Simplifying the estimation of difference in differences treatment effects with Stata

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*** DRAFT VERSION ***

Abstract. This paper explains the insights of the Stata's user written command `diff` for the estimation of Difference in Differences treatment effects (DID). The options and the formulas are detailed for the single DID, Kernel Propensity Score DID, Quantile DID and the balancing properties . An example of the features of `diff` is presented by using the dataset from Card and Krueger (1994).

Keywords: Difference in differences, causal inference, kernel propensity score, quantile treatment effects, quasi-experiments.

1. Introduction

Difference in Differences treatment effects (DID) have been widely used when the evaluation of a given intervention entails the collection of panel data or repeated cross sections. DID integrates the advances of the fixed effects estimators with the causal inference analysis when unobserved events or characteristics confound the interpretations (Angrist and Pischke, 2008).

Despite the existence of other plausible methods based on the availability of observational data for quasi-experimental causal inference -i.e. matching methods, instrumental variable, regression discontinuity-, DID estimations offer an alternative reaching the unconfoundedness by controlling for unobserved characteristics and combining it with observed or complementary information. Additionally, the DID is a flexible form of causal inference because it can be combined with some other procedures, such as the Kernel

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Propensity Score (Heckman et al., 1997, 1998) and the quintile regression (Meyer et al., 1995).

In this paper, the Stata's command `diff` is explained and some details on its implementation are given by using the datasets from the Card and Krueger (1994) article on the effects of the increase in the minimum wage. Similarly, it is explain how the balancing properties can be tested when observational data is provided.

In the next section the equations behind the estimation of the DID are explained along with the features of the `diff` command. In the third section and example is provided and, in the fourth section, the balancing properties are tested with the options that can be specified with the command.

2. `diff` syntax and equations

`diff` can be installed or updated from the SSC archive by running the command:

```
ssc install diff, replace
```

The `diff` syntax is detailed as follows:

```
diff outcome_var [if] [in] [weight] ,[ options]
```

The command requests the specification of the outcome variable (`outcome_var`) and allows the use of weights, except for some options. The initial required option is the `period(varname)`, which contains a dummy variable indicating the baseline (`period==0`) and a follow-up (`period==1`) periods. Additionally, the option `treated(varname)`, is need, containing a dummy variable with the indicator of the control (`treated==0`) and treated (`treated==1`) individuals.

For the individual i, this initial setting performs the following linear regression:

$$outcome\_var_i = \beta_0 + \beta_1 \cdot period_i + \beta_2 \cdot treated_i + \beta_3 \cdot period_i \cdot treated_i + e_i$$

The estimated coefficients have the following interpretation:

- $\widehat{\beta_0}$: Is the mean outcome for the control group on the baseline.
- $\widehat{\beta_0} + \widehat{\beta_1}$: Is the mean outcome for the control group in the follow-up.
- $\widehat{\beta_2}$: Is the single difference between treated and control groups on the baseline.
- $\widehat{\beta_0} + \widehat{\beta_2}$: Is the mean outcome for the treated group on the baseline.
- $\widehat{\beta_0} + \widehat{\beta_1} + \widehat{\beta_2} + \widehat{\beta_3}$: Is the mean outcome for the treated group in the follow-up.

- $\widehat{\beta_3}$: Is the DID or impact.

