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Some (Maybe) Unpleasant Arithmetic in Minimum Wage Evaluations: The Role of Power, Significance and Sample Size

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ABSTRACT

Some (Maybe) Unpleasant Arithmetic in Minimum Wage Evaluations: The Role of Power, Significance and Sample Size*

In this paper, we discuss the importance of sample size in the evaluation of minimum wage effects. We first show which sample sizes are necessary to make reliable statements about the effects of minimum wages on binary outcomes, and second how to determine these sample sizes. This is particularly important when interpreting statistically insignificant effects, which could be due to (i) the absence of a true effect or (ii) lack of statistical power, which makes it impossible to detect an effect even though it exists. We illustrate this for the analysis of labour market transitions using two data sets which are particularly important in the minimum wage research for Germany, the Integrated Labour Market Biographies (IEB) and the Socio-Economic Panel (SOEP).

JEL Classification: C12, C80, J38

Keywords: power calculation, sample size, significance testing, evaluation, minimum wage

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1. Introduction

Understanding the effects of minimum wages on labour-market outcomes, especially on wages, employment and unemployment, has been of prime interest for academic economists, policy makers and a broader public at least for the last two decades.[1] This is not surprising given that minimum wages can potentially have strong effects on these outcomes. More recently, interest has shifted towards analysing minimum wage effects on labour market transitions, i.e. worker flows out of employment or out of unemployment.[2] Understanding these effects of minimum wages is crucial as they are closely related to the job stability and to the unemployment duration of individual workers. Both are aspects that directly affect individual welfare. Furthermore, analysing labour market transitions means that one can understand better how changes in employment and unemployment stocks come about, e.g. if changes in unemployment come about through increases in inflows into unemployment or reductions in outflows from unemployment.

An important question that has rarely been discussed in this context is how precisely we can estimate minimum wage effects in practice, and what imprecision means for the interpretation of the results. Put simply, finding a null effect in a minimum wage evaluation in statistical terms can either be the truth, i.e. there really is no effect of minimum wages, or the found null effect can be due to a low number of observations and therefore a lack of precision of the estimates. If precision is too low, even relatively large effects would be found to be insignificant. This results in a Type II error, i.e. wrongly accepting a null hypothesis – in this case: the minimum wage does not have an effect – even though there were effects in reality. This issue is particularly relevant when the analysis has to rely on data sets with small sample sizes.

In this article, we therefore investigate the role of statistical power, significance and sample size in the context of minimum wage evaluations for labour market transitions, i.e. the analysis of whether an individual makes a labour market transition or not, which implies a binary variable for the transition investigated. To that end, we discuss the econometric background, drawing on existing research (in particular Djimeu/Houndolo 2016), and relate this to the evaluation of minimum wages. We then apply this framework to the German case, where a statutory minimum wage was introduced on 1 January, 2015. We use two micro data sets as illustrating examples, the Sample of Integrated Labour Market Biographies of the IAB (SIAB) and the Socio-economic Panel (SOEP).

The German case is interesting for at least two reasons. First, while sectoral minimum wages have been in existence since 1997, a statutory minimum wage was introduced only recently. Therefore, the interest in evaluating minimum wages in Germany – both from an academic and a policy perspective – is high and rising, which implies that methodological guidance in this context seems warranted. Second, there are several data sets for Germany which can be used to analyse minimum wages. The two data sets we focus on, stemming from administrative sources and from a household survey, respectively, are comparable to data sets in other countries. This means that the results for the two German data sets we analyse can act as a point of comparison to data sets in others countries.

Our results show that, for a standard difference-in-differences evaluation framework, for the SIAB data, observation numbers are sufficiently high to investigate most labour market transitions in the context of minimum wage evaluations. This is even true when sample restrictions with respect to the region (East/West) and the education level are made. For the SOEP, however, the sample size is so

[1] See Neumark (2018) for a review of the US evidence on this topic.

[2] See Brochu and Green (2013), Dube et al. (2018) and Bachmann et al. (2015) for analyses of the effects of minimum wages on labour market flows in Canada, the US and Germany, respectively.

small that it appears impossible to analyse labour market transitions in the difference-in-differences framework. Our results have important implications for conducting minimum wage evaluations, which are discussed in the conclusion.

2. What econometric theory tells us about statistical power, significance, and necessary sample size

The relevance of type I errors is very present in empirical research given the widespread acknowledgment of 90%, 95% or 99% confidence intervals. Type I error means that a null hypothesis is wrongly rejected, for example, because unsystematic error leads to an association that erroneously is considered significant although the association does not exist.

In contrast, the relevance of type II errors receives less attention in applied research. Type II error means that a null hypothesis is wrongly accepted, for example, because an existing but small effect is correctly estimated but the point estimate is falling within the confidence interval around zero and is thus considered to be insignificant.[3] In recent years, the spread of laboratory and field experiments has revived the discussion of type II errors and of power calculations. In randomized controlled trials (RCT) power calculations are a fundamental issue when making decisions about the minimum sample size required to detect statistically significant effects if the real effect equals some minimum size (minimum detectable effect). But power calculations are not only relevant for RCTs. Also for empirical analyses based on existing (secondary) data, power calculations are important to determine *ex-ante* whether sample sizes in that data are large enough for the specific research question to have the power to detect statistically significant effects of a certain minimum size.

