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Regional impacts of environmental regulations and technical change in the US forestry sector: a multiregional CGE analysis ☆

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Abstract

In this paper, a multiregional computable general equilibrium model, which divides the United States (US) into four broad geographical regions and aggregates other nations into the rest of the world, is used to analyze the effects associated with environmental and technological policy shifts in the US forest sector. In particular, we analyze the impacts of: (i) a 20% reduction in the harvest of timber in the Pacific Northwest relative to other regions; (ii) a 5% increase in the cost of timber production in the US South relative to other regions due to environmental regulations; and (iii) a 2% Total Factor Productivity (TFP) improvement in the South and 1% TFP improvement in the other three US regions. The results show that a 20% reduction in timber harvest induces a shift in regional production and visible gains in welfare, especially in the US South. Furthermore, higher technical progress in the South as compared to the other three regions contributes to an overall increase in forest products' output and welfare in the US and the rest of the world. On the contrary, an increase in the cost of production in the US South, in response to additional environmental regulations, is shown to reduce welfare for the US and globally. Results of this analysis help forest companies and landowners make production decisions and guide policy makers toward developing appropriate policies to further forest conservation and economic development in the US.

Keywords: CGE; Environmental regulation; Policy; Total Factor Productivity; Welfare

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1. Introduction

Historically, the United States (US) maintained a comparative advantage in industrial wood production based on the vast coverage of old growth forestlands. In the recent past, however, growing environmental concerns has ushered in new legislation regarding conservation and use of forestlands. On the one hand, there is growing pressure to limit timber harvest on national forestlands. For example, regulations for protecting the northern spotted owl and restrictions on the use of public lands in the Pacific Northwest (PNW) region has led to declining timber removals, shifts in timber production to the US South, and higher imports from Canada. More recently, congressional bill HR 1494 entitled the 'National Forest Protection and Restoration Act' proposed the elimination of commercial logging activity on all national forestlands. Further restrictions on timber production are possible, given increasing environmental concerns and associated regulations which are expected to increase production costs. On the other hand, technological change via advances in forest biotechnology and increasing investments in intensive forest management are improving forest productivity.

The anticipated impacts of environmental regulations and improvements in forest productivity may not be uniform across the US as there are significant regional variations in forest ownership and investment potentials for productivity enhancements. For example, private forestland is more concentrated in the US South while public forestland is more pronounced in the West. One can, therefore, expect higher forest investment and higher productivity improvements in the US South relative to the West. Alternatively, one can expect more forest set-asides in regions where public forests dominate relative to private forests. As such, the impact of HR 1494 or other forest set-asides may be more significant in the West relative to the South.

The purpose of this paper is to estimate the effects of a set of potential forest policy changes using an inter-regional model that divides the US into four broadly defined regions namely: the Pacific Northwest (PNW); the US South (South); the North; and the Pacific Southwest (PSW) (see Appendix A). We also assume that the forest sector is a significant part of the United States economy and the US is a major player in global forest products markets. Finally, we link US forest sectors with other sectors of the US economy and the US with the rest of the world by using an inter-sectoral and inter-regional model. The primary objective of this analysis is to illustrate regional impacts accruing from forest policy changes in different US regions. In this paper, a multi-regional computable general equilibrium model, which segregates the US into four broad geographical regions and aggregates the other foreign economies into the composite rest-of-the-world (ROW), is used to analyze the effects associated with environmental and technological policy repercussions. Thus, the analysis, by furnishing the impacts of potential policy changes, has significance for providing a basis for formulation of public policy in promoting investment in research in technological improvement in the forestry sector and also helps policy makers devise appropriate forest policies so as to foster economic benefits in the US. The applied general equilibrium framework enables us to evaluate the impacts via inter-sectoral and inter-regional linkages.

