Economic Growth and Infrastructure Investments in Energy and Transportation: A Causality Interpretation of China's Western Development Strategy

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ABSTRACT

Were the large investments in energy and transportation infrastructure effective in fostering economic growth? Or did economic growth trigger these infrastructure developments? To answer these questions, we develop a simple model of production capacity constraints and use China's Western Development Strategy (WDS) as an example to investigate how the relationships among energy investment, transportation infrastructure expansion and economic growth differ in the pre- and post-WDS periods. Our Granger causality analysis uses a panel data sample for China's 30 provinces in the Western and non-Western regions for the period of 1991–2012. We find Granger causality only in the post-WDS period from transportation infrastructure expansion to economic growth and from economic growth to energy investment. These results suggest energy and transportation capacity constraints in the post-WDS period but not the pre-WDS period. Their policy implication is that China should continue its energy and transportation infrastructure investments with improved coordination.

Keywords: Economic growth, Energy and transportation infrastructures, Causality, China

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1. INTRODUCTION

China is now the second largest economy of the world, thanks to three decades of an average annual growth of 9.7% since the economic reform that began in 1978. Along with this unsurpassed growth, China has become the world's largest energy-consuming country and leader in CO_2 emissions. Its vast regional income disparities in the 1990s led to the Western Development Strategy (*Xibu Da Kaifa*, or WDS hereafter) launched in 2000 to construct large infrastructure projects in the Western region shown in Figure 1. Fifteen years later, expanding the region's energy and transportation infrastructures (ETI) remains prominent on China's development agenda.[1]

This paper aims to answer two questions. First, were the large investments in ETI effective in fostering economic growth? If "yes", the need for maintaining the ETI expansion to mitigate the regional income disparities would diminish. As a result, the ETI expansion could slow down in

1. http://www.gov.cn/2011lh/content_1825838.htm

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Figure 1: Provinces, Autonomous Regions and Municipalities in China

Source: http://www.chinatoday.com/city/a.htm
Note: The non-Western region houses the 19 provinces of Anhui, Beijing, Fujian, Guangdong, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shandong, Shanghai, Shanxi, Tianjin, and Zhejiang. The Western region houses the 11 provinces of Gansu, Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Sichuan, Shaanxi, Tibet, Xinjiang, and Yunnan.

sympathy with China's commitment to reduce its fossil fuel consumption and carbon emissions announced in the 2015 Paris Summit on Climate Change.[2]

China's Paris commitment coincides with an annual economic growth of 6.9% immediately prior to the 2016 release of its thirteenth five-year plan.[3] This leads to the second question: did economic growth trigger these infrastructure developments? If "yes", the ETI expansion would continue in response to China's goal of achieving by 2020 a per capita income twice the 2010 level.

We empirically answer these two questions by estimating the causal relationship between regional ETI expansion and economic growth. An affirmative answer to the first question is premised on an empirical finding of ETI expansion causing economic growth. An affirmative answer to the second question is premised on an empirical finding of economic growth causing ETI expansion. A bidirectional causal relationship between ETI expansion and economic growth suggests a balancing act of cutting CO_2 emissions and maintaining an annual growth rate of about 7%.[4]

2. http://www.cop21.gouv.fr/en/

3. http://www.telegraph.co.uk/sponsored/china-watch/politics/12006280/china-five-year-plan.html

4. This act's formulation cannot come from ETI initiatives alone. It needs a broader consideration of policy initiatives to: (a) shift China's energy-intensive manufacturing (e.g., steel and petrol chemical) to high-value added production (e.g.,

To provide a contextual background of our empirical analysis, we first recognize that the WDS was designed to remedy the regional income inequalities documented in the extant literature (e.g., Jian et al., 1996; Wu, 2001; Grewal and Sun, 2002; Lin and Liu, 2005; Kanbur and Zhang, 2009; Fleisher et al., 2010; Huang and Todd, 2010; Li and Wei, 2010). Further, infrastructure investments gained national policy priority in the 1980s (Jin, 1994). Despite the large investments made since 2000, little is known of the causal relationship between ETI expansion and economic growth in China.

