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Differentiated products and supply controls in the analysis of agricultural policy reform: the case of tobacco

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ABSTRACT

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With a multi-market model of the U.S. tobacco and cigarette industries, we analyze the impact of a reduction in the assistance to U.S. tobacco producers by relaxing production quotas with nonbinding price support and by lowering tariffs on tobacco imports. The results show the importance of incorporating differentiated product and supply control assumptions into agricultural policy analysis.

INTRODUCTION

With a multi-market model of the U.S. tobacco and cigarette industries, this paper analyzes the impact of a reduction in assistance to U.S. tobacco producers by alternatively relaxing production quotas and lowering tariffs on imported tobacco. The model accounts for heterogeneity of tobacco and forward linkage to the cigarette industry and provides explicit policy representation of domestic and trade distortions.

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The study was triggered by the extensive use of Producer Subsidy Equivalents (PSE) in a series of recent articles using the common framework of the SWOPSIM model (e.g. Krissoff and Ballenger, 1989; Roningen and Dixit, 1989; and Webb et al. 1989). [1] PSEs are summary measures of various distortions such as trade barriers, domestic programs, and economy-wide policies (Tangermann et al., 1987; USDA, 1988). For U.S. tobacco, these papers predict that lower distortions in tobacco markets would lead to smaller U.S. exports and domestic production. These conclusions are counterintuitive for the following reasons. Removal of domestic distortions that account for most of the assistance to U.S. growers would free the large production capacity currently constrained by production quotas. Larger U.S. supplies would lower U.S. prices and expand U.S. exports. As a result, the world price of foreign substitutes would decrease; that is, the current tobacco program benefits foreign producers with higher prices induced by a less than competitive equilibrium quantity of U.S. tobacco (Sumner, 1989; Grise, 1990).

By assimilating domestic distortions to border measures and by assuming homogeneous commodities, the studies cited above have made extreme assumptions. By contrast, this paper separates the impacts of trade barriers and domestic distortions, and introduces non-homogeneous products and linkages to the processing industry. The first scenario relaxes domestic tobacco production quotas, allowing domestic prices to fall and output and exports to expand; the second reform assumes lower tariffs on imported tobaccos, inducing substitution of imported tobacco for domestic tobacco in cigarette production. The next section reviews key features of the U.S. tobacco industry to motivate our assumptions. The following section presents a nonmathematical summary of our multi-market model of the U.S. tobacco and cigarette industries. In the empirical section, we first estimate the U.S. cigarette industry derived demand for tobacco to determine the substitutability between two domestic and two imported tobacco types and to link the two sectors. It is important to establish the cigarette/tobacco linkages to quantify changes in tax and export revenues in both sectors brought about by the two policy reforms. The two policy experiments

[1] Roningen and Dixit have developed the SWOPSIM model, which is a multi-country, multi-commodity constant elasticity model centered on the agricultural sector. It is used to compute market equilibrium and trade flow changes induced by trade liberalization in agriculture.

The SWOPSIM model assumes homogeneous commodities and well-behaved supply and demand schedules and treats all distortions as tariff equivalents or price wedges between domestic producer price and border (world) price. The model ignores supply controls, two-way trade, and most forward linkages.

follow: they are calibrated to simulate identical decreases in assistance as measured by the PSE as in Hertel (1989). Our results reveal first that there is limited substitutability among tobaccos, then that the two reforms have very specific effects on production, trade flows, and tax and trade revenues.