The paper is organized as follows. Section 2 provides an empirical basis for simulating: (i) the impact of a 20% reduction in logging output in the PNW; (ii) the effects of a 5% increase in the cost of logging production in the South; and (iii) the effects of differential rates of TFP improvements in the South (i.e. 2%) vis-à-vis the other three US regions (i.e. each 1%). Section 3 describes the methodology, model and database used to conduct simulations. Section 4 presents selective simulation results. Section 5 concludes.

2. Contemporary issues affecting the US forestry and simulation design

2.1. Reductions in timber harvest in the Pacific Northwest

Over the past 2 decades, the role of public forestlands in biodiversity conservation and ecosystem management has been emphasized (Thomas et al., 1990). For example, protection of the habitat for the northern spotted owl (Strix *Occidentalis Caurina*) has put more restrictions on the use of public lands in the PNW. According to Haynes (2001), timber harvest in the PNW fell from 26% of US production in 1986 to 15% in 1996, while the value of this timber fell from 40% to 24%. As a result, there has been a subsequent

$PM\ (i,\ r)$ be the market price of 'i' sector's output in region 'r'.
$E\ (i,\ r)$ be the environmental cost incurred by sector 'i' in region 'r'.

Without any policy-imposed environmental cost factor, the relation between the price variables is given by:

$$PS(i,\ r) = TO(i,\ r) \times PM(i,\ r)$$

Where $TO\ (i, r)$ is the ad valorem tax rate (i.e. 1 plus tax rate).

With imposition of proportional environmental costs, the price linkage equation becomes

$$PS(i,\ r) \times E(i,\ r) = TO(i,\ r) \times PM(i,\ r)$$

By taking total differentials on both sides and denoting generically for any variable X, $\frac{vdX}{X} \times 100 = x$ the level equation above translates into the percent age change form (i.e. denoted in lower case letters for the percent age change in concerned variables) as:

$$ps(i,\ r) = to(i,\ r) + pm(i,\ r) - e(i,\ r)$$

The exogenously specified environmental cost variable in the price linkage equation above creates a wedge between the supply price and the market price of commodities. Supply price is assumed endogenous while the environmental cost variable is assumed to be exogenous. Assuming that environmental costs enter the price linkage equation exogenously is consistent with assuming an exogenous perturbation in the system, and further helps to keep the model tractable. Based on the foregoing discussion, we shock the variable '$e\ (i,\ r)$' in the forestry sector by 5% in the South.

2.3. Productivity improvement in the South via investments in forestry biotechnology

The North American forest sector is experiencing significant technological progress due to intensive timber management, mechanization and biotechnological innovations (Stier and Bengston, 1992; Sedjo, 1997; Sedjo and Simpson, 1999; Parry, 1999; Simpson, 1999). Industrial wood productivity in the US increased by 39% from 1900 to 1998 (Ince, 2000). In the face of increasing environmentalism and expanding forest set-asides, productivity improvements are thought to be a potential alternative for meeting the increase in demand for forest products (Sedjo and Botkin, 1997).

Forest biotechnology through genetic engineering and manipulation of biological processes develops trees with superior and commercially valuable traits (Gaston et al., 1995). For example, inventions such as: herbicide; pest and disease resistant seedlings; and improved fiber properties have resulted in significant productivity gains. The potential economic benefits of technological innovations can be perceived in the form of an increase in the output for a given set of inputs (an upward shift in the production function) or in the form of a decrease in the unit cost of production for a given level of output. The spin-off effects of productivity improvements will be manifold. First, it will reduce demands on environmentally sensitive forest set-asides and will enable the conservation of additional environmentally sensitive areas as forest set-asides. Second, consumers will benefit from lower prices of forest products. Third, the returns on investment in plantation forests will increase. As a result, both non-industrial and industrial private forest landowners will invest more in biotechnology development.

