REGULATION AND FIRM SIZE, FOREIGN-BASED COMPANY MARKET PRESENCE, MERGER CHOICE IN THE U.S. PESTICIDE INDUSTRY

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CES 94-6   June 1994

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Abstract

This paper uses Two-Stage Least Squares to examine the impact of pesticide product regulation on the number of firms and the foreign-based company market share of U.S. Pesticide Companies. It also investigates merger choice with a multinomial logit model. The principal finding is that greater research and regulatory costs affected small innovative pesticide companies more than large ones and encouraged foreign company expansion in the U.S. pesticide market. It was also found that the stage of the industry growth cycle and farm sector demand influenced the number of innovative companies and foreign-based company market share. Finally, firms that remain in the industry were found to have greater price cost margins, lower regulatory penalties costs, and a much greater multinational business presence than those that departed.

Keywords: Pesticide Industry, regulation, firm size, multinational companies

Special thanks go to Robert McGuckin, Sang Nguyen, Arnie Reznek, David Ryan, and Robert Bechtold. Any findings, opinions, or conclusions expressed here are those of the authors and do not necessarily reflect the views of either the U.S. Census Bureau or the U.S. Department of Agriculture. The authors are economists at the U.S. Department of Agriculture and gratefully acknowledge the help and assistance given by the Center for Economic Studies in their research effort.

I. INTRODUCTION[1]

Many economists have examined the impact of Food and Drug Administration (FDA) regulation on the pharmaceutical industry. Less attention has been given to how Environmental Protection Agency (EPA) regulation may have affected the pesticide industry. In particular, how it may have influenced the existence of the number of innovative pesticide companies, foreign-based company U.S. market share, and merger choice. Some historical data suggest that a linkage may exist between regulation and the number of innovative pesticide companies and foreign-based company U.S. market share. As the costs of environmental testing rose from about 17.5% to 45.5% of total research costs over the 1972-89 period, the number of innovative pesticide companies dropped from 33 to 19 and the U.S. market share held by foreign-based companies rose from 18% to 43%. Much of the structural change came as major pesticide companies sold their operations to even larger companies. Among the most newsworthy combinations were the sales of the pesticide divisions of Shell, Stauffer, and Union Carbide to DuPont, ICI, and Rhone Poulenc. Companies with smaller pesticide operations, such as PPG, Mobil, and Pennwalt, were even

[1] This paper contains some illustrative data on individual companies. These data are from publicly available sources. Printing them here does not violate the Census Bureau's legal requirement (under Title 13 U.S. Code) not to disclose data from individual respondents to the Census Bureau's Censuses and surveys. Further, these companies are not necessarily included in the sample of companies used to estimate the econometric models presented in this paper. Census Bureau data are used to estimate these models.

more affected. The number of these small pesticide operations dropped from 16 in 1972 to 6 in 1989 (Table 1).

Some clues to the impact of regulation on market structure comes from studies of the pharmaceutical industry. Thomas (1990) found that FDA regulation of the pesticide industry affected small imitative companies more than larger innovative firms. As a result, firm rank by sales remained stable over the 1960-80 period. In the pesticide industry, however, domestic firm pesticide sales rankings were not stable. Five of the top ten 1974 domestic producers no longer sold pesticides by 1989 and the number of foreign-owned companies in the top ten rose from one to four. Moreover, on a worldwide basis, one company no longer makes pesticides, another dropped out of the top ten, and none retained their rankings between 1981 and 1991 (SRI International). Aside from Thomas (1990), Pashigian (1984) and Bartel and Thomas (1987) have given considerable attention to the differential effects of regulation. Pashigian (1984) and Bartel and Thomas (1987) found that OSHA regulation favors large firms and factories over small ones and union over nonunion workers.

The purpose of this paper is to examine how regulation affected the total number of firms, the number of large and small firms, foreign-based company market share, and merger choice in the U.S. Pesticide Industry. Extending the concept of interaction between size and regulation, we hypothesize that pesticide regulation affected the domestic pesticide industry to such an extent that it encouraged consolidation and the expansion of foreign-based company market share in the U.S. Pesticide industry. The firms that remain are the most efficient innovators and those most able to cope with a more stringent regulatory environment.

In the next section, we present necessary background information on pesticide regulation and industry changes. In Section III, we present reduced form empirical models of the number of pesticide companies and foreign-based company market share of the U.S. Pesticide Industry. We discuss a multinomial logit model of merger choice in Section IV. Section V contains variable definitions, data description, and the estimation procedures. The empirical results are reported and discussed in Section VI. The last section concludes the paper.

II. PESTICIDE REGULATION AND INDUSTRY CHANGES

Pesticide regulation in its modern form began with the enactment of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1948. Under this mandate, Congress required that all chemicals for sale in interstate commerce be registered against the manufacturers' claims of effectiveness. The law also required manufacturers to indicate pesticide toxicity on the label. Congress added amendments in 1954, 1959, and 1964, but, in practice, pesticide regulation by 1970 meant efficacy testing and labeling for acute (short term) toxicity.

Pesticide regulation passed into a new era at the end of 1970, with the transfer of regulatory jurisdiction to the EPA, and the 1972 amendment to FIFRA. Under this new regulatory regime, Congress gave the EPA the responsibility of reregistering existing pesticides, examining the effects of pesticides on fish and wildlife safety, and evaluating chronic and acute toxicity. At the same time, efficacy criteria were de-emphasized.