U.S. TOBACCO INDUSTRY

The U.S. tobacco program consists of price support combined with production controls (quotas). U.S. tobacco aggregate output is restricted below its competitive level (Johnson, 1965; Johnson and Norton, 1983). If the market bid price is not 1 cent per pound higher than the support price level, the Flue-Cured Tobacco Cooperative Stabilization Corporation or one of the Burley Cooperatives takes control of the tobacco. This tobacco is processed and sold over a period of years. The program has been working on a 'no net cost' principle since 1982; farmers contribute to a fund covering part of the cost of the program. Quota rights can be leased within counties and have a market-determined rental rate (the lease rate). With flue-cured, however, this lease and transfer provision was dropped beginning with the 1987 crop. Quota can be sold (purchased) within a county for both flue-cured and burley, although 1991 is the first year for burley. Total U.S. quotas are based on intended tobacco use by the cigarette industry, expected exports and stocks objectives (Grise and Griffin, 1988).

Tariffs on imported tobacco vary from 0 to 20 cents per pound depending on quality (average of 8.7 cents per pound of imported flue-cured and burley, and 11.5 cents per pound of imported oriental). The actual tariff is slightly less, since the U.S. Customs Service rebates 99% of tariff payments on imported tobacco used in U.S. cigarette exports. Domestic tobacco prices systematically have been higher than world prices of foreign substitutes, a difference sustained partly by trade barriers and partly by the imperfect substitution between imported and domestic tobacco types. Imported oriental tobacco and premium domestic flue-cured and burley are used as flavoring agents in cigarette production. Imported flue-cured and burley are used as fillers.

A MODEL OF THE TOBACCO AND CIGARETTE MARKETS

Following Muth (1965), the model is expressed in differential logarithms ($\mathrm{d}\log x = \mathrm{d}x/x = E(x)$). Under this approach only variables influenced by policy shocks appear in the system of equations. The model has strong similarities to that of Sumner and Wohlgenant (1985), with the added feature of four non-homogeneous tobacco inputs. The two industries,

cigarette and tobacco, are linked through tobacco use in cigarette production, which is assumed to exhibit constant returns to scale.

Two tobacco inputs are domestically grown: they are U.S. flue-cured (first input), and U.S. burley and Maryland (second input). Total demand for these tobaccos is the sum of tobacco use in the cigarette industry and export demand. Their supply depends on government programs (quota). The other two tobacco categories are imported oriental and other special tobaccos (third input), and imported flue-cured and burley (fourth input); both are imported at prevailing world prices inclusive of tariffs. U.S. cigarette producers are price takers in all markets because U.S. imports represent a small share of world tobacco production and because of empirical evidence on absence of market power in the U.S. cigarette industry (Sumner, 1981; Sullivan, 1985). Hence, changes in cigarette prices are caused by input price changes. Changes in the tobacco and cigarette markets alter tobacco prices but do not affect the prices of non-tobacco inputs; therefore, the latter do not appear in this model. U.S. cigarettes are consumed domestically and exported.

The model specifies supply and demand relationships for the four tobacco markets and for the cigarette market, which are all assumed to be in equilibrium. The model abstracts from inventory problems by assuming a period long enough to allow supply and demand to adjust. Domestic supply is totally inelastic because of binding production quotas. The model solves for percentage changes in endogenous variables induced by exogenous policy shocks (increases in production quotas and lower tariffs on imports). The important endogenous variables are the five markets' equilibrium quantities and prices, trade flows, tax and net export revenues, tobacco lease rates, production revenues, and producers' rents. Export revenues come from the tobacco and cigarette exports net of tobacco imports costs. Tax revenues consist of excise taxes on cigarette domestic consumption and of tariffs on tobacco imports, net of reexportation rebates. The lease rate is the difference between the unit price of tobacco and its marginal cost of production. Producer rents are the Marshallian producer surplus net of the value of the aggregate quota. Changes in lease rate, rents, and revenues capture the change in producers' welfare. The model is linearized; that is, it assumes constant share and elasticity parameters in the comparative statics. This assumption is appropriate for small shocks as in our simulations, but it involves some approximations. Equations and variable definitions are presented in the Appendix.

