Unobservable Industry Characteristics and the Innovation-Concentration-Advertising-Maze: Evidence from an Econometric Study Using Panel Data for Manufacturing Industries in the FRG, 1979—1986*

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ABSTRACT. In discussing the nexus between innovations and market structure it is often argued that industry characteristics (called 'opportunities') might play an important role as determinants of innovation, and that simultaneity rather than one-way causality prevails. We consider a three-equation model for innovation, advertising, and concentration. Based on pooled cross-section time-series data for 26 German manufacturing industries we estimate single equation models with and without fixed industry and/or time effects (to control for unobservable industry or time effects, respectively) and simultaneous equation systems including fixed effects, and controlling for extreme cases ('outliers') or not. Furthermore, we use two different measures for innovations, i.e., the percentage of shipments due to new products, and the percentage of firms which classified themselves as innovators. Our results can be summarized as follows: (1) The firm size has no significant effect on innovation. One can, therefore, not conclude from this data set that large firms are more innovative than small ones; (2) unobservable industry effects do matter; (3) the treatment of outliers does matter; (4) simultaneity does matter; (5) the way innovations are measured does matter; (6) different stories could be told based on the results of the systems of interdependent equations estimated.

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1. Introduction

The nexus between innovation, market structure, and firm size is one of the core topics of small business economics. During the last decades a fairly large body of academic literature has been devoted to econometric investigations on the determinants of innovation (see, e.g., the recently published surveys by Baldwin and Scott (1987) and by Cohen and Levin (1989)). For the Federal Republic of Germany a number of studies using data at the industry or firm level has been published during the eighties, too (e.g., Neumann, Böbel and Haid, 1982; König and Zimmermann, 1986; Bellmann and Wagner, 1987; Wagner and Bellmann, 1987; Zimmermann, 1987; Entorf, 1988; Entorf, Krader and Pohlmeier, 1988; FitzRoy and Kraft, 1990; Kraft, 1989; Pohlmeier, 1989; Zimmermann, 1989; and Schulenburg and Wagner, 1991). Our motivation to add another piece to this literature is twofold.

First, it has long been recognized that inter-industry differences in technological opportunity might play a key role in understanding the determinants of the variations in the degree of innovativeness between industries. Discussing inter-industry differences in patenting, holding firm sales constant.

Scherer (1965, p. 1100) argued 25 years ago that "(p)erhaps most important is a set of influences best described under the heading 'technological opportunity'. Technological opportunity

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in this context could relate partly to industry traditions or to demand conditions not manifested in mere sales volume, but it seems most likely to be associated with dynamic supply conditions dependent in turn upon the broad advance of scientific and technological knowledge". As Cohen and Levin (1989, p. 1083) put it in their recent survey: "Although it is widely accepted that industries differ in the opportunities they face for technical advance, there is no consensus on how to make the concept of technological opportunity precise and empirically operational."

Furthermore, they point out the relevance of two other groups of industry characteristics in this context, namely demand (e.g., size of the market and price elasticity) and appropriability conditions as regards the "fruits" of innovative effort (cf. Cohen and Levin, 1989, p. 1080, and p. 1090). According to Cohen and Levin (1989, p. 1096) we have a substantial body of descriptive evidence on how the nature and effects of demand, opportunity, and appropriability differ across industries, but progress in many areas is still constrained by the absence of suitable data.

One way to deal with differences in technological opportunities consists in adding dummies for industries known as (or supposed to be) traditional innovators (or non-innovators). A recent example for this approach can be found in Scherer (1991). A more satisfactory way to deal with unobserved inter-industry differences of any kind consists in modelling these unobservables as effects in a model applied to pooled cross-section time-series or panel data (cf. Cohen and Levin (1989) for a short review of this type of studies and Geroski (1989) for a recent example). In a nutshell, this is done by adding dummy variables for all industries and, therefore, estimating models with industry-specific intercepts. These intercepts capture the *unobservable* industry effects which cannot be measured, and the effects of the *observable* industry characteristics are estimated after controlling for any influences of the unobservables. To put it differently, if there are unobservable industry effects which are not uncorrelated with the industry characteristics included in the models, this approach leads to unbiased estimations of the coefficients of the industry characteristics considered (cf. Hsiao, 1986). The nexus between market structure and innovation has not been investigated for the FRG using panel data before (Bellmann and Wagner (1987) studied the role of import pressure for innovations without referring to market structure), and this is the first motive for the study presented here.

Second, our study analyses the interrelationship between innovation, concentration and advertising in a model of simultaneous equations, and simultaneous studies of those characteristics of market structure are still rare (e.g., Schulenburg (1988); for a short survey of simultaneous equation models including innovations and market structure see Cohen and Levin, 1989, p. 1075). Simultaneous equation models for innovations in the FRG include Neumann, Böbel and Haid (1982), Entorf, Krader and Pohlmeier (1988) and Pohlmeier (1989, Ch. 6), but only Schulenburg and Wagner (1991) consider innovation, advertising, and concentration.

