CONTROL OF A MOBILE PEST: THE IMPORTED FIRE ANT*

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Entomologists and other pest control specialists recognize that pest mobility creates difficulties when control is left to individual property owners. Control of mobile weeds, insects or contagious diseases has characteristics of a public good with high exclusion costs and near equal availability to all people in the affected area. If abatement benefits for areas to which the pest is spreading are not considered, there will be under production of abatement. Cooperatives, county abatement districts or state and federal agencies are often set up to administer area-wide abatement efforts. Economies of scale in pesticide treatments, coordination of efforts to limit spatial spread of the pest (quarantine activities) and scale economies in technology to reduce adverse side effects of pesticides are given as justifications for public or large-scale pest control programs.

However, it is not as widely recognized that there are conditions under which mobile pests can best be controlled by individuals or small groups. Just as a private recreation club cannot devote excessive resources to exclude all free-riders, so also there might be some free-riders in efficient pest control.[1] Quarantine of some pests may be technologically infeasible unless weather, terrain, water or other barriers can be put to use. Supression of pest populations may have different scale economies than those for only pesticide application, given costs of determining pest location and severity. Pest abatement demand may differ between people because of income, duration of exposure and pest population differences.

This study evaluates the productivity of efforts to limit the spread of the imported fire ant (IFA), and elements affecting demand for its abatement in southeastern states. The following section presents quarantine model and parameter estimates for the 1959 to 1973 period. The demand section gives estimates from two models for evaluating public pest abatement demand. The last section uses quarantine and demand results, with some observations on scale economies, to discuss IFA treatment policy. Examination of both spread reduction and demand factors seems appropriate for mobile pests besides the IFA.

The IFA is an important example of a mobile pest.[2] It is both a health and an agricultural pest. The sting of the ant is quite painful to humans and livestock. Ant mounds can cause damage to farm equipment. Farm laborer productivity can be reduced by potential or actual ant stings. In recent years, about 10 to 15 million acres have been treated annually by publicly funded, aerial applications. There is, however, concern that the relatively persistent insecticides used may be causing damage to non-target species.

FIRE ANT QUARANTINE PRODUCTIVITY

The imported fire ant is believed to have entered the United States in Alabama about 1920 [6]. The fan-like spread of the ant continued at about 5 miles per year with increases in rate of

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[1] See J. Buchanan, [4], for general conditions permitting some free-riders in an organization.

[2] Another important mobile pest which is currently being considered for major area-wide control is the cotton boll weevil. See Lacewell, *et. al.*, [9], for and evaluation of the quarantine efforts in the eastern section of the Texas High Plains.

spread in recent decades. The spread is by means of a queen which periodically establishes a new colony. Public participation at the national level began under the Federal Plant Pest Act of 1957, with nine cooperating states agreeing to share the costs of IFA control (see Table 1 for list of states). In 1958 there was an infested area of 33 million acres (out of a total land area of 448 million acres) in the nine states. Initial efforts "involved treatment with chlorinated hydrocarbon insecticides, including heptachlor or dieldrin. Since 1962, the cooperative program has applied another insecticide, mirex," formulated as corncob grit. It is applied by aerial application at about 1.75 grams of technical material per acre. The U.S. Department of Agriculture, in cooperation with state agencies, contracts with private firms for treatment of large contiguous land blocks — usually about 500-1000 thousand acres per contract.

Table 1. LOGISTIC APPROXIMATION TO SPREAD OF THE IMPORTED FIRE ANT[a]

State	Const.	A_{t-1}	A_{t-2}	t	R^2	Durbin-Watson
Alabama	21.87 (5.95)	.0000815* (2.34)	-.00005 (1.40)	-.0111** (5.92)	.83	1.76
Arkansas	-32.625 (.85)	-.00256 (1.54)	-.00181 (.95)	.0168 (.86)	.24	2.39
Florida	11.79 (1.06)	.000033 (1.39)	.000002 (.09)	-.00596 (1.05)	.24	1.64
Georgia	122.65 (3.89)	.0000118 (.517)	.000025 (1.11)	-.062** (3.88)	.80	2.05
Louisiana	32.16 (6.37)	-.000012 (.98)	-.0000027 (-.21)	-.016** (6.333)	.90	1.15
Mississippi	1.688 (.53)	-.000017** (3.38)	-.000003 (-.576)	.000888 (.54)	.73	2.10
North Carolina	153.47 (1.03)	-.0166** (3.87)	.0114* (2.49)	-.078 (1.03)	.61	2.42
South Carolina	89.10 (3.10)	-.00003 (.482)	-.00003 (.43)	-.0451** (3.088)	.77	2.26
Texas	34.16 (1.16)	.000086 (.19)	.00018 (.36)	-.017 (1.11)	.11	2.36

