

Online Appendix: Replication of *A Spatio-temporal Model of House Prices in the USA*

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Abstract

I narrowly replicate [Holly, Pesaran, and Yamagata \(2010\)](#)'s analysis of the housing market in the US, using the open source R software instead of the original ad-hoc GAUSS routines. When available, results are double-checked against Stata procedures. The main findings of the original paper are confirmed and most results are matched exactly. Attention is given to providing a self-contained and fully reproducible analysis, exclusively using user-level features available in the public domain.

Keywords: panel time series, common factors, spatial panels, R.

1. This document

This is the Online Appendix for Giovanni Millo, "Narrow replication of *A spatio-temporal model of house prices in the USA* using R".

Using R, and in particular features from packages 'plm' ([Croissant and Millo 2008](#)), 'spdep' ([Bivand, with contributions by Micah Altman, Anselin, Assunção, Berke, Bernat, Blanchet, Blankmeyer, Carvalho, Christensen, Chun, Dormann, Dray, Halbersma, Krainski, Legendre, Lewin-Koh, Li, Ma, Millo, Mueller, Ono, Peres-Neto, Piras, Reder, Tiefelsdorf, and Yu. 2012](#)) and 'splm' ([Millo and Piras 2012](#)), most results in [Holly *et al.* \(2010\)](#) (HPY) are replicated up to all decimals reported. There are two exceptions. Table 10 has been exactly replicated for 10 models out of 12, with minor differences in coefficients for the other two; and neither of the results related to unit root testing could be replicated.

This document aims at being replicable in the sense of [Peng \(2011\)](#): it is self-contained and fully self-reproducing without the need for any further resources other than the files provided with it and FOSS software from the R project ([R Core Team 2013](#)).

2. Replication

2.1. Data sources and materials

Data and procedures have been retrieved from the Internet page of the Economic and Social Research Council (ESRC) funded project titled "Cross-sectional Dependence in Panel Data Models" (<http://www.econ.cam.ac.uk/CSDPDM/>). They are available on Prof. Pesaran's home page as well (<http://www.econ.cam.ac.uk/people/emeritus/mhp1/wp.htm#2010>).

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The data on States' contiguity have been adapted from the weights matrix 'usaww' in the R package 'splm' adding the row and column relative to the District of Columbia.

It must be noted that, while the data for the paper have been published in a convenient Excel format by HPY, the actual computations in the original GAUSS procedures (and hence results in the paper) regarding Tables 9 and 10, the only ones for which replication code is published, have been carried out on the basis of the data contained in the file `HPsort.fmt`, in proprietary GAUSS format. This file can be opened and converted either using GAUSS itself, which is non-free, or through any version of Ox (Doornik 2009), including a console version free for academic use.

There are slight differences between the "HPsort" data and those published in the Excel worksheet: in particular, some variables in the former (most notably the real house price) are normalized so that 1980=100. Although this scale change is transparent for most of the procedures considered, using the Excel version yields different results for the intercept of the MG model in Table 7 and for all models in Table 10.

A copy of the "HPsort" data in plain text format is included in the materials accompanying this Appendix, and is pointed at by the replication code.

In order for this procedure to work, the files

- `HPsort.txt`
- `BEACODE.txt`
- `regions.txt`
- `cortab.R`
- `ffilter.R`

must be placed in the working directory, or else the correct path must be set in the relevant calls to `read.table()` (.txt) and `source()` (.R).

All R software can be freely downloaded from cran.r-project.org. See the Computational Details Section for packages and versions thereof needed to compile this document.

