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# Phytosanitary Regulation and Agricultural Flows: Tobacco Inputs and Cigarettes Outputs

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This paper examines the effects of the use of increasingly-popular phytosanitary regulations on production costs, and output and factor trade flows. The case addressed is that of the European regulation of maximum chemical residues in cigarettes manufactured with tobacco containing maleic hydrazide. The paper presents simulations of the effects of tightening the EU regulation on the tobacco growing and manufacturing industries. The analysis focusses on input/output market linkages and on the substitution away from the residue-contaminated U.S. input to residue-free non-U.S. inputs. This induced substitution results in higher costs, lower quantity supplied of the final product, and higher prices for U.S. cigarettes in Europe. Cross-price effects lead to higher quantities of EU cigarettes sold and a corresponding increase in the use of all inputs, including U.S. tobacco. When the U.S. tobacco price is allowed to fall, direct price effects stimulate the EU derived demand for U.S. tobacco. Although the regulation is protectionist in the output market, it leads to increased EU imports of the residue-contaminated input. When the price of U.S. tobacco adjusts, the regulation is actually antiprotective for EU growers. The regulation also indirectly influences production practices of U.S. tobacco growers and leads to lower levels of MH residues on U.S. leaf.

The importance of understanding the effects on trade flows due to sanitary and phytosanitary regulations has grown in recent years as the number of these non-tariff barriers have increased while the number and level of tariffs have declined. The translation of environmental and product safety concerns into regulation has occurred for two central reasons (Kinsey and Houck): in part there has been an increasing demand for environmental and health protection associated with rising incomes; and scientific advances have improved the ability to detect threats to safety (Sheldon and von Witzke). Yet the suppression of trade protectionism is also a widely held objective and there is an increasing anxiety over trade effects as provisions for environmental issues and food safety have been added to the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA) (e.g., USDA, 1994). These provisions allow for the establishment of rules ostensibly designed to protect consumers and the en-

vironment, though they would also influence trade flows.

As a case in point, some members of the European Union (Germany, Italy, and Spain) presently restrict to 80 parts per million the level of maleic hydrazide (MH) in domestic and foreign cigarettes (Yelverton). This affects almost exclusively U.S. tobacco, which taken alone exceeds this limit on average (Sheets *et al.*). MH is a systemic cell-division inhibitor that raises tobacco leaf quality through the control of nutrient depletion due to lateral branching. Mechanization of U.S. production has made substitutes to MH, such as hand removal and use of fatty alcohols, relatively less profitable. Future harmonization or expanded adoption of EU phytosanitary regulations, which would amplify the trade effect of MH restrictions, appear to be legal under GATT (e.g., GATT Secretariat) and generally in the spirit of other international agreements, such as NAFTA (Forsythe and Lynch). MH restrictions do not explicitly discriminate between domestic and foreign producers, and they are transparent with respect to their scientific merit and their technical measures. Nevertheless, the suspicion that this regulation is a trade barrier rather than a safety measure is enhanced by conclusions of U.S. government consumer-safety investigations that, with usual pro-

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duction methods, no limit on MH residues is necessary (USDA, 1979).

Maleic hydrazide restrictions make a particularly interesting case in the study of the influence of phytosanitary regulations on agricultural trade flows: the chemical is associated only with an imported input that has close domestic and foreign substitutes, but the regulation and monitoring are applied to an imported and domestically-produced output; *and* both inputs and outputs are traded. Furthermore, most U.S. tobacco is grown under a government-sponsored cartel raising prices by limiting output. This issue can be cast in the broader context of minimum quality standards in international trade. Although the standards are nontariff trade barriers their welfare effects can be ambiguous because terms-of-trade effects can increase welfare (Chambers and Pick). Hence empirical investigation of the impact of the standards is important to determine losers and gainers. One addition to the literature made here is elucidation of a specific case of quality standards: the EU regulation of maleic hydrazide residue on tobacco products. The analysis also fills in a gap in the literature by addressing the effect of an output standard on derived demand.

The MH case provides an example of the importance of taking into account the interdependence between agriculture production and manufacturing. In 1991, U.S. tobacco shipments to Europe were over 26 percent of domestic production, over 40 percent of its total exports, comprising 105 and 64 million pounds of flue-cured and burley leaf. Almost 28 percent (49,617 million pieces) of U.S. cigarette exports went to the EU representing 26 million pounds of flue-cured and 22 million pounds of burley (Creek, Capehart, and Grise). This implies that 77 percent of U.S. tobacco going to Europe is imported as unmanufactured leaf and 23 percent arrives in the form of cigarettes. At least two derived demands—for the residue-contaminated and residue-free inputs—and two supply curves—the domestically and foreign produced outputs—would be affected by regulation. Moreover, at current usage rates an EU-wide adoption of the 80 ppm standard would not directly affect the demand for U.S. unmanufactured tobacco imports. It would, however, affect cigarette imports because of compliance costs faced by U.S. manufacturers, who use a greater proportion of U.S. leaf; and thus it would indirectly increase EU aggregate tobacco leaf demand.

This paper presents simulations of the effects of tightening the EU regulation on the tobacco growing and manufacturing industries by analyzing its influence on production costs, factor demands, and

trade flows. The paper stresses two contributions: to the analysis of trade effects of phytosanitary rules regarding chemical residues generally, and to the understanding of the tobacco case in particular. The analysis focusses on input/output market linkages and on the substitution away from the residue-contaminated U.S. input to residue-free non-U.S. inputs. This induced substitution results in higher costs, lower quantity supplied of the final product, and higher prices for U.S. cigarettes in Europe.