[a]Figures are ordinary least squares estimates. Figures in parenthesis are "t" values. Sample size in all cases was 14. 1958 and 1959 observations were lost in order to have two year lags for insecticide treatments, A_{t-1} and A_{t-2}.

**,*significant at .01, and .05 level, respectively.

Any unrestricted pest population is commonly believed to expand at a logistic growth rate [13]. More breeding sites lead to a constantly expanding supply of future breeding sites. However, as competition for sites and feeding area increases, the growth rate slows.[3] Adverse temperature and soil habitat can also limit spread.

Insecticide treatments might also limit the rate of spread of infested acreage. Small area insecticide tests have shown that the average number of mounds per acre can be reduced for several years with the use of persistent insecticides [2]. However, insecticide materials may not kill all ant colonies in an area if insecticide drift or airplane guidance problems arise. Small numbers of missed mounds may enable the pest to continue to spread. Consequently, insecticide materials are sometimes applied to the same area in successive treatment periods when the ant is most susceptible (fall and spring).

[3]The IFA favors open grass land to wooded area. Non-cultivated land is favored over row-crop areas, and heavy, clay soils are preferred to light-sandy soils [6].

The model used to incorporate the above biological assumptions in estimating whether there has been a reduction in rate of spread of the IFA is a variant of the logistic growth curve of a population [10]:

$$Y(t) = \frac{k}{1+be^{-at}} \qquad (1)$$

where, Y(t) is acreage infested at time t, k is an upper asymptote, e is base of natural logarithms and b and a are unknown parameters. Hotelling [8] has shown how this equation, whose parameters enter in non-linear fashion, can be approximated in linear fashion as:

$$(Y_t - Y_{t-1})/Y_t = a + bt + u_t, \qquad (2)$$

where u_t is an error term. To determine the effects of insecticide treatments on percent change in acreage infested (let $Z_t = [Y_t - Y_{t-1}]/Y_t$) with IFA, acreages treated in the previous two years A_{t-1}, A_{t-2}, were added to equation 2:[4]

$$Z_t = a + b_1 t + b_2 A_{t-1} + b_3 A_{t-2} + u_t \quad (3)$$

Equation three, which might be called an abatement function, was estimated for each of nine states, using U.S. Department of Agriculture data on IFA infestation and acreage treated by year for the period 1958-1973. Parameter estimates and related statistics are given in Table 1.

In Alabama, Georgia, Louisiana and South Carolina, where the majority (60-70 percent) of insecticide applications occured, there is a significant negative effect of time (t) on IFA population spread. This is a reflection of competition for scarce IFA sites as the population approaches the upper asymptote. Mississippi and Arkansas appear to be the only states where the population has not reached a declining portion of the logistic growth curve. A first difference model ($Y_t - Y_{t-1} = Z'$) was fit for those states where the time variable was not significant in the logistic model. The coefficient estimates for most states were not changed significantly. However, the difference model resulted in a better fit for Arkansas; its R^2 was .85 and the A_{t-1} coefficient and the time (t) coefficient were significant at the .05 level.[5]

Only three states (North Carolina, Mississippi and Arkansas) showed statistically significant negative effects of insecticide treatments on rate of spread. These findings agree with the observed difficulty of controlling IFA spread in many states, as well as its success near the pest's northern boundary in North Carolina, Arkansas and northern Mississippi. There is no evidence of reduced westward spread in Texas or reduced southern spread in Florida.