2.2. Summary

The empirical analysis proceeds from the initial assessment of spatial dependence of the two main variables (disposable income and house prices) to that of unit root tests. Established integration of order one of both p and y , the model on levels

$$p_{it} = \alpha_i + \beta_i y_{it} + e_{it}$$

is estimated by MG, CCEMG and CCEP. The hypothesis $\beta = 1$ is assessed. Subordinated on this latter test, the hypothesis of panel cointegration is tested as a stationarity test on

$$\hat{u}_{it} = p_{it} - y_{it} - \hat{\alpha}_i.$$

Given panel cointegration, the error correction specification

$$\Delta p_{it} = \alpha_i + \phi_i(p_{i,t-1} - y_{i,t-1}) + \delta_{1i}\Delta p_{i,t-1} + \delta_{2i}\Delta y_{i,t-1} + \nu_{it}$$

is estimated, again, by MG, CCEMG and CCEP, in order to assess the short-term dynamics of the system and its equilibrium-reverting behaviour. Spatial autocorrelation in the defactored residuals from the long-run model is assessed by estimating a SAR model by maximum likelihood. Lastly, factor loadings are estimated for each State.

The following is divided into sections matching those of HPY from 4 (Preliminary data analysis) on.

2.3. Preliminary data analysis

The preliminary spatial dependence analysis (Tables 3 and 4 in HPY) highlights the correlation between neighbouring regions and also some cases of correlation with distant ones, as is the case for California and some more developed States on the East Coast.

Within and between regions correlation tables are constructed by means of the `pcdtest` function, setting `test='rho'` for the average correlation coefficient and supplying an appropriate proximity matrix W . For average correlation within Region A, W has ones corresponding to each possible pair of neighbours between States belonging to A. For average correlation between Regions A and B, W has ones corresponding to each possible pair where the first element belongs to A, the second to B. A function `cortab` automating this procedure is provided with the supplementary materials.

All four panels in Tables 3 and 4 of HPY match exactly with our calculations reported here.

	East	Middle	West
East	0.55		
Middle	0.51	0.64	
West	0.46	0.49	0.48

Table 1: Average of correlation coefficients within and between regions, first difference of log real per capita disposable income; three geographical regions (Table 3i in HPY).

	NE	ME	SE	GL	PI	SW	RM	FW
New England	0.74							
Mideast	0.58	0.57						
Southeast	0.48	0.50	0.61					
Great Lakes	0.54	0.56	0.70	0.85				
Plains	0.33	0.34	0.50	0.59	0.61			
Southwest	0.38	0.46	0.54	0.60	0.46	0.45		
Rocky Mountain	0.24	0.38	0.44	0.51	0.39	0.49	0.48	
Far West	0.51	0.51	0.56	0.66	0.44	0.50	0.41	0.68

Table 2: Average of correlation coefficients within and between regions, first difference of log real per capita disposable income; eight BEA regions (Table 3ii in HPY).

By contrast, the replication of Table 5 was unsuccessful, although the main finding (residuals from separate ADF regressions are cross-sectionally correlated) is confirmed by our own calculations.

Residual cross-correlations between individual regressions have been calculated applying the `pcdtest` function directly to the `pmg` model objects relative to each ADF regression. First

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	East	Middle	West
East	0.48		
Middle	0.42	0.65	
West	0.19	0.45	0.50

Table 3: Average of correlation coefficients within and between regions, first difference of log real house prices; three geographical regions (Table 4i in HPY).

	NE	ME	SE	GL	PI	SW	RM	FW
New England	0.80							
Mideast	0.68	0.66						
Southeast	0.40	0.32	0.52					
Great Lakes	0.40	0.35	0.57	0.81				
Plains	0.27	0.20	0.53	0.62	0.61			
Southwest	0.07	-0.05	0.35	0.28	0.39	0.52		
Rocky Mountain	-0.03	-0.11	0.40	0.52	0.53	0.57	0.70	
Far West	0.13	0.17	0.29	0.52	0.42	0.31	0.46	0.57

Table 4: Average of correlation coefficients within and between regions, first difference of log real house prices; eight BEA regions (Table 4ii in HPY).

and second panel are obtained setting `test` at, respectively, `'rho'` and `'cd'`.