An important point to emphasize is that cross-price effects lead to higher quantities of EU cigarettes sold and a corresponding increase in the use of all inputs, including U.S. tobacco. In addition, when the U.S. tobacco price is allowed to fall direct price effects stimulate the EU derived demand for U.S. tobacco. These results imply that, although the regulation is protectionist in the output market, it leads to increased EU imports of the input which is the cause of the regulation in the first place. Furthermore, when the price of U.S. tobacco adjusts, the regulation is actually antiprotective for EU growers. The regulation also indirectly influences production practices of U.S. tobacco growers and leads to lower levels of MH residues on U.S. leaf.

The paper is organized as follows: The first section outlines the general effects of a residue regulation when the regulation is associated with a particular input having close substitutes. These effects can be separated into the effects on manufacturers of the final product and the effects on the suppliers of the input in question. The second section presents a model of tobacco trade and cigarette manufacture, and discusses its practical implementation by use of a displacement model of proportionate changes in endogenous variables due to shifts in exogenous variables. The third section gives the results of simulations and discusses their implications. The paper ends with a concluding section.

### **Modeling Residue Regulations**

Before turning to the analysis of the influence of a residue restriction, a brief discussion of tobacco manufacture is warranted. Cigarette production involves the blending of flue-cured, burley, and oriental tobacco types, establishing flavor characteristics. Within each major type there is also a range of quality correlated with production region. Desired blend characteristics can be achieved both by mixing types and by mixing qualities of a given type. Manufacturers differentiate blends by mixing leaf from different areas of the world. Beyond to-

bacco exports, cigarettes as a final product are also widely exported and compete in multi-product markets based on their price and flavoring characteristics.

U.S. manufacturers rely mainly on high quality U.S.-grown flue-cured and burley for blends, although recently there has been increased reliance on foreign-grown substitutes for U.S. leaf (Sumner and Alston). A notable import, without a close U.S.-grown substitute is oriental tobacco. Oriental tobacco from Greece, made up 9.6% of U.S. cigarette tobacco imports in 1990 (see Creek, Capehart, and Grise Table 183). EU flue-cured and burley on the other hand are not major U.S. imports. By contrast EU cigarette manufacturers import large amounts of U.S. tobacco. Recently subsidy reforms and relative price changes traceable to demand shifts have altered EU-grown tobacco quality (Ferrara), possibly affecting future U.S. tobacco demand.

The introduction of a residue regulation associated with a particular input gives incentives to manufacturers to substitute away from inputs with high residue levels to those with lower or no residues. This substitution moves manufacturers away from the cost minimizing choice of inputs in the absence of the regulation, and unit costs increase under compliance.

This result can be seen by examining in Figure 1 the unit isoquant of constant returns to scale production using two essential inputs,  $T1$  and  $T2$ , in a blending process. The horizontal axis measures the amount of use of the residue-contaminated input,  $T1$ , which has a fixed residue level of  $\gamma$  ppm (this is generalized to endogenous residues below), and the vertical axis measures a residue-free input,  $T2$ . The total residue level in the final product is given

Figure 1: Unit Isoquant for the Tobacco Blend

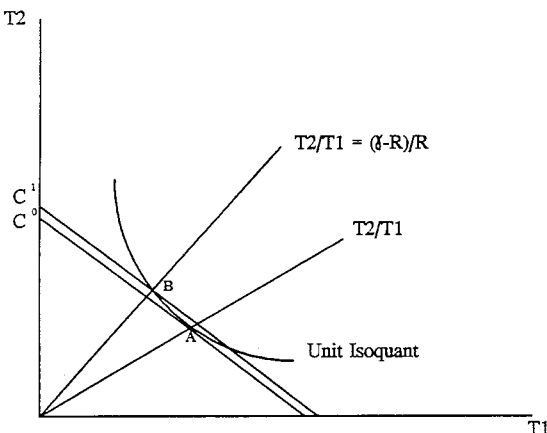


Figure 1. Unit Isoquant for the Tobacco Blend

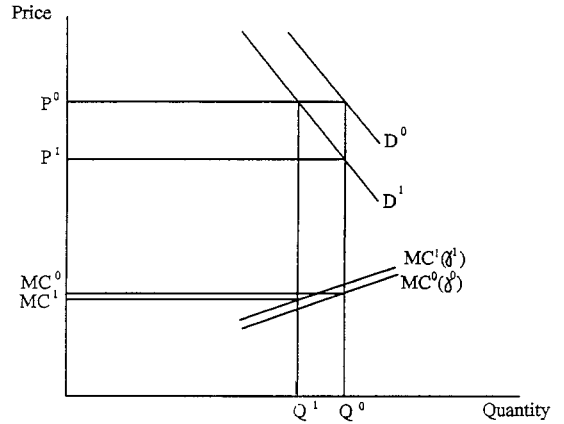


Figure 2. U.S. Flue-cured Tobacco Market

by the amount of the chemical relative to the use of both inputs, i.e.,  $(\gamma T1)/(T1 + T2)$ . The ray passing through point A is the initial expansion path without regulation. The ray passing through point B is the expansion path resulting from compliance with a regulation of no more than  $R$  ppm. Compliance leads to a unit cost increase from  $C^0$  to  $C^1$  and clearly this increase depends upon the substitutability of the inputs. With perfect substitutes, compliance is merely a move along a linear isoquant implying no cost increases. With fixed proportions the regulation could not be met, costs of continued production would be infinite, and the manufacturer would retire from the regulated market.

