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Policy Implications of the Entry of Black Sigatoka (*Mycosphaerella fijiensis*) into Puerto Rico

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ABSTRACT.

Plantains and bananas are the principal crops in Puerto Rico, with the 2004 crop valued at US $89.8 million, representing 29 percent of the total annual Gross Agricultural Crops Income (GACI). After many years of being free of black sigatoka, the disease was detected in Puerto Rico in August 2004. The disease, which is caused by the fungus Mycosphaerella fijiensis, affects plantains and bananas and can reduce yields by as much as 90 percent. Government agencies have been funding research and assisting growers with the cost of treating the disease, but budgetary constraints may force the government to substantially scale back on funding these programs. The presence of the disease and the fact that eradication is highly improbable has also raised concerns over whether the current trade policy that restricts, the importation of plantains and bananas is no longer warranted. Consequently, this paper addresses two questions:

1. Should the government continue to subsidize the cost of treating the disease while maintaining strict prohibitions on plantain and banana imports? 2. Should the government remove the prohibitions on plantain and banana imports while still providing assistance to growers to treat the disease? The research utilizes an Equilibrium Displacement Model (EDM) to assess the effects of the proposed policy changes on plantain and banana prices, production, consumption, and revenue and welfare.

The results suggest that it make sense for the government to continue to assist growers with treating the disease. The results also suggest that the modest gains to be made from opening of the market to imports of these commodities might not be sufficient to outweigh the potential losses that could arise from inadvertently introducing other invasive pests and diseases such a Moko disease and Papaya Fruit Fly which are sometimes transmitted via banana imports and can cause serious damage to the agriculture and ornamental industries.

KEYWORDS: invasive species, equilibrium displacement model, black sigatoka (*Mycosphaerella fijiensis*)

INTRODUCTION

The plantain and banana commodities are the principal crops in Puerto Rico. In 2004, the Agricultural Sector in Puerto Rico reported an annual Gross Agricultural Income (GAI) at the farm level of $803.0 million (Puerto Rico Department of Agriculture (DAPR, 2005). At $89.8 million, plantains and bananas represent approximately one-third of the total crop GAI. The gross income generated from plantain and banana production was $62.1 million and $27.7 million, respectively. In 2002, the Census of

Agriculture reported 6,340 plantain farms, covering 25,582 "cuerdas" (1 acre = 0.97 "cuerda"), and 3,958 banana farms, covering 11,071 "cuerdas." Plantains are cultivated on 35.9 percent of the total farms of the island and bananas are cultivated on 22.4 percent.

Although plantains and bananas are grown throughout the island, their main production areas are located in the mountain regions in close proximity to high population areas. In the central mountain regions, plantains and bananas are intercropped with coffee, where they provide shade for the coffee plants and most importantly a steady source of income for growers during the early stages of coffee production. Because the mountain regions are the main water sources for the island, they have high humidity conditions that are very conducive to the spread of the black sigatoka disease (discussed below). In contrast, the south coastal region has dry weather conditions.

Plantains and bananas constitute a major part of the Puerto Rican cultural diet. Between 1995 and 2004, total plantain consumption increased from 73,920 tons to 118,907 tons, and per capita consumption increased from 39.7 pounds to 60.9 pounds (Figure 1). In the case of bananas, consumption decreased slightly over the corresponding period from 43,400 tons to 41,465 tons, and per capita consumption decreased from 23.3 to 20.1 pounds (Figure 2). The relatively high per capita consumption of plantains as compared to other starchy foods is a common feature among Latin American and Caribbean countries where plantain and green banana consumption features prominently in the national diets.

