Construction Economics and Building

Vol. 17, No. 3
September 2017

Citation: Ahmadi, N. and Shahandashti, M. 2017. Comparative empirical analysis of temporal relationships between construction investment and economic growth in the United States. *Construction Economics and Building,* 17:3, 85-108. http://dx.doi.org/10.5130/AJCEB.v17i3.5482

ISSN 2204-9029 | Published by UTS ePRESS | ajceb.epress.lib.uts.edu.au

VIEWPOINT

Comparative empirical analysis of temporal relationships between construction investment and economic growth in the United States

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DOI: http://dx.doi.org/10.5130/AJCEB.v17i3.5482
Article History: Received 08/04/2017; Revised 25/05/2017; Accepted 26/06/2017; Published 21/09/2017

Abstract

The majority of policymakers believe that investments in construction infrastructure would boost the economy of the United States (U.S.). They also assume that construction investment in infrastructure has similar impact on the economies of different U.S. states. In contrast, there have been studies showing the negative impact of construction activities on the economy. However, there has not been any research attempt to empirically test the temporal relationships between construction investment and economic growth in the U.S. states, to determine the longitudinal impact of construction investment on the economy of each state. The objective of this study is to investigate whether Construction Value Added (CVA) is the leading (or lagging) indicator of real Gross Domestic Product (real GDP) for every individual state of the U.S. using empirical time series tests. The results of Granger causality tests showed that CVA is a leading indicator of state real GDP in 18 states and the District of Columbia; real GDP is a leading indicator of CVA in 10 states and the District of Columbia. There is a bidirectional relationship between CVA and real GDP in 5 states and the District of Columbia. In 8 states and the District of Columbia, not only do CVA and real GDP have leading/lagging relationships, but they are also cointegrated. These results highlight the important role of the construction industry in these states. The results also show that leading (or lagging) lengths vary for different states. The results of the comparative empirical analysis reject the hypothesis that CVA is a leading indicator of real GDP in the states with the highest

DECLARATION OF CONFLICTING INTEREST The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. **FUNDING** The author(s) received no financial support for the research, authorship, and/or publication of this article.

shares of construction in the real GDP. The findings of this research contribute to the state of knowledge by quantifying the temporal relationships between construction investment and economic growth in the U.S. states. It is expected that the results help policymakers better understand the impact of construction investment on the economic growth in various U.S. states.

Keywords

Construction value added, economic growth, U.S. States, granger causality test, unit root test, GDP

Introduction

The value added by construction industry or Construction Value Added (CVA) is the contribution of the construction industry in the larger economy usually shown by Gross Domestic Product (GDP). CVA as a percentage of GDP in the United States (U.S.) declined from a high of 6.2% in 1997 to a low of 3.7% in 2011 and then rose to the still-low 3.9% in 2015. CVA as a percentage of GDP varies dramatically among the states. In 2015, it has ranged from a high of 7.6% for North Dakota to a low of 3.1% for New York. Share of CVA in GDP varies even more dramatically within a state over time. For example, in Nevada, it has decreased form a high of 10.6% in 2005 to a low of 5% in 2015, or in Montana this share ranges from a high of 7.4% in 2005 to a low of 5.8% in 2015. Surprisingly, Montana with a share of 5.8% is ranked the 3rd among the U.S. states, which shows the huge decrease of construction investment over the past decade. These variations raise the question whether these fluctuations lead (or lag) the overall economy of the states.

Many policymakers believe that investments in the infrastructure construction would boost the economy of the U.S. (Landers, 2014; Aschauer, 1989; Munnell, 1990). They also assume that construction investments have similar impacts on the state economies in the U.S. This assumption is the foundation of several policies, especially those that are promoting infrastructure investments in the U.S. However, this critical assumption has not been tested empirically and the temporal relationships between construction investments and economic growth have not been assessed at the state level in the U.S. The Construction Value added (CVA) and real Gross Domestic Product (GDP) quarterly time series data collected by the U.S. Bureau of Economic Analysis provide an opportunity to investigate this temporal relationship. The objective of this study is to investigate the lead-lag relationships between CVA and real GDP for every state of the U.S. using empirical time series tests. In the next section, a review of the literature is conducted. A statistical approach for evaluating the temporal links between CVA and real GDP in the U.S. states is provided under the research method section. The results of the statistical analyses are discussed in Empirical Results section. Finally, conclusions are presented in the last section.

Research background

Over the past few decades, several studies have assessed the relationship between construction and economic growth around the world. These studies could be classified into two major categories (Giang and Pheng, 2010). The first category indicates that construction investments have positive impact on economic growth (e.g., Landers, 2014; Markstein, 2016). The second category points out that construction investments might have negative impact on economic growth (e.g., Kocherlakota and Yi, 1996; Drewer, 1980).

