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Highlights

- We investigate the impact of market structure on industry performance.
- We employ a novel pooled panel threshold GMM model.
- Our theoretical model is based on a growth-accounting TFP framework.
- We use the concentration ratio (CR4) as the threshold variable.
- There is an inverse U-shaped curve between competition and industry performance.

On the examination of non-linear relationship between market structure and performance in the US manufacturing industry

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Abstract

This paper attempts to investigate the causal link between market structure and industry performance using a micro panel data set of USA manufacturing industries over the period 1958-2007. We employ a novel panel GMM model strongly accounting for endogenous regressors and threshold variable. The empirical findings denote the existence of a non-monotonic relationship between market structure and total-factor productivity (TFP). Our findings call for future research on the impact of market structure on consumer welfare.

JEL classifications: C24, L1; L6

Keywords: Market structure; TFP; Threshold; Competition; Non-linear effects.

1. Introduction

We investigate the impact of competition on industry performance by employing threshold model techniques within a growth-accounting TFP framework. In this way, we are able to test the validity of the well-known Structure-Conduct-Performance paradigm (S-C-P) introduced and developed by Mason (1939) and Bain (1956). The latter attempts to assess the performance of a given industry and explain the two-way (linear) causation among key variables that run the S-C-P model. The key concept of this paradigm is that market performance is determined by the behavior of market participants, which in turn, is determined by market structure and vice versa. Although, there are certain limitations to this model, the S-C-P paradigm provides useful information to the policy makers and practitioners in several ways (Carlton and Perloff, 1989).

The novelty of our study is that we use for the first time a panel sample splitting methodology linking competition with the level of industry performance. In this way, we argue that an industry needs to cross a certain level of market concentration (competition) in order to achieve a certain level of performance. Our findings clearly reveal the existence of a non-monotonic relationship between market structure and industry efficiency. This gives rise to an inverted U-shaped curve between market competition and industry performance, which in turn affect consumer welfare.

The rest of the paper is organized as follows. Section 2 develops the theoretical model. Section 3 introduces the data and describes the empirical methodology, while section 4 discusses the empirical results and concludes the paper.

2. Model

We assume that the production in the economy at time t, $Y_{i,t}$, is given by the following production function:

$$Y_{i,t} = f(K_{i,t}, L_{i,t}, \mathrm{E}_{i,t}) \quad (1)$$

where $K_{i,t}$, $L_{i,t}$ and $E_{i,t}$ are, respectively, the non-homogenous sector-wide capital, labor and energy services. Following Hsieh (1999), the dual extraction of TFP growth is based on the following equation:

$$Y_{i,t} = r_{i,t}K_{i,t} + w_{i,t}L_{i,t} + m_{i,t}E_{i,t} \tag{2}$$

where r, w and m denote the real input costs (rental rate of capital, wage rate, and energy rate respectively). Taking logarithms and after some derivation with respect to time t, we get:

$$\dot{Y} = s_K\left(\dot{r} + \dot{K}\right) + s_L\left(\dot{w} + \dot{L}\right) + s_T\left(\dot{m} + \dot{E}\right) \tag{3}$$

By rearranging we end up with the following expression:

$$\dot{Y} - s_K\dot{K} - s_L\dot{L} - s_T\dot{E} = s_K\dot{r} + s_L\dot{w} + s_T\dot{m} \tag{4}$$

where s is the weighted share of each input to the overall production of the economy. The left hand side of Eq. (4) gives us the Solow residual (growth rate of TFP), which is equal to the weighted sum of the growth rate of real input prices (Acemoglu, 2009). In order to estimate the TFP growth rate, we take the total derivative of Eq. (1) with respect to time t:

$$\frac{dQ}{dt} = \sum_{i=1}^{m} \frac{\partial Q}{\partial Xi}\frac{dXi}{dt} + \frac{\partial Q}{\partial t} \tag{5}$$

