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Economic Impact and Trade Implications of the Introduction of Black Sigatoka (*Mycosphaerella fijiensis*) into Puerto Rico

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This article addresses the issues of the potential impacts of the introduction of black sigatoka into Puerto Rico under situations in which the government assists growers in managing the spread of the disease, with and without prohibitions on imports of plantains and bananas. An equilibrium displacement model is used to quantify the impact of black sigatoka. The results indicate that under both scenarios the net economic benefits to society were negative. Over the long term, the government would be well-advised to invest in research to develop plantain and banana varieties that are resistant to black sigatoka.

Key Words: banana, black sigatoka (*Mycosphaerella fijiensis*), economic impact analysis, equilibrium displacement model, invasive species, plantain

JEL Classifications: Q17, Q18

After many years of being free of black sigatoka, Puerto Rico was affected by the disease in August 2004. The disease, which is caused by the fungus *Mycosphaerella fijiensis*, affects both plantains and bananas and can reduce yields by as much as 90%. The introduction and spread of this dreaded disease has been of major concern for growers, consumers, and policy makers. Growers are concerned about potential reductions in their net income due to lower yields and higher production costs. Consumers are concerned about the possible impact the disease could have on prices and product availability. Policy makers (and the public in general) are concerned about the additional financial and environmental burdens that the spread of the disease and disease control methods are likely to place on society. Many of the "cocktails" of systemic fungicides and petroleum oil-based sprays, which have proven effective against the disease, if not properly managed, can end up contaminating important potable water sources. The presence of the disease has also raised concern over the existing trade policy restricting imports of plantains and bananas. Currently the Puerto Rican plantain and banana market is supplied entirely by domestic producers as a result of phytosanitary restrictions on plantain and banana imports. However, in light of the presence of the disease and the fact that eradication is highly improb-

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able, the view has been expressed that such prohibitions are no longer warranted.

Consequently, the paper addresses two questions:

1. What are the potential impacts of the introduction of the disease, given the government's decision to assist growers in managing the spread of the disease while maintaining strict prohibitions on plantain and banana imports?
2. What are the potential effects of removing the prohibitions on plantain and banana imports while still providing assistance to the growers to treat the disease?

The research utilizes the standard comparative static partial equilibrium framework with the aid of the equilibrium displacement model (EDM) to assess the effects on plantain and banana prices, production, consumption, and welfare. The choice of the EDM as our analytical framework stems from its flexibility in modeling a wide variety of market structures (Alston, Norton, and Pardey), and as pointed out by Piggot, using the EDM is particularly suited, and preferable, to econometric estimations of simultaneous systems of market equations in cases where there are insufficient data for econometric modeling and where data are unreliable. These characteristics are often the case in many developing countries in the tropics.

Although our simple framework was not robust enough to allow us to quantify all of the possible impacts, including dynamic adjustment in the industry, second-round resource allocations, and some of the environmental consequences, it does draw attention to the challenges of conducting a study within a tropical environment characterized by mixed cropping systems. As far as we know, our analysis is the first to try to combine the effects of the disease with trade liberalization using an EDM. Given that many small developing countries in the tropics will likely face similar decisions without sufficient resources to conduct elaborate studies, we believe the methodology offered will provide a simple and useful illustration of how economics can contribute to the decision-making process.

The next section highlights the economic and cultural importance of plantain and banana crops to the economy of Puerto Rico. Section 3 provides information on the biology and ecology of black sigatoka and the disease-control methods being used in Puerto Rico. Section 4 presents the economic model used to quantify the economic impact of the disease. Section 5 identifies the analysis data sources and the biological and economic parameters. The next section presents the results of the simulated impacts of the diseases. The final section explores the policy implications of the findings and offers the concluding remarks.

The Importance of Plantain and Banana Production to Puerto Rico

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% of the total farms of the island and bananas are cultivated on 22.4%.

Although plantains and bananas are grown throughout the island, their main production areas are located in the mountain regions in 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 important, 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.