As a robustness check, the first panel of HPY, Table 5 as estimated here was replicated exactly also using lower-level functions in base R, i.e. estimating separate by-country ADF regressions through the `lm` function¹, constructing the matrix of pairwise correlation coefficients between residuals and averaging over the upper triangle of the latter, diagonal excluded.²

This guarantees also for the second panel, as in general $CD = \sqrt{NT(N-1)/2\bar{\rho}}$ (see note to Table 5 in HPY) and the `pcdtest` function produces both average correlation coefficients and CD test statistics using the same matrix of estimated pairwise correlations $\hat{\rho}_{ij}$ for calculating either one until this last step.

	ADF(1)	ADF(2)	ADF(3)	ADF(4)
y	0.465	0.443	0.338	0.317
p	0.346	0.326	0.252	0.194
g	0.074	0.072	0.074	0.077
c	0.370	0.357	0.358	0.283

Table 5: Residual cross-correlation of ADF(p) regressions: average correlation coefficients (first panel of Table 5 in HPY).

¹The `lm` function is considered reliable enough to use here as a benchmark, instead of calculating least squares residuals explicitly through basic matrix algebra.

²Transformed data and R procedures for replicating this check are available upon request.

	ADF(1)	ADF(2)	ADF(3)	ADF(4)
y	82.84	77.40	57.96	53.21
p	61.73	57.02	43.21	32.52
g	12.95	12.31	12.40	12.71
c	64.66	61.17	60.12	46.55

Table 6: Residual cross-correlation of ADF(p) regressions: CD test statistics (second panel of Table 5 in HPY).

2.4. Panel unit root test results (HPY 5.1)

We were not able to replicate the panel unit root test results for any variable. Nevertheless, as discussed in the paper, the qualitative findings are substantially confirmed. Our calculations for the two panels of HPY’s Table 6 are reported in Tables 7 and 8

$CADF(i)$ test statistics were calculated through the `cipstest` function, setting truncation off.

	CADF(1)	CADF(2)	CADF(3)	CADF(4)
diff(y)	-3.43	-2.46	-1.89	-1.82
diff(p)	-2.42	-1.89	-1.87	-1.81
y	-2.05	-2.15	-2.23	-2.49
p	-2.06	-2.03	-2.43	-2.84
g	-2.44	-2.07	-1.92	-1.97
c	-2.44	-2.12	-2.08	-1.95

Table 7: Pesaran’s CIPS panel unit root test results: with an intercept (first panel of Table 6 in HPY). 5 percent and 10 percent critical values for rejection of the unit root hypothesis are, respectively, -2.11 and -2.03.

	CADF(1)	CADF(2)	CADF(3)	CADF(4)
y	-2.07	-2.03	-2.02	-2.09
p	-2.18	-2.23	-2.55	-2.30

Table 8: Pesaran’s CIPS panel unit root test results: with an intercept and a linear trend (second panel of Table 6 in HPY). 5 percent and 10 percent critical values for rejection of the unit root hypothesis are, respectively, -2.62 and -2.54.

We performed robustness checks by comparing results against different software. Both panels in our Tables 7 and 8 can be replicated exactly in Stata using the `pescadf` function (Lewandowski 2007), confirming the discrepancies with HPY’s original calculations in their Table 6. Differently from the case in their Table 5, here the input is a single variate, and lags and differences are calculated inside the testing procedure without the need for preliminary manipulation, hence manual double-checking was unnecessary in this case.

2.5. Income elasticity of real house prices (HPY 5.2)

Static models have been estimated with `pmg` (MG, CCEMG) and by `pcce` (CCEMG, CCEP). Only the former outputs an intercept, hence it has been used for replicating HPY’s Table 7; nevertheless, all other results (β , standard errors and diagnostics) are the same using `pcce`.

The results of the static model of income elasticity of house prices match Table 7 of HPY exactly. The same estimation performed with Stata’s `xtmg` for MG and CCEMG also yielded results that are exactly corresponding. As discussed, there is no Stata code available to check our CCEP estimates; anyway, these too do match HPY well.