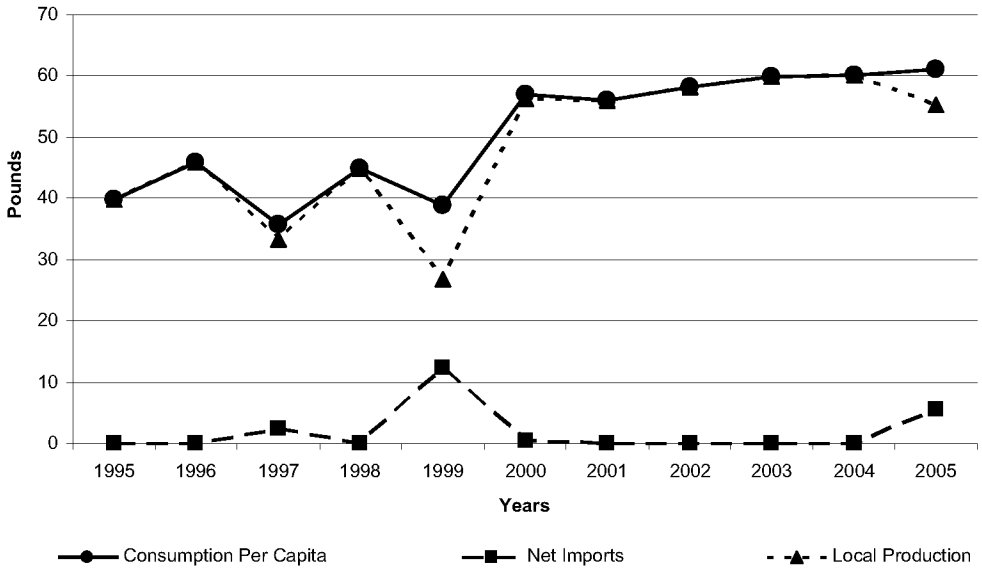

Figure 1. Plantain: Per Capita Consumption, Imports, and Local Production, 1995-2005

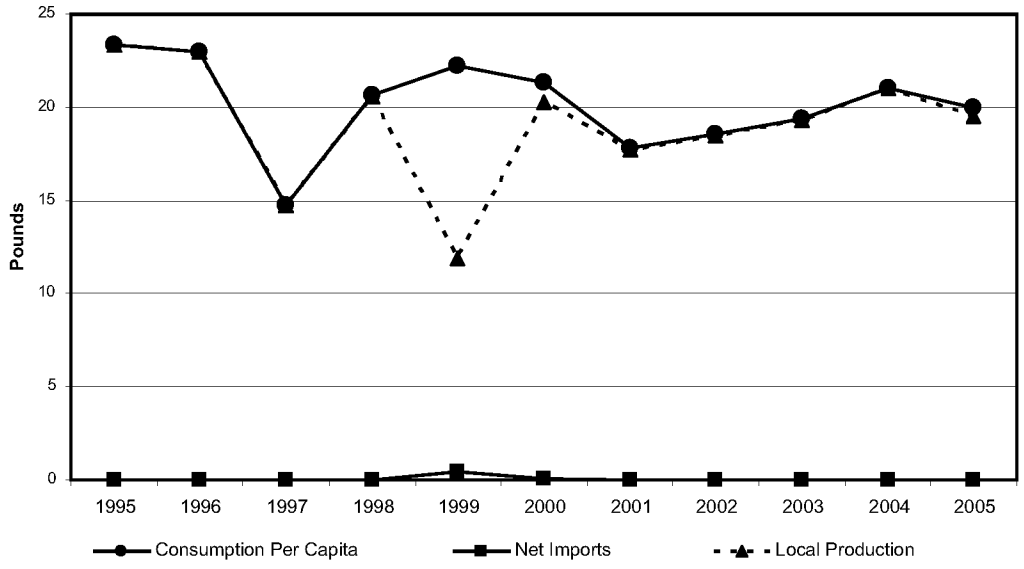

Figure 2. Bananas: Per Capita Consumption, Imports, and Local Production, 1995-2005

Plantain consumption increases with population growth, product availability, and the consumer preferences for ethnic dishes. Outside-of-home consumption of plantains has increased because of restaurants and fast-food places including them on their menus. In Puerto Rico, for example, "mofongo" (a ball of fried green plantain mashed with fried pork rinds and seasoned with thickened stock, garlic, and other condiments) is a favorite ethnic dish on the menus of restaurants, including those in the tourist areas. Moreover, technological advances have greatly facilitated the processing of various plantain and banana products. Between 1990 and 2006, plantain per capita consumption increased while other starchy crops, such as sweet potato, tannier, and taro, decreased (Departamento de Agricultura de Puerto Rico, 2007). This was due to changes in consumer preferences (Cortés, 2006).

As can be seen from Figures 1 and 2, the domestic market for plantains and green bananas is currently supplied entirely by domestic producers as a result of phytosanitary restrictions on imports of such commodities. Imports are only allowed in the years when domestic production is interrupted by hurricanes. When this occurs, the Department of Agriculture in Puerto Rico issues licenses to a number of importers to source the products from areas of countries certified to be free of black sigatoka and moko disease (*Ralstonia solanacearum*). The importers sell to the domestic retailers and processors. On the few occasions when the country must import these commodities, they are sourced mainly from the Dominican Republic, Venezuela, and Ecuador. As mentioned earlier, in light of confirmation of the disease in Puerto Rico, there is a growing debate as to whether trade restrictions should be lifted to supply the local market if production decreases significantly due to the disease.

