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Market Concentration: The Effects of Technology

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I. Introduction

Market concentration is often viewed as an important indicator of monopoly power, which makes it a key aspect for analyzing antitrust and other cases. A good understanding of what market concentration is and how it arises is crucial to policy decision making, especially in today's world where large corporations often tend to dominate the business scene. In this paper I investigate how factors accounting for technological change affect market concentration holding constant the effects of other recognized determinants of concentration.

The welfare implications of concentration are ambiguous and depend largely on the causes of high (or low) concentration. According to Mueller and Hamm (1974) "concentration ratios are the single best available index of the degree of oligopoly," and thus, market power. If firms are successful in their strategy to secure market power, they will be in a position to control output and raise prices, which may have negative welfare effects (Gwemawat, 1984). On the other hand, a number of studies in industrial organization yield support for the Schumpeterian hypothesis that "monopolistic and oligopolistic firms would more aggressively pursue innovative activity than would firms with little or no market power" (Waldman and Jensen). Hence, we must analyze the causes of concentration in industries in order to adequately assess its costs and benefits. In this paper I concentrate on technological innovations.

I posit a two-way relationship between innovation and market concentration:

$$Innovation_t = F_1\ (Market\ Concentration_{t-1};\ Other\ factors_{t-i}); \qquad (1)$$

$$Market\ Concentration_t = F_2\ (Innovation_{t-1};\ Other\ factors_{t-i}). \qquad (2)$$

Fortunately these two relationships can be sorted out because of their lag structures and the problem of simultaneous equation bias can be avoided. Equation 1 presumes that the market concentration that causes innovation would precede the innovation, while equation 2 presumes that the innovation that causes market concentration would precede the concentration.

While the issues are not fully resolved, a great deal of work has been done concerning equation 1. Traditionally, firms with greater market power have been viewed as stodgy, and hence not innovative. A strong dissent by Joseph Schumpeter and others holds that monopoly profits due to concentration are a strong incentive for the innovation he dubs "creative destruction." Schumpeter argues that the introduction of new goods into the market negatively affects the demand fro the competitors' products, especially if the new good is superior in quality. This effect of "creative destruction" creates incentives for innovation, as a technological breakthrough will guarantee market power for its owners (Waldman and Jensen).

Much less work has been done concerning equation 2. A few studies, such as Mueller and Hamm (1974) and Kessides (1990), provide evidence suggesting that concentration depends on technological growth and industry specific factors. I concentrate on understanding how technology affects variation in concentration within different industries.

Recall that the core hypothesis is that concentration depends on technology, *ceteris paribus.* In particular, we hypothesize that the variation in industrial concentration depends on two sets of variables: (1) technological growth factors (such as R&D levels and human capital intensity), and (2) industry specific control variables (industry size and age, product differentiation, advertising levels and costs of entry, etc.). Many of these variables are difficult to measure and define, and thus, proxies have to be constructed.

Part II lays out the theoretical basis for my hypotheses. A common framework is obtained for relating the rate of arrival of innovations (technological growth) to market concentration. The theoretical basis for the use of certain variables is discussed in the context of existing literature. In Part III, I identify the dependent variable and a range of independent variables that are hypothesized to be important in explaining the variation in market concentration. A major challenge in this section is identifying ways to represent those independent variables that cannot be measured directly. Part IV deals with empirical analysis and research design. The regression model(s) are presented and predictions are made about the signs of the independent variables. Part V presents and explains the results of the empirical model. Econometric problems are assessed. Finally, conclusions are drawn in Part VI, including a discussion of potential policy implications and further research possibilities.

II. Theory

A large section of literature on industrial organization deals with explaining the relationship posited by equation 1 above. Scott (1984) finds that the relationship between market concentration and research and development (input and output) may exhibit the inverted-U relationship. After controlling for differences across industries in demand conditions and technological opportunity, though, the inverted-U relationship between concentration and spending on R&D disappears (Scott, 1984). Lunn and Martin (1986) find empirical support for the hypothesis that market power encourages investment in innovation in low-technology markets, as well as high-technological-opportunity industries.

More recent evidence suggests that the effect of concentration on R&D expenditures can be negative, contrary to the Schumpeterian hypothesis (Bylinsky, 2000). In the quickly changing and technology based dot-com industry, small companies often invested in R&D, in hopes of getting market share. This may be attributed to low entry costs into the market and relatively low capital-intensity (lesser extent of economies of scale).

Significantly less work has been done on explaining the reverse relationship between technology and concentration. As mentioned earlier, this paper focuses on explaining the relationship in equation 2, namely the effect of innovation on market concentration.

A. General Theory

Aghion and Howitt (1992) assume that innovations lead to vertical differentiation, i.e. changes in the quality of products. They assume that these innovations are "drastic" and introduce the notion of "creative destruction" – that "no one will continue to buy the qualitatively inferior goods when given a chance to buy the superior (new) product" (Aghion&Howitt, 1992). The article states that technological progress results from "competition among research firms that generate innovations" and that the more the extent of creative destruction the more volatile is the market concentration (Aghion&Howitt, 1992). This paper suggests that innovations put their owners at the cutting edge of the market. Consequently, we can conclude that technological innovation yields market power for its owners, and thus should have a positive effect on concentration, everything else held constant.