The within and between regions cross-correlation coefficients of residuals have been calculated as described above; interestingly, it was possible to calculate $u_{it} = p_{it} - y_{it} - \alpha_i$ on the fly from original data as `Within(log(Y)-log(P))` using the data transformation capabilities of `plm`. They match Table 8 in HPY up to all decimals reported.

	MG	CCEMG	CCEP
(Intercept)	3.85	-0.11	
	0.20	0.26	
y	0.30	1.14	1.20
	0.09	0.20	0.21
avg. rho	0.38	0.02	0.00
CD test	71.03	4.45	0.62

Table 9: Estimation result: income elasticity of real house prices (Table 7 in HPY).

	NE	ME	SE	GL	PI	SW	RM	FW
New England	0.62							
Mideast	0.56	0.45						
Southeast	0.18	0.29	0.95					
Great Lakes	0.04	0.21	0.75	0.82				
Plains	0.10	0.24	0.92	0.80	0.93			
Southwest	0.07	0.17	0.90	0.63	0.87	0.94		
Rocky Mountain	-0.23	-0.08	0.70	0.70	0.77	0.75	0.86	
Far West	-0.12	-0.01	0.03	0.25	0.13	0.06	0.24	0.21

Table 10: Average residual cross correlation coefficients within and between eight BEA geographical regions: $u.it=p.it-y.it-\alpha.i$ (Table 8 in HPY).

2.6. Panel cointegration test results (HPY 5.3)

As with other CIPS/CADF tests throughout the paper, the unit root test on long-run residuals $p_{it} - y_{it} - \alpha_i$ does not correspond to those reported in HPY, Section 5.3 for any order of augmentation. The unit root hypothesis, nevertheless, is confirmed at any significance level even more strongly than in the original paper.

R Results were again successfully checked against Stata's `pescadf` function.

	CIPS(1)	CIPS(2)	CIPS(3)	CIPS(4)
p.it-y.it-alpha.i	-2.37	-2.48	-2.72	-2.29

Table 11: Panel cointegration tests as in HPY, 5.3. 1 percent and 5 percent critical values for rejection of the unit root hypothesis are, respectively, -2.23 and -2.11.

2.7. Panel error correction specifications

Panel error correction specifications have been estimated with `pmg`, `pcce` as detailed above.

The basic panel error correction estimates in HPY, Table 9 correspond exactly to our calculations, including measures of fit and cross-sectional correlation diagnostics.

The augmented specifications in HPY, Table 10, adding lagged values of the rate of growth of population g (η in HPY's Table 10) and of the real cost of borrowing net of house price appreciation, do correspond to our results exactly with the exception of:

- the intercept of the full MG model (first column), which upon comparison with the

	MG	CCEMG	CCEP
lag(p - y)	-0.105	-0.183	-0.171
	0.008	0.016	0.015
diff(lag(p))	0.524	0.449	0.518
	0.030	0.038	0.065
diff(y)	0.500	0.277	0.227
	0.040	0.059	0.063
half-life	6.248	3.429	3.696
R2	0.540	0.700	0.660
avg. rho	0.284	-0.005	-0.016
CD test	50.600	-0.840	-2.800

Table 12: Panel error correction estimates without net cost of borrowing and population growth (Table 9 in HPY).

original GAUSS procedures turns out to be a typo in HPY: to be read 0.359567 as in our replication;

- the full CCEMG model (fifth column), whose coefficients and standard errors are all slightly different
- the full CCEP model (ninth column), idem
- the CD statistics for all 12 models, which are only slightly different.

All coefficients and standard errors of the single problematic CCEMG specification, and all the CD statistics for the first 8 models (MG and CCEMG) have been checked against Stata and found exactly corresponding to our R results.