Although some studies of this kind with U.S. data do exist (cf. Levin and Reiss, 1984; but Lunn, 1986) none have used panel-data (but see Domowitz, Hubbard and Petersen (1986) for an empirical investigation based on pooled industry data in an simultaneous framework including concentration, advertising, and the price-cost margin). Simultaneity, however, has to be expected between advertising, innovation and concentration for several reasons. Advertising and innovation are both results of imperfect information. They are both activities producing information and are frequent phenomena in concentrated markets working as barriers-to-entry. Because advertising activities as well as innovations increase the monopoly power of the firm, they might have an influence on the market-structure, too. The degree of concentration in a market has, therefore, not only to be considered as a factor influencing advertising and innovation but as a result of those activities, too. This is also in line with the theoretical findings of "the new industrial organization" (cf. Stiglitz and Mathewson, 1986) which consider the characteristics of technology, including the technology of innovation and invention to be key factors contributing to industry market structure. Thus, innovation is not exogenous to market structure but endogenous (see Stiglitz, 1986).

Furthermore, as regards the potential role of "opportunity" (or other industry characteristics not modelled explicitly due to missing data or vagueness of concept) similar arguments compared to those mentioned above when discussing innovations can be put forward here for advertising and concentration. Therefore, a simultaneous equation model should be estimated based on panel data to control for these unobservable industry characteristics. There is no such model (at least, as far as we know, using data for the Federal Republic of Germany), and this is the second motive for the study presented here.

Before we start, another comment on the approach used is in order. Reviewing econometric studies of structure and performance Richard Schmalensee (1989, p. 952) recently declared inter-industry studies to be out of fashion now. We agree that "cross-section studies rarely if ever yield consistent estimates of structural parameters", mainly because "in the long-run equilibria with which cross-section studies must be primarily concerned, essentially all variables that have been employed in such studies are logically endogenous", and that all this holds for panel studies, too, if they do not employ an explicit model of disequilibrium behavior (cf. Schmalensee, 1989). However, we share his view that this kind of studies may produce useful stylized facts to guide theory construction and analysis of particular industries: "The appropriate mind-set ... is accordingly that of descriptive statistics, not structural hypothesis testing" (Schmalensee, p. 957). Furthermore, we agree that one should especially look for empirical relations that are robust to plausible variations in measurement methods as well as to variations in model specification. The aim of our paper, therefore, is to check up whether there are such empirical relations in our FRG data or not.

The paper is organized as follows: *Section 2* discusses the theoretical background, in *Section 3* we present the result of our econometric study, and *Section 4* concludes with a research perspective.

2. Theoretical considerations

The general structure of our argumentation is represented in Table I. As pointed out in the introductory section, our study focuses on three key-variables: *innovation, advertising* and *concentration.*

Many studies have dealt with the factors influencing *innovation.* In a most recent study representing the 'state-of-the-art' of empirical innovation research, Acs and Audretsch (1987 and 1988) have analysed the impact of different market-characteristics on innovation with a point of emphasis on the firm size. According to the Schumpeterian hypothesis, industries with mainly large firms should be more innovative than those with mainly small firms (see Baldwin and Scott, 1987). Acs and Audretsch have also found a positive relationship between firm size and innovation.

Since the seminal contribution by Scherer (1965) economists, however, were mostly interested in the question whether concentration has an impact on innovation (see, e.g., Scherer, 1980 and 1983; Kamien and Schwartz 1975; Acs and Audretsch 1988; Mansfield, 1981; and Connolly and Hirschey 1984). This interest was initiated by Schumpeter's work (1950) who argued, that markets with imperfect competition are most conductive to innovation, because in imperfect markets firms are able to capture economic rents accuring from innovations. Although empirical studies do not generally support the Schumpeterian hypothesis, it has some plausibility from a theoretical point of view.

As regards the consequences of advertising for innovation, Hula (1988, p. 125) argues that by increasing the demands for new products and raising the size and speed of the anticipated profit payoff of R&D expenditures, advertising may be able to spur the research and development upon which innovation depends. Economic theory also predicts that all kinds of barriers-to-entry (see Weizsäcker, 1980) increase the rents of an innovator and therefore increase the incentives in innovative activities. Therefore, we expect that advertising, human capital and R&D expenditures, all known as sources of barriers to entry for new firms, will have a positive effect on innovation.

As we have pointed out already in the introductory section, advertising is not only a determinant of innovation but also a result of innovative activities (for surveys see Comanor and Wilson (1979) and Farris and Albion (1981)). Advertising exists only in markets with imperfect information (cf. Butters, 1977; Grossman and Shapiro, 1984; and Nelson, 1974). Besides persuading consumers and/or erecting barriers to entry, it is a tool to inform consumers. We expect, therefore, that firms with innovations spend more for advertising than other firms. Because corporate and professional consumers are much better informed about prices and quality levels than private consumers (see Finsinger and Schulenburg, 1987), we do expect that private consumption oriented industries spend more for advertising (cf. Buxton, Davies and Lyons, 1984). The beverage, liquor, toiletry and detergent industries for instance are known for their costly and massive advertising campaigns to attract the attention of the ordinary consumers.

