A Prey-Predator Model of Trade Union Density and Inequality in 12 Advanced Capitalisms over Long Periods

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I. INTRODUCTION

An extensive literature explains what determines trade union membership (see the review in Wallerstein and Western, 2000). A similarly vast literature explains what causes income inequality (see the review by Neckerman and Torche, 2007, Kenworthy, 2007). These two literatures are connected, as trade unions decrease inequality, while inequality harms trade unions (Kahn, 2000, Western and Rosenfeld, 2011, Hirsch, 1982, Gustafsson and Johansson, 1999: 600, Checchi et al., 2010, Card, 2001). Superficially, the relationship between inequality and trade union density therefore seems like a simple negative correlation: more inequality is associated with lower union membership, and vice versa.

While this negative link between inequality and union density is widely documented, its simplicity contradicts the idea that trade unions can use inequality as a rallying cry to recruit new members, so that high inequality could cause higher, not lower union density, possibly with a time lag, as more and more people join trade unions to fight inequality. In other words, trade unions may grow based on past inequality, while trying to reduce present inequality. This dynamic is similar to a prey and predator model, where predators eat prey, but thereby destroy the resource that ensures their future survival.

We show for the first time that such a prey and predator model, derived from Lotka (1925) and Volterra (1931), contributes to two ostensibly competing theories, notably to the dominant theory that 1) trade union density lowers inequality (negative relationship), but also to an existing weaker theory, according to which

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2) inequality promotes trade union density (positive relationship). After presenting these two theories, we construct a model that captures both relationships. In doing so, we do not aim to explain trade unions density and inequality with an exhaustive list of explanatory variables. Instead, we want to test the mutual influence of each on the other. Instead of a simple negative relationship, our model shows that 1) trade unions recruit members when past inequality was high, 2) strong trade unions then reduce present inequality, leading to the widely observed negative relationship between inequality and trade union density, 3) but low past inequality then decreases trade union density, which results in 4) increasing inequality, which means that we are back in the first situation, where 1) trade unions recruit members when past inequality was high. The following section presents the two ostensibly contradictory theories, which this model incorporates.

II. LITERATURE AND THEORETICAL CONSIDERATIONS

II.1. Strong trade unions come with inequality

The first strand of theories that we focus on suggests that inequality causes trade union growth. Marx and Engels were the first to argue prominently that when the wages of large parts of the population decline relative to a small elite, associations eventually form to fight for higher incomes of the poor:

“as machinery obliterates all distinctions of labour, and nearly everywhere reduces wages to the same low level […] the workers begin to form combinations (Trades’ Unions) against the bourgeois; they club together in order to keep up the rate of wages” (Marx and Engels, 1848 [2010]: 19).

While workers join trade unions for a number of reasons, their material incentive to do so increases when their wages decline relatively to a small elite, from which they can demand higher collective wages through trade unions (Korpi, 2006: 173 ff., Bendix, 1974: 155). Indeed, trade unions in many countries came into existence at the end of the 19th century by rallying against the inequality of 19th century capitalism (Brown, 1990: 2, Kelly, 1998: 39 f.). However, as trade unions succeeded in decreasing inequality over the next century, fewer workers had an interest in joining a union to fight the inequality that remained:

“a change of outlook was brought about by a progressive rise in the standard of living of the working population: all manner of amenities that had once been the privilege of the well-to-do, or had not existed at all, became possessions of the wage earners. […] It also undermined egalitarianism. There seems to be a certain level of the standard of living such that those who reach it become more concerned with enjoying and improving it than with brooding on the gap that separates them from still higher incomes” (Brown, 1990: 7 f.).

This suggests that trade unions become stronger when past inequality is higher, while becoming weaker when past inequality is lower. There should thus be a positive correlation between the two variables: High inequality leads to
strong trade unions, while low inequality lowers union density. However, the following section shows how a second view argues for the opposite.

**II.II. Strong trade unions come with equality**

Until the 1970s, it was widely assumed that trade union density is positively related to inequality, with high inequality leading to stronger trade unions, as mentioned above (Card et al., 2004: 519). Around 1980 however, scholars such as Freeman (1980: 23) found evidence of a negative relationship, for an obvious reason: unions lower inequality. But not only do unions lower inequality, low inequality may also strengthen unions. In 1990, power resources theory (Esping-Andersen, 1985, Korpi, 1985, 2006) argued that “social rights, income security, equalization, and eradication of poverty […] are necessary preconditions for the strength and unity that collective power mobilization demands“ (Esping-Andersen, 1990: 16). Opposing the Marxist view that inequality strengthens unions, scholars in this tradition argued that “[i]n the Marxist perspective, proletarianization is the necessary (occasionally even the sufficient) condition for socialist success” (Esping-Andersen, 1985: 26). But these scholars thought that for “the victory of vertically organized and nationally centralized trade unionism”, it is necessary to “endow all individuals with income and welfare entitlements of such scope that even the marginally weakest (or strongest) worker will refrain from breaking the rules of solidarity” (Esping-Andersen, 1985: 33). Thus, while Marx argued that large inequality between the working class and a small elite leads to strong trade unions, Esping-Andersen and others (cf. Mares, 2001, Paster, 2011) argued that relative equality leads to strong unions. They suggested not a positive (higher inequality = higher trade union density), but a negative relationship (lower inequality = higher trade union density).