By taking logarithms and after some algebraic formulation, we have:

$$\frac{d\ln Q}{dt} = \sum_{i=1}^{m} \frac{\partial \ln Q}{\partial \ln Xi}\frac{d\ln Xi}{dt} + \frac{\partial \ln Q}{\partial t} \tag{6}$$

If we use the elasticity of production and the growth rate of technical progress {T(x;t) = dlnQ/dt when d X_i = 0} we get:

$$\dot{Q} = \sum_{i=1}^{m} \varepsilon_i \dot{X}_i + T(x;t) \tag{7}$$

By subtracting the Divisia index $\dot{X} = \frac{1}{\mathrm{E}}\sum_{i=1}^{m} \varepsilon_i \dot{X}_i$ from both sides of the Eq. (7), we take the following expression:

$$TF\dot{P} = \left(1 - \frac{1}{\mathrm{E}}\right)\sum_{i=1}^{m} \varepsilon_i \dot{X}_i + T(x;t) \tag{8}$$

3. Data and methodology

The sample consists of an unbalanced panel data set of manufacturing industries at the four-digit level (N = 459) over the period 1958-2007 (T=13). Similarly to Polemis and Stengos, (2015), all variables are taken from the National Bureau of Economic Research. Table 1, provides the descriptive statistics of the variables included in this study. It is worth mentioning that the market concentration variable (CR4), which will be used as the threshold variable displays a relatively small coefficient of variation (relative standard deviation) equaling to 0.52. It has a sample mean equal to 40 approximately, implying that the four largest companies of the sample sectors included in this study absorb around 40% of the market (i.e medium concentration). This measure departures from the threshold estimates (21.7%-25%) as seen bellow (see Table 3).

Table 1: Summary statistics

Variables	Observations	Mean	Standard deviation	Min	Max
TFP5	4,361	1.016	1.049	0.161	49.040
CR4	4,361	40.050	20.930	1.000	99.300
lnSHIP	4,361	3.359	0.539	1.221	6.517
lnK/L	4,360	0.455	0.298	1.966	1.128
lnINV	4,361	1.789	0.634	0.489	4.084
lnMAT	4,361	3.059	0.554	0.631	5.249
lnENER	4,361	1.564	0.625	0.720	3.810

Note: TFP5, is the five factor Total Factor Productivity index (1997=1.000). CR4 denotes the sum of the market shares of the four largest firms in each of the sample sectors, while lnSHIP is the logged value of shipments expressed in real terms. LnK/L is the logged capital to labour ratio expressed in real terms, while lnINV stands for the real logged total capital expenditure. The logged real total cost of materials is expressed by lnMAT, while lnENER is the real logged cost of electricity and fuels. The variables lnK/L, lnINV amd lnENER were transformed to log (X_i + 0.001) in order to eliminate some zero values respectively.

We use the pooled panel GMM threshold method of Seo and Shin (2016). In this case, the model takes the following form:

$$Y_{i,t} = a_i + \beta_1^{\mathrm{T}} X_{i,t} + v_t + \varepsilon_{i,t}, q_{i,t} \le \gamma_0 \tag{9}$$

$$Y_{i,t} = a_i + \beta_2^{\mathrm{T}} X_{i,t} + v_t + \varepsilon_{i,t}, q_{i,t} > \gamma_0 \tag{10}$$