Implementation of the 1972 FIFRA mandate came about gradually. The physical change in jurisdiction and staffing at the EPA involved the transfer of people from the USDA and the FDA. Thus, many of the early testing procedures were based on what these regulators had done previously. More significantly, ambiguities existed in the 1972 amendment with clarification not forthcoming until the 1978 amendment to FIFRA. Moreover, it was not until 1982 that the EPA finalized field testing guidelines.

Current field test requirements can include up to 70 different types of tests that can take several years to complete and cost millions of dollars. They consist of toxicology studies, a two generation reproduction and teratogenicity study, a mutagenicity study, oncogenicity studies, and chronic feeding studies. The toxicology studies include acute (immediate), subchronic (up to 90 days), and chronic (long term) effects. Other tests are used to evaluate the effects of pesticides on aquatic systems and wildlife, farm worker health, and environmental fate. Staffing levels reflect growing EPA regulatory requirements. It took an average of 54.2 EPA pesticide division employees to approve each new pesticide during the 1972-75 period. The labor requirement rose to 91.4 pesticide division employees to approve each new pesticide by the 1986-89.[2]

The EPA considers chemical pesticides as toxic substances and thus The Clean Air Act of 1970, Clean Water Act of 1972, the Resource Conservation and Recovery Act of 1976 (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) apply to producers. The Clean Water Act and the Clean Air Act mandated limits on the discharge of pollutants and specified the type of equipment necessary for compliance. RCRA specified how organizations should contain and dispose of toxic substances. Superfund legislation stipulated who pays for existing toxic dump sites and established a trust fund to use for dump site clean-ups.

The stage in the growth cycle of the pesticide industry and the economic outlook of the farm sector also changed significantly over the 1972-89 period. Between 1966 and 1976, sales of herbicides, the most commonly used type of pesticide, rose from 101 million pounds of active ingredient (a.i.) to 373.9 million pounds of a.i. By 1982 herbicide sales increased to 455.6 million pounds and then rose to only 478.1 million pounds by 1992 (Osteen and Szmedra, 1989; Delvo, 1993). In terms of acres treated,

[2] Based on the number of new products [Aspelin and Bishop, 1991] and employment levels at the Pesticide Division of the EPA.

farmers applied pesticides to almost 95% of their corn, cotton, and soybean acreage by 1982.

After rising during the 1970's, farm sector demand for inputs dropped during the 1980's as farm exports stabilized and farm surpluses encouraged congress to provide incentives to farmer to reduce their planted acreage. From 1970 to 1982 American total grain production rose from 187 to 332 million metric tons. By 1989, however, production dropped to 283.7 million metric tons. In addition, future prospects for farm prosperity also declined as changes in the 1985 and 1990 Farm Bills made the reduction of farm subsidies a policy goal. Reflecting these changed circumstances, farm real estate values dropped to $215 billion in 1989 from $304 in 1982 (United States Department of Agriculture, 1974 and 1991).

III. THE NUMBER OF INNOVATIVE PESTICIDE COMPANIES AND FOREIGN-BASED COMPANY MARKET SHARE.

Below, we consider two reduced form empirical models concerned with the affect of regulation on the number and type of companies in the U.S. Pesticide Industry. First, we present a model of the impact of regulation on the number and size distribution of pesticide firms. Next, we discuss a model of the effect of regulation on the market share of the U.S. Pesticide Industry held by foreign-based companies.

A number variables may affect the number and size distribution of pesticide firms. Baily (1972) argued that firms deplete research opportunities over time because the stock of possible innovations at any given level of basic science is limited. Advancements beyond any existing level requires expenditures on basic research. Hence, as research opportunities diminish at one level of science, firms must invest in both applied and basic research. As a result, research costs may rise.

Greene, et al. (1976) suggested that research opportunities are declining in the Pesticide Industry. They also show that the probability of developing a successful pesticide is dropping. Finally, they asserted that large multinational companies can better bear the higher research costs and greater risks of this product development environment because they have diverse earnings streams and can market new products in a larger number of geographic markets. Hence, rising research costs should affect smaller companies more than larger ones.

Exogenous factors that may affect the number of pesticide firms and their size distribution include pesticide product and manufacturing effluent regulation and the stage of the industry growth cycle. As discussed earlier, Thomas (1990) found that product regulation in the pharmaceutical industry adversely affected small firm productivity but had little impact on large companies. Bartel and Thomas (1987) found that OSHA regulation benefitted large companies at the expense of smaller ones. Extending these findings to worldwide company size, product regulation should negatively affect the survival of smaller firms more than larger ones.

Pashigian (1984) found that environmental regulation of production facilities favored large factories over small ones and capital over labor. Unclear is whether pollution regulation favors larger firms over smaller ones. Census data indicates that companies in the pesticide industry are also major producers of other chemicals. Thus, small pesticide companies may have large factories and actually benefit from environmental regulation.

Numerous economists have discussed the stage of the industry growth cycle. Klepper and Graddy (1990) contend that considerable uncertainty exists about market demand in the initial stages of industry evolution. They also assert that some firms may make misguided investments while others will meet market needs. Hence, uncertainty about market demand can lead to initial overinvestment and an eventual industry consolidation. Accordingly, the number of firms in an industry depends on the stage of the industry growth cycle.