While this debate tries to explain how trade unions grew, another debate tries to explain how they declined. After income inequality had fallen to relatively low levels in western societies in the 1970s, many observed how trade unions began to decline as well, first in the US and the UK, then in other developed countries (Card et al., 2004: 528, Card, 2001). Where weak trade unions were unable to prevent it, income inequality resurfaced (Western and Rosenfeld, 2011, Asher and DeFina, 1997, Acemoglu et al., 2001, Gustafsson and Johansson, 1999: 600, Rueda and Pontusson, 2000: 352, also cf. Koeniger et al., 2007: 347). Most researchers “treated union decline as one of the causes of rising earnings inequality”, arguing that unions are the independent, and inequality the dependent variable (Checchi et al., 2010: 86). After the 1970s, the prevailing view of a positive correlation, according to which inequality brings strong trade unions, had been superseded by the opposite view, that strong unions lower inequality, so that high inequality correlates with weak trade unions (Acemoglu et al., 2001: 251).
II.III. A prey-predator model of trade unions and inequality

How is it possible that strong unions resulted from the high inequality of the 19th century (high inequality = stronger trade unions), while at the same time trade unions first decreased inequality (strong trade unions = lower inequality), but then suffered when inequality was low (low inequality = weak trade unions)? Does this mean that trade unions are strong when inequality is high (positive correlation)? Or are trade unions strong when inequality is low (negative correlation)? Existing work has not reconciled these apparently contradictory views, but speculated about different phases. Boswell and Chase-Dunn (2000) argue that inequality produces social movements that fight it, leading to a long-run “Spiral of Capitalism and Socialism.” However, critics argue that they hardly provide data to show this (Arrighi, 2002). Kelly (1998: 86ff.) speaks of Kondratieff “long waves” between worker unrest and their economic situation. But he lacks long-run time series data to test this empirically (Kahn, 2000: 577, Wallerstein and Western, 2000). We therefore introduce a non-linear model of trade union density and inequality, in which trade unions and inequality act like prey and predator (cf. Lotka, 1925, Volterra, 1931). This model explains the ostensibly contradictory relationship between union density and inequality. Figure 1 shows this model.

The mutual influence of inequality and trade union density begins in the lower right corner, from a situation of “Alienation” (1), where unions are weak, but recruit members based on high inequality. High trade union density marks the next

![Figure 1](image-url)

The influence of inequality and trade union membership density on each other
stage, in the upper right part of the graph, a “Class Clash” (2) where powerful unions fight inequality that remains elevated. This situation is also unstable, since trade unions eventually succeed in using their powerful membership base to lower inequality, leading to the situation in the upper left corner (3), which one can call “Success of Labour”, where strong unions have managed to decrease inequality, but remain strong based on members they have recruited during the past phase of inequality. However, this situation is unstable as well, as unions hardly recruit new members when inequality is persistently low, so they become weaker. This leads to the lower right part (4) of the graph, the “Classless society”, where inequality has been low for a while, and – for this reason, trade unions have become weak. Again, this situation is unstable, as weak unions fail to contain inequality. With increased inequality, the vortex has returned to the lower right quadrant, the first situation of Alienation. This perpetually unstable equilibrium can be expressed through a dynamic differential equation model, in which inequality explains trade union density and is simultaneously explained by trade union density. A system of two differential equations defines such a model with the following equation:

\[
\begin{align*}
\frac{d(\text{inequality})}{dt} &= -\alpha (\text{density} - \text{density}_o) + \beta (\text{inequality} - \text{inequality}_o) \\
\frac{d(\text{density})}{dt} &= \gamma (\text{density} - \text{density}_o) + \delta (\text{inequality} - \text{inequality}_o).
\end{align*}
\]

If $\beta$ (beta) and $\gamma$ (gamma) are small, so that outcomes do not increase like an expanding spiral, and if $\alpha$ (alpha) and $\delta$ (delta) are positive, then this equation expresses a circular (or elliptic) vortex motion, which captures four trends:

a) High inequality generates rising union density,
b) high union density generates declining inequality,
c) low inequality generates declining union density,
d) low union density generates rising inequality.

These trends are those of Figure 1, and they account for the move of the vortex from one situation to the next. “High” and “low”, means union density and inequality above the long-run average of a country, which is denoted $\text{density}_o / \text{inequality}_o$, representing the midpoint of union density and inequality, which the vortex turns around in each country. Each variable and its change is plugged into the equation of the other variable. Since this makes each variable dependent and independent, a structural equation model is needed to capture the dynamic empirically. In Equation 1, the “$dX/dt$” denotes the derivative, the rate of change of a variable at a given point in time, where $X$ is alternatively density or inequality. When $\beta$ (beta) and $\gamma$ (gamma) are relatively small, so that we can neglect the
pertaining terms, then the first equation expresses that more union density generates a decline in inequality, when \( \alpha \) (alpha) is positive; conversely, the second equation means that more inequality increases union density, if \( \delta \) (delta) is positive. Therefore, we expect a vortex-like motion, as long as \( \alpha \) and \( \delta \) are positive, and when \( \beta \) and \( \gamma \) are small for the sake of stationarity.