Black Sigatoka Disease in Puerto Rico

Black sigatoka is considered worldwide as the most devastating disease of plantains and bananas. The disease, which was first reported in Sigatoka Valley in Fiji in 1963, is known to exist in almost every region around the globe where banana is cultivated. Within the Western Hemisphere, it is established in Honduras (1972), Belize (1975), Guatemala (1977), Cuba (1990), Venezuela (1991), Peru (1994), Jamaica (1995), the Dominican Republic (1996), Florida in the United States (1998), and Trinidad and Tobago (2003). In August 2004, the fungus was detected in Añasco, Puerto Rico, a municipality in the western part of the island. By December 2005, it had been identified in 25 municipalities (32.1%) of the island.

The disease, which is also known as black leaf streak, is a pathogenic fungus that significantly reduces leaf area and results in yield loss and premature fruit ripening. Severe infestation has been reported to result in an 80 to 100 percent yield reduction (Orozco, 1998). Black sigatoka is more damaging and difficult to control than the related yellow sigatoka (*Mycosphaerella musicola)* disease, and has a wider host range that includes plantains as well as dessert and ABB-cooking bananas, which are not usually affected by yellow sigatoka. High temperatures and humidity contribute significantly to the introduction and spread of the disease into previously uninfected areas.

The most important vectors of the disease are contaminated plant material, wind, and travelers. International legal and illegal travel and trade (particularly from the Dominican Republic) and weather conditions have been identified as possible pathways by which the disease was introduced into the island.

Once the disease has been introduced and detected, efforts to stem the spread involve a combination of local quarantine and chemical and cultural treatments. Attempts are usually made to isolate affected fields and all unauthorized personnel are prohibited from the area. However, on an island such as Puerto Rico, restricting the movement of people is very limited.

In terms of chemical treatment, a variety of fungicides are recommended for aerial application. On the large export plantations such as those found in Central America, applications are usually done via airplane/helicopter. As Ploetz (2001) points out, this form of application usually accounts for as much as 20 percent of the purchase price of the exported fruit. However, given the average size of plantain and banana farms in Puerto Rico and their close proximity to residential areas and the fact that most of the farms are intercropped with coffee, this form of application is not recommended.

The more common methods of applying the fungicides in Puerto Rico are via motorized tractor implements and backpacks. The general recommendations for treatment frequency of fungicide application in Puerto Rico (Diaz, 2006) and tropical regions, such as Mexico (Orozco, 1998) and Ecuador (Ministerio de Agricultura y Ganadería, 1995), are 14 to 21 days for systemic fungicides. Considering the application recommendations, the number of treatments per year is between 17 and 26. The mean number of treatments per year in Puerto Rico is 18, which is in the lower application range.

However, because there is a tendency for resistance or tolerance in *M. fijiensis* towards systemic fungicides, many farmers use a combination of fungicides mixed with petroleum oil sprays (Ploetz, 2001). Fungicides of the chemical groups of triazoles, pyrimidines, morpholines, and strobilurines should not have back-to-back applications

and no more than eight applications per year. This application number consists of a rotation of systemic and protectant fungicides to prevent pesticide resistance. The registered fungicides most frequently applied in Puerto Rico for black sigatoka are Propiconazole, Tebuconazole, Azoxystrobin, and Banana Spray Oil (Díaz, 2006). These are systemic fungicides, with Azoxystrobin being the only one in the pyrimidin chemical group.

Ploetz (2001) notes that although such "cocktail" mixtures usually provide an effective control, their effect on the environment is a cause for concern. The risk factors associated with the use of fungicides are related to potential ground water contamination and harm to farm workers. Potential harm to farm workers covers a spectrum from eye and skin irritations to possible carcinogenic diseases.

Further complicating the matter is the fact that the fungicides approved for the treatment of black sigatoka in Puerto Rico are not approved for use in farms intercropped with coffee. Because Puerto Rico is controlled by the United States Environmental Protection Agency (EPA), the pesticides used for crop protection must be registered for specific crops. The effective registered fungicides that control black sigatoka are not allowed on coffee, which is the principal crop in the intercropping system. Therefore fungus control must be limited to cultural practices in such circumstances. The cultural practices recommended are usually labor-intensive and costly. They include manual removal of affected leaves and infected plants, burning, and field sanitation to ensure adequate spacing of plants and efficient drainage within plantations. Although burning the entire field is quite effective against the spread of the disease, it has limited application where there is intercropping.