In the empirical section, the model specified by equations (A1)–(A13) is used to simulate the effects of two policy reforms. In the first scenario, production quotas of U.S. tobacco are increased to induce a 2-cent decrease in U.S. tobacco prices (or in the gap between domestic price and

world price). The second reform reduces the protection to domestic producers by lowering the tariffs on tobacco imports by 2 cents. Although the two reforms operate at different levels, they give comparable decreases (2 cents) in assistance as it would be measured in a price wedge approach. The impact of the policy shocks is obtained by solving system (A1)–(A13) for the changes in endogenous variables induced by the policy reforms. The empirical section discusses share parameters and elasticity estimates used in that step. The exogenous shocks have an impact on tobacco prices, which in turn affect the cost of cigarette production and level of output. The latter output effect feeds back into the derived demand for tobacco. Once the changes in cigarette and tobacco prices and quantities are known, changes in tax and export revenues, and in producer welfare are easily computed. Beghin and Chang (1991) present detailed derivations of the policy impact multipliers.

Figures 1a and 1b illustrate the impact of the two policy experiments on domestic tobacco. In Fig. 1a the quota relaxation induces an increase in

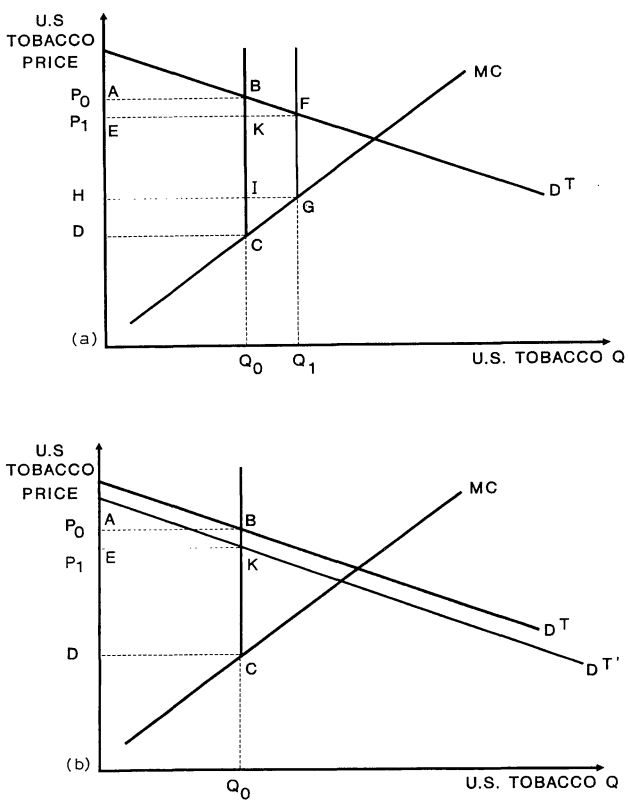

Fig. 1. (a) Change in lease rate and producer's surplus with larger production quota. (b) Change in lease rate with smaller import tariffs.

tobacco use from Q_0 to Q_1 and a decrease in price from P_0 to P_1. The change in producer rent is the sum of the area HDCI and ICG, which is described by (A13). The change in lease rate is the difference AD minus EH or the change in price minus the change in marginal cost. That difference expressed in percentage change terms is represented by equation (A12). Figure 1b shows that demand for U.S. tobacco shifts inward to $D^{T'}$ because of lower tariffs on imported tobacco. The lease rate decreases by AE, which measures the price change. Neither producer's rent nor marginal cost are affected in this latter experiment.

DATA

The data contain two parts. The first set is made up of 1950–1984 time-series which refer to the cost of U.S. cigarette production. These series are used in the next section to estimate the elasticities of tobacco derived demand. Description and sources are in Chang (1988). The second part of the data contains the other parameters (shares, elasticities), price and quantity data necessary to quantify the model.