Before proceeding to our data and method to estimate this model empirically, we hasten to clarify that this model does not try to comprehensively account for union density and inequality. We are aware that inequality and trade union density depend on more than their influence on each other, which is also visible in the graphs below. For example, Scandinavian countries prevented the move from “Success of Labour” (low inequality/high union density) to “Classless society” (low inequality/low union density), by coupling union membership to unemployment insurance, so that union density remains high, even under long-run equality. The aim of the model is to show however, that – in spite of exogenous influences – union density and inequality influence each other over long periods in a significant way.

III. DATA

We are modelling a long-run historical relationship between union density and inequality. We therefore need internationally comparable income inequality data over very long periods. The World Top Incomes Database (Alvaredo et al., 2015, Piketty, 2014) estimates the income share of the richest 10 and 1 percent of the population (including capital gains), relative to the rest of the population. This shows the inequality between a small elite, which is likely to thrive on capital accumulation, compared to a large class of wage earners. It fits with Marx’ understanding of a relatively small bourgeoisie, whose incomes compare to a large working class (Marx and Engels, 1848 [2010]: 15). It is also highly correlated with the Gini, for the period for which data on both exists (Solt, 2014).\(^1\) Since inequality data does not exist for every year, it has to be interpolated from neighbouring years. Our main analyses focus on inequality as the incomes of the top 10 percent versus the rest, as this data contains fewer missing values than the income share of the top 1 percent. However, the connection between trade union density and inequality that we present below is fairly similar when using the income share of the top 1 percent (compare Figure 3 in the main text to Figure 2 in the Supplementary Information, hereinafter SI).

\(^1\)Since 1960, for which data on the Gini exists, the income share of the top 10 percent is significantly (.01-level) correlated to the net and gross Gini in all countries except Germany and Japan when we use the Gini from the Solt World Income Inequality database.
The best way to measure trade union density is provided by the Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts (Visser, 2013b), which measures “net union density as a proportion of wage and salary earners in employment” since 1960 (Visser, 2013a: 23). For earlier periods, this can be supplemented by the variable “net density employed rate” of the dataset that accompanies the Handbook on Trade Unions in Western Europe since 1945 (Ebbinghaus and Visser, 2000a, 2000b) and with the variable “netden” from Golden et al. (2009). Yet earlier data can be obtained from Colin Crouch’s (1993) figures on “total known union density as % of dependent labour force”, and from the encyclopaedia of economic history, which contains data on “Union Members per 100 Nonagricultural Workers” before the Second World War (Friedman, 2015). As the latter data is not exactly the same as the earlier, we have only included it when it fits with Crouch’s (1993) data. We have uploaded a table with our sources for union strength in all countries in the SI (see Table 1 in the SI). We thus measure union density as net density, and therefore as the percentage of all those that are in a trade union, relative to all those that could realistically join a trade union. This is widely accepted as measuring the strength of organized labour (Wallerstein and Western, 2000: 356 f.) and as a proxy for the mobilisation of the working class (cf. Tilly, 1978: 90 ff.). We perform our analyses with countries for which data on long-run inequality and trade union density exist. These are Australia (with data on inequality and trade union membership from 1950-2010), Canada (1941-2010), Denmark (1870-2010), France (1905-2009), Germany (1891-1998), Italy (1974-2009), Japan (1947-2010), the Netherlands (1914-1999), Norway (1900-2008), Sweden (1903-2010), the UK (1918-2009) and the US (1917-2011). Table 1 in the SI lists our data sources for each country. Table 2 in the SI shows descriptive data for all variables, and Figure 1 in the SI shows how trade union density and the top 10 income share have developed in each country over time.

Because left governments may be more union friendly and decrease inequality, they may confound the relationship between the two variables. We therefore use robustness tests that control for the (inverted) left_right variable from the Parliaments and governments database (Döring and Manow, 2016).2 A country’s economic development may also interact with union density and inequality, so we control for each country’s GDP in later robustness tests, by including – for each country and year – GDP per capita in 1990 International Geary-Khamis dollars (The Maddison-Project, 2013, also cf. Bolt and van Zanden, 2014). Descriptive information on these variables is also contained in the SI.

2We use data on that party, which provides the prime minister of a country in a certain year. In years in which party control over government changed in a country, we took the average from the two parties that controlled government in that year.
IV. METHOD

First, we show graphically how the vortex between union density and inequality in different countries develops over time. Cross-correlograms then show that trade union strength and inequality are negatively related in the same year, but the relationship often changes into a positive one with successive time-gaps between the two variables. This means that trade unions and inequality decrease each other in the same year: In years where inequality is high, union density is low and vice versa. But past inequality increases present union density. We then use an autoregressive structural equation model that takes into account that current inequality is negatively correlated with current union density, while trade union density is higher if past inequality was higher. The structural equation model (SEM) behind this applies Bollen and Curran’s (2004) Autoregressive Latent Trajectory (ALT). In recent years, traditional types of path analysis (Blau and Duncan, 1967) have been adapted to make more causal claims about status attainment and social mobility (Pfeffer and Hällsten, 2012). The model used in this article relies on the development of time series analysis and structural equation models that use cross-lagged autoregressive variables (Schlueter et al., 2007). In such models, change in trade union density can depend on prior union density and prior inequality, while change in inequality depends on prior inequality and prior union strength. Last, the model also captures that past inequality and past union density are related. Figure 2 presents what this model looks like.