In this section, we discuss how to calculate the minimum sample size in cases in which the treatment and the outcome variable are binary.[4] As discussed in the first section of the article, binary outcomes are specifically relevant when analysing the reaction of labour market transitions to the introduction of minimum wages, because the question whether a worker makes a transition boils down to a 0/1 decision. For example, the probability to move from unemployment at one point in time to employment at the next point in time (e.g. from one year to the next) or from full-time to part-time employment are modelled as binary outcomes when using individual-level micro data. We consider the case of a binary treatment, which is relevant in many applications of policy impact evaluations and also for evaluating minimum wages. For example, the treatment would be considered to be binary when defining everybody as treated after the minimum wage introduction and comparing the time after with the time before the minimum wage introduction or if one is interested in analysing effects on the entire population (e.g. including spill-over effects). We can also define the treatment group as all those who are affected by the minimum wage introduction as they had lower earnings before, and the control group as those unaffected due to sufficiently high hourly wages. This will also result in a binary treatment indicator.[5]

[3] In many analyses the insignificance of a point estimate is interpreted as the effect being zero.

[4] See Djimeu and Houndolo (2016) for the corresponding framework with respect to continuous variables.

[5] The treatment would not be binary if the identification strategy is based on differences in the minimum wage *bite* between regions or sectors as e.g. in vom Berge and Frings (2017). Fitzenberger and Doerr (2016) and Neumark (2018) discuss several identification strategies for the evaluation of minimum wage effects in Germany and the US, respectively.

This raises the questions how the minimum sample size is calculated, and which are the parameters that influence the minimum sample size. Equation (1) is taken from Djimeu and Houndolo (2016) and provides the formula for the minimum sample size *n*:

$$n = \left\{\frac{P}{T\delta^2}\frac{-P+1}{-T+1}(-t_1 - t_2)^2(-R^2 + 1)\right\} \quad (1)$$

The minimum sample size depends on several parameters: First, it depends on the relevant t-value. This is based on two criteria: we have to decide whether one or two sided significance tests are appropriate, and we have to choose a significance level of the test. The corresponding critical t-value is indicated by t_1. Second, we have to decide about the desired power of the design. The power indicates the probability of not committing a type II error. The corresponding critical t-value is indicated by t_2. Third, *T* is the proportion of the treated individuals in the data. Fourth, *P* indicates the baseline value of the outcome, which is the proportion of the population for whom the outcome is 1 in the absence of the treatment. Fifth, δ is the minimum detectable effect. The minimum detectable effect is the smallest effect that, if it were the true effect, has a chance equal to the power of the design of leading to statistically significant estimates. If the regression includes other control variables, the precision of the estimates can be increase, leading to a lower minimum sample size. Hence, lastly, R^2 indicates the proportion of the outcome variance explained by the other control variables.

Given this formula, the minimum sample size will be larger if the statistical power is set at a higher level (i.e. t_2.is larger), if the significance level is set at a lower level (i.e. t_1.is larger), if the proportion of persons treated (*T*) approaches zero or one, if the minimum detectable effect is set a lower level and if the probability of making a transition in the absence of an intervention (*P*) is approaching zero or one.

In order to give an example for the minimum sample size in different situations, we use the following parameter values: As it is a priori unclear whether the minimum wage leads to an increase or a decrease of the outcome considered, we recommend using two-sided significance tests. In the example we opt for a 10% significance level. Similar to most power analyses, the power is set to 80%. Furthermore we assume that R^2, the proportion of the outcome variance explained by the other control variables, is equal to 0.2. Note that an R^2 of 0.2 is chosen rather high and a 10% significance level is chosen rather low, both leading to a rather small minimum sample size. Those are also the parameters we use when discussing whether the SIAB and the SOEP are suitable for analysing labour market dynamics. To give a first impression on required sample sizes, Table 1 discusses results for cases where the baseline value of the outcome is around 0.03, around 0.10 and around 0.50. Instead, in section 3 where we assess the relevance of IEB and SOEP we use the actual transition rates. In all cases we define the minimum detectable effect to be 10% of the baseline outcome if the outcome is between 0 and 0.5, and 10% of one minus the baseline outcome if the outcome is between 0.5 and 1. This means that we want to find the minimum sample size such that in the case of a baseline value of 0.50, an actual increase to 0.55 should detect statistically significant effects, while in the case of a baseline value of 0.10 (0.03) an actual increase to 0.11 (0.033) should suffice.

In Table 1 and similarly in section 3, we discuss two different scenarios for the proportion of individuals in the data that are treated. In one case we assume that 50% are treated and in the other case 7%. The first case with 50% treated individuals would coincide with a situation where we have data on the outcome from two periods, one from before the minimum wage introduction and one from afterwards, and consider all individuals to be treated in the second period. The second case with 7% treated individuals would also coincide with a situation where we have data on the outcome from one period before the minimum wage introduction and from one period afterwards but now consider only those individuals to be treated in the second period who earned less than a certain hourly wage before

the minimum wage introduction. (According to calculations based on the SOEP, in 2014 around 14% of the employed workforce earned less than 8.50 euros per hour (Burauel et al. 2017).)

Clearly, the two examples considering as treated either everybody or only those with hourly wages below 8.50 Euro before the reform, constitute extreme cases but they help to provide upper and lower bounds for the required minimum sample size. Furthermore, clearly for case 2, hourly wages earned before the minimum wage introduction have to be observed, as one has to identify the persons who earned a wage below the minimum wage before its introduction. This is less likely to be the case for individuals whose initial labour market state is unemployment or non-employment as individuals may have been never been employed or a long time a ago. Yet, for expositional reasons section 3 also indicates whether the actual number of observations is large enough for case 2 also for transitions from unemployment or non-employment.