where subscripts $i = 1, \ldots, N$ represent the industry and $t = 1, \ldots, T$ indexes the time. $Y_{i,t}$ is the dependent variable (growth rate of TFP)[1]. $I(\cdot)$ is the indicator function denoting the regime defined by the threshold variable and the threshold level γ_0 (sample split value), while $q_{i,t}$ is a scalar endogenous threshold variable (CR4) that splits the sample into two different regimes (low and high). $X_{i,t}$, is a $d_x \times 1$ vector of covariates. Similarly to Polemis and Stengos (2015), we include the value of shipment (SHIP) as a proxy for market size, the capital to labor ratio (K/L), the real total capital expenditure as a proxy for capital (INV), the real total cost of materials (MAT) as a proxy for intermediate inputs and finally the real cost of electricity and fuels (ENER) as a proxy for energy cost. Moreover, β_1 and β_2 are regime specific coefficients. Lastly, we include the relevant year (time) fixed effect (v_t) and the i.i.d error term and we note that $q_{i,t}$ is also part of the $X_{i,t}$ vector. The method proceeds in two steps. In the first step estimates of the parameters β_1, β_2 and γ are obtained by GMM for a selected parameter value of γ. Step one is repeated for $\gamma's$ belonging in a strict subset of the support of the threshold variable, resulting in different estimates of β_1 and β_2 for each selected γ. The value of γ which minimizes the GMM objective function and its corresponding slope estimates are the optimal estimated parameters (Asimakopoulos and Karavias, 2016). Finally, following Hansen (1999; 2000) we use the S*up*Wald test to check the

[1] The standard approach to measuring firm-level performance is to identify TFP levels or growth (Aghion et al, 2015).

validity of the H_0 hypothesis regarding the linear formulation against a threshold formulation.

4. Results and discussion

Table 2 presents the results from the benchmark parametric (linear and quadratic) specifications. We must stress though that estimating the relevant specifications with OLS fixed effects (FE) may lead to spurious results since market concentration is endogenously determined by the rest of the covariates. To effectively tackle with this problem, we adopt the instrumental variable (IV) approach using 2SLS. In the first stage, we predict the values of CR4 and $CR4^2$ while in the second stage we perform the regressions by using the lagged once covariates as instruments. In this case, we notice that without the inclusion of the quadratic term the effect of market structure appears to be insignificant. However, if the impact of market structure exhibits an inverse-U shape, its marginal effect will be positive before reaching a threshold and become negative afterward. This may result in an overall zero effect if we force a monotonic relationship (Dai et al, 2014). With an additional quadratic term though, the estimated effects of market concentration on industry performance become statistically significant and their estimate coefficients alternate in sign starting from positive to negative. This suggests a non-monotonic relationship in a form of an inverted U-shaped curve.

Next we apply the nonlinearity test of the baseline (parametric) specifications against the threshold model. The relevant test is based on bootstrap critical values of a Wald type heteroskedasticity-consistent test where rejection of the null hypothesis implies that there is a significant threshold. From Table 3, we find that all the bootstrapped tests strongly reject linearity in favor of the threshold model in all of the specifications. As a consequence, the baseline model does not capture the nonlinear effects of market structure on industry performance.

Table 2: Parametric results

Variable	**(1) OLS-FE**	**(2) IV-FE**	**(3) OLS-FE**	**(4) IV-FE**
Constant	-0.6003*** (0.0000)	-	-0.6017*** (0.0000)	-
CR4	0.0013** (0.0498)	-0.0003035 (0.425)	0.0014** (0.0461)	0.002426** (0.027)
$CR4^2$	-	-	0.0001*** (0.0000)	-9.28e-07** (0.039)
lnSHIP	0.57567*** (0.0000)	-	0.5791*** (0.0000)	-
lnK/L	0.0695*** (0.0000)	-	0.0700*** (0.0000)	-
lnINV	-0.156*** (0.0000)	-	-0.1567*** (0.0000)	-
lnMAT	-0.3964*** (0.0000)	-	-0.3986*** (0.0000)	-
lnENER	0.0118 (0.2184)	-	0.0116*** (0.0005)	-
CR4×lnSHIP	-0.0001*** (0.0069)	-	-0.00011** (0.0121)	-
CR4×lnK/L	-0.0007*** (0.0003)	-	-0.0007*** (0.0002)	-
CR4×lnINV	0.0002*** (0.4858)	-	0.0002*** (0.0000)	-
CR4×lnMAT	0.0011*** (0.001)	-	0.0012*** (0.0016)	-
CR4×lnENER	-0.0001 (0.7496)	-	-0.0001*** (0.0000)	
Observations	4,361	3,902	4,360	3,902