If $-I$ and $-D$ are variables that represent inequality and density, standardized by country, and if $\Delta$ denotes the yearly variation of each variable, then we can estimate the model between inequality and union density via the following Equation 1:

$$\begin{align*}
\Delta(-I_t) &= -a - D_{t-x} + \beta - I_{t-x} \\
\Delta(-D_t) &= \gamma - D_{t-x} + \delta - I_{t-x}
\end{align*}$$

This means that changes in inequality and union density are modelled as the result of a linear combination of prior inequality and union density $x$ years ago. The variable $x$, and thus with which time lag prior inequality and union density influence changes in both, has to be determined empirically (which we do below). Based on the theories and literature above, we would expect that prior union density and inequality (the left/vertical two-way arrow in Figure 2) are strongly negatively related, as they both represent data from the same year in the past, e.g. inequality and union density 5 years ago. The negative relationship should exist, as most studies argue that inequality is high when union density is low and vice versa. In addition, prior union density should have a negative influence on changes in inequality (upper arrow in Figure 2) if strong unions have a lasting dampening impact on inequality. The influence of prior union density on
changes in present union density, and the influence of prior inequality on changes in present inequality should also be negative (middle arrows in Figure 2), as both should show a regression to the mean, in the sense that if union density or inequality was above a country’s long-run average in the past, it is more likely than not that it will return back to the country’s long run average value. Last and most important, prior inequality should have a positive influence on later change in union density when unions recruit members based on inequality of the past. This would make for the vortex-like quality that characterizes a prey and predator model, as it would show that trade unions destroy inequality when they are strong, but as a result of low inequality lose members in the future. The following section tests this relationship empirically.

V. RESULTS

V.I. Descriptive Graphs

Figure 3 graphs the two time trends of inequality and union density for the twelve countries for which data exists. It shows inequality on the x-axis (income share of the top 10 percent) and net union density on the y-axis. A line connects adjacent time points.

Many of the graphs in Figure 3 can be roughly characterized by a line from the upper left to the lower right corner of each graph, indicating a negative relationship between trade union strength and inequality. In other words, years where
trade unions are strong tend to be years where inequality is low (the constellation we call “Success of Labour”); and years where trade unions are weak tend to be years where inequality is high (“Alienation”). Given long periods where trade unions and inequality seem to depress each other, the two are strongly negatively correlated in Germany, the US, the UK, Japan, Sweden, Italy and Denmark ($r > .8$, sig = .0000). For example, from 1870 onwards, Danish trade unions gained new members and inequality decreased, until a stable situation of strong trade unions and weak inequality was reached. In Sweden, the vortex moved towards a similar equilibrium of low inequality and high trade union density and then also stabilized there. In contrast, Japanese unions became ever weaker, while inequality kept on increasing. In the UK, unions first became stronger and inequality decreased from 1928 until 1978; then inequality increased while trade unions
became weaker. In this sense, a simple negative relationship between inequality and union density explains much of their mutual variation over time.

However, other countries fit a negative linear relationship less well. The correlation between union density and inequality is only \( r = .6, \text{sig} = .0000 \) in Canada and Italy, and no linear relationship between the two variables exists in Norway, the Netherlands and France. In this sense, the data reveals a more complicated relationship than “if union density is high, inequality is low.” Instead, the two variables seem connected through a positive relationship in some historical situations: where trade unions become stronger when inequality is higher and vice versa. Notably, trade union density grew under conditions of high inequality in France from 1905 to 1938, in Germany from 1891 to 1919, in Norway from 1900 to 1938, and in the US from 1925 to 1940. In these situations, countries moved from what we call a situation of “Alienation” to a situation of “Class Clash”, where trade union density increases under persistently high inequality. In addition, strong trade unions temporarily coexist with high inequality, but then inequality declines, while trade unions remain strong (movement from the upper right to the upper left corner). This is the case in Australia from 1941 to 1957, in France from 1935 to 1950, in Italy from 1974 to 1983, in the Netherlands from 1946 to 1975, and in Norway from 1938 to 1989. These are situations where countries move from the scenario of “Class Clash” to “Success of Labour.” Last, there are also periods where trade unions lose members during times of low inequality, such as in France from 1947 to 2009, in the Netherlands from 1973 to 1999, and in the US from 1954 to 1986, which is a move from “Success of Labour” to the “Classless Society”, with low inequality and few union members.

Figure 3 suggests the possibility that trade unions reduce inequality, but thereby diminish what increased their membership in the first place. Thus, while inequality and union density are mostly negatively related (low union density = high inequality), positive relationships may also exist, as inequality may increase union density with a time lag (high inequality = high union density). Because the vortex-like prey and predator model allows for periods with negative and positive relationships, it captures the relationship between union density and inequality better than a simple negative link, even though the latter does prevail most of the time. In the following, cross-correlograms show that the relationship between union density and inequality indeed moves from a negative to a positive one with successive time lags in many countries. This indicates that union density and inequality may decrease each other in the same year, but past inequality can actually increase current union density.

