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by

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The Cyclical Dynamics of Industries in West Germany - Testing the Industry Life Cycle Hypothesis

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Abstract

We test the industry life cycle hypothesis for 205 industries in West Germany between 1976 and 2009. In particular we analyse whether population indicators follow a cyclical path. Using a novel non-linear regression approach to identify life cycles we find that the number of establishments, employees, entries and exits follow in most industries a path that is well represented by at least a part of a cycle. Most industries that show cyclical behaviour run (partially) through their life cycle in the considered time period.

Keywords: Industry life cycle, cyclical development, establishment, employment, industry dynamics

JEL classification: C23, L16, O33

1. Introduction

Research on the evolution of industries has produced a substantial body of empirical studies and theoretical models (Jovanovic and MacDonald, 1994; Klepper, 1996, 1997). In particular the highly stylized industry life cycle (ILC) framework has been frequently used to explain the evolution of industries. Among numerous studies applying the ILC (Klepper, 2007; Klepper and Simmons, 2000), only few (Agarwal, 1998, Audretsch, 1987) have examined the statistical properties of industry evolution across a wider set of indicators and with a focus on more than one single (product) industry. We address this shortcoming here.

To this end, we interpret the ILC literally and develop a regression framework which allows testing for cyclical instead of quadratic dynamics as done in previous studies (Agarwal, 1998; Audretsch, 1987). Two aims are central: Testing whether cyclical dynamics are found for different indicators and industries and identifying for each of them the ILC stage.

The analysis exploits rich industry level data for West Germany comprising the evolution of 205 industries from 1976 to 2009. We study four population indicators: the number of establishments, employment, entries and exits. This unpreceded large set of data allows for a more conclusive test of the ILC than provided so far in the literature.

2. The industry life cycle

The development of firm populations in an industry is often found to follow a path that can be described by a life cycle. Overwhelming empirical support by numerous empirical studies led to the formulation of the ILC as a general and long-term population model (Gort and Klepper, 1982; Klepper, 1997).

Dynamics of innovation, technological change and market structure are integrated in theoretical models to explain the life cycle pattern of industries. Abernathy and Utterback (1978) and Utterback and Suarez (1993) relate industrial dynamics to the evolution and implementation of a de facto dominant (product) design, the resulting shift in innovation from product to process R&D and intensifying competition on prices leading to an increase of exits. Jovanovic and MacDonald (1994) use exogenous technological developments to explain the

creation of new industries which, as a result of intensifying competition by additional entries, grow until profits are driven to zero. Further inventions induce new entry but also put pressure on incumbent firms. Klepper (1996) introduces a model that assumes market structure and innovation from product to process R&D as co-evolving. In this model entries after the initial phase of an industry must predominantly compete on their R&D abilities with established firms who have a competitive advantage from increasing returns to process R&D. After some time this leads to continuous exits until the entire output of an industry is concentrated on the most capable early entrants.

From the various theories the following predictions for the industry life cycle can be derived: In its initial phase, industries exhibit only a slow increase in the number of firms that is typically followed by rapid growth until a peak is reached. After this peak population size declines sharply, before eventually the number of firms stabilizes at a low level. There is a wave of entries at the beginning and a wave of exits (the so-called shake-out) in a later stage. Hence, entries and exits show similar dynamics as the number of firms, but at different stages of the ILC. The number of employees also increases at the beginning of the life cycle but might not decrease later.

3. Data

We use a data set for West Germany covering 205 industries in the NACE Rev. 1 system and at the 3-digits level between the years 1976 and 2009. We analyse industries at this particular level because it approximates a self-contained (product) industry with an autonomous development quite well in the majority of cases. The data set was aggregated from administrative linked employer-employee data available at the Institute for Employment Research (IAB). The raw data originate from standardised reporting procedures of the population of employees and establishments recorded in the German social security system. We obtain a time consistent NACE Rev. 1 classification for establishments using the methodology proposed by Eberle et al. (2011). Entries and exits of establishments are identified using the (de-)registration of establishment identifiers (EID) that are recorded conditional on the establishment employing at least one worker subject to social security. We additionally use the method of clustered worker flows between establishments to identify

artificial changes in EID that would otherwise contaminate the measurement of entries and exits (Hethey-Maier and Schmieder 2013). Table 1 presents the summary statistics.