Most of this second set is for 1986 and comes from Grise and Griffin (1988) unless otherwise noted. Definitions and values of variables and parameters are presented in Beghin and Chang (1991). The elasticities of domestic and export cigarette demands come from Sumner and Alston (1987); estimates of tobacco export demand elasticities are from Johnson and Norton (1983). Cross-price elasticities of export demands are assumed to be zero because no estimate is available from the literature. Estimates of tobacco marginal cost responses to changes in output come from Goodwin et al. (1987). The lease rate information and the market shares of tobaccos and cigarettes come from Grise and Griffin (1988). The domestic tariff and tax data come from USDA (1986) and Grise and Griffin (1988). The proxy for the foreign tariff on tobacco is the EEC tariff rate given in USDA (1986), since the EEC is a major importer of U.S. tobacco. The share of foreign trade barriers in the cigarette export price is arbitrarily set at 40% as a lower-bound estimate. Many countries impose higher tariffs on cigarette imports (Delman, 1985); unfortunately, recent estimates are not available for all major cigarette trade partners (Grise, 1990). Sensitivity analysis indicates that substantial variations in the value of that share parameter do not affect the qualitative results.

ESTIMATION OF PRICE ELASTICITIES OF TOBACCO DEMANDS

Time series data of the U.S. cigarette manufacturing industry are used to estimate share equations derived from a translog cost function. The share

equations are:

$$\alpha_{t_i} = b_i - \sum f_{Ij} \ln P_{t_j} + a_{Ni} N_i \qquad \text{for} \quad i = 1, 2, 3, 4, K \tag{1}$$

The shares refer to the four tobaccos, and other inputs, K. An index of average nicotine content per cigarette, N, is included as a trend variable to capture over time the changing characteristics of cigarettes (lower tar and nicotine content and lower tobacco content). The nicotine level, N, depends on the quantity of tobacco used in cigarette production. Hence, it is simultaneously determined with the input hiring decision, and it is treated as an endogenous variable. The three-stage least-squares estimation technique is employed. Linear homogeneity, symmetry of the Hessian of the cost function, and constant returns to scale are maintained hypotheses.

Table 1 presents the estimated f_{ij} parameters and the corresponding price elasticities computed at the mean predicted shares. Thirteen estimates are significant among the 20 estimated parameters. The small elasticity estimates reveal the limited substitutability among the four tobacco types in cigarette production. Domestic and foreign tobaccos are substitutes, which is consistent with Sumner and Alston's (1987) results. With one exception, all the estimates are smaller than one in absolute value. The elasticity estimates are combined with other parameter values to simulate the two policy reforms.

SIMULATION RESULTS

The impact multipliers of the two policy changes on the endogenous variables are presented in percentage changes in Table 2. Changes in export and tax revenues, tobacco producers' rent and revenues are also expressed in dollars. Column 1 of Table 2 shows that larger production quotas induce lower domestic tobacco prices and larger U.S. tobacco total demand but influence tobacco imports negatively. Cigarette demand expands with relaxation of production quotas. Relative prices of tobacco (imported versus domestic) increase at the expense of imported tobacco. Since the cigarette output effect does not offset the substitution effect, the demand for imported tobacco decreases with a more substantial effect on imported oriental tobacco imports. Tax and export revenues increase by \$1.6 and \$22 million, respectively; increases in cigarette demand and export drive this result. Domestic tobacco producers increase their rents, but burley-Maryland producers' gross revenues fall slightly ($-\$0.587$ million). Both quota lease rates decrease by more than 5% because of lower U.S. tobacco price and higher marginal cost. The second column of Table 2 indicates that lower tariffs on tobacco imports increase the derived demand for foreign tobacco; the cigarette industry substitutes away from U.S.

