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If you call it a wave: system parameters of merger waves - a wave pattern analysis

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Abstract

This study presumes merger waves as a periodical wave phenomenon and fits a continuous function with five parameters to the annual time series data of US mergers over a 116 year period. The function describes the annual number of mergers as the sum of an exponential trend term with a doubling time of 19.05 years and a periodical term with a non-growing amplitude. Parameters are determined with reasonable criteria to identify salient characteristics. With the implied periodicity the relation of mean reversion parameter to inertia parameter is calculated characterizing the underlying US merger system.

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1. Introduction and literature

One of the most conspicuous characteristic of merger activity is that it fluctuates severely over time. Periods with minimal merger activity are followed by periods when nearly every firm is directly or indirectly affected by mergers happening in the market. This massive concentration of merger activity involves fundamental changes in the organization of whole industries. Due to the severe fluctuations in merger activity, the merger time series behavior is paraphrased as ‘merger wave’, a term widely used in the literature (Duchin and Breno, 2013; Ahern and Harford, 2012; Clougherty and Duso, 2009). However, it is not yet noted what essential consequences arise when using the term ‘merger wave’. This study unambiguously shows what consequences arise when the term ‘merger wave’ is used presuming that merger activity follows a periodical wave pattern.

Modelling the wave pattern behavior of merger waves earlier arose interest of a number of researchers. Town (1992) was the first to apply a two-state Markov-switching-regime model to the time series of mergers covering all U.S. mergers from 1885 to 1989. He finds that the aggregated merger series is well described by dichotomous shifts between two levels of high and low activity (Town, 1992). Shortly after, Golbe and White (1993) set a sine wave to a similar database of US merger data to directly test the wave character. They find statistically significant explanatory power. Their approach should be refined in this study to test the wave hypothesis with recent data and to further draw conclusions regarding system parameters. Barkoulas et al. (2001) model the time series of merger waves as long memory process that is strongly auto-correlated using the same database as Town (1992). Identifying merger activity as being a non-periodic cycle, Barkoulas et al. (2001) find that *‘merger activity exhibits stretches of high and low values with no obvious hidden or strict periodicity’* (Barkoulas et al., 2001, 238). The authors find that – over time – the duration and the amplitude of merger waves have declined doubting that the wave hypothesis is valid (Barkoulas et al., 2001). Gärtner and Halbheer (2009) find that merger activity can be described by a mean and variance switching autoregressive process employing a Markov regime switching model to U.S. merger data for the period from 1973 to 2003. Therewith, they give quantitative evidence on the wave pattern of the merger time series.

The study at hand follows the once successful approach of Golbe and White (1993) by fitting a sine curve to the time series of US merger data over the 116 year period from 1895 to 2011. The merger time series can be well described with the composition of an exponential trend function and a periodical sine function. The curve fitting identifies salient characteristics of the US merger time series with a uniquely simple model. Accepting the wave hypothesis, natural consequences are drawn concerning the internal forces of the merger wave system. The relation of a mean reversion parameter to an inertia parameter can be calculated. Finally, this study arrives at one single number that mathematically describes the relation between these two system parameters.

The remainder of this paper is organized as follows: Section two describes the methodology and the model used. The data approach is described in section three followed by the curve fitting in section four. System parameters are calculated in section five while section six discusses the findings and limitations. Finally, section seven concludes.

2. Model and Methodology

Although authors like Barkoulas et al. (2001) and Gärtner and Halbheer (2009) suspect that a sine curve would fit their new data, the once successful approach of Golbe and White (1993) should be refined in this study to describe the US merger activity over the past century based on the wave hypothesis. The advantage of this simple mathematical approach is that the wave pattern can clearly be isolated and components can reasonably be determined, investigated and interpreted. Therefore, this study pursues a refined approach similar to the one of Golbe and White (1993).

To describe merger activity, the total number of mergers $M_{(t)}$ in dependence on time t is decomposed into two components: the overall M&A trend (non-periodic) and the periodic number of mergers:

(1) $$M_{(t)} \approx M_{(t)\,\text{trend}} + M_{(t)\,\text{periodic}}$$

The trend $M_{(t)\,\text{trend}}$ is expressed with a simple exponential function[1]:

(2) $$M_{(t)\,\text{trend}} \approx 2^{\left(\frac{t}{t_d} + C\right)}$$

where t denotes the year, t_d denotes the doubling time and C a constant.