Note: The numbers in parentheses denote p-values. Time dummies are included but not reported. Significant at ***1%, **5% and *10% respectively. CR4 denotes the sum of the market shares of the four largest firms in each of the sample sectors, while lnSHIP is the logged value of shipments expressed in real terms. LnK/L is the logged capital to labour ratio expressed in real terms, while lnINV stands for the real logged total capital expenditure. The logged real total cost of materials is expressed by lnMAT, while lnENER is the real logged cost of electricity and fuels. Control variables (lnSHIP, LnK/L, lnINV, lnMAT, and lnENER) are included but not reported. Instruments for the IV models (column 2 and 4) include the lagged set of the covariates.

We proceed to estimate the threshold model under four alterative methodologies. The first two models follow Hansen's (1999, 2000) approach where the regressors and the threshold variable are assumed to be exogenous with and without fixed effects, while the last two are the GMM models with and without fixed effects.

From the inspection of Table 3, we find that the optimal threshold level in all of the four different methodologies ranges from 21.7% (GMM-FE) to 25.2% (TR), with relatively tight confidence intervals (CI).

Table 3: Threshold model results

Method	**(1) TR**		**(2) TR-FE**		**(3) GMM**		**(4) GMM-FE**	
Threshold	**24.7**		**25.0**		**23.1**		**21.7**	
10% CI	**[24.7, 25.2]**		**[24.5, 41.4]**		**[21.1, 25.0]**		**[15.6, 27.7]**	
Regimes	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
$Constant$	-0.5539***	-0.4763***	-	-	-0.8687***	-0.5987***	-	-
	(0.0000)	(0.0000)	-	-	(0.0000)	(0.0000)	-	-
$lnSHIP$	0.5373***	0.4808***	0.9261***	0.9200***	0.6821***	0.5686***	1.0187***	1.0271***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$lnINV$	-0.1299***	-0.1311***	-0.0455***	-0.0533***	-0.2616***	-0.2393***	-0.2627***	-0.2567***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$lnMAT$	-0.3662***	-0.2984***	-0.6075***	-0.5578***	-0.4298***	-0.3395***	-0.5303***	-0.6031***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
lnK/L	0.0511***	0.0488***	-0.0441***	-0.0720***	0.1000***	0.0734***	-0.0731***	-0.0733***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$lnENER$	0.0006	-0.0104***	-0.1420***	-0.1921***	0.0455**	0.0413***	-0.1431***	-0.1127***
	(0.9300)	(0.0000)	(0.0000)	(0.0000)	(0.0459)	(0.0000)	(0.0007)	(0.000)
$CR4$	0.0002*	-0.0010***	0.0001	-0.0001***	0.0054	-0.0008***	0.0005**	-0.0033**
	(0.0527)	(0.0000)	(0.3014)	(0.0000)	(0.4244)	(0.0001)	(0.0498)	(0.0132)
$SupWald$	34.3***		45.5***		54.5***		42.6*	
	(0.0000)		(0.0000)		(0.0021)		(0.0589)	
Observations	3,902		3.902		3,902		3,902	

Note: This table presents the estimations of the Threshold Model of Hansen with no endogeneity (1999, 2000), with (TR-FE) and without fixed effects (TR), the GMM Threshold model of (Seo and Shin, 2016), with (GMM-FE) and without fixed effects (GMM). The threshold variable is the level of market concentration of the four largest company in each sector of the sample ($CR4_i$). CR4 denotes the sum of the market shares of the four largest firms in each of the sample sectors, while lnSHIP is the logged value of shipments expressed in real terms. LnK/L is the logged capital to labour ratio expressed in real terms, while lnINV stands for the real logged total capital expenditure. The logged real total cost of materials is expressed by lnMAT, while lnENER is the real logged cost of electricity and fuels. Instruments for the GMM models (column 2 and 4) include the lagged set of the covariates. The numbers in braces are the 10% Confidence Intervals (CI) for the threshold in each of the four different methodologies. The numbers in parentheses denote p-values. Time dummies are included but not reported. Significant at ***1%, **5% and *10% respectively.