TABLE 1

3SLS parameters of translog share equations for different inputs (t-ratios are in parentheses)

Variables	Tobaccos				Other input
	1	2	3	4	K
Intercept	−0.0360	−0.1577	−0.1865	0.0348	1.3454
	(−0.16)	(−1.34)	(−3.61)	(2.45)	
1	−0.0064	−0.0628	0.0314	0.0012	0.0366
	(−0.13)	(−2.89)	(3.06)	(0.53)	
2	−0.0628	0.0769	0.0117	0.0013	−0.0271
	(−2.89)	(4.54)	(1.96)	(1.19)	
3	0.0314	0.0117	0.0135	−0.00006	−0.0567
	(3.06)	(1.96)	(1.19)	(−0.97)	
4	0.0012	0.0013	0.00006	0.0025	−0.00506
	(0.53)	(1.19)	(−0.97)	(1.07)	
N	0.0263	0.0108	−0.0024	−0.0040	−0.0307
	(7.54)	(6.30)	(−3.01)	(−15.19)	
K	0.0366	−0.0271	−0.0567	−0.00506	0.05226

Output-constant demand elasticities for factors in cigarette production at the mean predicted shares. (approximate standard errors are in parentheses)

P	Q				
	1	2	3	4	K
1	−0.91544	−0.53263	1.19838	0.49132	0.182282
	(0.366574)	(0.229993)	(0.34838)	(0.673033)	(0.073402)
2	−0.37817	−0.090355	0.491524	0.502022	0.0575868
	(0.163298)	(0.17952)	(0.202244)	(0.343143)	(0.0380682)
3	0.265712	0.153495	−0.51102	−0.1614	−0.046191
	(0.0772449)	(0.0631577)	(0.140931)	(0.196306)	(0.170043)
4	0.0121911	0.0175442	−0.018062	−0.2317	−0.0026729
	(0.0166999)	(0.0119919)	(0.0219683)	(0.714389)	(0.004712)
K	1.01571	0.451941	−1.1608	−0.60024	−0.19101
	(0.409009)	(0.298759)	(0.427335)	(1.058212)	(0.845481)

tobacco, which causes its price to fall. Because of the binding quotas, total demand for U.S. tobacco does not vary, and U.S. tobacco exports offset the decrease in domestic demand. The lower prices of imported tobacco have an expansionary effect on cigarette production. However, this output effect does not offset the substitution effect in cigarette production induced by lower tariffs. The net impact on U.S. tobacco prices is negative. The second column of Table 2 indicates that lower tariffs on tobacco imports increase the derived demand for foreign tobacco; the cigarette industry substitutes away from U.S. tobacco, which causes its price to fall. Because of the binding quotas, total demand for U.S. tobacco does not vary, and U.S.

TABLE 2

Impact of policy changes

	Increase in output quotas [a]		Decrease in tariffs [c]	
Total demand for U.S. flue-cured tobacco	1.903%		0.000%	
Total demand for U.S. burley and Maryland tobaccos	1.218%		0.000%	
Exports of U.S. flue-cured tobacco	2.182%		0.196%	
Exports of U.S. burley and Maryland tobaccos	2.267%		0.365%	
Imports of oriental tobacco	−2.057%		0.476%	
Imports of flue-cured and burley tobacco	−1.199%		0.535%	
Price of U.S. flue-cured tobacco	−1.232% (≈ −2¢)		−0.111%	
Price of U.S. burley and Maryland tobaccos	−1.279% (≈ −2¢)		−0.206%	
Price of imported oriental tobacco	0.000%		−1.286% (≈ −2¢)	
Price of imported flue-cured and burley tobaccos	0.000%		−2.021% (≈ −2¢)	
Total cigarette demand	0.049%		0.017%	
Wholesale price of cigarettes	−0.082%		−0.053%	
Net export revenues from cigarettes and tobacco	1.0269%	(22.532) [b]	0.316%	(6.943) [d]
Tax revenues from cigarettes and tobacco	0.018%	(1.664)	−0.066%	(−6.225)
U.S. flue-cured tobacco revenues	0.670%	(9.712)	−0.111%	(−1.605)
U.S. burley and Maryland tobacco revenues	−0.062%	(−0.587)	−0.206%	(−1.943)
U.S. flue-cured producers' rent		(11.832)	0.000	
U.S. burley producers' rent		(4.053)	0.000	
U.S. flue-cured lease rate	−6.025%		−0.404%	
U.S. burley lease rate	−5.591%		−0.744%	

[a] The quota increases are 1.903% and 1.218% for U.S. flue-cured and U.S. burley-Maryland tobaccos.

