Towards A General Equilibrium Model for Forestry and Sustainable Development

Srijita Ghosh
Assistant Professor in Economics, Department of Economics,
St. Xavier's University, Kolkata
West Bengal, India

Kausik Gupta
Professor of Economics, Department of Economics,
University of Calcutta, Kolkata
West Bengal, India

Abstract

Sustainable forestry has been considered as an integral component of sustainable development. In our study, we consider a simple Heckscher-Ohlin-Samuelson model consisting of four sectors along with agricultural and forestry sectors. We have compared different types of policy measures to find out which policy is best suited for the expansion of the forestry sector and the well-being of the rural population dependent on forestry. Our study shows that an increase in employment subsidy along with a boost in investment in the sector promotes not only the employment situation in the sector but also it improves the employment situation in other sectors as well. However, the goal of well-being of people through increase in wage rate is attained only through a policy mix of trade liberalization and investment in forestry.

Keywords: *General Equilibrium, Forest-based Industry, Government Policy, Sustainable Forestry*
JEL Classification: Q23, F11, J68

1. Introduction

Forestry serves both as an economic resource (food for animals and wood products) and an environmental resource (biodiversity, water quantity, wildlife habitat). There is widespread agreement that the forest sector can advance a nation's efforts towards economic growth, social cohesion, and environmental sustainability in a variety of ways, as evidenced by its inclusion under numerous goals throughout the 2030 Agenda for Sustainable Development of the United Nations (Li et al., 2019). Especially, in India, it is acknowledged that forest produce, particularly, non-timber forest products (NTFPs) can help to reduce poverty. About 100 million people in India live in or near forests, and their livelihoods are primarily reliant on the collection and sale of forest products (Rasul et al., 2008). However, population growth, socioeconomic and environmental reasons and agricultural expansion have led to deforestation in India (Kumari et al., 2019). Although the government has prioritized agriculture compared to forestry, there is a trade-off between the two, as, overexploitation of land due to agricultural purposes has turned it into wastelands. Moreover, due to the increasing pressure on forest land because of timber production, the government has shifted towards conservation and sustainable management of the forestry sector, which has created an excess demand for timber. Due to a massive disparity between supply and demand for timber caused by a lack of domestic production, imports have increased sevenfold over the past 20 years. In order to meet domestic demand, the option of boosting timber production from trees outside of forests has gained

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importance (Ghosh & Sinha, 2016). Therefore, sustainable forest management should be addressed along with meeting the growing demand for timber and policy measures that can aim to bring a balance between the usage of agricultural and forest land. The purpose of this paper is to search for alternative policies for sustainable management of the forestry sector in terms of a trade theoretic general equilibrium framework. Hence, in our study, we are motivated to rank different policy actions through a trade theoretic general equilibrium framework, because, different policies, such as trade liberalization, increased investment in forestry and employment subsidies in the sector can be helpful in the expansion of forestry sector, as well as different industries which use forest produce as intermediate inputs. This expansion of forestry can also help to generate more employment opportunities in forest-dependent areas and these policies can be successful to improve the well-being of inhabitants in the forest as well. Any theoretical work is usually built up on the basis of empirical facts and figures. As our intention is to proceed towards theoretical model building towards sustainable forest management we have focused first on some relevant empirical facts and figures on forestry and on the basis of these figures we have attempted to develop a stylized theoretical model. Empirical section has been developed for motivational purpose and not for doing any rigorous econometric analysis or data analysis. Hence, to proceed in this line we would like to focus first on brief literature survey on forestry which is dominated by empirical analysis and sometimes by computable general equilibrium models. In the literature on forestry we come across studies that have mentioned sustainable forest management programme, linkages between trade openness and deforestation and steps taken by the government for the development of forest and environment. One can refer to the works of Jafari et al. (2018), Rawat et al. (2008) and Tumaneng-Diete et al. (2003) in this regard. While Rawat et al. (2008) have discussed criteria and indicators of sustainable forest management programme in India, Jafari et al. (2018) have addressed the issue of sustainability of the current management in the Dopolan community forest in Iran and evaluated what could be alternative management scenarios towards sustainable forest management (SFM). According to the authors, attracting local investment in forest conservation along with capacity building of forest occupants can be useful to achieve the goal. Tumaneng-Diete et al. (2003), on the other hand, have drawn attention to the forest policies of Philippines over time. The authors have applied computable general equilibrium model and results from their study shows that while export subsidies help to develop the wood industry, other policies such as prohibition of log export, commodities tax on logs and taxes on the import of pulp do exactly the opposite. Gupta and Chatterjee (2018), Ghiga et al. (2018) on the other hand have focused on theoretical aspects of natural resource management especially forest management in terms of optimal control theoretic dynamic models. Furthermore, Singh et al. (2018) and Stille et al. (2011) have thrown light on the recent agro-forestry policies and measures that have been taken in India and economic performance of those policies. Nathaniel & Bekun (2020), too, have found out the effect of trade openness, economic growth and urbanisation on deforestation in Nigeria. They have used data on energy consumption, deforestation, trade openness, and economic growth from 1971 to 2015 and have found that energy consumption, population density and growth led to environmental degradation. Nathaniel (2021), too, has conducted the same study for Indonesia where he has found that economic growth, urbanisation, and energy consumption escalate environmental degradation, while trade deteriorates it in the long run. Although we have come across a plethora of studies which found different factors behind deforestation in a country, effect of deforestation on economy and environment, the role of sustainable forest management in the growth of sector, we find a lack of policy analysis that takes into account not only the forestry sector but also its implications on other sectors. Moreover, theoretical structures to analyse these issues for developing economies are also missing in the literature. One cannot deny that there are some works on general equilibrium modelling but that general equilibrium structure is completely