	MG1	MG2	MG3	MG4	CMG1	CMG2	CMG3	CMG4
lag(p - y)	-0.117	-0.114	-0.148	-0.138	-0.253	-0.219	-0.256	-0.215
	0.013	0.009	0.010	0.009	0.021	0.018	0.019	0.017
diff(lag(p))	0.481	0.444			0.072	-0.114		
	0.079	0.071			0.166	0.126		
diff(y)	0.533	0.544	0.669	0.679	0.311	0.272	0.332	0.309
	0.045	0.045	0.048	0.047	0.064	0.063	0.057	0.056
lag(c)	0.057	-0.053	-0.375	-0.438	-0.152	-0.524	-0.269	-0.492
	0.071	0.056	0.034	0.027	0.180	0.126	0.044	0.036
lag(g)	1.189		1.211		1.409		1.709	
	0.360		0.331		0.529		0.532	
half-life	5.571	5.727	4.328	4.668	2.376	2.804	2.344	2.863
R2	0.573	0.544	0.532	0.500	0.780	0.731	0.758	0.706
avg. rho	0.286	0.293	0.342	0.339	-0.006	0.002	-0.005	-0.005
CD test	50.990	52.180	60.900	60.350	-1.080	0.410	-0.800	-0.870

Table 13: Panel error correction estimates with net cost of borrowing and population growth (Table 10 in HPY): MG and CCEMG results.

	CCEP1	CCEP2	CCEP3	CCEP4
lag(p - y)	-0.240	-0.208	-0.242	-0.195
	0.021	0.017	0.021	0.016
diff(lag(p))	0.042	-0.134		
	0.112	0.125		
diff(y)	0.293	0.258	0.290	0.272
	0.046	0.052	0.064	0.060
lag(c)	-0.211	-0.583	-0.304	-0.553
	0.138	0.113	0.080	0.054
lag(g)	0.940		0.931	
	0.366		0.381	
half-life	2.526	2.972	2.502	3.196
R2	0.718	0.692	0.709	0.666
avg. rho	-0.015	-0.015	-0.015	-0.015
CD test	-2.690	-2.680	-2.690	-2.660

Table 14: Panel error correction estimates with net cost of borrowing and population growth (Table 10 in HPY): CCEP results.

2.8. Testing for spatial autocorrelation (HPY 5.5)

In their Section 5.5, HPY report the results of an analysis of spatial autocorrelation in the residuals of the long-run model, $\hat{u}_{it} = p_{it} - y_{it} - \hat{\alpha}_i$. These residuals are first defactored by regressing them on their first 1, 2 or 3 principal components, which are meant as an estimate of the common factors. Then a spatial autoregressive (SAR) model is estimated by maximum likelihood on either the defactored residuals or on a standardized version of the same, obtained dividing them by their timewise variance.

Principal-components “filtering” has been performed through a function `ffilter`, included in the supplementary materials. As for SAR estimation, given the absence of panel-specific features like individual effects, we experimented with two alternative routines: the `lagsarlm` function in package ‘`spdep`’ (Bivand *et al.* 2012) (a cross-sectional estimator implementing the one-step procedure in Anselin (1988, Ch.6) and calculating the covariance matrix analytically) pooling the data and using an extended spatial matrix defined as $W_{NT} = I_T \otimes W_N$ where W_N is the original neighbourhood matrix of 49×49 US States, and function `spml` in package ‘`splm`’ (a native panel data estimator using a numerical Hessian-based procedure for estimating the parameters’ covariance) (for a detailed comparison of the two methods, see Millo and Piras 2012, p. 28).

	m=1	m=2	m=3
psi, SAR by <code>lagsarlm()</code>	0.652	0.487	0.298
analytical SE	0.022	0.027	0.033
psi, SAR by <code>spreml()</code>	0.652	0.487	0.298
numerical SE	0.020	0.027	0.031

Table 15: Estimates of spatial autocorrelation in defactored residuals as in HPY, 5.5 (p.169).

	m=1	m=2	m=3
psi, SAR by <code>lagsarlm()</code>	0.673	0.513	0.393
analytical SE	0.021	0.027	0.030
psi, SAR by <code>spreml()</code>	0.673	0.513	0.393
numerical SE	0.020	0.025	0.029

Table 16: Estimates of spatial autocorrelation in standardized defactored residuals as in HPY, 5.5 (p.170).