As regards the influence of market structure on advertising, Maddala and Miller (1989, p. 417) argue that "in a competitive industry no individual firm has an incentive to advertise because the benefits from advertising accrue to all firms in the industry while the advertising firm bears the costs. Under monopoly, the monopolist receives all the benefits, but in this case advertising is done only to increase the demand for the product, since there is no question of capturing rival firms' sales. Under oligopoly, advertising has two benefits — increasing the demand for the product, and capturing sales from rivals. . . . Thus, incentives to advertise are higher under oligopoly than under perfect competition or monopoly." Therefore, one should expect a nonlinear, inversely u-shaped relation between the advertising-to-sales ratio and market concentration. However, none of the industries considered in our empirical study can be viewed as monopolistic. Therefore, we should expect a positive influence of a higher degree of concentration on the advertising intensity. But as Miller (1972, p. 471) puts it, above some level of concentration there may be an increase in the probability of advertising cooperation in the form of tacit oligopolistic reduction in offsetting advertising expenditures. If this is the case in the industries considered here, we should expect a negative impact of concentration on advertising (cf. Schmalensee (1989), for a review of studies using US data).

To compare the market structures of different industries one can take the *concentration* ratios. As Stiglitz (1986) and others have argued nonconvexity and irreversibilities, or sunk cost, are decisive in determining concentration. While many different technologies fulfill one of these characteristics, innovation and product differentiation strategies typically match both, non-convexity and irreversibilities (see Dasgupta, 1986). Accordingly, we expect a positive impact of innovation, advertising, capital intensity and wage level on market concentration because all these factors empede the market entry of new firms (see Schmalensee (1986) for advertising). All these factors are well-known standard variables to explain market concentration (for a review of the literature mainly based on studies using US data see Cubbin (1988); and Schmalensee (1989)).

Table I summarizes the various theoretical hypotheses of the determinants of innovation, advertising, and concentration. Each equation contains two additional groups of variables controlling for *time invariant industry effects* ('opportunities') and *industry invariant time effects*. Because we will use time-series and cross-sectional data to estimate the model presented in Table I we are able to control for these time and industry specific effects on innovation, advertising and concentration.

Evidently, one important variable is missing that surely is part of the maze, i.e., profitability. Profits should be included in the advertising and innovation equations, and should be explained in a further equation of the system using, among others, concentration, advertising, and innovation as determinants. However, reliable data for profitability are not yet available at the industry level for the German manufacturing sector. Furthermore, our approach is static, and no reference is made to processes of lagged adjustment. Estimation of a *dynamic* simultaneous model using panel data, however, is beyond the scope of this paper, and not in line with the rather modest aim of our research as stated at the end of the introductory section.

3. Econometric study

The model outlined in Table I was estimated using data for 26 German manufacturing industries from the years 1979 to 1986. Table II provides information on the variables, details are given in the appendix. Most of the variables are standard, but three of them deserve comment.

First, the innovative intensity of an industry is

TABLE I
General structure of the model

Equation No.	Endogenous variable	Exogenous variables (theoretically expected sign given in brackets)
1	Innovation	Concentration (+), Advertising (+), Human capital (+), Firm size (+), R&D (+), Industry effects (?), Time effects (?)
2	Advertising	Concentration (+), Innovation (+), Private consumption (+), Industry effects (?), Time effects (?)
3	Concentration	Innovation (+), Advertising (+), Capital intensity (+), Wage level (+), Industry effects (?), Time effects (?)

TABLE II
Empirical measures used in the study[a]

Variable	Definition
Innovation	A: Percentage of shipments due to products recently introduced in the market and still in the market entry phase B: Percentage of firms which classified themselves as (product and/or process) innovators
Concentration	Herfindahl-Index
Advertising	Percentage of employees in marketing activities
Human capital	Percentage of skilled labourers (Facharbeiter)
Firm size	Number of employees per firm
R&D	Percentage of employees in R&D
Capital intensity	Capital stock per man hour
Wage level	Wage/salary per man hour
Private consumption	Percentage of shipments delivered for private consumption

[a] Details on data sources are given in the appendix.

measured in two ways, with both variables coming from the '*innovation test*' conducted regularly by the IFO-Institute for Economic Research in Munich. On the one hand, we use the *percentage of shipments due to products recently introduced in the market and still in the market entry phase* (which we call for short "*Innovation A*"), and on the other hand, we refer to the *percentage of firms in an industry which classified themselves as product and/or process innovators* (for convenience called "*Innovation B*"). Both variables measuring innovation are output measures. They are positively correlated with $r = 0.50$ for the industries considered here in the period covered. In our study each equation is estimated in two ways using either "Innovation A" or "Innovation B" to see in what extent the results do differ due to the way innovation is measured.

Second, from official statistics no advertising-to-sales ratio data are available for the Federal Republic of Germany, and, therefore, we apply a *proxy* based on figures for *employees in marketing activities*. The percentage of employees in marketing activities is highly positively correlated with estimates of the ratio of outlays for media-advertising to sales, which, however are available for some years only (Wagner, 1991).

Third, data on R&D expenditures are available only for some industries in some years. Therefore, we used the percentage of *employees in R&D* as a proxy. This proxy is highly positively correlated with figures for R&D expenditures (cf. Wagner, 1991, p. 131).

The correlation matrix for the variables used (which is available on request) shows a rather high correlation between some measures included as exogenous variables in an equation (e.g., concentration and firm size, concentration and R&D, human capital and R&D, firm size and R&D, or capital intensity and wage level), and this might cause a problem because the effects of some variables might not be identifyable due to multicollinearity.