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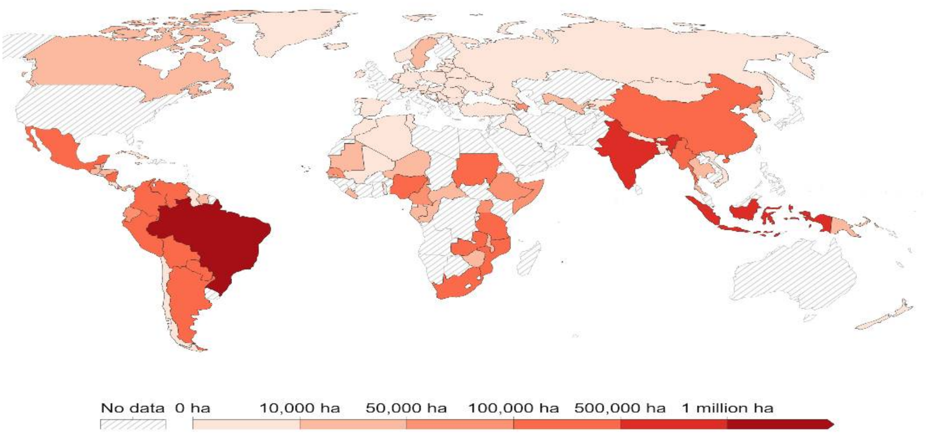
different from what we intend to construct here. In the literature the general equilibrium works that we find are mainly computable general equilibrium models whereas here we are interested to develop a trade-theoretic general equilibrium model where the economy is a price taker in the world market so that the prices of products are given. These models take into account different sectors with different features that are relevant for a developing economy. The main contribution of this work is integration of a trade theoretic general equilibrium framework with the forestry sector that considers the sectoral linkages as well. We want to examine the effect of employment subsidy, boost in investment and trade liberalization on forestry and connected sectors in our study. Our paper will thus be helpful for policymakers of developing countries who deal with sustainable natural resource management, especially forestry resource management. The rest of the paper is organised in the following manner. We mention some facts and figures in section 2 which motivates us to take up this present study. The basic model is discussed in Section 3 and the effect of different policy measures on forestry and forest-based industry are analysed in section 4. Finally, the concluding remarks are made in section 5.

2. Some Facts and Figures on Forestry Sector

Forestry sector plays a crucial role in providing livelihood to billions of people in the world especially in India. However, since 2010, net loss in forests was 4.7 million hectares per year in the world due to expansion in agricultural land use and urbanization due to population growth (Ritchie & Roser, 2021).

Figure 1. Deforestation Rates Across the World in 2015



Source: UN Food and Agriculture Organization (FAO), Forest Resources Assessment[8]

Among the countries, Brazil, India and Indonesia had high rates of deforestation in 2015 (Figure 1). Nonetheless, the positive aspect is that the world has already passed a peak in deforestation in the 1980s and it has been falling since then. Yet, on an individual level, some countries still have not passed the stage of the peak in deforestation which is a matter of concern for local governments because it can adversely affect both the economy and environment of a nation (Ritchie & Roser, 2021). In India too, the forest cover has increased over time especially in states like Andhra Pradesh, Telangana, Odisha, Karnataka and Jharkhand (Figure 2).

[8] The UN FAO publish forest data as the annual average on 10- or 5-year timescales. The following year allocation applies:"1990" is the annual average from 1990 to 2000; "2000" for 2000 to 2010; "2010" for 2010 to 2015; and "2015" for 2015 to 2020.

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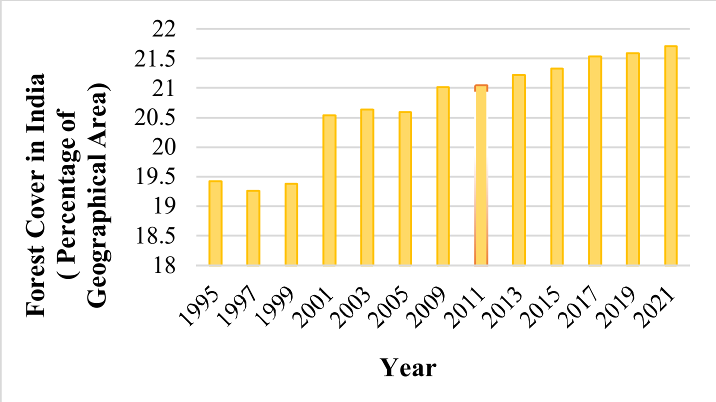
Figure 2. Forest Cover in India (Percentage of Geographical Area)



Source: Compiled by author from India State of Forest Report

However, the contrary situation has been observed in the Northeast region of the country (Table 1) (India State of Forest Report, 2021). Shifting agriculture, rotational felling, diverting forest lands for development purposes, other biotic stresses, etc. are the main factors that have led to this decline. The country's microclimate, hydrological cycle, soil quality, biodiversity, etc. have all been harmed by ongoing illegal tree cutting, making it more susceptible to any untoward incident (Reddy et al., 2013).