To this basis the periodic term $M_{(t)\,\text{periodic}}$ is added to capture the wave pattern:

(3) $$M_{(t)\,\text{periodic}} \approx A \cdot \cos\left(2 \cdot \pi \cdot \frac{t-t_h}{t_w}\right)$$

where A denotes the amplitude of the wave, t the year, t_h the year of the first wave's height and t_w the wave-length.

Assuming a non-linear model with an exponential trend the R^2 measure does not deliver optimal results when determining the parameters of the proposed function. Therefore, other optimizing criteria are employed to ensure a reasonable curve fitting. I set four reasonable requirements to the function resulting from an analysis of characteristics of the dataset:

I. The integral of $M_{(t)}$ should equal the accumulated number of mergers.
II. The frequency, captured with wavelength t_w, should on average fit the real data to capture the observed frequency of merger waves.
III. The magnitude of every wave crest over the trend should equal the average observed magnitude of the five merger waves over the trend.
IV. The number of mergers for a year t cannot be negative.

[1] As shown in section 5, a linear logarithmic function covers the trend of the accumulation of the number of mergers quite well.

These requirements ensure a reasonable estimation of parameters.

3. Data

A unique, extensive dataset of US merger data is created combining the most reliable series of mergers from different sources. These different sources should roughly be presented:

- Nelson (1895-1920): In a seminal contribution to merger wave research, Nelson (1959) recorded over the period 1895 to 1920 the number of disappearing firms in manufacturing and mining industry through M&A (Nelson, 1959, 166-167). For this period, it seems to be the best data set available and a sufficient proxy for merger activity.
- Thorp (1919-1954): Willard Thorp recorded US merger data from 1919 to 1939. His data that is used in this study was published by Nelson (1959, 166-167).
- FTC (1940-1979): The U.S. Federal Trade Commission collected the number of mergers in manufacturing and mining industries for the period 1940-1979. The data used by Golbe and White (1993) was not publicly available anymore. Therefore, the data was extracted by a reliable, millimeter-method from the figures provided in Golbe and White (1993).
- MA (1967-1989): The periodical Mergers and Acquisitions magazine counts the number of deals from 1967 to 1989. The data was not publicly available and thus the same extraction method was used as in the case above.
- Thomson (1986-2011): The FTC database is known as the most accurate M&A database. To encompass the real extent of merger activity all mergers were selected with a deal value exceeding 1 million US $, where more than 50% of the shares were acquired, more than 95% of shares owned after the acquisition and where the acquirer was a US company. Against the background of global M&A development this criteria seems to be most accurate in order to capture US merger activity.

Since the databases are not continuously consistent it was decided on the most reliable data source when creating a continuous function. The data series use different methods of recording mergers and different cut-off points. The only valid characteristic that can be extracted is the intra-series proportion that indicates merger waves. Nevertheless, the data reflects all merger waves accepted in the literature. Therefore, the different series are a sufficient proxy to reflect US merger activity of the last century.

Accepting these limitations a continuous series is created from the five different databases and this series is used to adapt a function in order to determine the time series behavior of mergers. In the periods where databases overlap either one database is favored if it appears more reliable or the mean of the databases is used. Table 1 documents the data selection.