VII. Bivariate analysis: Cross-correlograms

The preceding Figure 3 has shown that a negative relationship between inequality and trade union density exists during most historical periods in most
countries. This means that in those years where inequality is high, union density is low – and vice versa. However, Figure 3 has also shown that unions often gained members in situations of persistently high inequality and lost members after periods of persistently low inequality. It is therefore possible that inequality and union density of the same year are negatively correlated, while past inequality is positively correlated to union density.

The cross-correlograms of Figure 4 can show whether this is true, by showing simple bivariate correlations between the two variables. In the cross-correlograms, one variable is lagged by the number of years that the x-axis

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**Figure 4**

Relationship between union density and inequality at different time lags
specifies. This means that at lag 0, the height of the bars show how strongly union density and inequality of the same year are correlated; the direction of the bar (up or down) shows whether the correlation is positive or negative. Bars at negative values on the x-axis (left of 0) show how prior inequality correlates with later trade union density. For example, bars at the x-value of -20 show how trade union density is linked to inequality that existed 20 years earlier. Bars at an x-value of +20 show how trade union density correlates with inequality 20 years later. The cross-correlograms of Figure 4 therefore show how union density relates to current inequality (lag 0), as well as past and future inequality (respectively negative and positive lags on the x-axis).

While the graphs of Figure 4 indeed always show a negative correlation at lag 0 (trade unions are stronger when inequality is weaker and vice versa), they also indicate a positive relationship at negative lags. This indicates that trade unions actually have more members when past inequality was higher.

Even though Figure 4 shows that, in all countries, trade union density correlates negatively with income inequality of the same year (lag 0), important differences between countries also exist. Most importantly, prior inequality is not linked to higher union density in Denmark, and hardly in Sweden and Norway (see the negative bars left of 0 in these graphs). This is because these Nordic countries have stabilized in a low-inequality/high-union density equilibrium (presumably by linking unemployment insurance to trade union membership). Current union density is also not very strongly linked to past inequality in Canada, Germany and Japan. These countries also did not have a very circle-like structure in Figure 3, as their vortex stabilized at different points. In Canada, it stabilized around a midpoint of inequality and union density, in Japan, it stabilized in a high inequality/low density scenario, and in Germany around a low inequality/high density scenario, which likely would have changed if our data had reached beyond 1998.

In other countries, the patterns of Figure 4 conform exactly to the expectations from a vortex-like relationship. Current inequality is correlated negatively with current union density (negative bars at lag 0), and past inequality is correlated positively to current union density in many country (positive bars at negative lags, left of 0). In Australia, France, the Netherlands and the US, the positive correlations of previous inequality with later union density even approach or exceed correlation coefficients of $r = .5$.

It thus seems that union density is low in those years where inequality is high – and vice versa (see the negative correlations around lag 0), while high inequality of the past lets trade unions gain more members (positive correlation at negative lags left of 0). In the following, we use a structural equation model to test whether this pattern shows up in a statistically significant way when analysing data from all countries together.
After having shown the bivariate correlation between inequality and trade union density over successive time lags in each country separately, this section uses a structural equation model to capture the relationship between inequality and union density by analysing data from all countries together. For this structural equation model, we have standardised all variables to have a country-mean of 0, as we are not interested in whether some countries have – on average – more inequality or union density than others. Our model is therefore a fixed effects model. We have also standardized all variables to have a standard deviation of 1 in each country, so that all effects can be interpreted as standardized coefficients, which show by how many standard deviations a dependent variable changes if an explanatory variable changes by a standard deviation.

To understand how past inequality and union density influence current inequality and union density, we have tested with which time lag prior inequality and union density explain current inequality and union density. We have therefore used the structural equation model explained above, and lagged inequality and union density by 2, 4, 6 … 20 years, to explain current inequality and union density (see the results in Table 3 in the SI). The different r² values of the models of Table 3 in the SI indicate that the best model fit exists with a time lag of ten years. This means that inequality and union density ten years ago influence current union density and inequality more strongly than, say, inequality or union density 4, 8, 12 or 20 years ago. We therefore use a time lag of ten years for our main calculations in Table 1 below. In the regressions of Table 1, the first Model 1 explains changes in inequality with inequality and union density ten years earlier. Model 2 of Table 1 explains changes in union density with inequality and union density ten years prior. Finally, Model 3 of Table 1 combines both models by explaining changes in inequality and union density through prior inequality and union density.

Since all variables used for Table 1 are standardized to have a mean of zero and a standard deviation of one, the effect of the variable “Union density lag 10” of -0.080 in Model 1 indicates that when union density ten years ago was one standard deviation above its typical value in a country, then inequality ten years later decreases by 8 percent of a standard deviation. In other words, strong unions decrease inequality with a time lag of ten years. This confirms the hypothesis behind Equation 1 above. The effect of “Inequality lag 10” of -0.209 indicates that when inequality ten years ago was one standard deviation above its average long-run value in a country, then inequality ten years later decreases by about 21 percent of a standard deviation. Substantively, this suggests a regression to the mean. When inequality is above or below its average long-run value in a country, it is more likely than not that it will return to the country-average over time. The constants are close to zero and insignificant, which should be the case,
as all variables are standardized to have a mean of 0. The effect size “Covariance (inequality, union density)” of -0.604 shows that inequality and union density of the same year are strongly and negatively related, meaning that in those years where inequality is one standard deviation above its typical value, trade union density is 60 percent of a standard deviation below its typical value and vice versa. Finally, the $r^2$ of Model 1 indicates that only 2.9 percent of the variation in inequality can be explained through prior inequality and union density.