Table 1. Top Five States with Fall in Forest Cover in 2021 with Respected to 2019 (in Percentage)

Top 5 States	Fall in Forest cover in 2021 w.r.t. ISFR 2019 (in percentage)
Arunachal Pradesh	-257
Manipur	-249
Nagaland	-235
Mizoram	-186
West Bengal	-70

Source: Compiled by author from India State of Forest Report, 2021

The global data on production and trade patterns in the forestry sector shows that both production and export of different forest-based products such as industrial wood, firewood, sawn wood, paper and paperboard have fallen in 2020 compared to 2019 (Table 2). In India, the aggregate domestic production of forestry sector goods has risen in 2019-20.

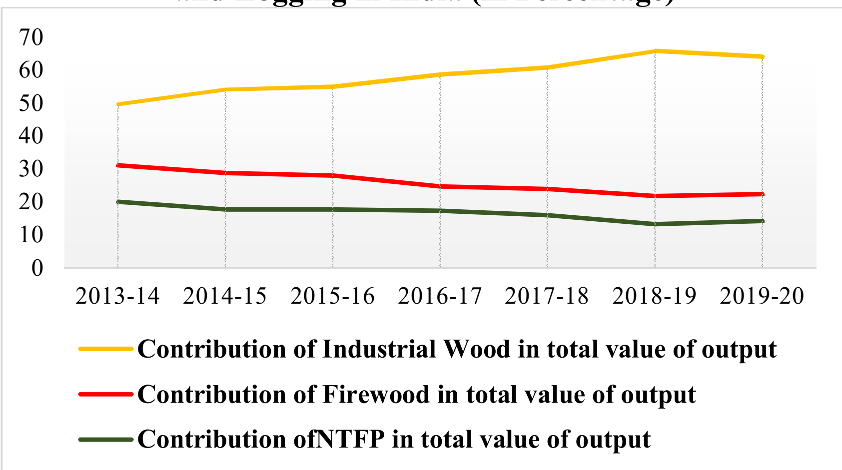
Table 2. Change in Production and Export of Forest Based Products in 2020 compared to 2019 (in Percentage)

Product	Change in Production in 2020 compared to 2019 (in Percentage)	Change in Export in 2020 compared to 2019 (in Percentage)
Wood fuel	-1%	-15%
Industrial round wood	-2%	-1%
Wood pellets and other agglomerates	3%	6%
Sawn wood	-3%	-3%
Wood-based panels	-1%	-2%
Wood pulp	-2%	1%
Pulp from fibres other than wood	-1%	7%
Recovered paper	-1%	-8%
Paper and paperboard	-1%	-2%

Source: FAOSTAT-Forestry database

Yet, the share of firewood in total products shows a downward trend from 2013-14 to 2019-20 while production of industrial wood has increased over time[9] (Figure 3).

Figure 3. Contribution of Different Forest Produce in Total Value of Output in Forestry and Logging in India (in Percentage)



Source: Compiled by Author from MOSPI (2022)

On the other hand, the share of non-timber forest products has also fallen in 2017-18 compared to previous years, post which it has increased in 2019-20. The data on trade patterns in the forestry sector shows that India has always been a net exporter of forest-based products, such as live trees and other plants; bulbs; roots and the like; cut flowers and ornamental foliage, wood and articles of wood; wood charcoal. Although India did not experience much change in import of the forest products, export in different goods such as, wood and articles of woods, live trees and other plants and wood products have fallen in last few years (Table 3).

[9] Forest products in India can be broadly divided into two categories: a) Timber, and b) Non-timber Forest Products (NTFP). NTFPs include plants used for food, beverages, forage, fuel, medicine, fibres and biochemical; animals, birds and fish for food, fur and feathers; as well as their products such as honey, lac and silk (MOSPI, 2022). Rosewood, teakwood, jungle wood, etc. are all examples of timber. Either trees found in forests or trees found outside of forests (TOF) are the sources of timber production. All trees growing outside government Recorded Forest Areas (RFAs) are known as trees found outside of forests (TOF).