If industry upturns encourage firm entry and downturns induce exits, then farm sector demand should also affect the composition and number of firms in an industry. Liebermann (1990) contends that small firms are the most likely companies to exit under declining demand conditions. Thus, farm sector demand should positively affect the number of innovative companies and may impact small firms more than large ones.

A. Empirical Model of the Number of Innovative Pesticide Companies

The foregoing discussion leads us to the following reduced form model of the number (N_t) of innovative pesticide companies.

(1) $$N_t=\$_1+\$_2LRDSALE_t+\$_3ALLREG_t+\$_4LPOLLUTE_t+\$_5LSTAGE_t+\$_6LRESTATE_t+,_t$$

where $LRDSALE_t$, $ALLREG_t$, $POLLUTE_t$ denote one-year lag of Research & development/sales ratio, a pesticide regulation variable, and pollution compliance costs, respectively. $LSTAGE_t$ denotes one-year lag of the stage of the industry growth cycle, whereas $LRESTATE_t$ represents one-year lag of farm sector demand. Detailed description of these variables is presented in Section V.

As indicated above, large companies have more product and geographic diversification and thus may be better able to bear the risks of product development than small firms. Thus, research and regulatory costs should negatively affect the total number of companies and have a larger impact on small firms. Also as indicated earlier, an uncertain relationship exists between pollution control costs and the number of innovative companies. In addition, the stage of the industry growth cycle should positively affect the number of pesticide companies if firm entry occurs at the beginning of the growth cycle and firm exit occurs as the industry matures (Gort and Klepper, 1982). Finally, farm sector demand should positively impact the number of innovative companies if better farm sector economic conditions encourages firm entry and discourages exit.

B. Empirical Model of the U.S. Pesticide Market Share of Foreign-Based Companies

Greene, Hartley, and West (1976) suggest that only large multinational companies can cover the research and regulatory expenses associated with pesticide product development. Therefore, foreign-based multinational companies may wish to expand their U.S. marketing presence to complement their existing research efforts.

We use the following reduced form model to examine the causes of the growth of foreign-based firm U.S. market share ($FORSHARE_t$).

$$(2) \qquad FORSHARE_t = \beta_7 + \beta_8 LRDSALE_t + \beta_9 ALLREG_t + \beta_{10} POLLUTE_t + \beta_{11} LSTAGE_t + \beta_{12} LRESTATE_t + \varepsilon_t$$

If geographic diversification enables firms to spread the costs and risks of research and regulation, then a positive relation should exist between research and regulatory costs and foreign-based firm U.S. market share. Pollution control costs may positively or negatively affect foreign-based company market share because plant size may or may not correspond to firm size. The stage of the industry growth cycle should positively influence foreign-based firm market share if firms tend to enter new markets only after becoming established in their home market. Finally, industry demand should negatively affect foreign-based company market share if foreign-based firms enter the U.S. market because they are highly successful and thus better able to withstand market changes than their domestic competitors.

IV. EMPIRICAL MODEL OF MERGER CHOICE

Industry consolidations often generate concern over the underlying motives of acquiring companies. Of particular concern is whether acquirers merge with other companies to gain market power. Also of interest is how the economic environment may have changed to cause some firms to exit the industry and others to grow and prosper.

Klepper and Graddy [1990] believe that firms that remain in an industry after it consolidates are those companies with the lowest production costs and highest product qualities. Regulatory costs can also affect firm survival because special skills may be required to avoid environmental penalties.

Firms that cannot survive an industry consolidation may merge with another company as a way to realize value from their assets. Potential acquirers place different values on the assets, however. It may be that a company feels that it can gain market power through an acquisition. Alternatively, a firm may see a merger as an efficient way to gain complementary capabilities, if these companies lack some resources.

The prior discussion leads to the following empirical model of merger choice ($MERGE_{it}$).

(3) $$MERGE_{it}=\beta_{13}+\beta_{14}PRICCOST_{it}+\beta_{15}EPACOST_{it}+\beta_{16}WRLDSALE_{it}+\beta_{17}USSHARE_{it}+\varepsilon_{it}$$

where $PRICCOST_{it}$ is profitability; $EPACOST_{it}$ is firm regulatory costs; and, $WRLDSALE_{it}$ is world pesticide sales. Finally, $USSHARE_{it}$ is U.S. market share. Note, $MERGE_{it}$ is set equal to 2 if the firm is an acquirer, 1, if the firm makes no transaction, 0 if the firm is being acquired.

If higher profitability positively influences and greater regulatory compliance costs negatively affects the decision to merge, then the coefficient on $PRICCOST_{it}$ should be positive and the coefficient on $EPACOST_{it}$ should be negative. If acquirers make transactions as a way to gain market power in the U.S. market, one would expect an uncertain relation between world sales and merger choice and a positive relation between merger choice and U.S. market share. Alternatively, foreign-based firms may view the assets of some existing companies as complements to their worldwide operations and as a less costly way to develop new capacities than internal development. As a result, world sales should positively affect merger choice and U.S. market share should have a negative impact.

V. VARIABLE DEFINITIONS, DATA AND ESTIMATION

A. Variable Definitions:

The number of innovative (N_t) firms includes only those companies that conducted agricultural research during the 1972 to 1989 period. From this set of firms, we retained all companies that introduced pesticides. We also kept companies that were ranked among the top twenty in sales in at least one year over the 1972-89 period but failed to introduce new products. Some of these firms had introduced products during the 1960's and others entered the industry through mergers. All other firms were assumed to be not affected by pesticide regulation and were dropped.