While a Granger-causality analysis is a fruitful first step to answer the two questions posed above, its empirical reasonableness is debatable for two reasons. First, an econometric inference of Granger-causality between ETI expansion and economic growth may be biased due to its omission of likely important drivers of China's regional growth.[5] Second, economic interdependence between the Western and non-Western regions is complicated, and a Granger-causality analysis like ours oversimplifies this interdependence.

While conceptually valid, these reasons can apply to *any* econometric investigation not based on a full blown model of China's locational growths by region, province or county. They also imply an infeasible scope of research due to limited availability of data and research time and resources. Hence, using these reasons to reject a causality investigation is counter-productive, resulting in a research paralysis that does not aid the understanding of the nexus of ETI expansion and economic growth. That said, these reasons do point out our analysis' limitations that we try address to the extent possible.

Our causal analysis of ETI expansion and economic growth adds to the sparse literature on the WDS. To the best of our knowledge, there are only two extant studies: (a) Grewal and Ahmed (2011) develop a regional growth model to assess the WDS's progress; and (b) Lu and Deng (2013) offer a qualitative analysis of the WDS. However, neither study informs the next policy step for the WDS-related ETI expansion: deceleration, continuation, or acceleration?

Our investigation entails the pre- and post-WDS periods during 1991–2012, so as to provide insights on the fundamental differences in the causal relationships among these variables. Using a panel data sample for China's 30 provinces in the Western and non-Western regions, we conduct a Granger causality analysis of the relationships between ETI expansion and economic growth. Interpreted through a model of production capacity constraints that treats other economic variables (including land, labor and materials) as given, we find Granger causality between ETI expansion

advanced electronics and high-quality consumer goods); (b) promote conservation and energy-efficiency to cost-effectively cut energy consumption; (c) replace aging coal-fired generation units with renewable and nuclear energy; (d) electrify transportation; and (e) use electricity and natural gas to displace domestic coal consumption for heating and cooking that is still common in China's older homes (Williams et al., 2012).

5. The list of such drivers is nearly limitless, exemplified by: (a) consumption or production of energy of various types: oil, coal, electricity, natural gas, and vehicular fuels; (b) labor mobility, skilfulness and availability; (c) capital stock and its heterogeneous qualities; (d) education improvement and technology advance; (e) China's policies on foreign exchange and urbanization; (f) China's fiscal and monetary policies; (g) China's accession to the World Trade Organization; (h) China's market opening and related regulatory and legal reforms; (i) the extent of China's privatization and improved corporate governance of state-owned industries; (j) foreign direct investments in China by region; (k) China's pervasive corruption that has triggered President Xi Jinping's anti-graft campaign; and (l) the trade and monetary policies of the U.S. and European Union. A comprehensive examination of these drivers is well beyond the current paper's scope. It is also beyond the scope of any study that only addresses a subset of (a) to (l). Even if a study covers all of (a) to (l), it can still be criticized for omitting variables not listed above (e.g., China's aging population, gender imbalance and shrinking population due to the one-child policy, and environmental deterioration).

and economic growth in the post-WDS period but not the pre-WDS period. This suggests capacity constraints in the energy and transportation sectors following the implementation of the WDS.

Using a trivariate formulation, our causality investigation enriches the literature on energy-GDP nexus that focuses on how GDP may vary with energy consumption and production (Ozturk, 2010 and references thereof), as well as the China-specific literature on the same topic (e.g., Yuan et al., 2008; Yu and Meng, 2008; Wu et al., 2008; Zhang and Cheng, 2009; Chang, 2010; Li et al., 2011; Wang et al., 2011a; Wang et al., 2011b; Yalta and Cakar, 2012).[6] It also enriches the literature on the causal linkage between transportation infrastructure and economic growth (e.g., Yu et al., 2011; Gao, 2005; Zhang and Sun, 2008; Tan and Yang, 2009; Sahoo et al., 2010) and among energy consumption, transportation infrastructure and economic growth in India (Pradhan, 2010). To the best of our knowledge, our paper is the first study that documents the causal relationships among energy investment, transportation infrastructure expansion and economic growth for China.

The paper proceeds as follows. Section 2 is a brief background of the WDS. Section 3 presents our economic model used to explain the econometric results in Section 5, which are based on the data described in Section 4. Section 6 concludes.