In our econometric study we successively investigate the following four questions:

1. Should unobservable time invariant industry effects ("opportunities") and/or industry invariant time effects be considered in an analysis of the determinants of innovation, advertising and concentration?
2. Do the results depend to a large extent on 'unusual' observations (i.e., extreme values for a small number of industries in some years)?
3. Does simultaneity matter when investigating innovation, advertising and concentration?
4. Paying attention to the answers to question (1) — (3) above, do the data produce stylized facts in line with our theoretical considerations?

To answer the first question we have pooled the data for the 26 industries in the eight years (1979 — 1986) to form a set of combined cross-section time-series or panel data and have estimated the three equations given in Table I (each one in two ways, employing either "Innovation A" or "Innovation B") using four different types of econometric models (see Hsiao (1986) for different models for panel data):

- A pooled model (M1) where it is assumed that the intercept and the slopes are identical for all industries and all years covered. This is a very restrictive model where it is assumed that neither unobservable industry nor time effects are present.
- A pooled model with fixed time effects (M2F) where it is assumed that the intercept varies between the years (but identically for all industries), while the slopes are identical for all industries and all years covered. This model is less restrictive than M1 because it allows for unobserved industry invariant time effects. It is easily estimated by augmenting the pooled data set with dummy variables for each year (but one — to avoid perfect collinearity of the regressor matrix) and applying ordinary least squares (OLS).
- A pooled model with fixed industry effects (M3F) where it is assumed that the intercept varies between the industries (but is identical for all the years), while the slopes are identical for all industries and all years covered. This model is less restrictive than M1 because it allows for unobserved time invariant industry effects ('opportunities'). It is easily estimated by augmenting the pooled data set with dummy variables for each industry (but one to avoid perfect collinearity of the regressor matrix) and applying OLS.
- A pooled model with fixed industry effects and fixed time effects (M4F) which is a combination of M2F and M3F, and which is less restrictive than each of these. Again, this model can easily be estimated by OLS applied to a set of pooled data augmented with time and industry dummies in an appropriate way.

Obviously, M1 is nested in the other models, and M4F nests all the models considered. Therefore, it is easy to test whether the restrictions imposed are valid or not by a conventional F-Test. For example, to test the null hypothesis that unobservable time invariant industry effects do not matter in the equation for innovations, M1 and M3F are to be estimated and the hypothesis that all the coefficients of the industry dummies are jointly zero is to be tested by comparing the results from M1 and M3F.

The results from the tests of restrictions in the models for panel data — i.e., whether time invariant fixed industry effects and/or industry invariant fixed time effects are present in the models considered here, or not — show that the null hypothesis of no industry effects can be rejected at any level of significance for all the equations considered here (details are available on request). This is a strong evidence for the presence of time invariant unobserved industry effects of 'opportunities' in the sense discussed above. Furthermore, for half of the models tested the null hypothesis of no fixed time effects is rejected at a conventional level when testing both M1 vs. M2F and M3F vs. M4F. Therefore, we will concentrate on the least restrictive version of the models for panel data, M4F (with fixed industry and time effects).

A comparison of M4F — our preferred model due to the results of the tests of various restrictions — and M3F (i.e., the exclusion of time effects) reveals only minor differences. Not including unobserved industry effects, however, often changes the results drastically. For example, in the equation explaining 'Innovation B' the coefficient of the 'Human Capital'-variable is negative and highly significant in M1 and M2F, but positive and significantly different from zero in M3F; and in both of the concentration equations the 'Wage Level' has a highly significant positive impact in M1 and M2F, but the coefficient is negative and highly significant in M3F and M4F (a complete set of tables with the results is available on request).

To summarize the results we got thus far, the answer to the first of our four questions is "Yes, unobservable industry and time effects should be included in a study of the determinants of innovation, advertising and concentration."

It is well-known that the results of OLS estimations can be heavily influenced by a small number of unusual observations or outliers (cf., e.g., Rousseeuw and Leroy, 1987; for an example in the context of innovations see Cohen, Levin and Mowery (1987)). We have applied, therefore, a mean-shift outlier test to detect such cases by successively adding dummy variables for each industry in each year to the equations of M4F and testing the maximum t-values of the coefficients (cf. Cook and Weisberg, 1982). In a second step, we augmented all equations by adding dummies for the outliers detected to see whether the results depend to a large extent on these 'extreme' values. Furthermore, since heteroscedasticity is often present in cross-sectional analysis and panel data, we have computed heteroscedasticity-consistent t-values (ATV) as well employing the method proposed by White (1980).

A comparison of these estimates for the augmented M4F-models including the outlier dummies with the M4F-results reveals differences in the order of magnitude and in the level of significance for some coefficients, but only for one of the 24 coefficients the sign (which is not significantly different from zero in both models, however) changes (cf. the 'Firm Size'-variable in the innovation equation using 'Innovation A'; again the complete tables with the results are available on request).

Therefore, we can answer our second question by stating that the results do not depend to a very large extent on a small number of 'unusual' observations. To investigate the fragility of the estimates, however, we will consider both the M4F-models and the M4F-models augmented with outlier dummies.

