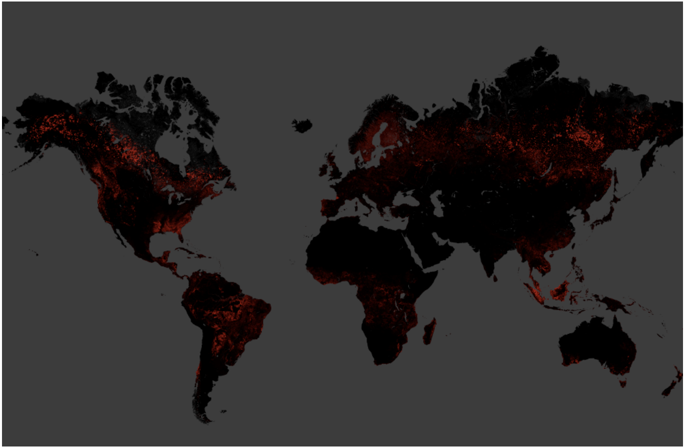
Importance of Forest

- About 30% of the world's land surface is forest.
- Over 2 billion people rely on forests for shelter, livelihoods, water, food and fuel security.
- 300 million people live in forest including 60 million indigenous people.
- More than 13 million people across the world are employed in the formal forest sector.

Source: WWF http://wwf.panda.org/about_our_earth/deforestation/importance_forests/

Forest Cover Loss (2000-2014)



Source: http://earthenginepartners.appspot.com/science-2013-global-forest

Motivation

- Many environmental NGOs try to conserve forest by various ways (planting, protection for illegal logging, etc.)
- Climate change added new role and incentive to forest.
- Paper recycling is considered as one of these conservation activities.
  - But is it true all the time?

Literature

- Darby (JPE, 1976) was first who casted a doubt that paper recycling could reduce forest resources.
- The assertion by Darby (1976) was formally presented by Tatoutchoup and Gaudet (CJE, 2011).
- Tatoutchoup (2016) recently conducted numerical simulation for Canada.
  - This paper aims at the East Asian Countries.

Basic Settings (1)

- Suppose that there is a fixed area of land A for forestry and agriculture.
- In the case of forestry, we assume *á la* Faustmann type of rotation (Let $i(\geq 1)$ be such i th rotation).
- We also denote the length of ith rotation, $t_i - t_{i-1} \equiv T_i$.

Basic Settings (2)

- The decision making by the owner of this land must satisfy the following;

$$f_{i-1} + a_{i-1} = A, \quad \text{for } i = 1, 2, \cdots, \infty, \tag{1}$$

- f_i and a_i denotes land devoted to forestry and agriculture respectively.
- Furthermore we assume that $X(T_i)$ denotes the volume of wood per unit of forest area at the rotation T_i.

Profit Maximization by Land Owners (1)

- No other production than wood production and we confines the wood production only to paper.
- After consumption of paper, the part of the paper could be recycled (No quality difference).
- The total quantity of paper available at t_i, $S(t_i)$, is as follows (δ: recycling rate).

$$S(t_i) = f_{i-1}X(T_i) + \delta S(t_{i-1}), \quad i = 1, 2, \cdots, \infty \tag{2}$$

Profit Maximization by Land Owners (2)

- The inverse demand function is $p_{t_i} = P(S_{t_i})$.
- Suppose that $k \geq 0$ is per-unit planting cost and $c \geq 0$ the per-unit cutting cost.
- We assume that $P(0) > c$ to make planting rational to a landowner.
- Then the present value of running the forest business to this landowner is as follows.

$$\Pi_f = [P(S_{t_i}) - c] f_{i-1} X(T_i) e^{-rT_i} - k f_{i-1}. \qquad (3)$$

Agricultural Use

- $a_{i-1}(= A - f_{i-1})$ is devoted to agricultural use.
- Let $g(a_{i-1})$ be a net benefit function from agriculture with $g' > 0$ and $g'' < 0$.
- The present value of the benefit from agriculture during the time T_i is

$$\Pi_a = \int_{t_{i-1}}^{t_i} g(a_{i-1}) e^{-r(\tau - t_{i-1})} d\tau = \frac{g(a_{i-1})}{r}(1 - e^{-rT_i}) \quad (4)$$

Land Owner

- Denote the sum of (3) and (4) as V.

$$\max V = \sum_{i=1}^{\infty} (\Pi_f + \Pi_a) e^{-r(t_{i-1} - t_0)}, \quad \text{s.t. } f_{i-1} + a_{i-1} = A \quad (5)$$

- Our purpose is to find to what extend a landowner should allocate his/her land to forestry and how long the landowner should waits before clear-cutting the trees in order to maximize his/her profit.