At the regional level, the South holds great promise for intensively managed forest plantations via forest biotechnology (see Sedjo, 1997, 1999a). Also, most of the highly productive forestlands in the US (approx. 91 million acres) are situated in the South (Smith and Sheffield, 2000). Therefore, not surprisingly, the South accounts for more than 50% of total US softwood production and a little less than 50% of total US hardwood production (Wear, 1995). Sedjo (1999a,b) suggests that aggregate productivity improvements in southern softwood inventories registered an average annual growth rate of 0.5 to 1% between 1935 and 1980. Ince (2000) documents that industrial wood productivity growth for the US as a whole hovered at approximately 1% between 1995 and 1998.[8] As

[8] Consideration of biased technical change of land-saving type would have been useful if the analysis was focused on the potential impacts of types of technical changes on forestland usage pattern and on the impacts of such technical changes on variations in land categories across various uses as well as compositional changes in forestland. However, these issues are beyond the scope of the paper.

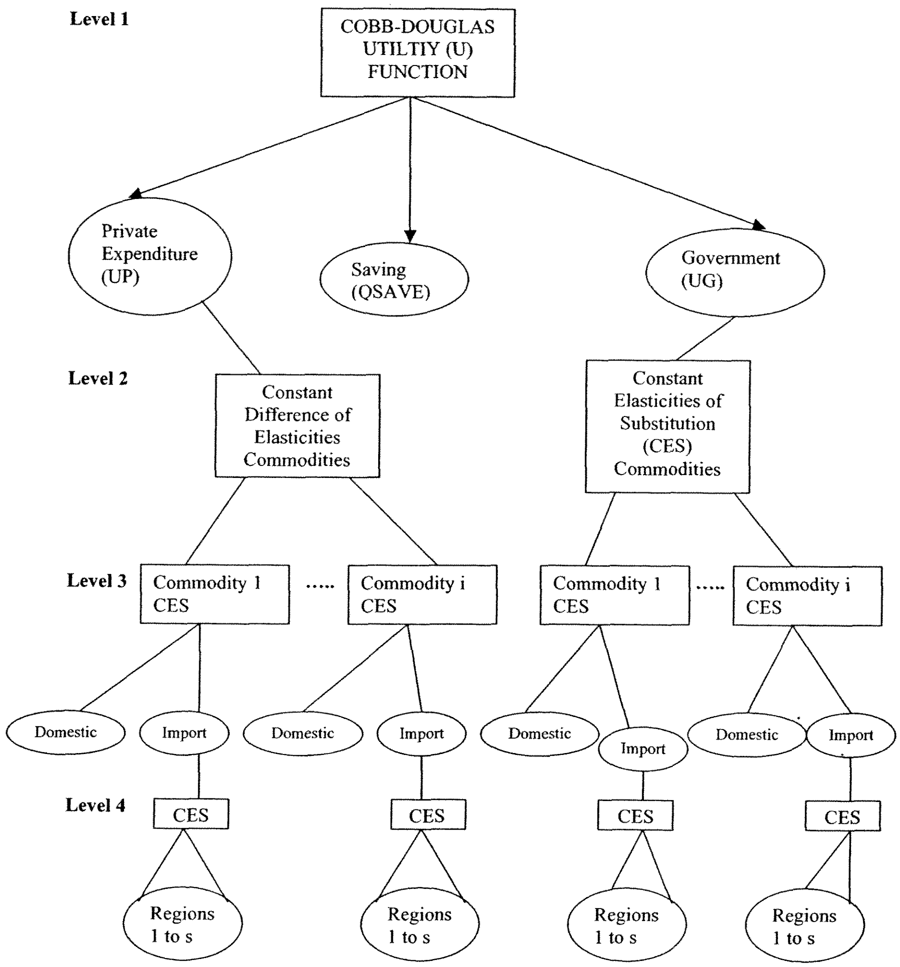

Fig. 1. Nested structure for allocation of demand across commodities.

imported and intra-regional sources. The final stage allocates imported goods across regions and the ROW.