Table 1 shows the minimum sample size for the six settings.[6] Note that the minimum sample sizes presented in the table do not refer to the number of observations that are necessary in each wave of data, rather they refer to the overall number of observations when pooling all waves of data that are considered meaningful for the identification of a treatment effect. Furthermore, in the case when we are interested in analysing labour market transitions, the outcome is defined conditional on being in a certain labour market state at the start of a period and the relevant number of observations does not comprise the entire data, rather it refers to those individuals who are in the relevant labour market state at the start of the period. For example, if the baseline value of the outcome is close to 0.10 (as is the case for the transition rate from part-time to full-time employment) then a sample size of slightly less than 18 000 is sufficient to obtain significant estimates if the treatment actually leads to an increase of the transition rate by 1 percentage point and half of the individuals in the data are treated. If the data comprises information from two periods, this would imply around 9 000 individuals per period (who are working part-time at the start of the period). In contrast, if there are four periods of data, comprising two periods before and two periods after the minimum wage introduction and the identification strategy allows to compare all four periods, i.e. the four periods are pooled in the empirical analysis, then each period would require around 4 500 individuals (working part-time).

Table 1 – Minimum sample sizes for several scenarios

Proportion of individuals in the data that are treated (T)	50% (e.g. 2 periods, 100% treated in the 2nd period)			7% (e.g. 2 periods, 14% treated in the 2nd period)		
Baseline value of the outcome (P)	0.50	0.10	0.03	0.50	0.10	0.03
Minimum sample size (n)	1 981	17 833	64 066	7 609	68 482	246 029

*Note: Parameter values used for calculating the minimum sample size are 10% significance level, 80% power, minimum detectable effect=0.1*P if P≤.5 and =0.1*(1-P) if P>.5 and R^2=0.20.*

For the discussion in section 3, we always assume that we pool data from four waves, or more specifically two periods of time before the minimum wage introduction and two periods of time afterwards. We discuss whether the actual sample size is sufficiently large for either the T=50% or the T=7% case or for none of them.

[6] For calculating the minimum sample size using other parameters one can use the excel file provided by Djimeu and Houndolo (2016) which is available online at www.3ieimpact.org/media/filer_public/2016/03/22/3ie-sample-size-minimum-detectable-effect-calculator.xlsx. Djimeu and Houndolo (2016) also discuss formulas for the minimum sample size in other settings and for continuous outcomes.

Finally, note that when analysing labour market transitions, outcomes might not be available for all waves of the data. For example, if the reference period for measuring transitions refers to the time between interviews and if the interviews only include information on the current labour market status, we lose one wave of data because a transition can only be defined using information from two consecutive waves. Furthermore, we might lose another wave if the interviews are spread over the year and are not timed to take place at the exact point in time when the reform is implemented because then the intermediate period is only partially observed after the treatment. In contrast, this is no problem for spell data such as the IEB.

3. What this means in practice

In this section, we illustrate the research potential of two prominent German data sets in evaluating the impact of minimum wages on labour market transitions, the SIAB, i.e. the scientific use file which allows the use of the Integrated Labour Market Biographies (IEB), and the Socio-Economic Panel (SOEP). Most studies evaluating German minimum wages, both on the sectoral and federal level, rely on these data sets. For analyses based on the IEB, see among others Frings 2013, Aretz et al. 2013, and for those based on the SOEP see among others Caliendo et al. 2017, Bonin et al. 2018.

Based on the previous power calculations, we assess both data sets in terms of their applicability for evaluating the German federal minimum wage introduction. More precisely, we analyse for both data sets which types of labour market transitions fulfil the minimal requirement for the number of observations to detect significant effects considering two cases. Again, we revert to the two cases described above: Case 1 assumes that the full population is treated by the minimum wage introduction, whereas case 2 reflects a treatment group which only includes individuals earning below the newly introduced minimum wage. Furthermore, we demonstrate the data sets' potential for heterogeneity analyses by educational attainment and geographical region. Last, we elaborate on three additional crucial data properties for the evaluation of the impact of minimum wages on labour market transitions. Apart from the sample size, these are the most important characteristics for determining whether a data set is suitable for use in minimum wage evaluations.

First, we present the number of distinct labour market states contained in the respective data set. The higher this number, the more comprehensively the impact of minimum wages can be evaluated. In particular, we distinguish different types of employment, unemployment and non-participation, and consider single as well as multiple states.

Second, we address to what extent the data sets are exposed to measurement error in labour market transitions. Hereby, we consider the recall and the time aggregation bias. The recall bias concerns only survey data and arises from participants' wrong recollection of their labour market history. In contrast, the time aggregation bias may also be present in register data and denotes the distortion due to time aggregation in the data. The lower the periodicity of data collection, the higher the probability for unobservable transitions between two time points.

Third, we discuss the availability of hourly wages in the data sets. This is important for minimum wage evaluations for two reasons. It enables researchers to identify which individuals are directly affected by a change in the minimum wage and facilitates the investigation of heterogeneous employment effects across the wage distributions.

3.1. Analysing labour market transitions using the IEB

The Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB) of the Federal Employment Agency (BA) are the central administrative data set for employment subject to social insurance contributions and registered unemployment in Germany. The IEB includes all women and men who are at least once in one of the following labour market states: (i) employment subject to social insurance contributions, (ii) marginal employment or (iii) receipt of unemployment benefits. The data are available for West Germany from 1975, for East Germany from 1993, and for marginal employment from 1999. The data are derived from social security records on a daily basis.

For all individuals the IEB provides important socio-demographic characteristics such as age, gender, education and place of residence. In addition, it contains detailed information on the current job such as occupation, sector, wage, and place of work. Furthermore, the data set allows researchers to distinguish full-time, part-time and marginal employment as well as spells in vocational training. Unemployment is reported either as receiving unemployment benefits (Arbeitslosengeld I) or unemployment assistance (Arbeitslosengeld II).[7]

The data set only contains periods spent in employment subject to social insurance contributions and receipt of unemployment benefits. Therefore, neither self-employed nor civil servants are covered and the concept of unemployment roots solely on receiving benefits, not on unemployed individuals' actual search behaviour. Non-participation is not directly identifiable in the IEB. Instead, gaps that lie between two observable states are considered as the state of non-participation. However, one has to be cautious to interpret these gaps exclusively as non-participation, since other employment states not recorded in the data, such as self-employment and being unemployed without receiving benefits, can also lead to these gaps.