For the sake of generality, I assume that the effect of process innovation is the same as that of product innovation. The incentives in the former case would be cost reductions, which lead to increasing profits. In fact, firms with successful process innovations can increase their market share by underpricing their rivals and driving them out of the market. This paper does not distinguish between the two kinds of innovations, but it is important to note that both give their owners market power, and hence are expected to cause concentration.

I should note here that technology is not the only factor expected to affect different industries. In this study I also try to account for the extent of creative destruction, which will lead to a higher probability of innovations being more drastic. Hence, the higher the creative destruction effect, the higher the expected concentration in the market.

Consider two fairly different industries: *iron and steel mills and ferroalloy* and *computer and peripheral equipment*. This example provides an intuition for including explanatory variables other than technological innovation in our model.

The combined market shares of the 8 largest firms in these are 51.4% and 52.1%, respectively (US Census Bureau). In the former case, though, we are dealing with a fairly well established industry in which creative destruction and technological progress would have little significance and where high concentration would most probably be the result of the age and relative stability of the industry.

On the other hand, the latter industry is more human capital intensive, and it is more plausible to assume that introduction of new products would have a negative effect on the demand for older, technologically inferior goods, and the extent of creative destruction would be higher. Here we are dealing with an industry best described by Aghion and Howitt's paper, although, again, the assumption of completeness of creative destruction is not fully satisfied (e.g., Intel did not stop marketing the inferior "Celeron" processor even after a new "Pentium 3" chip was introduced).

In the former case (iron&steel), concentration is high due to the fact that the industry is relatively old and well-established, in addition to having high entry costs. In the latter instance (computers&peripherals), an innovation would make all the competitors' products relatively inferior, negatively affecting the demand for these products and giving the owner market power. As a result, we are facing two industries that have different levels of innovation and still are equally concentrated. Hence, there are variables, other than technological innovation, that cause concentration. These include industry size, growth/age, size variability and advertising.

The basic intuition behind technological growth affecting market concentration is that innovations place their holders at the very frontier of the market. In this paper I try to flesh out the effects of technological growth on concentration by controlling for factors that account for industrial specificity, and thus, explain the extent to which innovations benefit their owners by providing market power.

As a result, we are facing a major challenge of recognizing the variables that would account for technological growth, as well as those for industrial specificity and the extent of creative destruction. There are several studies that prove useful in identifying such variables.

B. Technological Factors

I argue that the industries in which R&D expenditures are high have a greater probability of a drastic innovation that would give one or several firms significant market power. Thus R&D expenditures are expected to have a positive effect on industrial concentration.

Avner Shaked and John Sutton (1987) claim, "it is the interplay between consumers' tastes and the underlying technology which simultaneously determine the degree of concentration and fixed costs" (Shaked&Sutton, 1987). They use technology as an exogenous variable and argue that often manufacturers can keep shifting the technological frontier constantly forward towards more sophisticated products by incurring additional fixed costs in the form of R&D expenditures. As a result, the authors are led to question the familiar argument that "certain industries are highly concentrated because the level of fixed costs involved is high" (Shaked&Sutton, 1987). Instead, they claim that conducting R&D gives the incumbent firms a possibility to create advanced products to match the growth in market demand and defer further entry. Thus, we would expect industries with high R&D levels to be more concentrated. In fact, we would expect the industries with high initial concentrations to remain largely that way. This would account for the extent to which incumbents dominate the market.

I use R&D expenditures as one of the proxies for technological growth, as it is plausible to assume that the more a firm invests in research and development the higher its probability of making a discovery before others, and thus, being placed at the market frontier. Hence, the predicted sign would be positive.

It is also important to acknowledge that investments, other than pure R&D expenditures, can increase the likelihood of an innovation occurring. These would include installation of new and improved machinery and safety facilities, construction of buildings etc. For example, it is reasonable to suppose that working in a healthy environment can make the labor force more productive and even facilitate creativity. Together with R&D expenditures, these investments comprise the physical intensity part of the model for measuring technology.

So far the emphasis has been placed strictly on the physical capital aspect of technological growth, namely resources committed to R&D, and nothing has been said about human capital intensity and its effect on technological growth and concentration. This is another important way of accounting for the rate of arrival of innovations, and thus, growth (Romer, 1990).

Paul Romer in his paper assumes that technology is "a non-rival, partially excludible good": once an innovation occurs, the access to it cannot be fully restricted. He supposes that innovations introduce a new dimension to the market by creating differentiated products (Romer, 1990). He also assumes that old inventions are still marketable and somewhat in demand. The main conclusion of the paper is that the stock of human capital is a major determinant of technological growth. The higher the level of human capital (quality of labor) employed by a firm the higher its probability of making an innovation, and thus, we would expect the concentration to be higher in industries where more high skilled labor is employed. It is also likely that human capital, as opposed to physical capital, is becoming more important over time as we make the transition from a physical capital based economy to a "knowledge" based economy.