Model 2 explains union density through current inequality, prior inequality, and prior union density. It shows that when union density ten years ago was one standard deviation above its long-run average value in a country, then union density decreases by 25.5 percent of a standard deviation ten years later. Again, this can be understood as a regression to the mean. When trade unions were stronger than they usually are in a country, they are more likely than not to regress to the long-run typical strength that they have in a country. Model 2 also shows that – and this is remarkable – trade union density increases by almost 25 percent of a standard deviation, when inequality ten years ago was one standard deviation above its long-run typical value in a country. Together with the strongly negative covariance of -0.604, this indicates that trade unions are weaker when current inequality is higher, but stronger when inequality ten years ago was higher. Therefore, inequality and union density of the same year are inimical to each other: when inequality is low, trade union density is high, and vice versa. But past inequality actually increases union density, instead of decreasing it. In other words, trade unions recruit more members when inequality ten years ago was higher than what it typically is in a country. The $r^2$ of
Model 2 of 0.135 shows that prior trade union density and inequality explain changes in union density much better than they explain changes in inequality (compare the relatively low $r^2$ of 0.029 of Model 1 to the relatively high $r^2$ of 0.135 of Model 2).

Model 3 sums up both models into one dynamic structural equation model, which explains both changes in inequality and trade union density through prior inequality and prior trade union density. While the effect sizes stay the same as in the prior models, the $r^2$ of Model 3 shows that it explains 15.8 percent of the variation of union density and inequality over time in the different countries. The following Figure 5 sums up Model 3 as a path diagram, visualizing the same effect sizes as Model 3 in Table 1, but giving a graphical representation of which variable influences which.

Starting on the left, Figure 5 shows how inequality and union density of the same year are related negatively with the same effect size of -.6 that also exists in Model 3, indicating that when inequality is one standard deviation higher, trade union density is 60 percent of a standard deviation lower in the same year and vice versa. The upper left arrow shows that the growth of inequality is 8% of a standard deviation lower, if union density ten years ago was one standard deviation above its long-run country-typical value. In addition, change in inequality declines by 21 percent of a standard deviation, when inequality ten year ago was one standard deviation above its country-typical value. Third, changes in union density are 22 percent lower, when union density ten years ago was one standard deviation higher ten years ago. Last, and this is the important part, the lowest arrow indicates that union growth is 25 percent of a standard deviation
higher, when inequality ten years ago was one standard deviation above the country’s long-run typical value. This is exactly the result to expect, based on the theoretical section and the model of the Vortex that we have developed. This is because the central idea of the vortex is that trade unions that are currently strong decrease current inequality (negative relationship between union density and inequality of the same year). But trade unions increase their membership based on past inequality (positive relationship between past inequality and later changes in union density). Thus, while current union density is lower when current inequality is higher (negative relationship), union density thrives on inequality of the past, so that current union density is higher when past inequality is higher (positive relationship). Therefore, by lowering inequality now, trade unions destroy the cause that they can rally around, and therefore lose members in the future, as few have a reason to stay in a trade union when the main reason why they should join one – inequality, has been reduced. This is the central dynamic, which makes the Vortex turn through the different stages highlighted above. It also conforms to a prey and predator model where predators eat prey, but by doing so, destroy what ensures their future survival.

V.IV. Robustness tests: left governments and GDP

We now test whether our results are explained away through variables that could co-vary with union density and inequality. An obvious correlate of inequality and union density is the political orientation of the ruling government, mainly because left governments may reduce inequality and increase union density. We have therefore used the ParlGov database, to get an indicator for the right-left political orientation of parties in government (see data section and Döring and Manow, 2016). This allows us to measure to what degree the party that provides the prime minister has a left political orientation in each country and year. We have again standardized this variable to have a mean of 0 and a standard deviation of 1 per country. Using the same structural equation model as above, we have tested whether left governments decrease inequality and increase union density with lags of 0, 2, 4, 6, 8, 10 and 12 years, but no connections emerged (see Table 4 in the SI). So while left parties do not influence inequality or union density in the long run, we still included it as a control variable in Table 2.

Second, our results may hinge on how developed countries are. Countries with a higher GDP may have stronger or weaker trade unions, and more or less inequality. As GDP tends to increase in countries over time, including GDP also controls for time trends in our data. We have again first tested whether inflation-adjusted per capita GDP in 1990 International Geary-Khamis dollars (The Maddison-Project, 2013, also cf. Bolt and van Zanden, 2014) can explain union density and inequality. Table 5 in the SI shows that the inequality in a
country is indeed 13.2-16.2 percent (depending on the time lag) of a standard deviation higher, when prior GDP is one standard deviation above its long-run mean value. In addition, a country’s union density grows 32.4-40.7 percent of a standard deviation less (again depending on the time lag), when the country’s GDP was one standard deviation above the country’s long-run mean value in the past (for all results, see Table 5 in the SI). Keep in mind however, that per capita GDP in countries tends to increase over time. In other words, it is mainly correlated to a time trend, so that its relation to inequality and union density might simply reflect that as time progresses, inequality tends to increase and union density tends to decrease.