To ensure the proper application of fungicides, the government of Puerto Rico subsidizes the operation by providing the spray equipment and crews for the fungicides purchased by the growers. The DAPR has a general labor subsidy program that reimburses participant growers a maximum of 50 percent of the cultural practices cost. These programs have limited budgets, thereby limiting the services they provide to the growers.

METHODOLOGY

Economic Analysis

To assist with quantifying the effects of the introduction of the disease and the supply shocks, we utilized an equilibrium displacement model (EDM), following the general approach adopted by Choi et al. (2003). In this model, a system of demand and supply conditions is laid out in log-linear form to determine how the equilibrium quantities, prices, and other variables respond to shocks (e.g., yield reductions and increased production costs). The model is parameterized with a range of economic and biological data, focusing on the intermediate-run impact without examining the path of adjustment.

The following set of equations in log-linear form characterizes the situation:

$$(1) \qquad d\ln Y = \delta$$

$$(2) \qquad d\ln A = \varepsilon d\ln P - \varepsilon d\ln C$$

(3) $d\ln S = \varepsilon d\ln P - \varepsilon d\ln C + \delta$

(4) $d\ln D = -\eta d\ln P$

(5) $d\ln S = d\ln D$

In equation (1), Y represents the yield of plantain and banana per acre, and δ denotes the actual percentage amount by which yield can be expected to change as a result of the disease. In equation (2), A represents the acreage of plantains and bananas as a function of price (P) and production costs (C), where ε is the price elasticity of supply (area planted). As pointed out by Choi et al. (2003), the elasticity of the area with respect to marginal costs per acre is the negative value of ε under the assumption of constant returns to scale. In equation (3), S denotes the percentage change in market supply of plantains and bananas and is obtained by summing the percentage change in yield (equation 1) and the percentage change in acreage (equation 2). In equation 4, D represents the demand for plantains and bananas, and η represents the absolute value of price elasticity of demand. Equation 5 reflects the market clearing condition and implies that the percentage change in quantity demanded will equal the percentage change in quantity supply.

The above set of equations can be solved by giving formulas for changes in price, acreage, equilibrium quantity, and revenue as shown in equations 6 to 9 below:

(6) $$d\ln P = \left(\frac{1}{\varepsilon+\eta}\right)\left(\varepsilon d\ln C - \delta\right)$$

(7) $$d\ln A = \left(\frac{-\varepsilon}{\varepsilon+\eta}\right)\left(\delta + \eta d\ln C\right)$$

(8) $$d\ln Q\left(= d\ln S = d\ln D\right) = \left(\frac{-\eta}{\varepsilon+\eta}\right)\left(\varepsilon d\ln C - \delta\right)$$

(9) $$d\ln(PQ) = d\ln P + d\ln Q = \left(\frac{1-\eta}{\varepsilon+\eta}\right)\left(\varepsilon d\ln C - \delta\right)$$

The welfare effects of the disease in terms of changes in the surpluses for both the producers and the consumers can be approximated by using the following equations:

(10) $\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\eta)$

(11) $\Delta CS = P_0 Q_0 Z(1 + 0.5Z\eta)$

where

$$Z = K\left(\frac{1}{\varepsilon+\eta}\right) = -d\ln P, \qquad K = -\left(\varepsilon d\ln C - \delta\right),$$

and P_0 and Q_0 are the initial equilibrium price and quantity before the supply shifts. Using the above framework and parameters and data (discussed below), we estimated the impact on plantains and bananas caused by yield and cost shocks (i.e., the likely reduction in yield and increased cost of production).

Biological and Economic Data

Data used in the analysis were based on the result of a 2005 survey of plantain and banana growers conducted by the Agricultural Experiment Station in collaboration with the Agricultural Extension Service of the University of Puerto Rico, Mayaguez Campus, and extensive discussions held with industry experts and agricultural extension agents. Secondary data were obtained from the Department of Agriculture of Puerto Rico, Statistical Office (DAPR, 2006 and 2005). Regarding the 2005 survey, a total of 91 farms were surveyed to determine, among other things, the distribution of the disease, impact on yield, control methods employed, and additional costs of such treatments.