Table 1: Summary statistics of full industry sample

Variable	Industries considered	Obs.	Mean	Std. Dev.	Min	Max
Employment	205	6970	93026	147254	309.8	1304090
Establishments	205	6970	7796	17936	20	164723
Entries	188	6363	648.34	1630.2	0	18489
Exits	171	5743	630.21	1697.4	0	18998

Notes: Variables may contain missing data cells due to data anonymisation for N<=3. Industries with missing data in more than 4 out of 34 years are excluded from the analysis. Employment figures are computed as full-time equivalents using part-time weights.

4. Method

In order to test the ILC concept, the cyclical dynamics are formulated mathematically. In real data we have to deal with left and right censoring. Hence, we define $p_{i,a}$ as the initial phase stage in 1976 for each industry i and each variable a. Furthermore, not all variables will decrease to zero at the end of the analysis period in 2009. Therefore, the population indicators are assumed to be given by

$$v_{i,a,t} = m_{i,a} + r_{i,a} \cdot \sin\left(2\Pi \cdot \left(p_{i,a} + d_{i,a,t}\right) - \frac{\Pi}{2}\right) \tag{1}$$

with $d_{i,a,1976}$=0 and

$$d_{i,a,t+1} = d_{i,a,t} + s_{i,a} \cdot b_{i,a}^{t-1976}. \tag{2}$$

$m_{i,a}$ denotes the mean, $r_{i,a}$ is the cycle radius, $s_{i,a}$ is the speed of the dynamics in 1976, and $b_{i,a}$ (≤1) denotes the slowdown of the dynamics with each year. Function (1) is defined such that if $p_{i,a}=0$ and $b_{i,a}=1$, the indicator a starts in 1976 in its lowest value $v_{i,a,t}=m_{i,a}-r_{i,a}$ and reaches this value again after $1/s_{i,a}$ years after running through one complete cycle.

We test for each industry i and indicator a four different models: A linear dependence of $v_{i,a,t}$

on t, a quadratic dependence of $v_{i,a,t}$ on t, the model given by (1) and (2), and a reduced form of this model given by the restriction $b_{i,a}=0$ (meaning that the dynamics do not slow down). While the linear and quadratic models can be calculated directly, the cyclic models represent non-linear regression[1].

The Akaike Information Criterion (AIC) is used to evaluate the fit of the models. The regression approach assumes normally distributed residuals. Hence, we test this proposition using the Shapiro test, which is violated ($p<0.05$) in some industries. Dynamics in these cases exhibit more complex patterns, so that we count these cases as non-cyclical even if the cyclic model fits better than the linear or quadratic model.

5. Results

Table 2 presents the results of our test for cyclical dynamics.

Table 2: Results of fitting the different models

Variable	Industries considered	Industries with better fit for cyclical models	Industries with cyclical dynamics and normally distributed residuals
Employment	205 (13/98/92)	145 (8/61/75)	121 (6/52/62)
Establishments	205 (13/98/92)	154 (8/72/73)	109 (8/56/44)
Entries	188 (9/88/89)	140 (4/59/75)	105 (3/55/45)
Exits	171 (10/88/71)	92 (4/50/38)	70 (4/42/24)

Note: In parentheses: numbers for the sectors agriculture & mining / manufacturing / services.

Overall, we find in 52% of the studied industries cyclical dynamics. 32% of the cases are better represented by simpler functional forms (linear or quadratic), while in 16% of the cases we find dynamics more complex than the cyclical models tested here. When comparing the indicators, the ILC model seems to fit best for employment numbers (59%) and worst for exit numbers (39%). Evidence for cyclical dynamics is found in all aggregate sectors, although slightly more cases (55%) are found in the manufacturing sector and slightly less cases (47%)

[1] Standard R routines did not work in most cases. Therefore, a modified Levenberg-Marquardt algorithm varying starting values was programmed.

in agriculture & mining compared to the rather average number (51%) in the service sector.