Are our main results robust after controlling for these variables? Model 1 of Table 2 reruns our main calculations with only those countries and time periods, for which control variables exist. Model 2 then adds the political orientation of government as a control. Model 3 additionally controls for GDP. We use a lag of ten years for all explanatory variables, as this was a reasonable lag in the tests above.

**Table 2**

Main results after controlling for left parties and GDP

|                      | (1)                   | (2)                   | (3)                   |
|----------------------|-----------------------|-----------------------|-----------------------|
|                      | Main result           | Left parties controlled | GDP controlled        |
| **Change in inequality** |                       |                       |                       |
| Union density lag 10 | -0.078*** (-2.05)    | -0.063*** (-1.99)     | -0.078 (-1.72)        |
| Inequality lag 10   | -0.191*** (-7.71)     | -0.186*** (-8.07)     | -0.148*** (-4.53)     |
| Left party lag 10   | -0.071** (-3.12)      |                       |                       |
| GDP lag 10           |                       | 0.035 (1.71)          | 0.034 (1.58)          |
| Constant             | 0.035 (1.71)          | 0.034 (1.58)          | 0.020 (0.82)          |
| **Change union density** |                       |                       |                       |
| Union density lag 10 | -0.271*** (-4.19)    | -0.274*** (-4.01)     | -0.271*** (-6.59)     |
| Inequality lag 10   | 0.213*** (5.12)       | 0.212*** (5.01)       | 0.082* (2.03)         |
| Left party lag 10   | 0.016 (0.28)          | 0.016 (0.28)          | 0.016 (0.28)          |
| GDP lag 10           |                       | 0.088*** (3.64)       | 0.088*** (3.56)       |
| Constant             | 0.088*** (3.64)       | 0.088*** (3.56)       | 0.135** (3.13)        |
| cov(Union density,Inequality) | -0.472*** (-9.19) | -0.472*** (-9.19)     | -0.472*** (-9.19)     |
| Constant             | 0.112 (1.22)          | 0.112 (1.22)          | 0.112 (1.22)          |
| cov(Left party,Union density) | -0.042 (-0.66) | -0.042 (-0.66)        | -0.042 (-0.66)        |
| Constant             | 0.235 (1.87)          |                       |                       |
| cov(GDP,Union density) |                       |                       |                       |
| Constant             | -0.394*** (-4.15)     |                       |                       |
| r²                   | 0.143                 | 0.148                 | 0.175                 |
| aic                  | 7745.358              | 9844.047              | 9376.184              |
| bic                  | 7791.848              | 9890.536              | 9422.674              |
| Observations         | 772                   | 772                   | 772                   |

* t statistics in parentheses *p < 0.05, **p < 0.01, ***p < 0.001
Model 1 reproduces the main result from Model 3 of Table 1. As it can only use country-years with control variables, its indicators are marginally different. Model 2 uses the same country-years, but controls the relationship between inequality and union density for the influence of left parties on both. It shows that when the political orientation of the party that controls government is one standard deviation above the country-mean, changes in inequality are depressed by 7.1 percent of a standard deviation ten years later. Thus, when the political orientation of the government is more left-leaning, inequality ten years later is a bit lower (after controlling for union density). However, the influence of left parties on union density ten years later is nonsignificant and weak substantively. Comparing the results from Model 1 and 2 indicates that whether left parties control the government hardly influences our results, as the indicators from Model 1 are similar to those of Model 2.

Model 3 is more interesting, as it shows that for every standard deviation increase of GDP in a country, later inequality growth increases by 8.7 percent of a standard deviation. It also shows that for every standard deviation increase of GDP, later union density growth decreases by 26.5 percent of a standard deviation. Thus, with rising GDP, inequality grows at a faster rate, while union density growth decreases. As GDP tends to rise in countries over long periods, the increase of inequality and decrease of union density can also be seen as a long-term secular trend. Possibly even more important is the effect of controlling for GDP on the mutual influence of inequality and union density. Notably, after controlling GDP, prior union density influences inequality non-significantly. As the substantial influence of union density on inequality remains the same as in Model 1 however, this simply indicates that after adding a control variable that is correlated to an explanatory variable, the effect of the latter becomes less statistically significant. However, controlling for GDP reduces not only the statistical significance, but also the substantive effect of prior inequality on current changes in union density. That is, union growth is still 8 percent of a standard deviation higher when inequality ten years ago was one standard deviation higher, but before controlling GDP, this effect size amounted to plus 21.3 percent. However, even this model shows that unions gain more members when inequality ten years ago was higher, even though union density and inequality of the same year are strongly negatively related (see the negative covariance of union density and inequality, which shows up in every model). Our results are therefore only mildly affected by controlling for the most important political and economic control variables.

