TI 2013-165/VIII
Tinbergen Institute Discussion Paper

Do Income Disparities dissipate across the US States? Experimenting with a Vector Error Correction Model

Stilianos Alexiadis[a]
Konstantinos Eleftheriou[b]
Peter Nijkamp[c]

a Ministry of Rural Development & Foods, Greece;
b Abu Dhabi University, United Arab Emirates;
c Faculty of Economics and Business Administration, VU University Amsterdam, and Tinbergen Institute, The Netherlands.

Do income disparities dissipate across the US States? Experimenting with a Vector Error Correction Model*

Stilianos Alexiadis [a]

[a] Ministry of Rural Development & Foods

Department of Agricultural Policy & Documentation

Greece

Konstantinos Eleftheriou [b]

[b] College of Business Administration,

Abu Dhabi University United Arab Emirates

Peter Nijkamp [c]

[c] VU University Amsterdam
Department of Spatial Economics
Tinbergen Institute
The Netherlands

Abstract

This paper examines the long-run trends in per-capita income across the US states (1929-2005). Our analysis advocates and implements a Vector Error Correction Model (VECM), in order to investigate whether disparities in per-capita income embody a stable long-run relation. The empirical application is supplemented with Factor Analysis to identify groups of States with a common behaviour in terms of per-capita income.

Key Words: Intraregional income disparities, Vector Error Correction Model, Factor Analysis

JEL Classification: C22, R10

1 Introduction

Spatial disparities have, in the past few decades, been a frequently studied topic in economics (see Aghion and Howitt, 1998; Le Gallo, 2004; Rey and Janikas, 2005; Ezcurra et al. 2007; Li and Haynes, 2010). A related strand of this literature is focused on regional employment/unemployment, using an Error Correction Model (ECM) (e.g. Gray, 2004; Hunt, 2006; Alexiadis and Eleftheriou, 2010). Fewer studies use a

* Corresponding author: Peter Nijkamp, Department of Spatial Economics, Free University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. E-mail: p.nijkamp@vu.nl. The findings, interpretations and conclusions are those entirely of the authors and do not necessarily represent the official position, policies or views of the Ministry of Rural Development and Foods and/or the Greek Government.

bivariate ECM to examine the long-run trends in per-capita *income disparities* (e.g. Alexiadis et al., 2013). This can be attributed to the difficulty in defining a suitable proxy for steady-state equilibrium.

In the case of regional employment/unemployment such definition is simple and straightforward, namely using employment/unemployment at the national level (e.g. Martin, 1997; Keil, 1997; Gray, 2005). Such a definition is, however, not so clear when income disparities are the main focus of interest. Notwithstanding that per-capita income at national level (average per-capita income) seems to be a good candidate, nevertheless such a proxy does not always reflect the implied social preferences.

From an econometric point of view, bivariate models may result to a potential loss of information and problems of endogeneity, causing a simultaneity bias in the coefficients. A multivariate cointegration model, however, tackles with such issues in a more effective way and is implemented here. In that sense, this paper fills an important gap since, to the best of our knowledge, this model has so far not received due attention in examining income disparities across the US states.

The rest of this paper is structured in four sections. Section 2 sets the appropriate framework within which the empirical analysis will be conducted, namely a Vector Error Correction Model (VECM). The econometric application takes place in Section 3, together with a detailed presentation of the obtained results. A fourth section concludes the paper, and suggests avenues for future research.

2 The Empirical Framework

Examining the trends in the evolution of a given variable can be said to be equivalent to test for stationarity. Non-stationary series can become stationary by differencing them up to the point where the conditions for stationarity hold.[1] In most cases, economic time series have been found to be integrated of order one, i.e. $I(1)$, determined through the Augmented Dickey Fuller (ADF) and the Phillips Perron (PP) tests. Although several time series can be characterized as non-stationary, it is possible that certain combinations among these series exhibit common behaviour over time. Stated in alternative terms, a (linear) combination of non-stationary series might be integrated of a lower order than the individual series themselves; *cointegration*.[2]

In order to test for cointegrating relations across the US States, we use the maximum likelihood methodology proposed by Johansen (1988). According to Johansen a Vector Autoregression (VAR) model of order p can be written as follows:

$$\Delta y_t = \Pi y_{t-1} + \sum_{\rho=1}^{p-1} \Gamma_\rho \Delta y_{t-\rho} + \varepsilon_t \tag{1}$$

[1] Constant mean and variance over time, and the (auto) covariances between two different points in time depend only on the absolute difference between them. If one of the above conditions does not hold, then the time series in question is non-stationary.

[2] A process described initially by Engle and Granger (1987).

In equation (1) y_t is a set of k given time series variables (in our case, k, is the number of the States in each Bureau of Economic Analysis region), Γ_ρ are short run parameter matrices and Δ is the first difference operator. As a technical note, under cointegration, the matrix Π can be written as $\Pi = \alpha\beta'$, where α and β are $k \times r$ matrices each with rank r, with β being the matrix of the r cointegrating vectors (i.e. the columns of β represent the r cointegrating relations) and α being the matrix of adjustment coefficients (α represents the short-run speed of adjustment to the long-run equilibrium relationship). Finally, ε_t is a vector of independent Gaussian errors with zero mean and time invariant positive definite covariance matrix.