The survey results indicated that approximately 50 percent of the total plantain and banana acres were infected with the black sigatoka as of December 2005. As stated earlier, the disease affects yield in two ways: directly by reducing the number of bearing plants, and indirectly by affecting the quality of the fruit in terms of number (hands and fingers), size, and weight of marketable fruits. The extent to which yields are affected depends on several factors: variety (plantain or banana), disease severity, location, humidity, plant growth stage at time of infestation (before or after flowering), and whether treatment had been applied. On the basis of discussions with the industry experts, it was noted that if the disease infected the plant during the pre-flowering stage and no control treatments were applied, overall yield was likely to decrease by as much as 90 percent. If attempts were made to control the disease during this stage, losses could be lowered by as much as 75 percent (i.e., yield would be reduced by only 25 percent). If, on the other hand, infestation occurs after the pre-flowering stage, the impact would be less severe (yields would decrease by about 50 percent). Applying treatments during the pre-flowering stage would further reduce expected losses to about 15 percent (Diaz, personal communication).

Further discussions with extension agents and industry specialists, and findings in the literature review indicated that the average yield reductions experienced in cases where no controls were applied were 50 percent for plantains and 80 percent for bananas. Given that the survey results indicated that approximately 50 percent of the acres were infected, the industry-wide yield impact if growers did not control the disease would be about 25 percent for plantains (50% of 50%) and 40 percent for bananas (50% of 80%).

As mentioned earlier, controlling the disease involves using a combination of chemical and cultural methods. The survey results indicated that growers with black sigatoka control programs reported an increased average annual control cost of about $582 per acre. The mean cost for control application was about $33 per acre, and there were approximately 18 treatments per year. Given that the average annual costs of plantain and banana production in situations where the disease is not present have been estimated as $5,273 and $6,744, respectively (Ortiz, unpublished), control of the disease can be expected to add 11.0 percent and 8.6 percent to production costs of plantains and bananas, respectively. Since a 75 percent efficacy of the treatment can be assumed, the estimated national impact on yield, if all affected growers were to treat the disease, is

estimated at 6.25 percent for plantains (25% of 25%) and 10 percent (25% of 40%) for bananas.

With respect to economic data and parameters, the average price, quantity, and industry values of plantains and bananas over the three-year period of 2001 to 2003 were used as the initial equilibrium values (Table 1). Since imports of plantains and bananas are restricted except when the domestic supply is interrupted by hurricanes, we had to construct estimates of the import prices for plantains and bananas during the period. Our estimate was determined on the basis of information provided by the importers and phytosanitary inspectors regarding farm gate prices for plantains and bananas in Ecuador (one of the overseas suppliers), transportation and insurance costs, and costs of inspection and certification. Based on such information and the allowance for a 10 percent profit margin, we estimated an import price of around 19 cents per pound for plantains and 17 cents per pound for bananas.

Table 1. Price and Quantity Variables

Commodity	Price(dollars/pound)	Quantity (million pounds)
Banana	$0.18	84.0
Plantain	$0.25	237.8

We use acreage supply elasticities of 0.25 and 0.1 to reflect the inelastic nature of the supply response of both plantains and bananas. Most of the agricultural lands are currently under production. Although there are pure stands of plantains and bananas, most are usually grown as shade crops for coffee. In addition, both plantains and bananas are considered as cash crops, providing a source of weekly income for many of the growers. A review of the literature found only one study that had attempted to estimate the acreage supply elasticity. The study, which is somewhat dated, indicated a supply elasticity of .01 (Cortés, 2005) for banana. The economic model also requires that we provide estimates of the demand elasticity. In view of the fact that a reliable data series was unavailable for estimating the demand elasticity and searching the literature proved unsuccessful, the data estimates supplied were based on discussions with consumers and what is known with respect to the consumption of the commodities. Numerical values assigned for the demand elasticity were in the range of -0.25 to -0.5 and -0.5 to -0.75 for plantains and bananas, respectively. The demand for plantains is assumed to be more inelastic than that for bananas since there are only a couple of imperfect substitutes available, namely cassava and potatoes (Cortés and Gayol, 2006). In the case of banana demand, there is a wide range of local fruits and vegetables that can be substituted; however, bananas are still the favorite fruit in Puerto Rico.

RESULTS

Using the above discussed estimates and data, we estimated the economic welfare consequences of introducing the disease in situations where import prohibitions for plantains and bananas are maintained and farmers treat the disease with some assistance from the government. Under this scenario, the average production costs were estimated to have increased by 11 percent and 8.6 percent for plantain and banana cultivation, respectively. Yields, on the other hand, were estimated to have decreased by 6.25 percent

and 10 percent respectively. Tables 2 and 3 provide the simulated effect, given the range of economic parameters for plantains and bananas, respectively.