VI. DISCUSSION

Existing studies have looked at many different indicators to explain union strength (cf. the review by Wallerstein and Western, 2000) and inequality
Our aim was not to contribute to these studies by amassing an even more exhaustive list of variables that could explain union density or inequality. Instead, we conceptualize their reciprocal influence over long periods for the first time, by showing that inequality and union density are negatively correlated at each point in time, but positively correlated with successive time lags. This indicates that unions recruit members based on past inequality, so when inequality was low in the past, unions have fewer members, even though inequality tends to be low in those years where union density is high and vice versa. It is therefore true that unions decrease inequality, but in doing so, they destroy their own ability to recruit members in the future. With few trade union members, inequality eventually increases. After inequality has been persistently high, people have an incentive to join trade unions again. For this reason, a negative linear relationship explains how trade union density and inequality interact at each point in time. However, a positive relationship exists in the sense that past inequality increases current union density.

To be sure, the data does not suggest a deterministic spiral between inequality and union density. Scandinavian countries have stopped the vortex from turning in an equilibrium of low inequality and high union density, by letting trade unions administer unemployment schemes, which stabilize union membership regardless of inequality. The model thus explains about 16 percent of the variation in inequality union density. While we are thus aware that union density and inequality are not comprehensively accounted for through their mutual influence on each other, our aim was to show that the interaction between the two explains a considerable part of how both develop over time.

Our model therefore contributes to explanations of inequality and trade union density. Economic models argue that skill-biased technical change promotes inequality, as computers increase the incomes of those that use them, while increasing unemployment among those that do not (Goldin and Katz, 2008). This means that people get divided into high-income earners and low-income earners – both of which are more likely to leave unions (Acemoglu et al., 2001). Studies also show that trade unions decrease inequality through their egalitarian wage agreements and the corresponding norms that they set, even in non-unionized sectors (Wallerstein and Western, 2000). While such explanations of union density and inequality may be true for the 1970s onwards, our data suggests a more general link, notably that trade unions thrive on past inequality, while decreasing current inequality, and that trade unions actually fare worse when they were successful in decreasing inequality in the past.

The model proposed in this article also complements theoretical approaches that postulate a “Spiral of Capitalism and Socialism” (Boswell and Chase-Dunn, 2000), according to which social movements fight capitalism’s inequality. Others argue that long-run economic cycles can be linked to worker mobilization (Kelly, 1998, also cf. Brown, 1990). Our model explains the long-run waves of
inequality and worker mobilization that this literature has only postulated. We can show that social movements form in response to inequality, and that they then lower inequality. While our model shows that trade unions react to inequality, it also shows that they react too late, too much, and they face a delayed backlash after they have lowered inequality. In this sense, there indeed seems to be a spiral between “capitalism and socialism”, as trade unions react to inequality with delay and overshooting, so that the between union density and inequality dynamic is similar to a prey and predator model.

In terms of policy recommendations, we caution that our historical analysis must not necessarily provide a guide to the future. That inequality increased in the past does not guarantee that a social movement will arise to fight it in the future. However, if the patterns that we found in the past provide any guide to the future, then it is likely that periods of above-average inequality lead to countermovements after a time lag of about ten years. From this perspective, it seems likely that a mobilization against global inequalities, which could have followed the financial crisis of 2009, has not yet fully materialized. It might simply take ten year or longer for social movements to react to inequalities.

Our results therefore also indicate that future researchers would be well advised to work with longer time lags in their analysis. They might also want to consider that effects can be opposite depending on the time lags used, for example that unions decrease present inequality (negative link), but thrive on past inequality (positive link). In turn, policymakers should not expect that inequality is met by instantaneous reactions, but that social reactions to inequality are significantly retarded, so that society reacts to problems of the past. It is simply possible that social problems have to be on people’s minds for extended periods, to stimulate protests and reactions.

Generally, the model that we have presented is applicable to any interaction between social problems and consciousness about them. The general idea behind it is to introduce a theoretical scheme into the social sciences, which can model disequilibria between social problems, their consciousness, and the lags between both, as a motor of social change. The general dynamic that we wanted to highlight is that a social problem may lead to a social movement that tries to fight it. After this social movement was successful in fighting a problem, it declines and the underlying problem consequently resurfaces anew. With the increasing availability of long-run historical data on social movements as representations of the consciousness about a problem, and historical data about the objective degree of a social problem, unprecedented opportunity exists to study the non-linear historical dynamic between social problems and social movements that deal with these problems. If this article could provide a first idea of such non-linear relationships between social problems and social reactions to these problems, it has fulfilled its purpose.
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INEQUALITY AND UNION DENSITY AS PREY AND PREDATOR

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SUMMARY

This article shows empirically how trade union membership and income inequality are mutually related in twelve countries over more than 100 years. While past research has shown that high income inequality occurs alongside low trade union membership, we show that past income inequality actually increases trade union membership with a time lag, as trade unions recruit more members after inequality has been high. But we also show that strengthened trade unions then fight inequality, thereby destroying what helped them to recruit new members in the past. As trade union density decreases, inequality increases and eventually re-incentivises workers to join unions again. By showing this empirically, we reconceptualise the relationship between inequality and union density as a prey and predator model, where predators eat prey – unions destroy inequality, but thereby also destroy their own basis for survival. By empirically showing that trade union density and social inequality influence each other in this way over long periods, this article contributes to a dynamic approach on how social problems and social movements interact.