Turin (1969) analyzed the role of the construction industry in economic growth in 87 countries with different levels of GDP. The results of that study showed a relatively high correlation between construction industry investments and overall economic conditions. They also realized that the share of value added by the construction industry falls somewhere between 5-8% for developed countries while it is between 3-5% for developing countries. Further studies during the following decades also pointed out the positive impact of construction investments on economic growth in developed countries, such as the U.S. (Aschauer, 1989; Munnell, 1990), Canada (Wylie, 1996), and Sweden (Berndt and Hansson, 1992). Wells (1986), Turin (1973), and Strassman (1970) showed that over the period of economic growth, the construction industry is required to grow at a higher rate than the whole economy. Ofori (1988) found that the construction industry plays a major role in the economy of Singapore. Kirmani (1988) introduced the construction industry as a powerful engine for economic growth. World Bank (1994) showed that infrastructure needs to grow fast enough to generate enough facilities for economic growth. The positive impact of construction investment on economic growth is not exclusive to North America and Europe. Infrastructure investment also led to economic growth in Asia and the Pacific region by improving the capacity and efficiency of the economy (United Nations, 1990). Easterly and Rebelo (1993) demonstrated a considerably positive correlation between transport and communication investments, and economic growth rate, using the historical time series data of 28 developed countries. Anaman, Kwabena and Osei-Amponsah (2007) discussed the importance of construction activities by demonstrating their role in utilizing local human and material resources that promote local employment.

Construction pushes demand for construction materials and equipment beyond the construction activity itself. Financial services (for financing projects and purchases of projects), transportation services for delivering materials to construction sites, and sales and leasing services are additional effects of construction on the economy that are not included in the contribution of the construction industry to GDP. Taking all these effects into account, a conservative estimate of additional effect of the construction industry on the economy would be around 2-3% (Markstein, 2016). Hosein and Lewis (2005) acknowledged this additional effect by indicating that "one of its most important economic features is that it creates the facilities that are necessary for the production and distribution of all other goods and services."

The construction industry's share in GDP has been recognized as an important factor for economic growth. For example, Edmonds (1979) suggested that for a steady economic growth in developing countries, the contribution of the construction industry to GDP needs to be 5%. Lopes, Ruddock and Ribeiro (2002) also showed that the economy would enter a steady growth while the share of value added by the construction industry to the GDP is 4-5 %.

In contrast to the studies indicating the positive impact of construction on economic growth, some studies have shown the negative impact of the construction industry on the economy. Drewer (1980) analyzed the data of the United Nations Economic Commission for Europe (ECE) region between 1970 and 1976 and concluded that more construction does not necessarily enhance the economic conditions. The author reported that the uncontrolled expansion of construction could have a negative impact on the economy. Kocherlakota and Yi (1996) suggested that infrastructure investments do not necessarily improve economic growth rate. Excessive supply of construction outputs even caused recessions in Southeast Asia in 1997, in Singapore in 1985, and in Trinidad and Tobago around the same time (Ganesan, 2000; Lewis, 1984). Thus, excessive growth of construction activity might negatively affect the macroeconomic stability by misallocation and waste of resources (Giang and Pheng, 2010). In fact, these scholars reported that production capacity should be accounted for, to avoid overestimating the positive impact of construction investment on economic growth.

The Granger causality test has been used in economics to analyze the temporal relationships between the variables. The Granger causality test is a statistical hypothesis test which determines whether the time series of a variable is useful to predict the time series of another variable (Granger 1969). Shahandashti and Ashuri (2012) implemented the Granger causality test to identify the leading indicators of Construction Cost Index (CCI). The Granger causality test is widely used to analyze the temporal relationship between the construction industry investments and macroeconomic growth. Anaman (2003) investigated the relationship between the GDP contributions of the construction industry and overall GDP in Brunei using Granger causality tests. Barot (2002) used Granger causality tests to study whether growth rate in investment impacted growth rates in total factor productivity for agriculture and financial institutions, real estate, and other businesses. Ofori (1988) studied the impact of construction in Singapore's economy and concluded that the construction sector played a major role in Singapore's economic development. Green (1997), based on Granger causality tests, showed that residential construction investment Granger-caused GDP; however non-residential construction investment does not Granger-cause GDP. Tse and Ganesan (1997) indicated that growth in the economy measured by GDP led to an increase in activity of the construction sector of Hong Kong from 1985 to 1995. Kirmani (1988) introduced the construction industry as a powerful engine for economic growth. Anaman, Kwabena and Osei-Amponsah (2007) analyzed the causal links between the growth of the construction industry and the growth of the macro-economy in Ghana using the Granger causality test.

The direction of the causality between the construction sector and GDP has also been analyzed. Tse and Ganesan (1997) showed that the causality ran from GDP to construction in the case of Hong Kong. Lean (2001) indicated a bi-directional causal relationship between construction and GDP in Singapore. Zheng and Liu (2004) also found a bi-directional causal relationship between construction and GDP in China and concluded that construction had short-term impacts on economic growth, while the economy had long-term impacts on the construction industry. Lewis (2009) showed that this relationship in Trinidad and Tobago changed over time depending on different circumstances.

Research method

The Bureau of Economic Analysis of the U.S. Department of Commerce has published both CVA and GDP for all the U.S. states since 2005 (BEA, 2016). CVA and GDP time series data for every individual state in the U.S. are collected and used in this study. A time series is a sequence of data, usually presented across equal time intervals. Since both CVA and GDP are time series data, statistical bivariate time series tests are used to assess temporal relationships between CVA and GDP at the state level. Statistical time series tests, are usually preceded by unit root tests, to examine the stationarity of the data. The Augmented Dickey-Fuller (ADF) test is used as a unit root test to examine the stationarity of the data. The Granger causality test is implemented to empirically analyze the temporal relationship between the CVA and GDP for all the U.S. states. The Cointegration test (Johansen 1988) is used to evaluate the long-run relationship between time series variables. If value added by construction at the state level is cointegrated with GDP at the same state, then there exists a long-run relationship between the time series of these two variables over time.