Turning to our third question, we tested whether simultaneity matters when investigating the determinants of innovation, advertising and concentration by using a Hausman-test (Hausman, 1978) applied in a RESET-version (Nakamura and Nakamura, 1981). It turns out that the null hypothesis of no simultaneity is rejected for all the equations of the M4F-type, and for the augmented version of M4F when the concentration equation is considered. The answer to our third question is, therefore, "simultaneity matters".

To take these interdependent relations into account, the three equations were estimated using three-stage least squares (3SLS). Hereby we have considered four different systems of equations, using either "Innovation A" or "Innovation B" in each of the equations, and computing either models of the type M4F (pooled model with fixed time and industry effects) or of M4F-models augmented by the outlier dummies. The results of the estimations for systems 1 — 4 are reported in Table III.

The results reveal that it does matter how innovations are measured, and if one does or does not control for outliers. Consider, for instance, the coefficient of the degree of concentration in the equation explaining innovation. For "Innovation A" we have a positive and statistically significant coefficient in M4F (system 1), positive but insignificant values in M4F augmented by outlier dummies (system 2) and in M4F using "Innovation B" (system 3), and a negative (but insignificant) value in M4F with outlier dummies using "Innovation B" (system 4).

Another example for large differences in the results is the 'Wage Level'-variable, which has a

TABLE III
Estimation results for systems of equations[a]

Exogenous variable	Model system	... using "Innovation A" (1) M4F Innov.	Advert.	Concen.	(2) M4F & Outlier dummies Innov.	Advert.	Concen.	... using "Innovation B" (3) M4F Innov.	Advert.	Concen.	(4) M4F & Outlier dummies Innov.	Advert.	Concen.
Innovation	β		0.0055	2.424		0.0005	0.2007						
Innov. A	$\|t\|$		5.28**	1.13		0.97	2.78**						
Innov. B	β								0.0039	0.1639		0.0011	−0.0123
	$\|t\|$								1.73	0.02		0.21	0.18
Concentrtion	β	0.3260	−0.0022		0.0283	−0.0022		0.2749	−0.0027		−0.0572	−0.0022	
	$\|t\|$	5.44**	9.01**		1.47	14.89**		1.55	8.24**		0.84	14.63**	
Advertising	β	155.19		−456.37	12.994		−14.879	85.334		−464.48	9.3493		−9.061
	$\|t\|$	5.93**		8.58**	2.88**		1.81	1.61		1.32	0.58		1.04
Human	β	0.0515			0.1728			0.0287			0.3452		
capital	$\|t\|$	0.49			2.10*			0.25			1.20		
Firm	β	0.0069			0.0068			0.0129			0.0669		
size	$\|t\|$	0.33			0.60			0.30			1.91		
R&D	β	−0.1899			0.3791			1.535			0.6092		
	$\|t\|$	0.16			0.50			0.75			0.23		
Private	β		0.00062			0.0020			0.0028			0.0020	
consumption	$\|t\|$		0.63			1.84			1.81			1.91	
Capital	β			4.899			5.594			26.708			6.4913
intensity	$\|t\|$			0.36			2.52*			0.82			2.83**
Wage	β			4.894			−16.511			39.973			−13.656
level	$\|t\|$			0.15			3.68**			0.42			3.11**

[a] The number of cases for all equations is 208 (26 industries in 8 years). β are the estimated regression coefficients; $|t|$ are the absolute t-values, *(**) indicates a coefficient significantly different from zero in a two-tailed test for $\alpha = 0.05$ (0.01). For reasons of space the results for the constant term and any time, industry, and outlier dummies are not reported.

positive (but insignificant) coefficient in the concentration equation in the systems 1 and 3 (made up from M4F-type models), but a statistically significant negative one in the systems 2 and 4.

There are, however, more cases in which the results are rather stable, and do not change significantly if we control for outliers.

In the *innovation* equation 'Advertising', 'Human Capital', and 'Firm Size' are positive in all systems, although these signs cannot be considered to be statistically different from zero in all but three cases. In particular, the results of our models do not support the widespread believe that big firms are significantly more innovative than smaller firms. Contrary to our expectations, 'R&D' never has a positive and significant sign — in system 1 its coefficient even turns out to be negative. One explanation here could be that industries can and do import research and development done in other industries by buying investment goods and intermediate inputs. Therefore, the nexus between innovational input (measured by the percentage of employees working in R&D) and innovational output might be a rather loose one. The result, furthermore, may be influenced by the rather high correlation between R&D and other variables included here, namely concentration. Still, the weak relation between innovational input and output should seem to be worthy of notice because other studies employing U.S. data did even find a negative impact of scientists on innovation (Audretsch and Schulenburg, 1990; and Schulenburg and Wagner, 1991).

The most striking result in the *advertising* equation is that we found a highly significant negative coefficient for concentration. This suggests that sellers in more concentrated industries collude to reduce advertising outlays because they realize that these expenditures are mutually offsetting, and that this effect dominates the positive influence of concentration on advertising discussed above. On the other hand the coefficient of advertising is negative, too, in the *concentration* equation. One possible explanation for this is that potential entrants may perceive a greater chance of survival in an industry where advertising is important (cf. Kessides, 1986). The results of our model, therefore, do not support a number of hypotheses derived from theoretical economic models and frequently tested in empirical models employing U.S. data

Turning back to the *advertising* equation, the other variables, 'Innovation' and 'Private Consumption' have the expected positive sign in all four systems.