Much remains unknown about quantitative aspects of IFA population dynamics.[6] The estimated positive effect of insecticides on IFA spread in Alabama was unexpected. It may be due to reporting errors in IFA infested areas. Perhaps more monitoring occurred there in years immediately following treatments. If a larger percent of infested acres were detected, this may account for infestation increase following insecticide treatments. Differences in monitoring accross states may partially account for inconsistencies in data quality and model fit in Table 1.[7]

There is little evidence in Table 1 that the fire ant would now be occupying more area had insecticide treatments not been implemented. However, treatment might be justified for temporary supression purposes, as in the case for mosquitoes or agricultural pests. Demand for treatment in infested areas needs evaluation to determine the benefit of IFA supression.

DEMAND FOR PUBLIC IFA ABATEMENT

In the past, value of IFA abatement was determined by asking county agents and others, "What sum of money would you pay to avoid being stung by fire ants?" [11]. This type of evalutation suffers from free-rider problems — overstatement of values of benefits by some who may not have to pay taxes for abatement. What one person is willing to pay may be contingent on

[4] Two years were thought to be sufficient to capture residual effects of insecticides (see Blake, *et. al.*, [2]).

[5] Arkansas: $Z_t = 82014 - \underset{(2.37)}{5.02}\, A_{t-1} + \underset{(1.07)}{4.27}\, A_{t-2} + \underset{(3.03)}{41.8}\, t,\ R^2 = .85$

[6] A more elaborate model which included habitat, soil type and winter temperatures might help explain more variation. Unfortunately, the habitat dispersion, soil type and temperature effects are not well enough known at this time. See Environmental Protection Agency, [6], for a summary of unknown biological dimensions.

[7] Data on treatments are probably quite accurate since private contracts are audited and compiled. Infestation data comes from county agents reports of new locations of infestations. Monitoring by state-federal entomologists determine reductions of infestations.

financial arrangements, such as how many others will pay. Also, the time period for the question is ambiguous (avoidance of one sting or all possible stings?).

Pest abatement, like other public services, probably has a downward sloping demand schedule.[8] Expenditure authorizations of local (state and local in this case) tax funds may reflect the value of IFA abatement for the median voter. Public knowledge on a wide-spread irritant like a mobile pest may be transmitted by the voting process in the long run.

Local expenditures [3] and quantity of major factors of public service production — such as public employees — have been used as measures of quantity in public service demand studies. If there are not input price differences of output per unit of input differences across observations, they can usefully serve as quantity proxy variables. An examination of 24 IFA treatment contracts for fiscal 1972 (about 95 percent of cooperative state-federal treatments in 1972) indicated constant costs per acre treated. However, the abatement service received per acre treated is likely to depend upon degree of infestation of acres treated and variables affecting susceptibility of the human population protected.

Building on the work of Borcherding and Deacon and DeBord, *et. al.* two demand models were formulated. The first, has state expenditures per capita (Y_1) as the measure of service quantity:

$$\log Y_1 = b_0 + b_1 x_1 + \sum_{i=2}^{7} b_i \log x_i + u \qquad (4)$$

It includes a price variable (price per acre treated in the previous year, X_{2t-1}) and an income variable (state per capita income, X_4). Degree of infestation (X_5) was measured by number of counties with greater than 50 percent IFA infestation as determined by an 1968 survey [11].[9] Expected future infestation level might also induce expenditures for abatement. Annual change in percent acres infested was used to measure future IFA threat (X_1). Agricultural susceptibility was measured by acres of hay in the state (X_6) and livestock numbers (X_7). Most ant mounds are established in perennial crops such as pasture or hay or in forests. Finally, local expenditures may be induced by level of federal funding available per person for IFA control (X_3).[10] All variables except price (X_2) are expected to have positive signs. Data on private substitute purchases of IFA abatement are not available.

Given that the basic production of services is similar to a Cobb-Douglas process, non-discrimination in taxation and non-discrimination in service consumption, it follows that the expenditure per capita function should also be Cobb-Douglas or estimable in linear-log form [3].[11] The data set is state observations for the 9 states in Table 1 for the 4 year period 1970-1973.