UNIT ROOT TEST

Unit root tests are normally used to identify the order of integration of the variables before the Granger causality test is implemented. The minimum number of times that a time series needs to be differenced to become stationary is the order of integration of the time series. The augmented Dickey-Fuller (ADF) test, proposed by Dickey and Fuller (1979) and extended by Said and Dickey (1984) was implemented to examine the stationarity of the variables:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + u_t \qquad (1)$$

Where t is the time index, Yt is the value of time series at time t, ΔYt denotes the lagged first differences (i.e., Yt – Yt-1). α is an intercept constant (a drift term), β is a coefficient on a time trend and γ is a coefficient to test whether we need to difference the data to make it stationary. P is the lag length of the test and determined when applying the test. The Akaike Information Criterion (AIC) is used to identify the lag lengths. It is an independent identically distributed residual term. The null hypothesis of the test is that the time series under study is not stationary ($\gamma = 0, \beta \neq 0$), and the alternative hypothesis is that the time series is stationary ($\gamma < 0, \beta \neq 0$).

GRANGER CAUSALITY TEST

The Granger causality test (Granger, 1969) is a statistical hypothesis test to determine whether the time series of a variable is useful to predict the time series of another variable. In other words, this test determines whether the time series of a variable leads the time series of another variable. The null hypothesis of this test is that the past P values of X are not helpful to predict Y (X does not Granger cause Y). P is the lag length of the Granger causality test, and the results of the test depend on the chosen lag lengths. Therefore, different lag lengths (1, 2, 3, 4, 5, 6, 7, 8, 9, 10 lag lengths) are used in this study. These lag lengths represent a 2.5-year horizon since the data are quarterly. The following bivariate autoregressive models are used to test whether the value added by construction Granger causes GDP at the state level and vice versa (GDP Granger causes CVA):

$$\Delta GDP_{(t)} = \sum_{i=1}^{p} \alpha_i \Delta GDP_{(t-i)} + \sum_{i=1}^{p} \beta_i \Delta CVA_{(t-i)} + u_{(t)} \qquad (2)$$

$$\Delta CVA_{(t)} = \sum_{i=1}^{p} \alpha_i \Delta CVA_{(t-i)} + \sum_{i=1}^{p} \beta_i \Delta GDPA_{(t-i)} + u_{(t)} \qquad (3)$$

Where $CVA_{(t)}$ represents the time series of the Construction Value Added in the state, $GDP_{(t)}$ is the time series of Gross Domestic Product in the same state, P is the maximum number of lagged observations included in the model, and u_t represents the time series of the residuals. CVA does not Granger cause GDP if βi = 0 (i=1,…,P) in Equation 2. GDP does not Granger cause CVA if βi = 0 (i=1,…,P) in Equation 3.

COINTEGRATION TEST

Two-time series variables are cointegrated if the time series variables are integrated in the same order and a linear combination of these two-time series has a lower order of integration. If a combination of two variables is cointegrated, they do not drift apart as time passes and they are related in the long run.

In this paper, a cointegration test proposed by Johansen (1988) and extended by Johansen and Juselius (1990) was implemented to examine whether CVA is cointegrated with GDP in each state of the U.S. The lag length (p) for this test was selected based on Akaike Information Criterion (Akaike, 1974). r represents the number of cointegrating relationships between GDP and CVA. The trace statistics show that whether the null hypothesis of $r = 0$ could be rejected. If the null hypothesis is rejected, there is a cointegrating relationship (or are relationships) between GDP and CVA at the state level.

Data

Non-seasonally adjusted quarterly data of real GDP and CVA published by the Bureau of Economic Analysis (BEA, 2016) was used in this study. Real Gross Domestic product (real GDP) is a monetary measure of final goods and services. This measure has been widely used for economic analyses. The Bureau of Economic Analysis (BEA) has published "quarterly real GDP by state" since 2005. The contribution of each industry to the overall GDP by state is called value added by the industry. In concept, value added of an industry is equivalent to the industry's gross output minus its intermediate inputs (Strassner and Wasshausen, 2014). Construction Value Added (CVA) represents the contribution of the construction industry to the GDP by state. It includes the value added by several construction activities, such as construction of highways and streets, manufacturing structures, health care structures, educational and vocational structures, and residential structures. As an illustration, Table 6 and Table 7, in appendix A, represent GDPs and CVAs for all U.S. states and the District of Columbia from the 3^{rd} quarter of 2012 up to the 4^{th} quarter of 2014.

Empirical results

The results of ADF unit root tests for the state GDPs and CVAs are represented in Table 1. Data of GDPs for the states are not stationary first. The GDPs of 47 states and the District of Columbia become stationary by applying the differencing operator once (ΔGDP). These results also show that the CVAs of 38 states and the District of Columbia become stationary after applying the differencing operator ΔCVA.