Considering the *concentration* equation, only 'Capital Intensity' has the sign expected theoretically in all four systems, which, however, is only significantly different from zero in the systems with outlier dummies.

To summarize, different stories could be told based on the results of each of the four systems of interdependent equations estimated. This might be rather unsatisfactory to the reader. However, it is more unsatisfactory in our view to report, say, the results for system 1 only, and conclude that there is a positive impact of concentration on innovation in the Federal Republic of Germany etc. Results as fragile as the one just mentioned due to minor changes in the specification of the model should not be considered to add to our knowledge about the innovation-concentration-advertising-maze. This, too, answers the fourth of our questions: the data lead to results which are in line with only some of our theoretical considerations, and we are far from convinced at all.

4. Conclusions

What did we learn from our econometric study about the innovation-concentration-advertising-maze in the Federal Republic of Germany? Alas, the maze is still there, but we found strong evidence for three propositions: firstly, unobservable industry effects ('opportunities') matter; secondly, the treatment of outliers matters; and, thirdly, simultaneity matters. Neither of these phenomena should be neglected in the future.

There are some caveats to be mentioned as regards our models. To point to the most important ones, our models are static, they do not take into account international linkages (Bellmann and Wagner, 1987; and Wagner, 1988) and profitability, and they employ rather highly aggregated data. A promising research perspective, therefore, seems to be to derive a data set from a *panel of firms* which would allow to control for unobservable firm-specific effects in a dynamic framework including variables related to the international linkages and the profitability of the firm. That is why we are currently starting such a study as part of an international research network (cf. Autorengemeinschaft (1990) for an outline of the study).

Note

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References

Acs, Zoltan J. and David B. Audretsch, 1987, 'Innovation, Market Structure and Firm Size', *Review of Economic and Statistics* **69**, 567—575.

Acs, Zoltan J. and David B. Audretsch, 1988, 'Innovation in Large and Small Firms: An Empirical Analysis', *American Economic Review* **78**, 678—690.

Audretsch, David B. and J. -Matthias Graf von der Schulenburg, 1990, 'Union participation, Innovation, and Concentration: Results from a Simultaneous Model', *Journal of Institutional and Theoretical Economics* **146**, 298—313.

Autorengemeinschaft, 1990, *Zur Konzeption der Pilotstudie für das Firmenpanel 'Produzieren in Niedersachsen und Europäischer Binnenmarkt'*, Fachbereich Wirtschaftswissenschaften Universität Hannover Diskussionspapier Nr. 149.

Baldwin, William L. and John T. Scott, 1987, *Market Structure and Technological Change*, London: Harwood Academic Publishers.

Bellmann, Lutz and Joachim Wagner, 1987, *Innovation, Import Pressure, and Factor Inputs in West German Manufacturing Industries: An Econometric Study Using Pooled Cross-section Time-series Data, 1979—1983*, Fachbereich Wirtschaftswissenschaften Universität Hannover Diskussionspapier Nr. 113.

Butters, G. R., 1977, 'Equilibrium Distribution of Prices and Advertising', *Review of Economic Studies* **44**, 465—492.

Buxton, J. A., S. W. Davies, and B. R. Lyons, 1984, 'Concentration and Advertising in Consumer and Producer Markets', *Journal of Industrial Economics* **32**, 451—464.

Cohen, Wesley M. and Richard C. Levin, 1989, 'Empirical Studies of Innovation and Market Structure', in Richard Schmalensee and Robert Willig (eds.), *Handbook of Industrial Organization, Vol. II*, Amsterdam: North-Holland, 1059—1107.

Cohen, Wesley M., Richard C. Levin, and David C. Mowery, 1987, 'Firm Size and R&D Intensity: A Re-examination', *Journal of Industrial Economics* **35**, 543—565.

Comanor, William S. and Thomas A. Wilson, 1979, 'The Effect of Advertising on Competition: A Survey', *Journal of Economic Literature* **17**, 453—476.

Connolly, Robert A. and Mark Hirschey, 1984, 'R&D, Market Structure and Profits: A Value Based Approach', *Review of Economics and Statistics* **66**, 682—686.

Cook, R. Dennis and Sanford Weisberg, 1982, *Residuals and Influence in Regression*, London: Chapman & Hall.

Cubbin, John S., 1988, *Market Structure and Performance — The Empirical Research*, Chur: Harwood.

Dasgupta, Partha, 1986, 'The Theory of Technological Competition', in Joseph Stiglitz and F. F. Mathewson (eds.), *New Developments in the Analysis of Market Structure*, Cambridge, MA: The MIT Press, 519—547.

Domowitz, Ian, R. Glenn Hubbard and Bruce C. Petersen, 1986, 'The Intertemporal Stability of the Concentration-Margins Relationship', *Journal of Industrial Economics* **35**, 13—34.

Entorf, Horst, 1988, 'Die endogene Innovation: Eine mikroempirische Analyse von Produktphasen als Innovationsindikatoren', *Jahrbücher für Nationalökonomie und Statistik* **204**, 175—189.

Entorf, Horst, Wolfgang Krader und Winfried Pohlmeier, 1988, 'Entscheidungen über Innovation, Beschäftigung und Außenhandel: Empirische Ergebnisse eines simultanen Probitansatzes', in Horst Kräger (ed.), *Empirische Wirtschaftsforschung*, Frankfurt: Campus, 27—47.