- This is equal to find an optimal sequence of $\{f_{i-1}, T_i\}$ for $i = 1$ to ∞.

FOCs

- To make the model simple, we only consider a steady state.

$$V(S) = \frac{[P(S) - c] f X(T) e^{-rT} - kf}{1 - e^{-rT}} + \frac{g(A - f)}{r} \qquad (6)$$

- The first order conditions (interior solution) are;

$$\frac{\partial V}{\partial f} \equiv V_f = [P(S) - c] X(T) e^{-rT} - k - g'(A - f) \cdot \frac{1 - e^{-rT}}{r} = 0 \qquad (7)$$

$$\frac{\partial V}{\partial T} \equiv V_T = [P(S) - c] X'(T) - r \frac{[P(S) - c] X(T) - k}{1 - e^{-rT}} = 0 \qquad (8)$$

Analysis

- Totally differentiating (7) and (8) with respect to δ, T and f,we can get the following results.

$$\frac{df}{d\delta} = -\frac{1}{H}\left[\frac{fX(T)}{(1-\delta)^2}V_{fS}V_{TT}\right] < 0 \tag{9}$$

and

$$\frac{dT}{d\delta} = -\frac{1}{H}\left[\frac{fX(T)}{(1-\delta)^2}V_{ff}V_{TS}\right] \geq 0 \tag{10}$$

- V_{fj} denotes a differentiation of V_f by j and

$$H = V_{ff}V_{TT} + \frac{1}{1-\delta}\left[V_{TT}V_{fS}X(T) + V_{ff}V_{TS}fX'(T)\right] > 0. \tag{11}$$

Sum-up so far

- From (9), increase in δ means less forestry in land area A.
  - The decrease in demand of virgin pulp is perfectly substituted by recycled paper which leads to a price down in the market and reduces the incentive to keep land as forestry.
- Having steady increase in recycling rate, a landowner gradually begins earning their profit more through agricultural sector.This means there are fewer trees.
- On the other hand, the optimal length of the rotation could become longer.
  - This is because a landowner tries to compensate their decrease in the price by making the tree larger or delay to pay next planting cost.

Inverse Demand Function

- The first step to estimate both the inverse demand function and profit function of agriculture.
- For the inverse demand function for paper related wood production, we assume the following simple linear function;

$$P(S) = a - bS + \epsilon \tag{12}$$

Data for paper related wood production

- FAO's *Forestry Production and Trade* (2015) is used.
- Paper related here means the following.
  - "Coated Papers", "Household+Sanitary Paper", "Other Paper+Paperboard", "Other Papers Packaging", "Paper+Paperboard NES", " Printing+Writing Paper", "Wrapg+Packg Paper+Board", "Wrapping Paper", " Graphic Papers", "Paper and Paperboard", "Paper+-Board Ex", "Newsprnt Pulp for Paper", "Recovered Paper".

Estimation Result of IDF

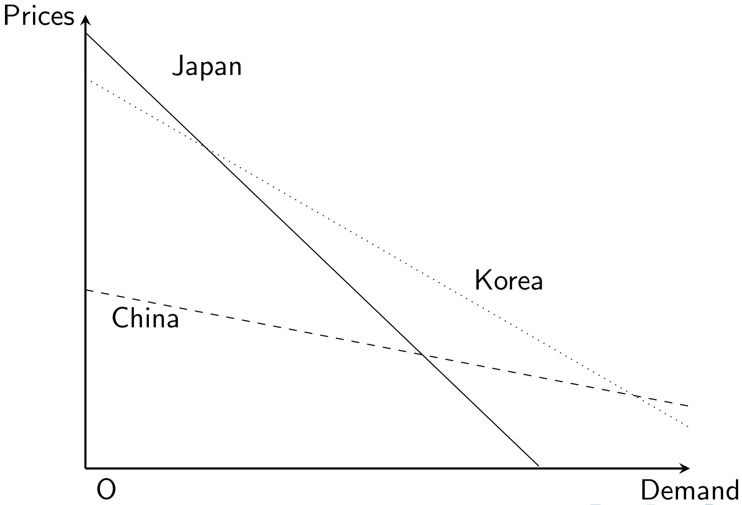
- Estimates of `Intercept` (`log(S/GDP)`) is $\hat{a}$ ($\hat{b}$) in (12).
- In all countries, $\hat{b}$s are negative and significant.