2. WESTERN DEVELOPMENT STRATEGY

China has three stages of regional development: (1) *Balanced Development* (1949–1978) marked by the central government's promotion of similar growth among China's provinces, (2) *Unbalanced Development* (1979–1999) marked by the central government's targeted promotion of the coastal provinces' rapid growth, and (3) *Coordinated Development* (2000-present) marked by the central government's effort to achieve a more even growth pattern for all provinces.

Endowed with favorable geographical and natural conditions (e.g., large urban cities, availability of skilled labor and exposure to international commerce), the coastal provinces (e.g., Guangdong and Fujian) had been developing at a faster rate than provinces in China's interior (e.g., Guangxi and Sichuan). The second stage of *Unbalanced Development* exacerbated the unequal development because the coastal provinces benefited from the central government's exclusive preferential policies for investment, industry reform and market opening.

In 1999, the central government proposed the WDS to accelerate the development of the Western region, so as to reduce regional disparities. Officially launched in January 2000, the WDS extended many programs started by the Ninth Five-Year Plan (1996–2000). Implementation of the WDS, along with the promotion of coordinated regional economic development, was accorded strategic importance under the Tenth Five-Year Plan (2001–2005). The WDS envisioned that the Western region will by 2050 become a "prosperous" and "advanced" new West.

The WDS entailed infrastructure development (e.g., transportation, energy and telecommunications), restructuring industries, consolidating agriculture, promoting education, and strengthening environmental protection. To steer the entire development program, both the central and local governments had devoted resources to the construction of major infrastructure projects, exemplified by airports, highways and railways, telecommunication facilities, pipelines, electricity generation

6. One could arguably use the two reasons of omitted variable bias and complicated causal relationship to criticize these published studies on the important policy issue of energy-income nexus. Had the reasons been judged to be meritorious, these studies would have been rejected. The fact that these studies appear in peer-reviewed journals cast doubts on the reasons' usefulness in advancing the understanding of the energy-income nexus.

and transmission. While the government presumes that WDS could help narrowing the income gap among the regions, whether this presumption is supported by empirical evidence is not fully known.

3. METHODOLOGY

3.1 Theory

To provide an economically meaningful interpretation of our econometric results, we develop a simple model of production capacity constraints to explore how GDP and ETI may move with each other.[7] To account for other possible variables which exist in the economy, this model is based on the following transformation function that is conditional on $\boldsymbol{H}$ = other inputs (e.g., land, labor and materials):

$$G(X, Y, Z|\boldsymbol{H}) = 0, \tag{1}$$

where X = energy sector's normalized output (e.g., a province's per capita electricity generated); Y = transportation sector's normalized output (e.g., goods transported per km^2 of a province's geographic size); and Z = per capita GDP. Here, X and Y are intermediate outputs associated with the production of Z. For a given $\boldsymbol{H}$, total differentiation of equation (1) yields:

$$G_X \Delta X + G_Y \Delta Y + G_Z \Delta Z = 0, \tag{2}$$

where $G_X = \partial G(\bullet)/\partial X > 0$, $G_Y = \partial G(\bullet)/\partial Y > 0$ and $G_Z = \partial G(\bullet)/\partial Z < 0$.

We assume that the production of X obeys an engineering process (Johansen, 1972; Stewart, 1979):

$$X = \mathrm{Min}(E/\alpha, K), \tag{3.a}$$

where α = conversion rate of E to X (e.g., the heat rate (GJ/MWH) in electricity generation); E = energy input (e.g., GJ of fuel input) used to produce X; and K = capacity that caps the maximum value of X (e.g., the per capita MW of electricity generation). Similarly, we assume:

$$Y = \mathrm{Min}(F/\beta, M), \tag{3.b}$$

where β = conversion rate of F to Y (e.g., the per-kg-km fuel efficiency (liter / kg-km)); F = vehicular fuel (liter) used to produce Y ; and M = transportation capacity (kg-km) that caps the maximum value of Y.