These proxies for technological growth (physical and human capital intensity) are predicted to be positively correlated with industrial concentration, *ceteris paribus*. Thus, we would expect that a relatively slow-growing (in terms of technological advances) industry, such as *iron and steel and ferroalloy manufacturing* mentioned above, would not be highly concentrated, which is not true (recall that the market share of top 8 firms is above 50%). This means that there are other variables we need to include in our analysis in order to avoid bias in the estimates. Hence, we need to introduce a set of control variables.

C. Industry Specific Factors

There have been many studies conducted, where authors tried to include such explanatory variables as *Industry Growth Rate, Size of Industry, Product Differentiation* (Mueller&Hamm, 1974), or *Existence of Second-Hand Market for Capital, Rate of Capital Depreciation, Sunkenness of Costs* (Kessides, 1990), or *Advertising Levels* (Mueller&Rogers, 1984 and Woodrow, 1987 and 1988), or *Minimum Optimum Plant Size, Differentiation and Durability of Products* (Weiss, 1963). All of these papers aim to provide empirical results that would explain what influences market concentration, but none of them have managed to obtain high R-square estimates, except for Kessides, who actually uses technology and some industry specific factors as control variables (Kessides, 1990).

The task of this paper is then to pick the other explanatory variables that are significant determinants of concentration. One such variable would undoubtedly be the industry age; the older the industry, the less it is affected by creative destruction. The likelihood of an innovation being drastic is rather low in these industries. On the other hand, relatively new sectors of manufacturing tend to be more affected by creative destruction, as the likelihood of a "breakthrough" would be higher.

Unfortunately, due to unavailability of data, it is impossible to measure industry age directly, and alternative ways need to be sought. One such way is to proxy the age by growth. It is reasonable to suppose that an old "well established" industry would tend to exhibit little or no growth over a recent period of time. A relatively fast-growing industry would be predicted to be less concentrated:

> Industries that are growing slowly, or, worse still, declining are likely to create a particularly difficult 'displacement problem' for new entrants. Contrarywise, when an industry is growing rapidly, new firms face a less difficult displacement problem, which has the effect of reducing entry barriers.(Mueller&Hamm, 1974)

Industry size would be another factor to affect concentration. The larger the absolute size of an industry and, the lower its entry barriers, and thus the lower the concentration ratio (Mueller&Hamm, 1974), since "economies of scale become 'less important' as a barrier to entry in 'large economies'" (Shaked&Sutton, 1987). Intuitively, it makes sense that a large market demand can accommodate for more firms. On the other hand, Shaked and Sutton argue that this is not necessarily true, as incumbent firm(s) may want to incur additional sunk costs in the form of R&D and advertising expenditures "with a view to enhancing consumers' willingness to pay for their (respective) products" (Shaked&Sutton, 1987). At this point, I argue that industry size is negatively correlated with concentration.

Another factor that would influence the extent of creative destruction among industries would be the size variability. This variable measures how volatile the industrial size had been historically (prior to 1997). If an industry's size were historically volatile, this would mean that the industry is unstable and is subject to more structural fluctuations. Hence, we would expect this variable to be positively correlated with concentration, as it is plausible to suppose that the more stable the industry (low variability), the less creative destruction occurs in it potentially, and the less is the probability of an innovation being drastic.

Finally, I also consider advertising levels for different industries. It is particularly interesting to see what the effect of advertising intensity is on concentration, since there is major disagreement in the literature on this. Interestingly enough, different authors predicted different signs for the coefficient of *Advertising Levels* and after conducting empirical analysis, ended up finding support for their theories. Mueller and Rogers (1980) hypothesize that firms (especially in consumer goods industries) are able to use advertising to create and maintain product differentiation. The most important finding of their study is that TV advertising has played an especially potent role in increasing concentration of these industries (Mueller&Rogers, 1984). Woodrow (1988), on the other hand, has found evidence that provides strong support for the view that advertising is actually pro-competitive and that it has a beneficial consumer welfare effect (Woodrow, 1988). He also rejects the hypothesis that advertising reduces leading firms' market share instability by creating market power, and again argues that the effect of advertising is to decrease market concentration and increase consumer welfare. Controlling for advertising intensity, by including it in the regression analysis, also helps emphasize the effects of industry size. Aside from this, product differentiation creates additional barriers to entry, which restrict the ability of new firms to enter the market, and thus, could cause high concentration. It is not clear from the literature whether advertising would have a positive or a negative effect on concentration.

In the next section I deal with formalizing the definitions of the dependent and the explanatory variables and finding proxies for those that cannot be measured directly.