Acres treated per capita (Y_2), as an alternative dependent variable, is a measure of a major component of abatement. Others include monitoring, research, specialized quarantine activities and administration.[12] Model two has Y_2 as dependent with all other variables except change in acres infested (X_1) entering in log form:

$$Y_2 = c_D + c_1 x_1 + \sum_{i=2}^{7} c_i \log x_i + u \qquad (5)$$

As in equation (4), there is expected to be a negative price effect and a positive income effect. Federal matching grants (X_3) should have a positive effect, as should measures of agricultural susceptibility (acres of hay, X_6 and livestock, X_7). Change in infestation (X_1) and existing infestation in 1968 (X_5) should increase insecticide use if they are used as treatment criteria. If not, they should have little effect.

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[8] T. Borcherding and R. Deacon [3], have developed a general model of demand for non-federal services. See DeBord, *et. al.*, [5], for an analysis of mosquito abatement demand.

[9] All other variables are for the 1970-1973 period for which there was no complete county survey of infestation. Thus, X_5 as measured is past (t−2 to t−6) infestation level.

[10] Note that level of federal expenditure (X_3) might also depend upon availability of state matching funds (Y_1). A simultaneous equation model was estimated. There were indications of simultaneity, but specification of the political forces affecting federal expenditures was incomplete and most variables were insignificant.

[11] Except for the first difference variable, X_1, which is entered in linear form.

[12] USDA refers to inspections of interstate vehicles, international products, etc. as quarantine activities. In the previous section quarantine refers to insecticide treatments to limit the spread of the IFA.

Estimates of equations (4) and (5) are given in Table 2. Average (local and state) expenditures (Y_1) on public IFA were about 12 cents per person per year. This is much smaller than is spent for mosquito abatement in coastal mosquito districts — a mean of $1.30 in 1970 [5]. All variables have the expected directional effects on local expenditures except agricultural exposure variables, X_6 and X_7. Federal IFA expenditures (X_3), per capita income (X_4), and level of infestation (X_5), account for a significant amount of variation in Y_1. Although price (X_{2t-1}) and change in infested area (X_1) had the proper signs, and standard errors were smaller than coefficients, they were not significantly different from zero. Previous year's price (X_{2t-1}) is used for budget plans for Y_1, while current price (X_{2t}) is used for application decisions, Y_2.

Table 2. DEMAND FOR FIRE ANT ABATEMENT

Variables	Local expenditure per capita Y_1	Acres treated per capita Y_2
Constant	-20.885	-11.995
X_1 - Δ infested acres	4.14 (1.15)	1.59 (.60)
X_{2t} - treatment price	---	-.048* (1.84)
X_{2t-1} - lagged price	-.087 (1.26)	
X_3 - fed. exp. per capita	.885** (9.20)	.437** (8.02)
X_4 - state income per capita	2.48** (2.34)	1.54** (3.45)
X_5 - counties > 50% infested in 1968	.219* (1.99)	-.09* (1.92)
X_6 - hay acres	---	.208** (2.63)
N - sample size	36	35
R^2	.89	.77

*,**significant at the .05 and .01 levels, respectively.

means are

Y_1 = $.117, Y_2 = .387, X_1 = .012, X_{2t} = $.76, X_{2t-1} = $.74

X_3 = $.15, X_4 = $3261.5, X_5 = 9.78, X_6 = 615,000, X_7 = 2874,550

Elasticities of Y_2 equation are −.12 for price and +3.8 for income.

From the Y_1 equation, one can see that IFA abatement is increased by federal expenditures and personal income.[13] The matching rules of 50 percent federal-sharing of many of the IFA abatement costs seems to induce more local expenditure rather than substitute for local funds. IFA abatement expenditures appear to be very income elastic as was the case for mosquito abatement [5].

Most variables have the expected directional effect on use of insecticides for IFA control. The acreage treated per capita (Y_2) equation has a significant price coefficient while that for Y_1 did not. Perhaps the price per acre treated pertained more directly to the dependent variable Y_2 than to Y_1. Estimated price elasticity is quite inelastic, −.12 at the geometric mean. Income and federal expenditures as statistically signifcant, estimated income elasticity being 3.8. The susceptibility variable, hay acres (X_6), is statistically associated with insecticide treatments.[14] Hay acres affects per capita treatment (Y_2), but not expenditures (Y_1). This appears consistent, since agricultural constituents would favor acres of treatment, but not all expenditures.