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Table 3. Growth in Export and Import of Forestry Sector Based Products in India in 2022-23 compared to 2021-22 (in Percentage)

Product	Growth in Export in 2022-23 compared to 2021-22 (in Percentage)	Growth in Import in 2022-23 compared to 2021-22 (in Percentage)
Wood and articles of wood; wood charcoal	-8.21%	0.36%
Pulp of wood or of other fibrous cellulosic material; waste and scrap of paper or paperboard	94.37%	0.56%
Paper and paperboard; articles of paper pulp, of paper or of paperboard	-0.07%	0.44%
Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishing; lamps and lighting fittings not elsewhere specified or inc	-9.66%	0.25%
Lac; gums, resins and other vegetable saps and extracts	18.24%	0.09%
Live trees and other plants; bulbs; roots and the like; cut flowers and ornamental foliage	-8.36%	0.004%

Source: Compiled by Author from Ministry of Commerce and Industry, GOI

Therefore, it is quite evident that even though total forest cover has risen in India, there are certain states in Northeast region where it has alarmingly gone down. Moreover, the export of some of these products has fallen in 2022-23 compared to the previous year. Apart from urbanization and increasing pressure on land due to development and agricultural land expansion existing forest policies are also responsible for it as they have exclusively focused on the conservation of forests instead of emphasizing on forest production too. Hence there exists a trade-off between forest conservation and production of forest-based products. So, in our study we are motivated to consider different policy mix that can focus on with three-fold objectives- a) increase in the forest cover in the economy, b) expansion of forestry and associated sectors in terms of both production and employment opportunities, and c) improvement in the well-being of stakeholders in forestry through a rise in their wage rates[10].
The above study motivates us to rank different policies based on their effectiveness on achieving the above mentioned goals. In the next section, we have developed a stylized theoretical model in a small open developing economy which is a hybrid of Jones (1965) (or Heckscher-Ohlin) and Jones (1971) (or specific factor) structures. Our objective is to examine the impact of different policies taken by the government and to check whether they can help to improve employment levels and well-being in different sectors of the economy.

[10] Our study remains incomplete without the perspectives and responses of a stakeholder in a forest fringe area, as it reflects the importance of the sector in rural regions as an alternative employment option. For that reason, we have conducted a household survey from March, 2022 to September,2022 in the Jhalda-I and Jhalda-II blocks of Purulia district of West Bengal where a small sample of two hundred respondents have been interviewed on their socio-economic status, average monthly level of household income, primary and alternative occupations. Although the household members have mentioned that they depend on agriculture as their primary occupation, the return from it isn't sufficient for them to run a family. Hence, they rely on forestry and migration to neighbouring cities like Ranchi for earning their livings. Around 93.5 per cent of the respondents have mentioned that they are engaged in logging and extraction of other forest resources, such as fuelwood and plants as their alternative source of income. We have also conducted chi-squared test to find out association between forest dependency and the average monthly income of the households. The probability value has come to be 0.003, because of which we accept the alternative hypothesis that there is a significant association between forest dependency and the average monthly income of the households. As the stakeholder's dependency on forestry rises as an alternative source of income, their income rises as well.

3. A Stylized Theoretical Model

In this section, we consider a small open economy with many sellers and buyers where both type of agents are price-takers. This standard trade theoretic general equilibrium framework consists of three sectors – rural sector (R), manufacturing sector (M) and forest-based industry (V). The rural sector (R) is further divided into two sub-sectors- the agricultural sector (A) and forestry sector (B) which produce two commodities- agricultural products (X_A) and forest products (X_B), such as timber and non-timber forest products. Agricultural product (X_A) is produced using two types of factors- labour (L) and capital (K). Production of forest products (X_B) requires labour (L) and forest land (G). In the manufacturing sector M, commodity X_M is produced with labour (L) and capital (K).The fourth sector, i.e. the forest-based industry (V) produces commodity X_V using labour (L) and forest products (X_B) as inputs. We assume, both sectors A and V to be export sectors and sector M to be an import competing sector. Sector B is a non-traded intermediate good producing sector. We have all other standard assumptions of a small open economy general equilibrium trade models. Prices of commodities X_A, X_M and X_V are given internationally and they are denoted by P_A^*, P_M^* and P_V^* respectively. However, the price of X_B is determined endogenously as it is a non-traded intermediate product and it is denoted by P_B.

Competitive wage rate, return to capital (K) and return to land (G) are denoted by w, r, r_G respectively. It is further assumed that workers in the manufacturing sector receive a fixed wage rate ($\overline{w}$). Workers first move to sector M to earn high wage rate ($\overline{w}$). If they fail to get a job they are absorbed in the remaining sectors. This is a random assumption borrowed from the literature (Marjit, 2003).

We denote by a_{ij} as the amount of i^{th} input required to produce one unit of commodity j ($\forall i = L, K, G, B; \forall j = A, M, V, B$ and $i \neq j$).[11] Here we assume that the manufacturing sector produces relatively more capital (of type 1) intensive good both in value sense ($\frac{\theta_{LA}}{\theta_{KA}} > \frac{\theta_{LM}}{\theta_{KM}}$) and physical sense($\frac{\lambda_{LA}}{\lambda_{KA}} > \frac{\lambda_{LM}}{\lambda_{KM}}$) than the agricultural sector [12].