III. Variables

Due to the fact that no one data set provides the information on all the variables that are used in the empirical analysis, three of them are combined. The combined sample contains data on some 386 NAICS* industries, industrial sectors ranging anywhere from "Lumber and Wood" to "Industrial Machinery and Equipment." The first data set used is obtained from the U.S. Census Bureau, *1997 Economic Census*, available through "American FactFinder" and it contains data for 536 6-digit NAICS industries for 1997. The second data set is obtained through EconoMagic.com and it contains the data on the size of the SIC industries from January 1992 to December 1997 on a monthly basis. The third data set is obtained through the *Research and Development in Industry: 1997* annual report available through the National Science Foundation web page. This last data set contains information on R&D expenditures as a percent of net sales in R&D- performing companies by industry and size of company for the years 1987 through 1997, as well as the data on the number of scientists employed in each industry. All industries included in

* The North American Industry Classification System (NAICS) replaced the U.S. Standard Industrial Classification (SIC) system in 1997. NAICS was developed jointly by the U.S., Canada, and Mexico to provide new comparability in statistics about business activity across North America (**U.S. Census Bureau**, *1997 Economic Census*).

the final data set are comparable to the SIC equivalents (sales or receipts from NAICS are within at most 3% of SIC sales or receipts).

Unfortunately, the latter two data sets are available only for 2- and in several cases 3-digit SIC industries. More detailed information is confidential and can only be available if granted an official security clearance. Official clearance was denied. As a result, a large part of the data had to be generalized; the values for general industrial sectors are assigned to the subsectors.

A. Dependent Variable

There are several ways to measure market concentration. Here are only a few of them: CR4, the sum of market shares of the four largest companies in the market, CR8, the sum of market shares of the eight largest companies in the market, or Herfindahl-Herschmann concentration ratio, the sum of squared market shares of all the firms in the market. In this paper, CR8 for 1997 is used as a measure of market concentration, as this measure proved to be most readily available through the data sets mentioned. We denote concentration as C.

B. Technological Factors

As noted above, it is virtually impossible to measure levels of technology and its growth directly, since these are determined by a variety of factors. Several proxies are used to account for technological growth. The basic idea is that improvements in technology require research by highly educated people in a productive environment. Therefore, as outlined in section II, reasonable proxies for technology would be R&D expenditure, net investment and human capital of workers (quality of labor) in itself proxied by average production wage and the number of scientists.

All these variables are lagged, as explained below. The underlying reasoning is that it takes time for an innovation to get transformed from a mere idea into a manufacturing process, and hence, affect concentration.

1. Research and Development (R&D)

R&D expenditures are measured as Company and other (except Federal) industrial R&D funds as a percent of net sales of R&D performing companies for 1994. The data are only available for the 2- and in several cases 3-digit SIC industries, and thus the same values are assigned to all industries within the available subgroups. The implicit assumption here is that the R&D expenditures do not vary among sub-industries. This assumption can have a negative affect on the explanatory power of the variable and we would expect the coefficient of R&D to be biased towards zero. Note that the expected sign would be positive.

2. Net Investment

Net investment is to account for all the other expenditures, aside from direct R&D. We hypothesized that factors like good machinery or safe work environment can further facilitate productivity and even creativity. This variable is measured by the ratio of total capital expenditures minus total depreciation to total value added for each of the NAICS industries for 1997. The expected sign of its coefficient is positive. This is a rather weak proxy for innovation, as high net investment may be caused by high economies of scale and capital-intensive methods of production. So, capital-intensive industries have high expenditure on capital and they are highly concentrated even with constant quality of capital. If the investment variable then is highly correlated with concentration in the absence of technological innovation, it may not be a very good proxy for technology.

3. Human Capital Intensity

This variable is rather abstract and difficult to measure. Thus, proxies are required. There are several measures that could serve as proxies for human capital intensity, one of them being average educational attainment of the workers (in years). Unfortunately, due to unavailability of this sort of data on different industries, we are unable to use this proxy and other ways need to be sought.

John S. Heywood in his paper called "Labor Quality and the Concentration-Earnings Hypothesis" argues that workers in more concentrated industries tend to be paid higher wages (Heywood, 1986), and that this is because firms in highly concentrated industries get higher profits and can afford to share it with the workers in exchange for such things as loyalty, for example. I would suggest that this takes place also because of human capital differences. I use the 1997 ratio of total production workers' wages to total number of production worker hours as a proxy for human capital intensity of industries. This makes perfect sense when one takes into consideration the (relative) quickness of adjustment of U.S. (labor) markets and low unemployment rates in recent years. A worker is being paid more if he/she is more productive (possesses more human capital), and vice versa. If this were not the case, then either the firm would be able to find someone better fitting its needs, or the worker would look for another higher-paying job. The expected sign for the coefficient for this variable is positive.

Another variable used to account for human capital intensity is the number of R&D scientists employed by each industry (for 1994). This is a more direct measure of the human capital side of the model, but unfortunately the effects are biased towards zero, due to the same data unavailability problems as in the case of R&D expenditures. The expected sign is once again positive.