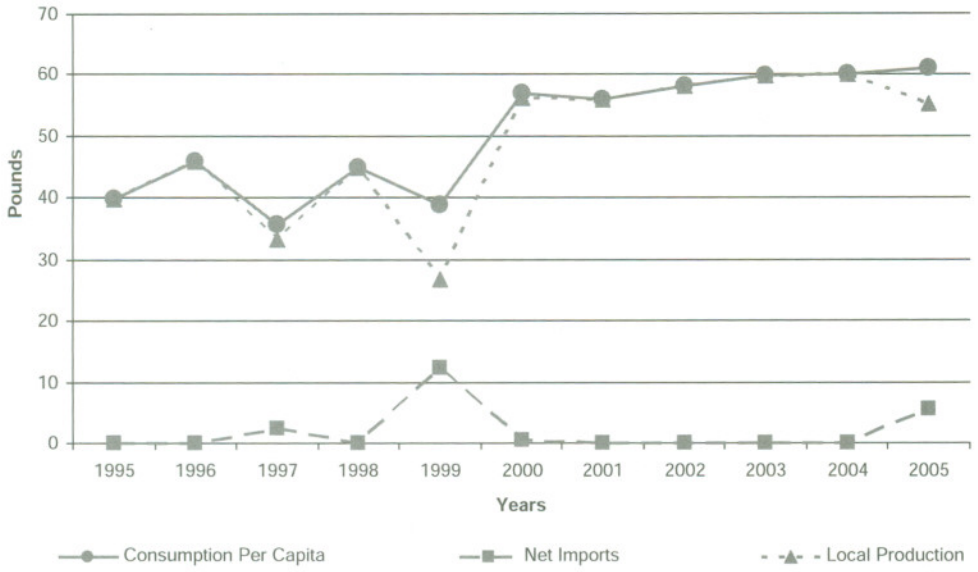

Figure 1. Plantain: Per Capita Consumption, Imports, and Local Production, 1995–2005

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 with 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.

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 and Gayol).

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 DAPR issues licenses to several 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 because of the disease.

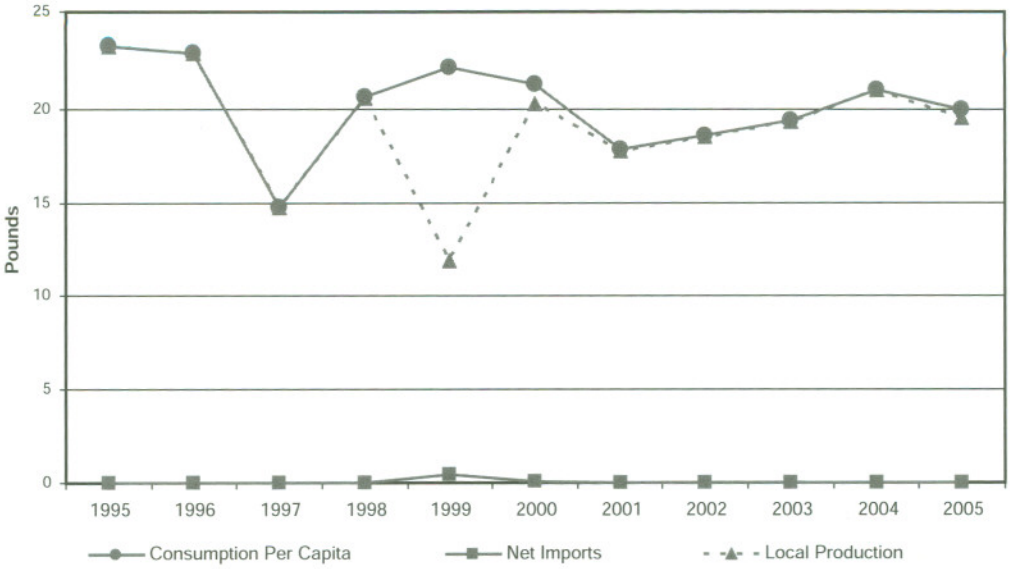

Figure 2. Bananas: Per Capita Consumption, Imports, and Local Production, 1995–2005

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% yield reduction (Orozco). 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 onto 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 points out, this form of application usually accounts for as much as 20% of the purchase price of the exported fruit. However, given the average size of plantain and banana farms in Puerto Rico and their 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) and tropical regions, such as Mexico (Orozco) and Ecuador (Ministerio de Agricultura y Ganadería), 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* toward systemic fungicides, many farmers use a combination of fungicides mixed with petroleum oil sprays (Ploetz). 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). These are systemic fungicides, with azoxystrobin being the only one in the pyrimidin chemical group.

Ploetz 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 groundwater 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 U.S. Environmental Protection Agency, 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% of the cultural practices cost. These programs have limited budgets, thereby limiting the services they provide to the growers.