We define foreign-based company market share ($FORSHARE_t$) as the sum of U.S. market shares held by foreign-based companies. We define foreign-based companies as those firms with central offices outside of the United States.

The independent variables of Equations 2 and 3 are in lagged form because we assume that entry (exit) decisions are based on prior year beliefs about the state of the economy. We use the lag of the research to sales ratio ($LRDSALE_t$) to capture the relative cost of research and development. If this ratio rises, then research costs are growing faster than revenues and companies may be less able to cover research costs.

Regulation affects firm choices over several years. Sharp (1986) indicates, for example, that the product commercialization decision is reached about three years into an eleven year product development cycle. Hence, a new product can be withdrawn for regulatory reasons at any point beginning at eight years prior to pesticide registration. Moreover, the lag from the time when legislation is passed by Congress until it is fully implemented extends this period. As a consequence, we assume that lagged regulatory costs affect the firm exit choice.

Pesticide research and development includes expenditures for environmental and health effect tests. Spending for these types of tests as a fraction of research and development expenditures should increase as pesticide regulation becomes more stringent. Hence, we define pesticide regulation ($ALLREG_t$) as the four year moving average of the ratio of expenditures for environmental and health testing purposes to total research expenditures.

Capital expenditures include the costs incurred for accommodating pollution regulation and reflects current and anticipated business plans. If environmental regulation deters entry, it may act through the required cost of capital because some economists (Orr, 1974; Mata, 1993) view this cost as a deterrent to entry. Hence, we define pollution compliance costs ($POLLUTE_t$) as the ratio of capital expenditures for pollution abatement equipment to industry sales. As a measure of the stage of the industry growth cycle ($LSTAGE_t$), we use the lag of the capital expenditures to sales ratio. Relatively high levels of capital expenditures should reflect a period of relative growth and low levels a time of industry maturity because the early stage of industry growth is characterized by overinvestment.

Conley and Simon (1992) believe that real estate values accurately reflect farm sector wealth. They also show that it acts as a measure of long-term farm sector demand for tractors. Real estate values are particularly well suited for our study because firm entry and exit decisions, like farmer investment decisions, depend on a long run assessment of farm sector economic conditions. Moreover, real estate values may be less influenced by temporary government farm programs because they reflect current and future farm subsidies. Thus, we define farm sector demand for pesticides as lagged real estate values ($LRESTATE_t$).

Now consider the variable definitions for Equation 3. We define merger choice ($MERGE_{it}$) as two for an acquiring company *i* in year *t*, one for status quo firms *i* in year *t*, and zero for a company *i* that merged into another firm in year *t*. Note, that we define *t* as the years in which at least one merger of pesticide companies occurred. Also, we define status quo companies as firms that made no acquisitions throughout the study period. We include acquired and acquiring companies only in the years in which they make a transaction. We include status quo companies every year that a transaction takes place.

The margin between prices and costs reflect both the ability of the firm to command a high price (product quality) and the ability of the firm to control operating costs. Yet, it may be that firms have high margins but also have costly research operations. Hence, we use price cost margins adjusted for the research to sales ratio ($PRICCOST_{it}$) as a measure of firm profitability.

We define price cost margin as follows:

$$(5) \qquad PRICCOST_{it}=((VALADD_{it}-COST_{it})/VALADD_{it})-(RD_{it}/SALES_{it})$$

where $PRICCOST_{it}$ equals the price cost margin; $VALADD_{it}$ equals the total value of shipments plus the end of year inventory minus the beginning of the year inventory minus the cost of resales; $COST_{it}$ includes building rental payments, fuels, materials, purchased communication, purchased electricity, contract work, machinery depreciation, salaries and wages, plus beginning of period materials and work in process minus end of year materials and work in process; RD_{it} equals research and development expenditures; and, $SALES_{it}$ is company sales.

Regulatory costs include fines levied by the EPA for particularly egregious violations of environmental standards. It also includes lost sales of pesticides banned by the EPA because of their potential harm to either human health or the environment. We define $EPACOST_t$ as

$$(6) \qquad EPACOST_{it} = \frac{\left(\sum_{z=72}^{z=t} EPAFINE_{iz} + \sum_{z=72}^{z=t} LOSTSALE_{iz}\right)}{SALES_{it}}$$

where $EPACOST_{it}$ is regulatory costs for firm *i* in year *t*, $EPAFINE_{iz}$ is EPA fines levied on firm *i* in year *z*, $LOSTSALE_{izj}$ is sales lost by company *i* in the year *z* that product *j* was banned, and $SALES_{it}$ is defined as sales by firm *i* in the year *t*. For all companies that merged, year *t* is their merger year. For companies that do not merge, it is any year in which at least one merger occurs. See Table 2 for a complete list of mergers.

We define world sales $WRLDSALE_{it}$ as world pesticide sales and U.S. market share $USSHARE_{it}$, as U.S. sales divided by U.S. industry sales.

B. Data

Our data came from several sources. Data on firms conducting agricultural research come from the Survey of Research and Development at the Census Bureau and Kline and Company data from EPA. We use Kline and Company industry survey data to determine whether a firm was ranked in the top twenty in sales. We employ Aspelin and Bishop (1991) to determine companies that registered new pesticides.