One advantage of the IEB data is that they may contain multiple parallel states. Each labour market state, both employment and unemployment, has a daily start and end date. Based on this information, every observable combination of employment and unemployment and thus any type of transition between the states can be analysed.

The daily periodicity of the data is very beneficial for the analysis of labour market transitions, since the "time aggregation bias" discussed above does not distort the investigation.[8] The "recall bias" is also unproblematic, as employment and unemployment states can be tracked retrospectively until 1975 (or 1993 in East Germany).

The salary is recorded in the IEB as daily wage including all special payments subject to social security contributions, with a very high quality regarding measurement accuracy and completeness. However, the IEB do not provide any information on the hours worked, which makes the calculation of hourly wages, which are eminent for the minimum wage research, considerably more difficult. A distinction in working time is only possible between the broad categories of full-time and part-time employment, which we use in our analyses below.

We use the Sample of Integrated Labour Market Biographies (SIAB) to illustrate in more detail the research potential of the IEB in evaluating the impact of minimum wages on labour market transitions. The SIAB is a 2% representative sample of the IEB. The current version covers over 1.7 million men and women, resulting in almost 43 million individual spells. All results presented in the following are based

[7] See the Appendix for a detailed description of the data preparation.

[8] As a small caveat, changes within yearly spells and within the same firm (in particular transitions between full-time and part-time employment) may be slightly underreported.

on this sample. Due to the availability of the labour market state information on a daily basis, several transitions may be recorded for one person per year. Persons who remain in the same labour market state all year round (stayers), however, are only recorded once. Accordingly, the investigation of the number of observations for each transition shows how many persons do not change their labour market state over the entire calendar year (the diagonal elements in the transition matrices). It also shows how many transitions from the different initial states (non-diagonal elements) can be observed within a calendar year.

Table 2 displays the number of labour market transitions observed in the SIAB between single states in employment, unemployment and non-participation in 2013. For case 1, assuming all individuals are treated by the minimum wage introduction, taking the transitions from full-time employment to part-time employment as an example, note that this transition rate requires a minimum observation number of 261 557 overall,[9] i.e. approximately 65 000 observations in each of the four periods. This minimum is comparatively high because the transition rate is relatively low (according to SIAB, only around 0.7% of employees working full-time switch to part-time each year). The observation number of individuals working full-time in the sample is 408 325 in 2013. Therefore, there are enough observations in the data set in the respective initial labour market state to perform the desired analysis.

Overall, all stayers and state transitions between full-time, part-time, marginal employment, vocational training, unemployment and non-participation provide sufficient observations for an empirical analysis both for case 1 and case 2 except for the transitions between vocational training and marginal employment and part-time employment to vocational training. As these transitions are not particularly relevant, these exceptions do not really limit the research potential of the data set. Note that the numbers for non-movers (diagonal elements in the transition matrix) are especially high. As mentioned above, self-employment and unemployment without receiving benefits are not captured in the SIAB.

Next, we discuss the IEB research potential for heterogeneity analyses. We first focus on East Germany, where separate analyses may be particularly interesting because the bite of the minimum wage is much higher than in West Germany. This implies that stronger effects can be expected in the east. Table 3 shows the number of labour market transitions for individuals working in East Germany. Note that all transitions displaying sufficient numbers of observations for East Germany to detect significance are sufficient for West Germany, too. Numbers for stayers are large in every state. The strongest restriction compared to the full sample applies to the investigation potential for transitions from and to marginal employment. The number of outflows from marginal employment are only high enough for transitions to part-time employment and non-participation for case 1. In case 2, where the treated group is smaller, only transitions to non-participation can be analysed. Flows to marginal employment display sufficient observation numbers from unemployment and non-participation. Similarly, only transitions from non-participation are high enough for case 2. The problem for transitions from and to vocational training worsens concentrating on East Germany instead of the entire country. They cannot be empirically analysed for case 2 and are limited to flows to full-time employment and unemployment and flows from non-participation. Furthermore, transitions between full-time and part-time employment are restricted to case 1 in the East German sample.

[9] The baseline transition from full-time employment to part-time employment is 3 070/408 325=0.0075 in the IEB. If we set the minimum detectable effect to 10% of the baseline, it equals 0.00075. The critical t-values are 0.84 and 1.65 when setting the power to 80% and using a 10% significance level for a two-sided test. Assuming that R^2=0.20 gives a minimum sample size of (0.0075/(0.5*0.00075^2)*(1-0.0075)/(1-0.5)*(-1.65-0.84)^2*(1-0.20))=261 557.

Table 4 displays the number of labour market transitions for individuals with a low educational attainment who can be suspected to be particularly strongly affected by the introduction of a minimum wage. Numbers for stayers are sufficient in every state and case except for unemployment in case 2. The strongest restriction compared to the full sample concerns the investigation potential for transitions from part-time and full-time employment. For case 1, only the number of flows into unemployment and into non-participation are sufficient, the other transitions do not display sufficient numbers; for case 2 only the flows from part-time employment into non-participation are high enough.