The `diff` command arranges these coefficients in the output table. The number of observations, r-squared, standard errors, t-statistic -or the z-stat when standard errors are bootstrapped- and the p-value are also reported:

```
Number of observations in the DIFF-IN-DIFF: #
            Baseline       Follow-up
   Control: #              #
   Treated: #              #

R-square:  0.0
                              DIFFERENCE IN DIFFERENCES ESTIMATION
------------------ ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------------
 Outcome Variable | Control |  Treated  | Diff(BL) | Control  |     Treated     | Diff(FU) | DIFF-IN-DIFF
------------------+---------+-----------+----------+----------+-----------------+----------+-------------
outcome_variable  | β0_hat        β0_hat + β2_hat        β2_hat        β0_hat + β1_hat     β0_hat + β1_hat + β2_hat + β3_hat       β2_hat + β3_hat       β3_hat
Std. Error        |         |           |          |          |                 |          |
t/z               |         |           |          |          |                 |          |
P>|t/z|           |         |           |          |          |                 |          |
-------------------------------------------------------------------------------------------------------------
* Means and Standard Errors are estimated by linear regression
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

2.1 Options

cov(*varlist*) - Specifies the pre-treatment covariates of the model. These variables are also known as controls or observable characteristics. If we denote $X_{k,i}$ as the kth covariate, `diff` runs the following regression with this option:

$$outcome\_var_i = \beta_0 + \beta_1 \cdot period_i + \beta_2 \cdot treated_i + \beta_3 \cdot period_i \cdot treated_i + \beta_k \cdot X_{k,i} + e_i$$

The coefficients β_k are not reported in the output table. However, it is possible to request them if option report is specified.

kernel - Performs the Kernel-based Propensity Score DID. At a first stage, this option runs a `probit` model -or `logit` if this option is selected- of the `treated(`*varname*`)` on the `cov(`*varlist*`)`. It generates the variables `_weights` that contains the weights derived from the kernel density function and `_ps` when the Propensity Score is not specified in `pscore(`*varname*`)`. This option requires the `id(`*varname*`)` of each individual, hence it is not compatible with repeated cross section. It also allows the estimation of the DID on the common support by specifying the option support.

In a second stage, `diff` runs a regression applying the Stata's average weights option `[av=_weights]`, obtained from the propensity score:

$$outcome\_var_i \cdot weights_i = \beta_0 + \beta_1 \cdot period_i + \beta_2 \cdot treated_i + \beta_3 \cdot period_i \cdot treated_i + e_i$$

Option kernel can be customized by selection the bandwidth, bw(#) and the kernel type, ktype(*kernel*), according to the Stata's kdensity choices. Finally, the first stage is explicitly showed if report is specified.

qdid(quantile) - Performs the Quantile Difference in Differences estimation at the specified quantile from 0.1 to 0.9 (quantile 0.5 performs the QDID at the medeian). It may be combined with kernel and cov(*varlist*) options. qdid(quantile) does not support weights nor robust standard errors. This option uses Stata's qreg and bsqreg for bootstrapped standard errors. See Angrist and Pischke (2008) for detailed information on Quantile Treatment Effects and Meyer et al. (1995) for a illustrative example.

cluster(*varname*) - Calculates clustered standard errors by *varname*.

robust - Calculates robust Std. Errors.

bs - Performs a Bootstrap estimation of coefficients and standard errors. reps(*int*) specifies the number of repetitions when the bs is selected. The default are 50 repetitions.

nostar - Removes the inference stars from the p-values.

2.2 Option: balancing test

test - Performs a balancing t-test of difference in means of the specified covariates between the control and treated groups in period == 0. The option test combined with kernel performs the balancing t-test with the weighted covariates. Stata's ttest command is used to estimate the t-statistics and standard errors.

For each variable in cov(*varlist*), test option runs the command:

```
ttest cov(varname) if period == 0, by(treated)
```

When combined with kernel, the differences, t-statistics and standard errors are generated with linear regression.

3. Example

diff offers an example with the dataset from Card and Krueger (1994). It can be downloaded into the working directory by running net get diff and then, use cardkrueger1994,clear. In this case, the authors study the impact of the increase in the minimum wage in the state of New Jersey -the treated group- on the employment level at the fast food industry. They compare the changes in the number of employees at the restaurants in this treated group to the ones of the neighbor state, Pennsylvania -the control group-. They collect a baseline in February, 1992, and a follow-up in November.

The description of the variables in the dataset are is the following:

```
Contains data from cardkrueger1994.dta
  obs:           820                          Dataset from Card&Krueger (1994)
 vars:             8
 size:        18,860 (99.9% of memory free)
-------------------------------------------------------------------------------------------------------------------
storage  display     value
variable name   type   format      label      variable label
-------------------------------------------------------------------------------------------------------------------
id              int    %8.0g                  Store ID
t               byte   %8.0g                  Feb. 1992 = 0; Nov. 1992 = 1
treated         long   %8.0g       treated    New Jersey = 1; Pennsylvania = 0
fte             float  %9.0g                  Output: Full Time Employment
bk              byte   %8.0g                  Burger King == 1
kfc             byte   %8.0g                  Kentuky Fried Chiken == 1
roys            byte   %8.0g                  Roy Rogers == 1
wendys          byte   %8.0g                  Wendy's == 1
-------------------------------------------------------------------------------------------------------------------
Sorted by:  id  t
```

With 820 observations, the number of individuals or stores are 331 and 79 in the treated and control groups, respectively. The outcome variable is fte, while some covariates are defined as dummy variable indicating whether the observation belongs to a given fast food restaurant. The basic statistic are show as follows:

```
      Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
          id |       820    246.5073    148.1413          1        522
           t |       820          .5    .5003052          0          1
     treated |       820    .8073171    .3946469          0          1
         fte |       801    17.59457    9.022517          0         80
          bk |       820    .4170732    .4933761          0          1
         kfc |       820     .195122    .3965364          0          1
        roys |       820    .2414634    .4282318          0          1
      wendys |       820    .1463415    .3536639          0          1
-------------+--------------------------------------------------------
```

3.1 DID with no covariates

```
diff fte, t(treated) p(t)
```

The output table of this initial setting is:

```
Number of observations in the DIFF-IN-DIFF: 801
            Baseline       Follow-up
   Control: 78             77          155
   Treated: 326            320         646
            404            397

R-square:  0.00805

                              DIFFERENCE IN DIFFERENCES ESTIMATION
-------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable    | Control |  Treated  | Diff(BL) | Control |  Treated  | Diff(FU) | DIFF-IN-DIFF
---------------------+---------+-----------+----------+---------+-----------+----------+--------------
fte                  | 19.949  | 17.065    | -2.884   | 17.542  | 17.573    | 0.030    | 2.914
Std. Error           | 1.019   | 0.499     | 1.135    | 1.026   | 0.503     | 1.143    | 1.611
t                    | 19.57   | 14.17     | -2.54    | 17.60   | 20.45     | -0.33    | 1.81
P>|t|                | 0.000   | 0.000     | 0.011**  | 0.000   | 0.000     | 0.979    | 0.071*
```

```
-------------------------------------------------------------------------------------------------------
* Means and Standard Errors are estimated by linear regression
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

The baseline information contains the columns with the mean outcome for each group and its difference (-2.88 in this case). These estimators are presented along with standard errors, t-statistics and p-values. The same information is showed for the baseline (with a difference of 0.03). The last column is the difference in differences, that is, 0.03 - (-2.88) = 2.94. The p-value is accompanied by a star interpreted as the statistical inference at different significant levels.

Alternatively, bootstrapped standard errors can be requested by adding the potion `bs`:

```
diff fte, t(treated) p(t) bs rep(50)
```

```
Bootstrap replications (50)
----+--- 1 ---+--- 2 ---+--- 3 ---+--- 4 ---+--- 5
..................................................    50

Number of observations in the DIFF-IN-DIFF: 801
            Baseline       Follow-up
   Control: 78             77          155
   Treated: 326            320         646
            404            397

R-square:  0.00805
Bootstrapped Standard Errors

                                DIFFERENCE IN DIFFERENCES ESTIMATION
--------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable    | Control |  Treated  | Diff(BL) | Control |  Treated  | Diff(FU) | DIFF-IN-DIFF
---------------------+---------+-----------+----------+---------+-----------+----------+--------------
fte                  | 19.949  | 17.065    | -2.884   | 17.542  | 17.573    | 0.030    | 2.914
Std. Error           | 1.330   | 0.494     | 1.381    | 0.830   | 0.477     | 0.920    | 1.792
z                    | 15.00   | 14.12     | -2.09    | 17.05   | 20.76     | 0.28     | 1.63
P>|z|                | 0.000   | 0.000     | 0.037**  | 0.000   | 0.000     | 0.974    | 0.104
-------------------------------------------------------------------------------------------------------
* Means and Standard Errors are estimated by linear regression
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

3.2 DID with covariates