For cigarette manufacturers producing a tobacco blend, either of these extremes is unlikely. Manufacturers place a premium on maintaining blend characteristics (Beghin and Chang) suggesting imperfect input substitutability. Beghin and Chang, and Sumner and Alston have shown that tobaccos are not combined in fixed proportions. The closer an industry is to fixed proportions the more costly is regulation compliance and the more likely regulation is to affect the price and quantity demanded of the final product.

The effect on U.S. tobacco growers is complicated by an output-limiting, price-enhancing government-sponsored cartel. Figure 2 describes the possible effects of a binding residue regulation on the market for U.S. grown tobacco. Total demand is initially represented by the demand curve  $D^0$  and supply by the marginal cost curve  $MC^0(\gamma^0)$  conditioned on residue level  $\gamma^0$ . The quota level is set at  $Q^0$  such that marginal cost is  $MC^0$  and the market-clearing price is  $P^0$ . The quota lease rate ( $L$ ) is equal to the difference between the market price and the marginal cost of production for the given output level (i.e.  $L^0 = P^0 - MC^0$ ).

**Table 1. Equations of the Model**

Supply and Demand for each cigarette:*	$Q_C^i = S^i(P_C^i, P_{T1}^i, P_{T2}^i, P_K^i, R)$ $= D_C^i(P_C^i, P_C^i, P_O, Y)$
U.S. tobacco market equilibrium condition	$T1^E + T1^U + T1^O = Q_{T1}$
The regulatory restriction:	$R \geq \frac{\gamma(T1^i)}{(T1^1 + T2^1)}$
Derived demands for factors of production:**	$X_j^i(P_C^i, P_{T1}^i, P_{T2}^i, P_K^i, R) = J^i$
The quota lease rate:	$L = P_{T1} - MC(Q_{T1}, \gamma)$
The level of MH residues:	$\gamma = F(Q_{T1}, L)$

\*where  $i = E$ , for Europe, and  $U$ , for the United States.  
\*\*where  $J$  is U.S. tobacco  $T1$ , other tobaccos  $T2$ , and other non-tobacco inputs  $K$ .

An EU residue regulation shifts the demand to curve  $D^1$ . Two cases are considered: one maintains the program price constant; and the other maintains a constant quota level. To maintain the initial price, production limits are reduced to  $Q^1$ . Growers adjust their production practices in response to the new output level, resulting in a new residue level of  $\gamma^1$  and a new marginal cost curve,  $MC^1(\gamma^1)$ . An altered marginal cost of production  $MC^1$  determines a new quota lease rate,  $L^1 = P^0 - MC^1$ . Figure 2 also shows the effects of allowing the price to adjust to the new demand conditions while quota levels remain constant. The market price must fall to  $P^1$ . Because quota levels do not change, there is no shift in marginal costs, although the lease rate decreases to  $L^2 = P^1 - MC^0$ .

To generalize this discussion, consider the following algebraic model, summarized in Table 1, which allows a parametric approximation of international tobacco and cigarette markets. Let variable  $T1$  represent U.S. tobacco and the variable  $T2$  represent other residue-free tobaccos used by both EU and U.S. cigarette manufacturers producing outputs  $Q_C^i$  (where  $i = E, U$  representing Europe and the United States). The EU and U.S. cigarette supplies,  $S_C^i$ , depend on their own-price,  $P_C^i$  the price of U.S. tobacco inputs,  $P_{T1}^i$ , the composite price of non-U.S. tobacco input  $P_{T2}^i$ , the price of non-tobacco inputs  $P_K^i$ , and the maximum allowable residue level  $R$  for the cigarette blends consumed in Europe. The demands,  $D_C^i$ , for the two types of cigarettes depend on the own-price,  $P_C^i$ ,

<sup>1</sup> The use of 10 percent cost share is the result of discussions with industry experts and the examination of cost shares used by Sumner and Alston and Beghin and Chang.

**Table 2. Endogenous Variables**

$T1^{i*}$	U.S. tobacco used by EU and U.S. manufacturers in cigarettes for sale in Europe
$T1^T$	Total amount of U.S. tobacco used in cigarettes for sale in Europe
$T1^O$	Total amount of U.S. tobacco demanded by others than those selling cigarettes in Europe
$P_{T1}^i$	The price of U.S. tobacco for EU and U.S. manufacturers (fixed quota case)
$T2^i$	non-U.S. tobacco used by EU and U.S. manufacturers in cigarettes for sale in Europe
$Z^i$	The quantity of the tobacco blend used by EU and U.S. manufacturers
$P_C^j$	The per unit value of the EU and U.S. tobacco blends
$Q_C^j$	The quantity of EU and U.S. produced cigarettes for sale in Europe
$P_C^i$	The price of EU and U.S. cigarettes in Europe
$\gamma$	The MH residue level on U.S., tobacco
$L$	The quota lease rate in the U.S.

\*where  $i = E, U$

the price of the competing cigarette,  $P_C^j$ , prices of other goods  $P_O$ , and consumers' disposable income,  $Y$ .