Economic Analysis

Figure 3 is used to illustrate plantain and banana markets at the farm level. As mentioned earlier, our analytical framework is based on the standard comparative static partial equilibrium framework. Here we assume the usual straight-line demand and supply curves. In Figure 3, D_0 represents the derived demand for the commodity, and S_0 represents the farm supply. The intersection of the demand and supply curves gives the market-clearing equilibrium price P_0, and quantity supplied Q_0 under autarky and in the absence of the diseases. With the introduction of the disease, the supply curve shifts upward because of supply shocks (reduced yields and increased costs associated with treating the disease). Here we assume a parallel shift of the supply curve. With the prohibition remaining in place, the new equilibrium price and quantity are shown in Figure 3 as P_1 and Q_1, respectively. With the removal of the prohibition on imports of the commodities, the domestic price falls to the free trade price represented by P_f. At this price,

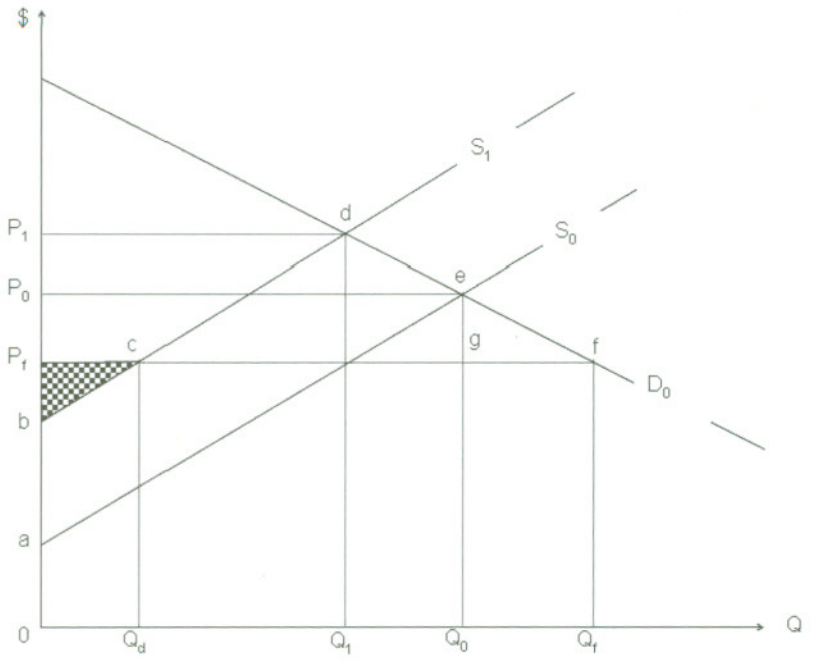

Figure 3. Hypothetical Farm Level Market for Puerto Rican Plantains and Bananas

the total quantity demanded is Q_f, the domestic quantity supplied is Q_d, and the quantity imported is the difference between Q_f and Q_d.

To assist with quantifying the effects of the introduction of the disease and the supply shocks, we utilized EDM, following the general approach adopted by Choi et al. 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:

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

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

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

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

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

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., 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 6–9 below:

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

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

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

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

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:

$$(10)\quad \Delta PS = P_0Q_0(K - Z)(1 + 0.5Z\eta)$$

$$(11)\quad \Delta CS = P_0Q_0Z(1 + 0.5Z\eta)$$

where

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

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).

To quantify the impact of removal of the trade restrictions (scenario two), we continue to assume that only the supply curve shifts (parallel) as a result of the introduction of the disease; hence the supply elasticity remains the same (see Figure 3). Given the supply elasticity, the new equilibrium price and quantity, P_1 and Q_1, as determined above, and an estimate of the free trade price, P_f, it is relatively straightforward to determine the domestic quantity, Q_f, that would be supplied under free trade conditions. Moreover, since the demand curve did not shift, the total quantity demanded as a result of lifting the ban, Q_f, can be determined by substituting the free trade price, P_f, into the original demand equation. The changes in the surpluses for the producers and the consumers can be found by calculating the relevant areas as shown in Figure 3. In the case of the producers, the welfare change is represented by the area P_1dcP_f (the difference between the areas P_1db and P_fcb), and in the case of consumers, it can be found by estimating the area of the trapezoid P_1dfP_f.