Note that the wages are not lagged. The implicit assumption here is that the wages stay relatively constant within industries.

C. *Industry Specific Variables*

1. Industry Size (Mueller&Hamm, 1974)

The industry size is defined as 'total value added by the industry' (Mueller&Hamm, 1974). Its coefficient is expected to have a negative sign. Recall that the larger the industry the more room there is for more firms to emerge, and thus, concentration would decrease. The total industry value added for 1997 is used here.

2. Industry Growth (Mueller&Hamm, 1974)

Industry growth is measured by computing trends for the sizes of 2-digit SIC manufacturing industries. The data cover the period from January 1992 to December 1997. These values are then assigned to the sub-industries. Again, the implicit assumption here is that these values do not differ among the industry sub-sectors, similar to the case of R&D discussed above. The expected sign is negative, although again the coefficient is biased towards zero.

We should note here that industry growth could also act as an indirect proxy for age, as outlined earlier. The hypothesis would be that the older the industry the smaller would the growth variable measured by the trend.

3. Size Variability

Size variability is measured by computing the variances for the sizes of 2-digit SIC industries from January 1992 through December 1997 (monthly data). The assignment to the sub-industries is done in the same manner as in the case of the growth variable discussed above. Recall that a large variance would mean high size volatility. This would indicate that the market is relatively unstable. The probability that an innovation will be more drastic in such market is higher and the likelihood of a small group of firms controlling most of the market would be higher. Hence, we would expect the coefficient to be positive.

The size variability measure would act as a proxy for the extent of creative destruction.

4. Advertising Intensity

This variable accounts not only for advertising per se, but also acts as a proxy for product differentiation across industries. The impact of advertising on concentration is not quite clear:

> Advertisements that contain a high proportion of informational content (e.g. price advertising in newspapers by local retail outlets) may encourage competitive market structure. On the other hand, advertising to achieve product differentiation through subjective image-building may increase entry barriers and concentration. (Mueller&Rogers, 1980)

This variable is defined as the industry's total advertising-to-sales ratio for 1997. For now, no prediction on the variable's coefficient sign is made.

The information on all the above variables is summarized in Table 1 below.

Table 1: The Variables

Name of the variable	Type	Proxy used and units of measurement	Exp. Sign
Industrial Concentration (C)	DEPENDENT	CR8 (the sum of market shares of the eight largest companies in the market) (percent) – 1997	N/A
R&D (r&d1994)	INDEPENDENT	Company and other (except Federal) industrial R&D funds as a percent of net sales of R&D performing companies – 1994	+
Net Investment (investment)	INDEPENDENT	The ratio of total capital expenditures minus depreciation to value added (percent) - 1997	+
Scientists (scientists1994)	INDEPENDENT	Number of full-time-equivalent (FTE) R&D scientists and engineers in thousands – 1994	+
Human Capital Intensity (wage)	INDEPENDENT	The ratio of total production workers' wages to total production worker hours ($ per hour) - 1997	+
Industry Size (size)	INDEPENDENT	Total value added by the industry ($ blns.)* - 1997	-
Industry Growth (trend)	INDEPENDENT	Slope of the trend line of industry total value of shipments over the period of time from January 1992 to December 1997 (monthly data) (units)	-
Size Variability (variance)	INDEPENDENT	The variance of the industry total value of shipments taken from January 1992 to December 1997 (monthly data) (units)	+
Advertising Intensity (advertising)	INDEPENDENT	The industry's total advertising-to-sales ratio (percent) - 1997	?

* Industry size was originally measured in thousands of dollars. The measurement units are changed to billions in order to aid in the interpretation of the coefficients.

IV. Empirical Model

After running several regressions involving different specifications, I conclude that the linear models provide the best fit. Two regression specifications are considered: one with stronger proxies and generalized data, and the other with more precise data, but weaker proxies. The two models are given by equations 3 and 4 respectively:

Model 1: $C = a + b_1 * r\&d1994 + b_2 * scientists1994 + b_3 * wage + b_4 * trend + b_5 * variance + b_6 * advertising;$ (3)

Model 2: $C = a + b_1 * wage + b_2 * investment + b_3 * size + b_4 * advertising.$ (4)

The former is a stronger model from a theoretical perspective. The level of technology here is proxied by the 1994 expenditures on R&D, which is the most direct measure of the physical capital side of the model, as well as by the number of scientists working in the R&D sector and the average production wage. The scientists1994 variable aims at accounting for the quantity of human capital employed directly in research. The average production wage, on the other hand is to account for the quality of the overall labor used in the industry, as we would expect more qualified laborers to be paid higher wages.

The control variables include industry growth, as measured by trend in size, size variability and advertising intensity. For more detailed description of the variables and their predicted effects, see sections II and III.