The total amount of U.S. tobacco for the manufacture of cigarettes consumed in Europe equals the demand of EU and U.S. manufacturers (i.e.  $T1^E + T1^U$ ). In equilibrium, the total U.S. tobacco supply, which equals the established quota level ( $Q_{T1}$ ), is the sum of that consumed for EU-destined cigarettes and the amount demanded by other users of U.S. tobacco ( $T1^O$ ). Endogenous and exogenous variables described above are listed and defined in Tables 2 and 3. In the simulations which follow, we consider two cases of adjustment of the U.S. tobacco program. In the first case, the price of U.S. tobacco is held constant by adjustments to the quota levels. In the second case, the quota is held fixed and the price of U.S. tobacco adjusts. These two cases represent two polar cases of possible policy response to decreases in demand. Any intermediate policy that adjusts both quota and price would be bounded by the two cases described.

**Table 3. Exogenous Variables**

$R$	The maximum allowable MH residue level on the tobacco blend of cigarettes
$P_{T1}^{i*}$	The EU and U.S. prices of U.S. tobacco (fixed price case)
$P_{T2}^i$	The EU and U.S. prices of non-U.S. tobacco
$K^i$	EU and U.S. aggregates of non-tobacco inputs used in cigarette production
$P_K^i$	A price index for the aggregate non-tobacco inputs

\*where  $i = E, U$ .

**Table 4. Parameters, their Definitions, and Initial Values for the Simulation**

$T1^E/T1^T$	The share of U.S. tobacco going to Europe as unmanufactured leaf	77%
$T1^U/T1^T$	The share of U.S. tobacco going to Europe in U.S. cigarettes	23%
$\eta_C^U$	The EU elasticity of demand for the U.S. produced cigarettes	-0.85
$\eta_C^{UE}$	The cross-price elasticity of the U.S. cigarettes	0.20
$\eta_Z^U$	The U.S. elasticity of demand for the tobacco blend	-2.0
$\eta_{T1}^U$	The U.S. elasticity of demand for U.S. tobacco used in export cigarettes	-1.0
$\eta_C^E$	The EU elasticity of demand for the EU produced cigarettes	-0.60
$\eta_C^{EU}$	The cross-price elasticity of the EU cigarettes	0.20
$\eta_Z^E$	The EU elasticity of demand for the tobacco blend	-2.0
$\eta_{T1}^E$	The EU elasticity of demand for U.S. tobacco used in cigarettes	-3.0
$\eta_{T1}^O$	The weighted average of the elasticity of demand for U.S. tobacco by other users	-1.8
$\alpha_1^U$	The cost share of U.S. tobacco in U.S. cigarette tobacco blends	0.70
$\omega_1^U$	The marginal product of U.S. tobacco in U.S. cigarette tobacco blends	0.75
$\alpha_2^U$	The cost share of non-U.S. tobacco in U.S. cigarette tobacco blends	0.30
$\omega_2^U$	The marginal product of non-U.S. tobacco in U.S. cigarette tobacco blends	0.25
$\alpha_1^E$	The cost share of U.S. tobacco in EU cigarette tobacco blends	0.20
$\omega_1^E$	The marginal product of U.S. tobacco in EU cigarette tobacco blends	0.20
$\alpha_2^E$	The cost share of non-U.S. tobacco in EU cigarette tobacco blends	0.80
$\omega_2^E$	The marginal product of non-U.S. tobacco in EU cigarette tobacco blends	0.80
$\alpha_2^U - \omega_2^U$	The difference in the restricted cost share and the input contribution	0.05
$\alpha_Z^{iE}$	The cost share of the tobacco blend in the EU and U.S. cigarettes	0.10
$\delta_{T1}^E$	The ratio of the U.S. market price for tobacco to the EU price inclusive of tariffs	0.94
$\beta_{MM}$	The change in marginal cost of MH residues as MH residue increases	$1 * 10^{-10}$
$\beta_{TM}$	The change in marginal cost of output as MH residue increases	$-1 * 10^{-10}$
$\beta_{TT}$	The change in marginal cost of output as output increases	$1.48 * 10^{-8}$
$\epsilon_{T1}^U$	The elasticity of supply of U.S. tobacco growers at current quota levels	10

\*where  $i = E, U$ .

### Simulations of Tobacco and Cigarette Trade

Initial parameters to calibrate the model representing current conditions derive from previously-estimated demand- and production-related elasticities, calculated cost shares, and consensus expert opinion. From this basis, we simulate the effects of a 10 percent decrease in the allowable residue rate limited by the EU phytosanitary MH regulation. We also carry out sensitivity analyses by varying price elasticities and cost parameters and identifying their influence on the effects of decreasing the allowable residue rate. These results are summarized at the end of the section.

For the simulations the cost share of the tobacco blend in cigarettes is taken to be 10 percent for both EU and U.S. manufacturers.<sup>1</sup> The derived demand elasticity of the tobacco blends is set at -2.0 also for both manufacturers, and this parameter is increased in the sensitivity analysis. The demand elasticity for U.S. cigarettes is initially taken to be at -0.85, and for EU cigarettes -0.60. The cross-price elasticity of both EU and

U.S. cigarettes is set at 0.20.<sup>2</sup> The supply elasticity of U.S. tobacco is thought to be relatively large at current quota levels, and following Babcock and Foster, it is set at 10. Finally, an estimate of the divergence between the marginal rate of technical substitution and the price ratios of the tobacco inputs of the tobacco blend, associated with the forced substitution away from the inputs containing residues, is set at 0.05 and increased for the simulations. Table 4 lists the parameters, a brief definition, and their original values.