7. Thanks to the comments of a very helpful referee, we recognize that investments are made to: (a) replace cost-inefficient production facilities; (b) relieve capacity constraints; or (c) both (a) and (b). We do not have the relevant marginal cost data to delineate (a); this is notwithstanding that the vertical segment of a marginal cost curve signifies a capacity constraint. Hence, we decide to use the capacity-constraint line of reasoning to interpret the causality between economic growth and infrastructure expansion. Our decision reflects that China's rapid growth points to capacity constraints, rather than rising marginal costs caused by input price increases for labor and materials, as the primary limiting factor. While China has been losing its cost-competitiveness as the world's leader in manufacturing in the last few years when compared to other countries like Vietnam and India, our capacity constraint model fits the empirical fact that China's economic growth in our sample period is more related to production capacity constraints than rising marginal costs.

Define (a) $A = 1$, if $X < K$; 0 otherwise; and (b) $B = 1$, if $Y < M$; 0 otherwise. Using equations (3.a) and (3.b), we rewrite equation (2) as:

$$G_X[A(\Delta E/\alpha) + (1 - A)\Delta K] + G_Y[B(\Delta F/\beta) + (1 - B)\Delta M] + G_Z\Delta Z = 0, \tag{4}$$

where ΔV denotes the change in variable V for $V = E, K, F, M, Z$.

Equation (4) specifies the data requirement for our empirical investigation. *Sans* data on the physical amount of ΔK (e.g., electricity generation capacity and oil refinery capacity), we assume ΔK can be proxied by the energy sector's per capita investment (yuan).[8] Similarly, we assume ΔM can be proxied by the km change in a province's highways and railways as more km implies a larger transportation capacity to serve the province's fixed geographic size.

To use equation (4) to interpret the causal relationships among ΔZ, ΔK and ΔM, we consider the four cases below. Our consideration assumes $\Delta Z > 0$, $\Delta K > 0$ and $\Delta M > 0$, which reflect China's average growth data portrayed in Figure 2. The cases are as follows:

- Case 1: $A = 0$ and $B = 0$, implying that both sectors face capacity constraints. Hence, ΔZ is associated with movements of ΔK and ΔM, implying that ΔK and ΔM are likely causally related.
- Case 2: $A = 1$ and $B = 0$, implying that only the transportation sector has a capacity constraint. Hence, ΔZ moves with ΔM but not ΔK, implying that ΔK and ΔM are unlikely causally related.
- Case 3: $A = 0$ and $B = 1$, implying that only the energy sector has a capacity constraint. Hence, ΔZ moves with ΔK but not ΔM, implying that ΔK and ΔM are unlikely causally related.
- Case 4: $A = 1$ and $B = 1$, implying that both sectors have surplus capacities. Hence, ΔZ does not move with ΔK and ΔM, implying that ΔK and ΔM are unlikely causally related.

3.2 Estimation

Our trivariate formulation of Granger causality considers ΔZ_t, ΔK_t and ΔM_t for $t = 1991$–2012 for the 30 provinces in China. To assess the difference of causal relationships among energy investment, transportation infrastructure expansion and economic growth before and after the adoption of the WDS, we divide our sample into the pre-WDS period of 1991–2000 and post-WDS period of 2001–2012. We first examine the unit root properties of our panel data by applying the Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) tests for a panel unit root. We then estimate a panel vector autoregressive (VAR) model to explore the relationships among the provincial ΔZ_t, ΔK_t and ΔM_t.

Following Holtz-Eakin, et al. (1988) and Love and Zicchino (2006), we construct the following panel VAR model:

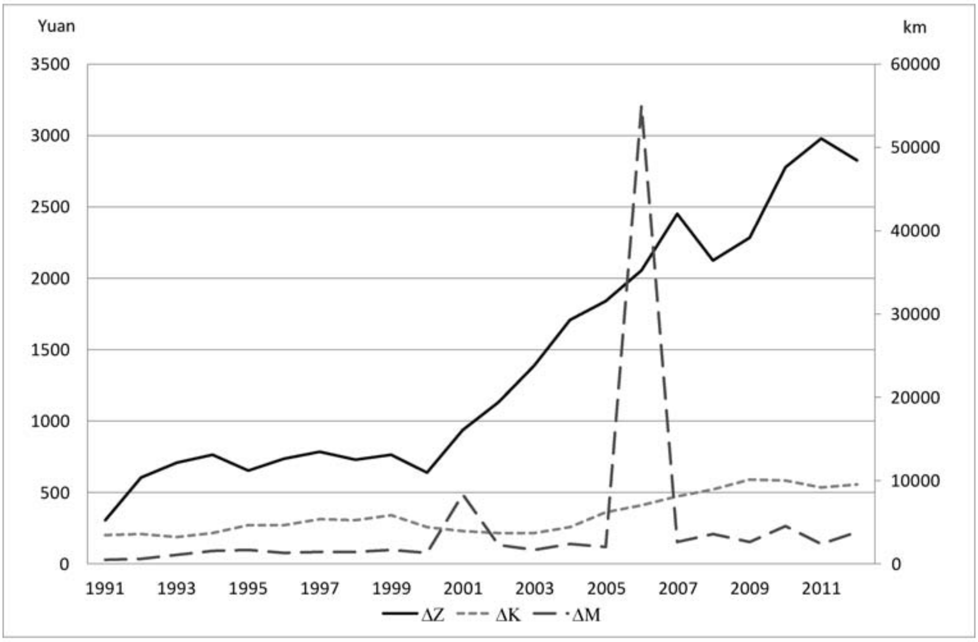
$$\begin{bmatrix} \Delta Z_{it} \\ \Delta K_{it} \\ \Delta M_{it} \end{bmatrix} = \sum_{j=1}^{p} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} \end{bmatrix} \begin{bmatrix} \Delta Z_{i,t-j} \\ \Delta K_{i,t-j} \\ \Delta M_{i,t-j} \end{bmatrix} + \begin{bmatrix} \eta_{1i} \\ \eta_{2i} \\ \eta_{3i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \end{bmatrix} \tag{5}$$

where i delineates the provinces, t denotes the time period, p indicates the lag length of each variable,

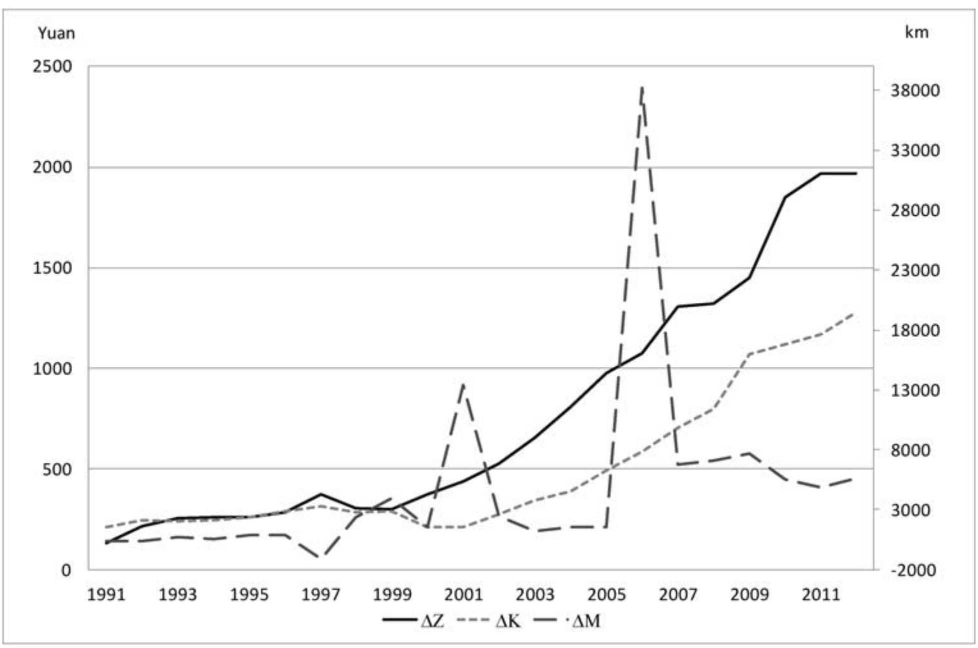
8. A possible limitation of using energy investment as a proxy for capacity expansion is that we do not know whether the investment was used for expanding existing capacity, or just to replace retiring capacity.

Figure 2: Regional Average of Per Capita GDP Growth (ΔZ_t), Per Capita Energy Investment (ΔK_t) and Transportation Capacity Expansion (ΔM_t)

(a) Non-Western Region



(b) Western Region



Note: The ΔM_t spike in 2006 is due to a change in the measurement of highways in the data sources.