Table 1 Results of ADF unit root tests of real GDP and CVA time series for different states

State	ADF t-statistics for ΔGDP	ADF t-statistics for ΔCVA
AK	-3.73**	-4.55 ***
AL	-4.61***	-3.33 *
AR	-4.59***	-5.37 ***
AZ	-2.55	-2.43
CA	-4.16**	-7.39 ***
CO	-4.49***	-3.54 **
CT	-3.86**	-3.73**
DC	-4.57***	-4.67***

Table 1 (*Continued*)

State	ADF t-statistics for ΔGDP	ADF t-statistics for ΔCVA
DE	-5.25***	-5.16***
FL	-2.32	-2.14
GA	-3.95**	-2.29
HI	-3.59**	-1.98
IA	-4.62***	-5.08***
ID	-3.59**	-4.26***
IL	-4.16**	-2.87
IN	-3.49*	-3.71**
KS	-4.06**	-4.52***
KY	-3.82**	-4.86***
LA	-4.21**	-4.73***
MA	-4.05**	-2.64
MD	-4.79***	-4.19**
ME	-5.18***	-4.42***
MI	-3.26*	-4.23***
MN	-4.77***	-3.99**
MO	-5.2***	-3.74**
MS	-3.92**	-3.99**
MT	-3.96**	-3.64**
NC	-4.13**	-2.72
ND	-3.16	-3.71**
NE	-5.66***	-4.95***
NH	-6.34***	-4.58***
NJ	-3.47*	-4.64***
NM	-5.57***	-2.78
NV	-2.75	-2.16
NY	-5.15***	-4.07**
OH	-3.96**	-3.74**
OK	-5.24***	-4.84***
OR	-3.94**	-2.63
PA	-5.84***	-4.43***

Table 1 (*Continued*)

State	ADF t-statistics for ΔGDP	ADF t-statistics for ΔCVA
RI	-4.47***	-3.6**
SC	-3.82**	-2.56
SD	-3.69**	-5.36***
TN	-3.93**	-3.87**
TX	-4.1**	-3.61**
UT	-4.13**	-2.1
VA	-5.48***	-4.21**
VT	-4.99***	-5.53***
WA	-3.72**	-2.16
WI	-5.15**	-5.39***
WV	-5.18***	-4.92***
WY	-4.48***	-4.7***

Notes: *, **, and *** represent rejection of null hypothesis at the 10%, 5%, and 1% significance levels, respectively. Akaike Information Criterion is used for lag selection.

To avoid the problem of spurious regression, the Granger causality test can only be applied on stationary time series data. Both CVAs and GDPs of 36 states and District of Columbia become stationary after applying the difference operator once. Therefore, the Granger causality test was applied on CVAs and GDPs of 36 states and the District of Columbia in which CVAs and GDPs become stationary after applying the differencing operator once. The Granger causality test investigates whether the first differenced time series of CVA of a specific state Granger causes the first differenced time series of GDP in the same state.

The results of Granger causality tests summarized in Table 2 indicate that CVA is a leading indicator of GDP in 18 states (Alaska, California, Colorado, Connecticut, Delaware, Idaho, Indiana, Louisiana, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New York, Oklahoma, Wisconsin, West Virginia, Wyoming) and the District of Columbia.

Figure 1 demonstrates the geographic distribution of the states where CVA leads GDP. These states do not belong to a specific geographical area.

Granger causality test is also applied to understand whether GDP is a leading indicator of CVA at the state level. Rejection of null hypothesis (GDP does not Granger cause CVA at the state level) for time series data of a state means that the Granger causality runs from GDP to CVA at that state. Table 3 shows the states in which GDP Granger causes CVA. The results indicate that in 10 states (Colorado, Delaware, Iowa, Kansas, Louisiana, Michigan, Montana, Minnesota, Nebraska, and Rhode Island) and the District of Columbia causality runs from GDP to CVA, which means CVA is a lagging indicator of GDP in these states.

Table 2 Results of Granger causality tests for the states where the null hypothesis was rejected (null hypothesis: CVA does not Granger cause real GDP at the state level)

State	F Statistics									
	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6	Lag 7	Lag 8	Lag 9	Lag 10
AK	2.39	1.98	2.33*	1.59	1.36	1.28	0.89	0.71	0.77	0.62
CA	8.53***	4.55**	2.35*	1.66	2.16*	2.33*	1.95	2	1.64	1.14
CO	3.48*	2.8*	2.14	1.86	1.32	2.43*	1.58	2.3*	1.53	1.25
CT	1.24	1.74	1.36	1.23	3.18**	2.7**	2.33*	3.53**	3.91***	6.4***
DC	0.47	0.83	1.03	3.08**	3.2**	1.54	1.16	1.19	0.77	0.61
DE	1.72	1.93	3.1**	2.16	1.79	1.58	1.14	1.13	1.17	1.22
ID	0.59	1.28	4.72***	3.38**	4.21***	4.16***	3.45**	3.2**	2.36*	2.06
IN	3.94*	1.99	0.87	0.67	0.59	0.53	0.49	0.54	0.51	0.46
LA	2.41	2.89*	2.27*	1.84	1.41	0.98	1.16	1.97	1.45	1.05
MN	3.55*	2.36	2.64*	2	1.2	1.09	1.8	2.85**	2.04	1.82
MO	1.04	0.68	0.58	1.39	1.89	1.52	1.93	2.02*	1.5	0.81
MT	3.29*	2.13	0.91	0.94	0.86	0.59	1.03	1.87	1.81	2.19*
NH	0.94	2.25	3.25**	3.46**	3.29**	3.71***	2.44*	1.65	2.27*	1.87
NJ	0.06	0.99	0.91	2.58*	2.61**	2.78**	2.29*	1.69	2.16*	1.67
NY	4.31**	2.04	1.51	0.93	1.21	0.87	1.07	1.3	0.91	0.98
OK	2.81	1.24	0.65	2.06	2.65**	2.3*	1.91	2	1.7	1.57
WI	1.03	0.92	1.43	1.05	0.84	1.18	2.34*	2.56**	2.83**	2.27*
WV	0.32	0.45	2.28*	1.86	1.47	1.49	1.44	1.32	0.89	0.75
WY	0.0001	0.001	1.69	4.85***	4.13***	3**	2.74**	2.41*	2.29*	1.82

Notes: *, **, and *** represent rejection of null hypothesis at the 10%, 5%, and 1% significance levels, respectively.