Over the period 1987 to 1991, on average the MH residue regulation of 80 ppm is nonbinding for EU producers. For example, U.S. flue-cured and

<sup>2</sup> Brown estimates the European demand for U.S. cigarettes to be -0.84. This estimate is lower than other estimates used in the literature (e.g. Sumner and Alston and Sumner and Wohlgenant) and thus the estimate of -0.85 is increased in absolute value during the simulations. The demand elasticity of the EU cigarette is set at -0.5 which is a mid-range estimate of many cigarette demand elasticities reported in Brown. Although, Brown finds the cross-price elasticity between U.S. and EU cigarette to be not statistically different from zero, it is initially set here at the low level of 0.2.

burley made up only 26 percent of tobacco used by German manufacturers. Given an average residue level of 145 ppm, which errs on the high side, the U.S. share results in less than 38 ppm MH residue for the whole tobacco blend, half of the regulated limit. Average use of U.S. tobacco over the same five years was 17 percent for Dutch manufacturers, 6 percent for Italian, and 6 percent for British. At these usage rates an EU-wide adoption of the 80 ppm regulation with not affect EU demand for U.S. tobacco. Even at an exaggerated rate of 25 percent of U.S. tobacco in EU blends, the average MH residues would have to be 320 ppm to make the limit binding, 50 percent higher than the highest residue crop average recorded.<sup>3</sup> For U.S. manufacturers, tobacco blends contain approximately 35 percent U.S. grown flue-cured and 30 percent U.S. grown burley.<sup>4</sup> At the 1991 residue levels of 145 ppm on flue-cured and 100 ppm on burley, the MH residue for U.S. manufactured cigarettes is approximately 81 ppm, making the EU standard slightly binding.<sup>5</sup>

In order to simulate the effect of the MH regulation on the trade flows of tobacco and cigarettes, further structure is added to the general model outlined above. Blended tobacco is taken to be an intermediate output in the production of cigarettes subject to a constant elasticity of substitution (CES) production process using residue-contaminated and residue-free inputs. The final cigarette output is also a CES process using the tobacco blend input and a composite (non-tobacco) input, and exhibiting constant returns to scale, assuring zero profits.<sup>6</sup>

<sup>3</sup> In 1987, the year of highest MH residues on U.S. flue-cured, the weighted average MH residues at moisture levels consistent with cigarette use were 231 ppm (Sheets *et al.*).

<sup>4</sup> The actual amount of tobacco types used in cigarette blends is not often revealed by cigarette manufacturers. Brown states that 60 percent of tobacco in U.S. produced cigarettes is domestic, while Sumner and Alston use a domestic tobacco content of 70 percent. In recent years, the domestic share has been 66 percent in 1991 and 55 percent in 1993. The 65 percent domestic use given here is in line with other estimates, although the use of domestic tobacco across U.S. manufacturers may vary.

<sup>5</sup> Tobacco use rates cited in the text are before a 1993 domestic content requirement of 75 percent for U.S. cigarettes (Zaini). This requirement has been ruled inconsistent with U.S. GATT commitments and politically unpopular with the incoming 104<sup>th</sup> Congress. The content requirement would increase the probability of U.S. manufacturers failing to meet the MH residue regulation when using U.S. tobacco and ignoring their MH residues. Because MH residues vary across areas within the United States, U.S. manufacturers might still meet the content requirement and satisfy the MH residue regulation, although costs would increase as manufacturers must find ways to identify the low residue leaf and keep this separate for use in export cigarettes where the MH regulations exist.

<sup>6</sup> The evidence on competition in the cigarette industry is mixed. Sullivan and Sumner find evidence of price-taking behavior. Appelbaum and more recently Tremblay and Tremblay find evidence of market power. Market power can easily be accommodated in our model by

Due to their use of a relatively high proportion of residue-free tobacco, in the fixed price scenario, EU manufacturers are affected only through the cross-price elasticity of EU cigarette demand. As the U.S. cigarette price increases due to compliance with a stricter MH regulation, the demand for the EU cigarette increases as well. Given constant returns to scale, EU manufacturers meet this demand by increasing output and inputs in equal proportions. Per unit production costs and the EU cigarette price remain unchanged. For U.S. manufacturers, however, costs increase as input combinations change to meet stricter residue requirements. In the fixed quota scenario, the price of U.S. tobacco falls which stimulates the EU use of U.S. tobacco and decreases the price of EU cigarettes leading to an additional feedback effect on the demand for U.S. cigarettes and a negative substitution effect on EU grown tobacco.

Table 5 presents the algebraic representations of the percentage changes of all the endogenous variables given some percentage decrease, ER, in the regulated MH level.<sup>7</sup> Table 6 presents the numerical results of simulating a 10 percent decrease in the MH constraint for endogenous variables.

We first discuss the results for the fixed price scenario (column 1 of table 6). The results show that an EU-wide adoption of more restrictive MH regulations could lower the demand for U.S. tobacco significantly. In the fixed price scenario, U.S. tobacco production declines to maintain U.S. price. However, a 10 percent decline in the regulated level, from 80 ppm to 72 ppm, is still non-binding for EU cigarette manufacturers. The regulation, which only directly affects U.S. manufacturers, results in increases in EU cigarettes sold. U.S. cigarette sales to Europe decline as prices rise with increases in costs associated with moving to blends that contain greater proportions of non-U.S. tobaccos. An indirect or second-round effect is that the use of U.S. tobacco by EU manufacturers *increases* by 0.02 percent, offsetting in part the decrease in U.S. tobacco use by U.S. manufacturers. This increase is in the same percentage as the sales of EU cigarettes, owing to the CRS production specification. The total amount of U.S. tobacco going to Europe decreases by 1.6 percent.