Producers use intermediate inputs along with the primary factors of production. The derived demand for primary factor inputs are based on static profit-maximizing (or its dual, cost-minimizing) behavior of firms. The Armington (1969) assumption specifies that produced commodities be differentiated by origin so that users (producers and consumers) can differentiate a commodity by region. That is, the imports from different sources are imperfect substitutes. Aggregate regional investment in making new capital goods is given by the output of a 'capital goods' sector. The production of capital goods involves use of intermediate inputs only. In our short-run analysis, although new investment goods are produced, they do not add to the productive capital stock so that capital supply is fixed in the simulated period. Each US region, depending on local and global transportation costs, participates in trade with other US regions and the ROW. Thus, relative price differences stimulate changes in regional demands. Prices for commodities are determined via market clearing through inter-regional and international trade. Similarly, factor prices are determined through market clearing conditions in the market for factor inputs. Each sector produces only one commodity with no joint production. Fig. 2 illustrates the nested production technology that underlies the model.

varieties of goods also influences direction of changes in regional terms-of-trade in the wake of a policy shock. In case of the composite foreign region ROW, these elasticities are not that relevant as there are no disaggregated sub-regions in it. However, for ROW as a whole, substitution elasticities apply when commodity trade is considered (see Tsigas 1997). In the policy simulations, it is assumed that following policy shocks, regional income distribution across categories of expenditures do not alter so that demand structure remains the same during the simulated period. Although, sensitivity of the results to different sets of parameters values will enable us to see the importance of behavioral parameters, (Alavalapati et al., 1999) that is beyond the scope of this paper.[10]

Labor and capital services are intersectorally mobile within a region. However, they are immobile across regions. Demanders treat imports from different sources as imperfect substitutes. Each US region, depending on transportation costs, participates in the trade of goods and services with other US regions and the ROW. Thus, the relative price differences stimulate demand shifts for commodities sourced across US regions as well as the ROW. Prices for commodities are determined via market clearing through interregional and international trade. Similarly, factor prices are determined through market clearing conditions in the market for factor inputs. Each sector produces only one commodity with no joint production. Given the regional focus on the US economy, the model separates state and federal government expenditures. However, the foreign composite region, ROW, has only one type of government. The original model has 52 regions within the US and a single ROW. However, in this paper, we use a different specification by aggregating the 52 US regions into four aggregate regions.

[10] Sensitivity of the results to the parameter changes was not considered due to the following compelling reasons: First, we believe that it is not critical to the objectives of the paper. Second, high level aggregation of regions posed challenges to sensitivity analysis. Third, paucity and non-availability of data at the micro-regional level precluded conducting sensitivity analysis. The values used in the disaggregated multi-regional model are based on Jomini et al. (1991) and a global CGE trade model (see Hertel, 1997).

3.2. Database

For computational convenience, we use an aggregated version of the database. The original database consisted of 35 commodities and 52 regions (Tsigas, 1997) expressed in US billion dollars. The data were aggregated into seven sectors and, as noted above, five composite regions using trade and production data from the GTAP database. Typically, the database comprises bilateral trade flows between all US domestic regions and the ROW. It further includes: tariff measures; transportation costs; domestic accounts for the US; and interstate and international transactions. For each sector, total costs equal total sales across regions. The regional economic accounts are taken from the Bureau of the US Census, whereby a 1987 regional input–output table of the US economy is used to build a 'microconsistent' regional dataset. For establishing the linkages between the ROW and the four US regions, Commodity Flow Survey Statistics and State Merchandise Export Statistics were used to determine the inter-state trade flows. We do not reproduce the methodology for building the database (see Tsigas, 1997 for details). Table 1 illustrates the regional and sectoral mapping of the model.

4. Policy simulations and key findings

4.1. A reduction of logging output in the Pacific Northwest (PNW) by 20%

Table 2 summarizes the post-shock impact on output, regional exports and prices in all US regions in response to the reduction of logging output in the Pacific Northwest (PNW) region by 20%. The results reported are post-shock percentage deviations of the respective variables from the base-case.