Johansen Cointegration test is also applied on time series data of the states in which either CVA Granger causes GDP or GDP Granger causes CVA. As discussed earlier, time series data of these states are integrated of order 1. If CVA and GDP time series data of a state are both integrated of order 1 and a linear combination of GDP and CVA is integrated of order 0, these two-time series data are cointegrated. Rejection of null hypothesis (r =0) in cointegration test at each state means that there exists a long-run relationship between GDP and CVA at the state level. The results of cointegration test summarized in Table 4 show that there is a statistically significant cointegrating relationship between GDP and CVA in 8 states of the U.S. (Connecticut, Idaho, Michigan, Montana, New Hampshire, New Jersey, Rhode Island, and Wisconsin) and the District of Columbia.

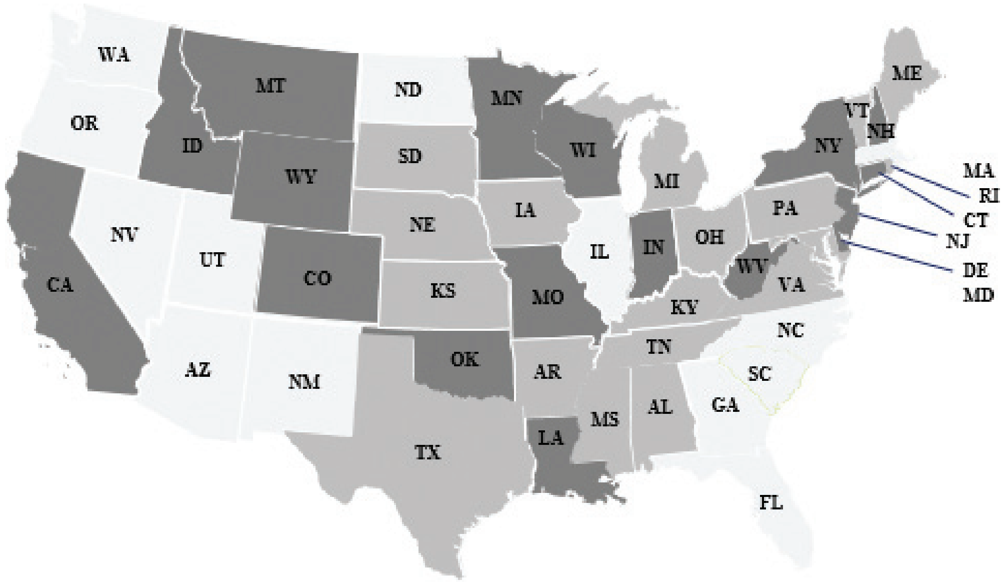

Figure 1 Granger causality map between CVA and GDP

Value added by construction industry leads GDP by state	18 states
Value added by construction industry does not lead GDP by state	18 states
Granger causality test could not be tested	14 states

Discussion of results

The results of this study show that out of 36 states in which the temporal relationship between GDP and CVA could be empirically tested, there exists a leading and/or lagging relationship between the construction industry and GDP in 23 states. CVA is a leading indicator of GDP in 18 states and the District of Columbia; CVA is a lagging indicator of GDP in 10 states and the District of Columbia, and there is a bi-directional relationship between CVA and GDP in 5 states and the District of Columbia. We did not find enough evidence showing any causality relationships between CVA and GDP in the other 13 states; however, it does not necessarily mean that the construction industry is not important in these states. The results of this study are summarized in Table 5.

STATES IN WHICH CVA IS A LEADING INDICATOR OF GDP

The results of this study show that CVA is a leading indicator of GDP in 18 states and the District of Columbia. CVA leads GDP in the short-term in 7 states (AK, CA, DE, IN, LA, NY, WV) and the District of Columbia. CVA leads GDP in the medium- to long-term in 5 states (CT, NJ, OK, WI, WY). CVA leads GDP in both short and medium to long-term in 6 states (CO, ID, MN, MO, MT, NH); therefore, construction activity is the consistent leading indicator of economic growth in these states.

STATES IN WHICH CVA IS A LAGGING INDICATOR OF GDP

The results of the Granger causality test from GDP to CVA show that CVA is a lagging indicator of GDP in 10 states and the District of Columbia that means changes in GDP

Table 3 Results of Granger causality tests for the states where null hypothesis was rejected (null hypothesis: real GDP does not Granger cause CVA at the state level)