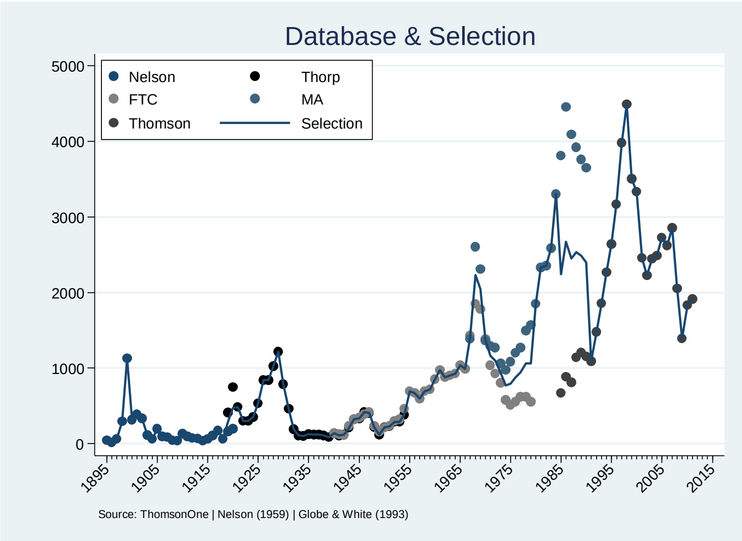

Figure 1: Database and Selection

Period	Data Selected
1895-1918	Nelson
1919-1920	Ø Nelson & Thorp
1921-1954	Thorp
1955-1966	FTC
1967-1979	Ø FTC & MA
1980-1984	MA
1985-1990	Ø MA & Thomson
1991-2011	Thomson

Table 1: Database covering the last century.

4. Curve fitting

With this renewed data a curve fitting approach should be conducted. Similarly to Golbe and White (1993) an approach with five parameters is used. On logarithmic scale a linear function covers the trend of the accumulated number of mergers over a 110 year period from 1901 to 2011 to a sufficient extent:

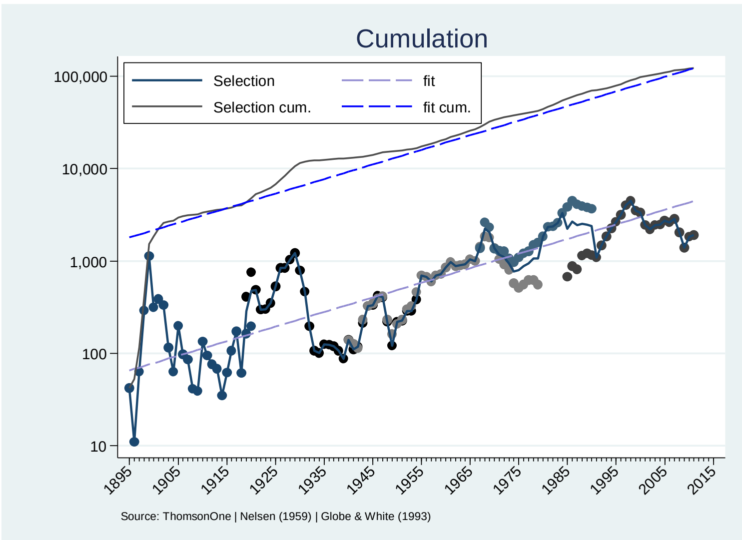

Figure 2: Cumulation of data.

Therefore an exponential function is used to cover the trend of the accumulated number of mergers:

$$\sum_{t=1895}^{t} M_{(t)} \approx 2^{\left(\frac{t}{t_d} - C\right)}$$

The doubling time in years can be calculated using the gradient of the straight line on logarithmic scale:

$$t_d = \ln(2)\cdot(2011-1901)\cdot\left[\ln\left(\sum_{t=1895}^{t=2011} M_{(t)}\right) - \ln\left(\sum_{t=1895}^{t=1901} M_{(t)}\right)\right]^{-1} = \frac{\ln(2)\cdot 110}{\ln(122{,}373) - \ln(2{,}237)} = 19.05$$

Applying requirement I to the integral the constant can be calculated:

$$C = \frac{1}{\ln(2)}\cdot\ln\left(\sum_{t=1895}^{t=1901} M_{(t)}\right) - \frac{1901}{t_d} = \frac{\ln(2237)}{\ln(2)} - \frac{1901}{19.05} = -88.66$$