Data on firm existence in the pesticide industry come from several sources. We use Eichers (1980) to determine if a company existed in 1967. If not, we assume the entry year to be either the first year in which the company reported research and development expenditures at the Census Bureau, the first year in which it registered a new product, as reported in Aspelin and Bishop (1991), or the first year in which it appeared in Kline and Company data (1974-89), whichever came first. We assumed exit years to be the year in which a company sold its agricultural chemicals business or the last year in which a company reported research and development expenditures at the Census Bureau.

We based company size on a sales ranking of companies according to 1972 world sales. Companies that entered the industry after 1972 had no sales and were thus identified as small companies. Sales rankings and worldwide sales for ($WRLDSALE_{i,t}$) comes from SRI International and the Kline and Company. Table 2 contains sales rankings in 1972 and significant mergers between 1972 and 1989.[3] Company domicile comes from Moody's Industrial Manuals.

The foreign share of U.S. sales ($FORSHARE_t$) and U.S. market share ($USSHARE_{it}$) are based on Kline and Company data and the value of domestic production computed from the Product File at the Census Bureau. The Kline and Company data give U.S. and worldwide pesticide sales estimates for all domestic companies and U.S. sales for foreign-owned companies. These reports are available over the 1974-89 period. The Product File contains value of

[3] See Footnote 1.

production data for single products defined at the five digit SIC level and miscellaneous production data. Neither the Kline and Company data nor the Product File data give true values of U.S. pesticide sales because the Kline and Company data are based on farmer surveys and value of production contains exported shipments and does not contain imported chemicals.

We developed estimates of U.S. sales in the following way. First, we computed the value of domestic production from Census Bureau product file SIC 28694 and SIC 2879 over the 1972-89 period. We assumed that the Census data reflect U.S. sales if values of pesticide production are greater than the Kline and Company data minus $20 million and less than the Kline and Company estimate plus $20 million. We assumed that pesticides are either exported or imported and used Kline and Company data if Census data were not within these limits. After making these adjustments, we computed industry sales. The estimates are consistent with industry sales data reported by the National Agricultural Chemicals Association (NACA). Finally, we computed both the share of the U.S. market held by foreign based companies and U.S. market share with this data.

Industry sales and research expenditures for the 1971-89 period and research costs for small and large companies for the 1977-89 period came from an annual industry survey conducted by NACA from 1971 to 1989 and Klein company data. Environmental and health test costs also came from the NACA survey.

Capital expenditures for computing $POLLUTE_t$ comes from the Census Bureau publication entitled *Pollution Abatement Costs and Expenditures - Current Industrial Reports*. Industry capital expenditures for the computation of $LSTAGE_t$ comes from the Census Bureau files of industry capital expenditures. Lagged real estate values ($LRESTATE_t$) comes from the *Agricultural Statistics Handbook*.

Merger data for $MERGE_{it}$ came from Kline and Company and various *Wall Street Journal Indexes.* Table 2 contains a list of pesticide company mergers.

We use the Longitudinal Research Database, the Survey of Research and Development, and U.S. sales data from SRI International and Kline and Company to compute firm price cost margin adjusted for research intensity. The Longitudinal Research Database contains over 100 factory-specific responses to survey questions on from 55,000 to 70,000 establishments for each year from 1972 to 1988. The sample size and reporting variables varies according to the survey mandate.

The Survey of Research and Development at the Bureau of Census includes information on total research and development spending, research costs by industry, state, and type, and other research related questions. We use research for agricultural chemicals as our measure research. Because data are missing in some years, we supplement these data with Annual Report data and Kline and Company data. If data are not of a sufficient level of detail, we estimated research and development expenditures based on total firm research for the surrounding years.

The cost of fines levied against pesticide companies came from various *Annual Reports*. A complete listing of banned products came from Dr. Kent Smith at the Pesticide Assessment Laboratory of the Agricultural Research Service of USDA. We defined lost sales due to regulatory action as the sales of a banned product in its last year prior to its banishment.

C. Estimation

According to Zellner (1962) and Dwivedi and Srivastava (1978) Seemingly Unrelated Regression (SUR) techniques are not necessary for the case in which regressors are the same across all equations and there are no theoretical restrictions for the regression coefficients. They show that the matrix is the same and single equation estimation yields the same results as SUR methods. Hence, we estimate Equations 1 and 2 separately. Additionally, we do not include Equation 3 in a system because it covers a different time period than the other two equations and is based on firm-level rather than industry data.

We first use Ordinary Least Squares adjusted for autocorrelation for the regressions of the factors influencing the number of firms (Equation 1) and foreign-based company market share (Equation 2). Tables 2 and 3 indicate the need for adjustment for autocorrelation for both regressions. For the foreign-based company market share model, we checked our results with a "two-limit" tobit because the regression is bounded between zero and one (Maddala, 1984). Results are similar to that of the OLS adjusted for autocorrelation model because the limits are not binding. We do not report the results.

Next, we used Two Stage Least Squares to avoid inconsistent estimates of the parameters in Equations 1 and 2. It is necessary to purge the research term of its dependence on regulation and other factors because research spending is affected by pesticide product regulation, which requires a number of toxicology studies and extensive field testing data. We employed all exogenous variables and new pesticide product sales as a fraction of industry sales as instruments. For the small and large firm research to sales ratios, we also used the industry research to sales ratio as an instrument. Results were also adjusted for autocorrelation.