As already mentioned, β collects the cointegrating vectors of the system. Seen in this light, $\beta' y_t \sim I(0)$ depicts long-run equilibrium relationships[3]. Equation (1) is the VECM, which constitutes the cornerstone of the empirical analysis in the subsequent section.[4]

3 Income Disparities across the US States

The exercise covers the period 1929-2005. We employ state-level per capita (personal) income data obtained from the Bureau of Economic Analysis (BEA) for the 49 contiguous states.[5] This data set enables the relative movements in per-capita income to be examined across the geographical units of the US in some detail.

In order to illustrate the income dynamics across the US state, equation (1) is applied. However, before doing so, it is important to test the underlying series for stationarity. According to the ADF and PP tests,[6] all the States are $I(1)$ for 1% level of significance, with the exception of Idaho, where only the ADF test does not reject the hypothesis of the first difference non-stationarity.

Applying the VECM for the States in three BEA regions (South East, Mideast and New England) indicates absence of a cointegrating relation. Consequently, we may argue that there is no long-run steady-state equilibrium relation between the States in the East Coast. It seems that income disparities do not dissipate in these States and each moves towards its own steady-state equilibrium. This is the outcome of a range of factors. Predominant among these are the high initial income differences among those States, the existing industrial structure, agglomerations in certain States (e.g. New York, District of Columbia, etc).

Attention, therefore, is turned to the States in the remaining BEA regions. The results for the region of Far West are set out in Table 1.

---

[3] For a more detailed analysis of the VECM, see Lütkepohl (2007).

[4] In empirical studies across the BEA Regions of the US it is not uncommon to introduce structural breaks. While the absence of them might constitute a criticism of our approach, nevertheless, the primary question to be tackled is intraregional (amongst the States within a broad region) and not interregional income disparities, as in previous studies.

[5] Owing to the lack of data, Alaska and Hawaii had to be omitted, since the datasets for these States begin at 1950.

[6] The relevant results are available upon request.

Table 1: Far West Region (VECM(6) of rank 2)

	$\hat{\alpha}$			
	CR1		*CR2*	
$\Delta California_t$	0.02**	(0.01)	-0.31*	(0.18)
$\Delta Nevada_t$	0.02***	(0.01)	-0.82***	(0.19)
$\Delta Oregon_t$	-0.02***	(0.00)	0.45***	(0.11)
$\Delta Washington_t$	-0.01***	(0.00)	0.28**	(0.11)
Cointegrating Relations (*CR*)				
CR1	$California + \underset{(7.23)}{42.42}^{***} Washington - \underset{(1.33)}{10.75}^{***}$			
CR2	$Nevada - \underset{(0.14)}{0.60}^{***} Oregon + \underset{(0.27)}{1.44}^{***} Washington + \underset{(0.05)}{0.04}$			
	Diagnostic Tests			
	Value of test statistic		*P*-value	
JB Test				
$\Delta California_t$	1.71		0.42	
$\Delta Nevada_t$	0.26		0.88	
$\Delta Oregon_t$	0.11		0.95	
$\Delta Washington_t$	2.62		0.27	
LM_1 / LM_2 test	24.14 / 24.60		0.09 / 0.08	
	# of unit moduli			
Stability test for VECM	2			

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Standard errors are in parenthesis. The lag order for the VECM is determined using a range of Information criteria. More specifically, we choose the lag order indicated by the majority of these criteria. The rank of the VECM is specified by the Johansen test at the 1% level of significance (1% is chosen instead of the 5% because this test exhibits low power). *JB* denotes the Jarque-Bera normality test of VECM residuals (with the null hypothesis that the residuals follow a normal distribution or equivalently the joint hypothesis that skewness and excess kurtosis are zero). LM_1 / LM_2 is the Lagrange multiplier test for first and second order serial correlation (with the null hypothesis that there is no serial correlation in the residuals up to the specified order). The stability test checks the stationarity of the cointegrating relations and that their number (the cointegrating rank of the VECM) is correctly specified. VECM is stable if the number of unit moduli is equal to #of endogenous variables - #of cointegrating vectors (i.e., all roots are inside the unit cycle). Constraints are imposed in the non-significant coefficients of the cointegrated equations. The validity of these constraints is tested using a Likelihood-ratio (LR) test for over-identifying restriction (with the null hypothesis that the restrictions are valid). All the results are available upon request.

Assuming that the error term in the first cointegrating relation (hereafter CR) is positive, then per capita income in the State of California is above its long-run equilibrium level and, so, it should be decreased. It is expected, therefore, that the associated adjustment coefficient should be negative. The estimation process, however, yields a positive value (0.02) and, consequently, no economic inference can be made. A similar difficulty is associated with the second adjustment coefficient for California (-0.31). The argument runs as follows. Since California does not appear in the second CR an attempt is made to relate the first CR (which includes the State of California) with the second CR by examining the dynamic interrelations between the States. Hence, a State that appears in both CRs is chosen, namely Washington. From the second CR, if the error term is positive, then per capita income in Washington is above its equilibrium value and therefore should be decreased. If this is so, however, then according to the first CR, the error term will become negative and the adjustment coefficient for the second CR in the case of California should be positive. The estimation process, nevertheless, yields a negative value.