The expected number of mergers per year covering the overall trend is the derivation function of the integral; thus, only the constant changes[2]:

$$M_{(t)\,\text{trend}} \approx 2^{\left(\frac{t}{19{,}05} - 93{,}43\right)}.$$

To identify the periodic component the observed number of mergers deviating from this exponential trend function is separated:

$$M_{(t)\,\text{periodic}} \approx M_{(t)} - M_{(t)\,\text{trend}}$$

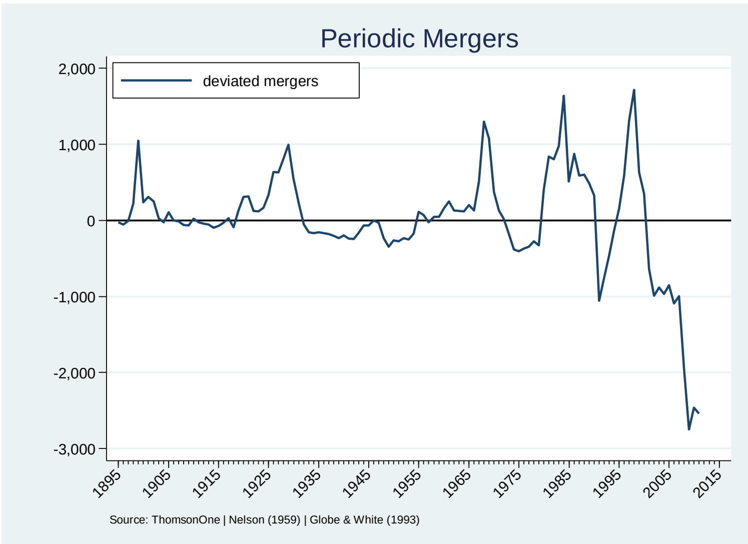

Figure 3: Periodic mergers: Deviation from exponential function.

Applying requirement II to the periodic term the wavelength can be determined that it on average represents the real frequency. The 99-year period from the wave peak in 1899 to the

[2] With $c = C - \frac{\ln\left(\frac{\ln(2)}{t_d}\right)}{\ln(2)}$

peak in 1998 has three troughs[3] which implies, according to requirement II, a wavelength of $t_w = 33$ years. This is taken as a starting point. However, only applying one wave length over the whole period does not capture both, the 1980s' and the 1990s' merger wave. Noticing that merger waves might have an irregular periodicity (Barkoulas et al., 2001), it seems adequate to use different wave lengths. To keep the approach simple the wavelength t_w should only be halved at a certain point of time. As a starting point the year 1977 is chosen as switching year where t_w is set to half, shortly before the beginning of the 1980s merger wave.

Next, requirement III is applied. The area of every wave crest over the trend should equal the average sum of the excess of observed mergers over the exponential trend:

$$\int_{t_h-\frac{t_w}{4}}^{t_h+\frac{t_w}{4}} A\cdot\cos\left(2\cdot\pi\cdot\frac{t-t_h}{t_w}\right)dt \overset{!}{=} \frac{1}{5}\cdot\sum_{i=1}^{5}\sum_{\substack{\text{wave}\\\text{crest } i}} M_{(t)} = \bar{E}$$

This requirement ensures for the first merger wave crest as well as for every following merger wave crest that the magnitude of the described merger crests on average equals the magnitude of the observed five merger waves. A single wave analysis of all U.S. merger waves with their specific volume excess over $M_{(t)\ \text{trend}}$ was conducted to determine E.

	Year of Maximum	Period	E
1st wave	1899	1898-1905	2167
2nd wave	1929	1919-1931	5341
3rd wave	1968	1955-1972	4752
4th wave	1984	1980-1990	8048
5th wave	1998	1995-2000	4741

Table 2: Single wave analysis regarding excess over trend.

The average excess of each wave crest over the trend has a magnitude of 5010 mergers and should be used for orientation to estimate E. For better calculation[4] $\bar{E}$ is chosen to be 5252. The amplitude is calculated as $A=\frac{\bar{E}\cdot\pi}{t_w}$ and with this the periodic term is determined as:

$$M_{(t)\ \text{periodic}} \approx \frac{16500}{t_w}\cdot\cos\left(2\cdot\pi\cdot\frac{t-1899}{t_w}\right)$$

[3] When interpreting the last two waves of the 1980s and 1990s as one large, stretched wave