In the merger choice model (Equation 3), we used a multinomial logit approach because there are three types of firms in the industry. They include companies that buy another, those that are bought, and those that are involved in no transactions. We include firms that make no transactions in every year of the study period and acquiring and acquired companies only in the year in which they are involved in a transaction. We report the chi-square (P^2) statistic in Table 5.

VI. RESULTS

We report both Ordinary Least Squares and Two Stage Least Squares estimates of Equation 3 in Table 3. The results indicate that rising research intensity and regulatory costs had a strong adverse effect and the stage of the industry growth cycle and farm sector demand had a positive bearing on the number of innovative companies. Pollution costs had no influence.

Splitting the sample into the largest and smallest firms by 1972 world sales reveals some similarities and differences. Regulation adversely affected both groups and the stage of the industry growth cycle and farm sector demand had a positive impact on both large and small firms.

Pairwise tests of the coefficients (Maddala, 1977, pg. 136) suggests that regulation more negatively affects small companies than large ones in both the Ordinary Least Squares and Two Stage Least Squares regressions. Significant differences also existed for the stage of the industry growth cycle in the OLS regression and the research to sales ratio for the Two Stage Least Squares approach.

Notice the consistency of the OLS and Two-Stage Least Squares estimates. Other than research and development expenditures for small companies, no coefficients become significant in the Two-Stage Least Squares that were not significant under OLS. Particularly noteworthy is the consistency of the magnitude of the regulation term coefficient.

The Ordinary Least Squares and Two Stage Least Squares results of the foreign-based company market share regression are reported in Table 4. We found that foreign-based company expansion in the U.S. market was positively influenced by rising research intensity and regulation; and, negatively affected by the stage of the industry growth cycle and farm sector demand. Contrast these results with those for small firms (Table 3), we find that the factors that caused small firms to exit the market are those that allowed foreign-based companies to expand their market presence. For example, for every 3% increase in regulatory costs, one small company exits the industry and foreign-based companies expand their U.S. market presence by about 2%.[4]

We ran three slightly different variations of both the OLS and Two-Stage Least Squares models. Significance levels do not change under any model specifications. As with the model of the number of pesticide companies, the magnitude of the coefficient for the regulation term is consistent for identical OLS and Two-Stage Least Squares models.

We present the results of the merger choice model in Table 4. Compared to other firms, acquiring companies had higher price cost margins, lower regulatory costs, large world sales, and a

[4] Regulatory variables with different lag structures and other measures of farm sector demand, such as farm assets, affected the results in a similar way. We also used a four year moving average of employment at the pesticide division of the Environmental Protection Agency as a measure of regulatory enforcement. These results are available from the authors.

relatively small U.S. market presence. Industry growth and several farm industry demand variables were not significant and dropped. Of primary interest is the negative influence of regulatory costs on the merger choice. Hence, the skills required to avoid regulatory costs are vital to firm survival in the pesticide industry. To examine the robustness of this finding, we constructed two variations of the reduced form model. The magnitude of the coefficient and level of significance do not change for price cost margins or regulatory costs under these alternative specifications.

Notice how the results of the merger choice model correspond with those of foreign-based company market share. Firms with a large world but small U.S. presence tended to acquire domestic American companies. The companies that remain are those firms best able to compete in a more stringent regulatory environment. Note also that merger activity did not significantly affect the competitive balance of the industry. Four and eight firm concentration ratios changed little over the 1972-89 period (Table 1). Moreover, four firm concentration ratios for individual pesticide products - herbicides, insecticides, and all other pesticide markets - declined.

VII. CONCLUSION

This paper examines the impact of pesticide product regulation on the number of companies, foreign-based company market share, and merger choice in the U.S. Pesticide Industry. Results indicate that regulatory costs adversely affected the number of companies in the industry, negatively affected small companies more than large ones, encouraged foreign-based company expansion in the U.S. market, and affected firm merger choice. The results also suggest that relative profitability and foreign-based companies wishing to expand their U.S. operations also influenced merger choice.

The results of this paper are consistent and yet different from previous studies of regulation (Pashigian, 1984; Bartel and Thomas, 1987; Thomas, 1990). They are similar in that the effects of regulation were shown to vary for different industry groups. Like Thomas (1990), we found that product regulation adversely affected small firms more than large ones. Our results differ in that this is the first study of pesticide product regulation. More generally, we showed that product regulation adversely company existence and that it affected small company existence more than large firms. Additionally, the results suggest that regulation allowed foreign-based companies to expand their U.S. market share. The results also correspond with Klepper and Graddy (1990) who believe that industry and consolidation results in the exit of the least efficient companies.

One ironic note concerns current legislative efforts to ban the export of the U.S. production of nonregistered pesticides. Our findings suggest that such legislation may be ineffective because regulation has encouraged foreign-owned companies to expand into the U.S. Consistent with this activity is the expansion by U.S. firms into overseas markets (Table 1). Since both foreign and U.S. firms have much of their manufacturing capacity overseas, they can shift production to these facilities if production is banned in the U.S. Hence, pesticide product regulation may hinder efforts to satisfy other legislative demands.