Applying a similar reasoning, adjustment coefficients with economic meaning in the region of Far West can be detected for the States of Nevada (-0.82), Oregon (-

0.02) and Washington (-0.01). It might be argued, therefore, that per capita income in the State of Nevada is in a long run equilibrium relationship with per capita income in the States of Oregon and Washington. Moreover, short run income disparities between the States of Nevada and Oregon and Washington dissipate at a rate of 82 per cent annually. By the same token, the adjustment rate for Oregon with the States of Nevada and Washington is 2 per cent while per capita income in Washington moves towards its steady-state equilibrium, approximated by per capita income in the States of Nevada and Oregon, at an annual rate of 1 per cent. The process described above for the region of Far West is illustrated in Figure 1.

Figure 1. Adjustment Process, Far West

A similar process is followed for the region of Great Lakes (Table 2) in which the rate of adjustment for Indiana to its equilibrium relation with Wisconsin is 79 per cent, while the corresponding rate for Wisconsin to Illinois is 2 per cent. The aforementioned relation for the States of Indiana and Wisconsin is clearly indicated in Figure 2. On the other hand, this relation is not so evident for both Wisconsin and Illinois; a situation (possibly) attributable to the relatively low rate of adjustment between these two States. The adjustment coefficients for the rest of the States in Great Lakes are rejected due to problems with the diagnostic tests (e.g. for Michigan and Ohio the residuals are not normally distributed in the corresponding VECM equation) or due to a wrong sign in the estimated adjustment coefficient (Illinois).

Estimations for Utah, Idaho and Colorado yield statistically insignificant adjustment coefficients (Table 3). Moreover, the corresponding VECM equation for Montana has a problem with the normality of residuals. Only Wyoming adjusts to its steady state equilibrium relationship with Utah and Colorado at a rate of 40 per cent per year. The relation between these States is depicted in Figure 3.

Table 2: Great Lakes (VECM(8) of rank 4)

	$\hat{\alpha}$							
	CR1		*CR2*		*CR3*		*CR4*	
$\Delta Illinois_t$	-0.00	(0.02)	1.31***	(0.47)	-1.40	(0.91)	0.92*	(0.54)
$\Delta Indiana_t$	-0.01	(0.01)	-0.79***	(0.19)	0.30	(0.37)	-0.42*	(0.22)
$\Delta Michigan_t$	-0.01	(0.01)	0.22	(0.27)	-1.33**	(0.54)	-0.56*	(0.32)
$\Delta Ohio_t$	-0.00	(0.01)	-0.26	(0.17)	-0.00	(0.33)	-0.55***	(0.19)
$\Delta Wisconsin_t$	-0.02***	(0.01)	-0.20	(0.20)	0.62	(0.40)	-0.81***	(0.23)

Cointegrating Relations (*CR*)

CR1 $\quad Illinois + \underset{(2.30)}{30.58}^{***} Wisconsin - \underset{(0.48)}{13.66}^{***}$

CR2 $\quad Indiana - \underset{(0.06)}{0.38}^{***} Wisconsin - \underset{(0.01)}{0.13}^{***}$

CR3 $\quad Michigan + \underset{(0.05)}{0.10}^{**} Wisconsin - \underset{(0.01)}{0.10}^{***}$

CR4 $\quad Ohio - \underset{(0.06)}{0.03} Wisconsin - \underset{(0.01)}{0.12}^{***}$

Diagnostic Tests

	Value of test statistic	*P*-value
JB Test		
$\Delta Illinois_t$	2.70	0.26
$\Delta Indiana_t$	1.38	0.50
$\Delta Michigan_t$	8.27	0.02
$\Delta Ohio_t$	8.44	0.01
$\Delta Wisconsin_t$	0.47	0.79
LM_1 / LM_2 test	27.35 / 22.85	0.34 / 0.59
	# of unit moduli	
Stability test for VECM	1	

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Standard errors are in parenthesis. The lag order for the VECM is determined using a range of Information criteria. More specifically, we choose the lag order indicated by the majority of these criteria. The rank of the VECM is specified by the Johansen test at the 1% level of significance (1% is chosen instead of the 5% because this test exhibits low power). *JB* denotes the Jarque-Bera normality test of VECM residuals (with the null hypothesis that the residuals follow a normal distribution or equivalently the joint hypothesis that skewness and excess kurtosis are zero). LM_1 / LM_2 is the Lagrange multiplier test for first and second order serial correlation (with the null hypothesis that there is no serial correlation in the residuals up to the specified order). The stability test checks the stationarity of the cointegrating relations and that their number (the cointegrating rank of the VECM) is correctly specified. VECM is stable if the number of unit moduli is equal to #of endogenous variables - #of cointegrating vectors (i.e., all roots are inside the unit cycle). Constraints are imposed in the non-significant coefficients of the cointegrated equations. The validity of these constraints is tested using a Likelihood-ratio (LR) test for over-identifying restriction (with the null hypothesis that the restrictions are valid). All the results are available upon request.