The dynamics within the considered time period may be characterised by comparing the phase stages at the beginning (1976) and the end (2009) of the period. The first is given by $p_{i,a}$, while the latter is given by $e_{i,a}=p_{i,a}+d_{i,a,2009}$. If a variable runs through a full cycle, we expect $p_{i,a}=0$ and $e_{i,a}=1$. Figure 1 shows the phase stages for all variables with cyclical dynamics.

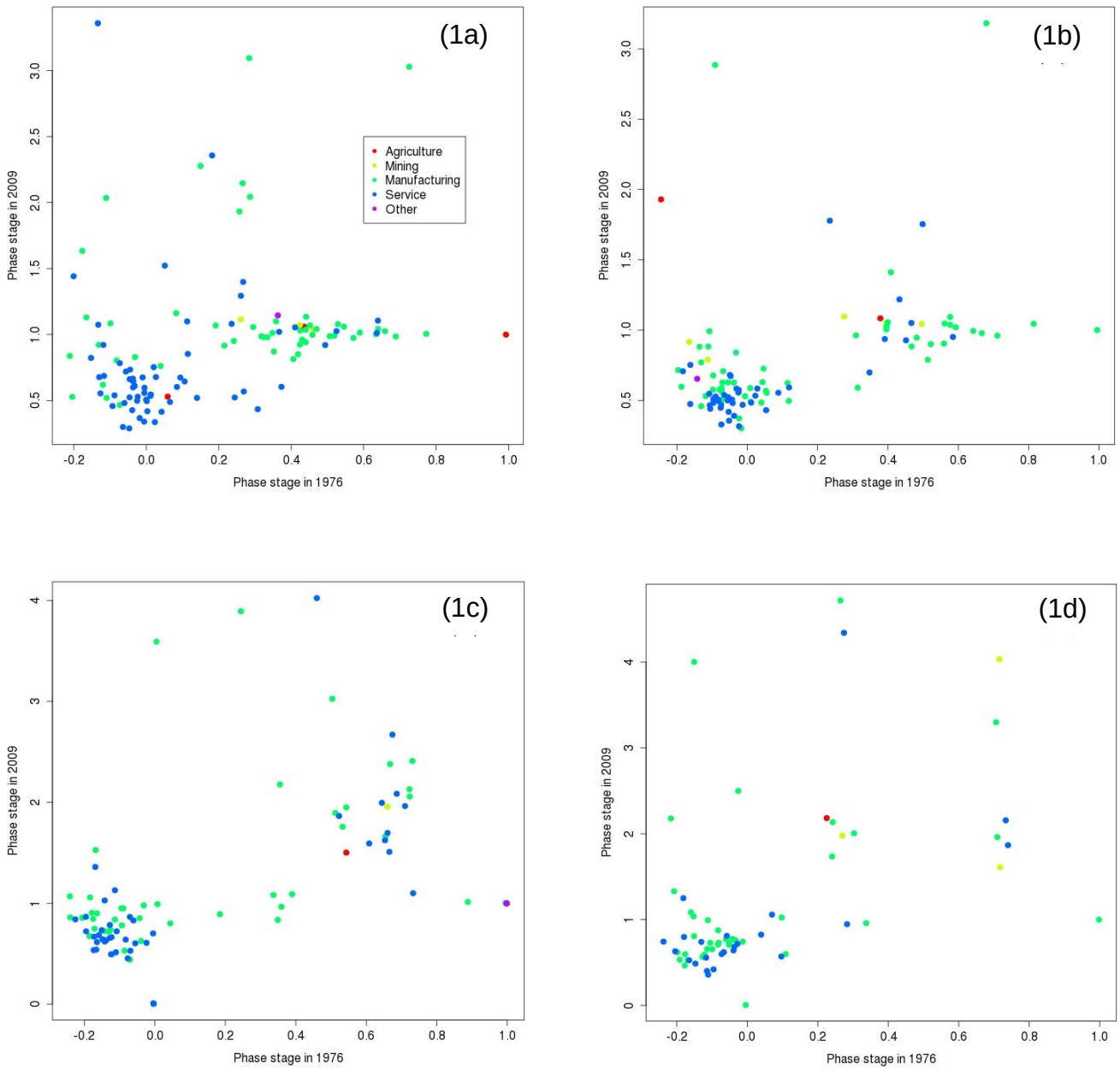

Figure 1: Phase stage in 1976 and 2009 depicted for employment (1a upper left), establishments (1b upper right), entries (1c lower left) and exits (1d lower right).

The comparison of life cycle stages in 1976 and 2009 yields four distinct categories:

A. Life cycle that begun around 1976 or later and is not finished by 2009: $-0.25<p_{i,a}<0.25$ and $e_{i,a}<0.9$ and an increase of the phase stage by at least 0.2 in the next 20 years.

B. Full life cycle that begun around 1976 or later and came to an end: $-0.25<p_{i,a}<0.25$ and $e_{i,a}<1.25$ and not belonging to Case A.
C. Full life cycle that was already running 1976 and came to an end: $p_{i,a}>0.25$ and $0.75<e_{i,a}<1.25$.
D. Multiple life cycles: $e_{i,a}>1.25$.

Categories A and B depict a cloud of points in the lower left corner of each of the graphs comprised in Figure 1. Category C is visible as another cloud that almost builds a horizontal line in Figures 1a and 1b. These cases are expected according to the ILC theories. From Table 3 it is evident that, indeed, these cases are most frequent. For the number of establishments, which represents the most prominent variable in the ILC literature, Category A dominates, indicating that the life cycle is still running in most German industries. This holds for the manufacturing and the service sector, although in the manufacturing sector there are also quite a number of industries that fall into Category C, with a concluded life cycle. For employment there are especially in the manufacturing sector many industries with a concluded cycle (Category C).

Category D is frequently found for the numbers of entries and exits. This indicates quite some industries in which several cycles or waves of entries or exits have occurred. Hence, both, entries and exits, seem to follow the ILC proposition of just one cycle per industry less often.