Both sets of estimates correspond up to the last decimal reported in HPY; the analytical standard errors of the former also do, while the numerical ones are always slightly underestimated.

2.9. Factor loading estimates across states (HPY 5.6)

Table 11 in HPY reports factor loading estimates obtained by separate regressions of $p_{it} - y_{it}$ on their cross-sectional averages. A compact way of obtaining this was to specify the model formula as `I(log(P)-log(Y)) ~ Between(log(P)-log(Y), effect="time")`, meaning: regress the difference $p_{it} - y_{it}$ on its average across time periods $\bar{p}_t - \bar{y}_t$; then feeding it to the `pvc` function for estimating separate individual regressions. Results are all correctly reproduced here.

	(pbar_t - ybar_t)	se
Connecticut	0.35	0.23
Maine	0.29	0.15
Massachusetts	-0.63	0.24
New Hampshire	0.81	0.22
Rhode Island	-0.11	0.24
Vermont	0.78	0.15
Delaware	0.32	0.11
District of Columbia	0.54	0.18
Maryland	0.62	0.10
New Jersey	-0.04	0.20
New York	-0.39	0.20
Pennsylvania	0.65	0.13
Alabama	1.72	0.09
Arkansas	1.77	0.10
Florida	1.44	0.08
Georgia	1.43	0.08
Kentucky	1.21	0.06
Louisiana	2.03	0.15
Mississippi	2.09	0.13
North Carolina	1.28	0.05
South Carolina	1.39	0.06
Tennessee	1.53	0.08
Virginia	0.91	0.09
West Virginia	2.08	0.11
Illinois	0.71	0.11
Indiana	1.14	0.05
Michigan	0.54	0.17
Ohio	1.01	0.09
Wisconsin	0.98	0.12
Iowa	1.55	0.11
Kansas	1.76	0.06
Minnesota	1.20	0.09
Missouri	1.37	0.04
Nebraska	1.57	0.10
North Dakota	2.00	0.15
South Dakota	1.39	0.08
Arizona	1.02	0.07
New Mexico	0.95	0.12
Oklahoma	2.10	0.17
Texas	2.12	0.18
Colorado	0.80	0.17
Idaho	1.19	0.11
Montana	0.75	0.16
Utah	0.68	0.19
Wyoming	1.62	0.18
California	-0.64	0.23
Nevada	0.84	0.11
Oregon	0.37	0.25
Washington	-0.12	0.17

Table 17: Factor loading estimates (Table 11 in HPY).

2.10. Computational robustness checks

In the following we discuss the possibility of errors in the R code, and the replication of non-matching results with different procedures and/or different software as a robustness check. All relevant scripts are available upon request. Results are discussed in order of appearance. After the unsuccessful replication of HPY Table 5, its first panel as estimated here was replicated exactly also using lower-level functions in base R, i.e. estimating separate by-country ADF regressions, constructing the matrix of pairwise correlation coefficients between residuals and averaging over the upper triangle of the latter, diagonal excluded.³ The second panel is a transformation of the first (see HPY, note to table 5, and our Online Appendix) therefore no check was performed.

Unit root test results from the R function `cipstest` were compared against different software. All of them were replicated exactly in Stata using the `pescadf` function (Lewandowski 2007), confirming the discrepancies with HPY’s original calculations.

CCEMG estimators have been implemented in R in two different ways, both available in ‘plm’: either through an explicit augmentation approach whereby cross-sectional averages and trends are added to an MG model specification (function `pmg`), or by the original projection approach in Pesaran (2006) (function `pcce`). Results from one CCEMG implementation have been successfully checked against the other; by contrast, and for obvious reasons, MG is only available in the former, CCEP in the latter.

Our estimates of MG and CCEMG models can be replicated exactly in Stata too, in particular using the `xtmg` and `xtcd` functions (Eberhardt 2012, 2011), up to all reported decimals and including $\hat{\rho}$ and the CD test on residuals. By contrast, Stata does not report R^2 but RMSE as a measure of fit; our calculations nevertheless match those of HPY up to all reported decimal places whenever the coefficients do.