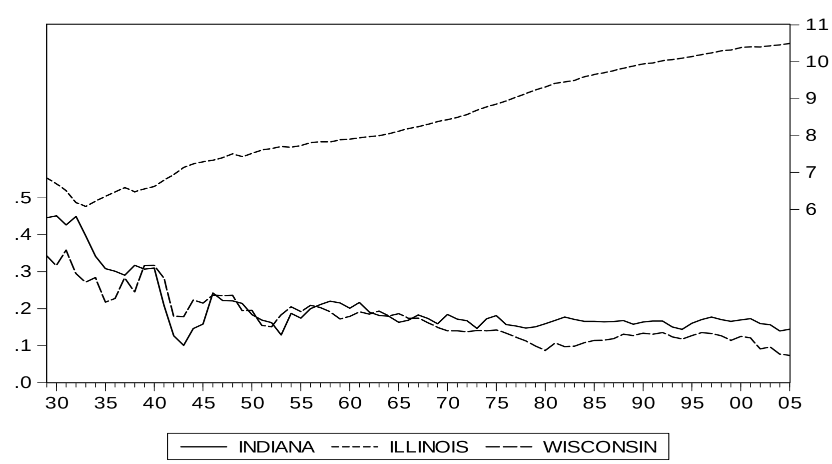

Figure 2. Adjustment Process, Great Lakes

Table 3: Rocky Mountains (VECM(6) of rank 3)

	$\hat{\alpha}$					
	CR1		*CR2*		*CR3*	
$\Delta Wyoming_t$	-0.01	(0.01)	-0.40*	(0.24)	0.53**	(0.24)
$\Delta Idaho_t$	0.00	(0.01)	-0.40	(0.27)	0.30	(0.27)
$\Delta Montana_t$	0.03***	(0.01)	0.10	(0.21)	-0.34	(0.21)
$\Delta Utah_t$	0.00	(0.01)	-0.17	(0.20)	0.24	(0.21)
$\Delta Colorado_t$	-0.01	(0.01)	0.25	(0.19)	-0.06	(0.19)

Cointegrating Relations (*CR*)

CR1	$Wyoming - \underset{(4.91)}{31.13}^{***} Utah + \underset{(2.44)}{12.24}^{***} Colorado - \underset{(0.93)}{3.45}^{***}$
CR2	$Idaho - \underset{(0.47)}{2.72}^{***} Utah - \underset{(0.23)}{0.57}^{**} Colorado + \underset{(0.09)}{0.16}^{*}$
CR3	$Montana - \underset{(0.54)}{3.00}^{***} Utah + \underset{(0.27)}{0.17} \quad Colorado + \underset{(0.10)}{0.32}^{***}$

Diagnostic Tests

	Value of test statistic	*P*-value
JB Test		
$\Delta Wyoming_t$	0.41	0.82
$\Delta Idaho_t$	8.92	0.01
$\Delta Montana_t$	10.34	0.01
$\Delta Utah_t$	2.54	0.28
$\Delta Colorado_t$	0.13	0.94
LM_1 / LM_2 test	31.59 / 24.00	0.17 / 0.52
	# of unit moduli	
Stability test for VECM	2	

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Standard errors are in parenthesis. The lag order for the VECM is determined using a range of Information criteria. More specifically, we choose the lag order indicated by the majority of these criteria. The rank of the VECM is specified by the Johansen test at the 1% level of significance (1% is chosen instead of the 5% because this test exhibits low power). *JB* denotes the Jarque-Bera normality test of VECM residuals (with the null hypothesis that the residuals follow a normal distribution or equivalently the joint hypothesis that skewness and excess kurtosis are zero). LM_1 / LM_2 is the Lagrange multiplier test for first and second order serial correlation (with the null hypothesis that there is no serial correlation in the residuals up to the specified order). The stability test checks the stationarity of the cointegrating relations and that their number (the cointegrating rank of the VECM) is correctly specified. VECM is stable if the number of unit moduli is equal to #of endogenous variables - #of cointegrating vectors (i.e., all roots are inside the unit cycle). Constraints are imposed in the non-significant coefficients of the cointegrated equations. The validity of these constraints is tested using a Likelihood-ratio (LR) test for over-identifying restriction (with the null hypothesis that the restrictions are valid). All the results are available upon request.

As shown in Table 4 in the South West region only Texas appears to have a valid adjustment coefficient. According to the results, per capita income in Texas moves towards its steady state equilibrium with per capita income in the States of Arizona and New Mexico (Figure 4), at an adjustment rate 2 per cent per annum. The VECM equations for Oklahoma and Arizona indicate problems with the normality of residuals while the adjustment coefficient for New Mexico does not have the correct sign.