Table 2. Plantains: Estimated Impacts Assuming Treatment with Ban on Imports

Yield Loss (%)	Change in Costs (%)	Acreage elasticity	Demand elasticity	Price ($/lb)	Production (million pounds)	Revenue ($m)	Δ PS ($m)	Δ CS ($m)
- 6.25	11.0	0.1	-0.25	0.30	225.32	68.16	7.90	-12.16
		0.1	-0.50	0.28	223.23	62.65	2.82	-7.06
		0.25	-0.25	0.30	227.10	66.99	5.23	-10.46
		0.25	-0.50	0.28	223.53	62.59	1.73	-6.92
Average				0.29	224.80	65.10	4.42	-9.15

Source: Authors, estimates.

Table 3. Bananas: Estimated Impacts Assuming Treatment with Ban on Imports

Yield Loss (%)	Change in Costs (%)	Acreage elasticity	Demand elasticity	Price ($/lb)	Production (million pounds)	Revenue ($m)	Δ PS ($m)	Δ CS ($m)
-10.0	8.6	0.10	-0.50	0.21	76.41	16.24	1.05	-2.61
		0.10	-0.75	0.20	75.95	15.42	0.28	-1.84
		0.25	-0.50	0.21	77.21	16.15	0.59	-2.35
		0.25	-0.75	0.20	76.35	15.41	0	-1.75
Average				0.21	76.48	15.81	0.48	-2.14

Source: Authors, estimates.

Information in Table 2 suggests that with pest control treatments, plantain production would be expected to decrease by a maximum of about 6 percent, or from 237.8 million pounds to 223.2 million pounds. The reduction in the availability of plantains induces a price increase of between 12 percent and 21 percent (prices increased from 25 cents per pound to between 28 cents and 30 cents per pound). Because of the moderate increase in prices, acreage would increase only slightly by about 1 percent. The surplus (welfare) for producers would increase in the range of $1.7 million to $7.9 million, depending on the responsiveness of consumers and producers. On the other hand, the surplus (welfare) for the consumers would decrease in the range of $6.9 million to $12.16 million. The overall net economic welfare would decrease (cost to society) by approximately, $5 million.

The information contained in Table 3 suggests that in the case of bananas, prices would increase from 18 cents per pound pre-infestation to about 21 cents per pound. Quantities produced would decrease about 9 percent, or from 84.0 million pounds pre-infestation to about 77 million pounds. Acreage response would be marginal, with an increase of about 1 percent. Despite the increased price, the surplus for the producers would only rise slightly (by at most $1 million) due to increased production costs and lower yields. The increased price facing consumers would cause a decline in the surplus for the consumers between $1.75 million and $2.61 million. On average, there would be a slight reduction in welfare of about $1.5 million (U.S. dollars).

However, as discussed earlier, the presence of diseases has called into question the rationale for maintaining import restrictions. Given the existence of the disease, the simulated production, consumption, trade, and welfare effects of moving from a ban to free trade are presented in Tables 4 and 5 for plantains and bananas, respectively. With respect to Table 4, the results indicate that removing the ban on plantains would cause producer price to fall by about 24 percent from the pre-infestation price, or a decrease from 25 cents per pound to about 19 cents per pound. Depending on the elasticities, the consumption of plantains would increase from 237.8 million pounds to between 252.07 million pounds and 266.34 million pounds. As a consequence of lower prices, higher production costs, and reduced yield, domestic production would decrease to between 205.6 million pounds and 216.9 million pounds, implying self-sufficiency of between 77 percent and 86 percent. The corresponding fall in the revenues for producers would be much higher than the drop in volume due, in part, to the larger proportionate fall in price. On average, the value of production would decline to about $40 million dollars, compared to the pre-infestation value of almost $60 million. The welfare of the producers would fall by up to $17.58 million while the welfare of the consumers would increase by about $13.88 million. Overall, economic welfare would decline by approximately $3.4 million.

Table 4. Plantains: Estimated Impacts Assuming Treatment with Import Ban Removed

Index	Unit	With Import Ban				Average
Import Price	$/lb	0.19	0.19	0.19	0.19	0.19
Producer Price	$/lb	0.19	0.19	0.19	0.19	0.19
Supply Elasticity	n/a	0.10	0.10	0.25	0.25	-
Demand Elasticity	n/a	0.25	0.50	0.25	0.50	-
Consumption	mil. lbs	252.07	266.34	252.07	266.34	259.20
Consumption expenditure	$ mil.	47.89	50.60	47.89	50.60	49.25
Production Marketed	mil. lbs	216.94	216.03	206.89	205.57	211.36
Value at Farm Gate	$ mil.	41.22	41.04	39.31	39.06	40.16
Imports	mil. lbs	35.13	50.31	45.18	60.77	47.85
Value of Imports	$ mil.	6.68	9.56	8.58	11.55	9.09
Self-Sufficiency	(%)	86.06	81.1	82.08	77.18	81.61
Change in Producer Surplus	$ mil.	-16.98	-17.08	-17.55	-17.58	-17.3
Change in Consumer Surplus	$ mil.	13.89	13.83	13.95	13.84	13.88
Net Change in Econ. Welfare	$ mil.	-3.09	-3.25	-3.6	-3.74	-3.42

Source: Authors, estimates.