State	F Statistics									
	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6	Lag 7	Lag 8	Lag 9	Lag 10
CO	4.98**	2.70*	2.98**	2.03	1.88	3.21**	2.51**	1.77	1.58	1.16
DC	3.77*	2.26	0.96	3.79**	2.99**	2.96**	2.37*	2.25*	2.02	1.77
DE	16.9***	7.91***	5.16***	0.33	0.41	0.87	1.35	1.04	0.78	0.71
IA	0.29	4.37**	2.70*	2.53*	2.32*	1.74	1.38	1.46	1.17	1.30
KS	0.007	1.41	0.86	0.59	0.58	0.45	0.90	0.74	2.09*	2.29*
LA	0.29	4.37**	2.70*	2.53*	2.32*	1.74	1.38	1.46	1.17	1.30
MI	2.79	3.69**	2.41*	1.99	1.44	2.43*	2.06*	1.79	1.47	1.32
MO	0.96	0.54	1.53	1.62	2.39*	1.78	1.21	1.09	1.03	1.13
MT	0.09	1.21	1.27	3.47**	3.51**	2.90**	2.37*	1.62	1.40	1.79
NE	0.45	0.30	1.31	2.21	2.08*	1.73	1.65	1.34	1.01	0.69
RI	0.38	0.96	1.87	2.09	3.00**	3.04**	3.09**	2.64**	3.41**	3.26**

Notes: *, **, and *** represent rejection of null hypothesis at the 10%, 5%, and 1% significance levels, respectively.

Table 4 Results of Johansen Cointegration tests for the vector of GDP and CVA at the state level for the states where null hypothesis was rejected

State	Trace statistics	5% critical value	1% critical value
CT	23.85***	17.95	23.52
DC	31.22***	17.95	23.52
ID	22.34**	17.95	23.52
MI	27.51***	17.95	23.52
MT	33.22***	17.95	23.52
NH	18.03**	17.95	23.52
NJ	26.96***	17.95	23.52
RI	24.32***	17.95	23.52
WI	31.37***	17.95	23.52

Notes: **, and *** represent rejection of null hypothesis at the 5%, and 1% significance levels, respectively; Akai Information Criterion is used for lag selection.

Table 5 Summary of the results

State	CVA as a percentage of GDP in 2015	CVA Granger causes GDP in short term	CVA Granger causes GDP in medium to long term	GDP Granger causes CVA in short term	GDP Granger causes CVA in medium to long term	Cointegrating relationship between CVA and GDP
AK	4.3%	✓				
CA	3.4%	✓				
CO	4.3%	✓	✓	✓	✓	
CT	3.1%		✓			✓
DC	1.0%	✓		✓	✓	✓
DE	3.2%	✓		✓		
IA	4.3%			✓		
ID	5.0%	✓	✓			✓
IN	3.8%	✓				
KS	3.9%				✓	
LA	5.5%	✓		✓		
MI	3.5%			✓	✓	✓
MN	4.0%	✓	✓			
MO	5.8%	✓	✓		✓	
MT	4.0%	✓	✓		✓	✓
NE	3.6%				✓	
NH	3.4%	✓	✓			✓
NJ	3.7%		✓			✓
NY	3.1%	✓				
OK	4.2%		✓			
RI	3.8%				✓	✓
WI	3.8%		✓			✓
WV	4.7%	✓				
WY	5.8%		✓			

would take place before a change in the construction sector. Economic variations in some states take place right before the construction sector (DE, IA, LA) while in some other states (KS, MO, MT, NE, RI) these variations will show up in the construction industry up to 2.5 years later. GDP Granger causes CVA in both the short and medium to long-term in two states (CO, MI) and the District of Columbia. These results confirm the dependency of the construction sector to the economic conditions in these 10 states and the District of Columbia.

STATES IN WHICH CVA IS A LEAD-LAG INDICATOR OF GDP

There exists a bi-directional causal relationship between CVA and GDP in 5 states (CO, DE, LA, MO, MT) and the District of Columbia that means while changes in the economic conditions of the state will appear later in the construction sector, construction activities are still an engine of economic variations in these states.

STATES IN WHICH CVA AND GDP ARE COINTEGRATED

The data of CVA and GDP are cointegrated in 8 states (CT, ID, MI, MT, NH, NJ, RI, WI) and the District of Columbia. The cointegration relationship means that the time series of the two variables do not drift apart as time passes and there is a long-run relationship between CVA and GDP in these states.

THE ASSOCIATION BETWEEN LEADING/LAGGING RELATIONSHIPS AND SHARE OF CVA IN GDP

The Bureau of Economic Analysis calculates the share of construction activity in the state GDP. North Dakota, Montana, Wyoming, Louisiana, and Utah are the top 5 states with respect to the share of construction activity in the state GDP in 2015 (BEA, 2016). New York, Connecticut, Delaware, Oregon, and Ohio are the bottom 5 states in this ranking (BEA, 2016). Some of the 18 states shown in Table 1 are among the states with high share of construction activity in the GDP. For example, Montana, Wyoming, and Louisiana are ranked among the top 5 states of the ranking table of construction activity as a percentage of state GDP. On the contrary, some other states of Table 1 are among the bottom 5 states of this ranking (New York, Connecticut, and Delaware). Thus, the hypothesis of an existing relationship between the "share of construction in state GDP" and the "impact of construction industry on state GDP" in all U.S. states would be rejected. In other words, a higher share of construction to the state GDP does not necessarily mean that construction investments have more impact on the state's economy. More interestingly, a lower share of construction to the state GDP does not necessarily indicate the low importance of construction in economic growth of the state.