[4] $5252 = 16500/\pi$ so that $A = 500$, resp. $A = 1000$ for $t > 1976$

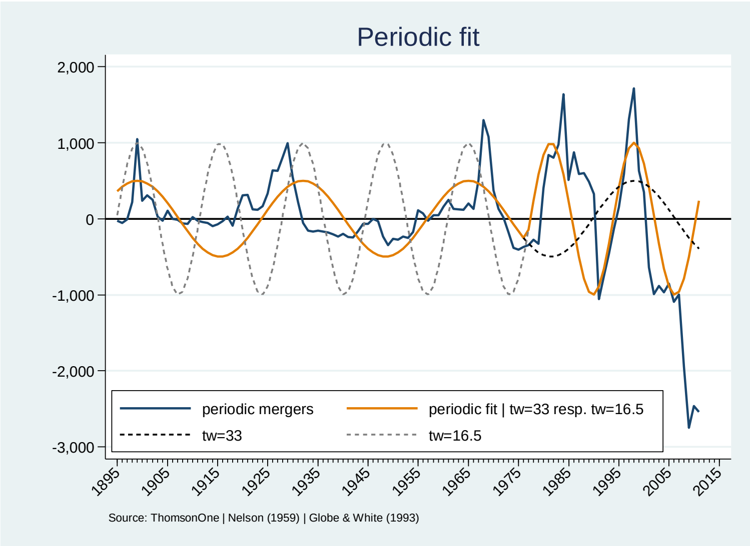

Figure 4: Periodic fitting – Number of periodic mergers.

The desired function of the annual number of mergers can be described by the combination of the exponential growth term and the periodic term. At this stage requirement I is only fulfilled for the exponential term but not for the sum of both terms. In order to fulfill all requirements the exponential and the amplitude constant were recalculated through iteration. Finally, the parameters are as follows:

$$M_{(t)} \approx 2^{\left(\frac{t}{t_{d,}}+c\right)} + \frac{D}{t_w} \cdot \cos\left(2 \cdot \pi \cdot \frac{t-t_h}{t_w}\right)$$

parameter	description	first fit	iterated
c	exponential constant	-93.431	-93.552
t_d	doubling time in years	19.052	19.052
D	amplitude constant	16500	18461
t_h	year of first wave hight	1899	1899
t_w	wave length in years	33	33
	year of switching t_w to half	1977	1977

Table 3: Parameters

$$M_{(t)} \approx 2^{\left(\frac{t}{19{,}05}-93{,}552\right)} + \frac{18461}{t_w} \cdot \cos\left(2 \cdot \pi \cdot \frac{t-1899}{t_w}\right)$$

with $t_w = 33$ for $t \leq 1976$ and $t_w = 16.5$ for $t > 1976$.