In the following, we extend the previous investigation of the IEB research potential in evaluating the impact of minimum wages on labour market transitions to flows between single and multiple labour market states. This is especially interesting in the context of minimum wage evaluations because persons with multiple spells (e.g. several jobs, or a job plus unemployment benefits) are likely to be comparatively vulnerable to the introduction or the increase of a minimum wage In particular, we distinguish between types of parallel employment spells and combinations of employment with unemployment states. Additionally, we separate aggregate unemployment into receiving unemployment benefits and social assistance.

Table 5 displays the number of labour market transitions observed in the SIAB between single and multiple states. For case 1, assuming all individuals are treated by the minimum wage introduction, all relevant states provide sufficient observations of stayers for an empirical analysis of the aggregate outflow rate from a respective state. The only exception is the state of receiving unemployment benefits. The common maximum potential unemployment benefit duration is 12 months. This explains the low observation number for stayers.

For the more restricted case 2, in addition the number of stayers holding multiple jobs subject to social insurance contributions and receiving social assistance is insufficient. In general, the flows from and to holding a single job subject to social insurance contributions, receiving social assistance, receiving benefits with a parallel marginal employment and non-participation allow researchers to detect significant effects in both cases. The opposite holds true for transitions from and to holding multiple jobs subject to social insurance contributions. The observation numbers for flows from and to the multiple state of holding a job subject to social insurance contributions and vocational training are especially problematic for case 2, where only individuals earning below the new minimum wage are considered as treated. All other transition labour market states of origin or destination, receiving unemployment benefits, marginal employment and the combination of holding a job subject to social insurance contributions with receiving social assistance, exhibit mediocre research potential in the SIAB.

Table 6 presents the number of labour market transitions between single and multiple states for individuals working in East Germany. The IEB research potential substantially narrows compared to the full sample. The same holds true for individuals with a low educational attainment, which is illustrated in Table 7 However, for case 1, the SIAB contains sufficient observations of stayers for most states. As before, the number of unemployment benefit recipients is inadequate for an empirical analysis. In addition, the number of stayers holding multiple jobs subject to social insurance contributions is insufficient for both cases. For case 2, only stayers in states connected to some type of unemployment can be investigated. In the East German sample, this corresponds to receiving social assistance and in the low education sample, this corresponds to the combination of unemployment with either a job subject to social insurance contributions or marginal employment. Transitions from and to holding a single job subject to social insurance contributions display promising observation numbers for both cases and sample restrictions. Similarly, transitions from and to unemployment with marginal employment as well as from and to non-participation provide scope to detect significant effects.

3.2. Analysing labour market transitions using the SOEP

The German Socio-Economic Panel (SOEP) is an annual longitudinal household survey collected by the DIW in Berlin. It is one of the most widely used data sets in economics and sociology in Germany. The SOEP has been conducted in West Germany since 1984 and in East Germany since 1990 and covers a wide range of topics. As a household survey, questions cover both the household and the individual members of the household. The household members answer questions from the age of 17 onwards. We use the v32.1 long version of the data (SOEP 2017) covering data from 1984 to 2015. Goebel et al. (2018) provide a detailed description of the data. In 2014, the SOEP comprised approximately 16 000 households with 28 000 persons. It also contains weights that make it possible to carry out representative analyses for Germany.

The most important topics for the analysis of labour market transitions are examined every year and are (largely) comparable over time. In particular, the SOEP covers socio-demographic characteristics, participation in employment and training as well as issues of occupational mobility. The SOEP further includes information on income and migration background. The majority of these questions relate to the status at the time of the survey.

In addition to questions about the current labour market situation and changes to the previous year (e.g. change of occupation), income from the previous year and employment states within the previous year are queried. The months in which someone was employed (full-time, part-time, marginal employed etc.), unemployed, on parental leave, etc. are recorded as calendar data. A number of employment states can be identified in the SOEP: We distinguish full-time employment, part-time employment, marginal employment, self-employment, unemployment with and without benefits, education and non-participation. Furthermore, second jobs and therefore multiple states can be observed.[10]

The SOEP is collected once a year, which is why annual transitions can be measured accordingly. In addition to the annual dates, there is the calendar of activities for the previous calendar year, which contains monthly information on labour market states. Here however, the memory horizon can be very large, and not as many different labour market states can be distinguished as is the case for the information at the time of the interview. Therefore, the “time aggregation bias” may distort the investigation. Jürges (2007) shows important recall bias, which results in important differences between the yearly data and the calendar data, especially for women. In addition, Bachmann and Schaffner (2009) compare transitions between SOEP and SIAB data and show that there are considerable differences, also especially for women. These may be due to at least partially systematic memory errors (presumably of short episodes), but also to the different definitions of labour market states. The calendar data in the 2015 questionnaire therefore covers January 2014 to December 2015. Depending on the time of the interview, respondents have to provide retrospective information up to almost two years ago which fosters the “recall bias”.

The SOEP also covers information on working hours. In detail, employees state the number of contractual as well as the number of hours they work on average per week (including overtime). There is no information on hourly wages in the SOEP, as in all other large nationwide surveys (Dütsch et al. 2017). However, gross earnings of the past month and the corresponding net earnings are available. Based on this information in combination with working hours, the hourly wage rate can be calculated.

[10] See Appendix B for a detailed description of the data preparation.

Since different components of working time are collected in the SOEP, the choice of the type of reported working hours is important for the calculation of hourly wages (e.g. Brenke/Müller 2013). It turns out that a certain proportion of the calculated hourly wages is clearly below the minimum wage and usual wages (e.g. below 2€) for all calculation methods. It is unclear in which cases this is due to outliers (measurement error) and which cases not.