[b] Figures in parentheses are millions of U.S. dollars except for the price of U.S. tobacco.

[c] The relative changes in tariffs are −17.6% and −24.7% for imported oriental and flue-cured-burley tobaccos.

[d] Figures in parentheses are millions of U.S. dollars except for the price of imported tobacco.

tobacco exports offset the decrease in domestic demand. The lower prices of imported tobacco have an expansionary effect on cigarette production. However, this output effect does not offset the substitution effect in cigarette production induced by lower tariffs. The net impact on U.S. tobacco prices is negative. Despite lower tariffs, export revenues rise by

$6.9 million because of larger cigarette exports, but tax revenues decrease by $6 million. Tobacco producers' rents remain constant, since tobacco production is unchanged in this second scenario, and lease rates fall slightly because of lower U.S. tobacco prices.

Sensitivity analysis suggests that the results obtained in the two experiments are very robust. First, we account for the underproduction of quota that makes domestic supply price-responsive. Underproduction occurs on a county basis in Tennessee. We assume that production under quota has price responsiveness of 0.5 (for both flue-cured and burley). All qualitative results remain invariant. With the tariff experiment, producers' rent now falls slightly ($ − 0.141 million and $ − 0.117 million for flue-cured and burley) because supply of both tobacco types decreases too. Lease rates do not decrease as much with price-responsive supply (− 0.295% and − 0.367% for flue-cured and burley). Second, we investigate sensitivity to the size of the shocks. All tendencies are monotonic with the size of the price gap reductions. Finally, sensitivity analysis around the price elasticity of export markets reveals that tobacco product exports and export revenues increase substantially, with foreign markets being more price-responsive (export demand elasticities = − 50 instead of − 2.3). Under the quota reform, flatter export demand curves imply larger quota relaxations. When tobacco export demands become very inelastic (export demand elasticities = − 0.5), domestic producers of both tobaccos face declining revenues with either reform.

The first policy reform is preferable in terms of tax and export revenues and producer rents; it is essentially an expansionary policy for the domestic tobacco market. Yet quota lease rates drop considerably and tobacco trade partners are worse off. Trade partners would prefer the second policy option, since it induces more tobacco imports, although total export revenues would increase because of larger cigarette exports. Overall, these results are consistent with Grise's conjecture on the expansion of domestic production and exports as likely impacts on U.S. tobacco of a decrease in assistance.

CONCLUDING COMMENTS

The gist of this empirical exercise was to show the diversity and specificity of trade, tax, and welfare impacts associated with a given reduction in assistance to U.S. tobacco growers, thereby showing the critical importance of how the modeler quantifies distortions. The imperfect substitution between U.S. and foreign tobaccos and the distinct nature of the reform (supply management program versus trade barriers) were salient features of our approach. In the case of tobacco, policy analyses ignoring imperfect

substitution and supply controls would be extremely misleading. Thus, our results cast doubts on the adequacy of studies such as that of Roningen and Dixit (1989) to assess the impact of policy reforms on domestic agriculture. Tobacco is not an isolated case of limited relevance for policy analysis. Anderson (1985), in his study of import quotas in the U.S. cheese industry, and de Gorter and Meilke (1987), in their analysis of wheat trade policy in the EC, have stressed the necessity of differentiating products and policy interventions. Finally, using a multi-country model of the grain market, Whalley and Wigle (1988) show that an ad valorem representation of U.S. wheat support programs misrepresents their welfare and output effects because it ignores endogenous participation to set-aside programs.