Farris, Paul and Mark S. Albion, 1981, 'Determinants of the Advertising-to-Sales Ratio', *Journal of Advertising Research* **21**, 19—27.

Finsinger, Jörg and J. -Matthias Graf von der Schulenburg, 1987, 'Nachfragerverhalten bei unvollständigen Preisinformationen', *Jahrbücher für Nationalökonomie und Statistik* **203**, 244—256.

FitzRoy, Felix and Kornelius Kraft, 1990, 'Innovation, Rent-Sharing and Organized Labor', *Small Business Economics* **2**, 89—94.

Geroski, Paul, 1989, *Innovation, Technological Opportunity, and Market Structure*, London Business School and University of Southampton, mimeo.

Grossman, Gene M. and Carl Shapiro, 1984, 'Informative Advertising with Differentiated Products', *Review of Economic Studies* **51**, 63—81.

Hausman, Jerry A., 1978, 'Specification Tests in Econometrics', *Econometrica* **46**, 1251—1271.

Hsiao, Cheng, 1986, *Analysis of Panel Data*, Cambridge: Cambridge University Press.

Hula, David G., 1988, 'Advertising, New Product Profit Expectations, and the Firm's R&D Investment Decisions', *Applied Economics* **20**, 125—142.

Kamien, Morton I. and Nancy L. Schwartz, 1975, 'Market Structure and Innovation: A Survey', *Journal of Economic Literature* **13**, 1—37.

Kessides, Ioannis N., 1986, 'Advertising, Sunk Costs, and Barriers to Entry', *Review of Economics and Statistics* **68**, 84—95.

König, Heinz and Klaus F. Zimmermann, 1986, 'Innovations, Market Structure and Market Dynamics', *Journal of Institutional and Theoretical Economics* **142**, 184—199.

Kraft, Kornelius, 1989, 'Market Structure, Firm Characteristics and Innovative Activity', *Journal of Industrial Economics* **37**, 329—336.

Levin, Richard C. and Peter C. Reiss, 1984, 'Tests of a Schumpeterian Model of R&D and Market Structure', in Zvi Griliches (ed.), *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 175—20 . .

Lunn, John, 1986, 'An Empirical Analysis of Process and Product Patenting: A Simultaneous Equation Framework', *Journal of Industries Economics* **34**, 319—330.

Maddala, G. S. and E. Miller, 1989, *Microeconomics: Theory and Applications*, New York: McGraw-Hill.

Mansfield, Edwin, 1981, 'Composition of R and D Expenditures: Relationship to Size of Firm, Concentration, and Innovation Output', *Review of Economic and Statistics* **63**, 601—615.

Miller, Richard A., 1972, 'Advertising and Competition: Some Neglected Aspects', *Antitrust Bulletin* **17**, 467—478.

Nakamura, Alice and Masao Nakamura, 1981, 'On the Relationships Among Several Specification Tests Presented by Durbin, Wu, and Hausman', *Econometrica* **49**, 1583—1588.

Nelson, P., 1974, 'Advertising and Information', *Journal of Political Economy* **82**, 729—754.

Neumann, Manfred, Ingo Böbel and Alfred Haid, 1982, 'Innovations and Market Structure in West German Industries', *Managerial and Decision Economics* **3**, 131—139.

Pohlmeier, Winfried, 1989, *Simultane Probit- und Tobitmodelle: Theorie und Anwendungen auf Fragen der Innovationsökonomik*, Berlin: Springer.

Rousseeuw, Peter J. and Annik M. Leroy, 1987, *Robust Regression and Outlier Detection*, New York: Wiley.

Scherer, F. M., 1965, 'Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions', *American Economic Review* **55**, 1097—1125.

Scherer, F. M., 1980, *Industrial Market Structure and Economic Performance*, Chicago, IL: Rand McNally College Publishing Co.

Scherer, F. M., 1983, 'The Propensity to Patent', *International Journal of Industrial Organization* **1**, 107—128.

Scherer, F. M., 1991, 'Changing Perspective on the Firm Size Problem', in Zoltan J. Acs and David B. Audretsch (eds.), *Innovation and Technological Change: An International Comparison*, London: Harvester Wheatsheaf, 24—38.

Schmalensee, Richard, 1986, 'Advertising and Market Structure', in Joseph Stiglitz and G. F. Mathewson (eds.), *New Developments in the Analysis of Market Structure*, Cambridge, MA: The MIT Press, 373—396.

Schmalensee, Richard, 1989, 'Inter-Industry Studies of Structure and Performance', in Richard Schmalensee and Robert Willig (eds.), *Handbook of Industrial Organization, Vol. II,*, Amsterdam: North-Holland, 951—1009.

Schulenburg, J.-Matthias Graf von der, 1988, 'Innovation, Markstruktur und Werbung', *Hamburger Jahrbuch für Wirtschafts- und Gesellschaftspolitik* **33**, 141—153.

Schulenburg, J.-Matthias Graf von der, and Joachim Wagner, 1991, 'Advertising, Innovation and Market Structure: A Comparison of the United States of America and the Federal Republic of Germany', in Zoltan J. Acs and David B. Audretsch (eds.), *Innovation and Technological Change. An International Comparison*, London: Harvester Wheatsheaf, 160—182.