Moreover, nearly all of the variables are statistically significant and properly signed. Specifically, market size (lnSHIP) increases TFP, while the opposite holds when capital intensity (lnINV) and material cost (lnMAT) are taken into account. Similarly, the energy cost (lnENER) when significant is negatively correlated with the TFP growth, while the capital to labour (lnK/L) exerts a strong positive impact. Our key variables of interest are β_1 and β_2 denoting the effect of competition on industry performance under the low and high regime respectively. From the relevant table, it is quite evident that the effect of competition on TFP is negative in the high ($\hat{\beta}_2$<0) and positive in the low regime ($\hat{\beta}_1$>0), indicating that industry performance increases up to a certain point (threshold) in the competitive part of the curve and decreases in the more concentrated part. The coefficients are statistically significant both bellow and above the threshold in all of the four models. This is consistent with an inverse U-shaped curve also evident in other empirical studies (Dai et al, 2014; Polemis and Stengos, 2017).

Overall, this study supports a non-linear relationship between market structure and TFP, unveiling an inverse U-shaped curve between competition and industry performance, which in turns validate the S-C-P. Our paper contributes to the New Empirical Industrial Organization (NEIO), since we are the first to uncover a novel non-linear relationship between competition and industry performance.

References

Acemoglu, D. (2009). *Introduction to Modern Economic Growth*. Princeton and Oxford, MIT Press.

Aghion P., Cai J., Dewatripont, M., Du, L., Harrison A., Legros, P (2015). Industrial Policy and Competition, *American Economic Journal: Macroeconomics*, 7(4): 1-32.

Asimakopoulos, S., Karavias, Y., (2016). The impact of government size on economic growth: A threshold analysis. *Economics Letters*, 139: 65-68.

Bain, J.S. (1956) *Barriers to New Competition: Their Character and Consequences in Manufacturing Industries*. Cambridge: Harvard University Press.

Carlton, D.W. and Perloff, J.M. (1989) *Modern industrial Organization*. USA: Harper Collins.

Dai, M., Liu Q., Serfes, K. (2014). Is the effect of competition on price dispersion nonmonotonic? Evidence from the U.S. airline industry. *The Review of Economics and Statistics*, 96(1): 161–170.

Hansen, B.E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics*, 93(2): 345-368,

Hansen, B.E. (2000). Sample splitting and threshold estimation. *Econometrica*, 68 (3): 575-603.

Hsieh, C.T. (1999). Productivity Growth and Factor Prices in East Asia, *American Economic Review*, 89(2): 133-138.

Mason, E.S. (1939). Price and production policies of large-scale enterprise. *American Economic Review* (Suppl), 29: 61–74.

Polemis, M., Stengos, T. (2017). Does Competition Prevent Industrial Pollution? Evidence from a Panel Threshold Model, Working Paper Series 17-07, *The Rimini Centre for Economic Analysis*.

Polemis, M., Stengos, T. (2015). Does market structure affect labour productivity and wages? Evidence from a smooth coefficient semiparametric panel model. *Economics Letters*, 137: 182-186.

Polemis, M. (2017). Revisiting the Environmental Kuznets Curve: a semi-parametric analysis on the role of market structure on environmental pollution. *Letters in Spatial and Resource Sciences*, https://doi.org/10.1007/s12076-017-0195-9.

Seo, M.H. and Shin, Y., 2016. Dynamic Panels with Threshold Effect and Endogeneity. *Journal of Econometrics* 195 (2), 169-186.