As in Whalley and Wigle (1988) and Hertel (1989), this paper's results warn against using PSEs as price wedges or tariff equivalents of distortions. We suggest instead disaggregating the information embodied in the PSEs by types of intervention (tariffs, supply control, input subsidies, etc.) in modelling the distortions. Finally, partial equilibrium models should include manufacturing industries with strong backward linkages to the agricultural sector to estimate the impact of agricultural trade and domestic policy reforms on foreign exchange and tax revenues. Although often overlooked in partial equilibrium models, these linkages are important in agriculture [e.g., Shui et al. (1992) for cotton and textiles]. General equilibrium models capture both backward and forward linkages but are more data- and computation-intensive than their partial equilibrium counterparts (e.g., Hertel and Tsigas, 1988; Beghin and Karp, 1992).

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APPENDIX

Subscripts indicate the commodity (tobacco types or cigarettes) and superscripts denote the market (domestic, export, or total). The tobacco types are numbered from 1 to 4 for U.S. flue-cured, U.S. burley and Maryland, imported oriental, and imported flue-cured and burley, respectively. Percentage changes in cigarette total demand, $E(D_c^T)$, are:

$$E(D_c^T) = k_c^d \, E(D_c^d) + (1 - k_c^d) \, E(D_c^e) \tag{A1}$$

with domestic and export demands, D_c^d and D_c^e, and the domestic share of

total demand, k_c^d. Percentage changes in domestic and export demands are:

$$E(D_c^i) = \eta_c^i E(p_c^i) \qquad \text{for} \quad i = \text{d, e} \tag{A2}$$

with the uncompensated own-price elasticities of cigarette demand, η_c^d and η_c^e, the wholesale price of cigarettes, p^d, including excise taxes, TX_c; and with p_c^e, being the import unit cost for the rest of the world. Changes in cigarette production cost caused by changes in tobacco input prices are:

$$E(p_c^d) = \sum_{i=1}^{4} [\alpha_{t_i} E(p_{t_i})] \tag{A3}$$

with the share of tobacco i in the average cost of production, α_{t_i}. The subscript t_i refers to tobacco i ($i = 1, \ldots, 4$). The cigarette export price, p_c^e, is equal to the sum of the wholesale price, p_c^d, net of domestic excise tax, TX_c, and tariff rebates and the rest of the world's taxes and tariffs on its imports of U.S. cigarettes, TA_c^*:

$$p_c^e = p_c^d - TX_c + TA_c^* - 0.99\, TA_3\, AV_{t_3} - 0.99\, TA_4\, AV_{t_4} \tag{A4}$$

with AV_{t_i} being the average content of imported tobacco i per cigarette ($i = 3, 4$, imported oriental and imported flue-cured and burley); and with TA_i being the U.S. import tariff on tobacco i. The 0.99 coefficient reflects tariff rebates on foreign tobacco reexports. By first differentiating equation (A4) with respect to the domestic price P_c^d, and tariffs TA_3 and TA_4, and then by substituting equation (A3) in the differentiated equation, we obtain:

$$E(p_c^e) = \frac{\alpha_{t_1} E(p_{t_1}) + \alpha_{t_2} E(p_{t_2}) + 0.01\, s_{TA_3} \alpha_{t_3} E(TA_3) + 0.01\, s_{TA_4} \alpha_{t_4} E(TA_4)}{1 - \alpha_{TX_c} + \alpha_{TA_c^*} - 0.99 \alpha_{t_3} s_{TA_3} - 0.99 \alpha_{t_4} s_{TA_4}} \tag{A5}$$

with $\alpha_{TA_c^*}$ being the share (TA_c^*/p_c^d); and α_{TX} being the share (TX_c/p_c^d). Variables s_{TA_3} and s_{TA_4} are the shares of tariff in tobacco import unit costs (TA_i/P_{t_i}). Percentage changes in total U.S. tobacco demand are:

$$E(D_{t_i}^T) = k_{t_i} E(D_{t_i}^d) + (1 - k_{t_i}) E(D_{t_i}^e) \qquad \text{for} \quad i = 1, 2 \tag{A6}$$