Schumpeter, Joseph A., 1950, *Capitalism, Socialism and Democracy*, 3rd edition, New York: Harper and Row.

Stiglitz, Joseph E. and G. F. Mathewson (eds.), 1986, *New Developments in the Analysis of Market Structure*, Cambridge, MA: The MIT Press.

Stiglitz, Joseph E., 1986, 'Theory of Competition, Incentives and Risk', in Joseph E. Stiglitz and G. F. Mathewson (eds.), *New Developments in the Analysis of Market Structure*, Cambridge, MA: The MIT Press, 399—446.

Wagner, Joachim, 1988, 'Innovationen und Entwicklung der internationalen Wettbewerbsfähigkeit', *Jahrbücher für Nationalökonomie und Statistik* **205**, 50—64.

Wagner, Joachim, 1991, *Die bundesrepublikanische Industrie auf dem Weltmarkt*, Berlin: Duncker & Humbolt.

Wagner, Joachim and Lutz Bellmann, 1987, 'Produkt- und Prozeßinnovationen als Unternehmensstrategien bei Importdruck', *IFO-Studien* **33**, 223—242.

Weizsäcker, Carl Christian von, 1980, *Barriers to Entry: A Theoretical Treatment*, Berlin: Springer.

White, Halbert, 1980, 'A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity', *Econometrica* **48**, 817—838.

Zimmermann, Klaus F., 1987, 'Trade and Dynamic Efficiency', *Kyklos* **40**, 73—87.

Zimmermann, Klaus F., 1989, 'Innovation Activity and Industrial Structure', *Empirica — Austrian Economic Papers* **16**, 85—110.

Data appendix

The data are for 26 industries at the two-digit SYPRO level of aggregation. The following manufacturing industries had to be excluded for reasons of data availability: iron and steel, iron and steel foundries, aircraft and aerospace. Furthermore, we did not include the foodprocessing and agricultural product based industries. With the exception of the industries mentioned, our data covered the whole manufacturing sector of the FRG from 1979 to 1986.

1. *Innovation*

The innovation data are based on results from the IFO-institute's innovation test. On the one hand, IFO asked the firms to specify what percentage of shipments are due to products in a certain stage of product life cycle, namely the entry stage, growth stage, stage where they have already reached the peak, and shrinking stage. We used the percentage of shipments of products in the market entry stage as one measure of innovation. On the other hand, the firms were asked to state whether they realized a product or a process innovation in the year under review. The percentage of firms who classified themselves as innovators according to this question form our second indicator for innovativeness of an industry. For details on the IFO innovation test, see Heinz Schmalholz, Lothar Scholz and Joachim Gürtler: Innovation in der Industrie. Struktur und Entwicklung der Innovationsaktivitäten 1979 — 1982, München (IFO Institut) 1985. The data for 1979 — 1982 are taken from the book mentioned, the data for 1983 — 1986 are from unpublished tables generously supplied by Heinz Schmalholz.

2. *Concentration*

The data for the Herfindahl — Index are taken from three publications of the Statistisches Bundesamt (Federal Statistical Office of the FRG):

- Data for 1979 — 1982 are reported in F4 RS.9.
- Data for 1983 — 1984 are reported in F4 R4.2.3 / 1983 and 1984.
- Data for 1985 — 1986 are reported in F4 R4.2.3 / 1985 and 1986.

3. *Advertising*

The data for the percentage of employees in marketing activities are computed from unpublished data for the structure of employees kindly supplied by Prof. Dr. Franz-Josef Bade, University of Dortmund, which are based on the official statistic of all employees with social insurance ("Beschäftigtenstatistik").

4. *Human capital*

The data for the percentage of skilled labourers refer to the the proportion of workers ranked in the highest class of performance, which as a rule covers all workers who passed the formal apprenticeship training successfully (the so-called 'Facharbeiter'). The data are computed from: Statistisches Bundesamt, F16 R2.1 (issues for 1979, 1980, . . ., 1986).

5. *Firm size*

The number of employees per firm is computed from data for the number of employees in the industry taken from Bernd Görzig, Joachim Schintke und Peter Baumann: Produktionsvolumen und -potential, Produktionsfaktoren des Bergbaus und des Verarbeitenden Gewerbes in der Bundesrepublik Deutschland, 29. Folge, 1970 — 1986, Berlin (DIW) 1987, table 18, and from data for the number of firms reported by Statistisches Bundesamt in the publications mentioned in 2. Concentration.

6. *R&D*

The data for the percentage of employees in research and development are computed from the unpublished data described in 3. Advertising.

7. *Capital intensity*

The data for the capital stock and for man hours worked are taken from the book by Görzig *et al.* mentioned in 5. Firm size.

8. *Wage level*

The data for wages and salaries per man hour are computed from the data given in Görzig *et al.* (cf. 5. Firm size).

9. *Private consumption*

The data for the percentage of shipments delivered for private consumption are based on the input-output tables for the FRG published by Statistisches Bundesamt. The values for 1980, 1982, 1984, and 1986 are from F18 RS.12. The values for the odd years (i.e., 1979, 1981, 1983, 1985) are estimated as the arithmetic mean of the values for the preceding and the following years given in F18 RS.12.