The competitive equilibrium conditions in all the sectors are given as follows:

$$wa_{LA} + ra_{KA} = 1 \quad (1)$$

[11] Here we have variable coefficient technology for all the sectors except sector V .In that sector we assume fixed coefficient technology. This is just a simplifying assumption.

[12] We assume that, $\frac{a_{LA}}{a_{KA}} > \frac{a_{LM}}{a_{KM}}$. It can also be written as $\frac{(wa_{LA}/P_A)}{(ra_{KA}/P_A)} > \frac{(wa_{LM}/P_M)}{(ra_{KM}/P_M)}$ i.e. $\frac{\theta_{LA}}{\theta_{KA}} > \frac{\theta_{LM}}{\theta_{KM}}$ It implies that, manufacturing sector is relatively capital intensive sector compared to agricultural sector in value sense. Similarly, $\frac{a_{LA}}{a_{KA}} > \frac{a_{LM}}{a_{KM}}$ can also be written as, $\frac{(X_A a_{LA}/L)}{(X_A a_{KA}/K)} > \frac{(X_M a_{LM}/L)}{(X_M a_{KM}/K)}$ which also implies that, manufacturing sector is relatively capital intensive sector compared to agricultural sector in physical sense.

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$$\overline{w}a_{LM} + ra_{KM} = P_M^*(1+t) \quad (2)$$
$$wa_{LB} + r_G a_{GB} = P_B \quad (3)$$
$$wa_{LV} + P_B a_{BV} = P_V^* \quad (4)$$
The full employment conditions for labour, capital, and land are given as follows,
$$a_{LA}X_A + a_{LM}X_M + a_{LB}X_B + a_{LV}X_V = L \quad (5)$$
$$a_{KA}X_A + a_{KM}X_M = K \quad (6)$$
$$a_{GB}X_B = G \quad (7)$$
Demand for intermediate goods like timber on part of the forest-based industry is equal to the supply of forest produce and it is given by
$$a_{BV}X_V = X_B \quad (8)$$
One can easily check that the model is decomposable. The factor prices and price of the intermediate input can be determined from the price system and output levels can be determined from the output system. To be more specific from equation (2) we can determine r. Putting the value of r in equation (1) we can determine w. Using the value of w in equation (4), we can determine P_B. Once P_B is known, equation (3) helps us to determine r_G. Once we solve for factor prices from commodity prices, variable input output coefficients are known. As a_{GB} is known, one can solve for X_B from equation (7). For known X_B, we can solve for X_V. Putting the values of X_V and X_B in equation (5) and solving equations (5) and (6) simultaneously, we can solve for X_A and X_M.

4. Alternative Policy Rankings

In the present section, we show the effects of different policy measures such as trade liberalization, investment in the forestry sector and employment subsidy, on forestry sector as well as forest-based industries. Many authors, such as Southgate et al. (2000), Stenberg & Siriwardana (2015) and Haddad et al. (2019) have discussed about effects of various policies on forest production, deforestation and ecological footprint in their study. Southgate et al. (2000) in their study have mentioned that in spite of trade liberalization in Ecuador in 1990s, lack of investment due to weak property rights, oligopolistic competitive market structure and corruption, forest dwellers' participation in economy remained limited. Stenberg & Siriwardana (2015) on the other hand, have studied the effects of unilateral trade liberalization of forest products amongst the Asia-Pacific Economic Cooperation (APEC) member countries and found that both domestic production and consumption of forest products fall as a result of trade liberalization. Haddad et al. (2019) in their study have mentioned that as forest products are frequently used in high-value-added and high-tech industries, investment in forestry sector would not only help to expand forestry sector, but would reduce "food-fuel-material" trade-offs pertaining to non-food usages for agricultural products while lowering greenhouse gas emissions.

4.1. Boost in Investment in Forestry Sector

We first study the effect of increase in investment in the forest land (G) on the forest stakeholders as well as the sector as whole.

Proposition 1*: As investment in forest land rises, not only the forestry sector expands in terms of employment and production but also it improves the production and employment situation in manufacturing sector and forest-based industry. However, the agricultural sector is adversely affected.*

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Proof of Proposition 1: See the appendix for algebraic proof. Here we consider only the economic intuition to prove the results.

Suppose the investment in the forest land G rises ($\hat{G} > 0$). From equation (7) total output in the forestry sector will rise($\hat{X}_B > 0$), as, $\hat{X}_B = \hat{G}$ [13]. Forest products (X_B) are used as intermediate goods in production of forest-based industry. Consequently, when X_B rises, forest based industry expands as well ($\hat{X}_V > 0$) as $\lambda_{BV} > 0$). As a result, total labour requirement in sectors V and B, i.e. $(a_{LB}X_B + a_{LV}X_V)$ rises and given the fixed endowment of labour in the economy, effective labour endowment available for sectors A and M fall (From equation 5, we get, $\lambda_{LB}\hat{X}_B + \lambda_{LV}\hat{X}_V = -(\lambda_{LA}\hat{X}_A + \lambda_{LM}\hat{X}_M)$). It creates a *'Rybczynski type'* effect. As manufacturing sector is relatively capital-intensive sector, fall in labour endowment expands manufacturing sector but size of agricultural sector shrinks, i.e. $\hat{X}_M > 0$ and $\hat{X}_A < 0$. Hence, higher expenditure on forest land by the government can lead to expansion of forestry as well as manufacturing and forest-based industry. However, there is no change in the wage rate in forestry sector, so, investment in forest land does not have any effect on the well-being of the people.