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 DAPR Statistical Office (2005, 2006). 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 used, and additional costs of such treatments.

The survey results indicated that approximately 50% of the total plantain and banana acres were infected with 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 preflowering stage and no control treatments were applied, overall yield was likely to decrease by as much as 90%. If attempts were made to control the disease during this stage, losses could be lowered by as much as 75% (i.e., yield would be reduced by

only 25%). If, on the other hand, infestation occurs after the preflowering stage, the impact would be less severe (yields would decrease by about 50%). Applying treatments during the preflowering stage would further reduce expected losses to about 15% (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% for plantains and 80% for bananas. Given that the survey results indicated that approximately 50% of the acres were infected, the industrywide yield impact if growers did not control the disease would be about 25% for plantains (50% of 50%) and 40% 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), control of the disease can be expected to add 11.0% and 8.6% to production costs of plantains and bananas, respectively. Since a 75% 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% for plantains (25% of 25%) and 10% (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. On the basis of such information and the allowance for a 10% profit margin, we estimated an import price of around 19¢ per pound for plantains and 17¢ per pound for bananas.

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 0.01 (Cortés and Villagomez) 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). 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 of the Simulation

Using the above discussed estimates and data, we estimated the economic welfare conse-

Table 1. Price and Quantity Variables

Commodity	Price (Dollars/ Pound)	Quantity (Million Pounds)
Banana	\$0.18	84.00
Plantain	\$0.25	237.80

quences 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% and 8.6% for plantain and banana cultivation, respectively. Yields, on the other hand, were estimated to have decreased by 6.25% and 10% respectively. Tables 2 and 3 provide the simulated effect, given the range of economic parameters for plantains and bananas, respectively.

Information in Table 2 suggests that with pest control treatments, plantain production would be expected to decrease by a maximum of about 6%, 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% and 21% (prices increased from 25¢ per pound to between 28¢ and 30¢ per pound). Because of the moderate increase in prices, acreage would increase only slightly, by about 1%. 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¢ per pound preinfestation to about 21¢ per pound. Quantities produced would decrease about 9%, or from 84.0 million pounds preinfestation to about 77 million pounds. Acreage response would be marginal, with an increase of about 1%. Despite the increased price, the surplus for the producers would only rise slightly (by at most \$1 million) because of 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% from the preinfestation price, or a decrease from 25¢ per pound to about 19¢ per pound. Depending on the elasticities, the consumption of plantains would increase from 237.8 million pounds to between 252.07 million pounds

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 (\$Million)	ΔPS (\$Million)	ΔCS (\$Million)
−6.25	11.00	0.10	−0.25	0.30	225.32	68.16	7.90	−12.16
		0.10	−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.
PS = Producer Surplus.
CS = Consumer Surplus.

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

Yield Loss (%)	Change in Costs (%)	Acreage Elasticity	Demand Elasticity	Price ($/lb)	Production (Million Pounds)	Revenue ($Million)	Δ PS ($Million)	Δ CS ($Million)
−10.00	8.60	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	0.00	−1.75
Average				0.21	76.48	15.81	0.48	−2.14

Source: Authors, estimates.

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% and 86%. 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, compared with the preinfestation 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.

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¢ per pound, slightly below the preinfestation price of 18¢ 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%. The volume of production would decrease to between 73 million and 75 million pounds, satisfying 85% 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%. 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.

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	81.10	82.08	77.18	81.61
Change in producer surplus	$Mil.	−16.98	−17.08	−17.55	−17.58	−17.30
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	−3.60	−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	0.10	0.10	0.25	0.25	-
Demand elasticity	n/a	0.50	0.75	0.50	0.75	-
Consumption	Mil. lbs	86.33	87.50	86.33	87.50	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	12.60
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.	0.80	0.80	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.

Policy Implications

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% for plantains and by about 17% for bananas when compared with the preinfestation prices. Production of both plantains and bananas would be expected to decrease by a maximum of about 6% and 9.5%, 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% and 6% for plantains and bananas, respectively. While consumption of plantains and bananas would increase, domestic production would decrease, on average, by 11% and 12%, 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 because of 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 preinfestation 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. 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. Because of 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 (e.g., P_0egP_f in Figure 3). 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 that could be used to support research toward 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 that are important watershed areas. In addition, some of the farms are in 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 use 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% and 8.6% 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 under way 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.

Concluding Remarks

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 that 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 using 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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