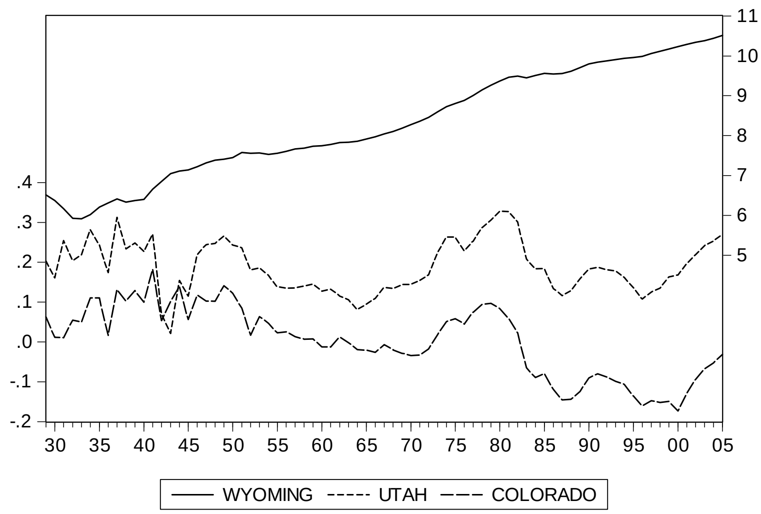

Figure 3. Adjustment Process, Rocky Mountains

Table 4: South West (VECM(2) of rank 1)

	$\hat{\alpha}$	
	CR1	
$\Delta Arizona_t$	-0.02** (0.01)	
ΔNew_Mexico_t	-0.01*** (0.00)	
$\Delta Oklahoma_t$	-0.02*** (0.01)	
$\Delta Texas_t$	-0.02*** (0.00)	
Cointegrating Relations (*CR*)		
CR1	$Arizona - \underset{(2.93)}{6.76}^{**} New\_Mexico + \underset{(3.09)}{24.27}^{***} Texas - \underset{(0.46)}{7.64}^{***}$	
Diagnostic Tests		
	Value of test statistic	*P*-value
JB Test		
$\Delta Arizona_t$	80.56	0.00
ΔNew_Mexico_t	4.21	0.12
$\Delta Oklahoma_t$	13.14	0.00
$\Delta Texas_t$	1.26	0.53
LM_1 / LM_2 test	16.63 / 23.78	0.41 / 0.09
	# of unit moduli	
Stability test for VECM	3	

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Standard errors are in parenthesis. The lag order for the VECM is determined using a range of Information criteria. More specifically, we choose the lag order indicated by the majority of these criteria. The rank of the VECM is specified by the Johansen test at the 1% level of significance (1% is chosen instead of the 5% because this test exhibits low power). *JB* denotes the Jarque-Bera normality test of VECM residuals (with the null hypothesis that the residuals follow a normal distribution or equivalently the joint hypothesis that skewness and excess kurtosis are zero). LM_1 / LM_2 is the Lagrange multiplier test for first and second order serial correlation (with the null hypothesis that there is no serial correlation in the residuals up to the specified order). The stability test checks the stationarity of the cointegrating relations and that their number (the cointegrating rank of the VECM) is correctly specified. VECM is stable if the number of unit moduli is equal to #of endogenous variables - #of cointegrating vectors (i.e., all roots are inside the unit cycle). Constraints are imposed in the non-significant coefficients of the cointegrated equations. The validity of these constraints is tested using a Likelihood-ratio (LR) test for over-identifying restriction (with the null hypothesis that the restrictions are valid). All the results are available upon request.

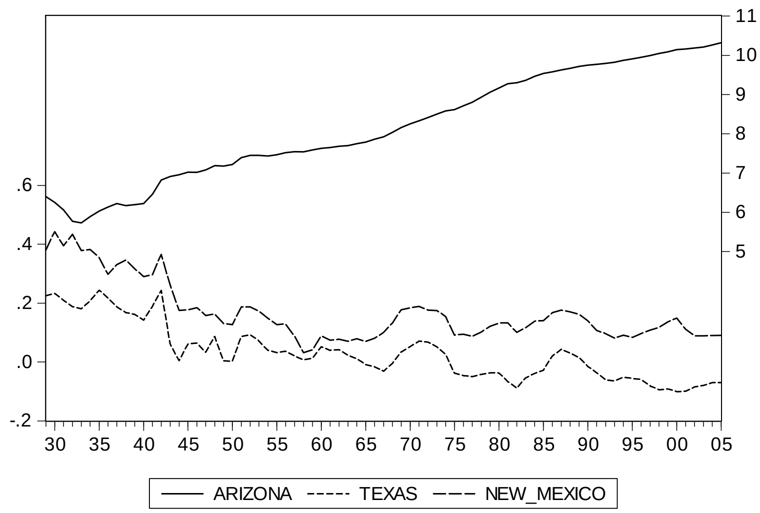

Figure 4. Adjustment Process, South West

In the region of Plaines, a speed of adjustment of 75 per cent is estimated for the State of Kansas, which is in relation with the States of Nebraska, South Dakota and North Dakota (Figure 5). According to the results in Table 5, the States of Minnesota, Iowa, Nebraska and South Dakota have non-significant coefficients. The value of the valid coefficients for the States of North Dakota and Missouri exceeds one; an outcome difficult to interpret in the present context.