Unfortunately, due to the problem of unavailability of data for detailed industries, as most of it proves to be confidential, the values for r&d1994, scientists1994, trend, and variance are generalized on a rather broad basis. The implicit assumption here is that these parameters are the same for all subsectors of more general (2-digit in SIC) industrial segments. As a result, I expect the coefficients to be biased towards zero

Model 2, on the other hand, can be run on more sound data. It does have a few theoretical weaknesses though, as the most direct proxies for the level of technology had to be removed. Here a new, considerably weaker, measure for the physical capital side of technology is used – net investments. As argued in section III, this variable is a fairly weak proxy for innovation, as high levels of net investment in physical capital can be a result of economies of scale in capital intensive industries, as opposed to expenditures on research and productivity enhancing factors. Industry size is used as a measure of how well-established the industries are, instead of growth and variability, as in Model 1. Advertising intensity and production wages are retained from the previous model.

Model 2, although allowing for a higher quality of data analysis, includes rather weak proxies for innovation. Hence we should be careful when drawing conclusions based on the results of this specification.

As discussed earlier, economic theory suggests that there may be a reverse relationship between innovation and industrial concentration. This raises the issue of simultaneous equation bias. As a result of the simultaneous equation bias, we can end up with inconsistent estimates for the coefficients, due to the violation of the Gauss-Markov condition that the disturbance term be distributed independently of the explanatory variables. This problem is accounted for in the design of the above models. Namely, lagging explanatory variables allows us to avoid such bias. In general, the question of the time lag that is required for an innovation to affect productivity and, eventually, concentration, is, in itself, of utmost importance. In the models discussed here a 3-year lag is used for R&D expenditures and the number of scientists. The other available years are 1992 and 1996. Neither yielded statistically significant results.

The former model is estimated using 258 observations (6-digit NAICS industries) with generalized data input. The latter one is run on a sample of 413 6-digit NAICS industries. The results are as follows:

Model 1 (R square = .059)

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Expected sign?*
Intercept	30.507	6.540	4.664	0.000	-----------
r&d1994	-1.150	1.187	-0.969	0.333	NO
scientists1994	0.050	0.132	0.381	0.703	YES
wage	1.421	0.492	2.889	0.004	YES
trend	-0.075	0.064	-1.172	0.242	YES
variance	0.571	0.359	1.592	0.113	YES
advertising	3.735	1.517	2.462	0.015	-----------

Model 2 (R square = .057)

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Expected sign?*
Intercept	28.955	5.005	5.786	0.000	-----------
investment	0.630	0.415	1.519	0.129	YES
wage	1.379	0.355	3.889	0.000	YES
Size	-1.200	0.577	-2.037	0.042	YES
advertising	3.201	1.214	2.636	0.009	-----------

When interpreting the results, we face a tradeoff between the quality of the proxies and their explanatory power. Model 1 yields very insignificant results. The only statistically significant coefficients are the ones for wage (1% level) and advertising (2%

level), and these are the only variables that are not generalized. Thus, we can state that an increase in average production wage and/or in advertising expenditures relative to total value added by the industry would correspond to an increase in the concentration ratio of that industry, as measured by CR8. These results support the initial hypothesis that innovation, in this case proxied by wage, causes higher concentration. Unfortunately, the rest of the variables prove to be highly insignificant, perhaps due to the generalized data sources. Recall that we expected the coefficients of the generalized variables (R&D1994, scientists1994, trend, variance) to be biased towards zero. It is worthwhile noting that the absolute size variable (measured by value added), when included in the specification, was also highly insignificant.

On the other hand, the second model presents us with more conclusive results. All signs are as predicted and all variables are significant, except for investment (significant only at the 13% level). These results suggest once again that wages and advertising would have a positive effect on concentration as predicted. Size is also significant and has the predicted sign, which means that we would expect larger industries to be less concentrated, everything else held constant.

The last thing we may want to look at is the significance of the regression results as a whole. This can be determined by conducting an F-test, which yields that the probability of the final regression results being random is less than 0.1% in both cases. This is not surprising, since several coefficients in the regression outputs are highly significant.

In spite of all this, the adjusted R^2 is rather low (=0.06), which means that only 6% of variation in industrial concentration is explained by the present model. There may be several explanations for this. One is that there are other variables that need to be included in the analysis and that are important in explaining the variation in industrial concentration. This is very plausible, since the works discussed in the theoretical part of this paper all deal with different variables and in all of them authors arrive at fairly significant results. Thus, there may be some omitted variable bias, which would make the coefficients biased and the statistical tests invalid. In order to avoid such bias, we would then be required to include additional variables that are related to concentration. This is something future researchers could consider.

There is a wide range of factors that are not included in my analysis. Most notably, as argued by Mueller and Hamm (1974), the beginning level of market concentration is of utmost significance when explaining current concentration. When included as an explanatory variable, lagged concentration had a flooding effect. The coefficient was significant, but the effects of other variables were weakened. As a result, I chose to keep lagged concentration out of the model.