The variables $D_{t_i}^T$, $D_{t_i}^d$, and $D_{t_i}^e$ are total, domestic, and export demands of domestic tobacco i; and k_{t_i} is the domestic share of total demand of tobacco i. Domestic demand for tobacco i is influenced by percentage changes in tobacco prices and cigarette output:

$$E(D_{t_i}^d) = \sum_{j=1}^{4} [\eta_{t_i t_j}^d E(P_{t_j})] + E(S_c) \qquad \text{for} \quad i = 1, \ldots, 4 \tag{A7}$$

where $\eta^{d}_{t_i t_j}$ is the compensated (constant output) demand elasticity for domestic tobacco i with respect to price of tobacco j; and S_c is the cigarette output. The elasticity of input demand with respect to output is equal to one, under the assumption of constant returns to scale. Changes in export demand for U.S. tobacco are:

$$E(D^{e}_{t_i}) = (1 - \alpha_{TA_i^*})\ \eta^{e}_{t_i t_i}\ E(P_{t_i}) \qquad \text{for} \quad i = 1, 2 \tag{A8}$$

with $\eta^{e}_{t_i t_i}$ denoting the own-price elasticity of tobacco export demand; $\alpha_{TA_i^*}$ is the share of foreign tariff on imports of U.S. tobacco i in the foreign price of that tobacco, or $TA_i^*/p_{t_i^*}$. Percentage changes in tobacco import unit cost are:

$$E(p_{t_j}) = s_{TA_j} E(TA_j) \qquad \text{for} \quad j = 3, 4 \tag{A9}$$

with TA_j denoting the tariff on imported tobacco j and s_{TA_j} being the tariff share in the unit import cost for tobacco j. Percentage changes in tax revenues are:

$$E(TAXREV) = r^{f}_{c} E(D^{d}_{c}) + r^{f}_{t_3}\left[E(D^{d}_{t_3}) + E(TA_3)\right] + r^{f}_{t_4}\left[E(D^{d}_{t_4}) + E(TA_4)\right] \tag{A10}$$

with r^{f}_{c}, $r^{f}_{t_3}$, and $r^{f}_{t_4}$ being the revenue shares of cigarette taxes, and tariffs from tobacco imports. The percentage change in net export revenues, XR, is:

$$\begin{aligned} E(XR) = {} & r^{e}_{c}\left[E(D^{e}_{c}) + (1 - \alpha_{TA^*_c})\, E(p^{e}_{c})\right] \\ & + \sum_{i=1}^{2} r^{e}_{t_i}\left[E(D^{e}_{t_i}) + (1 - \alpha_{TA_i^*})\, E(p_{t_i})\right] \\ & + \sum_{j=3}^{4} r^{e}_{t_j}\left[E(D^{d}_{t_j}) + s_{TA_j} E(TA_j)\right] \end{aligned} \tag{A11}$$

with r^{e}_{j} being the export revenue share of market j, and $r^{e}_{t_3}$, $r^{e}_{t_4}$ being negative. The change in lease rate (per unit of output), l_{t_i}, is:

$$E(l_{t_i}) = \frac{l_{t_i}}{\alpha_{l_i}} E(p_{t_i}) - \frac{(1 - \alpha_{l_i})}{\epsilon_{t_i} \alpha_{l_i}} E(D^{T}_{t_i}) \tag{A12}$$

with α_{l_i} denoting the cost share of the lease rate and ϵ_{t_i} being the elasticity of supply underlying the marginal cost. The producers' rent increment in dollars, $d(RENT_{t_i})$ is expressed in terms of percent changes in output and marginal cost, MC_{t_i}:

$$d(RENT_{t_i}) = D^{T}_{t_i}\ d\,MC_{t_i}\left(1 + 0.5\, E(D^{T}_{t_i})\right) \tag{A13}$$

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