Table 1 : Estimation result of inverse demand function

	Price		
	Japan	China	Korea
	(1)	(2)	(3)
log(S/GDP)	−0.956*	−0.193*	−0.578***
	(0.540)	(0.095)	(0.096)
Constant	5.764*	2.362**	5.162***
	(2.820)	(0.855)	(0.734)
N	30	30	30
R^2	0.101	0.129	0.566
Adjusted R^2	0.069	0.098	0.550
Residual Std. Error (df = 28)	0.141	0.112	0.100
F Statistic (df = 1; 28)	3.133*	4.154*	36.512***

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Estimated Inverse Demand Function



Profit Function for Agriculture

- Next step is to estimate the profit function of agriculture, $g(a)$.

$$g(a) = \alpha a^{\beta} + \epsilon \tag{13}$$

- For the Japan's data, MAFF's data[1] is used.
- For China, *China Statistical Yearbook* (2016) is used.
- For Korea, *Characteristics of Average Sample Farm Household by Province* is used (available at KOSIS).

[1] It is available at `http://www.maff.go.jp/j/tokei/kouhyou/sakumotu/menseki/`

Result of Agricultural Profit Function

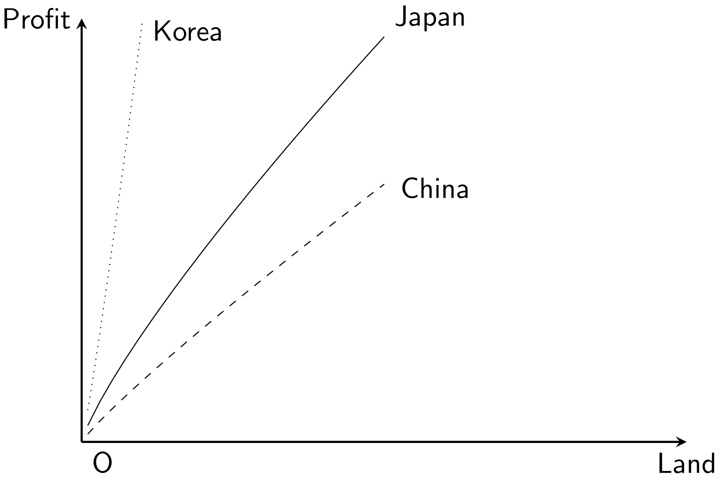
- Since the estimate is based on (13), $\hat{\alpha}$ and $\hat{\beta}$ must be positive.
- The result in the Table 2 satisfies it and significant.

Table 2 : Estimation result of agricultural profit

	log(profit)		
	Japan	China	Korea
	(1)	(2)	(3)
log(Land)	0.821***	0.895***	1.120***
	(0.062)	(0.083)	(0.136)
Constant	2.692***	1.284**	5.255***
	(0.263)	(0.603)	(1.354)
N	47	31	24
R^2	0.793	0.802	0.756
Adjusted R^2	0.789	0.795	0.745
Residual Std. Error	0.350 (df = 45)	0.497 (df = 29)	0.176 (df = 22)
F Statistic	172.781*** (df = 1; 45)	117.458*** (df = 1; 29)	68.224*** (df = 1; 22)

Notes:
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Estimated Profit Function (Agriculture)



Simulation Setting

- To meet $P(S) - c > 0$, I set parameter values, such as $k = 0.01$, $r = 0.04$ (based on Tatoutchoup (2016)).

- As for c, relative wage difference is considered.