Both our full R results (including measures of fit and CD diagnostics) and our Stata replication of MG and CCEMG match perfectly with HPY, Tables 7 and 9. By contrast, two out of twelve of the augmented MG and CCEMG specifications in HPY, Table 10, are again coincident between ‘plm’ functions (`pmg` and `pcce`) and Stata’s `xtmg`, but generally different from HPY. The other ten do match perfectly, but for slight differences in the CD statistic. No Stata check is possible with respect to the CCEP estimator; but the successful replication of HPY, Tables 7 and 9 testifies the quality of the R code in ‘plm’.

All calculations cited below were checked to produce the same result both when using ‘plm’s built-in lagging and differencing infrastructure and with lags and differences made “by hand” in a spreadsheet before importing the transformed data in either R or Stata.

3. Computational details

All calculations were originally performed in R 3.0.2 (R Core Team 2013), in particular using packages `plm` 1.3-3 (Croissant and Millo 2008), `splm` 1.2-0 (Millo and Piras 2012) and `spdep` 0.5-68 (Bivand *et al.* 2012), on the following systems: Ubuntu Linux 13.10, Windows XP SP3, Windows 7. Results were identical across platforms. Tables have been automatically typeset in L^AT_EX by the `xtable` package (Dahl 2013). A plain text version of the dataset and the full replication script are available in the accompanying materials to this Appendix. This

³Transformed data and R procedures for replicating this check are available upon request.

Appendix has been produced as a dynamic document through the Sweave utility for literate programming (Leisch 2002); the replication script has been extracted automatically by the `Stangle()` function.

References

- Anselin L (1988). *Spatial econometrics: methods and models*, volume 4. Springer.
- Bivand R, with contributions by Micah Altman, Anselin L, Assunção R, Berke O, Bernat A, Blanchet G, Blankmeyer E, Carvalho M, Christensen B, Chun Y, Dormann C, Dray S, Halbersma R, Krainski E, Legendre P, Lewin-Koh N, Li H, Ma J, Millo G, Mueller W, Ono H, Peres-Neto P, Piras G, Reder M, Tiefelsdorf M, Yu D (2012). *spdep: Spatial dependence: weighting schemes, statistics and models*. R package version 0.5-46, URL <http://CRAN.R-project.org/package=spdep>.
- Croissant Y, Millo G (2008). “Panel data econometrics in R: The plm package.” *Journal of Statistical Software*, **27**(2), 1–43.
- Dahl DB (2013). *xtable: Export tables to LaTeX or HTML*. R package version 1.7-1, URL <http://CRAN.R-project.org/package=xtable>.
- Doornik JA (2009). *An Object-Oriented Matrix Programming Language Ox 6*.
- Eberhardt M (2011). “XTCD: Stata module to investigate Variable/Residual Cross-Section Dependence.” *Statistical Software Components*.
- Eberhardt M (2012). “Estimating panel time-series models with heterogeneous slopes.” *Stata Journal*, **12**(1), 61–71.
- Holly S, Pesaran MH, Yamagata T (2010). “A spatio-temporal model of house prices in the USA.” *Journal of Econometrics*, **158**(1), 160–173.
- Leisch F (2002). “Sweave: Dynamic generation of statistical reports using literate data analysis.” In *Compstat*, pp. 575–580. Springer.
- Lewandowski P (2007). “PESCADF: Stata module to perform Pesaran’s CADF panel unit root test in presence of cross section dependence.” *Statistical Software Components*.
- Millo G, Piras G (2012). “splm: Spatial Panel Data Models in R.” *Journal of Statistical Software*, **47**(1), 1–38.
- Peng RD (2011). “Reproducible research in computational science.” *Science (New York, Ny)*, **334**(6060), 1226–1227.
- Pesaran MH (2006). “Estimation and inference in large heterogeneous panels with a multi-factor error structure.” *Econometrica*, **74**(4), 967–1012.
- R Core Team (2013). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.

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