η refers to province-specific fixed effects that allow for provincial heterogeneity in the variables, and ε represents idiosyncratic error terms.

When using the system GMM approach to estimate equation (5), we eliminate the unobserved province-specific fixed effects through the Helmert transformation (Love and Zicchino, 2006). The test for the non-causality of ΔK to ΔZ and ΔM to ΔZ can be conducted via the null hypotheses of $\beta_{12j} = 0\ \forall\ j$ and $\beta_{13j} = 0\ \forall\ j$, whereas the test for the non-causality in the opposite direction can be conducted via the null hypotheses of $\beta_{21j} = 0\ \forall\ j$ and $\beta_{31j} = 0\ \forall\ j$. Following the same logic, the null hypotheses of $\beta_{23j} = 0\ \forall\ j$ and $\beta_{32j} = 0\ \forall\ j$ test the non-causality between ΔK and ΔM.

4. DATA

Our data sample is based on the annual time series on provincial real GDP, energy capacity, and transportation infrastructure for China's 30 provinces shown in Figure 1 for the 22-year period of 1991 to 2012. These data come from various *China Statistical Yearbooks* and *China Energy Statistical Yearbooks*.[9]

We use the provincial real GDP in 2000 (100 million yuan) and real GDP growth rates to derive the real GDP series. The real energy investment data are proxied by the provincial investment in fixed assets of state-owned enterprises in the energy industry.[10] Both series are converted to a per capita basis using each province's population.

We use the sum of each province's length of railways (10,000 km) and length of highways (10,000 km) as a measure of transportation infrastructure. As a province's geographic size does not vary over time, we can use the total km of railway and highways to measure the provincial transportation capacity.

5. RESULTS

5.1 Unit root

Table 1 presents the panel unit root results for the Western and non-Western regions by period. The Levin-Lin-Chu test assumes a common unit root process across provinces while the Im-Pesaran-Shin test allows the individual unit root processes to vary across provinces. The Levin-Lin-Chu test rejects the unit root hypothesis for all series in all regions, while the Im-Pesaran-Shin test rejects the same hypothesis in all cases except energy investment in the Western region. This preponderance of evidence allows us to perform the causality tests on the premise that all data series are stationary.

5.2 Causality

We estimate four panel VAR models, each corresponding to a given region and period, to obtain the Granger causality results in Table 2.[11] We use equation (4) and the statistical-significance

9. Our panel dataset in Excel and its documentation are available from the corresponding author upon request.

10. These data are derived by dividing the nominal series (100 million yuan) by the price indices of investment in fixed assets, which is then deflated to constant 2000 prices. For provinces without any published price indices, we use the national average of all provinces in the year in question.

11. We use a binary indicator to control for the effect of the ΔM_t spike in Figures 2(a) and 2(b), which is caused by a change in how M_t was reported in 2006.

Table 1: Panel Unit Root Test Results

Region (Period)	Variable	Levin-Lin-Chu	Im-Pesaran-Shin
Non-Western (1991–2000)	ΔZ_t	−11.214***	−4.317*
	ΔK_t	−8.671***	−1.593*
	ΔM_t	−5.891***	−5.318***
Non-Western (2001–2012)	ΔZ_t	−8.535***	−3.109***
	ΔK_t	−5.049***	−2.850***
	ΔM_t	−13.560***	−7.055***
Western (1991–2000)	ΔZ_t	−12.631***	-3.505***
	ΔK_t	−3.523***	−0.180
	ΔM_t	−6.507***	−3.439***
Western (2001–2012)	ΔZ_t	−4.818***	−2.806***
	ΔK_t	−4.654***	-1.122
	ΔM_t	−1.545*	−4.419***

Note: The null hypothesis is H_0: the series has a unit root. A constant and the time trend are included in each test. The adjusted t* statistics are reported for the Levin-Lin-Chu test and the Z-t-tilde-bar statistics the Im-Pesaran-Shin test. Finally, *, ** and *** denote significance at 10%, 5% and 1%, respectively.