QED

4.2. *Impact of Increase in Employment Subsidy in Forestry Sector*

In sub-section 4.1 we find that boost in investment expands the size of forestry sector. However, this policy does not have any effect on well-being of forest dwellers. In the present sub-section, we find out the effect of employment subsidy in forestry sector.

Proposition 2*: Increase in employment subsidy in the forestry sector expands forestry, manufacturing and forest based industry. However, the size of agricultural sector shrinks.*

Proof of Proposition 2*:* See the appendix for algebraic proof. Here we consider only the economic intuition to prove the results.

Incorporating employment subsidy to the forestry sector we can rewrite equation (3) as

$$(w - s_B)a_{LB} + r_G a_{GB} = P_B \tag{3.1}$$

In equation (3.1) s_B implies subsidy given to the forestry sector. As the government increases employment subsidy to timber($\hat{s}_B > 0$), the effective wage paid by the forestry sector falls from w to $(w - s_B)$ and, for known w and P_B, it implies increase in r_G (from equation (3.1), $\hat{r}_G = \frac{s_B \theta_{LB} \hat{s}_B}{\widetilde{w}\theta_{GB}}$). Thus, there is reduction in a_{GB} and hence from equation (7) an increase in the production of X_B. Since timber is used as an input in production of X_V, there is an expansion of X_V as well. As the production of both X_B and X_V increase, total employment in sectors B and V, i.e. $(a_{LB}X_B + a_{LV}X_V)$, increases. It implies the effective labour endowment for sectors A and M fall like previous case. It creates a *'Rybczynski type'* effect and as sector M is more capital-intensive than sector A, production as a result of which X_A falls and X_M increases. As the unit labour requirement for sectors M, A and V remain unchanged (as there is no change in the factor prices in these three sectors) and as the unit labour requirement in sector B increases due to a fall in its wage –rental ratio we can infer about the employment levels of

[13]As G rises, there is no change in the factor prices because of the decomposability property of the model. Hence, unit input output coefficient a_{GB} remain unchanged. See Appendix for detailed mathematical proof.

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different sectors on the basis of the change in the levels of output. We have found that only X_A falls due to increase in employment subsidy to the forestry sector but the output levels of the other three sectors increase. Hence, X_M , X_B and X_B increase as a result of increase in employment subsidy to the forestry sector. We thus conclude that the manufacturing, agro-based industry and the forestry sector are benefitted due to increase in employment subsidy to the forestry sector in terms of employment and output though the agricultural sector is adversely affected.

QED

We next discuss the effect of trade liberalization as a policy measure in sub-section 4.3.

4.3. Impact of Trade Liberalization in Import- Competing Sector

In the first two cases, we observe that only the size of the forestry sector expands. Hence, we study the effect of another policy i.e., trade liberalization in the form of tariff cut import-competing Sector.

Proposition 3: *A policy of trade liberalization resulting from tariff cut causes an increase in the wage rate of workers in forestry. However, all the sectors except agriculture shrink due to this policy.*

Proof of Proposition 3: See the appendix for algebraic proof. Here again we consider only the economic intuition to prove the results.

When the government reduces tariff rate (t) to move towards free trade we find that $\{P_M^*(1+t)\}$ falls in equation (2) ($\hat{t} < 0$). As wage rate in the manufacturing sector remains fixed at $\overline{w}$, it leads to fall in rental rate of capital, r ($\hat{r} = \frac{\tau\hat{t}}{\theta_{KM}}$). Consequently, competitive wage rate (w) increases in equation (1). For known w and P_B, r_G falls in equation (3). It results in increase in a_{GB} and hence from equation (7), production of X_B falls. Since timber is used as an intermediate good in production of X_V, forest based industry (X_V) contracts as well. Due to fall in production levels of both X_B and X_V we find that total employment in sectors B and V falls as well. It implies the effective labour endowment for sectors A and M increase like previous case. It creates a *Rybczynski type* effect and as sector M is more capital-intensive than sector A, as a result of which X_A rises and X_M falls.

QED

We thus observe that trade liberalization raises the wage rate received by the forest stakeholders, but it can also lead to contraction of forestry sector. On the other hand, investment liberalization results in expansion of the sector without affecting the wage rate.