- Noting, in the case of a steady state,

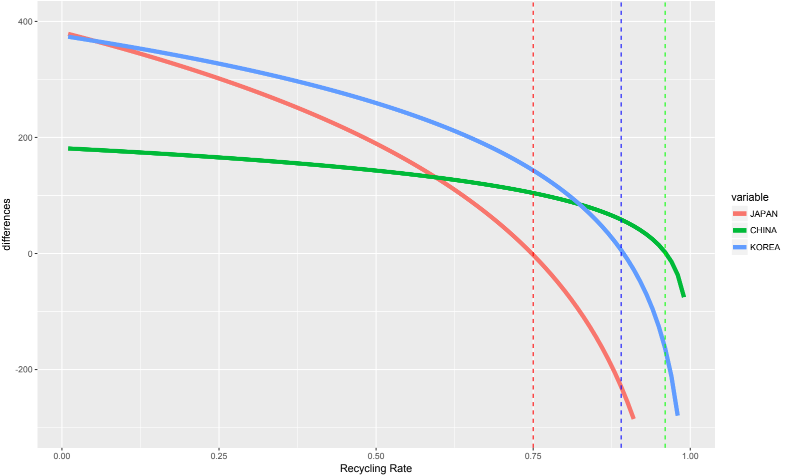
$$S = \frac{fX(T)}{(1-\delta)} \tag{14}$$

- Let us specify $X(T)$ as follows (Payandech(1973)).

$$S = X(T) = 5680.7 - 26660 \times T^{-0.5} \tag{15}$$

Result of Simulation

Using the information, calibrate (7) by changing a recycling rate.



Implication

- Too much recycling for Korea and Japan?
- Less recycling in China?

Table 3 : Comparison of recycling rate

	optimal rate	real rate
Japan	75%	78%
China	96%	46%
Korea	89%	93%

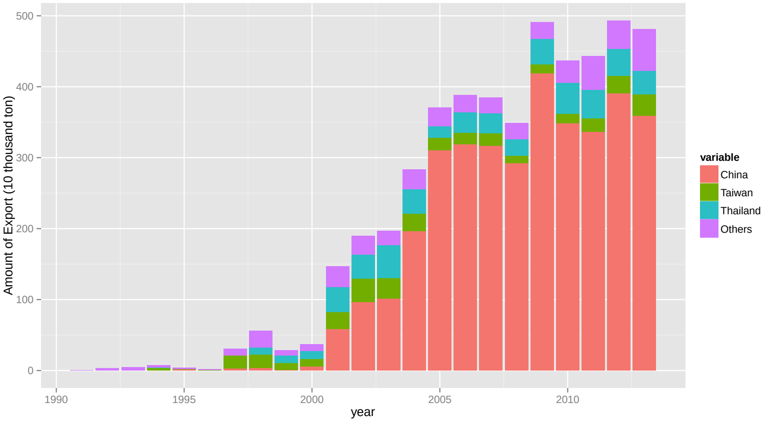
Next Step

- To examine how trade of used paper affects the result (Brander and Taylor (CJE, 1997)).
- Perhaps the easiest way is to add net import of used paper into (2) but not sure it generates any qualitative difference.

$$S(t_i) = f_{i-1}X(T_i) + \delta S(t_{i-1}) + \underbrace{NI_i}_{Net\ Import}$$

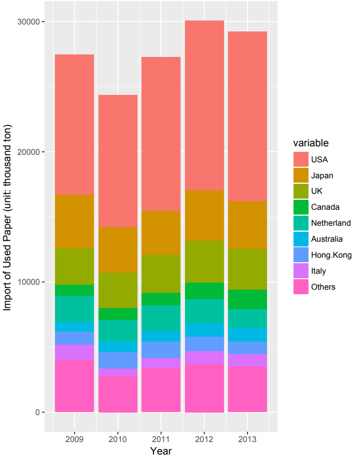
- Checking the robustness of the numerical simulation.
  - An interesting question is at what rate should a recycling rate go down to keep forest area at least the same.

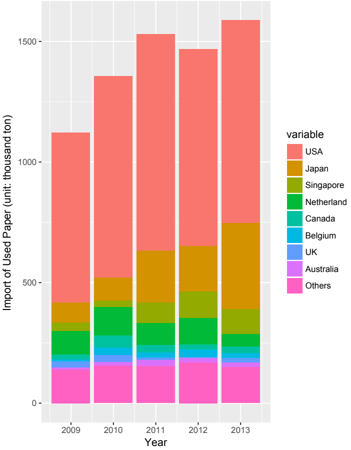
Used Paper Export from Japan



Source: Trade Statistics of Japan

Import of Used Paper (Left: China, Right: Korea)





Source: Used Paper Handbook 2015

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