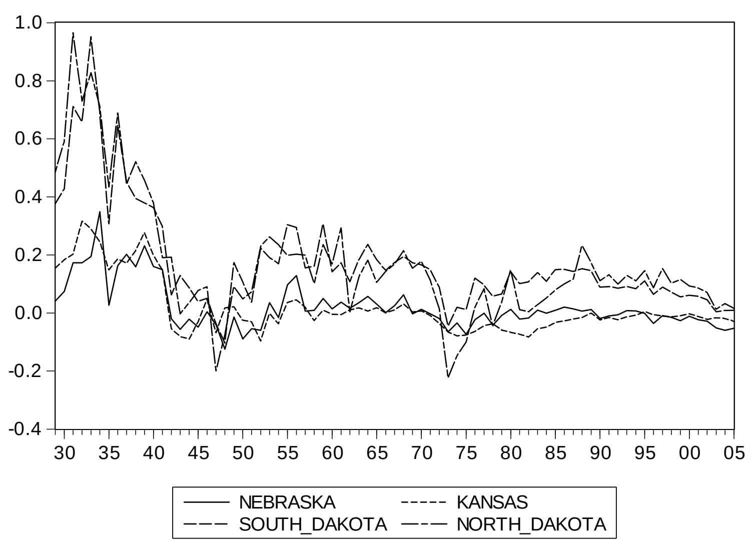

Figure 5. Adjustment Process, Plaines

Table 5: Plaines (VECM(6) of rank 4)

	$\hat{\alpha}$							
	CR1		*CR2*		*CR3*		*CR4*	
$\Delta Missouri_t$	0.05***	(0.02)	1.50***	(0.37)	0.77***	(0.26)	-0.26	(0.27)
$\Delta Kansas_t$	-0.02	(0.02)	-0.75*	(0.43)	-0.34	(0.31)	0.67**	(0.32)
$\Delta Minnesota_t$	-0.01	(0.02)	-0.22	(0.33)	-0.14	(0.24)	0.09	(0.25)
$\Delta Iowa_t$	0.03	(0.03)	-0.06	(0.61)	0.41	(0.44)	-0.47	(0.45)
$\Delta Nebraska_t$	0.03	(0.02)	-0.31	(0.45)	0.38	(0.32)	-0.03	(0.34)
$\Delta North\_Dakota_t$	-0.01	(0.06)	0.35	(1.24)	-0.02	(0.88)	1.68*	(0.92)

Cointegrating Relations (*CR*)

CR1	$Missouri + \underset{(42.90)}{100.31}^{**}\ Nebraska + \underset{(13.72)}{18.88}\ North\_Dakota - \underset{(21.07)}{31.85}\ South\_Dakota - \underset{(2.95)}{10.21}^{***}$
CR2	$Kansas + \underset{(0.36)}{1.47}^{***}\ Nebraska - \underset{(0.12)}{0.35}^{***}\ North\_Dakota - \underset{(0.18)}{0.58}^{***}\ South\_Dakota + \underset{(0.03)}{0.12}^{***}$
CR3	$Minnesota - \underset{(3.30)}{10.80}^{***}\ Nebraska - \underset{(1.06)}{1.72}\ North\_Dakota + \underset{(1.62)}{4.37}^{***}\ South\_Dakota - \underset{(0.23)}{0.02}$
CR4	$Iowa - \underset{(0.35)}{1.58}^{***}\ Nebraska - \underset{(0.11)}{0.62}^{***}\ North\_Dakota + \underset{(0.17)}{1.08}^{***}\ South\_Dakota - \underset{(0.02)}{0.06}^{**}$

Diagnostic Tests

	Value of test statistic	*P*-value
JB Test		
$\Delta Missouri_t$	2.03	0.26
$\Delta Kansas_t$	0.32	0.85
$\Delta Minnesota_t$	1.45	0.48
$\Delta Iowa_t$	0.40	0.82
$\Delta Nebraska_t$	0.48	0.79
$\Delta North\_Dakota_t$	1.14	0.56
LM_1 / LM_2 test	43.60 / 49.94	0.69 / 0.44
	# of unit moduli	
Stability test for VECM	3	

Notes: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Standard errors are in parenthesis. The lag order for the VECM is determined using a range of Information criteria. More specifically, we choose the lag order indicated by the majority of these criteria. The rank of the VECM is specified by the Johansen test at the 1% level of significance (1% is chosen instead of the 5% because this test exhibits low power). *JB* denotes the Jarque-Bera normality test of VECM residuals (with the null hypothesis that the residuals follow a normal distribution or equivalently the joint hypothesis that skewness and excess kurtosis are zero). LM_1 / LM_2 is the Lagrange multiplier test for first and second order serial correlation (with the null hypothesis that there is no serial correlation in the residuals up to the specified order). The stability test checks the stationarity of the cointegrating relations and that their number (the cointegrating rank of the VECM) is correctly specified. VECM is stable if the number of unit moduli is equal to #of endogenous variables - #of cointegrating vectors (i.e., all roots are inside the unit cycle). Constraints are imposed in the non-significant coefficients of the cointegrated equations. The validity of these constraints is tested using a Likelihood-ratio (LR) test for over-identifying restriction (with the null hypothesis that the restrictions are valid). All the results are available upon request.