For U.S. cigarette manufacturers, the lower residue limit leads to a 7.1 percent decline in the use

assuming a fixed markup i.e., a constant elasticity of demand for cigarettes, that leads to the same relative change in cigarette price and marginal cost of cigarette production.

<sup>7</sup> The symbol E is used as the percentage change operator here and in the equations given in Table 5. Given the variable X, the notation  $EX = d(\ln X) = dX/X$ , i.e. the percentage change in X.

**Table 5. Percentage Change Equations for the Endogenous Variables**

Quantity of U.S. cigarettes sold:	$EQ_C^U = \left( \frac{\gamma}{\gamma - R} \right) (\eta_C^U \alpha_Z^U (\alpha_2^U - \omega_2^U)) (1 - C) ER, \text{ (fixed price)}$ $EQ_C^U = \left( \frac{\gamma}{\gamma - R} \right) [\eta_C^U \alpha_Z^U \alpha_1^U (X/Y) - \eta_C^U \alpha_Z^U \alpha_2^U + \eta_C^U \alpha_Z^U \omega_2^U$ $+ \eta_C^E \alpha_Z^E \alpha_1^E \delta_{T1}^E (X/Y)] ER, \text{ (fixed quota)}$
Price of U.S. cigarettes in Europe:	$EP_C^U = \left( \frac{\gamma}{\gamma - R} \right) [-\alpha_Z^U (\alpha_2^U - \omega_2^U)] (1 - C) ER, \text{ (fixed price)}$ $EP_C^U = \left( \frac{\gamma}{\gamma - R} \right) [\alpha_Z^U \alpha_1^U (X/Y) - \alpha_Z^U \alpha_2^U + \alpha_Z^U \omega_2^U] ER, \text{ (fixed quota)}$
Quantity of the U.S. tobacco blend:	$EZ^U = \left( \frac{\gamma}{\gamma - R} \right) [\eta_Z^U (\alpha_2^U - \omega_2^U) - \eta_C^U \alpha_Z^U (\alpha_2^U - \omega_2^U)] (1 - C) ER, \text{ (fixed price)}$ $E_Z^U = \left( \frac{\gamma}{\gamma - R} \right) [P - \omega_2^U] ER, \text{ (fixed quota)}$
Value of the U.S. tobacco blend:	$EP_Z^U = \left( \frac{\gamma}{\gamma - R} \right) [-\alpha_2^U - \omega_2^U] (1 - C) ER, \text{ (fixed price)}$ $EP_Z^U = \left( \frac{\gamma}{\gamma - R} \right) [\alpha_1^U (X/Y) - \alpha_2^U + \omega_2^U] ER, \text{ (fixed quota)}$
U.S. tobacco usage by U.S. manufacturers:*	$ET1^U = \left( \frac{\gamma}{\gamma - R} \right) (A^U) (1 - C) ER, \text{ (fixed price)}$ $ET1^U = \left( \frac{\gamma}{\gamma - R} \right) (P) ER, \text{ (fixed quota)}$
Price of U.S. tobacco in the United States:	$EP_{T1}^U = 0, \text{ (fixed price)}$ $EP_{T1}^U = \left( \frac{\gamma}{\gamma - R} \right) (X/Y) ER, \text{ (fixed quota)}$
Non-U.S. tobacco usage by U.S. manufacturers:	$ET2^U = \left( \frac{\gamma}{\gamma - R} \right) (-1 + A^U) (1 - C) ER, \text{ (fixed price)}$ $ET2^U = \left( \frac{\gamma}{\gamma - R} \right) (-1 + P) ER, \text{ (fixed quota)}$
U.S. quota lease rate:	$EL = -\left( \frac{\gamma}{L} \right) \left[ \frac{\beta_{TM}^2 - \beta_{TT} \beta_{MM}}{\beta_{TM}} \right] (C) ER, \text{ (fixed price)}$ $EL = \left( \frac{\gamma}{\gamma - R} \right) \left( \frac{P_{T1}^U X}{LY} \right) ER, \text{ (fixed quota)}$
U.S. MH residue level:	$E\gamma = (C) ER, \text{ (fixed price)}$ $E\gamma = 0, \text{ (fixed quota)}$
Quantity of EU cigarettes sold:	$EQ_C^E = \left( \frac{\gamma}{\gamma - R} \right) A^E (1 - C) ER, \text{ (fixed price)}$ $EQ_C^E = \left( \frac{\gamma}{\gamma - R} \right) [\eta_C^E \alpha_Z^E \alpha_1^E \delta_{T1}^E (X/Y) + \eta_C^E \alpha_Z^E \alpha_1^U (X/Y) - \eta_C^E \alpha_Z^E \alpha_2^U$ $+ \eta_C^E \alpha_Z^E \omega_2^U] ER, \text{ (fixed quota)}$
Price of U.S. cigarettes in Europe:	$EP_C^E = 0, \text{ (fixed price)}$ $EP_C^E = \left( \frac{\gamma}{\gamma - R} \right) [\alpha_Z^E \alpha_1^E \delta_{T1}^E (X/Y)] ER, \text{ (fixed quota)}$