Measures of degree of infestation do not influence use of insecticides. Change in infested acres (X_1) has no effect on acres treated, while degree of infestation seems to have an unexpected negative effect on Y_2. These behavioral responses are probably due to the fact that quantitative infestation level information is not presently used in public treatment decisions. One mound per county is as sufficient a condition for insecticide treatment as high infestation in many areas, provided local funds can be raised. Likewise, it does not seem that high rates of spread have induced additional insecticide applications.

Willingness to be taxed can be used as a rough indicator of the public's value of abatement. For the southeast, people seem willing to spend about 12 cents of state and local tax funds per person per year. This increases with income levels, federal grants and degree of infestation.

Acres treated with insecticides for IFA control have averaged about .4 per capita over the past four years. States with more hay, income and federal support are treating more acreage. In

[13] The .885 coefficient of federal expenditures increases to 1.09 and the income coefficient is 4.05 for the simultaneous model mentioned in footnote 1, on page 9.

[14] Cow numbers, X_7, was dropped from both models because of high correlation with hay acres.

many counties, treatments fall with price and high levels of infestation.

IMPLICATIONS FOR IFA ABATEMENT POLICY

Several insecticides are capable of killing fire ants. However, large-scale quarantine efforts have not been associated with reduced rate of IFA spread, except along extreme northern boundaries of the current areas of habitation. **Publicly financed applications of mirex bait, other than in these northern areas, should be based on criteria other than the control of a mobile pest.**

Economies of scale is another justification for large-scale (but not necessarily public) abatement. As noted earlier, contract costs were approximately constant per acre over the 5 to 1500 thousand acre range in 1972. However, **large-scale treatment can result in treatment** of many uninfested acres. No minimum number of mounds per acre — or presence of suitable habitat — are required prior to initiation of treatment in the federal-state IFA program. A USDA survey of the USDA-state IFA program in 1972 found that about 29 percent of the acreage treated had no IFA mounds present at the time of treatment [12]. Thus, costs of aerial treatment per mound abated were 29 percent higher than previously believed.[15]

Private IFA suppression costs may be relatively low. An EPA study has estimated that ground application of pastures and fields which are normally traversed by tractor (such as for pasture seeding or fertilizing) could apply mirex per mound at a lower private than public cost (Environmental Protection Agency, 1973). If monitoring for mounds can be conducted as a **joint product of other private and local government activities, this would further lower the cost per mound treated. Local citizens paying** a high percentage of IFA control costs should encourage judicious use of chemicals, thereby reducing adverse side effects of mirex.

Demand for IFA abatement may vary from area to area. Several USDA, medical and other surveys [6] and [7], have indicated the medical and human health importance of IFA abatement. The demand analysis above is on a per person basis. The more people present, the higher the value of abatement per unit area. Contrarily, USDA-state IFA abatement efforts have been concentrated in sparsely settled areas. Major southern towns have not been treated. Some cities cannot be treated because they are near water. These areas are restricted from aerial application of mirex by label restrictions of the federal pesticide law, which does not permit aerial application in coastal counties or near large bodies of water. These untreated areas can serve as sources for further infestations.

Private IFA control efforts have increased even with the presence of public programs. Sales of mirex in types not formulated for sales to USDA (all but 2X and 4X) have increased from .441 to 1.050 million pounds from 1970 to 1972 [1]. This increase may be a reflection of the private demand not being fulfilled by the **federal-state IFA programs.**

The presence of variability in density of pests and in susceptibility of humans is a necessary condition for unequal provision of abatement service. Unequal demands need to be balanced against large-scale equal treatments for spread prevention in selecting a control strategy. Local abatement districts or private abatement can probably meet unequal demands better than federal agencies. Federal agencies have a role at **some IFA infestation boundaries to reduce spread. Each agency must attempt to use monitoring and treatment resources to equate marginal social returns and costs.**

[15] Some small amount of spread reduction may occur when uninfested areas have active insecticides for new colonies to feed on. However, the usual practice is to treat mounds not land to suppress the pest level and to prevent spread.

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