Table 2: *P*-values for Granger-causality Test Results

	Non-Western region		Western region	
Causal direction	1991–2000	2001–2012	1991–2000	2001–2012
$\Delta Z \rightarrow \Delta M$	0.382	0.255	0.820	0.207
$\Delta M \rightarrow \Delta Z$	0.684	0.015	0.997	0.044
$\Delta Z \rightarrow \Delta K$	0.731	0.005	0.975	0.031
$\Delta K \rightarrow \Delta Z$	0.167	0.056	0.967	0.116
$\Delta K \rightarrow \Delta M$	0.866	0.503	0.750	0.088
$\Delta M \rightarrow \Delta K$	0.870	0.305	0.935	0.923

Note: The null hypothesis is H_0: no pair-wise granger causality.

criterion of $\alpha = 0.05$ to interpret these causality results. As discussed below, the results are economically meaningful, matching the four cases derived from equation (4). They suggest: (a) the absence of capacity constraints in the energy and transportation sectors in the pre-WDS period of 1991–2000; and (b) the presence of both constraints in the post-WDS period of 2001–2012.

We now turn our attention to the result details. Consider the p-values in the second column of Table 2 for the non-Western region and pre-WDS period of 1991–2000. They lend support to Case 4 of capacity surpluses, obviating the pair-wise causality between ΔZ, ΔM and ΔK. For the post-WDS period, the third column suggests a unidirectional causal relationship of $\Delta M \rightarrow \Delta Z$, reflecting Case 2 of a transportation capacity constraint. As transportation infrastructure growth is found to precede economic growth, it suggests an active role of the government's investments in this area. There is a unidirectional causal relationship of $\Delta Z \rightarrow \Delta K$, mirroring Case 3 of an energy capacity constraint. This causal direction suggests the possibility of GDP growth driving the demand for energy and hence leading to energy capacity constraint. These two causal relationships, however, do not support Case 1 of bi-directional causality among ΔZ, ΔK and ΔM, thus explaining that ΔK and ΔM are not causally related.

Consider the p-values in the fourth column in Table 2 for the Western region in the pre-WDS period. Qualitatively similar to the non-Western's p-values, they suggest Case 4 of capacity surpluses and no causality between ΔZ and ΔK, between ΔZ and ΔM and between ΔK and ΔM. For the post-WDS period, the p-values in the fifth column indicate unidirectional causal relationships of $\Delta M \rightarrow \Delta Z$ (Case 2) and $\Delta Z \rightarrow \Delta K$ (Case 3), the same as those in the non-Western region. Hence, ΔM and ΔK are not causally related.

6. CONCLUSIONS

This paper offers a causality interpretation of China's WDS. Our finding of capacity constraints absent in the pre-WDS period but not the post-WDS period supports that the WDS was implemented in dealing with the capacity constraints through ETI expansion, reflecting the central government's policy of *Coordinated Development* (2000-present) to achieve a more even growth pattern for all provinces.

Our causality results also suggest two challenges in China's quest for sustainable growth. First, energy and transportation capacity constraints are found to exist in the post-WDS period, implying that China should continue its infrastructure investment, as it is doing now. Second, these constraints are unsynchronized, hinting the need to improve the coordination in investment planning for the energy and transportation sectors. As similar challenges are observed in other Asian countries (e.g., Cambodia, India and Vietnam), our recommendation of coordinated infrastructure expansions equally applies to these countries.

We would be remiss, had we failed to recognize our paper's limitations. First, our paper does not address the issue of infrastructure quality. A case in point is the clean energy development of renewable resources and low-emissions vehicular fuel is critical for China's sustainable future.

Second, our paper's focus is narrow, overlooking infrastructure investments in other sectors such as telecommunications and water supply. Although an analysis that includes these sectors is on our future research agenda, it is well beyond the current paper's scope. The same can be said about other drivers of China's regional economic growth (*supra* note 5).

Third, our paper does not analyze energy consumption that includes vehicular fuel. Thus, we plan to expand our causality analysis to explore the GDP-energy nexus within our model of capacity constraints in future research.

Finally, our paper does not address how the WDS may resolve the environmental aspect of regional disparities. Consider, as an example, the promotion of electricity generation in the Western provinces where China's coal and hydro resources mainly reside to support the rising electricity demands of the coastal provinces via high-voltage transmission lines. Whether the ensuing income-environment outcome is "fair and reasonable" for the people living in the Western provinces would require a separate analysis that is much broader than what we have done in this paper.

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