Table 5. Bananas: Estimated Impacts Assuming Treatment with Import Ban Removed

Index	Unit	Without Import Ban				Average
Import Price	$/lb	0.17	0.17	0.17	0.17	0.17
Producer Price	$/lb	0.17	0.17	0.17	0.17	0.17
Supply Elasticity	n/a	0.1	0.1	0.25	0.25	-
Demand Elasticity	n/a	0.5	0.75	0.5	0.75	-
Consumption	mil. lbs	86.33	87.50	86.33	87.5	86.92
Consumption expenditure	$ mil.	14.68	14.88	14.68	14.88	14.78
Production Marketed	mil. lbs	74.87	74.72	73.58	73.33	74.12
Value at Farm Gate	$ mil.	12.73	12.70	12.51	12.47	12.6
Imports	mil. lbs	11.47	12.78	12.75	14.17	12.79
Value of Imports	$ mil.	1.95	2.17	2.17	2.41	2.17
Self-Sufficiency	(%)	86.72	85.39	85.00	83.81	85.29
Change in Producer Surplus	$ mil.	-2.17	-2.21	-2.36	-2.39	-2.28
Change in Consumer Surplus	$ mil.	0.8	0.8	0.81	0.81	0.81
Net Change in Econ. Welfare	$ mil.	-1.37	-1.41	-1.55	-1.58	-1.48

Source: Authors, estimates.

In the case of bananas, the data in Table 5 indicate a somewhat similar pattern to that obtained for plantains. With the removal of the ban, the domestic price could be expected to fall to about 17 cents per pound, slightly below the pre-infestation price of 18 cents per pound. In that case, consumption would increase slightly from 84.0 million pounds to about 87.5 million pounds, or by a maximum of about 4 percent. The volume of production would decrease to between 73 million and 75 million pounds, satisfying 85 percent of the demand. Reflecting the drop in price and reduction in volume, farm gate revenues would decline to about $12.6 million, or by about 16.7 percent. These changes and the higher costs of production reduce the welfare of the producers by an amount ranging from $2.17 million to $2.39 million. The welfare of the consumers would increase marginally by about $0.8 million. Overall, economic welfare would decline by about $1.5 million annually.

DISCUSSION

The foregoing analysis provides estimates of the economic and trade effects of the introduction of black sigatoka under two scenarios: (1) prohibiting imports of plantains and bananas while providing assistance to the growers to treat the disease and (2) lifting import restrictions to allow for free trade of plantains and bananas while providing assistance to the growers to treat the disease. The results indicate that in the first scenario, prices could be expected to increase by as much as 20 percent for plantains and by about 17 percent for bananas when compared to the pre-infestation prices. Production of both plantains and bananas would be expected to decrease by a maximum of about 6 percent and 9.5 percent, respectively. In the case of plantains, the welfare of the producers would increase by about $4.4 million while the welfare of the consumers would decrease by about $9.2 million, given a net economic loss to society of around $4.7 million. For bananas, the welfare of the producers would increase by about $0.5

million while the welfare of the consumers would decrease by about $2 million. Overall, there would be a cost to society of about $1.7 million.

Removing the trade restrictions and opening import markets would prevent the upward adjustment of prices caused by the reduction in domestic supplies. Under this scenario, prices would decline by around 24 percent and 6 percent for plantains and bananas, respectively. While consumption of plantains and bananas would increase, domestic production would decrease, on average, by 11 percent and 12 percent, respectively. In the case of plantains, the surplus for the producers would decline by an average of $17.3 million while the welfare of the consumers would increase by $13.9 million, or a net change in economic welfare of loss of about $3.4 million. For bananas, the welfare of the producers would decline on average by $2.3 million while the welfare of the consumers would increase by less than $1.0 million. Overall net economic welfare would decline by about $1.5 million.