In the literature, the SOEP is used for the analysis of transitions. However, these are mostly based on monthly calendar dates (Kluve et al. 2009; Hertweck/Sigrist 2015) and examine the relationship between economic growth and changes in individual transitions in the labour market. By contrast, we apply yearly transition rates since more detailed information about labour market states is available at the day of the interview than in the monthly calendar. Table 8 presents the unweighted transition matrix of the SOEP displaying labour market transitions from 2013 to 2014. The biggest group are the full-time employed (first row and line). Most workers stay in their previous status (one exemption is the small group of unemployed without benefits) which can be seen in the main diagonal.

We calculate for each cell the minimum number of observations to detect 10% changes in the effect (see Section 2). The unweighted staying probability in full-time employment is 0.91 (7 946/8 748) and we assume a change of 0.009 (0.1*(1-0.91)). Taking into account that everyone is treated after the minimum wage introduction (i.e. case 1), we need at least 4 908 observations per wave to observe a significant effect with 4 waves, R^2=0.20, 10% significance level, 80% power. Since there are 8 748 observations in 2013, the number is sufficient to detect the required effect. If we want to analyse transitions using the assumptions of case 2, when only 14% are considered as treated after the minimum wage introduction[11] (i.e. those with a wage rate below 8.50 € before the minimum wage introduction), we already need 18 847 observations per wave which is much too high, i.e. for this case the number of observations available in the SOEP is not sufficient. For the transition rate from part-time to full-time employment, 3 667 and 14 083 observations are needed respectively, with only 3 420 available in the SOEP. The analysis cell-by-cell shows that only stayers in full-time employment, part-time employment, marginal employment, education, unemployment and non-participation can be analysed under the assumption that everyone is treated. None of the cells contains a sufficient number of observations for the case when only 14% are assumed to be treated.

We further distinguish between more detailed labour market states in Table 9. Due to the smaller cells, only for the staying probability in one single dependent employment, main marginal employment, unemployment benefit II receipt and non-participation, the number of observations is high enough to analyse the case when all workers are treated. In all other cases, the number of observations is too small.

For the SOEP it thus becomes clear that the yearly data do not contain enough observations to analyse labour market transitions after the minimum wage introduction. Applying the calendar data and also taking two years before and after the minimum wage introduction into account (48 months) can reduce the problem of the small sample sizes also when assuming that 14% of workers are treated. However, there are other problems arising: the bite of the minimum wage can only be observed at the time of the interview (time *t*). Since the calendar data is retrospective, the interview in year *t-1* (including the bite) must be combined with the calendar data included in the data wave for year *t* (including the labour market states). Therefore, if one wants to compare two years with each other, e.g. directly before and after the introduction of the minimum wage, three years of data are needed. Furthermore, in the calendar data only relatively broad labour market states can be distinguished.

[11] I.e. 7% when taking into account observations before and after the minimum wage introduction

4. Conclusion

In this article, we investigate the role of statistical power, significance and sample size in the context of minimum wage evaluations which use a difference-in-differences approach. In particular, we discuss and analyse which sample sizes are necessary to be able to make reliable statements about the effects of minimum wages on binary outcomes (i.e. labour market transitions), and how to determine these sample sizes. This is particularly important when interpreting statistically insignificant effects, which could be due to either the absence of an effect or the lack of power due to insufficient sample size, which may make it impossible to detect an effect although it exists.

From statistical theory, it follows that to make precise statements about the effects of minimum wages on labour market transitions for a given minimum detectable effect, the sample size required is higher if (i) the required power, i.e. the probability of not committing a type II error, is high, (ii) the significance level is low, (iii) the proportion of persons treated approaches zero or one, and (iv) the probability of making a transition in the absence of an intervention (e.g. the introduction of the minimum wage) is approaching zero or one.

We apply these considerations to the German case, where a statutory minimum wage was introduced on 1 January, 2015, which makes this illustrating example particularly interesting. We use two micro data sets as applications, the Sample of Integrated Employment Biographies of the IAB (SIAB), and the Socio-Economic Panel (SOEP). It turns out that for the SIAB data, observation numbers are sufficiently high to investigate most labour market transitions in the context of minimum wage evaluations. This is even true when sample restrictions with respect to the region (East/West) and the education level are made. For the SOEP, however, the sample size is so small that it appears impossible to analyse labour market transitions in the context of minimum wage evaluations.

Our results have important implications for the evaluation of the labour-market effects of minimum wages. First, one should take great care when interpreting insignificant effects in minimum wage evaluations, paying particular attention to the power of the econometric methodology used, and to the corresponding required sample size. Second, our statistical considerations and results provide ex ante guidance on which sample sizes are required for minimum wage evaluations, which makes the selection of appropriate data sets easier. Third, given that sample size is an issue for one of the most prominent micro data sets used for the German labour market, the SOEP, more effort should be devoted to the illustration of the precision of estimates. Besides a thorough discussion of the power of tests, this implies indicating standard errors for descriptive statistics, which is not common practice yet.

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Appendix: Data preparation

A.1. IEB

The data preparation in the IEB is complex, especially because multiple states are recorded. In the following the data processing routines are briefly described:

- Gaps of 7 days or less between two employment or unemployment records and at the beginning and end of the year are ignored.

- Gaps between an unemployment and employment states are defined as unemployment record.

- If there is a gap of less than 30 days between two employment records with the same employer, the employment relationship is considered to be continuous ("recalls").

- Persons who have records with an incorrect start and/or end date are deleted.

- Records that last less than 3 days are deleted.

- Employees who have more than 17 records in 2013 are deleted. This limit has been empirically determined: 1% of employees have more than 17 notifications within the year.

- Records with a gross wage of zero or a missing value: If this occurs within a continuous employment record (e.g. during parental leave), the wage from the previous observations is used. Employees who still have employment records with incorrect wage information (zero or missing value) after this procedure are deleted.