The results indicate that the shock in the PNW causes a shift in log production (FORE) to the other three regions. Log production is shown to increase by 10.2, 11.9 and 12.1%, respectively, in the South, the North and the PSW. Owing to the decline in the output in the PNW, the market price of logging output increase by 5.34% in the PNW as compared to very small percentage rises in the other regions. The large increase in the market price of logging (FORE) and wood products (WOOD) in the PNW will create a

Table 3
Impacts of a 20% fall in logging output in the PNW on regional exports (in percentage change)

Sources	Destinations				
	PNW	South	North	PSW	ROW
Logging (FORE)					
PNW	−15.70	−34.09	−30.30	−19.33	−17.60
South	42.55	6.13	9.64	31.50	29.99
North	42.13	5.86	9.33	31.08	29.70
PSW	35.97	1.25	4.62	25.30	24.93
Wood (WOOD)					
PNW	−2.48	−3.49	−3.24	−2.48	−2.67
South	1.89	0.53	0.63	1.62	1.36
North	1.76	0.42	0.51	1.49	1.27
PSW	−1.48	−2.79	−2.68	−1.80	1.66

translates into a rise in bilateral export sales of logging from these regions to the PNW by 42.55, 42.13 and 35.97%, respectively, while the PNW loses in its own market due to 15.7% fall in its sales. In the case of the wood sector, the relative price increased in the PNW relative to the South and the North. The South and the North gained market shares in the PNW by increasing their bilateral export sales by 1.89 and 1.76, respectively. Because of the price increase in the wood sector of the PSW relative to the South and the North, this region loses its market share. As expected, in the logging and wood products sectors, bi-lateral export sales from the PNW to all other destination regions declined after the shock. With the ROW as the destination, we observe that from all US regions except the PNW, there have been surges in regional export sales in forest products.

With respect to welfare changes (Tables 4–8; see Table 9), the reduction of logging output in the PNW causes a decrease in the welfare of that region by approximately $204 million. Although some expansion was noticed in forest sectors in the North, the PSW and the ROW, general equilibrium effects will decrease welfare in these regions. Only the South will experience an increase in welfare of approximately $56 million. Overall, this policy is expected to have approximately a $213 million dollar decrease in total US welfare since the gain in welfare in the South is mainly offset by huge welfare losses in the PNW. The shock resulted in a decline in regional aggregate income and per capita utility by 0.12 and 0.05%, respectively, in the PNW (not reported), thus resulting in large welfare losses (see Table 9 below).[11] On the other hand, regional welfare improved in the South due to an increase in regional income by 0.01%. Thus, the South is the major beneficiary of regional shift in production.

4.2. *A 5% increase in production costs due to environmental regulations*

Percentage changes in outputs, regional exports and prices following a 5% increase in production costs to the Southern region are reported in Table 4.

This policy shock results in an increase in the price of logging (FORE) by 1.59% in the South, whereas in other regions the percentage increases in prices are much smaller due to changes in regional competitiveness. In particular, the relative price in the logging sector in the South relative to all other US regions rose. These relative price changes are: 1.50% (relative to the PNW); 1.39% (relative to the North); and 1.38% (relative to the PSW). Furthermore, the South experiences a decline in aggregate regional exports to other regions in all forest product sectors. On the other hand, there was an increase in aggregate regional exports in all forest products sectors from all the remaining regions.

This, in turn, impacts on the trade balances in the three forestry-related sectors (Table 5). As expected, there was a fall in sectoral trade balances in the South in all forest sectors, with the largest decline being in the logging sector (FORE) itself.[12] All other regions experienced improvements in sectoral trade balances in that sector.

Furthermore, increases in domestic market prices in the logging, wood and pulp and paper sectors in the South results in a reduction in the sales of these products within the region itself. Clearly, the increase in cost has reduced intra-regional sales of all three categories of forest products with a more pronounced

[11] The welfare results for each of the three simulations are reported in the Section 4.3 so as to facilitate comparison of the impacts in each of the simulation.