Other important sets of variables barely accounted for in my analysis are those of entry and exit costs, product differentiation and the sunkenness of costs. These topics are important in themselves, and deserve special attention, perhaps a whole new research initiative.

The fact that the values of R-squared for both models are fairly low may also be a result of weak theoretical model, as in Model 2, or insufficient significance of the explanatory variables, as in Model 1.

V. Results

Unfortunately, neither of the models provides strong evidence in support of the initial hypothesis that innovation would positively affect market concentration by granting market power to its owners. In Model 1, we end up with very insignificant coefficients for direct measures of technology (that is to cause innovation), and nothing can be concluded. Model 2, on the other hand, represents a weaker model and cannot be used as a basis for clear conclusions. The only proxy for technology that comes out to be significant in explaining the variation in concentration is average production wage. This, in fact, is consistent with Romer's hypothesis that human capital is the single most important cause of innovation. We should note that the sign for the wage variable in both models is positive, which means that higher human capital intensity corresponds to higher concentration in industries, as predicted.

The variables for trend (growth) and size variability, although weakly significant, appear to have robust signs, as I tried to better fit the data and change model specifications. Recall that these two variables together are to account for the extent to which an industry is "well established" and for the extent of "creative destruction" respectively. The proposition is that the higher the growth rate, the younger the industry and the more potential for entry is exhibited, and thus, the industry is less concentrated. Conversely, high size variability would mean that the industry is subject to strong creative destruction effect and that an innovation is more likely to be drastic (higher extent of creative destruction), and thus, this industry would be more concentrated. The robustness of the signs for the coefficients of trend and variance in Model 1 suggests that the predicted relationship may hold, although no conclusive evidence can be drawn to support the hypotheses.

In Model 2, the variable for the size of an industry (total value added) also turns out to be significant and to exhibit the predicted sign (negative). This supports my initial proposition that the larger the industry, the more room there is for entry and the lower the concentration ratio.

It is also interesting that the variable that accounts for advertising levels is highly significant and bears a positive sign in both models. This evidence seems to support the hypotheses stated by Mueller and Rogers that advertising creates market differentiation and increases market entry costs, thus positively affecting concentration. As to the hypothesis that advertising is welfare increasing and pro-competitive (advertising as a source of information), the empirical evidence provided by 1997 Economic Census does not seem to support this view. It may have been more useful to look closely at different types of advertising (e.g., TV versus others) in order to flesh out both of these effects, but advertising is included here just as a "control" variable. For a more in-depth discussion of the effects of advertising on industrial concentration see Mueller&Rogers, (1980).

VI. Conclusions, Policy Implications and Suggestions for Further Research

The primary focus of this paper is to flesh out the effects of technological growth on market concentration. I start out by hypothesizing that concentration ratios depend on the levels of technology in different industries. It turns out though that there are other factors that can cause concentration. As a result, I arrive at a final hypothesis that industrial concentration depends not only on technological growth, but also on industry specific factors that determine the extent of creative destruction among industries. These industry specific factors are then included in the empirical model as control variables.

The next step is to identify variables and proxies that would measure technological growth and the level of creative destruction. The former is proxied by the human capital intensity and the physical capital/ R&D intensity variables, based on a proposition that the rate of arrival of technological innovations occurs as a result of combination of the human capital involved in the production (Romer, 1990) and the physical resources devoted to research and development. The basic reasoning behind this is that technological growth is a result of "smart people working with advanced machines." The following proxies for technology are identified: R&D expenditures, the number of scientists employed in the research sector, net investment, and last but not least, average production wage.

The variables accounting for the extent of "creative destruction," "well establishedness" and other industry specific factors are growth, size variability, size, and advertising intensity. The first three relate to the stability of industry sizes, and the last one accounts for advertising, product differentiation levels and entry costs.

Two empirical models are used to test the hypothesis of a positive effect of innovation on concentration. Model 1 includes direct proxies such as R&D expenditures and the number of scientists, but, due to data problems, no clear conclusions can be drawn. Model 2 deals with weaker proxies, but better quality of data. Both models yield positive significant coefficients for the wage variable, as predicted. Recall that the wage variable is to account for the human capital intensity side of the model for technology. No other coefficients provide significant support for the initial hypothesis.

The results for advertising levels seem to support the argument presented by Mueller and Rogers that advertising increases concentration through brand proliferation and product differentiation, as the coefficient estimates turned out to be significant at 1.5% level. Various sources in literature provide different arguments relating advertising levels to concentration, and here we find evidence supporting the argument that advertising decreases creative destruction by creating loyalty to brands. Thus, we can conclude that the effect of advertising on concentration is positive.

Generally, the conclusions of this study are rather ambiguous. I fail to find sufficient empirical evidence to support my claim that technological growth has a positive affect on industrial concentration, all other factors held constant. The only proxy that proves to be consistently significant is wage. On the other hand, a more plausible result is that the empirical evidence supports the argument that older industries that are subject to less creative destruction tend to be more concentrated, as suggested by the coefficients of size, growth and variance variables.