Conclusion

This study analyzes the temporal relationships between the construction industry and the economy at the state level in the U.S. The results of the present study show that the value added by the construction industry leads state GDP with different lags in 18 states of the U.S. (Alaska, California, Colorado, Connecticut, Delaware, Idaho, Indiana, Louisiana, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New York, Oklahoma, Wisconsin, West Virginia, Wyoming) and the District of Columbia. Since growth in the construction industry precedes growth in the larger economy in 18 states and the District of Columbia, the government had better provide a conductive requirement for construction firms at least in these states, to enhance their performance. This finding could be useful in policy planning while prioritizing investment opportunities.

The results of this study also show that CVA is a lagging indicator of GDP in 10 states (Colorado, Delaware, Iowa, Kansas, Louisiana, Michigan, Minnesota, Montana, Nebraska, and Rhode Island) and the District of Columbia that means changes in economic conditions will appear later in the construction sector in these states. Economic variations in some states take place right before changes in the construction industry such as in Delaware while in some other states (e.g. Rhode Island) these variations will show up in the construction industry up to 2.5 years later. Correspondingly, there is a bi-directional causal relationship between CVA and GDP in 5 states (Colorado, Delaware, Louisiana, Minnesota, and Montana) and the District of Columbia that shows the dependency of the construction sector and the economy on each other in these states.

We did not find enough evidence showing any relationships between the Value Added by Construction industry and state GDP in other states. The data of 14 states were not stationary; therefore, the Granger causality test could not be conducted. This limitation of the study should not be interpreted as minor importance of the construction industry in those states.

A comparison between the results of this study and the table of construction as a percentage of GDP shows that the hypothesis of an existing relationship between the "share of construction in state GDP" and the "impact of construction industry on state GDP" in all U.S. states would be rejected. In other words, a higher share of construction to the state GDP does not necessarily mean that construction investments have more impact on the state's economy. More interestingly, a lower share of construction to the state GDP does not necessarily mean the low importance of construction in economic growth of the state. It is recommended to further investigate the relationships between state GDP growth rates and construction share of GDP. Further studies could also be conducted analyzing the impact of investments in different sub-sectors of the construction industry on the economy of the U.S. states.

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Appendix A

Table 6 State GDPs

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
AL	178935	178500	177599	179258	181642	180827	182371	181601	183093	183779
AK	51178	50472	49882	49659	49273	49708	49593	49969	49018	48855
AZ	254067	256887	257076	258049	260439	259411	259754	261243	261114	262615
AR	108828	109146	109045	110220	110921	111822	110486	111781	112897	113346
CA	2061858	2112833	2087206	2109910	2138911	2139406	2171390	2212235	2214369	2229070
CO	268445	271617	272613	276277	281080	285328	286174	288976	289039	291043
CT	226879	227300	226985	229425	229938	229361	229321	231978	229385	230358
DE	56046	57720	57319	58846	59933	59316	59575	60472	59994	60130
DC	103057	103993	105848	105003	105125	105271	107217	108351	107724	108528
FL	748816	755814	755797	762998	770134	774429	777895	784759	795497	800852
GA	420406	424255	424297	429285	434753	436042	436309	440179	445108	447889
HI	68739	69414	69299	69691	69937	69720	70434	70936	70863	71147
ID	56433	57284	56666	56999	57949	58208	57942	58124	58687	58990
IL	665217	671901	668010	673469	678784	677412	687357	683853	694145	694274

Table 6 (*Continued*)

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
IN	288441	288919	289906	292309	295344	297708	294620	299013	299701	301936
IA	149590	150516	147805	153500	155537	157084	152865	155009	155944	154787
KS	130709	131913	130291	132067	133504	133481	132425	133287	132585	132366
KY	169783	170284	169449	171565	182109	182907	170981	173418	174014	175178
LA	204992	205357	204288	208631	211922	213340	212987	212544	213334	213315
ME	49687	49797	49644	50048	50473	50982	49476	50562	50826	50995
MD	316218	318069	317585	322371	324609	323452	325325	327067	326223	328281
MA	414608	411454	415164	415660	420931	425015	425445	430262	425836	428621
MI	406686	409097	408906	413001	415339	415507	413794	418825	420439	423123
MN	287668	288214	286626	289780	295170	296243	298574	298191	298579	300012
MS	96098	94836	94008	94100	94858	95096	94567	95124	95858	96255
MO	255354	256241	255033	257837	259725	260208	258672	261882	262197	263379
MT	39004	39395	39124	39809	40007	39999	40582	41192	41383	41279
NE	96820	96864	96457	98385	98953	100242	98934	100792	101193	101091
NV	118435	119959	121010	122009	123286	124473	123901	126110	127290	127324

Table 6 (*Continued*)

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
NH	63392	63582	63877	65047	65236	65801	64219	65194	66209	66401
NJ	494736	497397	494252	498586	501421	502217	500034	510270	509635	512791
NM	82987	83252	83173	84416	85926	87398	85679	85946	86007	85774
NY	1237814	1243658	1237357	1241710	1254955	1259174	1241349	1265456	1277992	1278094
NC	424872	427152	426500	428222	433200	435626	435476	441278	445578	447624
ND	49311	49824	49106	51239	51987	53393	51951	50067	49564	49815
OH	517256	522267	523628	531006	541594	543434	538949	543411	545609	549470
OK	163808	166402	165763	167691	171325	171369	174335	170862	170602	169376
OR	189958	191261	188892	180547	193510	193521	196721	198023	201378	201448
PA	603745	606849	609435	612800	619611	623666	624233	624516	627647	610361
RI	49418	49425	49851	50305	50679	51134	50557	51187	51132	51347
SC	170596	171735	170298	174222	174859	175761	174971	176207	178394	178991
SD	39981	40155	39026	39972	40404	40710	39711	40542	41252	41487
TN	270842	271368	271278	274585	275954	277284	274344	280149	282456	284123
TX	1378613	1386697	1388336	1407312	1437866	1453523	1478165	1469639	1474523	1479813