```
diff fte, t(treated) p(t) cov(bk kfc roys)
```

```
DIFFERENCE-IN-DIFFERENCES WITH COVARIATES


Number of observations in the DIFF-IN-DIFF: 801
            Baseline       Follow-up
   Control: 78             77          155
   Treated: 326            320         646
            404            397

R-square:  0.18784

                                DIFFERENCE IN DIFFERENCES ESTIMATION
--------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable    | Control |  Treated  | Diff(BL) | Control |  Treated  | Diff(FU) | DIFF-IN-DIFF
---------------------+---------+-----------+----------+---------+-----------+----------+--------------
```

```
fte                 | 21.161  | 18.837    | -2.324   | 18.758  | 19.369    | 0.611    | 2.935
Std. Error          | 1.142   | 0.851     | 1.031    | 1.158   | 0.853     | 1.037    | 1.460
t                   | 18.53   | 18.43     | -2.25    | 19.09   | 19.87     | 0.51     | 2.01
P>|t|               | 0.000   | 0.000     | 0.024**  | 0.000   | 0.000     | 0.556    | 0.045**
-------------------------------------------------------------------------------------------------------
* Means and Standard Errors are estimated by linear regression
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

Option report allows the output table of the coefficients from the cov(*varlist*):

```
Covariates and Coefficients:
-----------------------------------------------------------------
 Variable(s)         |   Coeff.   | Std. Err. |    t    |  P>|t|
---------------------+------------+-----------+---------+---------
bk                   | 0.917      | 0.889     | 1.032   | 0.303
kfc                  | -9.205     | 1.006     | -9.154  | 0.000
roys                 | -0.897     | 0.967     | -0.927  | 0.354
-----------------------------------------------------------------
```

3.3 Kernel Propensity Score DID

The Kernel Propensity Score DID can be estimated on the common support of the propensity score. I you have previously estimated the propensity score you can provide it with the option pscore(varname). The basic syntax is:

```
diff fte, t(treated) p(t) cov(bk kfc roys) kernel id(id)
```

The full options are:

```
diff fte, t(treated) p(t) cov(bk kfc roys) kernel id(id) report
```

With the following output table:

```
KERNEL PROPENSITY SCORE DIFFERENCE-IN-DIFFERENCES

Report - Propensity score estimation:

Iteration 0:   log likelihood = -198.21978
Iteration 1:   log likelihood =  -196.7657
Iteration 2:   log likelihood =  -196.7636

Probit regression                                 Number of obs   =        404
                                                  LR chi2(3)      =       2.91
                                                  Prob > chi2     =     0.4053
Log likelihood =  -196.7636                       Pseudo R2       =     0.0073

------------------------------------------------------------------------------
     treated |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          bk |   .1812529   .2090916     0.87   0.386    -.2285591    .5910649
         kfc |   .3888298    .246799     1.58   0.115    -.0948873    .8725469
        roys |   .2997977   .2318227     1.29   0.196    -.1545664    .7541618
       _cons |   .6476036   .1777446     3.64   0.000     .2992305    .9959767
------------------------------------------------------------------------------

Number of observations in the DIFF-IN-DIFF: 800
            Baseline       Follow-up
```

```
   Control: 78             76          154
   Treated: 326            320         646
            404            396

R-square:  0.02819

                                DIFFERENCE IN DIFFERENCES ESTIMATION
-------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable    | Control |  Treated  | Diff(BL) | Control |  Treated  | Diff(FU) | DIFF-IN-DIFF
--------------------+---------+-----------+----------+---------+-----------+----------+--------------
fte                 | 21.656  | 17.065    | -4.591   | 18.914  | 17.573    | -1.341   | 3.250
Std. Error          | 0.572   | 1.093     | 1.234    | 0.576   | 1.103     | 1.245    | 1.752
t                   | 37.88   | 17.46     | -3.72    | 16.89   | 17.27     | -1.98    | 1.85
P>|t|               | 0.000   | 0.000     | 0.000*** | 0.000   | 0.000     | 0.282    | 0.064*
-------------------------------------------------------------------------------------------------------
* Means and Standard Errors are estimated by linear regression
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

3.4 Quantile DID

The Quantile DID is obtained when specifying the option `qdid(quantile)`. For example, estimating the treatment effects on the median requires the following syntax:

```
diff fte, t(treated) p(t) qdid(0.50)
```

It may be combined with covariates:

```
diff fte, t(treated) p(t) qdid(0.50) cov(bk kfc roys)
```

With the following output:

```
QUANTILE DIFFERENCE-IN-DIFFERENCES WITH COVARIATES

Number of observations in the DIFF-IN-DIFF: 801
           Baseline       Follow-up
   Control: 78             77          155
   Treated: 326            320         646
            404            397

R-square:  0.14861

                                DIFFERENCE IN DIFFERENCES ESTIMATION
-------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable    | Control |  treated  | Diff(BL) | Control |  treated  | Diff(FU) | DIFF-IN-DIFF
--------------------+---------+-----------+----------+---------+-----------+----------+--------------
fte                 | 17.750  | 17.250    | -0.500   | 17.750  | 17.750    | -0.000   | 0.500
Std. Error          | 1.124   | 0.835     | 1.013    | 1.132   | 0.840     | 1.007    | 1.426
t                   | 15.79   | 17.15     | -0.49    | 17.75   | 17.85     | -0.00    | 0.35
P>|t|               | 0.000   | 0.000     | 0.622    | 0.000   | 0.000     | 1.000    | 0.726
-------------------------------------------------------------------------------------------------------
* Values are estimated at the .5 quantile
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

Quantile DID is combinable with the option `kernel`:

```
diff fte, t(treated) p(t) qdid(0.50) cov(bk kfc roys) kernel id(id)
report

KERNEL PROPENSITY SCORE QUANTILE DIFFERENCE-IN-DIFFERENCES
```

```
Report - Propensity score estimation:

Iteration 0:   log likelihood = -198.21978
Iteration 1:   log likelihood =  -196.7657
Iteration 2:   log likelihood =  -196.7636

Probit regression                                 Number of obs   =        404
                                                  LR chi2(3)      =       2.91
                                                  Prob > chi2     =     0.4053
Log likelihood =  -196.7636                       Pseudo R2       =     0.0073

------------------------------------------------------------------------------
     treated |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          bk |   .1812529   .2090916     0.87   0.386    -.2285591    .5910649
         kfc |   .3888298    .246799     1.58   0.115    -.0948873    .8725469
       roys |   .2997977   .2318227     1.29   0.196    -.1545664    .7541618
       _cons |   .6476036   .1777446     3.64   0.000     .2992305    .9959767
------------------------------------------------------------------------------

Number of observations in the DIFF-IN-DIFF: 800
           Baseline       Follow-up
   Control: 78             76          154
   Treated: 326            320         646
            404            396

R-square:  0.00477

                              DIFFERENCE IN DIFFERENCES ESTIMATION
--------------------- ------------ BASE LINE --------- ----------- FOLLOW UP ---------- --------------
 Outcome Variable     | Control |  Treated  | Diff(BL) | Control |  Treated  | Diff(FU) | DIFF-IN-DIFF
---------------------+---------+-----------+----------+---------+-----------+----------+--------------
fte                   | 18.500  | 16.000    | -2.500   | 18.500  | 17.500    | -1.000   | 1.500
Std. Error            | 1.578   | 0.732     | 1.739    | 1.614   | 0.727     | 1.770    | 2.482
t                     | 11.72   | 15.08     | -1.44    | 18.50   | 18.06     | -1.65    | 0.60
P>|t|                 | 0.000   | 0.000     | 0.151    | 0.000   | 0.000     | 0.572    | 0.546
-------------------------------------------------------------------------------------------------------
* Values are estimated at the .5 quantile
**Inference: *** p<0.01; ** p<0.05; * p<0.1
```