5. Concluding Remarks

From the study we find that for sustainable forest management, increase in employment subsidy to forestry sector along with boost in investment in forestry is an essential policy measure as it will not only benefit the forestry sector but also the manufacturing and the agro-based sectors. However, it affects adversely only the other rural sector apart from forestry, i.e. the agricultural sector. This result appears reasonable as in a developing economy when the

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forestry sector faces an increase in employment subsidy workers associated with agricultural sector should shift to the forestry sector in search of jobs and though the agricultural sector contracts the forestry sector is promoted. It promotes employment of all remaining sectors of the economy as well. Both the policies of boost in investment in forestry and hike in employment subsidy are effective to expand the forestry sector in terms of production and employment generation. Yet, based on our model none of the policies is useful to improve the well-being of forest dwellers. A policy of trade liberalization in this case can be effective in true sense, as it helps to raise the wage rate in forestry. Since a better wage rate in forestry sector implies a better well-being of the stakeholders, this policy can be helpful for forest management. However, implementation of this policy leads to contraction of the forestry sector in terms of employment and production, so it can be combined with other policies for better result.

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Appendix

Proof of Proposition 1

Totally differentiating equation (7) we get,

or, $\lambda_{GB}\hat{a}_{GB} + \lambda_{GB}\hat{X}_B = \hat{G}$

An increase in G does not have an effect on the factor prices due to decomposability property. Hence, $\hat{X}_B = \hat{G}$ [A.1]

Equation (8) implies $\hat{X}_V = \hat{X}_B$ [A.2]

Total differentiation of equation (5) and noting that, $\hat{L} = 0$, $\hat{G} > 0$, we get,

$$\lambda_{lA}\hat{X}_A + \lambda_{LM}\hat{X}_M = -(\lambda_{lB} + \lambda_{LV})\hat{G} \quad [A.3]$$

Equation (6) implies that,

$$\lambda_{KA}\hat{X}_A + \lambda_{KM}\hat{X}_M = 0 \quad [A.4]$$

Solving equations [A.3] and [A.4] simultaneously, we get the expressions for $\hat{X}_A$ and $\hat{X}_M$ we get,

$$\hat{X}_A = \frac{\{-\hat{G}(\lambda_{LB} + \lambda_{LV})\lambda_{KM}\}}{|\lambda|} < 0 \quad [A.5]$$

$\hat{X}_A > 0$ as $\hat{G} > 0$ and $|\lambda| = (\lambda_{LA}\lambda_{KM} - \lambda_{LM}\lambda_{KA})$

$|\lambda| > 0$ as agricultural sector is relatively labour intensive than manufacturing sector.

$$\hat{X}_M = \frac{\{\hat{G}(\lambda_{LB} + \lambda_{LV})\lambda_{KA}\}}{|\lambda|} \quad [A.6]$$

$\hat{X}_M > 0$ as $\hat{G} > 0$

Proof of Proposition 2

Equation (3.1) is given as, $(w - s_B)a_{LB} + r_G a_{GB} = P_B$

Taking total differentiation of the above equation and after some routine algebra we get,

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or, $\theta_{LB}\{\mu\hat{w}+(1-\mu)\hat{s}_B\}=\hat{P}_B-\hat{r}_G\theta_{GB}$ (Here, $\mu=\frac{w}{\widetilde{w}}$ and $(1-\mu)=\frac{-s_B}{\widetilde{w}}$)

or, $\hat{r}_G=\frac{\hat{P}_B-[\theta_{LB}\{\mu\hat{w}+(1-\mu)\hat{s}_B\}]}{\theta_{GB}}$

or, $\hat{r}_G=\frac{-[\theta_{LB}\{\mu\hat{w}+(1-\mu)\hat{s}_B\}]}{\theta_{GB}}$ as $\hat{P}_B=0$

or, $\hat{r}_G=\frac{s_B\theta_{LB}\hat{s}_B}{\hat{w}\theta_{GB}}>0$ [A.7]

Equation (7) can be written as, $\hat{X}_B=(\frac{\hat{G}}{\lambda_{GB}}-\hat{a}_{GB})$

In the above equation $\hat{G}>0$. Additionally, using elasticity of substitution between labour (L) and forest land (G) in forestry sector and using the Envelope condition for equation (3) we can rewrite the expression for $\hat{X}_B$ as, $\hat{X}_B=\sigma_B\theta_{LB}\hat{r}_G$ .Using (A.7), we get,

Or, $\hat{X}_B=\frac{\sigma_B\theta_{LB}^2 s_B\hat{s}_B}{\hat{w}\theta_{GB}}$ [A.8]

From equation [A.8], $\hat{X}_B>0$.

Equation (8) implies $\hat{X}_V=\hat{X}_B$. Hence, $\hat{X}_V>0$. From equation (5) and using equation [A.8] after some algebraic manipulation, we get,

$\lambda_{lA}\hat{X}_A+\lambda_{LM}\hat{X}_M=-\frac{(\lambda_{lB}+\lambda_{LV})\sigma_B\theta_{LB}^2 s_B\hat{s}_B}{\theta_{GB}}$ [A.9]

$\lambda_{KA}\hat{X}_A+\lambda_{KM}\hat{X}_M=0$ [From equation A.4]

Hence, by solving two equations [A.4] and [A.9] we get,

$\hat{X}_A=-\frac{(\lambda_{lB}+\lambda_{LV})\sigma_B\theta_{LB}^2 s_B\hat{s}_B\lambda_{KM}}{|\lambda|}$ [A.10]