**Table 5. Percentage Change Equations for the Endogenous Variables (continued)**

Quantity of the EU tobacco blend:	$EZ^E = \left(\frac{\gamma}{\gamma - R}\right) A^E (1 - C)ER$ , (fixed price)
	$EZ^E = \left(\frac{\gamma}{\gamma - R}\right) [\eta_2^E \alpha_1^E \delta_{T1}^E (X/Y)]ER$ , (fixed quota)
Value of the EU tobacco blend:	$EP_Z^E = 0$ , (fixed price)
	$EP_Z^E = \left(\frac{\gamma}{\gamma - R}\right) [\alpha_1^E \delta_{T1}^E (X/Y)]ER$ , (fixed quota)
U.S. tobacco usage by EU manufacturers:	$ET1^E = \left(\frac{\gamma}{\gamma - R}\right) A^E (1 - C)ER$ , (fixed price)
	$ET1^E = \left(\frac{\gamma}{\gamma - R}\right) [\eta_{T1}^E \delta_{T1}^E (X/Y)]ER + EZ^E$ , (fixed quota)
Price of U.S. tobacco in Europe:	$EP_{T1}^E = 0$ , (fixed price)
	$EP_{T1}^E = \left(\frac{\gamma}{\gamma - R}\right) [\delta_{T1}^E (X/Y)]ER$ , (fixed quota)
Non-U.S. tobacco usage by EU manufacturers:	$ET2^E = \left(\frac{\gamma}{\gamma - R}\right) A^E (1 - C)ER$ , (fixed price)
	$ET2^E = (1/\omega_2^E)EZ^E - (\omega_1^E/\omega_2^E)ET1^E$ , (fixed quota)
Total use of U.S. tobacco in cigarettes destined for Europe:	$ET1^T = \left(\frac{\gamma}{\gamma - R}\right) [(T1^U/T1^T)A^U + (T1^E/T1^T)A^E](1 - C)ER$ , (fixed price)
	$ET1^T = (T1^U/T1^T)ET1^U + (T1^E/T1^T)ET1^E$ , (fixed quota)
Use of U.S. tobacco by manufacturers producing for non-EU markets	$ET1^O = \left(\frac{\gamma}{\gamma - R}\right) [\eta_{T1}^O (X/Y)]ER$ , (fixed quota)
	$ET1^O = 0$ , (fixed price)

\*where

$$C = \frac{\left(\frac{\gamma}{\gamma - R}\right) (T1^U A^U + T1^E A^E)}{-\beta_{MM}\gamma + \left(\frac{\gamma}{\gamma - R}\right) (T1^U A^U + T1^E A^E)}$$

$$A^U = \omega_2^U - \eta_2^U (\alpha_2^U - \omega_2^U) - \eta_C^U \alpha_2^U (\alpha_2^U - \omega_2^U)$$

$$A^E = -\eta_C^{EU} \alpha_2^U (\alpha_2^U - \omega_2^U)$$

$$X = (T1^E/T1^U) \eta_C^{EU} \alpha_2^U (\alpha_2^U - \omega_2^U) - \omega_2^U + \eta_2^U (\alpha_2^U - \omega_2^U) + \eta_C^U \alpha_2^U (\alpha_2^U - \omega_2^U)$$

$$Y = W^U + (T1^E/T1^U) W^E + (T1^O/T1^U) \eta_{T1}^O$$

$$W^E = \eta_{T1}^E \delta_{T1}^E + \eta_2^E \alpha_1^E \delta_{T1}^E + \eta_C^E \alpha_2^E \alpha_1^E \delta_{T1}^E + \eta_C^{EU} \alpha_2^U \alpha_1^U$$

$$W^U = \eta_2^U \alpha_1^U + \eta_C^U \alpha_2^U \alpha_1^U + \eta_C^{UE} \alpha_2^E \alpha_1^E \delta_{T1}^E$$

and

$$P = -(T1^E/T1^U) W^E (X/Y) - (T1^O/T1^U) \eta_{T1}^O (X/Y) + (T1^E/T1^U) \eta_C^{EU} \alpha_2^U (\alpha_2^U - \omega_2^U).$$

of U.S. tobacco and a 12.9 percent increase in the use of non-U.S. tobacco. Lower output of U.S. cigarettes going to Europe results in higher product price, which in turn leads to an increase in EU cigarette production and the use by EU manufacturers of all inputs, including U.S. tobacco. Lower U.S. tobacco output indirectly leads to lower residue rates due to changes in production practices (a shift in the marginal cost of growing tobacco).

At the tobacco-growing level, the influence of stricter regulations on the residues of the U.S. tobacco input is negative. This is an indirect effect resulting from changes in the cartel production level. An 8 ppm (10% of the 80 ppm regulated level) decrease in allowable residues in EU cigarettes leads to a reduction of 3.51 ppm (2.8% of the 125 ppm actual level) in U.S. tobacco residues. The percentage change in U.S. quota lease rates