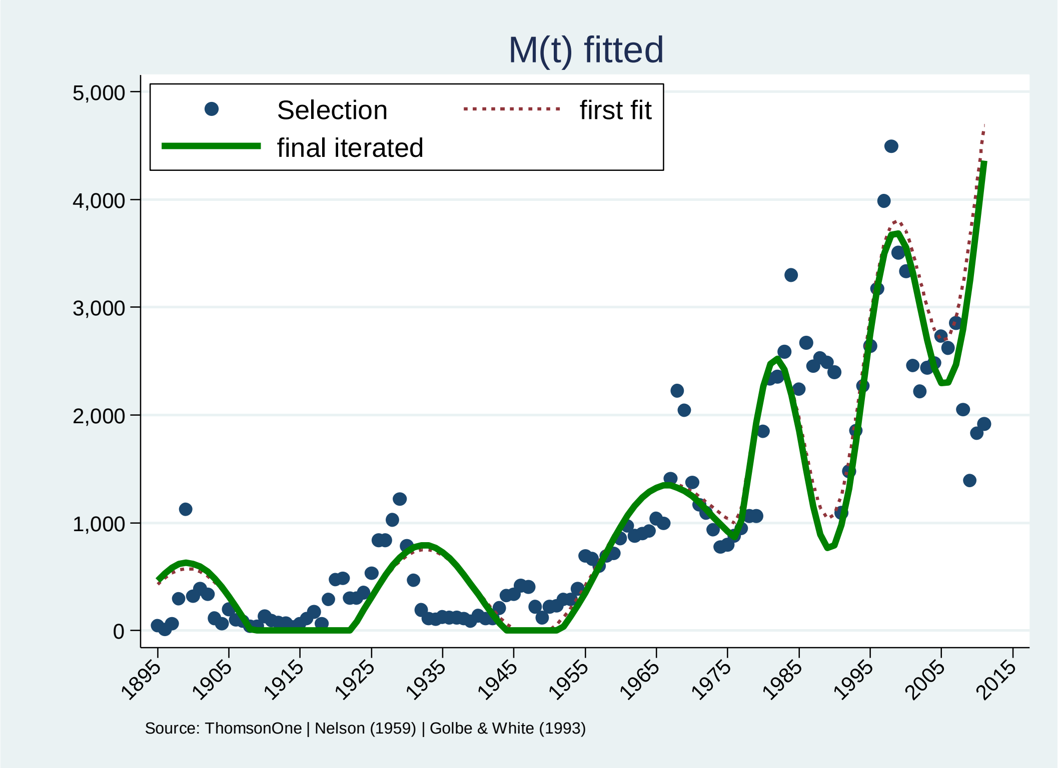

Figure 5: Fitted function – Total number of mergers.

With this function, the time series behavior of mergers can be well described by using only five parameters.

The pursued approach has three major advantages which makes it especially applicable to capture the natural extent of the US merger phenomenon. First, the sum of the calculated number of mergers until 2011 equals the observed number of mergers. Second, the frequency of $M_{(t)\ periodic}$ fits on average the observed frequency. Third, the magnitude of each wave crest over the trend equals on average the observed magnitude of the five merger waves over the trend.

From the chosen approach three salient characteristics can be identified: First, the US merger wave pattern followed an exponential growth trend with a doubling time 19.05 years. Second, there exists a distinct periodical pattern. Until 1976 the time series is well described with a wavelength of 33 years, holding all parameters constant. In order to deal with the increased frequency the wavelength t_w is halved after 1976 to 16.5 years. Third, the number of mergers of each wave crest is held constant over the whole 116 year period which implies a doubling of the amplitude due to the halved wavelength after 1976. The fact that the number of mergers in a wave crest does not increase with the exponential trend is an interesting observation because it implies a decreasing relative importance of the wave phenomenon over time.

5. Mean reversion and inertia parameter

This section draws mathematical consequences derived from the wave phenomenon. If merger activity follows a wave pattern in form of a sine curve, direct conclusions can be drawn regarding the implied parameters of the system. To examine the system parameters that would cause the periodic phenomenon the determined periodic term, showing the number of periodic cyclical mergers, should be investigated:

$$M_{(t)\ periodic} = \frac{D}{t_w} \cdot \cos\left(2 \cdot \pi \cdot \frac{t - t_h}{t_w}\right)$$

This equation is one solution of the differential equation $\ddot{M} + \left(\frac{2 \cdot \pi}{t_w}\right)^2 \cdot M = 0$.

In this differential equation, $\left(\frac{2 \cdot \pi}{t_w}\right)^2$ is the quotient of the two dynamic parameters characterizing the system. In case of physics this term may be the relation of a spring constant to an inertia force. For the merger system the determining parameters are the mean reversion parameter and the inertia parameter:

$$\left(\frac{2 \cdot \pi}{t_w}\right)^2 = \frac{\textit{Mean reversion parameter}}{\textit{Inertia parameter}}$$

The mean reversion parameter causes regression to the mean while the inertia parameter maintains the current trend; together resulting in a wave phenomenon.

Applying the initial wavelength t_w, of 33 years, the quotient of the mean reversion parameter and the inertia parameter can be determined as 0,036252/a².

6. Discussion

If one accepts the hypothesis that merger activity occurs in form of the described periodic sine waves one imperatively has to accept the existence of the parameters of the wave system: the quotient of mean reversion and inertia parameter. Both parameters should be interpreted economically. The inertia parameter causes the merger wave system to overreact. In line with this overreaction it can be expected that this parameter is driven by less efficient mergers. An overreaction of the merger wave system can occur simultaneously to an overreaction in the stock market since stock market valuation was identified as important driver of merger activity (Shleifer and Vishny, 2003). In overvalued stock markets firms might try to reallocate their assets through mergers (Javanovic and Rousseau, 2002, 2008; Andrade and Stafford, 2004). A merger in an oligopoly can trigger other mergers in the market and a merger can further take place in anticipation of those subsequent mergers (Hsu and Wang, 2010). One merger triggering another merger might cause an overreaction of the merger wave system. This may serve as an explanation for the inertia parameter. Further behavioral motives like general market optimism may drive merger waves which would contribute to this overreaction (Gugler et al. 2012). The inertia parameter also works in the opposite direction and causes merger activity to fall to a below-average level which might be influenced by economic downturns, stock market depressions and general market pessimism.