Table 1

Number of Pesticide Firms by Company Size and the U.S. Market Share of Foreign Owned of the U.S. Pesticide Industry, 1972-89[1]

Year	All Firms	Small Firms	Large Firms	Four Firm Concen-tration Ratio	Eight Firm Concen-tration Ratio	Foreign Firm U.S. Market Share[2]	Percent U.S. Firm Production Abroad[3]
1972	33	16	17	0.496	0.795	0.18	n.a.
1973	34	17	17	0.501	0.786	0.16	n.a.
1974	34	17	17	0.484	0.764	0.20	0.23 (0.54)
1975	36	18	18	0.487	0.756	0.20	0.18 (0.53)
1976	36	18	18	0.478	0.758	0.21	0.25 (0.56)
1977	36	18	18	0.441	0.712	0.20	0.25 (0.56)
1978	36	18	18	0.421	0.684	0.22	0.17 (0.55)
1979	36	18	18	0.407	0.675	0.21	0.20 (0.54)
1980	34	16	18	0.394	0.657	0.21	0.25 (0.60)
1981	34	16	18	0.378	0.633	0.21	0.24 (0.60)
1982	33	15	18	0.372	0.626	0.21	0.29 (0.64)
1983	32	14	18	0.392	0.644	0.21	0.33 (0.64)
1984	29	10	19	0.402	0.646	0.23	0.25 (0.56)
1985	28	9	19	0.385	0.613	0.28	0.31 (0.64)
1986	27	8	18	0.380	0.616	0.29	0.32 (0.62)
1987	23	8	15	0.454	0.712	0.36	0.33 (0.64)
1988	23	8	15	0.466	0.743	0.38	0.30 (0.55)
1989	19	6	13	0.483	0.775	0.43	n.a.

[1] Companies in the sample introduced at least one new product over the 1972 to 1989 period or were among the top twenty companies is size. The starting date is either the first year in which a company has sales in the top twenty for U.S. pesticide sales or four years prior to their first new product as reported in Aspelin and Bishop [1991].
[2] Share of production includes the production of foreign owned plants in the U.S. plus imports into the U.S. market by foreign owned companies.
[3] Percentage of sales by U.S. based firms that is produced overseas is in parentheses.

Source: See Section B.

Table 2

Listing of Pesticide Firms, Years Active in Industry, and Major Mergers, 1972-89
(Size ranking based on worldwide sales)

Largest 19 Firms [1]	Years	Smallest 19 Firms	Years	Firm Mergers [2]	Year
American Cyanamid	1972-89	Abbott	1972-83	Shell/DuPont	1986
BASF	1972-89	Buckman	1972-79	Gulf/Chevron	1984
Chevron	1972-88	D. Shamrock	1972-87	Union Carbide/ Rhone Poulenc	1986
Ciba-Geigy	1972-89	Fermenta	1984-89	PPG/Chevron	1989
Dow	1972-89	FMC	1972-89	Lilly/Dow	1989
DuPont	1972-89	Gulf	1972-84	Mobil/Rhone Poulenc	1981
Hoechst	1975-89	Hercules	1972-84	Pennwalt/Elf Aquatane	1989
ICI	1972-89	Hoffman LaRoche	1975-83	Rorer Amchem/ Union Carbide	1977
Lilly	1972-88	Merck	1972-89	Occidental/Sandoz	1983
Mobay	1972-89	Mobil	1972-81	Velsicol/Sandoz	1986
Monsanto	1972-89	Occidental	1972-83	Upjohn Chem/ Schering	1985
Rohm and Haas	1972-89	Pennwalt	1972-88	Hercules/Schering	1984
Rhone-Poulenc	1972-89	Phillips	1972-82	Stauffer/ICI	1985
Sandoz	1972-89	PPG	1972-88	D. Shamrock/ Fermenta	1985
Schering	1984-89	Sumitomo	1972-89	Celenese/Hoechst	1987
Shell	1972-86	Uniroyal	1972-89	Alpine Labs/ Uniroyal	1979
Stauffer	1972-85	Upjohn	1972-89	Phillips/Uniroyal	1982
Union Carbide	1972-86	U.S. Borax	1972-79	Gustafason/Uniroyal	1982
Velsicol	1972-86	W.R. Grace	1972-83	Olin/Uniroyal	1983
				Chevron/Sumitomo	1989

[1] No Census Bureau data appears in this table. Firms in this table are not necessarily used in the econometric analysis. See Footnote 1.

[2] Companies in the sample introduced at least one new product over the 1972 to 1989 period or were among the top twenty companies is size. The starting date is either the first year in which a company has sales in the top twenty for U.S. pesticide sales or four years prior to their first new product as reported in Aspelin and Bishop [1991]. Four years are assumed because average product development time was about nine years as reported by the National Agricultural Chemicals Association. The first company merged into the second one.

TABLE 3

The Number of Large, Small, and Total Innovative Pesticide Companies, 1972-89

(t-statistics in parenthesis)