**Table 6. Results of Simulating a 10 Percent Decrease in the Regulated MH Level**

Variable	Price fixed, Quota adjusts	Price adjusts, Quota fixed
regulated residue level, $R$	-10	-10
U.S. cig. sold, $Q_C^U$	-0.0849	-0.0134
U.S. cig. price, $P_C^U$	0.0999	0.1205
U.S. tob. blend, $Z^U$	-2.0835	-2.5139
U.S. tob. blend price, $P_Z^U$	0.9993	1.2052
U.S. tob. used by U.S., $T1^U$	-7.0799	-9.4583
price of U.S. tob. in U.S., $P_{T1}^U$	0	-0.2624
non-U.S. tob. used, $T2^U$	12.906	18.319
actual residue level, $\gamma$	-2.8052	0
quota lease rate, $L$	0.00001	-1.1479
EU cig. sold, $Q_C^E$	0.0200	0.0271
EU cig. price, $P_C^E$	0	-0.0049
EU tob. blend, $Z^E$	0.0200	0.1257
EU tob. blend price, $P_Z^E$	0	-0.0493
U.S. tob. used by EU, $T1^E$	0.0200	0.8656
price of U.S. tob. in EU, $P_{T1}^E$	0	-0.2466
non-U.S. tob. used, $T2^E$	0.0200	-0.0593
U.S. tob. destined to EU, $T1^T$	-1.6129	-1.5088
U.S. tob. used by others, $T1^O$	0	0.4723

are positive but near zero. The high elasticity of tobacco supply at current quota levels implies little change in marginal costs as quotas are reduced to maintain a constant price.

Column 2 of Table 6 presents the results of the fixed quota scenario. With the fixed quota the price of U.S. tobacco adjusts downward because of the decrease in derived demand in U.S. cigarette manufacturing. This price decrease stimulates directly exports of U.S. tobacco to the EU, induces a decrease in EU cigarette prices, and therefore an expansion of EU cigarette sales. EU tobacco use is influenced by the positive scale effect and a negative substitution effect due to the lower U.S. tobacco price. Overall EU tobacco use decreases slightly; that is, the MH residue regulation has an *anti-protective* effect on EU tobacco producers. Other cigarette manufacturers (for non-EU final consumption) expand their use of U.S. tobacco which is stimulated by the lower U.S. price. This expansion did not arise in the adjustable quota scenario due to fixed price.

In U.S. cigarette manufacturing, the regulation induces a substitution away from U.S. tobacco which is larger in the fixed quota case because tobacco growers have no incentives to adjust the

residue level since they sell the same amount of tobacco. Therefore there is no virtuous feedback effect on the residue level as there was in the case of adjustable quota. Finally, the negative effect on the U.S. quota lease rate is much larger in this second scenario because the price of U.S. tobacco falls and the marginal cost of growing tobacco remains the same (no shift due to falling residue levels).

These results are robust over a range of elasticity and share values (Results of sensitivity analyses are available upon request.) There is little change in the results if the EU demand for the U.S. cigarette is more elastic, i.e., as  $\eta_C^U$  increases in absolute value. Not surprisingly, the only notable changes are in the quantity of U.S. cigarettes sold. Beyond the direct own-price effect, changes in demand elasticity might have little influence in simulating trade flows of inputs and outputs as residue regulations are altered. Note also that, beyond its influence on manufacturers constrained by a regulation, there are few changes associated with the elasticity of the derived demand for the tobacco blend, i.e.  $\eta_Z^U$ .

The regulation implies a divergence between the cost share of the tobacco input and its contribution

to the production process. This divergence, or wedge ( $\alpha_2^U - \omega_2^U$ ), depends negatively on the substitutability of the inputs. Low substitutability implies a larger movement away from the cost minimizing input bundle and a higher wedge ( $\alpha_2^U - \omega_2^U$ ). With the higher wedge, the use of the residue-contaminated input declines further, implying greater costs and larger price increases. This results in more EU manufactured cigarette sales and less U.S. cigarettes sales in Europe. When the wedge becomes extremely large, the use of the residue-free input finally decreases in response to the regulatory change because, as compliance costs rise, the decrease in total output level may offset the per unit increase in the uncontaminated input.

### Conclusion

In recent years the importance of sanitary and phytosanitary regulations has grown. This paper examined the trade-flow effects of a particular phytosanitary regulation: maximum chemical residue limits. When residue regulations are written in terms of an output but the residues are associated with an input, manufacturers alter production practices and substitute toward residue-free inputs. This induced substitution increases the production costs of manufacturers for whom the regulation is binding. The increased marginal costs lead to lower sales and higher prices.

If, as is often the case, manufacturers in different countries use the residue-contaminated and the residue-free inputs in different proportions, then an ostensibly health-oriented regulation may have non-tariff protectionist implications. Furthermore, when foreign manufacturers use relatively more of the residue-contaminated input than domestic manufacturers, a regulation leads to greater costs for the foreign producers, lowering output and raising prices to domestic consumers. In addition, when the foreign output and the domestic output are substitutes, sales of the domestic output increase. This describes the European maleic hydrazide regulation of U.S.-tobacco using cigarettes.

Residue regulations on output also effect the trade flow of inputs when the residue is associated exclusively with a particular factor. If the regulation is nonbinding for domestic manufacturers, as is the case for MH, then their use of the foreign input may increase despite the high residues associated with that input. These results imply that residue regulations that are protectionist in output markets can actually increase trade flows in input markets. Furthermore, we noted in the case of

fixed quota that the EU residue regulation could have a surprising antiprotective effect on EU growers. Finally, the quantity of non-U.S. tobacco consumed by U.S. manufacturers increases substantially both under fixed price and quota scenarios. In terms of output expansion, foreign suppliers of tobacco in U.S. cigarette manufacturing appear to be the largest and unexpected gainers from the EU residue regulation.

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