The mean reversion parameter causes a regression to the mean in the merger wave system. Generally, the mean reversion parameter should be driven by more rational, efficient mergers that enhance shareholder value and constitute a basic level of M&A. A factor influencing this parameter can be valuation errors that were identified to cause merger waves (Rhodes-Kropf and Viswanathan, 2005). Further factors that cause merger waves in this way can be industry shocks caused by technological, regulatory or economic changes (Mitchell and Mulherin, 1996; Harford, 2005) to which firms react through restructuring activities via mergers (Mulherin and Boone, 2000). These mergers can be assumed to be efficient. Influencing factors like changes in the market environment to which firms are forced to react could potentially explain the mean reversion parameter. The interaction of inertia and mean reversion parameter, potentially driven by the described factors, causes the wave pattern in merger activity.

Considering all these different influencing factors that cannot be clearly attributed to one of the system's parameters it seems surprising that such a simple model can capture the entire US merger wave system over 116 years to a sufficient extent. This might indicate that there exists robust system structures that permanently apply to the M&A system. To identify these structures and to find what factors determine the system parameters may be an avenue for future research. In order to capture the fourth merger wave the wavelength t_w was halved from 1977 onwards. This could be interpreted as the second harmonic.

The results above illustrate that M&A volume became increasingly important in the last century. While the extent of merger waves remains nearly constant for all five merger waves, the entire U.S. merger activity has grown exponentially. The fact that the amplitude remains constant implies that the proportional importance of the merger wave phenomenon is declining with an increasing basic level of merger activity. This declining magnitude of merger waves is yet not noted in merger wave literature. The exponential growth of merger activity is an interesting finding that illustrates the increased and probably still increasing importance of M&A. M&A became an important component of strategic corporate management (Megginson, et al., 2004). Further, due to industry shocks like technological innovations (Harford, 2005) and global economic development whole industries are more frequently forced to restructure and reorganize. A path doing so is M&A (Javanovic and Rousseau, 2008).

One should note three limitations of this study's approach: First, the model is not meant to be a forecast model. It is adequate to describe the past 116 years of merger activity and to determine its characteristics; however, one should note that the exponential function is going to be erroneous in future. In recent years exponential growth does not cover the data that well due to a decreased number of US mergers in 2009[5]. Secondly, merger peaks may have an irregular periodicity (Barkoulas et al., 2001; Gärtner and Halbheer, 2009). For the underlying data the determined function fits the periodicity quite well; however the periodicity will probably not fit in the future. For the purpose of this study it is assumed that merger activity follows a periodical wave pattern in form of a sine wave. Thirdly, I restrict the model to one continuous function with five reasonably chosen parameters. Although taking different functions (e.g. Golbe and White 1993) would yield a higher explanatory power this seems inadequate to describe a real 'wave' phenomenon. Since this study draws unambiguous

[5] With global merger data the curves might fit better in recent years since the sixth merger wave was not distinct in the US but in most other countries.

consequences of accepting the hypothesis that mergers occur in a periodical wave pattern these limitations are knowingly accepted.

7. Conclusion

With a notably simple model this study characterizes the US merger wave phenomenon reasonably and is the first that operationalizes the time series of mergers over more than a century. The following characteristics were identified: US merger activity has grown exponentially over the past 116 years while the number of mergers has doubled approximately every 19 years. Distinct periodic fluctuations can be identified. Remarkably, the amplitude does not grow with the trend. That the time series of mergers can be paraphrased as ‘merger waves’ is widely accepted in literature and well known in practice. This study shows the consequences of using the term merger waves presuming that the underlying system follows a periodical wave pattern. The relation of mean reversion parameter to inertia parameter of the underlying system is calculated characterizing the US merger wave system in one single number. This finding is new in literature and may be considered when using the term ‘merger wave’.

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