Although the two scenarios considered above reflect relatively small overall changes in cost to society, the distribution of benefits and costs among producers and consumers differs considerably. Under the first scenario, the producers would benefit largely at the expense of consumers due to the upward adjustment of prices. As the results indicate, despite the increased costs and reduced yield, the surplus for the producers would still increase but would be insufficient to outweigh the fall in the welfare of the consumers.

With free trade, the situation is reversed, with the welfare of the producers declining and the welfare of the consumers increasing. Of interest is the fact that overall net economic welfare would remain negative. Because import prices are not significantly lower than pre-infestation prices, gains to consumers are insufficient to outweigh losses to producers. Producers are disadvantaged in terms of facing lower prices, higher production costs, and lower yields. Such a situation could create economic hardships for growers who depend on these crops for a steady stream of income. Moreover, removing the phytosanitary restrictions on plantain and banana imports is likely to increase the probability of introducing other invasive pests and diseases, which might affect other agricultural crops. The Moko disease and Papaya Fruit Fly are sometimes transmitted via banana imports and can cause serious damage to the agriculture and ornamental industries. If such a situation were to be realized the costs to society could be further increased.

Also, there is no guarantee that relaxing import restrictions would lead to any significant reduction in prices, as the past events of 1998 have clearly shown. Due to damages caused by the hurricane in that year, most of the total demand had to be satisfied from overseas sources. Prices were observed to remain virtually the same despite being supplied by imports because importers and retailers were not compelled to pass on any cost savings to the consumers. Such a policy could be effective if the system were redesigned to establish a research and promotion authority that could collect a portion of the rent from imports which could be used to support research towards control of the disease. Specific research for resistant cultivars and biological controls could reduce fungicide application. A portion of the rent from imports could be assigned to "incentive control programs" to reduce costs and enable growers to implement cultural practices that benefit the environment.

Another consideration on which the above results are predicated is the assumption that the affected growers would apply fungicides in a judicious manner which would minimize any adverse impact on the environment. As mentioned earlier, the bulk of the plantain and banana farms are located in mountainous areas which are important watershed areas. In addition, some of the farms are in close proximity to residential areas. Indiscretion in the use of such fungicides could lead to undesirable runoffs and contamination of important water sources. This analysis did not take into consideration possible adverse environmental impacts from the improper use of chemicals, given that the government has taken steps to oversee chemical applications by providing the required equipment and trained crews to apply the chemicals (discussed below). Hence, it is important that assistance continue and that growers be provided the necessary incentives to limit the use of fungicides and chemicals and to employ cultural practices. These incentives should be accompanied by educational programs to inform the growers about the potential adverse environmental impacts from improper chemical use.

Currently, the government of Puerto Rico assists growers with controlling the spread of black sigatoka. Our calculation implies that in spite of government assistance, production costs are likely to increase by 11.0 percent and 8.6 percent for plantains and bananas, respectively. Unconfirmed reports indicate that the government may reduce or eliminate their support because of budgetary constraints. This would further increase the cost to the growers and could undermine efforts to limit chemical use through more expensive cultural practices. Given the need of reducing control costs, increasing society's welfare, providing safe drinking water, and minimizing harm to the environment, government support should not be decreased or eliminated.

There could be a significant payoff in investing in research to develop plantain and banana varieties that are resistant to black sigatoka. Such research is currently underway but only to a limited extent in Puerto Rico. Support should be given to intensify efforts at developing resistant agronomically-acceptable cultivars, and organoleptic evaluations should be conducted to ensure that resistant cultivars possess the desirable characteristics that are essential in preparing ethnic dishes and have consumer acceptance.

CONCLUSION

A critical decision facing the government of Puerto Rico is whether in light of the presence of the diseases the current restrictions on the import of plantains and bananas should be removed. Our analysis did not find conclusive evidence that society would be made better off by removing such restrictions. Moreover, given that such actions are likely to create economic hardships for growers who depend on these crops for a steady stream of income as well as increase the probability of introducing other invasive pests and diseases, which might affect other agricultural crops, the decision to do so needs to be considered carefully. Governments have a key role to play in limiting the spread of invasive species. In that regard the Government of Puerto Rico has taken steps to assist the growers manage the disease. Currently, with assistance from the government, growers are employing a combination of cultural and chemical control methods to combat the spread of the disease. The judicious use of chemicals is crucial to the environment. Removal of government assistance could cause the growers to use cheaper combinations of chemicals that are more damaging to the environment. The potential gains to society of

providing safe drinking water and a safe environment suggest the need for the government to continue its support in restricting the spread of diseases and promoting research to develop resistant cultivars.

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