Further support to the process of adjustment described by the VECM is provided by Factor Analysis. The relevant results are set out in Table 6.

A striking fact from Table 6 is that the Highest Income State in each region (HISR) (i.e. California, Illinois, District of Columbia, Connecticut, Missouri, Wyoming, Florida and Arizona) has, in most of the cases, a negative factor loading. Finally, we run a 'national' VECM where all the HISRs[7] are included. The results indicate that no cointegrating relation is evident between those States.

[7] For a more general treatment of the dynamic patterns between US states and HISRs see Alexiadis et al. (2013).

Table 6: Factor analysis for the States in each BEA region

	Factor 1	Factor 2
Far West		
California	*-0.65*	
Nevada	0.24	
Oregon	**0.97**	
Washington	**0.97**	
Great Lakes		
Illinois	*-0.97*	
Indiana	**0.54**	
Michigan	-0.02	
Ohio	-0.04	
Wisconsin	**0.88**	
Mideast		
District of Columbia	0.04	0.03
Delaware	0.20	**0.36**
Maryland	0.20	0.29
New Jersey	**0.48**	0.11
New York	**0.98**	0.01
Pennsylvania	**0.45**	0.28
New England		
Connecticut	-0.08	**0.85**
Maine	**0.90**	0.16
Massachusetts	-0.01	0.12
New Hampshire	**0.41**	*-0.44*
Vermont	**0.79**	-0.21
Rhode Island	0.03	**0.94**
Plaines		
Missouri	-0.08	
Kansas	**0.84**	
Minnesota	-0.01	
Iowa	**0.93**	
Nebraska	**0.83**	
North Dakota	**0.94**	
South Dakota	**0.89**	
Rocky Mountains		
Wyoming	**0.90**	0.03
Idaho	*-0.30*	**0.71**
Montana	**0.46**	**0.68**
Utah	-0.08	**0.57**
Colorado	*-0.80*	0.09
Southeast		
Florida	-0.12	
Arkansas	**0.77**	
Alabama	**0.83**	
Georgia	**0.83**	
Kentucky	**0.49**	
Louisiana	0.12	
Mississippi	**0.89**	
North Carolina	**1.06**	
South Carolina	**0.94**	
Tennessee	**0.92**	
Virginia	0.01	
West Virginia	-0.03	
Southwest		
Arizona	*-0.81*	
New Mexico	**0.93**	
Oklahoma	**0.97**	
Texas	**0.96**	

Notes: Oblique rotation with Oblimin was used for the rotation of the factors. We keep only the factors with eigenvalues greater than 1 or those explaining 80% of the total variation. Factor loadings ≥ 0.3 are in bold. Factor loadings ≤ - 0.3 are in italics.

The geographical pattern of the group identified by the VECM is depicted in Figure 6[8].

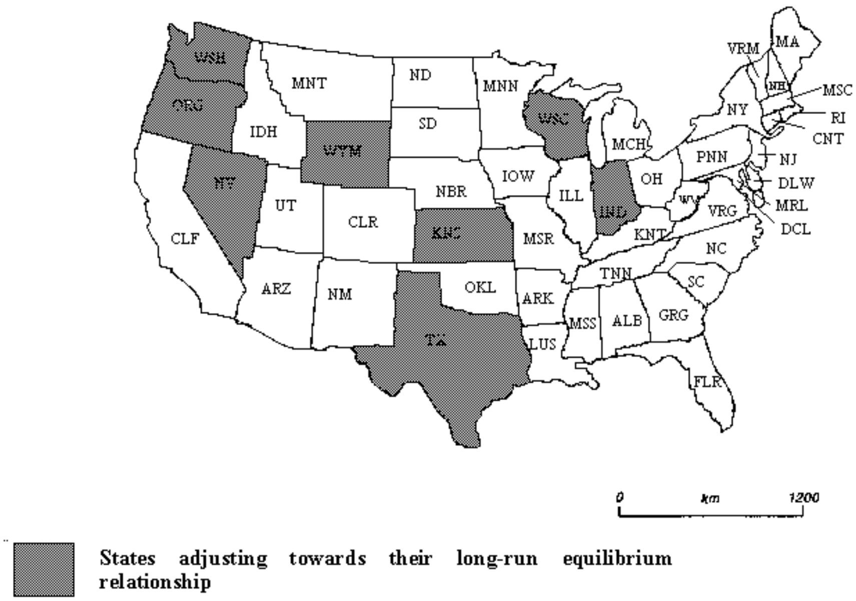

Figure 6. Adjusting States

At a glance, it can be stated that in the majority of the US states either short-run income disparities do not dissipate towards steady state equilibrium relations or a long-run equilibrium relation does not exist at all. A kind of ‘clustering’ of adjusting States for three States located in the north-west part of the country (Washington, Oregon and Nevada) is evident from Figure 6. This implies that the impact of spatial dependence *does* shape the path of income disparities to some degree..