$\hat{X}_M=\frac{(\lambda_{lB}+\lambda_{LV})\sigma_B\theta_{LB}^2 s_B\hat{s}_B\lambda_{KA}}{|\lambda|}$ [A.11]

Where, $|\lambda|=(\lambda_{LA}\lambda_{KM}-\lambda_{LM}\lambda_{KA})>0$ as agricultural sector is relatively labour intensive than manufacturing sector. So, $\hat{X}_A<0$, $\hat{X}_M>0$ when $\hat{s}_B>0$

Proof of Proposition 3

Taking total differentiation of equation (2) and using some routine algebra we get,

$\theta_{KM}\hat{r}=\hat{P}_M^*+\tau\hat{t}$ where, $\tau=\frac{t}{1+t}, 0<\tau<1$

The above equation can be written as, $\theta_{KM}\hat{r}=\tau\hat{t}$ as $\hat{P}_M^*=0$ [A.12]

From equation (1) we can write the expression of $\hat{w}$ as,

$\hat{w}=-\hat{r}(\theta_{KA}/\theta_{LA})$

or, $\hat{w}=-\frac{\tau\hat{t}\theta_{KA}}{\theta_{LA}\theta_{KM}}$ (Using [A.12]) [A.13]

As, $\hat{t}<0$, $\hat{w}>0$.

From equation (3) the expression of $\hat{r}_G$ can be written as,

$\hat{r}_G=-\hat{w}(\theta_{LB}/\theta_{GB})$

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Or, $\hat{r}_G = \dfrac{\pi\hat{t}\theta_{KA}\theta_{LB}}{\theta_{LA}\theta_{KM}\theta_{GB}}$ [A.14]

As, $\hat{t} < 0$, $\hat{r}_G < 0$.

From equation (7) we know, $\hat{X}_B = \{\dfrac{\hat{G}}{\lambda_{GB}} - \sigma_B\theta_{LB}(\hat{w} - \hat{r}_G)\}$

Using $\hat{G} = 0$, equation [A.13] and [A.14] we can rewrite the expression of $\hat{X}_B$ as,

$$\hat{X}_B = -\{\sigma_B\theta_{LB}(-\frac{\pi\hat{t}\theta_{KA}\theta_{LB}}{\theta_{LA}\theta_{KM}\theta_{GB}} - \frac{\pi\hat{t}\theta_{KA}}{\theta_{LA}\theta_{KM}})\}$$

$$\hat{X}_B = \frac{\sigma_B\theta_{LB}\pi\hat{t}\theta_{KA}(\theta_{GB} + \theta_{LB})}{\theta_{LA}\theta_{KM}\theta_{GB}} \quad \text{[A.15]}$$

As, $\hat{t} < 0$, $\hat{X}_B < 0$.

Using equation (8) and [A.15], we can write, $\hat{X}_V < 0$.

$$\hat{X}_A = \frac{-\pi\hat{t}\theta_{KA}\lambda_{KM}}{|\lambda|\theta_{LA}\theta_{KM}}[(\sigma_A\theta_{KA}\lambda_{LA} + \sigma_B\theta_{GB}\lambda_{LB}) + \{\frac{(\sigma_A\theta_{KA}\lambda_{LA} + \sigma_M\theta_{KM}\lambda_{LM})\theta_{LB}}{\theta_{GB}}\} + \theta_{LB}] \quad \text{[A.16]}$$

$\hat{X}_A > 0$ as $\hat{t} < 0$ and $|\lambda| = (\lambda_{LA}\lambda_{KM} - \lambda_{LM}\lambda_{KA}) > 0$

$$\hat{X}_M = -\frac{\{\sigma_A\theta_{KA}\lambda_{LA}(\hat{w} - \hat{r}) - \sigma_A\theta_{KM}\hat{r}\lambda_{LM} + \sigma_B\theta_{GB}\lambda_{LB}(\hat{w} - \hat{r}_G) + \sigma_V\theta_{BV}(\hat{w} - \hat{P}_B)\lambda_{LV}}{|\lambda|} < 0$$

$$\hat{X}_M = -\frac{-\{(\sigma_A\theta_{KA}\lambda_{LA} + \sigma_B\theta_{GB}\lambda_{LB})\frac{\pi\hat{t}\theta_{KA}}{\theta_{LA}\theta_{KM}}\} + \{(\sigma_A\theta_{KA}\lambda_{LA} + \sigma_A\theta_{KM}\lambda_{LM})\frac{\pi\hat{t}\theta_{KA}\theta_{LB}}{\theta_{LA}\theta_{KM}\theta_{GB}}\} + \{\sigma_B\theta_{GB}\lambda_{LB}(\frac{\pi\hat{t}\theta_{KA}\theta_{LB}}{\theta_{LA}\theta_{KM}\theta_{GB}})\}}{|\lambda|} \quad \text{[A.17]}$$

$\hat{X}_M < 0$ as $\hat{t} < 0$ and $|\lambda| = (\lambda_{LA}\lambda_{KM} - \lambda_{LM}\lambda_{KA}) > 0$