[12] The sectoral trade balance is the difference between the exports and imports by a particular sector in a region. Negative sectoral trade balance reflects that the export by a sector is outweighed by its imports. Converse is the case with an improvement in trade balance of a sector. Thus, it refers to trade performance of a sector in a particular region. Bi-lateral exports, on the other hand, capture export from one region (source) to the other (destination) in a particular sector.

Table 7
Impacts of a 2% TFP shock in the forestry sector in the South and a 1% TFP shock in each of the other three regions on price, output and exports (in percentage change)

Sectors	Price				Output				Exports			
	PNW	South	North	PSW	PNW	South	North	PSW	PNW	South	North	PSW
FORE	−0.35	−0.66	−0.41	−0.48	−0.92	1.341	−0.757	0.16	−0.96	1.38	−0.85	−0.04
WOOD	−0.06	−0.06	−0.04	−0.06	0.073	0.120	−0.093	0.10	0.07	0.12	−0.09	0.10
PULP	−0.01	−0.01	−0.01	−0.01	0.016	0.010	0.004	0.01	0.02	0.012	−0.00	−0.02
AGRI	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	−0.01	0.00	0.00
OMAN	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.03	−0.01	0.00	0.00
ORES	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.03	−0.01	0.00	0.00
SVC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	−0.01	0.00	0.00

Thus, productivity enhancements have mixed effects across sectors and regions due to general equilibrium repercussions.

Higher productivity improvements in the South were reflected in a relatively larger decline in prices for FORE, WOOD and PULP. This translated into an increase in demand for these products in the wake of inter-regional competition. As a result, we find an increase in the aggregate regional exports of forest products from the South. The South registered an increase in its aggregate regional export sales relative to other trading regions (Table 7). For agricultural (AGRI), manufacturing (OMAN), other resources (ORES) and the services sector (SRVC), the percentage changes in production and prices are almost zero since these sectors did not experience any productivity improvement.

Following the technology shocks there have been percentage increases in bi-lateral export sales in each of these forest products. After the changes in relative prices in the forest products across the regions, there is further scope for inter-regional competition. As the South experienced higher TFP improvement relative to the other regions, it appropriated more benefits from this technological progress. This is reflected in an increase in bilateral exports in log and wood products from this region to other regions (Table 8).

Overall, TFP improvements are welfare enhancing—especially for the South which experiences the largest increase in regional welfare. Also, the other three regions experience improvements in welfare following general equilibrium adjustments (Table 9). The accrual of the largest welfare benefits due to TFP improvement in the South is a result of improved resource allocation and technical efficiency of approximately \$35 million. However, the PNW, the PSW and the North experience less improvement in welfare. For the ROW, which experienced no TFP improvement, the increase in welfare was modest compared to the aggregate welfare improvement in the US of approximately \$82 million. Still, any TFP improvements in the US spill over to the ROW.

5. Concluding remarks

This paper analyses the regional implications for three important potential forest policy changes across four geographical regions in the United States. We employ a multi-regional, multi-sectoral CGE model and customize it such that it is suitable for our analysis. The analysis shows that all potential forest policy changes will affect the demand and supply of logging products output, both regionally and globally. Simulation experiments show that in the case of productivity

Table 8
Impacts of a 2% TFP shock in the South and a 1% TFP shock in each of the other three regions on bilateral export sales (in % changes)

Sources	Destinations			
	PNW	South	North	PSW
Logging (FORE)				
PNW	−0.55	−2.74	−2.12	−0.79
South	2.55	0.97	1.60	2.17
North	0.17	−1.71	−0.86	0.19
PSW	0.79	−1.08	−0.32	0.89
Wood (WOOD)				
PNW	0.07	0.05	0.06	0.06
South	0.10	0.12	0.15	0.10
North	−0.12	−0.12	−0.08	−0.11
PSW	0.08	0.09	0.12	0.11

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