In order to create the two central transition matrices, each person observed in 2013 was assigned to exactly one of the states defined in transition matrix 2 at any time.

A.2. The SOEP

The analysis of the SOEP is based on the years 2013 and 2014 of the long version v32.1 (SOEP 2016). Various variables determine the different labour market states. The broad classification is based on the employment status (pgemplst) and the number of contracted hours worked (pgvebzeit), which was utilised for the division into full-time and part-time employment. Employees who work 31 hours or more count as full-time employees (in the predefined division of the SOEP the limit is 30). In addition, interns and volunteers (plb0063) are assigned to vocational training if applicable. On the basis of the occupational status (stib), self-employed persons were identified separately among full-time and part-time employees.

Anyone who is registered as unemployed (plb0021) or participates in unemployment training or similar (PLB0038) is considered to be unemployed. Unemployment benefits (plc0130) or social assistance (plc0132) payments are also taken into account. Parallel second jobs are queried separately in the SOEP (plb0394, plb0395), which allows a further subdivision of several employment types. Non-participation in the transition matrices includes all those that could not be assigned to any other condition.

All the case numbers shown are unweighted. Accordingly, statements can be made about the observation units, but not about the proportions of certain states or transitions in the population.

Table 2 – SIAB: Transition matrix I, all persons
Transitions between aggregate labour market states

		Period t+1						
		Full-time employment	Part-time employment	Minijob as main job	Education	Unemployment	Nonparticipation	Total
Period t	Full-time employment	338,487	3,070	2,799	727	21,978	41,264	408,325
	Part-time employment	3,663	111,121	3,112	482	8,989	16,357	143,724
	Minijob as main job	3,808	6,029	39,021	1,496	3,660	29,185	83,199
	Education	5,896	646	329	17,835	2,658	2,487	29,851
	Unemployment	25,105	10,898	4,368	1,370	8,257	51,420	101,418
	Nonparticipation	40,226	18,218	35,007	5,075	49,211	n.E.	147,737

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 3 – SIAB: Transition matrix I, East Germany
Transitions between aggregate labour market states

		Periode t+1						
		Full-time employment	Part-time employment	Minijob as main job	Education	Unemployment	Nonparticipation	Total
Periode t	Full-time employment	62,656	689	285	84	4,983	7,385	76,082
	Part-time employment	770	21,605	371	69	2,295	3,135	28,245
	Minijob as main job	437	663	3,597	97	679	3,663	9,136
	Education	684	126	36	2,310	459	313	3,928
	Unemployment	6,763	3,205	889	287	2,741	15,163	29,048
	Nonparticipation	7,008	3,553	4,504	675	14,944	n.E.	30,684

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 4 – SIAB: Transition matrix I, low education
Transitions between aggregate labour market states

		Periode t+1						
		Full-time employment	Part-time employment	Minijob as main job	Education	Unemployment	Nonparticipation	Total
Periode t	Full-time employment	14,923	179	256	192	2,114	3,462	21,126
	Part-time employment	234	6,419	389	141	1,208	1,485	9,876
	Minijob as main job	396	715	4,378	513	703	3,651	10,356
	Education	678	99	114	8,863	918	1,155	11,827
	Unemployment	2,452	1,410	772	673	1,619	9,994	16,920
	Nonparticipation	3,418	1,493	4,329	2,113	9,400	n.E.	20,753

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 5 – SIAB: Transition matrix II, all persons
Transitions between detailed labour market states

		Periode t+1										
		Dependent employment	Multiple jobs	Dependent employment plus minijob	Dependent employment plus UB (ALG II)	Minijob as main job	Education	ALG I receipt	ALG II receipt	ALG receipt with minijob	Non-participation	Total
Periode t	Dependent employment	399,298	2,609	19,125	5,359	2,209	1,023	18,995	2,083	965	55,305	506,971
	Multiple jobs	2,444	910	308	29	27	<20	87	<20	<20	245	4,050
	Dependent employment plus minijob	18,542	350	23,888	405	3,634	109	167	24	1,361	498	48,978
	Dependent employment plus UB (ALG II)	11,193	46	884	4,592	41	72	1,091	5,214	972	1,585	25,690
	Minijob as main job	5,014	36	4,741	46	39,021	1,496	241	601	2,818	29,185	83,199
	Education	5,975	<20	406	156	329	17,835	2,010	491	157	2,487	29,846
	ALG I receipt	17,377	<20	80	1,531	641	407	161	2,629	3,689	13,728	40,243
	ALG II receipt	1,441	<20	<20	9,133	442	758	1,066	1,339	7,402	35,277	56,858
	ALG receipt with minijob	1,924	<20	1,598	2,904	3,285	205	2,018	5,957	4,939	2,415	25,245
	Nonparticipation	56,000	92	325	2,039	35,007	5,075	11,636	34,578	2,997	n.E.	147,749

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 6 – SIAB: Transition matrix II, East Germany
Transitions between detailed labour market states

		Periode t+1										
		Dependent employment	Multiple jobs	Dependent employment plus minijob	Dependent employment plus UB (ALG II)	Minijob as main job	Education	ALG I receipt	ALG II receipt	ALG receipt with minijob	Nonparticipation	Total
Periode t	Dependent employment	77,684	498	1,788	1,898	334	134	4,116	505	347	9,975	97,279
	Multiple jobs	438	175	40	<20	<20	0	<20	<20	0	36	689
	Dependent employment plus minijob	1,687	39	2,079	78	311	<20	<20	<20	152	61	4,407
	Dependent employment plus UB (ALG II)	3,738	<20	154	1,752	<20	<20	394	1,469	254	452	8,213
	Minijob as main job	674	<20	411	<20	3,597	97	51	111	517	3,663	9,121
	Education	748	<20	29	31	36	2,310	323	122	<20	313	3,912
	ALG I receipt	4,336	<20	<20	575	114	63	34	811	1,078	3,346	10,357
	ALG II receipt	439	<20	<20	2,799	108	185	381	547	2,092	11,176	17,727
	ALG receipt with minijob	719	0	244	839	667	39	550	1,678	1,567	641	6,944
	Nonparticipation	9,870	<20	40	643	4,504	675	3,050	11,057	837	n.E.	30,676