4 Concluding remarks

The evolution or dynamics of regional income disparities is one of the foremost topics in economic research. Different empirical studies using various econometric techniques in diverse contexts were conducted. For the US States and Regions, in particular, this issue has generated a vast literature, and continues to do so. Our paper provides new evidence by using a VECM, and extending its applicability.

One conclusion to emerge from this study is that it makes little sense to concentrate upon the simple question concerning whether income differences are reduced or not. The appropriate question would rather be to ask: ‘Do different steady-state equilibria relationships exist across regions?’ Following the econometric estimations, reported in Section 3, the long-run behaviour varies across the US States.

[8] See the Appendix for the abbreviations used in Figure 6.

This comes as a natural outcome of the VECM proposed in this paper. The empirical applications of such models, however, raise as many questions as they answer. The evidence that is put forward should, however, be seen as indicative at best, and the analysis should be replicated as additional data become available, in order to check whether the conclusions that we have reached can be confirmed. Furthermore, income disparities are affected by a wide range of factors, including cost of living, labour force migration, industrial base, natural resources, etc. It is a challenge, however, to introduce such factors in our framework. Nevertheless, this goes beyond the aims and scope of this paper and constitutes an item in our future research agenda. What is then the purpose of such a paper? Perhaps our main intention is to provoke further interest in the applicability of models based on the structure of error-correction mechanisms in examining the morphology of income disparities across spatial units.

References

Aghion, P., and P. Howitt. 1998. *Endogenous Growth Theory*, MIT Press: Cambridge, MA.

Alexiadis, S., Eleftheriou, K. and Nijkamp, P. (2013) 'Intraregional income convergence: Cross section and time series evidence from the USA', in Kourtit, K., Nijkamp, P. and Stimson, R. (eds.), *Applied Regional Growth and Innovation Models*, Berlin: Springer-Verlag, pp. 217-240

Alexiadis, S. and K. Eleftheriou. 2010. A note on the morphology of regional unemployment in Greece. *Economics Bulletin* 30 (4): 2779-2786.

Engle R. and C. Granger. 1987. Co-integration and error-correction: Representation, estimation and testing. *Econometrica* 55: 251-276.

Ezcurra, R, P. Pascual and M. Rapún. 2007. Spatial inequality in productivity in the European Union: Sectoral and regional factors. *International Regional Science Review* 30 (4): pp. 384-407.

Gray, D. 2004. Persistent regional unemployment differentials revisited. *Regional Studies* 38: 167-176.

Gray, D. 2005. An examination of regional interaction and super-regions in Britain: An error-correction model approach. *Regional Studies* 39: 619-632.

Hunt, G. 2006. Population-employment models: Stationarity, co-integration, and dynamic adjustment. *Journal of Regional Science* 46 (2): 205-244.

Johansen S. (1988) Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12: 231–254.

Keil, S. 1997. Regional trends in British manufacturing employment: Tests for stationarity and co-integration, 1952-1989. *Regional Studies* 31: 13-24.

Le Gallo, J. 2004. Space-time analysis of GDP disparities among European regions: A Markov chains approach. *International Regional Science Review* 27 (2): 138-163.

Li, H. and K. Haynes. 2010. Economic structure and regional disparity in China: Beyond the Kuznets transition. *International Regional Science Review* 34 (2): 157-190.

Lütkepohl H. (2007) *New introduction to multiple time series analysis*. Springer, Berlin.

Martin, R. 1997. Regional unemployment disparities and their dynamics. *Regional Studies* 31: 237-252.

Rey, S. and M. Janikas. 2005. Regional convergence, inequality and space. *Journal of Economic Geography* 5 (2): 155-176.

Appendix

The States used in the empirical analysis
Alabama (ALB)
Arizona (ARZ)
Arkansas (ARK)
California (CLF)
Colorado (CLR)
Connecticut (CNT)
Delaware (DLW)
District-of-Columbia (DCL)
Florida (FLR)
Georgia (GRG)
Idaho (IDH)
Illinois (ILL)
Indiana (IND)
Iowa (IOW)
Kansas (KNS)
Kentucky (KNT)
Louisiana (LUS)
Maine (MA)
Maryland (MRL)
Massachusetts (MSC)
Michigan (MCH)
Minnesota (MNN)
Mississippi (MSS)
Missouri (MSR)
Montana (MNT)
Nebraska (NBR)
Nevada (NV)
New Hampshire (NH)
New Jersey (NJ)
New Mexico (NM)
New York (NY)
North Carolina (NC)
North Dakota (ND)
Ohio (OH)
Oklahoma (OKL)
Oregon (ORG)
Pennsylvania (PNN)
Rhode Island (RI)
South Carolina (SC)
South Dakota (SD)
Tennessee (TNN)
Texas (TX)
Utah (UT)
Vermont (VRM)
Virginia (VRG)
Washington (WSH)
West Virginia (WV)
Wisconsin (WSC)
Wyoming (WYM)