3.5 Balancing test

The balancing test is obtained only on the baseline. The syntax is similar to the one presented before, except for the supply of option `test`.

```
diff fte, t(treated) p(t) cov(bk kfc roys wendys) test
```

```
TWO-SAMPLE T TEST

Number of observations (baseline): 404
           Baseline       Follow-up
   Control: 78             -           78
   Treated: 326            -           326
            404            -

t-test at period = 0:
-------------------------------------------------------------------------------------------------
 Variable(s)          |   Mean Control   | Mean Treated |    Diff.   |   |t|   |  Pr(|T|>|t|)
----------------------+------------------+--------------+------------+---------+---------------
fte                   | 19.949           | 17.065       | -2.884     |  2.44   | 0.0150**
bk                    | 0.443            | 0.411        | -0.032     |  0.52   | 0.6035
kfc                   | 0.152            | 0.205        | 0.054      |  1.08   | 0.2818
roys                  | 0.215            | 0.248        | 0.033      |  0.61   | 0.5448
```

```
wendys               | 0.190           | 0.136        | -0.054     |  1.22   | 0.2241
-------------------------------------------------------------------------------------------------
*** p<0.01; ** p<0.05; * p<0.1
```

When combined with option `kernel`, the covariates are weighted and the differences obtained by linear regression:

```
diff fte, t(treated) p(t) cov(bk kfc roys wendys) test id(id) kernel
```

```
TWO-SAMPLE T TEST

Number of observations (baseline): 404
           Baseline       Follow-up
   Control: 78             -           78
   Treated: 326            -           326
            404            -

t-test at period = 0:
-------------------------------------------------------------------------------------------------
Weighted Variable(s) |   Mean Control   | Mean Treated |    Diff.   |   |t|   |  Pr(|T|>|t|)
---------------------+------------------+--------------+------------+---------+---------------
fte                  | 21.656           | 17.065       | -4.591     |  3.22   | 0.0014***
bk                   | 0.618            | 0.408        | -0.210     |  3.55   | 0.0004***
kfc                  | 0.104            | 0.209        | 0.104      |  2.60   | 0.0097***
roys                 | 0.183            | 0.252        | 0.068      |  1.42   | 0.1570
wendys               | 0.095            | 0.132        | 0.037      |  1.01   | 0.3123
-------------------------------------------------------------------------------------------------
*** p<0.01; ** p<0.05; * p<0.1
Attention: option kernel weighs variables in cov(varlist)
Means and t-test are estimated by linear regression
```

4. Saved results

`diff` saves in the memory each number of thee output table as return-type scalars:

- `r(mean_c0)`: mean of *`output_var`* of the control group in `period == 0`.
- `r(mean_t0)`: mean of *`output_var`* of the treated group in `period == 0`.
- `r(diff0)`: difference of the mean of *`output_var`* between treated and control groups in `period t=0`.
- `r(mean_c1)`: mean of *`output_var`* of the control group in `period == 1`.
- `r(mean_t1)`: mean of *`output_var`* of the treated group in `period == 1`.
- `r(diff1)`: difference of the mean of *`output_var`* between treated and control groups in `period == 1`.
- `r(diffdiff)`: DID - Treatment Effect.
- `r(se_c0)`: Standard Error of the mean of *`output_var`* of the control group in `period == 0`.
- `r(se_t0)`: Standard Error of the mean of *`output_var`* of the treated group in `period ==0`.
- `r(se_d0)`: Standard Error of the difference of *`output_var`* between the treated and control groups in `period ==0`.

- `r(se_c1)`: Standard Error of the mean of *`output_var`* of the control group in `period ==1`.
- `r(se_t1)`: Standard Error of the mean of *`output_var`* of the treated group in `period ==1`.
- `r(se_d1)`: Standard Error of the difference of *`output_var`* between the treated and control groups in `period == 0`.
- `r(se_dd)`: Standard Error of the difference in difference.

5. Acknowledgements

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