Table 6 (*Continued*)

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
UT	125355	124920	125847	126295	127398	128446	129370	130806	131913	132836
VT	26708	26948	26774	26982	27437	27666	26984	26989	27503	27599
VA	424707	425647	422467	425835	426678	426932	424677	430568	434308	436890
WA	377023	377658	380431	384994	387199	391376	390467	398049	399756	401011
WV	66810	67424	66009	67267	67704	67964	67783	67069	67135	67189
WI	263867	265374	263336	268464	271053	272114	270003	272376	276020	276284
WY	34873	35181	34564	34848	35231	35996	35678	35326	35264	34957

Table 7 State CVAs

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
AL	7271	7351	7588	7540	7691	7924	7816	7819	8082	8268
AK	2208	2251	2421	2331	2239	2241	2554	2507	2337	2332
AZ	10942	11184	11356	11027	10780	11155	11101	11234	11312	11649
AR	4281	4277	4394	4424	4478	4769	4621	4746	5167	5291
CA	74531	76271	76517	77436	78985	80603	84465	85895	88598	91028
CO	12289	12831	13162	13437	13632	14086	14308	14154	14505	15043
CT	7258	7265	7341	7606	7803	757	7860	8205	8448	8636
DE	2007	2070	2006	2133	2173	2166	2148	2194	2267	2321
DC	1543	1561	1585	1561	1574	1614	1444	1613	1596	1622
FL	33916	34724	35264	35874	36822	37966	39141	40236	41495	42497
GA	15494	15922	15987	16363	16766	17389	17743	17763	18251	18820
HI	4059	4103	4131	4179	4289	4349	4588	4703	4841	5082
ID	2962	3020	3010	3061	3077	3184	3451	3319	3267	3374
IL	23044	23278	23480	23927	24624	25671	25778	26852	27425	27942
IN	12192	12368	12014	12334	12606	12994	12642	13063	13330	13679

Table 7 *(Continued)*

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
IA	6497	6629	6806	7146	7271	7579	7955	7696	7575	7857
KS	5619	5843	5968	5918	5763	5777	5922	6071	5950	6092
KY	6941	7109	7246	7485	7641	7871	7714	8076	8170	8412
LA	11813	12133	12431	12760	13325	13494	13476	12957	13550	13994
ME	2118	2150	2117	2153	2169	2247	2181	2180	2209	2267
MD	15365	15408	15498	16032	16288	16440	16133	16725	17205	17668
MA	15670	15883	16040	16262	16710	17197	17429	17948	18499	19023
MI	15079	15577	15652	15988	16524	16881	16357	17354	17375	17759
MN	11625	12016	11993	12180	12563	12796	13561	13745	13827	14067
MS	4986	5042	4886	4802	4794	4719	4670	4587	4751	4974
MO	10206	10358	10477	10473	10415	10592	10939	11108	11160	11519
MT	2303	2336	2384	2430	2501	2584	2711	2612	2793	2862
NE	3649	3613	3654	3782	3867	4106	4176	4090	4207	4321
NV	5867	5993	6246	6444	6673	6847	7035	7036	7343	7532
NH	2252	2302	2325	2354	2370	2464	2466	2482	2581	2664

Table 7 (*Continued*)

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
NJ	18932	19492	18955	19743	20276	20799	20609	21645	22019	22770
NM	3139	3270	3183	3217	3260	3395	3351	3350	3379	3395
NY	38939	39975	39353	41404	42401	43248	42285	44877	45741	47581
NC	14974	15175	15307	15629	16037	16584	16721	17268	17725	18149
ND	4073	4104	4189	4352	4512	4874	5025	4438	4206	4162
OH	19485	19983	19929	20624	20808	21447	21247	21303	21758	22354
OK	7769	7902	8024	7846	7888	8025	8285	8180	8521	8664
OR	6934	7354	7478	7452	7407	7473	7553	7408	7632	7797
PA	25428	25550	25372	26625	26774	27287	26224	27107	28027	28455
RI	2082	2100	2075	2154	2187	2212	2142	2215	2301	2370
SC	7920	8114	8189	8278	8320	8534	8594	9796	9094	9322
SD	1735	1750	1781	1818	1824	1867	2033	2025	1913	1983
TN	10256	10526	10644	10802	10832	11156	11390	11749	12246	12604
TX	73435	73750	76125	77666	76510	82174	83153	82352	86144	88033
UT	7150	7005	7418	7423	7466	7708	8109	8189	8215	8562

Table 7 (*Continued*)

State	Year 2012		Year 2013				Year 2014			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
VT	1159	1181	1191	1214	1253	1284	1268	1266	1273	1309
VA	18294	18539	18398	18920	18984	19269	19199	20010	20282	20714
WA	14613	14932	15081	16324	15810	16377	17131	17652	17457	17794
WV	3680	3756	3534	3713	3816	3830	3540	3633	3686	3688
WI	10313	10482	10407	10639	11127	11463	11511	11767	12047	12307
WY	2131	2333	2340	2407	2436	2352	2399	2273	2308	2348