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 7 – SIAB: Transition matrix II, low education
Transitions between detailed labour market states

		Periode t+1										
		Dependent employment	Multiple jobs	Dependent employment plus minijob	Dependent employment plus UB (ALG II)	Minijob as main job	Education	ALG I receipt	ALG II receipt	ALG receipt with minijob	Nonparticipation	Total
Periode t	Dependent employment	17,282	157	1,405	725	244	269	1,378	340	53	4,595	26,448
	Multiple jobs	149	<20	27	<20	<20	<20	<20	<20	0	<20	176
	Dependent employment plus minijob	1,386	31	1,586	67	392	23	<20	<20	100	30	3,615
	Dependent employment plus UB (ALG II)	1,516	<20	132	785	<20	39	161	1,098	178	304	4,213
	Minijob as main job	579	<20	520	<20	4,378	513	40	146	517	3,651	10,344
	Education	700	<20	42	34	114	8,863	609	270	39	1,155	11,826
	ALG I receipt	1,046	0	<20	190	103	148	<20	496	453	1,803	4,239
	ALG II receipt	192	0	0	1,699	116	443	252	340	1,641	7,724	12,407
	ALG receipt with minijob	154	0	105	475	553	82	228	1,321	908	467	4,293
	Nonparticipation	4,564	<20	20	321	4,329	2,113	1,388	7,488	524	n.E.	20,747

Source: SIAB, own computation. Note: Employment is dependent employment, without self-employment or civil service. Unemployment only includes unemployment with benefit receipt. Education includes only dual education. Nonparticipation includes persons outside the labour force, self-employment and civil service. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 8 – SOEP: Transition matrix I, all persons
Transitions between aggregate labour market states

		period t+1								
		Full-time dependent employment	Part-time dependent employment	Minijob as main job	Self-employment	Education	Unemploy-ment	Unemploy-ment without UB	Non-participation	Total
period t	Full-time dependent employment	7,946	262	22	71	24	166	23	234	8748
	Part-time dependent employment	407	2,504	133	37	13	121	22	183	3420
	Minijob as main job	28	140	415	12	24	26	8	130	783
	Self-employment	62	57	7	1,150	6	16	6	55	1359
	Education	156	29	6	4	392	31	6	59	683
	Unemployment	163	155	44	24	21	937	76	201	1621
	Unemployed without UB	39	20	5	2	10	49	56	58	239
	Non-participation	162	253	200	61	151	133	68	2,980	4008

Source: SOEP, own computation. - Note: Full-time and part-time employment includes employees covered by social security legislation and civil servants. UB = unemployment benefits. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.

Table 9 – SOEP: Transition matrix II, all persons
Transitions between detailed labour market states

	period t+1															
period t	Dependent employment	Multiple jobs	Dependent employment plus minijob	Dependet employment and UB (ALG II) receipt	Minijob as main job	Self-employment	of which: self-employed persons without employees	Vocational training	Other training	ALG I -receipt	ALG II -receipt	ALG-receipt and minijob	Unemployment without UB	Retirement	Non-participation	Total
Dependent employment	9,839	179	171	51	140	33	51	27	7	160	54	0	42	60	327	11141
Multiple jobs	160	148	44	0	1	2	11	1	2	5	1	0	0	0	12	387
Dependent employment plus minijob	111	47	208	1	3	1	7	0	0	9	1	1	2	0	8	399
Dependet employment and UB (ALG II) receipt	56	2	2	100	5	0	3	0	0	6	58	5	0	1	3	241
Minijob as main job	141	6	9	3	405	1	11	17	5	7	12	2	8	20	102	749
Self-employment	38	1	1	1	0	423	67	0	1	2	1	0	1	6	8	550
of which: self-employed persons without employees	58	14	5	1	7	72	588	3	2	2	12	0	5	6	34	809
Vocational training	142	5	3	4	5	0	4	365	6	21	11	0	6	0	32	604
Other training	26	3	1	1	1	0	0	6	15	1	1	0	0	0	24	79
ALG I -receipt	118	4	5	8	16	6	8	6	1	62	73	0	23	20	31	381
ALG II -receipt	104	2	7	82	17	2	8	15	2	22	989	14	54	34	69	1421
ALG-receipt and minijob	3	1	0	5	5	0	0	2	0	0	10	3	0	1	4	34
Unemployment without UB	57	0	1	1	5	0	2	7	3	10	42	0	56	8	47	239
Retirement	3	1	0	0	19	1	7	0	0	1	15	1	7	741	13	809
Non-participation	375	16	4	4	176	9	44	97	51	24	85	1	57	59	2,016	3018

Source: SOEP, own computation. - Note: Full-time and part-time employment includes employees covered by social security legislation and civil servants. UB = unemployment benefits. Dark shaded cells indicate that the transitions can be analysed for case 1 and 2, light shaded cells indicate that the transitions can be analysed for case 1 only. Assumptions for case 1: 80% power, 10% significance level, minimum detectable effect at 10% of the baseline value, R^2=0.20, data for 4 periods and proportion of treated observations 50%. Assumptions for case 2: same as for case 1 but proportion of treated observations 7%.