As mentioned earlier, studying the factors influencing market concentration can be extremely important for policy makers. This paper is to provide a new dimension to the factors causing concentration, and to deciding on policies in anti-trust legislation that often use industrial concentration (and market shares) as a measure of market power. It is still necessary to empirically test the relationship that is hypothesized in this paper. Unfortunately, restricted access to key data made this task next to impossible at this point. If supported though, the results here would suggest that high concentration may not always be bad for the economy, since it may be a result of high technological growth in the industry. It is also shown that high concentration may be attributed to the fact that some industries are "well established," that is they do not significantly vary in size. In the latter case, the opportunities for additional entry would be limited and we would expect high concentration ratios even though technology does not grow as fast. All these factors, together with ones considered in literature are to help us understand the origin of industrial concentration, and thus, improve our ability to implement meaningful policies.

There are three ways this research can be developed further: 1) finding more independent variables to explain the origin of concentration, which would increase R^2, 2) applying similar reasoning to another sector of industry (e.g., Finance&Insurance or Information), 3) trying to solve the problem of data unavailability for the key measures of technology levels among industries. All three require further investigation and will hopefully provide a better explanation of what factors affect industrial concentration and how.

It would also make sense to extend the main ideas of this paper into international markets, or try to perform a similar analysis using data from a foreign country, and then compare the conclusions identifying the differences and trying to explain them theoretically. This will require a more complicated analysis, incorporating factors accounting for trade and political structure of the countries studied. Another possible topic for future research is investigating how changes in the structure of the consumer demand would influence market concentration. It would be extremely interesting to see whether changes in consumer tastes and preferences, as well as consumer income, education, etc. can influence market concentration.

LIST OF REFERENCES:

Aghion, Philippe and Howitt, Peter. "A Model of Growth Through Creative Destruction", *Econometrica*, Volume 60, Issue 2 (March 1992), 323-351.

Bylinsky, Gene. "Look Who's Doing R&D", *Fortune*, 11/27/2000, Vol.142, Issue 13, p242B, 4p, 3c.

EconoMagic. *Manufacturing Shipments, Inventories, and Orders.* Available at URL: http://www.economagic.com (subscription required).

Gwemawat, P. "Capacity Expansion in the Titanium Dioxide Industry", *Journal Of Industrial Economics*, Dec.1984, 145-163.

Heywood, John S. "Labor Quality and the Concentration-Earnings Hypothesis", *The Review of Economics and Statistics*, Vol. 68, No. 2. (May 1986), pp.342-346.

Kessides, Ioannis N. "Market Concentration, Contestability and Sunk Costs", *The Review Economics and Statistics*, Volume 72, Issue 4 (Nov., 1990), 614-622.

Lunn, John and Martin, Stephen. "Market Structure, Firm Structure and Research and Development", *Quarterly Review of Economics and Business*, Vol26, No1, Spring 1986, 31-44.

Mueller, Willard F. and Hamm, Larry G. "Trends in Industrial Market Concentration, 1947 to 1970", *The Review of Economics and Statistics*, Vol. 56, No. 4. (Nov., 1974), pp. 511-520.

Mueller, Willard F. and Rogers, Richard, T. "The Role of Advertising in Changing Concentration of Manufacturing Industries", *The Review of Economics and Statistics*, Vol. 62, No. 1. (Feb., 1980), pp. 89-96.

Romer, Paul M. "Endogenous Technological Change", *Journal of Political Economy*, 98(5 part 2): S71-S102, October 1990.

Scott, John T. "Firm vs. Industry Variability in R&D Intensity" in Zvi Griliches, ed. R&D, Patents, and Productivity, 233-252. Chicago, University of Chicago Press, 1984.

Shaked, Avner and Sutton, John. "Product Differentiation and Industrial Structure", *Journal Of Industrial Economics*, Volume 36, December 1987, 131-146.

U.S. Census Bureau. *1997 Economic Census: Bridge Between SIC and NAICS.* Available at URL: http://www.census.gov/epcd/ec97brdg/INDXSIC2.HTM#D.

U.S. Census Bureau. *1997 Economic Census: Comparative Statistics for United States 1987 SIC Basis.* Available at URL: http://www.census.gov/epcd/ec97sic/E97SUS.HTM.

U.S. Census Bureau. *1997 Economic Census: Concentration Ratios in Manufacturing.* Available at URL: http://www.census.gov/prod/ec97/m31s-cr.pdf.

Waldman, Don E. and Jensen, Elizabeth J. Industrial Organization: Theory and Practice, Second edition, Ch. 13, 396-435.

Weiss, L. "Factors in Changing Concentration", *The Review of Economics and Statistics*, Vol. 45, No. 1. (Feb., 1963), pp. 70-77.

Woodrow Jr., Eckard E. "Advertising, Competition, and Market Share Instability", *Journal of Business*, Vol. 60, No. 4. (Oct., 1987), pp. 539-552.