Variable	Ordinary Least Squares			Two Stage Least Squares		
	All Firms	Largest Firms in 1970	Smallest Firms in 1970	All Firms	Largest Firms in 1970	Smallest Firms in 1970
INTRCEPT	16.73 (1.69)	10.50* (1.86)	8.92 (0.92)	26.98** (2.63)	9.72 (1.65)	14.19 (1.28)
LRDSALE	-65.59** (-2.37)	10.33 (0.53)	-29.74 (-1.15)	-95.0*** (-3.01)	13.62 (0.67)	-48.68 (-1.30)
ALLREG	-42.63*** (-5.15)	-14.24** (-2.51)	-35.39*** (-3.66)	-39.1*** (-4.86)	-14.6*** (-2.61)	-31.38** (-2.86)
POLLUTE	470.95 (1.39)	107.78 (0.62)	332.16 (1.17)	227.48 (0.72)	125.24 (0.71)	224.72 (0.77)
LSTAGE	122.7*** (3.89)	24.79 (1.15)	109.12*** (3.50)	121.0*** (4.41)	28.17 (1.24)	111.6*** (3.61)
LRESTATE	9.44*** (3.39)	3.19* (1.92)	4.43 (1.58)	6.60** (2.39)	3.32* (1.98)	3.16 (1.05)
Observations	18	18	18	18	18	18
ADJ. R^2	.93	.48	.80	.96	.49	.81
D^2	0.27 (0.92)	-0.24 (-0.81)	-0.22 (-0.77)	0.13 (0.45)	-0.23 (-0.77)	-0.25 (-0.86)

Dependent variable= number of innovative companies. See the Data Section for details of description. INTRCEPT=intercept term; LRDSALE=lagged research to sales ratio; ALLREG= regulation variable defined as industry average fraction of research devoted to environmental testing over the previous four years; POLLUTE=capital expenditures for pollution control equipment divided by sales; STAGE=lagged value of capital expenditures relative to sales; LRESTATE= value of farm real estate in hundreds of billions of 1972 dollars; D^2 = correlation coefficient on first lag of error term.
***=significant at the 1% level; **=significant at the 5% level; *=significant at the 10% level.

TABLE 4

Foreign-Based Company Market Share of the U.S. Pesticide Industry, 1972-89.[+]
(t-statistics in parenthesis)

Variable	Ordinary Least Squares			Two Stage Least Squares		
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
INTRCEPT	0.41***	0.30*	0.51***	0.29**	0.16	0.51***
	(3.20)	(2.03)	(4.04)	(2.34)	(1.05)	(4.04)
LRDSALE	0.50*	0.86**	-	1.07**	1.55***	-
	(1.90)	(2.99)		(2.93)	(3.39)	
ALLREG	0.77***	0.61***	0.95***	0.77***	0.64***	0.95***
	(6.40)	(-2.11)	(10.73)	(7.14)	(4.59)	(10.73)
POLLUTE	-3.39	-3.80	-5.20	-0.96	0.04	-5.20
	(-0.76)	(-0.74)	(-1.11)	(-0.24)	(0.01)	(-1.11)
LSTAGE	-1.07***	-	-1.46***	-0.92**	-	-1.46***
	(-2.70)		(-3.99)	(-2.67)		(-3.99)
LRESTATE	-0.14***	-0.12***	-0.17***	-0.12***	-0.09**	-0.17***
	(-4.06)	(-2.83)	(-4.54)	(-3.66)	(-2.15)	(-4.54)
Observations	18	18	18	18	18	18
ADJ. R^2	.96	.89	.92	.95	.90	.92
D^2	0.38	0.09	0.20	0.28	0.02	0.20
	(1.37)	(0.31)	(0.72)	(0.92)	(0.06)	(0.72)

Dependent variable= Foreign-based company market share of U.S. pesticide market. See the Data Section for details of description.
Case 1 and 4: entire model; Case 2 and 5: LSTAGE removed; Case 3 and 6: LRDSALE removed.
INTRCEPT=intercept term; LRDSALE=lagged research to sales ratio; ALLREG= regulation variable defined as industry average fraction of research devoted to environmental testing over the previous four years; POLLUTE=capital expenditures for pollution control equipment divided by sales; STAGE=lagged value of capital expenditures relative to sales; LRESTATE= value of farm real estate in hundreds of billions of 1972 dollars; D^2 = correlation coefficient on first lag of error term.
***=significant at the 1% level; **=significant at the 5% level; *=significant at the 10% level.

TABLE 5

Multinomial Logit Logistic Regression of the Merger Choice Equation, 1972-89

(standard errors in parentheses)

VARIABLE	Case 1	Case 2	Case 3
INTERCEPT1	-2.333*** (0.479)	-2.058** (0.449)	-2.11*** (0.432)
INTERCEPT2	1.050** (0.414)	1.206*** (0.408)	1.149*** (0.381)
PRICCOST	2.253** (1.123)	2.252** (1.112)	2.081** (1.024)
EPACOST	-6.885** (3.31)	-6.063** (2.785)	-6.07** (2.86)
USSHARE	-12.77* (7.42)	-1.955 (5.21)	-
WRLDSALE	0.0012** (0.0032)	-	-
OBS	104	104	104
P^2	18.90***	14.35***	14.20***

Dependent Variable: two for acquiring firm, one for firms that were either not acquired or made no acquisitions, and zero for acquired firms;
Case 1: all variable; Case 2: WRLDSALE removed; Case 3: USSHARE and WRLDSALE removed.
INTERCEPT1= first intercept term; INTERCEPT2 = second intercept term; PRICCOST=price cost margin, as defined in the text, minus the ratio of research and development costs to sales; EPACOST=the cumulative fines levied by the EPA from 1972 until the merger divided by sales at the time of the merger plus the first year of lost sales for banned pesticides divided by sales at the time of the merger; USSHARE =U.S. pesticide market share. WRLDSALE= world sales of the firm in millions of dollars.
*** =significant at the 1% level; **=significant at the 5% level; ***=significant at the 1% level.

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