Table 3: Number of cases for the different life cycle categories

Variable	Industries with cyclical dynamics	Category A	Category B	Category C	Category D
Employment	121 (5/52/62)	51(1/8/42)	12 (0/7/5)	41 (5/29/6)	14 (0/8/6)
Establishments	109 (8/56/44)	69 (1/31/36)	2 (1/1/0)	27 (4/18/5)	9 (2/5/2)
Entries	105 (3/55/45)	43 (0/17/26)	13 (0/9/4)	16 (1/11/3)	33 (2/18/12)
Exits	70 (4/42/24)	40 (0/22/18)	6 (0/5/1)	3 (0/2/1)	21 (4/13/4)

Note: In parentheses: numbers for the sectors agriculture & mining / manufacturing / services.

6. Discussion and conclusions

Using comprehensive administrative data capturing long term industry development for 205 (product) industries between 1976 and 2009 in West Germany, we show that population indicators follow in 52% of our studied cases a cyclical path, as suggested by the ILC literature. The results are quite similar across groups of different sectors and population indicators that are studied. We document that in most industries the life cycle has started around 1976 or earlier and is not concluded yet. Among manufacturing industries, however, cyclical dynamics tend to be concluded by 2009 more frequently than in other sectors.

For quite a number of industries the number of entries and exits run through multiple cycles, while the numbers of employees and establishments show only one life cycle. This pattern might be caused by new technological developments in the industry or related subindustries, allowing for new firms entering and increased competition.

In sum, our results confirm the relevance of the ILC hypothesis for industry development, at least for a large part of the studied industries. However, the mixed results for entries and in particular exits pose some doubts on the argument that the various variables run through a joint life cycle with a clear succession. We also found some industries showing more complex dynamics. More empirical research on these issues and the integration of further indicators is needed.

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